

A new genus of soft coral (Cnidaria, Octocorallia) from the Republic of Congo (Pointe-Noire Region)

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Abstract

A new genus of soft coral from the Republic of Congo is described, *Complexum* **gen. n.** Nine West African octocoral species previously described in the genus *Alcyonium* by Tixier-Durivault (1955) are referred to this new genus, and a new species is described and figured, *C. pusillum* **sp. n.** The new species is characterized by having encrusting growth form and abundant spiny clubs in the surface of the polyparium. It colonizes shallow calcareous rocky banks (5 to 20 m depth) existing in coastal water of the region of Pointe-Noire. Based on molecular phylogeny this new genus is well separated from *Alcyonium* species.

Keywords

Coelenterata, Cnidaria, Octocorallia, Alcyonacea, Alcyoniidea, *Alcyonium*, *Complexum*, Republic of Congo, new genus, new species



Figure 1. Location of sampling stations for *Complexum pusillum* sp. n. (black star).

Introduction

A new species from West Africa comparable to those from the same region identified as *Alcyonium* by Tixier-Durivault (1955) was studied. Unexpectedly, in a molecular study using mitochondrial markers COI-IGR and a nuclear marker 28S we found this species to be a sister taxon of *Eunicella* instead of grouping with other *Alcyonium* species. Dr. Cathy McFadden (Harvey Mudd College, Claremont, USA) informed us she had a similar result with a species from West Africa identified as *Alcyonium monodi* Tixier-Durivault (1955). Because of these molecular data we describe a new genus to incorporate West African species previously placed in *Alcyonium*.

The species here described comes from Pointe-Noire (a coastal locality of the Democratic Republic of Congo), 150 km to the north of the Congo river mouth (Fig. 1).

Abbreviations

- MNHN** Muséum National d’Histoire Naturelle, Paris, France.
NBC (RMNH) Naturalis Biodiversity Center, formerly Rijksmuseum van natuurlijke, Historie, Darwinweg 2, P.O. Box 9517, 2300 RA Leiden, The Netherlands.

Taxonomy

Class ANTHOZOA Ehrenberg, 1831

Subclass OCTOCORALLIA Haeckel, 1866

Order ALCYONACEA Lamouroux, 1812

Family ALCYONIIDAE Lamouroux, 1812

Genus *Complexum* gen. n.

<http://zoobank.org/FAE05097-0366-435B-9116-9CDB0CE30A96>

Type species. *C. pusillum* sp. n., here designated.

Diagnosis. Colonies form encrusting sheets or are lobate. Polyps monomorphic and retractile. Polyps with point spindles showing an arrangement in chevrons, a kind of collaret can be present, formed by the lowest point sclerites lying horizontally. Coenenchymal sclerites are wide spindles and ovals with simple and complex tubercles. The polyparium additionally can have clubs in the surface layer, which are derived from the spindles. When preserved, colonies are white or coloured; sclerites colourless or coloured. Azooxanthellate.

Etymology. From the latin *complexus*, a complex, an aggregate of parts, referring to the complex tubercles common on the coenenchymal sclerites of this genus.

Remarks. The following West African species hitherto placed in *Alcyonium* are referred to the new genus: *A. caparti*, *A. globosum*, *A. gruweli*, *A. laxum*, *A. miniatum*, *A. monodi*, *A. patulum*, *A. pobeguini*, and *A. strictum*; all were described by Tixier-Durivault (1955).

Complexum pusillum sp. n.

<http://zoobank.org/7CDCA56A-8F03-4525-9FCB-BC07E650E00F>

Figs 1–6

Type material. Holotype: Congo, “Pointe Noire”, Banc Mullet, 31.I. 2013, depth -10 m, 1 colony, (RMNH Coel. 41604); paratype: same data as holotype (RMNH Coel. 41605).

Description. The holotype is a colony consisting of two lobes, 2 × 1.3 cm in diameter and 1 cm thick, encrusting rock (Fig. 2A). The polyps are completely withdrawn into the coenenchyme and calyces are not present.

The anthocodiae have a collaret composed of 2–3 rows of spindles. These spindles are up to 0.15 mm long, slightly bent, and have simple tubercles (Fig. 3B). The points have spindles similar to those of the collaret, 4–5 pairs per point. They are also up to 0.15 mm long, have simple tubercles and a slightly spiny distal end (Fig. 3A). The tentacles contain no sclerites.

The surface layer of the top of the colony has clubs, up to 0.35 mm long, with complex tubercles and spiny heads (Fig. 3C–D). The interior has straight and bent spindles, up to 0.60 mm long, with simple or complex tubercles (Fig. 3E).

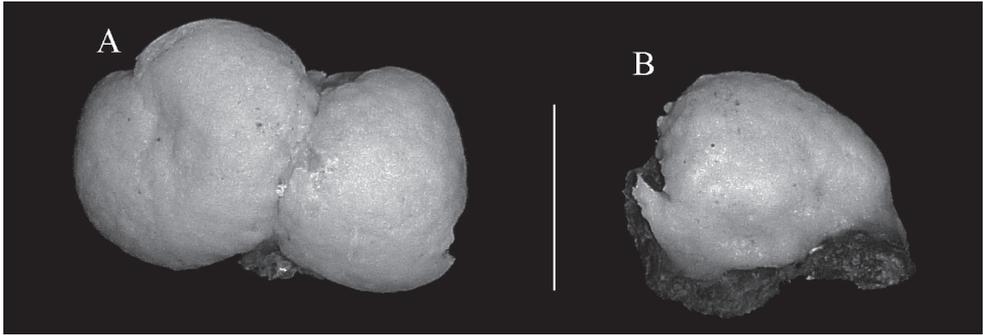


Figure 2. A, B *Complexum pusillum* sp. n. **A** holotype (RMNH Coel. 41604) **B** paratype (RMNH Coel. 41605). Scale bar 10 mm.

The base of the colony has spindles and ovals, up to 0.65 mm long, with simple or complex tubercles (Fig. 4).

Colour. The preserved holotype is white, and all sclerites are colourless.

Etymology. From the Latin, *pusil*, tiny, referring to the small size of the colonies.

Variability. The paratype is a single lobe-like colony (Fig. 1B). The sclerites are similar to those of the holotype.

Habitat. In the studied area, coastal waters show a general high turbidity due to the input of sediment and detrital and humic materials by the Congo River in the south and the Kouilou River in the north, as well as a high primary productivity in the ocean. As a consequence muddy bottoms dominate on the continental shelf (Giresse 1980). Nevertheless, shallow, cretaceous, calcareous banks emerge among them, at a depth of between 5 and 20 m (Giresse and Kouyoumontzakis 1973). These rocky banks constitute large, thin slabs (no more 1.5 m high) sometimes exposed to high hydrodynamics due to the swell, tides and the occurrence of complex exchanges of water bodies up to 80 m deep (Moroschkin et al. 1970; Piton 1988). *Alcyonium pusillum* sp. n. colonizes these shallow rocky banks, mainly in cryptic positions (under overhangs and in large holes) forming small white patches (< 1 m²) easily distinguishable by SCUBA divers (Fig. 5A, B). On these hard bottoms, the associated fauna is mainly composed of gorgonians (*Eunicella*, *Leptogorgia* and *Muriceopsis* species), stony corals (*Polycyathus* cf. *senegalensis* Chevalier, 1966 in the same cryptic positions as *A. pusillum* sp. n.) and sponges (Fig. 5C).

Comparison with other species. The two encrusting *Alcyonium* species previously described from Congo, *A. globosum* Tixier-Durivault, 1955, and *A. laxum* Tixier-Durivault, 1955, now referred to *Complexum*, differ from *C. pusillum* sp. n. in lacking clubs in the surface of the polyparium. Moreover, both these species have many lobes and coloured polyps. Other encrusting *Alcyonium* species reported from the west Atlantic now referred to *Complexum* are *A. patulum* Tixier-Durivault, 1955 and *A. strictum* Tixier-Durivault, 1955, from Mauritania. *A. patulum* resembles *A. strictum* but is red with yellow polyps and has no clubs. *Alcyonium strictum* resembles *A. pusillum*

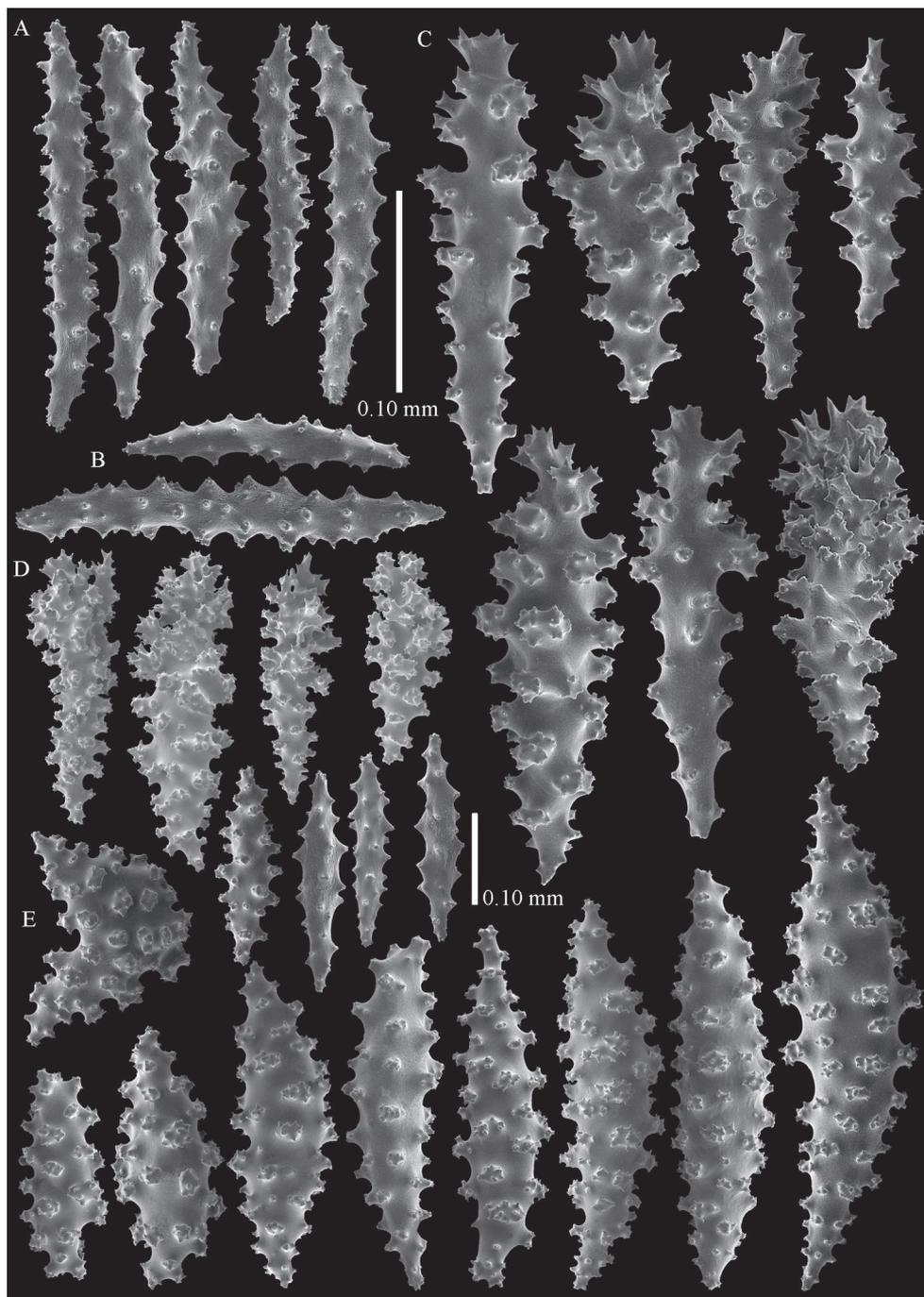


Figure 3. *Complexum pusillum* sp. n., holotype (RMNH Coel. 41604). **A** point spindles; **B** collaret spindles **C–D** clubs of surface layer **E** spindles of interior.

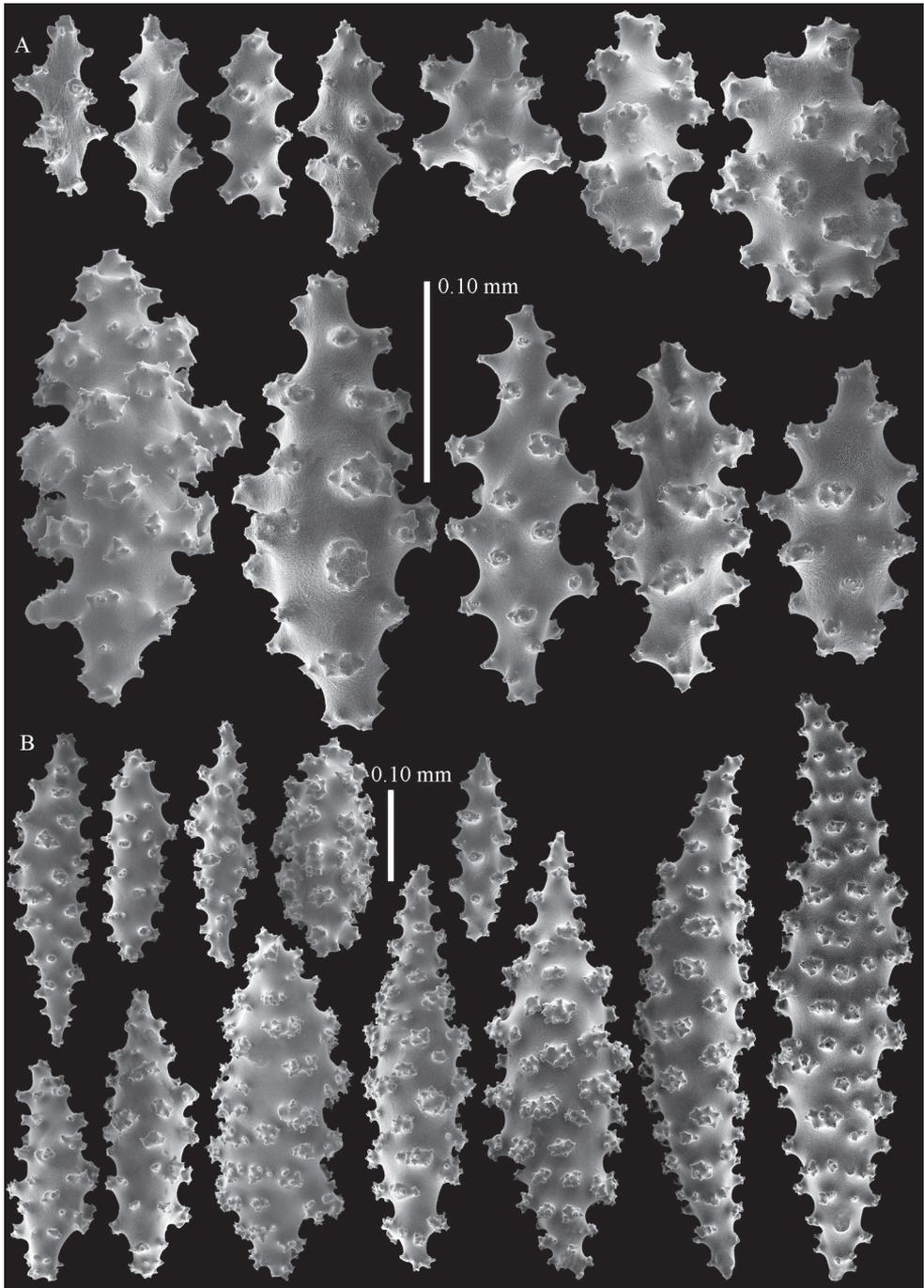


Figure 4. *Complexum pusillum* sp. n., holotype (RMNH Coel. 41604). **A–B** spindles of base of colony.

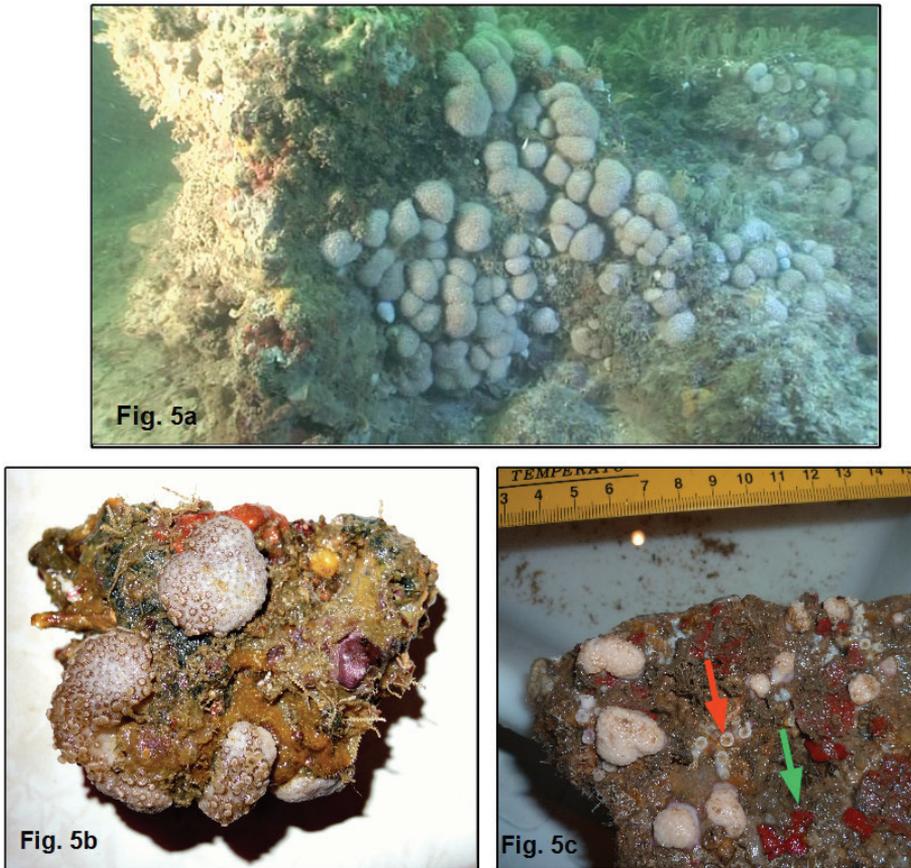


Figure 5. *Complexum pusillum* sp. n., Banc du Conflit, depth 10 m. **A** General view of a small patch of colonies on rocky bottom **B** Magnified view of some colonies **C** small piece of rock colonized by the new species, sponges (green arrow) and small stony corals (*Polycyathus* cf. *senegalensis* – red arrow).

sp. n. more than any other species, it also has clubs with a spiny head, but it has many small oval sclerites in the base, and is purple with yellow polyps.

Molecular phylogeny. A phylogenetic analysis has been performed, based on part of the mitochondrial COI gene and of the adjacent intergenic region (igr) which have been amplified according to McFadden et al. (2011). Additional Octocoral COI-igr sequences were retrieved from GenBank following a Blast search with the *C. pusillum* sequence as a query. As a comparison, *Alcyonium* spp. sequences were specifically retrieved from GenBank and included in the analysis. *Alcyonium monodi* sequences (referred to *Complexum monodi*) were kindly provided by Catherine McFadden and included in the dataset. They correspond to colonies sampled in 2012 in Senegal (10 km South of Dakar) at 15 m depth by Peter Wirtz. A phylogenetic reconstruction based on maximum likelihood (ML) has been performed with RaxML 8.1 (Stamatakis 2014) with a General Time Reversible + Gamma model and a rapid bootstrap analysis (1000 re-samplings).

The nuclear gene coding for 28S ribosomal RNA has also been sequenced for *C. pusillum* following McFadden and Ofwegen (2013a) and the obtained sequence has been compared to other octocoral sequences thanks to a Blast search and a similar ML analysis. The COI-IGR sequence of *C. pusillum* has been deposited in GenBank (KP006396).

Tixier-Durivault (1955) described three other *Alcyonium* species from West Africa, *A. altum*, *A. leave* and *A. violaceum*. Verseveldt and Bayer (1988) referred *A. altum* and *A. violaceum* to the genus *Nidaliopsis* Kükenthal, 1906. It is unknown to us why Verseveldt and Bayer did not mention *A. leave*, we consider it to also belong to *Nidaliopsis*. This leaves *Alcyonium senegalense* Verseveldt & Ofwegen, 1992 from Senegal as the only *Alcyonium* species in West Africa. However, it has capstans and ovals in the coenenchyme (Verseveldt and Ofwegen 1992: figs 20–21), and therefore also does not match the current diagnosis of *Alcyonium*. We prefer to wait till molecular data of this species are available before describing another new genus to accommodate it. Superficially *Complexum* is similar to *Alcyonium*, it has the same type of colony shapes, and the sclerite arrangement in the polyps is also similar. *Alcyonium* differs in having clearly different sclerite types in surface layer and interior, radiates and club-like forms in the surface layer, and long spindles in the interior.

The phylogenetic analysis based on mitochondrial COI-IGR clearly confirmed the separation of *Complexum* from *Alcyonium* species (family Alcyoniidae) (Fig. 6). Indeed these species appear close to *Eunicella* (family Gorgoniidae; 99% bootstrap support) but the precise relationships between *Complexum* and *Eunicella* remain to be investigated with more species and the use of additional markers to get more robust information inside that group. A Blast analysis of the 28S sequence of *C. pusillum* in GenBank confirmed the closer relationship of this group with *Eunicella* compared to *Alcyonium* (data not shown). The current family-level taxonomy of octocorals needs extensive revision (McFadden et al. 2010) and therefore we keep the new genus in the family Alcyoniidae.

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A new genus and species of Thyasiridae (Mollusca, Bivalvia) from deep-water, Beaufort Sea, northern Alaska

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Abstract

Bivalve mollusk shells were collected in 2350 m depth in the Beaufort Sea, Arctic Ocean off northern Alaska. Initial identification suggested the specimens were a member of the bivalve family Thyasiridae, but no known eastern Pacific or Arctic living or fossil thyasirid resembled these deep-water specimens. Comparisons were made with the type of the genera *Maorithyas* Fleming, 1950, *Spinaxinus* Oliver & Holmes, 2006, *Axinus* Sowerby, 1821, and *Parathyasira* Iredale, 1930. We determined the Beaufort Sea species represents a new genus, herein described as *Wallerconcha*. These specimens also represent a new species, herein named *Wallerconcha sarae*. These new taxa are compared with known modern and fossil genera and species of thyasirids.

Keywords

Thyasiridae, Beaufort Sea, Alaska, Mollusca, Bivalvia, *Maorithyas*, *Wallerconcha*, *Spinaxinus*, *Axinus*, *Parathyasira*, chemoautotrophic, endosymbiosis, taxonomy, Arctic Ocean

Introduction

In an effort to understand the tectonic and sedimentary history of the Arctic Ocean between Canada and Alaska, a joint US-Canadian ice breaker expedition working under the sponsorship of the Extended Continental Shelf Project conducted operations in the Canada Basin during August 2010. The primary mission of the expedition was to collect seismic-reflection and high-resolution bathymetric data. Occasionally there was an opportunity to collect gravity and piston core samples throughout the basin. One of these cores was collected on a mound previously identified on seismic records. Bivalve mollusk specimens were collected in some of these samples and have provided the material for this paper.

Geologic setting

The informally named “Canning Seafloor Mound” (Hart et al. 2011; hereafter referred to as the Canning Seafloor Mound), a probable cold seep, overlies the crest of a buried anticline in a region of sub-parallel compressional folds beneath the eastern Beaufort Sea outer slope. The collecting locality is adjacent to the frontier oil and gas regions offshore of Prudhoe Bay. The basin is host to extraordinarily deep sedimentary sections about 10 km thick with high organic matter content from river discharge, enhancing the probability of oil and gas generation at depth (Grantz et al. 2011, Grantz and Hart 2012).

Taxonomic background

Bernard (1972) reviewed the thyasird bivalves in western Canada. He examined specimens from throughout the northeast Pacific as well in the Arctic. In this treatment he synonymized a large number of genera into *Thyasira* Lamark, 1818, including *Axinus* G.B. Sowerby I, 1821 and *Conchocele* Gabb, 1866. Both genera are now known to be distinct (Oliver and Holmes 2007; Coan and Valentich-Scott 2012).

The only systematic treatment that included deep-water Beaufort Sea bivalves was presented by Bernard (1979). In the Beaufort Sea he documented four species of Thyasiridae between the intertidal zone and 2560 m, including a minute deep-water species *Axinulus careyi* Bernard, 1979.

Kristofovich (1936) reported on the *Thyasira* of Tertiary deposits on the western coast of Kamchatka, Russia. Fossil and modern species of *Thyasira* from northeastern Honshu, Japan, were detailed by Yabe and Nomura (1925).

Considerable research has been published in the last 15 years on thyasirds from cold seeps and hot vents (Oliver and Sellanes 2005, Oliver and Holmes 2006, 2007b, Oliver and Levin 2006, Taylor et al. 2007, Zelaya 2009, Oliver et al. 2013, Hryniewicz et al. 2014, Oliver 2014) and their associated with chemosynthetic communities, which are now known to be distributed widely throughout the world’s oceans (Sibuet

and Olu 1998, Fujikura et al. 1999, Fujiwara et al. 2001). The Canning Seafloor Mound probably represents a cold seep habitat (Hart et al. 2011).

Here we describe a new genus and new species of thyasirid bivalve from a deep-water seafloor mound in the eastern Beaufort Sea, off northern Alaska and compare it to other thyasirid genera and species.

Materials, methods, abbreviations

Bivalve specimens were examined from cores collected by the USCGC *Healy* (cruise HLY1002; USGS Station FAID H-3-10-AR; 71.3176°N, 143.9982°W) from the Canning Seafloor Mound, at a depth of 2530 m in the Beaufort Sea off northern Alaska (Figure 1). The Canning Seafloor Mound is conical and approximately 1200 m diameter and 180 m high (Figure 2).

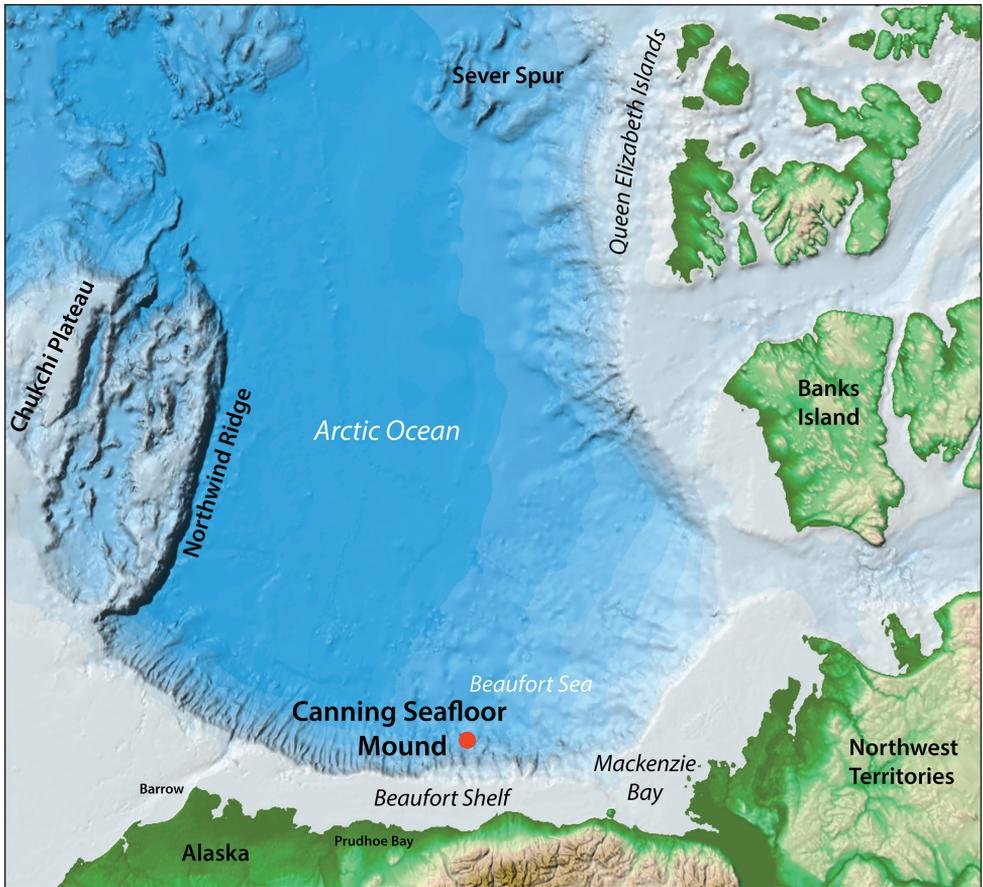


Figure 1. Base map adapted from Jakobsson et al. (2008) showing the location of the Canning Seafloor Mound off the coast of northern Alaska.

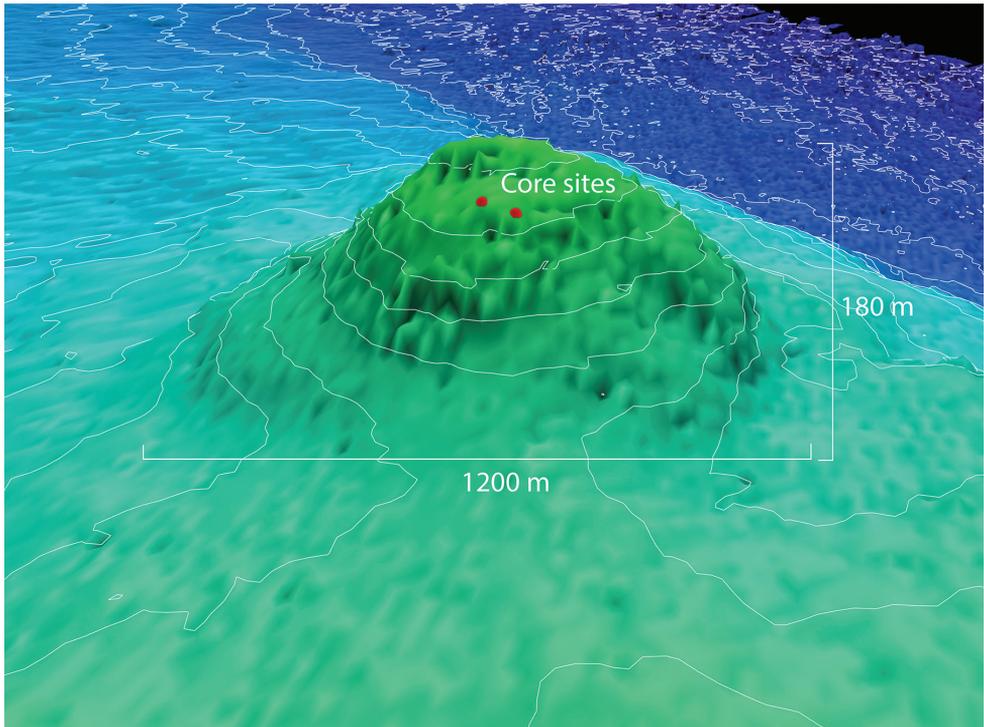


Figure 2. Shaded seafloor bathymetry showing shape and approximate dimension of the Canning seafloor mound. The core sites are shown as red dots.

The bivalve specimens were recovered in two cores (1P–1 and 1GB–1) from 0.02 to 4.65 meters below the seafloor. The greater depth indicates long-term residence of the bivalves (see below under Age), whereas the shallow depth and assumed young age could indicate that this species might still be living on or near the mound. The shells are associated with gas hydrate, methane saturated sediments and authigenic carbonates (Edwards et al. 2011, Hart et al. 2011, Lorenson et al. 2011, Pohlman et al. 2011). This strongly suggests that the bivalves had chemotrophic endosymbionts similar to other bivalves that inhabit active cold vents (Roberts and Carney 1997, Fujiwara et al. 2001, Oliver 2014).

For Figure 7, diagrammatic line drawings were made from digital images of the holotypes of each species. Outlines of each type specimen were made in Adobe Photoshop by selecting all space outside of the shell, inverting the selection and creating a clipping path along the shell edge. With the clipping path selected, we processed the “stroke path” command.

The following abbreviations are used in the text: ECS – Extended Continental Shelf; FAID – field activity identification; GNS – GNS Science, Lower Hutt, New Zealand; LACMIP – Invertebrate Paleontology section, Natural History Museum of Los Angeles County, California, USA; mbsf – meters below seafloor; SBMNH – Santa Barbara Museum of Natural History, California, USA; NHMUK – The Natural History Museum, United Kingdom; NMST – National Museum of Nature and

Science, Tokyo, Japan; NMW.Z – National Museum of Wales, Zoology, Cardiff, Wales, UK; USGS – United States Geological Survey; USNM – National Museum of Natural History, Smithsonian Institution, Washington D.C., USA.

Systematic account

Family Thyasiridae Dall, 1900

Wallerconcha Valentich-Scott & C. L. Powell, gen. n.

<http://zoobank.org/FD1C36AC-1554-4BBE-AFE6-C8955FA39558>

Figures 3A–H, 7B

Type species. *Wallerconcha sarae* Valentich-Scott & C.L. Powell, new species herein (Figures 3A–H, 7B). No other species are currently included in the genus.

Description. Shell moderate in size (length to 24 mm), subtrigonal, subequilateral, strongly inflated; beaks broad, strongly prosogyrous; posterior radial sulcus shallow; sculpture of moderate to strong, uneven commarginal ribs and striae; periostracum thick, dehiscent, medium to dark brown, wrinkled, without micro-spines; lunule absent; escutcheon long, moderately narrow, moderately impressed; ligament large, long, deeply sunken on a stout nymph; hinge edentulous or with minute tubercles; hinge plate well defined and strongly thickened posteriorly; anterior adductor muscle scar wide, long.

Etymology. The genus is named in honor of Thomas R. Waller (Smithsonian Institution) for his significant contributions to our understanding of the evolution, biogeography and systematics of fossil and modern marine bivalves.

Comparisons. *Wallerconcha* differs from all other members of the Thyasiridae by the combination of four primary shell characteristics: 1) a well-defined hinge plate; 2) a heavy, deeply sunken nymph; and 3) a broad, elongate anterior adductor muscle scar that is not divided into two sections; 4) a dark, thick, wrinkled periostracum, without micro-spines.

Wallerconcha is similar to the deep-water genus *Spinaxinus* Oliver & Holmes, 2006 (type species, *Spinaxinus sentosus* Oliver & Holmes, 2006) (Figure 4A–D). The latter genus has a thin, translucent, minutely spinose periostracum (Figure 4D), whereas the periostracum of *Wallerconcha* is thick and wrinkled but lacks periostracal spines (Figure 3D). In addition, *Wallerconcha* has a much longer and wider anterior adductor muscle scar, and a longer and deeper nymph.

Another similar genus is *Axinus* G.B. Sowerby I, 1821 (type species *Axinus angulatus* G.B. Sowerby I, 1821). Oliver and Holmes (2007a) reviewed several members of this genus and concluded that it has a large lunule, a moderate to strong posterior radial sulcus, a thin hinge plate, and lacks a heavy nymph, all features which separate it from *Wallerconcha*.

Parathyasira Iredale, 1930 (type species *Parathyasira resupina* Iredale, 1930) has an external sculpture of minute rows of spines, and a distinct radial sulcus. It also has

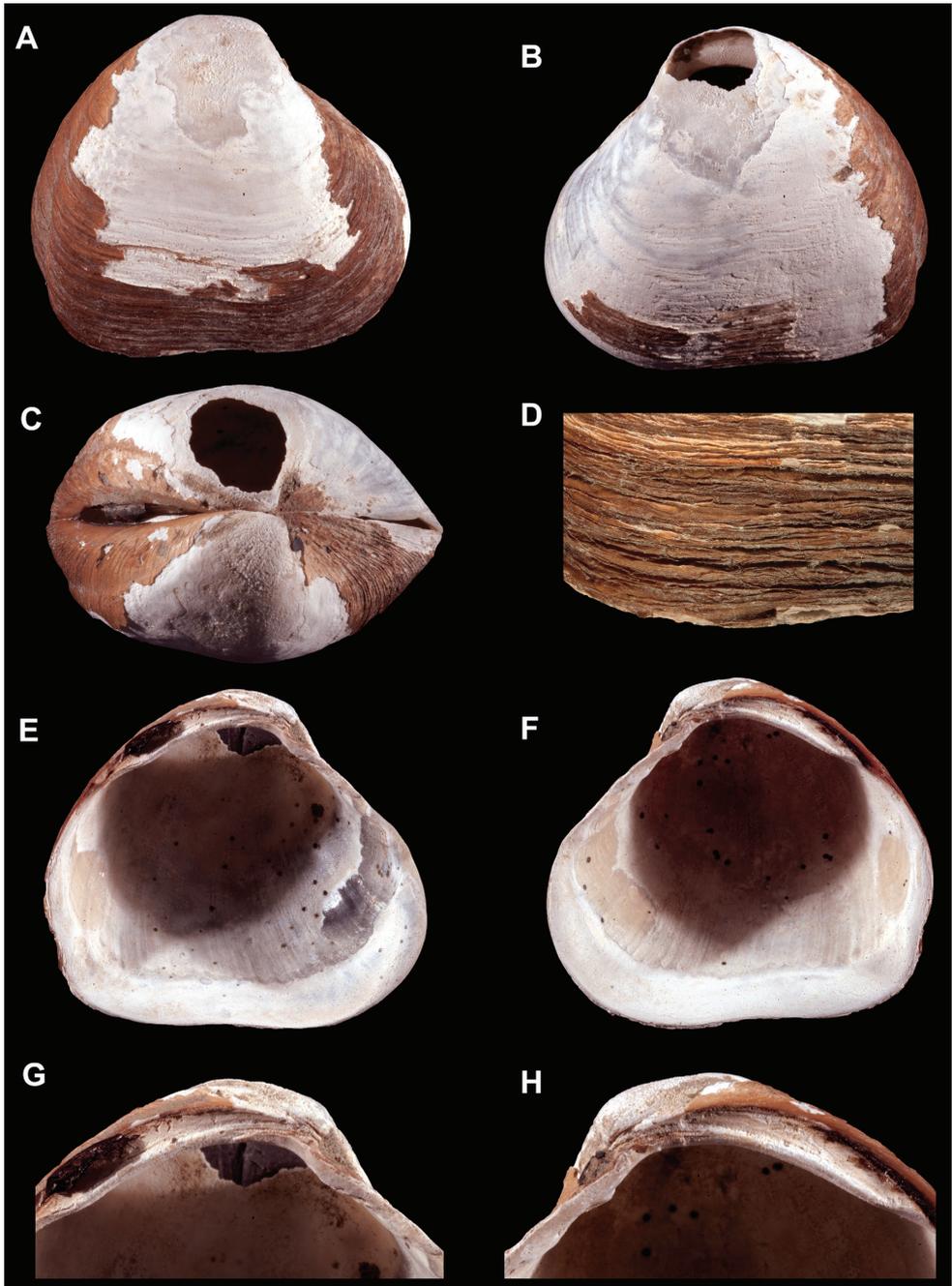


Figure 3. A–H. *Wallerconcha sarae* gen. n., sp. n. **A–H** holotype, SBMNH 235481, length = 23.9 mm, height = 21.3 mm, width = 16.7 mm. **A** Exterior of right valve **B** Exterior of left valve **C** Dorsal view of both valves **D** Close up of periostracum of right valve **E** Interior of left valve **F** Interior of right valve **G** Close up of hinge of left valve **H** Close up of hinge of right valve.

a thin hinge plate and weak nymph, which are less robust than *Wallerconcha*. Both genera have an elongate anterior adductor muscle scar, whereas in *Parathyasira* the scar is usually divided into several sections, *Wallerconcha* has a single, broad scar.

Maorithyas marama Fleming, 1950, the type species of the genus, has a very thin hinge plate, lacks a heavy nymph, and has a shorter anterior adductor muscle scar (Figures 5A–G, 7A) when compared to *Wallerconcha*.

Okutani et al. (1999) placed their new, deep-water Japanese thyasirid species into the shallow-water genus *Maorithyas* Fleming, 1950. They chose the generic placement of *Maorithyas hadalis* Okutani et al., 1999 based on the shallow posterior radial sulcus, and relatively heavy sculpture. The internal shell characteristics of *M. hadalis* (holotype, NSMT 71431), namely the periostracum, hinge plate, nymph and anterior adductor muscle scar place it outside of *Maorithyas* or *Wallerconcha* (Figure 6A–H). It potentially belongs in a new genus, but that description is outside the scope of this paper.

***Wallerconcha sarae* Valentich-Scott & C.L. Powell, sp. n.**

<http://zoobank.org/70B6274D-A766-48E3-B33E-4D353E78F69D>

Figure 3A–H, 7B

Description. Shell shape. Shell subtrigonal, moderately thin, equivalved, highly inflated; anterior margin broadly rounded; posterior end subtruncate; umbo broadly rounded, strongly prosogyrate; dorsal margin strongly sloping on both sides of the umbo; escutcheon moderately narrow, moderately deep, well-defined; lunule absent. Maximum length 24 mm, maximum height 24 mm, maximum width 17 mm.

Sculpture and periostracum. Shell with closely spaced, irregular commarginal striae and ribs; shallow, narrow radial sulcus extends from posterior of the umbo to the posterior ventral margin; shallow radial depression from the umbo to the central ventral margin, forming a slight undulation along the ventral margin; periostracum thick, wrinkled, dehiscent, light to dark brown, silky.

Hinge. Hinge heavy, edentulous, or with minute tubercles under beaks; anterior section narrow; posterior section with wide lateral platform, supporting deeply sunken nymph; ligament external, deeply sunken, long, dark brown.

Adductor muscle and pallial scars – anterior adductor muscle scar large, long, wide, subelliptical, with irregular upper and lower margins, upper margin of scar concave near the center; posterior adductor muscle scar smaller, irregular ovate, with a pointed projection in juveniles; pallial line scalloped, without a sinus.

Interior – interior dirty white to gray; with faint radial crescent-shaped lines that extend from near the umbo to the near the ventral margin, lines have broad depressions between them near the central ventral margin.

Type locality. USA, Alaska, Beaufort Sea, Canning Seafloor Mound. Specifically, 71.317°N, 143.999°W; 2,358 m water depth (ECS004 137, Core IP–1, section 3, 31 cm, 4.65 mbsf).

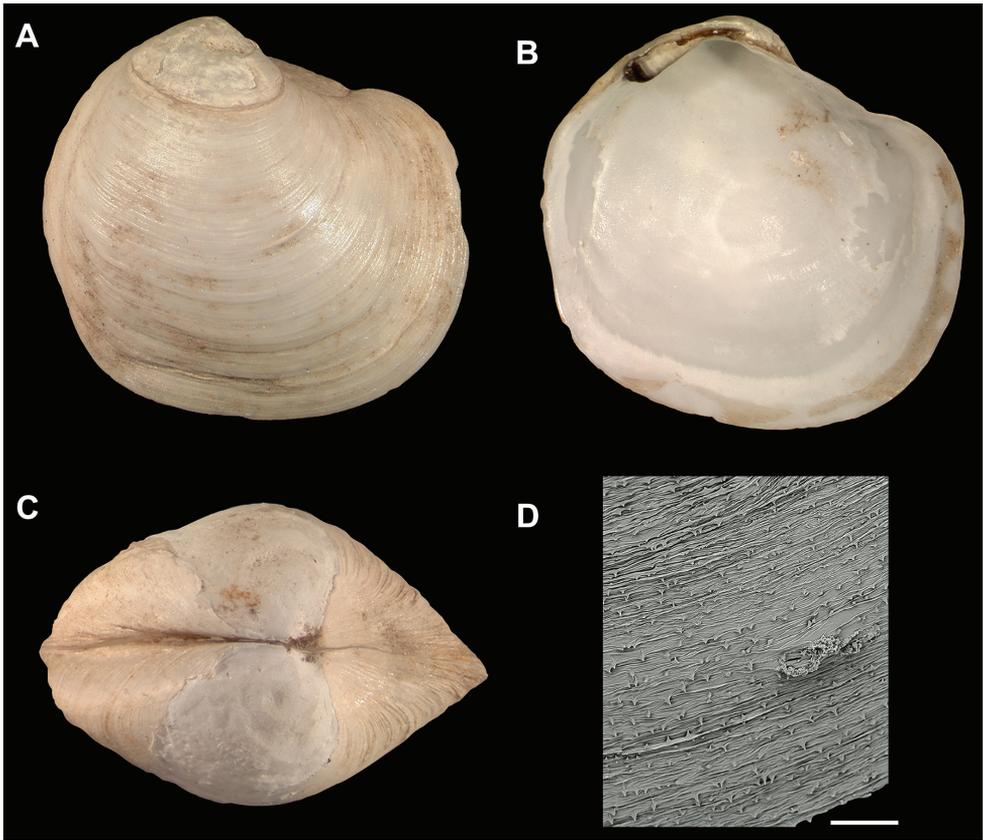


Figure 4. **A–D** *Spinaxinus sentosus*. **A–G** holotype, NMW.Z. 2002.108.1, length = 13.5 mm, height = 13.3 mm, width = 8.6 mm. **A** Exterior of right valve **B** Interior of left valve **C** Dorsal view of both valves **D** Scanning electron micrograph of periostracum, scale bar = 200 μ m. Photo credit P. Graham Oliver and Anna M. Holmes, National Museum of Wales.

Type specimens. Holotype – SBMNH 235481, 1 pair, length = 23.9 mm, height = 21.3 mm, width = 16.7 mm. Alaska, Beaufort Sea, Canning Seafloor Mound; 71.317°N, 143.999°W; 2,358 m water depth (ECS004137, Core IP–1, section 3, 31 cm; 4.65 mbsf)

Paratype 1 – CAS paratype 72852

Alaska, Beaufort Sea, Canning Seafloor Mound; 71.317°N, 143.998°W; 2,350 m water depth (ECS 004 122. Core 1GB–1 102 cm, 1.02 mbsf); length = 12.8 mm, height = 10.9 mm

Paratype 2 – LACMIP paratype 14470

Alaska, Beaufort Sea, Canning Seafloor Mound; 71.317°N, 143.999°W; 2,358 m water depth (ECS004242, Core IP1, section 1, 52 cm, 2/2, 0.52 mbsf); length = 15.0 mm, height = 13.1 mm

Paratype 3 – SBMNH paratype 235613

Alaska, Beaufort Sea, Canning Seafloor Mound; 71.317°N, 143.998°W; 2,350 m water depth (ESC004180, Core 1GB–1, 44 cm, 0.44 mbsf); length = 19.2 mm, height = 17.5 mm

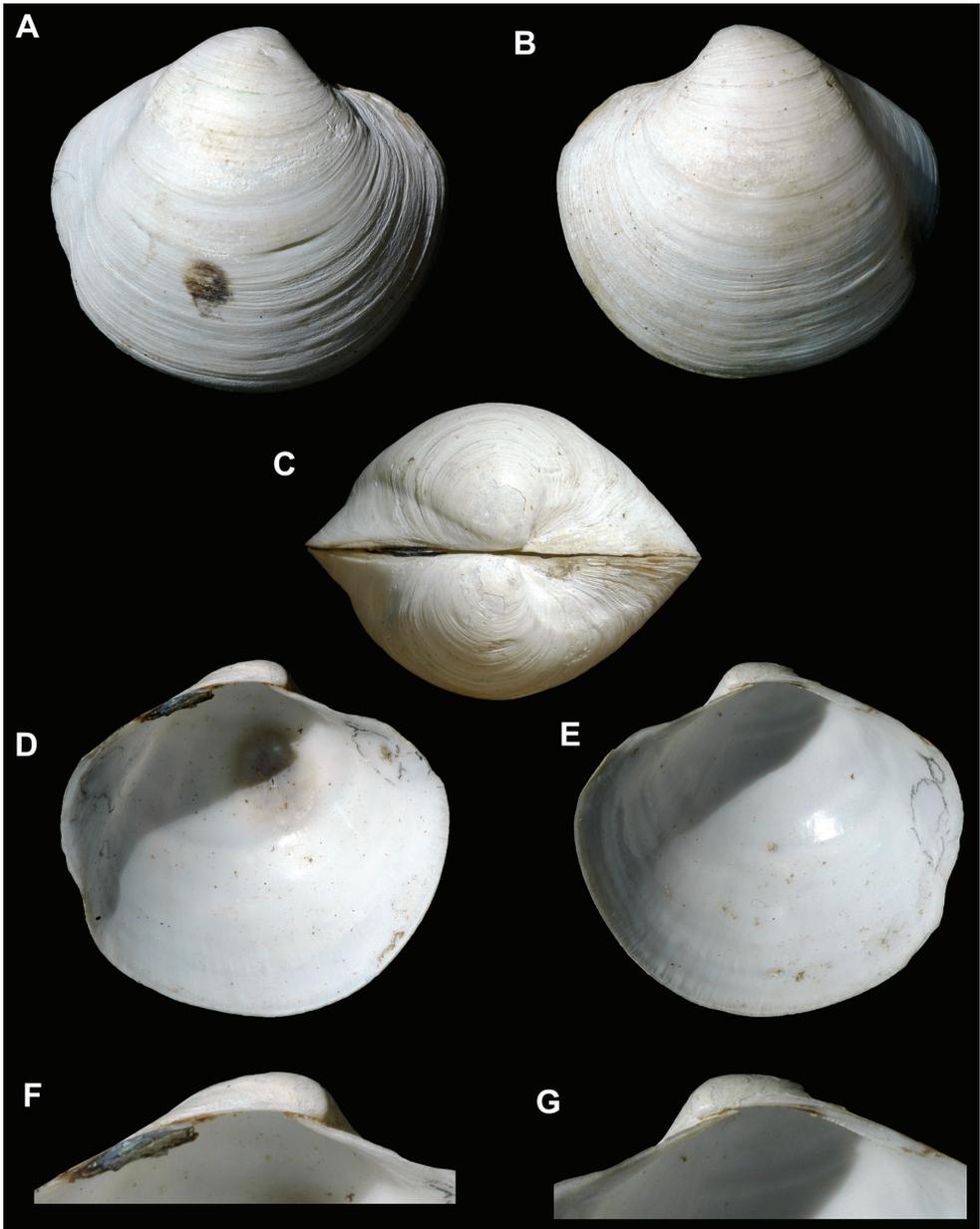


Figure 5. A–G *Maorithyas marama*, holotype, GNS–TM 305, length = 18.7 mm, height = 17.2 mm, width = 13.7 mm. **A** Exterior of right valve **B** Exterior of left valve **C** Dorsal view of both valves **D** Interior of left valve **E** Interior of right valve **F** Close up of hinge of left valve **G** Close up of hinge of right valve.

Paratype 4 – SBMNH paratype 235614

Alaska, Beaufort Sea, Canning Seafloor Mound; 71.317°N, 143.998°W; 2,350 m water depth (ESC004180, Core 1GB–1, 44 cm, 0.44 mbsf); length = 23.9 mm, height = 23.8 mm.

Etymology. Named in honor of Sara Powell, of San Jose, California, daughter of Charles L. Powell.

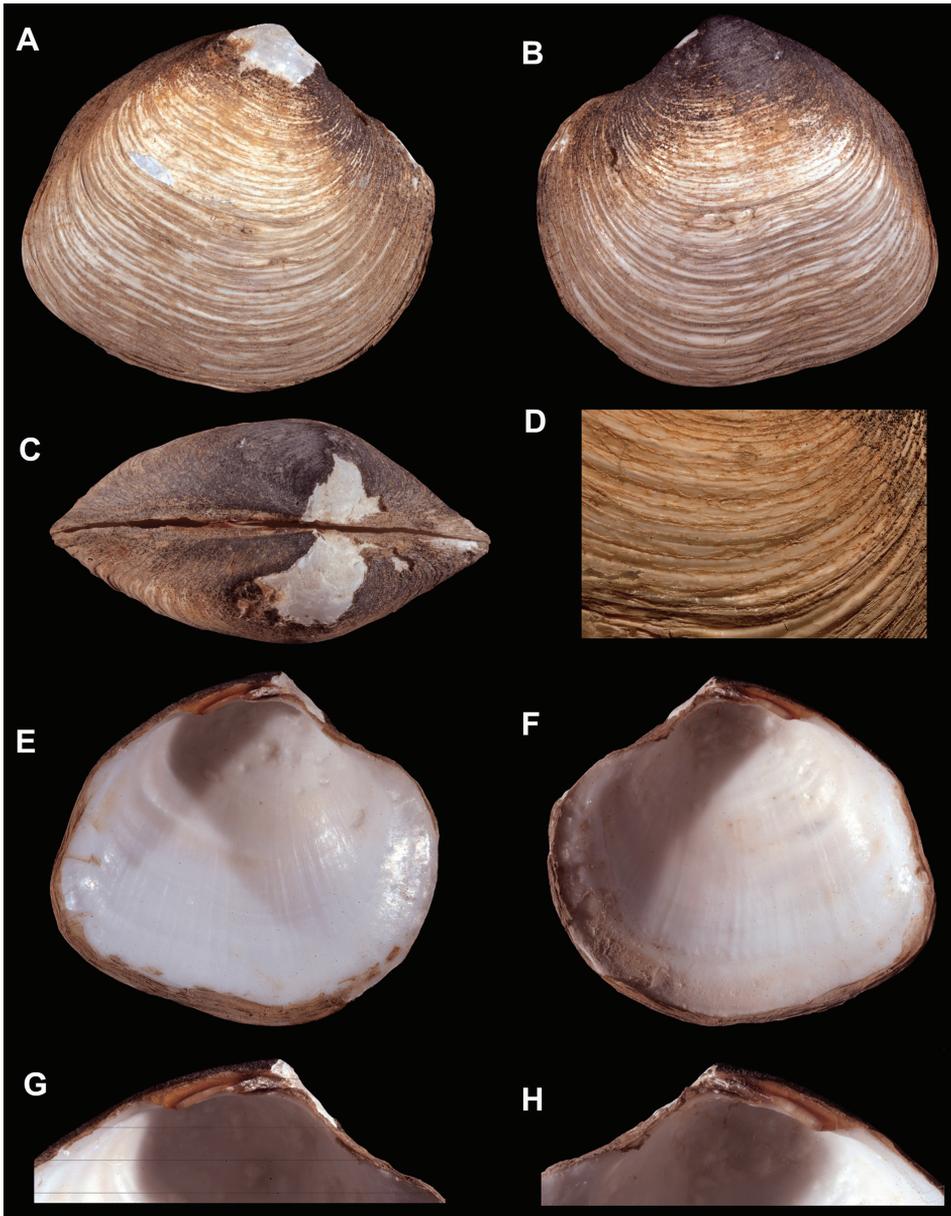


Figure 6. **A–H** *Maorithyas badalis*, holotype, NSMT 71431, length = 26.7 mm, height = 24.1 mm, width = 13.4 mm. **A** Exterior of right valve **B** Exterior of left valve **C** Dorsal view of both valves **D** Close up of periostracum of right valve **E** Interior of left valve **F** Interior of right valve **G** Close up of hinge of left valve **H** Close up of hinge of right valve.

Distribution. *Wallerconcha sarae* is presently only known only from the region around the type locality; the Canning Seafloor Mound (71.3175°N, 143.9997°W), Beaufort Sea, Alaska, USA. Given the collection depth of 0.02–4.65 mbsf, we sur-

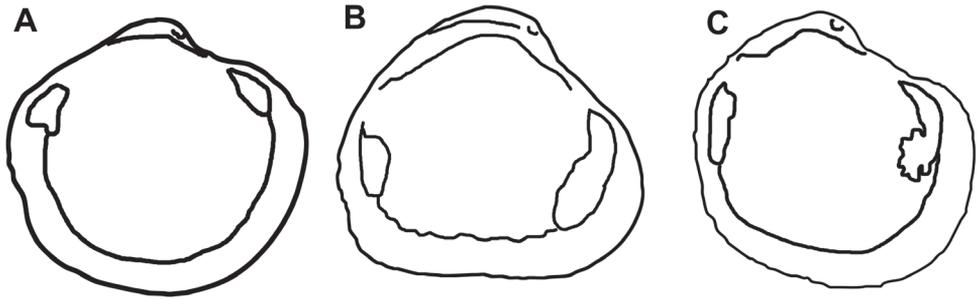


Figure 7. Comparison of adductor muscle scars and pallial lines of left valves of holotypes. **A** *Maorithyas marama*, holotype **B** *Wallerconcha sarae*, holotype **C** *Spinaxinus sentosus*, holotype. – Not to scale.

mise this is a fossil species. However we cannot discount that it could still be living in the region.

Other specimens examined. Piston core: ESC 004112, Core 1P1, section 4, 15 cm, 4.65 mbsf (articulated specimen; frozen for further analysis), ECS 004137, Core 1P1, section 3, 31 cm, 181 mbsf (one articulate specimen (holotype Figure 3A–G), three larger fragments), ESC 004242, 1P1, sec. 1, 52 cm, 0.52 mbsf (one left valve), ESC 004242, 1P1, sec. 1, 52–54 cm, 0.53 mbsf (seven large fragments), ECS 004242, 1P1, sec. 1, 52–54 cm, 0.53 mbsf (one fragment). Gravity Core: ESC 004115, Core 1GB1, 0.02 mbsf (left valve; used for chemical analysis), ESC 004122, 1GB1, 102 cm, 1.02 mbsf (one small left valve), CS 004180, Core 1GB1, 44 cm, 0.44 mbsf (one articulate specimen, one left valve, two fragments). EESC 004257, Core 1TC1, section 1, 72 cm, 0.72mbsf (two larger fragments).

Comparisons

The new species has shell characteristics closest to “*Maorithyas*” *hadalis* Okutani et al., 1999 (Figures 6A–H), collected from over 7,000 m in the Japanese Trench. *Wallerconcha sarae* is much more inflated, has broader umbones, and a much longer ligament and nymph. When compared to *M. hadalis*, *W. sarae* has a much larger, broader, and more elongate anterior adductor muscle scar.

There are also similarities between *Wallerconcha sarae* and members of the genus *Spinaxinus* Oliver & Holmes, 2006. However, all of the currently described species in this genus have a minutely spinose periostracum. The eastern Atlantic *S. sentosus* (Figures 4A–D) is less inflated than *W. sarae*, has narrower beaks, and a smaller anterior adductor muscle scar (Figure 7C). *Spinaxinus emicatus* Oliver in Oliver et al., 2013, from the Gulf of Mexico is compressed and circular in outline, has narrow beaks, an evident radial sulcus, and a much shorter nymph when compared to *W. sarae*. The Fijian *S. phrixicus* Oliver in Oliver et al., 2013, is also compressed and circular in outline with narrow beaks, but it has a distinctive shell sculpture of commarginal ridges.

The minute deep-water Beaufort Sea thyasirid, *Axinulus careyi* is much smaller (maximum length 2.7 mm), has a more defined escutcheon, and lacks the broad posterior hinge plate. It also has a relatively short, narrow anterior adductor muscle scar when compared to the long broad scar of *W. sarae*.

Axinus grandis (Verrill & Smith in Verrill, 1885) and *A. cascadiensis* Oliver & Holmes, 2007 have a few external similarities to *Wallerconcha sarae*. *Axinus grandis* is an Atlantic and Mediterranean species, that is easily separated from *W. sarae* by its roughly diamond-shaped shell outline. *Axinus cascadiensis* is known only from a seamount off Oregon (Oliver and Holmes 2007) and the shell outline serves to separate *A. cascadiensis* from *W. sarae*. With *A. cascadiensis* being less inflated, having narrower, more prosogyrate umbos, and a strong anterior protrusion. In addition, the escutcheon of *A. cascadiensis* is larger and more deeply impressed.

The Cretaceous fossil *Thyasira becca cobbani* Kauffman, 1967 (pl. 5, f. 34, 35; 1969, pl. 127, f. 20) has a deep radial sulcus and narrow, strongly prosogyrate beaks. *Thyasira becca cobbani* is known from the western interior of the North America in the Pierre Shale, Upper Cretaceous (Campanian-Maastrichtian) of Pueblo County, Colorado and in the Riding Mountain Formation, Upper Cretaceous (Campanian-Maastrichtian) exposed along the Assiniboine River, Manitoba, Canada. *Thyasira alaskensis* Kauffman, 1969, described from the Miocene and (or) Pliocene Nuwok Formation Member of the Sagavanirktok Formation on the Alaskan North Slope is easily separated by its more rounded outline, smaller and less prosogyrate umbo, and in having a prominent sulcus, although it is reportedly closely related to *T. becca cobbani* (Kauffman, 1967). Both of these fossil species have narrow hinge plate, narrow, strongly prosogyrate beaks and a deep radial sulcus, all of which excludes them from *Wallerconcha*.

Age

The sedimentation rate in this region, derived from seismic lines in Grantz et al. (2011) showing the depth of the Quaternary section at this approximate location, is estimated to be about 0.5 m per 1000 years. Measured sedimentation rates upslope of our site on the nearby Mackenzie prodelta by Bringué and Rochon (2012) of 1.43 m/1000 years indicates our estimated rates are reasonable. The sedimentation rate suggests that *Wallerconcha sarae* has been continuously present here from about 10,300 years to the near present. The age estimate is derived from the interspersed presence of the *Wallerconcha sarae* specimens from 0.02–5.16 mbsf in our suite of cores, where 5.16 m of sediment corresponds to an accumulation time of 10,320 years. The actual maximum age is likely greater because we have not taken sediment compaction into account, and there is a distinct possibility that *Wallerconcha sarae* is present below the penetration depth of our core samples.

Although we cannot be certain that *Wallerconcha sarae* is extinct, we have used associated specimens to determine the potential age of the deposits where it was collected. The planktic foraminiferan *Neogloboquadrina pachyderma* (Ehrenberg 1861),

a species that has been extinct for 1.8 million years, was collected from the base of the same cores as *W. sarae* at the same depth as the holotype specimen (4.65 mbsf), thus indicating an early Pleistocene age (Wan et al. 2011). A gastropod columella and part of the upper spire of *Neptunea* (Mollusca: Gastropoda: Buccinidae) was found at the Canning Seafloor Mound (ECS004230, Core 1P1, section 2, 31 cm) and associated with *Wallerconcha sarae*. *Neptunea* are predatory snails well represented in the earliest Miocene to Holocene of the northern Pacific and in the late Pliocene to Holocene of the Arctic and northern Atlantic. The presence of *Neptunea* gives a maximum age for these deposits of latest Miocene or early Pliocene, after the opening of the Bering Strait (Marincovich and Gladenkov 1999; Marincovich et al. 2002).

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Four new species of the genus *Saigona* Matsumura (Hemiptera, Fulgoromorpha, Dictyopharidae) from China

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Abstract

Four new species of the genus *Saigona* Matsumura, 1910, *S. anisomorpha* Zheng, Yang & Chen, **sp. n.**, *S. daozenensis* Zheng, Yang & Chen, **sp. n.**, *S. dicondylica* Zheng, Yang & Chen, **sp. n.** and *S. tenuisa* Zheng, Yang & Chen, **sp. n.**, from China, are described and illustrated. A key to the species of *Saigona* is provided.

Keywords

Fulgoroidea, Oriental region, Palearctic region, planthopper, taxonomy

Introduction

The dictyopharid planthopper genus *Saigona* was established by Matsumura (1910) for *Dictyophora* [sic] *ishidae* Matsumura, 1905, from Japan. Recently, Liang and Song (2006) revised this genus and recognized the following 9 valid species: *S. capitata* (Distant, 1914) (Indo-China, S.W. China: Yunnan), *S. fulgoroides* (Walker, 1858) (S. China, Sumatra, Borneo), *S. fuscochlypeata* Liang & Song, 2006 (C. China: Shaanxi, Hubei and Gansu), *S. henanensis* Liang & Song, 2006 (C. China: Henan), *S. latifasciata* Liang & Song, 2006 (S.W. China: Yunnan), *S. robusta* Liang & Song, 2006 (C. China: Hubei), *S. sinicola* Liang & Song, 2006 (C. China: Shaanxi), *S. taiwanella* Matsumura,

1941 (China: Taiwan), and *S. ussuriensis* (Lethierry, 1878) (Russian: Far Eastern Region, Japan, Korea, N.E. China: Jilin, Heilongjiang) (Liang and Song 2006). Subsequently, Zheng and Chen (2011) added a new species, *S. saccus* Zheng, Yang & Chen, 2011 from Guizhou Province, China.

While sorting and identifying Dictyopharidae from material in the Institute of Entomology, Guizhou University (IEGU), we found four new species of *Saigona*, which are herein described and illustrated. The purpose of this paper is to describe these four new species and to provide an identification key to the species of this genus.

Material and methods

The morphological terminology and measurements used in this study follow Liang and Song (2006). The genital segments of the examined specimens were macerated in 10% NaOH and drawn from preparations in glycerin using a light microscope. Figures of the specimens were made using Leica MZ12.5. Spinal formula of hind leg means the numbers of spines of the tibia, the lateral spines spread along the lateral margin, plus the 1st and 2nd tarsomeres.

The following abbreviations are used in the text, BL: body length (from apex of cephalic process to tip of fore wings); HL: head length (from apex of cephalic process to base of eyes); HW: head width (including eyes); FWL: forewing length.

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

Taxonomy

Genus *Saigona* Matsumura, 1910

Saigona Matsumura, 1910: 110; Melichar 1912: 28, 50; Metcalf 1946: 47; Nast 1972: 84; Chou et al. 1985: 63; Anufriev and Emeljanov 1988: 482; Emeljanov 1993: 70; Liang 2001: 235. Type species: *Dictyophora* [sic] *ishidae* Matsumura, 1905 [= *Almana ussuriensis* Lethierry, 1878], by subsequent designation of Melichar 1912: 50; Liang and Song 2006: 28, by comprehensive redescription.

Leptota Melichar, 1912: 91; Metcalf 1946: 74. Type species: *Dictyophora* [sic] *fulgoroides* Walker, 1858, by original designation and monotypy. [Synonymised by Liang and Song 2006: 28.]

Neoputala Distant, 1914: 412; Metcalf 1946: 78. Type species: *Neoputala lewisi* Distant, 1906 [not *Neoputala capitata* Distant, 1914, as stated by Liang 2001: 236]. [Synonymised by Liang 2001: 236.]

Piela Lallemand, 1942: 72. Type species: *Piela singularis* Lallemand, 1942, by original designation and monotypy. [Synonymised by Liang and Song 2006: 28.]

Type species. *Dictyophora* [sic] *ishidae* Matsumura, 1905 (original designation).

Diagnosis. For the relationships and diagnosis of *Saigona* see Liang and Song (2006: 28).

Distribution. China (Yunnan, Guizhou, Guangxi, Guangdong, Sichuan, Hubei, Hunan, Jiangxi, Zhejiang, Fujian, Gansu, Shaanxi, Henan, Taiwan, Jilin, Heilongjiang); Korea; Indochina; Japan; Russia (Far Eastern Region).

Key to species of the genus *Saigona* Matsumura

(Modified from Liang and Song 2006 and updated five species)

- 1 Vertex with cephalic process short, shorter than pronotum and mesonotum combined (Figs 1, 23).....2
- Vertex with cephalic process long, longer than or nearly as long as pronotum and mesonotum combined (Figs 12, 34)7
- 2 Postclypeus yellowish or yellowish brown3
- Postclypeus fuscous.....5
- 3 Mesonotum with a yellowish stripe along median longitudinal carina4
- Mesonotum without a yellowish stripe along median longitudinal carina (Fig. 51)..... *S. dicondylica* sp. n.
- 4 Mesonotum with median longitudinal yellowish stripe narrower; aedeagus with phallobase with apical ventral membranous lobe with numerous, fine spines at apex.....*S. ussuriensis* (Lethierry)
- Mesonotum with median longitudinal yellowish stripe much broader; aedeagus with phallobase with apical dorsal and ventral membranous lobes with numerous, fine spines at apex.....*S. latifasciata* Liang & Song
- 5 Frons with lateral carinae not reaching to frontoclypeal suture.....
.....*S. fuscoclypeata* Liang & Song
- Frons with lateral carinae almost reaching to frontoclypeal suture (Fig. 2)..... 6
- 6 Aedeagus with phallobasal conjunctival processes spiraled dorsally.....
.....*S. henanensis* Liang & Song
- Aedeagus with phallobasal conjunctival processes not spiraled dorsally (Figs 9–11).....*S. anisomorpha* sp. n.
- 7 Cephalic process bulbous apically, with 3 pairs of symmetrical knoblike protuberance on lateral regions8
- Cephalic process not bulbous apically, without knoblike protuberance on lateral regions.....9
- 8 Aedeagus with phallobasal conjunctival processes straight.....
.....*S. saccus* Zheng, Yang & Chen
- Aedeagus with phallobasal conjunctival processes reflexed laterad at apex
.....*S. fulgoroides* (Walker)
- 9 Frons with lateral carinae almost reaching to frontoclypeal suture.....
.....*S. capitata* (Distant)

- Frons with lateral carinae reaching to eyes, not to frontoclypeal suture (Figs 13, 35)..... **10**
- 10 Mesonotum with yellowish stripe along median longitudinal carina very narrow ***S. taiwanella* Matsumura**
- Mesonotum with yellowish stripe along median longitudinal carina broad (Figs 12, 48, 49) **11**
- 11 Posterior margin of pygofer produced into a large process dorsally (Fig. 40)..... ***S. tenuisa* sp. n.**
- Posterior margin of pygofer not produced into a large process dorsally **12**
- 12 Aedeagus with phallobase with apical dorsal and ventral membranous lobes with numerous, fine spines at apex..... ***S. sinicola* Liang & Song**
- Aedeagus with phallobase with apical ventral membranous lobe with numerous, fine spines at apex (Fig. 21) **13**
- 13 Aedeagus with phallobasal conjunctival processes subparallel apically (Figs 20–22)..... ***S. daozenensis* sp. n.**
- Aedeagus with phallobasal conjunctival processes diverging apically ***S. robusta* Liang & Song**

***Saigona anisomorpha* Zheng, Yang & Chen, sp. n.**

<http://zoobank.org/9611A27A-2A7D-4B8C-ACD0-4CC0E2D9C744>

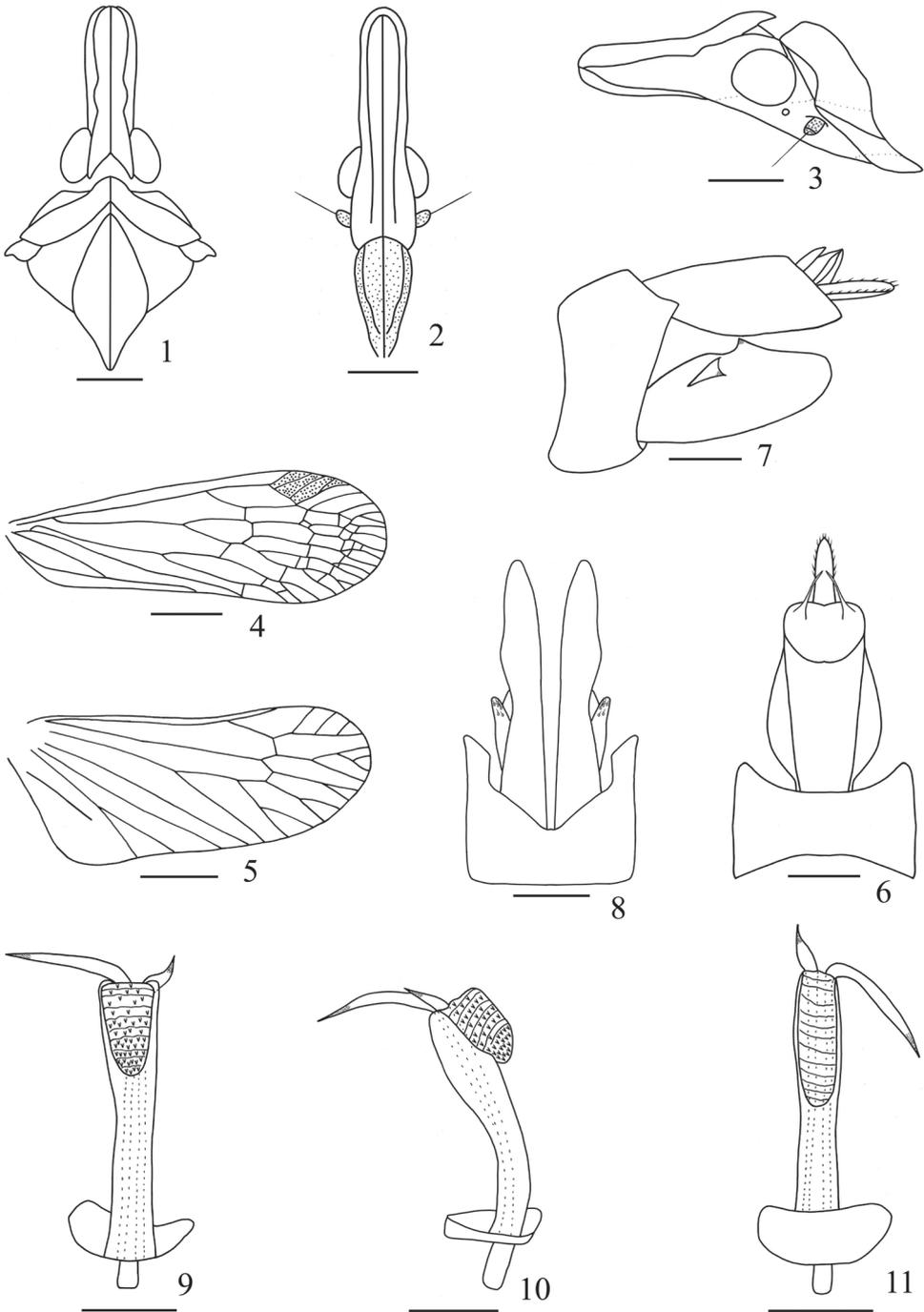
Figs 1–11, 45–47

Description. *Measurement.* ♂, BL: 15.7 mm; HL: 2.4 mm; HW: 1.5 mm; FWL: 11.8 mm.

Coloration. General color brown, marked with fuscous and ochraceous (Figs 45–47). Vertex brown with median carina ochraceous, lateral margins brown. Genae brown, eyes brown, ocellus yellowish, antenna brown and the areas surrounding ocellus and antenna beneath eye yellowish. Frons yellowish. Postclypeus, anteclypeus black. Pronotum pale brown, lateral, ventrally curved areas with a yellowish band. Mesonotum pale brown scattered white spots and yellowish at the apex. Thorax ventrally at the fore femur brown, the other area pale green. Abdomen dorsally dark, with yellowish band on disc, ventrally dark. Forewings venation brown and stigma dark. Legs dark, tibiae with green rings. Genitalia black.

Head and thorax. Head (Figs 1, 45–47) shorter than pronotum and mesonotum combined (0.75:1). Vertex (Fig. 1) with median carina very faint, only conspicuous at apex and base; lateral carinate margins curved. Frons (Fig. 2) with lateral carinae almost reaching to frontoclypeal suture. Mesonotum (Figs 1, 45–47) tricarinate on disc, lateral carinate curved towards media carinate at the front. Forewing (Figs 4, 45–47) longer than widest part (2.85:1), venation as in Fig. 4; hindwing longer than widest part (2.43:1), venation as in Fig. 5. Spinal formula of hind leg 8-12-11.

Male genitalia. Anal tube (Figs 6, 7) large, nearly triangular in lateral view (Fig. 41), large, long, round in dorsal view (Fig. 39), ratio of length to width at middle about 2:1. Pygofer (Fig. 7) large and broad in lateral view, posterior margin with a slightly



Figures 1–11. *Saigona anisomorpha* Zheng, Yang & Chen, sp. n. **1** Head and thorax, dorsal view **2** Frons and clypeus, ventral view **3** Head and pronotum, lateral view **4** Forewing **5** Hindwing **6** Pygofer and anal tube, dorsal view **7** Genitalia, lateral view **8** Pygofer and parameres, ventral view **9** Aedeagus, ventral view **10** Aedeagus, lateral view **11** Aedeagus, dorsal view. Scale bars: **1–5** = 1 mm, **6–11** = 0.5 mm.

sharp process dorsally. Parameres (Figs 7, 8) relatively large, broad in lateral aspect (Fig. 7), apex sharply rounded, protruded posteriorly. Aedeagus (Figs 9–11) with phallobasal conjunctival processes unequal in length, left one obviously longer than right one; phallobase narrow and long, curved dorsally; apical, dorsal, membranous lobe small in lateral view (Fig. 10), and long oval in dorsal view (Fig. 11); apical, ventral, membranous lobe converging towards apex and oval in ventral view (Fig. 9), directed anteroventrally in lateral view (Fig. 10), covered with numerous fine spines and veins.

Type material. Holotype: ♂, **CHINA:** Baiyun Mountain (N34°08', E112°05'), Henan Province, 13 Aug. 2008, X.-H. Hou. (IEGU).

Etymology. This new species is named for its aedeagus with two phallobasal conjunctival processes unequal in length.

Distribution. China (Henan).

Remarks. This species is similar to *S. henanensis* Liang & Song, 2006, but can be distinguished from the latter by its phallobasal conjunctival processes not spiraled at apical 1/5, left one obviously longer than right one; phallobase with apical, dorsal small, with apical, ventral, membranous lobe small, not hook-like in lateral view.

***Saigona daozenensis* Zheng, Yang & Chen, sp. n.**

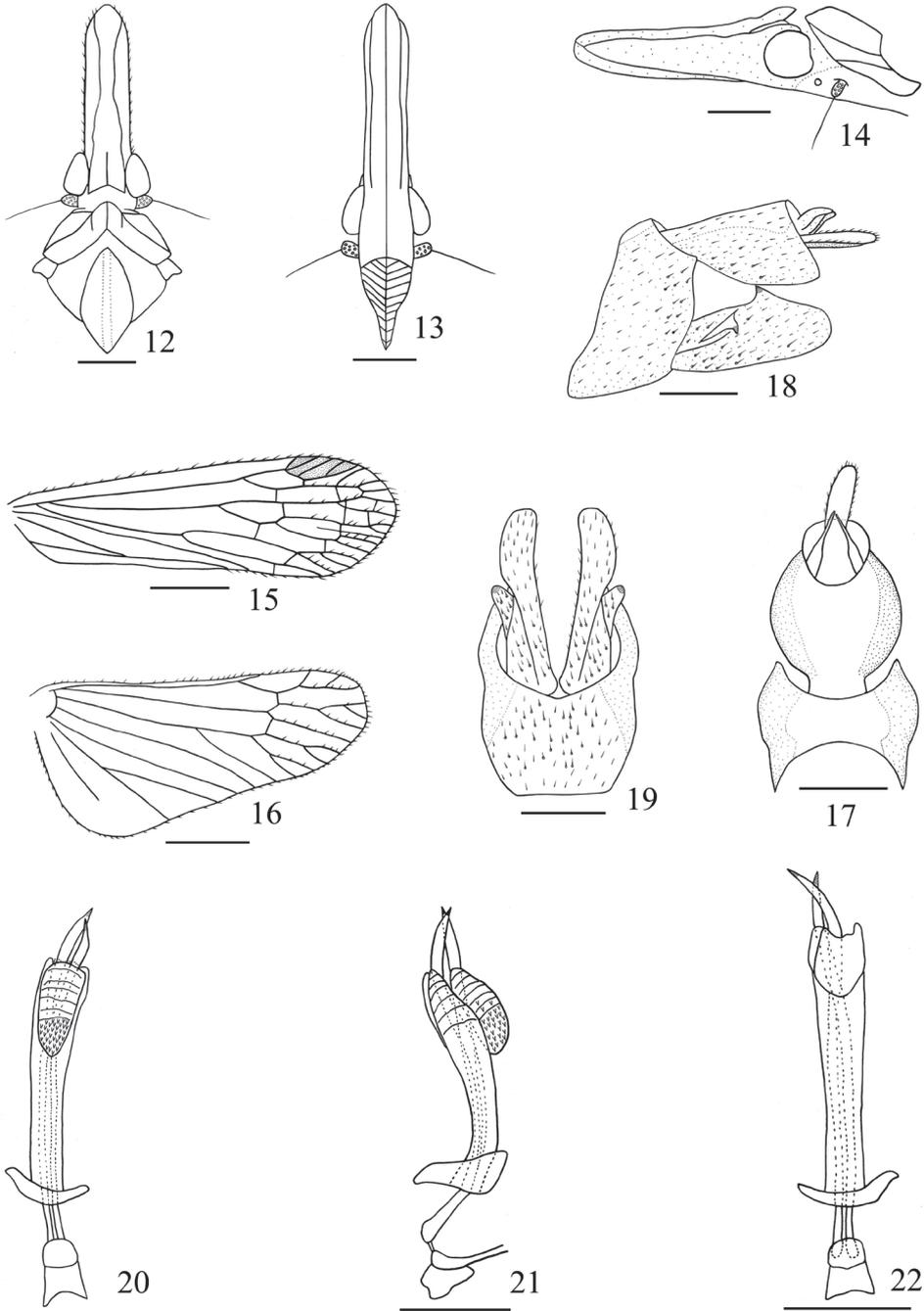
<http://zoobank.org/93A2289B-DD34-4A49-9F76-F307FE229E05>

Figs 12–22, 48–50

Description. *Measurement.* ♂, BL: 15.8 mm; HL: 3.2 mm; HW: 1.5 mm; FWL: 10.5 mm.

Coloration. General color brown, marked with fuscous and ochraceous speckles (Figs 48–50). Vertex brown with lateral carinate black, median carinate ochraceous. Genae brown, eyes brown, ocellus pink, antenna yellowish and the areas surrounding ocellus and antenna beneath eye yellowish. Frons yellowish, the apex of it black and media carina ochraceous. Pronotum brown with median carina yellowish; lateral, ventrally curved areas yellowish. Mesonotum ochraceous, with a narrow, yellow stripe along median longitudinal carina. Thorax ventrally yellowish; abdomen dorsally dark brown, with yellowish brown stripes, ventrally yellowish. Forewings with most veins fuscous, A and Cu yellowish, stigma dark brown. Legs pale yellowish, apex of tibia, digitus, claw pale brown. Pygofer, anal style and anal tube yellowish-brown.

Head and thorax. Head (Figs 12, 48–50) moderately long, longer than pronotum and mesonotum combined (1.18:1). Cephalic process relatively long and robust, somewhat upturned; Vertex (Fig. 12) with median carina very faint, only conspicuous at base, lateral carinate margins curved in front of eyes, disc conspicuous depressed. Frons (Fig. 32) with lateral carinate reaching to the front of eyes, not to frontoclypeal suture. Pronotum (Figs 1, 48–50) with median carina distinct, lateral carinae very faint; mesonotum with median longitudinal carina obsolete. Forewing (Figs 15, 48–50) longer than widest part (3.16:1), venations as in Fig. 15; hindwing longer than widest part (2.20:1), venations as in Fig. 16. Spinal formula of hind leg 8-12-10.



Figures 12–22. *Saigona daozenensis* Zheng, Yang & Chen, sp. n. **12** Head and thorax, dorsal view **13** Frons and clypeus, ventral view **14** Head and pronotum, lateral view **15** Forewing **16** Hindwing **17** Pygofer and anal tube, dorsal view **18** Genitalia, lateral view **19** Pygofer and parameres, ventral view **20** Aedeagus, ventral view **21** Aedeagus, lateral view **22** Aedeagus, dorsal view. Scale bars: **12–16** = 1 mm, **17–22** = 0.5 mm.

Male genitalia. Anal tube (Figs 17, 18) large, nearly triangular in lateral view; large, rounded in dorsal view, ratio of length to width at middle about 1.2:1. Anal style (Figs 17, 18) short, broad. Pygofer (Fig. 18) in lateral view with posterior margin slightly sinuate. Parameres (Figs 18, 19) with one robust spine laterally. Aedeagus (Figs 20–22) with phallobasal conjunctival processes produced posteriorly, asymmetry; phallobase narrow and long, curved dorsally; apical, dorsal, membranous lobe small in lateral view (Fig. 21), without spines; apical, ventral, membranous lobe converging towards apex and semi-oval in ventral view (Fig. 20), directed anteroventrally in lateral view (Fig. 21), covered with numerous fine spines at apex.

Type material. Holotype: ♂, **CHINA:** Sanqiao Town (N28°53', E107°36', 1,300–1,600 m), Daozhen County, Guizhou Province, 22–24 May 2004, X.-S. Chen. (IEGU).

Etymology. The specific name refers to the locality, Daozhen County, Guizhou Province, China.

Distribution. China (Guizhou).

Remarks. This species is similar to *S. robusta* Liang & Song, 2006, but can be distinguished from the latter by its anal tube rounded in dorsal view (oval in *robusta*); phallobasal conjunctival processes produced posteriorly (produced dorsally and ventrally, respectively in *robusta*); phallobase with apical, ventral, membranous lobe small, semi-oval in ventral view (large, triangular in *robusta*).

***Saigona dicondylica* Zheng, Yang & Chen, sp. n.**

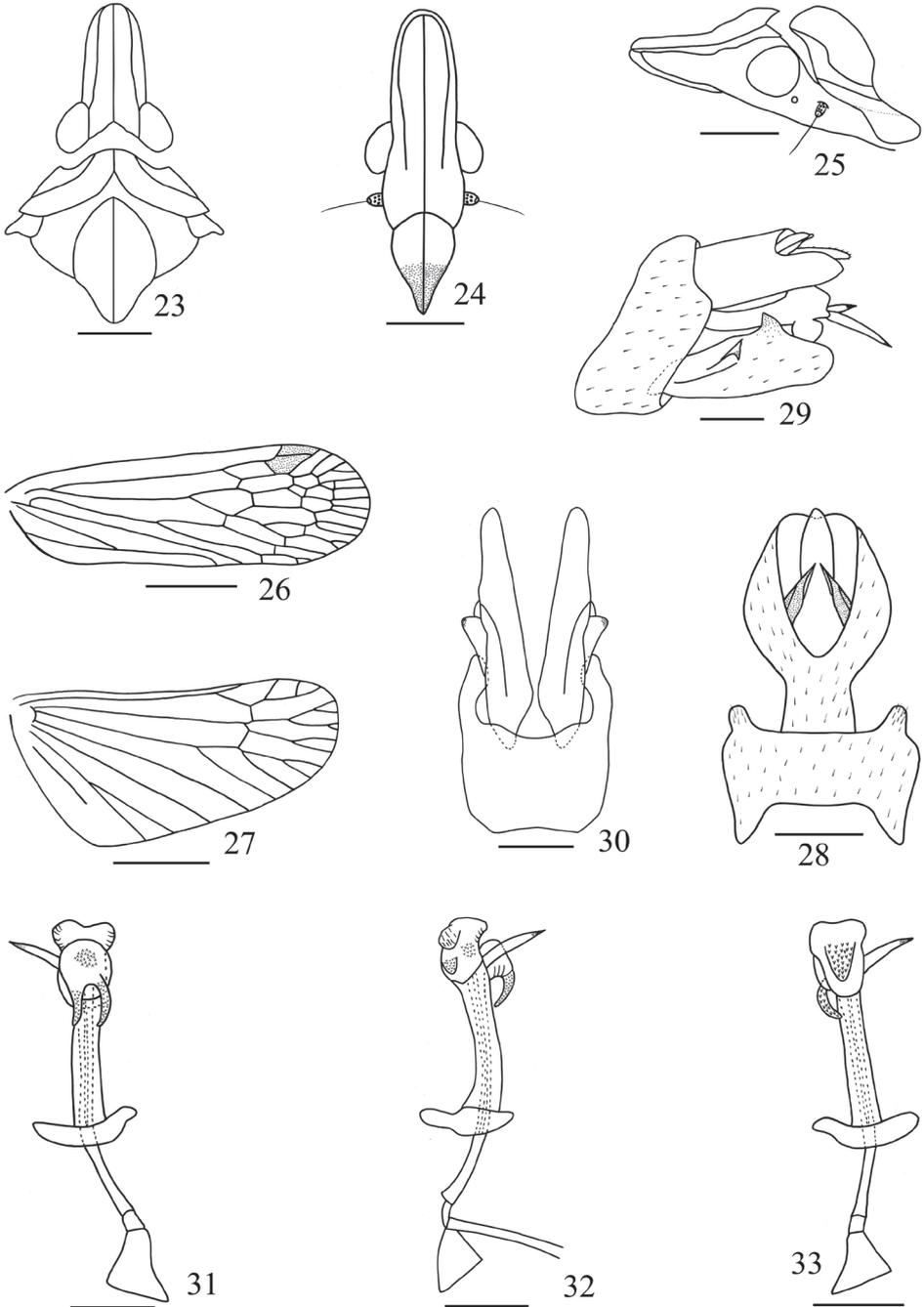
<http://zoobank.org/B185FB7C-239B-4191-8D0A-288F6936ED75>

Figs 23–33, 51–53

Description. *Measurement.* ♂, BL: 12.0 mm; HL: 1.9 mm; HW: 1.4 mm; FWL: 8.5 mm.

Coloration. General color brown, marked with fuscous and ochraceous (Figs 51–53). Vertex dark scattered numerous yellowish spots, median carina ochraceous, lateral carinae and margin dark. Genae brown, eyes brown, ocellus yellowish, antenna dark and the areas surrounding ocellus and antenna beneath eye brown scattered yellowish spots. Frons pale brown with brown spots. Postclypeus, anteclypeus yellowish-brown and the apex black. Pronotum dark scattered brown spots, median carina brown, lateral carinae dark; lateral, ventrally curved areas brown. Mesonotum ochraceous scattered black brown spots. Thorax ventrally dark brown. Forewings with venation and stigma brown. Legs dark with pale brown spots.

Head and thorax. Head (Figs 23–25, 51–53) slightly short and robust, shorter than pronotum and mesonotum combined (0.67:1). Vertex (Figs 23, 51, 52) with conspicuous median carina; disc sunken distinct. Frons (Fig. 24) with lateral carinae reaching to the behind of eyes, not to frontoclypeal suture. Pronotum (Figs 23, 51, 52) with distinct median carina, lateral carinae curved. Mesonotum (Fig. 23) tricarinate on disc, lateral carinae curved towards median carinae at the front. Forewing (Figs 26,



Figures 23–33. *Saigona dicondylica* Zheng, Yang & Chen, sp. n. **23** Head and thorax, dorsal view **24** Frons and clypeus, ventral view **25** Head and pronotum, lateral view **26** Forewing **27** Hindwing **28** Pygofer and anal tube, dorsal view **29** Genitalia, lateral view **30** Pygofer and parameres, ventral view **31** Aedeagus, ventral view **32** Aedeagus, lateral view **33** Aedeagus, dorsal view. Scale bars: **23–27** = 1 mm, **28–33** = 0.5 mm.

51–53) longer than widest part (3.06:1), venations as in Fig. 26; hindwing longer than widest part (2.13:1), venations as in Fig. 27. Spinal formula of hind leg 8-11-11.

Male genitalia. Anal style (Figs 28, 29) short, broad. Anal tube (Figs 28, 29) large, nearly oval in lateral view; long, capitate in dorsal view, ratio of length to width at middle about 1.5:1. Pygofer (Figs 28–30) large and broad in lateral view, posterior margin with a blunt process dorsally. Parameres (Figs 29, 30) relatively long in ventral aspect. Aedeagus (Figs 31–33) with phallobasal conjunctival processes produced dorsally and ventrally, respectively; left one obviously longer than right one; phallobase narrow and long, curved dorsally; apicodorsal membranous lobe large in lateral view (Fig. 32), with two small processes, one covered with numerous fine spines, another not; apicoventral membranous lobe converging towards apex and rounded in ventral view (Fig. 31) with two stout spine-like processes, directed anteroventrally in lateral view, covered with numerous fine spines.

Type material. Holotype: ♂, **CHINA:** Yujun Mountain (N30°04', E101°57', 3,000 m), Kangding County, Sichuan Province, 6 Aug. 1999, G.-D. Ren. (IEGU).

Etymology. This new species is named for its aedeagus having two stout spine-like processes apically.

Distribution. China (Sichuan).

Remarks. This species is similar to *S. ussuriensis* (Lethierry, 1878), but can be distinguished from the latter by its anal tube obviously narrowing at basal third; apicoventral lobe of pallobase with two stout processes at apex; phallobasal conjunctival processes asymmetrical apically.

***Saigona tenuisa* Zheng, Yang & Chen, sp. n.**

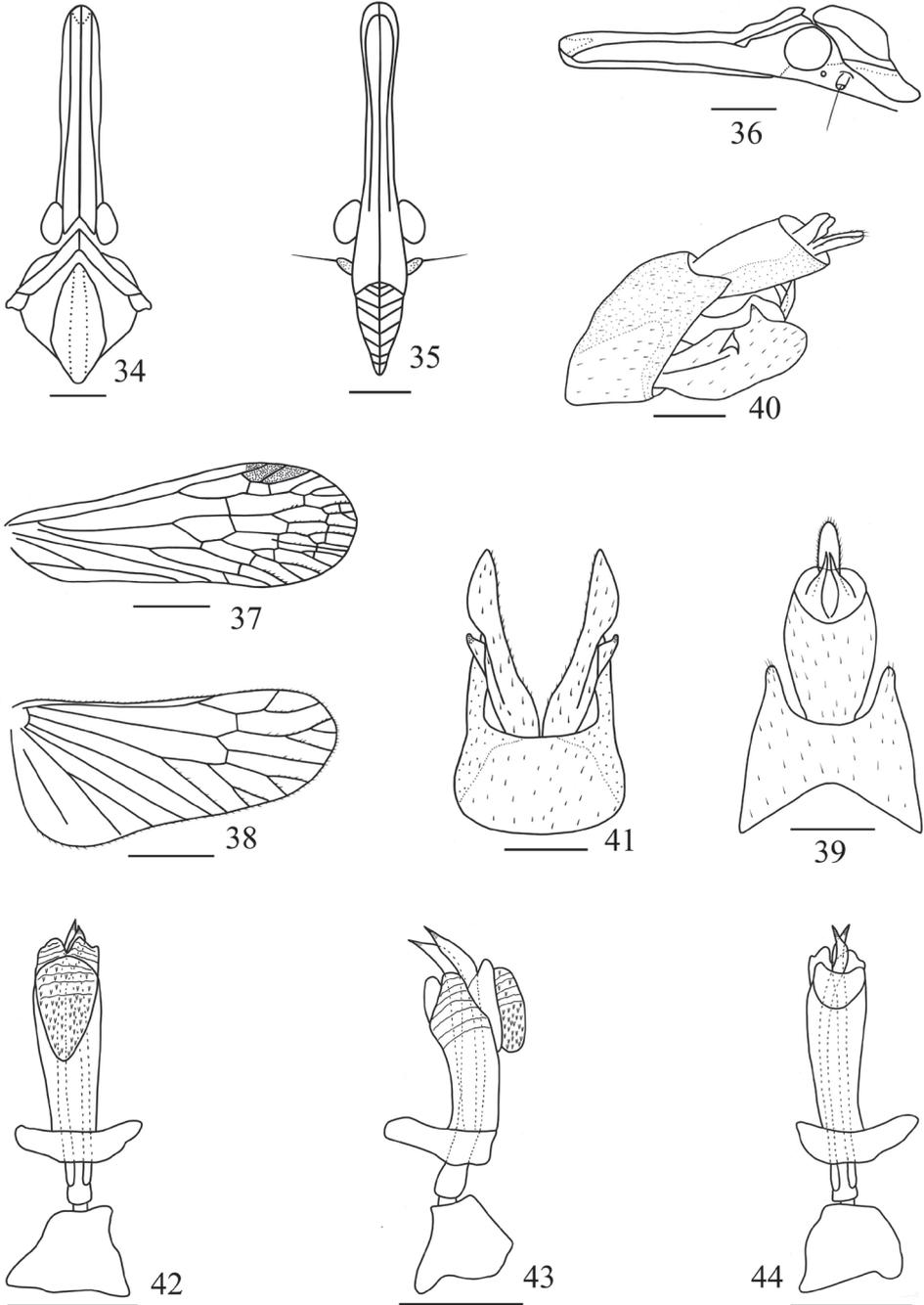
<http://zoobank.org/35594B4E-E88C-4967-890B-DCBE0E61786F>

Figs 34–44, 54–56

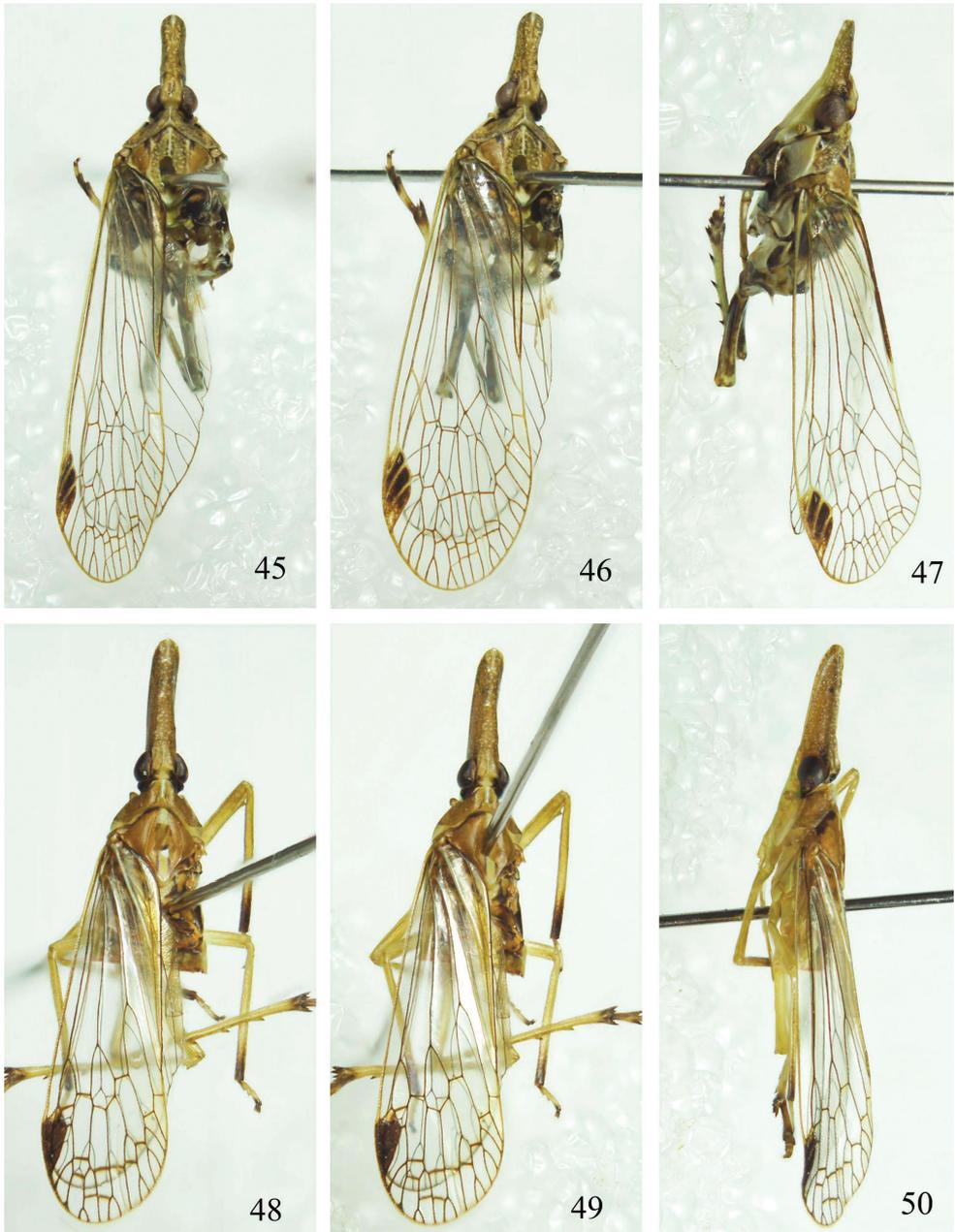
Description. Measurement. ♂, BL: 15.8 mm; HL: 3.9 mm; HW: 1.4 mm; FWL: 9.2 mm.

Coloration. General color dark brown (Figs 54–56). Vertex dark brown marked with fuscous and ochraceous and yellowish spots at apex. Genae pale brown, eyes pale brown, ocellus yellowish, antenna green and the areas surrounding ocellus and antenna beneath eye yellowish. Frons yellowish brown. Postclypeus, anteclypeus and rostrum yellowish. Pronotum and Mesonotum dark brown scattered yellowish spots. Pronotum with median carina yellowish green, lateral, ventrally curved areas yellowish. Mesonotum with a narrow, yellow stripe along median carina. Thorax ventrally yellowish; abdomen ventrally yellowish green, dorsally black with yellowish brown stripe on median carina. Forewings with most veins and stigma dark brown. Legs yellowish green, tibiae with brown ring spots. Genitalia black.

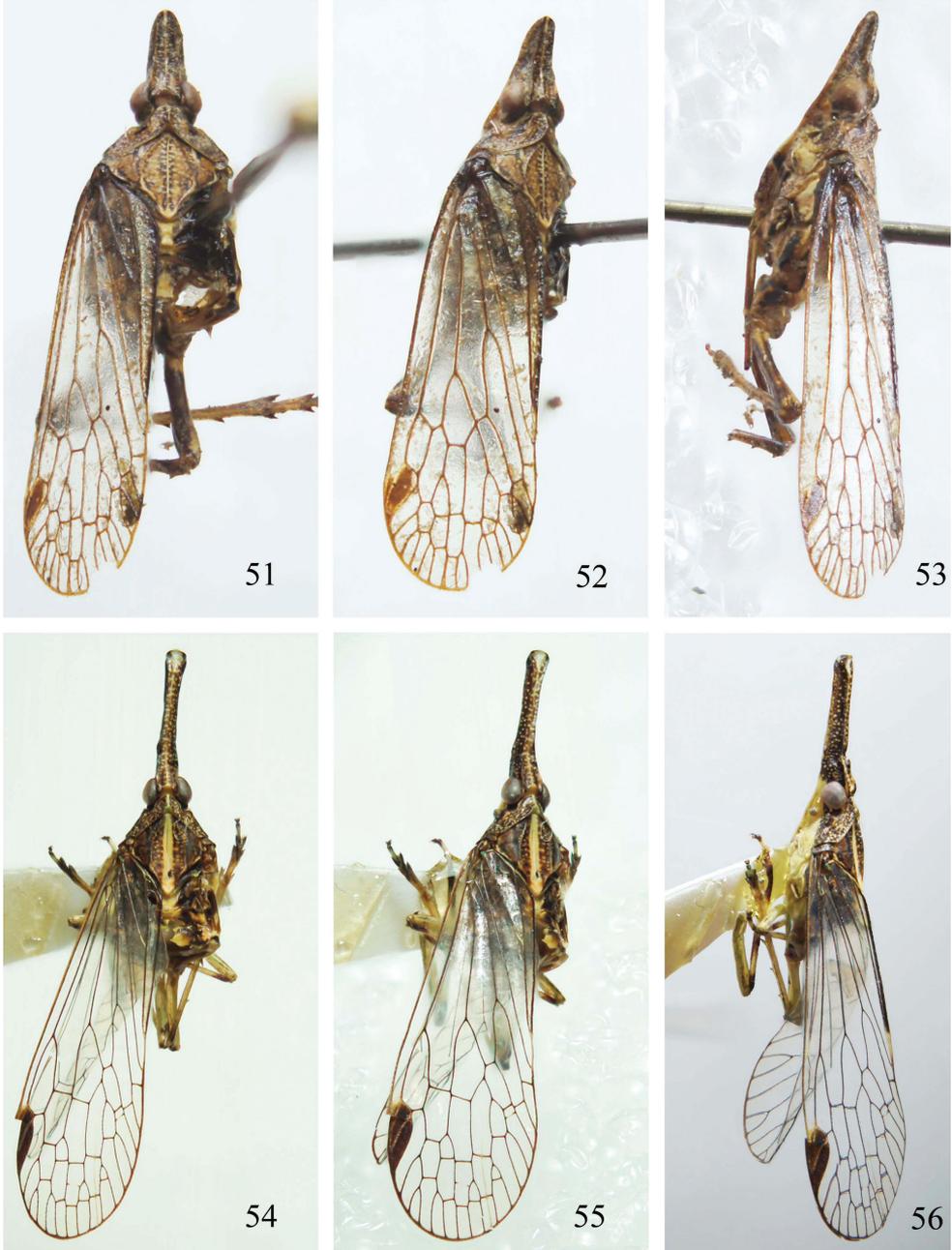
Head and thorax. Head (Figs 34–36, 54–56) very long, longer than pronotum and mesonotum combined (1.36:1). Vertex (Figs 34, 54–56) with median carina complete; cephalic process long and slender, somewhat upturned. Frons (Fig. 35) with lateral carinae reaching to the front of eyes, not to frontoclypeal suture. Pronotum (Fig. 34) with median



Figures 34–44. *Saigona tenuisa* Zheng, Yang & Chen, sp. n. **34** Head and thorax, dorsal view **35** Frons and clypeus, ventral view **36** Head and pronotum, lateral view **37** Forewing **38** Hindwing **39** Pygofer and anal tube, dorsal view **40** Genitalia, lateral view **41** Pygofer and parameres, ventral view **42** Aedeagus, ventral view **43** Aedeagus, lateral view **44** Aedeagus, dorsal view. Scale bars: **34–38** = 1 mm, **39–44** = 0.5 mm.



Figures 45–50. Habitus of *Saigona* species. **45–47** *S. anisomorpha* Zheng, Yang & Chen, sp. n.; **48–50** *S. daozhenensis* Zheng, Yang & Chen, sp. n. (**45, 48** dorsal view; **46, 49** dorsolateral view; **47, 50** lateral view).



Figures 51–56. Habitus of *Saigona* species. **51–53** *S. dicondylica* Zheng, Yang & Chen, sp. n. **54–56** *S. tenuisa* Zheng, Yang & Chen, sp. n. (**51, 54** dorsal view; **52, 55** dorsolateral view; **53, 56** lateral view).

carina distinct, lateral carinae very faint. Mesonotum (Fig. 34) with median longitudinal carina obsolete or inconspicuous, lateral carinae curving anteriorly. Forewing (Figs 37, 54–56) longer than widest part (2.79:1), venations as in Fig. 37; hindwings longer than widest part (2.23:1), venations as in Fig. 38. Spinal formula of hind leg 8-11-11.

Male genitalia. Anal style (Figs 39, 40) short, broad. Anal tube (Figs 39, 40) large, nearly triangular in lateral view; long, oval in dorsal view, ratio of length to width at middle about 1.7:1. Pygofer (Figs 39–41) in lateral view with posterior margin slightly concave, dorsoposterior angle produced into a sharply process. Aedeagus (Figs 42–44) with phallobasal conjunctival processes slightly produced dorsally, symmetrical; phallobase narrow and long, curved dorsally; apicodorsal membranous lobe small in lateral view (Fig. 43); apicoventral membranous lobe large, converging towards apex and coniform in ventral view (Fig. 42), directed anteroventrally in lateral view (Fig. 43), covered with numerous fine spines.

Type material. Holotype: ♂, **CHINA:** Forest Park (N26°35', E106°42'), Guiyang City, Guizhou Province, 19 July 2000, X.-S. Chen. (IEGU).

Etymology. The species name is derived from the Hellenic word “*tenuisa*”, referring to cephalic process slender and long.

Distribution. China (Guizhou).

Remarks. This species can be easily distinguished from other species of *Saigona* by its very long, slender cephalic process.

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We are grateful to Prof. Guo-Dong Ren (Life Science College, Hebei University, Baoding, Hebei, China) and Dr. Xiao-Hui Hou (Institute of Entomology, Guizhou University, Guiyang, Guizhou, China) for collecting valuable specimen. This work was supported by the National Natural Science Foundation of China (No. 31060290, 31093430, 31160163) and the International Science and Technology Cooperation Program of Guizhou (20107005).

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A new replacement name for *Tropidocephala speciosa* Ding, 2006 (Hemiptera, Fulgoromorpha, Delphacidae)

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Abstract

A new replacement name is proposed for the species *Tropidocephala speciosa* Ding, 2006 (Hemiptera: Fulgoromorpha: Delphacidae: Tropidocephalini), preoccupied by *Tropidocephala speciosa* (Bierman, 1908): *Tropidocephala dingi* Sun, Yang & Chen, **nom. n.** = *Tropidocephala speciosa* Ding, 2006. The photographs and illustrations of this species are also provided.

Keywords

Hemiptera, Fulgoroidea, *Tropidocephala*, homonym, replacement name

Introduction

The plant-hoppers species *Tropidocephala speciosa* Ding, 2006 (Hemiptera: Fulgoromorpha: Delphacidae: Tropidocephalini) is found to be preoccupied by *Tropidocephala speciosa* (Bierman, 1908). The purpose of the present paper is to propose a replacement name, based on new material.

Materials and methods

Morphological techniques and terminology follows Ding (2006). Dry specimens were used for the description and illustration. External morphology was observed under a stereoscopic microscope and characters were measured with an ocular micrometer. The genital segments of the examined specimens were macerated in 10% KOH and drawn from preparations in glycerin jelly using a Leica MZ 12.5 stereomicroscope. Photographs of the specimens were taken with a KEYENCE VHX-1000C. Illustrations were scanned with Canon CanoScan LiDE 200 and imported into Adobe Photoshop CS3 for labeling and plate composition.

Specimens examined are deposited in the Institute of Entomology, Guizhou University, Guiyang, Guizhou Province, China (IEGU).

Nomenclatural changes and notes

Tropidocephala dingi Sun, Yang & Chen, nom. n.

Figs 1–12

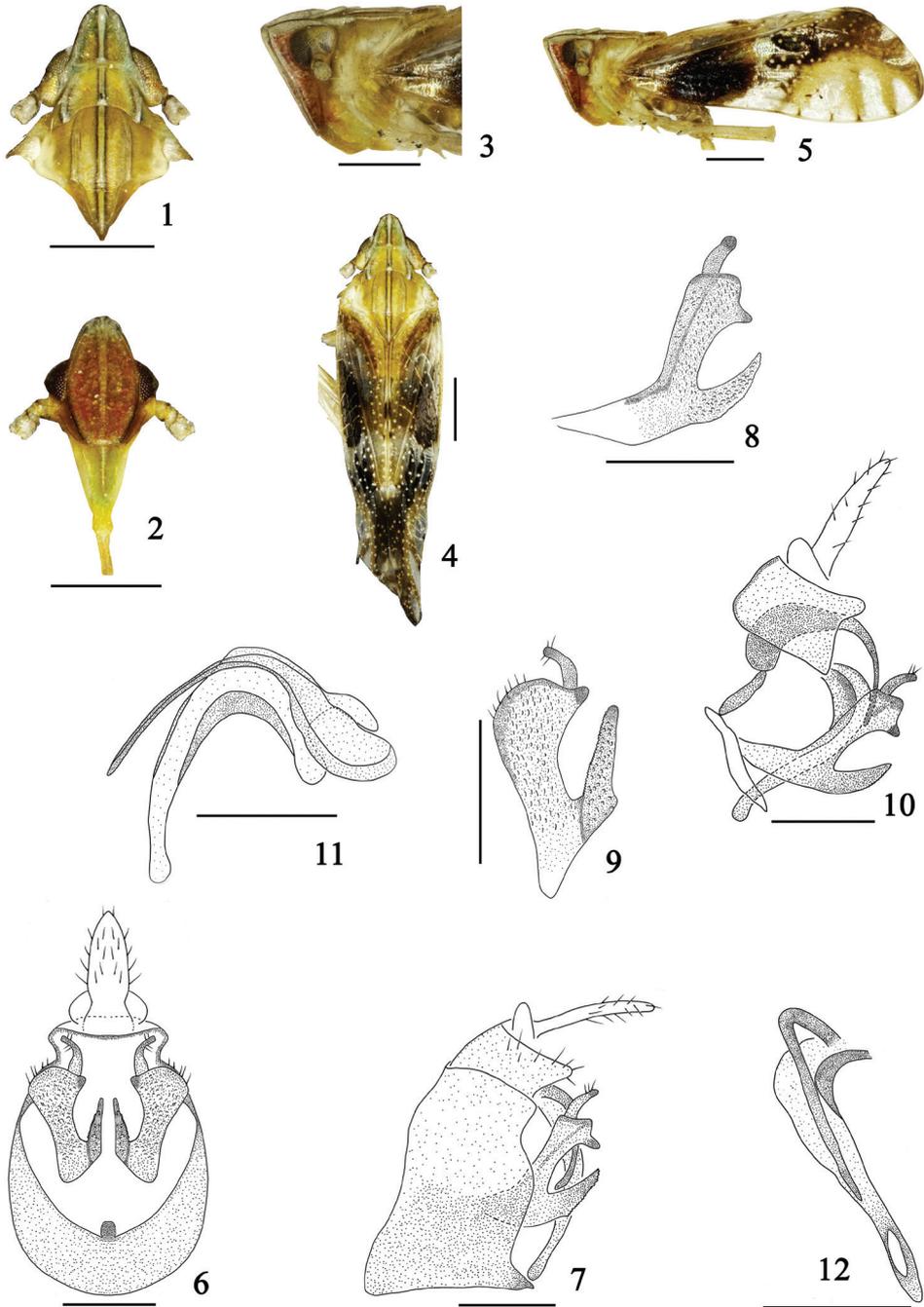
Tropidocephala dingi, nomen novum for *Tropidocephala speciosa* Ding, 2006: 167, preoccupied by *Tropidocephala speciosa* (Bierman, 1908).

Remarks on nomenclatural change. Melichar (1914) transferred *Orchesma speciosa* Bierman, 1908 to *Tropidocephala* as a new combination. Ding (2006) described a new species, *Tropidocephala speciosa*, and failed to recognize the homonym. Thus, the species *Tropidocephala speciosa* Ding, 2006 is a secondary homonym of the species *Tropidocephala speciosa* (Bierman, 1908). According to Article 60 and 57.3.2 of the ICZN, we propose a new replacement name *Tropidocephala dingi* nom. n. for *Tropidocephala speciosa* Ding, 2006.

Etymology. This new name is based on the surname of the author of the junior homonym.

Distribution. China (Hainan and Yunnan Province).

Specimens examined. 1♂1♀, Diaoluoshan National Natural Reserve, Hainan, 9–12 Apr. 2009, X.-H. Hou; 1♂1♀, Bawangling National Natural Reserve, Hainan, 24–28 Apr. 2009, X.-H. Hou; 2♂♂, Bawangling National Natural Reserve, Hainan, 6–7 Jan. 2011, J.-K. Long; 4♂♂2♀♀, Yinggeling National Natural Reserve, Hainan, 17–18 Apr. 2014, H.-Y. Sun; 1♂, Diaoluoshan National Natural Reserve, Hainan, 27 Apr. 2009, H.-Y. Sun.



Figures 1–12. *Tropidocephala dingi* Sun, Yang & Chen, nom. n. **1** head and thorax, dorsal view **2** frons and clypeus **3** head and thorax, lateral view **4** male habitus, dorsal view **5** the same, lateral view **6** male genitalia, posterior view **7** the same, lateral view **8** genital style, lateral view **9** the same, posterior view **10** anal segment, aedeagus and genital style, left lateral view **11** aedeagus, lateral view **12** aedeagus, posterior view. Scale 0.5 mm (Figures 1–5); 0.2 mm (Figures 6–12).

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Revision of the planthopper genus *Nycheuma* Fennah (Hemiptera, Fulgoromorpha, Delphacidae)

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Abstract

Chinese species in the genus *Nycheuma* Fennah, 1964a (Hemiptera: Fulgoromorpha: Delphacidae: Delphacinae: Delphacini) are revised to include three species: *N. cognatum* (Muir, 1917), *N. dimorpha* (Matsumura, 1910) and *N. nilotica* Linnavuori, 1973. *N. coctum* Yang, 1989 is placed in synonymy with *N. nilotica* Linnavuori, 1973. *N. dimorpha* (Matsumura, 1910) is newly recorded from China. The generic characteristics are redefined. The main morphological characters, male genitalia of 3 species are described or redescribed and illustrated. A key to Chinese species in the genus is provided.

Keywords

Hemiptera, Fulgoroidea, Delphacini, *Nycheuma*, synonymy, new record, taxonomy

Introduction

The delphacid genus *Nycheuma* was erected by Fennah (1964a) with *Dicranotropis capensis* Muir, 1926 as its type species. It belongs to the tribe Delphacini within subfamily Delphacinae (Hemiptera: Fulgoroidea: Delphacidae) (Fennah 1964a; Kuoh et al. 1983; Yang 1989; Ding 2006) and is easily separated from other members in this tribe by the following diagnostic features. Head including eyes slightly wider than pronotum. Vertex quadrate, wider at base than long submedially about 1.2:1. Frons median carina forked about level of ocelli. Antennae surpassing the level of frontoclypeal suture. Pronotum lateral carinae not reaching hind margin. Pygofer ventral margin with 3 small medioventral processes (*N. endymion* only 1 and *N. menuis* absent). Aedeagus with a long retrose process at apex (Kuoh et al. 1983; Yang 1989; Ding 2006). This genus is known to occur in the Afrotropical, Indo-Malayan, Australian and Pacific regions. To date, 9 species have been recorded in the worldwide, *Nycheuma afrocognata* Asche (Ivory Coast), *Nycheuma cognatum* (Muir) (Australia, China, Fiji, Philippines, Sri Lanka, West Caroline Is., Bonin Is., New Caledonia), *Nycheuma coronata* Asche (Ivory Coast), *Nycheuma dimorpha* (Matsumura) (Australia, Cape Verde, Italy, Ivory Coast, Nigeria, South Africa), *Nycheuma endymion* (Fennah) (Senegal), *Nycheuma menia* Fennah (Sudan), *Nycheuma menuis* Fennah (Sudan), *Nycheuma nilotica* Linnavuori (Sudan), *Nycheuma sectator* (Fennah) (Cameroon, Sudan: Blue Nile, Umm Banein) (Matsumura 1910; Muir 1917; Fennah 1958, 1963, 1964a, 1964b, 1969; Linnavuori 1973; Asche 1988). But only 2 species have been described in China. Only the host plant of *N. cognatum* is known (*Paspalum orbiculare* G. Forst), most of species in the genus *Nycheuma* feed unknown.

Here, the Chinese species of the genus *Nycheuma* are revised to include three species: *N. cognatum* (Muir, 1917), *N. dimorpha* (Matsumura, 1910) and *N. nilotica* Linnavuori, 1973. *N. coctum* Yang, 1989 is placed in synonymy with *N. nilotica* Linnavuori, 1973. *N. dimorpha* (Matsumura, 1910) collected from Datian National Natural Reserve, Hainan Province, is newly recorded from China. The generic characteristics are redefined. The main morphological characters and male genitalia of 3 species are described or redescribed and illustrated. A key for identifying the Chinese species of *Nycheuma* is also provided.

Material and methods

The methods and morphological terminology used in this study follow that of Yang and Yang (1986) and Ding (2006). The genital segments of the examined specimens were macerated in 10% KOH and drawn from preparations in glycerin jelly using a light microscope. Illustrations of the specimens were made by using Leica MZ 12.5 stereomicroscope and enhanced using Adobe Photoshop 7.0 (Adobe Systems). Spinal formula means the numbers of apical spines of the hind tibiae and 1st and 2nd hind tarsomeres. The type specimens and materials examined are deposited in the Institute of Entomology, Guizhou University, Guiyang, Guizhou Province, China (IEGU).

Taxonomy

Nycheuma Fennah, 1964

Figs 1–36

Nycheuma Fennah, 1964a: 145; Kuoh et al. 1983: 81; Yang 1989: 95; Ding 2006: 247.

Type species. *Dicranotropis capensis* Muir, 1926, by original designation.

Description. The characters used by Fennah (1964a), Kuoh et al. (1983), Yang (1989) and Ding (2006) are modified as follows:

Body size. Macropterous form, body length (including forewing): male 3.20–3.44 mm, female 3.70–4.32 mm.

Coloration. General color light yellowish brown to yellowish brown. Pronotum and mesonotum with carinae and border pale yellowish brown. The terminal of first segment and the base of second segment antennae dark brown (Figs 2, 14, 26). Metapleura with round spot dark brown. Abdomen brown to dark brown. Forewings hyaline, veins dark brown (Figs 3, 15, 27). Hindwings hyaline with veins dark brown.

Head and thorax. Head, including eyes (Figs 1, 13, 25), as wide as pronotum or slightly wider. Vertex quadrate, shorter submedially than wider at base about 1:1.2, moderately rounding into frons, apical margin transverse with submedian carinae moderately prominent, Y-shaped carina feeble, submedian carinae not uniting at apex, basal compartment of vertex wider at base than greatest length about 2.2:1, than medium length about 2.7:1. Frons (Figs 2, 14, 26) in midline longer than wide at widest part about 2.0:1, widest at level of ocelli, lateral margins straight and converging distad beyond this level, median carina forked at base. Postclypeus in profile apical part of median carina bend. Rostrum with apical segment about as long as subapical. Antennae cylindrical, reaching slightly beyond frontoclypeal suture, basal segment longer than wide about 2:1, shorter than second about 1:2 (Figs 2, 14, 26). Pronotum (Figs 1, 13, 25) with lateral carinae not attaining hind margin. Spinal formula of hind leg 5–7–4. Posttibial spur with about 20 teeth.

Male genitalia. Pygofer short dorsally, long and strongly convex ventrally (Figs 5, 17, 29), posterior opening about as long as wide, laterodorsal angle not produced, lateral margins rather feeble, medioventral processes present (3 or 1 small processes) or absent (Figs 7, 19, 31). Diaphragm deeply impressed with dorsal margin membranous (Figs 6, 18, 30). Phallus rather long, laterally compressed, with a long retrose process at apex (Figs 8, 9, 20, 21, 32, 33). Suspensorium in posterior view Y-shaped (Figs 10, 22, 34). Genital styles simple, rather narrow, tapering distally, rectangulately or subacutely bent dorsad, if produced caudad at point of flexure, then lobe narrow and very small, divergent in opposite direction apically (Figs 11, 12, 23, 24, 35, 36). Anal segment of male (Figs 4, 5, 8, 16, 17, 20, 28, 29, 32) short, lateroapical angles widely separated, each produced ventrad in a spinose process.

Host plant. *Paspalum orbiculare* Forst (Ding 2006).

Distribution. Afrotropical, Indomalayan, Australian and Pacific regions.

Remarks. In the genera of Delphacini, this genus is most similar to *Euidopsis* Ribaut, 1948 (with the single species *E. truncata* Ribaut, 1948), but differs in the following: Frons median carina forked level of ocelli (in *Euidopsis*, frons median carina forked above level of ocelli); antennae reaching the level of frontoclypeal suture (in *Euidopsis*, antennae reaching the level of end part of post-clypeus); metatarsal tibial spur with 20 small teeth on lateral margin (in *Euidopsis*, metatarsal tibial spur with 30 small teeth on lateral margin); pygofer ventral margin with medioventral processes (3 or 1) or absent (in *Euidopsis*, pygofer ventral margin with 1 small medioventral process); diaphragm without armature (in *Euidopsis*, diaphragm with 1 armature); aedeagus with 1 long retrose process arising near apex (in *Euidopsis*, aedeagus with 2 long retrose processes arising near apex).

Key to known Chinese species of *Nycheuma*

- 1 Forewing of macropterous male without marking apically; phallus with process on right side near apex (Figs 3, 8) *N. cognatum*
- Forewing of macropterous male with marking apically; phallus with process on right side near middle (Figs 15, 20, 27, 32) **2**
- 2 Pygofer ventral margin with 3 identical medioventral process, all processes in a row (Fig. 31); phallus with processes strong and long (Fig. 33); genital styles inner basal angle moderate and stout (Figs 35, 36) *N. nilotica*
- Pygofer ventral margin with 3 distinct medioventral process, intermediate process shorter than lateral processes, processes not in a row (Fig. 19); phallus with processes slender and short; genital styles inner basal angle obvious and plate-like (Figs 23, 24) *N. dimorpha*

Nycheuma cognatum (Muir, 1917)

Figs 1–12

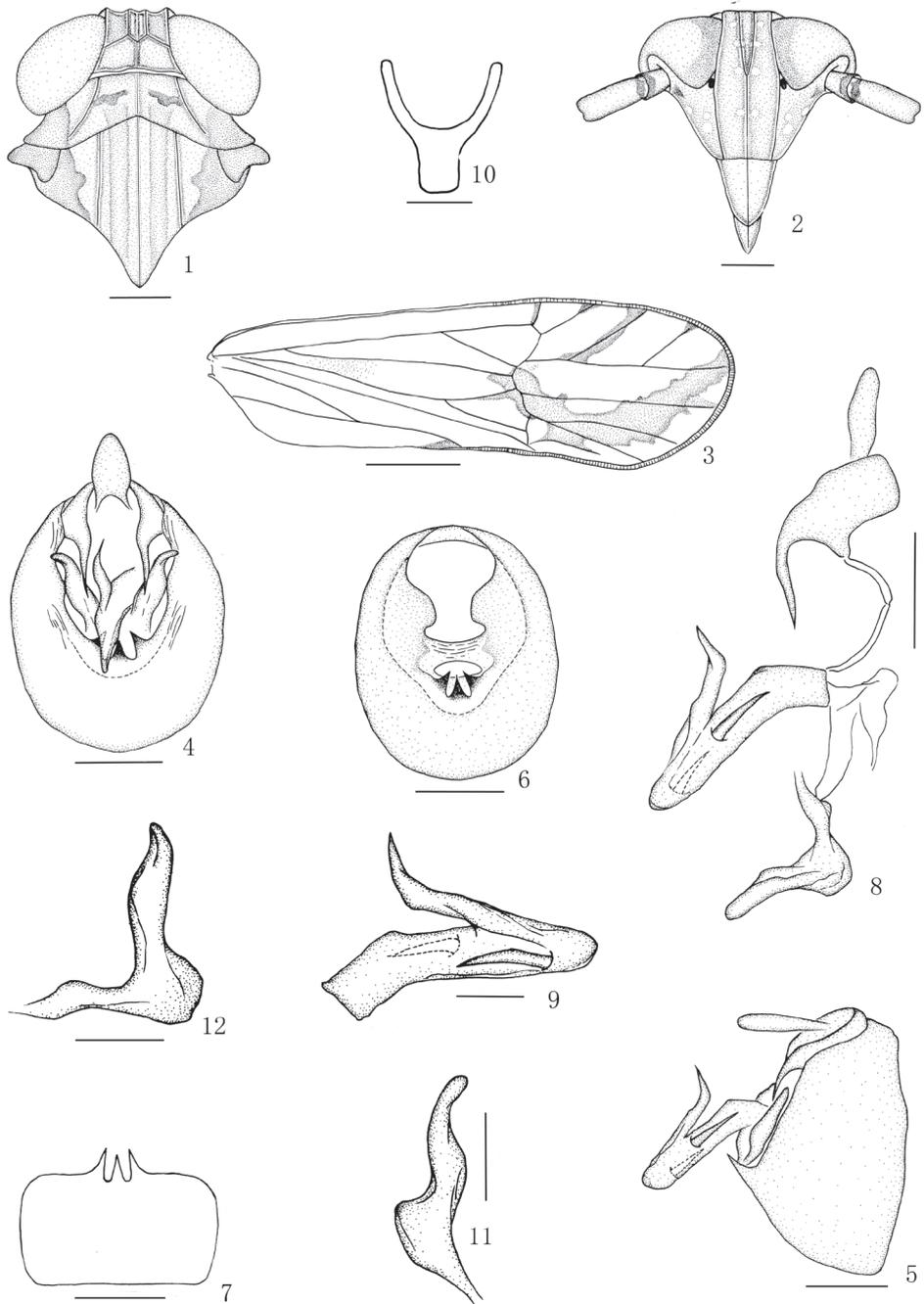
Dicranotropis cognata Muir, 1917: 317.

Nycheuma cognatum (Muir), comb. by Fennah 1964a: 145; see also Fennah 1969: 37; Fennah 1971: 571; Fennah 1973–75: 89; Kuoh et al. 1983: 81; Ding 2006: 249.

Description. Body length including forewing 3.44 mm (male), 3.95 mm (female).

Coloration. General color uniformly brown. Forewing subhyaline, brown, in brachypterous male with a large black marking at apex.

Head and thorax. Vertex (Fig. 1) shorter submedially than wide at base about 1:1.1, Y-shaped carina moderately distinct, basal compartment of vertex wider at base than greatest length about 1.8:1. Frons (Fig. 2) in midline longer than wide at widest part about 2.2:1, widest at level of ocelli. Postclypeus wider at base than frons at apex, slightly wider at base than length in middle line. Rostrum reaching to metatrochanters,



Figures 1–12. *Nycheuma cognatum* (Muir) **1** Head and thorax, dorsal view **2** Frons and clypeus **3** Forewing **4** Male genitalia, posterior view **5** Male genitalia, lateral view **6** Diaphragm of pygofer **7** Pygofer, ventral view **8** Anal segment, aedeagus, connective and genital styles, lateral view **9** Aedeagus, lateral view **10** Suspensorium **11** Genital style, posterior view **12** Right genital style, lateral view. Scale 1 mm (Figure **3**); 0.2 mm (Figures **1, 2, 4–8**); 0.1 mm (Figures **9–12**).

apical segment distinctly shorter than subapical. Antennae (Fig. 2) surpassing level of middle of postclypeus, basal segment longer than wide about 1.7:1, shorter than second about 1:1.8. Post-tibial spur with about 27 teeth.

Male genitalia. Anal segment of male (Figs 4, 5, 8) moderately long, collar-shaped, lateroapical angles very widely separated, each produced caudad and slightly mesad in a stout spinose process. Pygofer in profile (Fig. 5) wider ventrally than dorsally, posterior margin strongly produced caudad medially, in posterior view (Figs 4, 6) with opening small, distinctly wider than long, lateral margin weakly defined, ventral margin shallowly concave, with 3 distinct medioventral processes, middle the longest. Phallus (Figs 8, 9) long, tubular, slightly arched upward medially, reflected cephalad at apex in a flagellum on right side, top of flagellum slightly turned mesad than laterad, pointed at apex, with a large, stout process at middle left and a smaller one near apical fourth right. Orifice terminal dorsad. Suspensorium (Fig. 10) Y-shaped, arms longer than stem. Diaphragm (Fig. 6) rather broad, membranous, triangularly incised dorsally. Opening for genital styles elongate oval. Genital styles (Figs 11, 12) slender, widely divergent, narrowing to apex, inner margin nearly straight, outer margin moderately produced laterad medially.

Material examined. 2 ♂♂, CHINA: Jianfengling National Natural Reserve (18°43'N, 108°53'E), Hainan Province, 17–20 Apr. 2009, collected by X.-H. Hou; 3 ♂♂, CHINA: Bawangling National Natural Reserve (19°05'N, 109°07'E), Hainan Province, 24–28 Apr. 2009, collected by X.-H. Hou; 1 ♂, CHINA: Datian National Natural Reserve (19°06'N, 108°47'E), Hainan Province, 21–23 Apr. 2009, collected by X.-H. Hou; 1 ♂, CHINA: Volcano Park (19°55'N, 110°13'E), Hainan Province, 6–8 Apr. 2009, collected by X.-H. Hou; 1 ♂, 1 ♀, CHINA: Datian National Natural Reserve (19°06'N, 108°47'E), Hainan Province, 9 Jul. 2007, collected by Z.-G. Zhang.

Host plant. *Paspalum orbiculare* Forst.

Distribution. China (Hainan, Taiwan), Philippines, West Caroline Is., Bonin Is., Sri Lanka, New Caledonia, Fiji, Australia.

Nycheuma dimorpha (Matsumura, 1910)

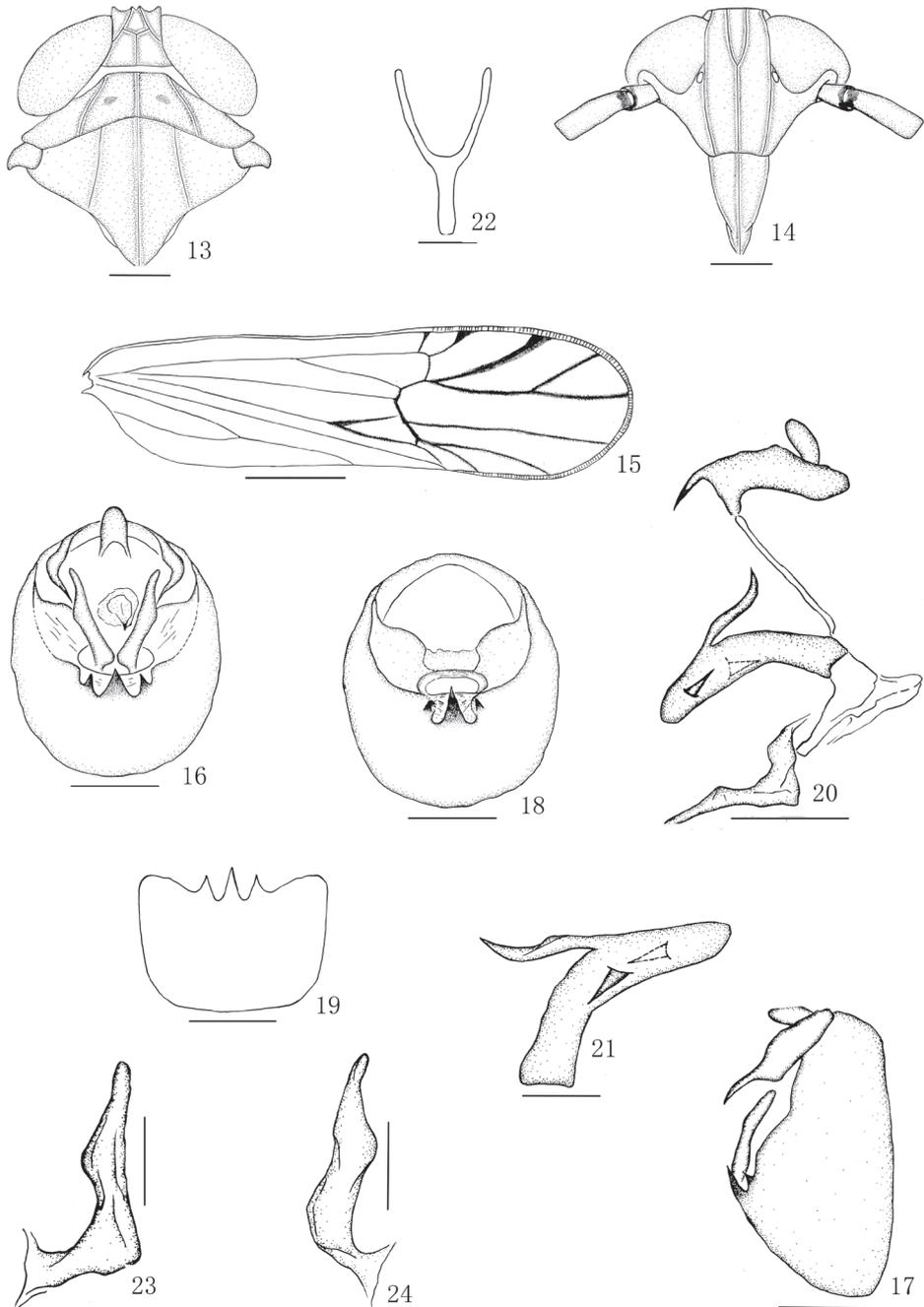
Figs 13–24

Dicranotropis dimorpha Matsumura, 1910: 37.

Nycheuma dimorpha (Matsumura), comb. by Asch 1988: 195.

Description. Body length including forewing 3.20–3.36 mm (male), 4.20–4.32 mm (female).

Coloration. General color dirty yellowish brown to yellowish brown. Vertex, pronotum and mesonotum (Fig. 13) dirty yellowish. Frons and genae (Fig. 14) dirty yellowish brown, with several circular spots light yellowish brown. Clypeus (Fig. 14) dark yellowish brown. Eyes blackish brown, ocelli reddish brown. Antennae general dirty yellowish brown, with apex of scape ring with dark yellowish brown. Thorax with ventral parts light yellowish brown to yellowish brown. Legs with trochanters



Figures 13–24. *Nycheuma dimorpha* (Matsumura) **13** Head and thorax, dorsal view **14** Frons and clypeus **15** Forewing **16** Male genitalia, posterior view **17** Male genitalia, lateral view **18** Diaphragm of pygofer **19** Pygofer, ventral view **20** Anal segment, aedeagus, connective and genital styles, lateral view **21** Aedeagus, lateral view **22** Suspensorium **23** Genital style, posterior view **24** Right genital style, lateral view. Scale 0.2 mm (Figures 13–20); 0.1 mm (Figures 21–24).

light yellowish brown to yellowish brown. Forewings (Fig. 15) hyaline, with apex of irregular spot brown. Abdomen with ventral parts dirty yellowish brown.

Head and thorax. Head including eyes wider than pronotum about 1.1:1. Vertex (Fig. 13) wider at base than long submedially about 1.4:1. Pronotum (Fig. 13) slightly shorter than vertex submedially about 0.8:1. Mesonotum (Fig. 13) longer than pronotum and vertex combined about 1.5:1. Frons (Fig. 14) longer in middle line than wide at widest part about 2.1:1, widest about level of ocelli, lateral carinae nearly straight below ocelli, median carina forked at level of ocelli. Postclypeus (Fig. 14) wider slightly at base than frons at apex, as long as wide at base. Rostrum reaching metacoxae, apical segment distinctly shorter than subapical. Antennae (Fig. 14) reaching frontoclypeal suture, basal segment longer than wide about 1.6:1, shorter than second about 1:2.1. Post-tibial spur with about 26 teeth.

Male genitalia. Anal segment of male (Figs 16, 17, 20) short, moderately, collar-like, lateroapical angles separated and produced into a stout spinose process. Pygofer in profile (Fig. 17) distinctly longer ventrally than dorsally, with laterodorsal angle not produced, in posterior view (Figs 16, 18) with opening as long as wide, lateral margin weakly defined, ventral margin concave, with 3 small medioventral processes, in ventral view pointed at different level. Phallus (Figs 20, 21) large, tubular, apex reflected cephalad at right, turned dorsad near apex, with 2 long, stout processes directed basad, one on apical fifth left, another on apical third right. Suspensorium (Fig. 22) Y-shaped, arms distinctly longer than stem. Diaphragm (Fig. 18) narrow, partly membranous, dorsal margin distinctly concave. Opening for genital styles small, dorsal and ventral margins evenly planus. Genital styles (Figs. 23, 24) moderately long, divergent, slender, wider at base than at apex, inner base angle obvious, inner margin planus, outer margin slightly sinuate, with a nodule-like process nearly middle.

Material examined. 3♂♂, 2 ♀♀, CHINA: Datian National Natural Reserve (19°06'N, 108°47'E), Hainan Province, 12–15 Apr. 2009, collected by X.-H. Hou.

Host plant. Unknown.

Distribution. China (Hainan: Datian).

Nycheuma nilotica Linnavuori, 1973

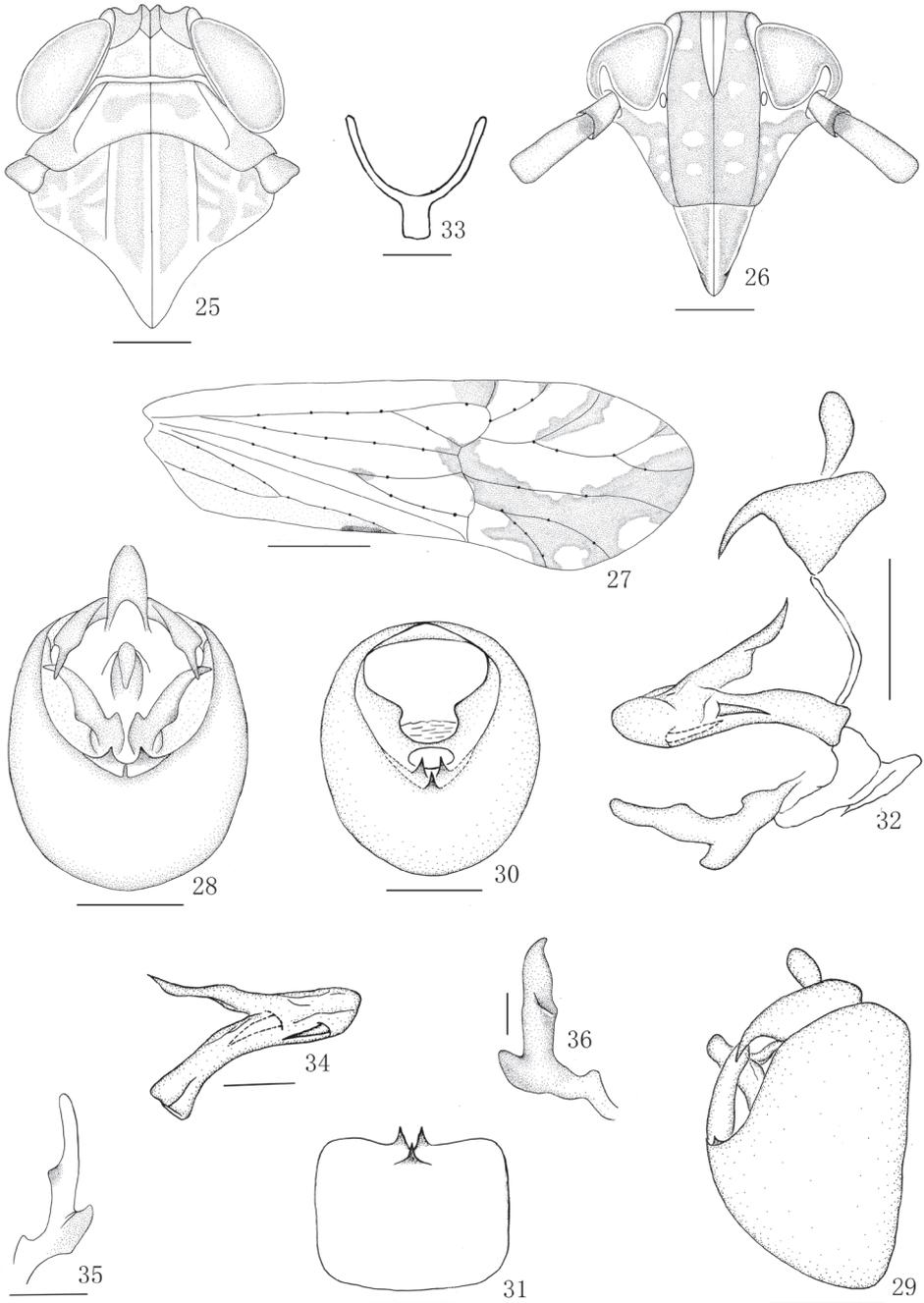
Figs 25–36

Nycheuma nilotica Linnavuori, 1973: 105.

Nycheuma coctum Yang, syn. by Yang 1989: 98; see also Ding 2006: 247.

Description. Body length including forewing 3.28–3.37 mm (male), 3.88 mm (female).

Coloration. General color pale yellowish brown. Apex of first antennal segment and base of second, abdomen and pygofer brown, metapleura with large rounded brown spot. Forewing (Fig. 27) hyaline, with brown marking on hind margin near end of clavus, anterior area of Cu, on ends of Sc₁, Sc₂, wider on R₁, narrower on R_s, oblique area along posteroapical area, reaching to end of M₁ except for 3 hyaline areas.



Figures 25–36. *Nycheuma nilotica* Linnavuori **25** Head and thorax, dorsal view **26** Frons and clypeus **27** Forewing **28** Male genitalia, posterior view **29** Male genitalia, lateral view **30** Diaphragm of pygofer **31** Pygofer, ventral view **32** Anal segment, aedeagus, connective and genital styles, lateral view **33** Aedeagus, lateral view **34** Suspensorium **35** Right genital style, posterior view **36** Left genital style, lateral view. Scale 0.5 mm (Figure 27); 0.2 mm (Figures 25, 26, 28–32); 0.1 mm (Figures 33–36).

Head and thorax. Vertex (Fig. 25) wider at base than long submedially about 1.1:1, at apex as wide as at base, basal compartment at base wider than greatest length about 1.8:1. Frons (Fig. 26) in midline longer than wide at widest part about 2.3:1, widest about level of ocelli, lateral carinae nearly straight below ocelli, median carina forked at level of ocelli. Postclypeus (Fig. 26) wider at base than frons at apex, slightly longer than wide at base. Rostrum reaching metacoxae, apical segment shorter than subapical. Antennae (Fig. 26) reaching frontoclypeal suture, basal segment longer than wide about 1.8:1, shorter than second about 1:2.0. Post-tibial spur with about 26 teeth.

Male genitalia. Anal segment of male (Figs 28, 29, 32) short, collar-shaped, latero-apical angles each produced into a long spinose process, widely separated each other, directed ventrad. Pygofer in profile (Fig. 29) distinctly longer ventrally than dorsally, in posterior view (Figs 28, 30) with opening longer than wide, lateral margins defined, ventral margin shallowly concave with 3 medioventral processes, in ventral view pointed at same level. Phallus (Figs 32, 33) large, tubular, apex reflected cephalad at right, turned dorsad near apex, with 2 long, stout processes directed basad, one on apical fourth left, another near middle right. Suspensorium (Fig. 34) Y-shaped, arms slightly longer than stem. Diaphragm (Fig. 30) not distinctly membranous, dorsal margin slightly concave. Opening for genital styles small, dorsal and ventral margins evenly convex. Genital styles (Figs 35, 36) moderately long, divergent, apical half slightly twisted, turned caudad apically, inner margin slightly sinuate, outer margin shallowly concave at apical half, outer angle pointed.

Material examined. 3 ♂♂, 3 ♀♀, CHINA: Datian National Natural Reserve (19°06'N, 108°47'E), Hainan Province, 10 Jul. 2007, collected by Q.-Z. Song and B. Zhang; 2 ♂♂, CHINA: Sanzhao Yangguangzui (22°16'N, 113°34'E), Guangdong Province, 8 Oct. 2008, collected by X.-H. Hou; 1 ♂, CHINA: Diaoluoshan National Natural Reserve (18°40'N, 109°52'E), Hainan Province, 14 Jul. 2008, collected by H.-R. Li.

Host plant. Unknown.

Distribution. China (Guangdong, Hainan, Taiwan).

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Species delimitation using morphology, morphometrics, and molecules: definition of the *Ophion scutellaris* Thomson species group, with descriptions of six new species (Hymenoptera, Ichneumonidae)

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Abstract

The diverse genus *Ophion* is almost entirely undescribed in the Nearctic region. In this paper we define the *Ophion scutellaris* species group. This species group is well-supported by analysis of DNA (ITS2, COI, and 28S D2-D3) and morphology. It includes the Palearctic species *O. scutellaris* and the Nearctic species *O. idoneus*. An integrative analysis of DNA, geometric wing morphometrics, classical morphometrics and qualitative morphology indicates that this species group contains a minimum of seven species in North America, although the full diversity of the group has likely not been sampled. *O. clave* Schwarzfeld, **sp. n.**, *O. aureus* Schwarzfeld, **sp. n.**, *O. brevipunctatus* Schwarzfeld, **sp. n.**, *O. dombroskii* Schwarzfeld, **sp. n.**, *O. keala* Schwarzfeld, **sp. n.** and *O. importunus* Schwarzfeld, **sp. n.** are described, and a key to the known Nearctic species of the *O. scutellaris* group is provided.

Keywords

Barcoding, geometric morphometrics, Ichneumonidae, integrative taxonomy, molecular taxonomy, *Ophion*, species delimitation

Introduction

Ophion Fabricius is a genus of large nocturnal Ichneumonidae in the subfamily Ophioninae. Most species parasitize medium to large-sized Lepidoptera larvae, especially Noctuoidea (Townes 1971; Brock 1982). Whereas Ophioninae are generally more diverse in the tropics, *Ophion* is most diverse in temperate regions (Townes 1971; Gauld 1985). Gauld (1985) estimated that the Nearctic fauna consists of approximately 50 species, and molecular work suggests the number is much higher (Schwarzfeld and Sperling, in prep.). However only eleven Nearctic species of *Ophion* are currently described (Yu et al. 2012), the most recent of which were described a century ago (Hooker 1912; Morley 1912).

While several species groups of *Ophion* have been proposed (summarized by Gauld 1985), almost all Nearctic species were included within the “*O. luteus* species group”. Gauld (1985) acknowledged that this species group was paraphyletic and defined by plesiomorphies, but not enough was known about the Nearctic species to further subdivide it into monophyletic groupings.

Ophion species are difficult to distinguish morphologically and have a great deal of intraspecific variability (Townes 1971; Brock 1982). Molecular taxonomy has been proposed as a method to accurately delimit and identify species that lack useful morphological characters (Caterino et al. 2000; Tautz et al. 2003; Blaxter 2004). In particular, DNA barcoding, or the sequencing of a standardized 658 bp segment of the mitochondrial cytochrome c oxidase I gene (COI), has been promoted as a method for species discovery, identification and delimitation (Hebert et al. 2003). Among the advantages of COI are its rapid evolution (hence potentially informative at the species level) and presence in multiple copies (hence easily amplified). However, many studies have argued that COI alone is not sufficient to accurately delimit species due to factors such as hybridization, retained ancestral polymorphisms and high intraspecific variability (Funk and Omland 2003; Cognato 2006; Meier et al. 2006; Schmidt and Sperling 2008; Dupuis et al. 2012).

To avoid relying on a single mitochondrial gene, nuclear genes provide an additional data source to evaluate species boundaries (Simon et al. 2006). The internal transcribed spacer of nuclear ribosomal DNA (ITS2) is another rapidly evolving gene that has been successfully used for species delimitation in insects (e.g. Alvarez and Hoy 2002; Hung et al. 2004; Wagener et al. 2006). It too, however, can potentially give misleading results due to high intraspecific or even intra-individual variation (Rich et al. 1997; Harris and Crandall 2000; Li and Wilkerson 2007). It can also be difficult to align accurately due to the presence of numerous insertion-deletion events. A second nuclear gene, the nuclear ribosomal 28S gene is a highly conserved gene that has often been used for higher level insect phylogeny (Caterino et al. 2000), though it has also proved useful in distinguishing species (e.g. Monaghan et al. 2005; Derycke et al. 2008; Raupach et al. 2010). In particular, the D2-D3 expansion region of 28S rDNA is among the most commonly used molecular markers for Hymenoptera phylogenies (e.g. Mardulyn and Whitfield 1999; Dowton and Austin 2001; Laurenne et al. 2006; Quicke et al. 2009; Klopstein et al. 2011).

Quantitative morphometric analyses have been shown to be at least as accurate as molecular analyses in the delimitation of morphologically challenging species, and possibly more so (Lumley and Sperling 2010). Classical (or traditional) morphometrics involves direct measurement of various characters that are then analyzed using multivariate methods (Marcus 1990; Mutanen and Pretorius 2007). This technique is often successful at separating similar species, even when there is overlap between the individual characters (e.g. Lumley and Sperling 2010; Buck et al. 2012). Alternatively, geometric morphometrics analyzes overall changes in shape by using landmarks of homologous structures (Rohlf and Marcus 1993). Insect wings are an ideal subject for geometric morphometric studies, as they are two-dimensional, easily imaged and the venation provides many points that are clearly homologous and straightforward to landmark accurately. Geometric morphometric analysis of wing venation has been used successfully to discriminate species of several complexes of closely related insect species (e.g. Villemant et al. 2007; Tofilski 2008; Francuski et al. 2009; Milankov et al. 2009), but to our knowledge has not yet been used for Ichneumonidae. Although not using geometric morphometrics, two studies show promise for separating closely related Ichneumonidae species based on overall wing venation (Yu et al. 1992; Weeks et al. 1997).

The use of multiple lines of evidence to circumscribe species is often referred to as “integrative taxonomy” (Dayrat 2005; Will et al. 2005; Sperling and Roe 2009; Schlick-Steiner et al. 2010; Dupuis et al. 2012). Our study more closely conforms to the concept of “iterative taxonomy” (Yeates et al. 2011), as we used morphology, multiple genes, geometric morphometrics and classical morphometrics to iteratively assess and evaluate species hypotheses. Specimens were first chosen for sequencing based on the identification of morphospecies. The molecular work identified the species group as a whole, and presented a framework for the relationships of taxa within the group. Putative species were then analyzed morphometrically and re-examined morphologically to assess the validity of the species hypotheses and to refine morphospecies concepts.

In this paper, we define the *O. scutellaris* species group, the first *Ophion* species group to be circumscribed based on both molecular and morphological characters. We then revise the known Nearctic species within this group, including descriptions of six new species.

Methods

Depositories of material examined

- BMNH** The Natural History Museum, London, UK
CNC Canadian National Collection of Insects, Arachnids and Nematodes, Ottawa, Ontario, Canada
CUIC Cornell University, Ithaca, New York, USA
NFRC Northern Forest Research Centre, Edmonton, Alberta, Canada
RBCM Royal British Columbia Museum, Victoria, British Columbia, Canada

- SEMC** Snow Entomological Museum, University of Kansas, Lawrence, Kansas, USA
SFUC Simon Fraser University, Burnaby, British Columbia, Canada
UASM E. H. Strickland Entomology Collection, University of Alberta, Edmonton, Alberta, Canada
UBCZ Spencer Entomology Collection, University of British Columbia, Vancouver, British Columbia, Canada

Recognition of a putative species group and overall approach

This species group was first identified as part of a large-scale taxonomic and phylogenetic study of *Ophion* (Schwarzfeld et al., in prep.). From the sequencing results of several dozen *Ophion* morphospecies, a well-supported clade that included the Palearctic species *O. scutellaris* Thomson was identified (Schwarzfeld et al., in prep.). Morphological comparison showed that several of the characters that define *O. scutellaris*, according to Brock (1982), were characteristic of the group as a whole. Additional characters were recognized based on examination of all specimens recovered within this group. We named the group the *O. scutellaris* species group, after the oldest described species within the group, and used this suite of characters (defined in the Taxonomic Part, below) to locate all specimens within the group from available unsequenced material. We then used an iterative analysis of quantitative morphometrics, morphology, and molecular data to assess all sequenced and unsequenced specimens and to determine species boundaries within this newly-defined species group.

Specimens and sampling

Most specimens were newly collected as part of a large-scale study of Canadian *Ophion*. Out of more than 4000 specimens that were collected from a range of habitats and localities across Canada (primarily from light-traps and Malaise traps), 196 were from the *Ophion scutellaris* species group. We also borrowed 662 specimens of *Ophion* from the following institutions: CUIC, UBCZ, SEMC, RBCM, CNC, NFRC, SFUC; these included 42 specimens from the species group. Five specimens of *Ophion scutellaris* were sequenced from British material provided by G. Broad (BMNH). We examined three of these, while for two specimens, we were sent legs for sequencing but have not seen the specimens.

DNA sequencing

We sequenced one mitochondrial and two nuclear genes for the *O. scutellaris* group: the cytochrome c oxidase I gene (COI), the internal transcribed spacer 2 (ITS2), and the D2-D3 variable region of 28S rRNA. We also sequenced these three genes for eight

species of *Ophion* outside of the target species group; these were chosen to represent the diversity across *Ophion*, based on a large-scale molecular analysis of *Ophion* (Schwarzfeld and Sperling, in prep.). Finally we sequenced one individual of *Enicospilus*, another genus within Ophioninae, as an outgroup. DNA was extracted from a single hind leg using DNeasy Blood & Tissue Kits (Qiagen, Toronto, ON); the final elution volume was 150 μL . We conducted PCR in either 50 μL or 15 μL reactions. The 50 μL reactions contained 4–8 μL genomic DNA, 5 μL 10 \times PCR buffer (containing 15mmol/ μL MgCl_2) (Promega, Madison, WI), 3 μL of 25 mmoles/ μL MgCl_2 (Promega), 1 μL of 10 mmoles/ μL dNTP's (Roche, Switzerland), 1 μL each of 5pmol/ μL forward and reverse primers, 0.5 μL of 5 U/ μL *Taq* polymerase (Fermentation Service Unit, University of Alberta) and 30.5–34.5 μL of autoclaved Millipore water. The 15 μL reactions used 4–8 μL DNA, 1.5 μL PCR buffer, 0.9 μL MgCl_2 , 0.3 μL each of dNTP's, forward and reverse primers, 0.15 μL *Taq* and 3.55–7.55 μL water (all concentrations as above). All PCR products were purified using ExoSap-IT (USB Corporation, Cleveland, OH), and were sequenced using BigDye Terminator version 3.1 cycle sequencing kit (Applied Biosystems, Foster City, CA), followed by ethanol precipitation. Sequencing reactions were run on an ABI Prism 3730 DNA analyser. Sequences are deposited in NCBI GenBank, and Genbank accession numbers are listed in Appendix 1.

To sequence COI, we used the primers lco hym (5'–CAA ATC ATA AAG ATA TTG G–3') and hco out (5'–CCA GGT AAA ATT AAA ATA TAA ACT TC–3') (Schulmeister 2003), which produce a fragment equivalent to the “barcode” region (Hebert et al. 2003); in *Ophion*, this region is 676 base pairs in length. PCR conditions were: 94° for 2 min, 35 cycles of 94° for 30 s, 45° for 30 s, 72° for 2 min, and a final extension at 72° for 5 min. Alignment was unambiguous, and was confirmed by translating nucleotides to amino acids in Mesquite (Maddison and Maddison 2011). We sequenced COI for 30 Nearctic and 5 Palearctic specimens within the *O. scutellaris* group (Appendix 1).

We analyzed ITS2 using the primers ITS2-F (5'–GGG TCG ATG AAG AAC GCA GC–3') and ITS2-R (5'–ATA TGC TTA AAT TCA GCG GG–3') which anneal to the flanking 28S and 5.8S genes (Navajas et al. 1994). PCR cycling was 94° for 2 min, 35 cycles of 94° for 30 s, 55° for 1 min, 72° for 2 min and a final extension of 75° for 5 min. Sequences were aligned using ClustalW (Larkin et al. 2007), and then were modified by eye in Mesquite. Large numbers of indels and highly divergent sequences made alignment of the *scutellaris* group with the non-*scutellaris* group sequences subjective; however within the *scutellaris* group the alignment was unambiguous. We were not able to successfully sequence ITS2 for *Enicospilus*. Instead *O. minutus* was used as the outgroup, since it was recovered as basal by both the COI and 28S datasets, as well as having morphological characters indicating that it is likely basal within *Ophion* (Schwarzfeld et al., in prep.). The final alignment (including partial 28S and 5.8S) was 1307 base pairs in length. However the alignment for the *O. scutellaris* group, excluding all other specimens, was 996 base pairs long, with individual sequences ranging from 979–992 base pairs. We successfully sequenced 29 Nearctic and 2 Palearctic specimens within the *O. scutellaris* group.

We sequenced the D2-D3 region of 28S rDNA using the following primers: Forward: 5'–GCG AAC AAG TAC CGT GAG GG–3'; Reverse: 5'–TAG TTC ACC

ATC TTT CGG GTC-3' (Laurenne et al. 2006). PCR cycling was 94° for 2 min, 30 cycles of 96° for 15 s, 50° for 30 s, 72° for 30 s and a final extension of 75° for 7 min. Alignment was performed by eye in Mesquite; there were occasional small indels, but generally alignment was unambiguous. The aligned sequences were 725 base pairs in length. We sequenced 8 Nearctic and 1 Palearctic specimen(s) within the *O. scutellaris* group, and also included a single sequence of *O. scutellaris* from GenBank.

Alignments for all three gene regions have been deposited on TreeBASE, and can be accessed at: <http://purl.org/phylo/treebase/phyloids/study/TB2:S16341>.

DNA analysis

All molecular analyses were conducted using MEGA version 5 (Tamura et al. 2011). We conducted both maximum likelihood (ML) and maximum parsimony (MP) analyses for the three genes separately. The maximum parsimony analyses were run using heuristic searches with tree-bisection-reconnection, search level 5. We used all sites, 10 starting trees and set max trees to 1000. The best models for the ML analyses were selected in MEGA, using the Bayesian Information Criterion. The following models were selected: COI: TN93+G+I; ITS2: K2+I; 28S: T92+G. The ML search parameters were subtree-pruning-regrafting, with very strong branch swap filter; we used all sites, and the starting tree was obtained using NJ/BioNJ. The trees were tested using both ML and MP bootstrapping in MEGA. The bootstrap analyses used the same parameters as the tree searches, with 1000 replicates for the ML analysis and 10,000 replicates for the MP analysis. We calculated intra- and interspecific sequence divergences using both the Kimura-2-parameter model and as uncorrected p-distances.

Geometric morphometrics (GM)

We analysed wing morphometrics for 118 specimens (71 female and 47 male; Appendix 1). One sequenced specimen had a missing abdomen, so could not be classified by sex; all other sequenced specimens from the *O. scutellaris* group were included in this analysis, as well as in the classical morphometrics analysis below. The right fore and hind wings were removed at the base, soaked briefly in 95% ethanol, and then temporarily slide-mounted in 95% ethanol. Slides were placed on the pane of a lightbox, and photographed using either an 8 megapixel Nikon Coolpix 8400 or a 7.2 megapixel Sony Cybershot DSC-W80 digital camera. The Nikon camera was mounted on a camera mount at a distance of 3.3 cm from the in-focus wing, and wings were photographed using the macro setting and manual focus. The Sony camera was placed at a distance of 4.0 cm from the wing and photographed using the macro setting and autofocus. Several wings were photographed using both cameras to ensure that the two methods were comparable and we concluded that variability between cameras was negligible compared to the variability between specimens. Once photographed, the wings were glued at the base to a small square of cardstock, and included with the specimen as an extra label.

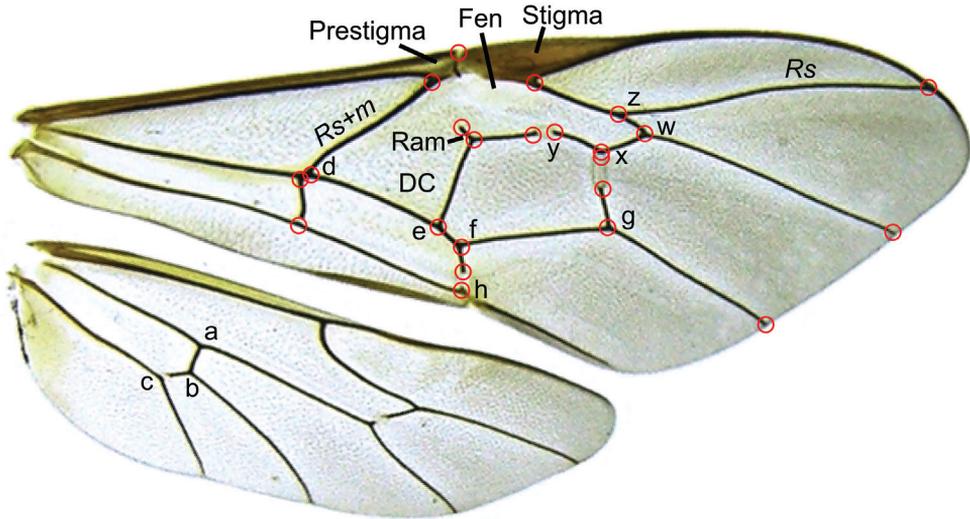


Figure 1. Wing characters used in classical morphometric analysis and in species descriptions. DC = discocubital cell; Fen = fenestra; Ram = ramellus. Wing indices: AI = xy/wz ; CI = ef/fh ; ICI = wz/wx ; SDI = fg/de ; $cu-a = ab/bc$; red circles indicate the locations of the 23 landmarks used for geometric morphometrics.

Only the fore wings were used for the geometric morphometrics. A total of 23 landmarks were digitized in tpsDig version 2.16 (Rohlf 2010) (Figure 1). The landmark data was analyzed in MorphoJ, version 1.03 (Klingenberg 2011). A preliminary analysis showed differences between male and female wings, therefore the sexes were analysed separately. A Procrustes fit was conducted on the male and female datasets to eliminate the variables of position, size and rotation (Rohlf and Slice 1990). We then calculated a covariance matrix of the Procrustes coordinates, and analyzed it using Principal Components Analysis.

Classical morphometrics (CM)

Eighty-four specimens (52 females and 32 males; Appendix 1) and thirteen morphometric variables were included in this analysis. Eleven of these are ratios of measurements: FW/FM; FW/FH; FW/HW; MS/MW; IOD/OL; OOD/OL; SL/SW; M1B/M1S; M1S/M1A; FL/FW; $cu-a$ (see Table 1 for descriptions). The other two variables are fore wing length and number of flagellomeres. We did not use any fore wing characters (aside from length) so that there is no character overlap between this analysis and the geometric morphometric analysis. The use of ratios, rather than direct measurements, was employed to limit the influence of size on the analysis. However we did include two variables that were not size-corrected (wing length and number of flagellomeres). While it is expected that larger individuals will have more flagellomeres, we have included this variable since there is evidence that the number of flagellomeres can nonetheless be useful for discriminating species of *Ophion*, even among individuals of the same size (Brock 1982). Fore wing

Table 1. List of abbreviations for morphological characters included in this study. Abbreviations marked with an asterisk were included in the classical morphometric analysis of the *O. scutellaris* species group.

Abbreviation	Character	Details
<i>Head</i>		
CAW	Clypeus apical width	A straight line across ventral margin of clypeus (Figure 2a)
CH	Clypeus height	At centre of clypeus, from ventral margin to epistomal sulcus (Figure 2a)
F1	Flagellomere 1 length/width	In ventral view at midpoint of flagellomere
F20	Flagellomere 20 length/width	In ventral view at midpoint of flagellomere
Flag*	Number of flagellomeres	For the morphometric analysis, three specimens of <i>O. idoneus</i> (one male and two females) had broken antennae. The number of flagellomeres for each of these specimens was estimated by averaging the number of flagellomeres for all remaining <i>O. idoneus</i> of the respective sex. One female specimen of an unknown species had broken antennae; since the analysis did not allow missing data, the number of flagellomeres was estimated by averaging the number of flagellomeres of all female specimens of a similar size (i.e. excluding <i>O. aureus</i> and <i>O. keala</i>).
FH*	Face height	From the ventral margin of the clypeus to the bottom of the facial tubercle in frontal view (Figure 2a)
FM*	Face maximum width	Widest part of the face between the maximum indentation of the eyes (Figure 2a)
FW*	Face width	Between the inner eye margins at the level of the clypeal foveae (Figure 2a)
GI	Genal inflection	Length of the hypostomal carina between base of mandible and intersection with genal carina (Brock 1982)
HW*	Head width	Across the widest part of the eyes in frontal view (Figure 2a)
IOD*	Interocellar distance	Shortest distance between the posterior ocelli in dorsal view
MS*	Malar space	Shortest distance between the eye and the base of the mandible (Figure 2a)
MW*	Mandible width	Measured at the base (Figure 2a)
OC	Postocellar vertex	Minimum distance between occipital carina and posterior ocellus
OL*	Ocellus length	Maximum length of the posterior ocellus
OOD*	Ocellar-ocular distance	Shortest distance from the eye margin to the deepest part of the sulcus adjacent to the posterior ocellus
<i>Mesosoma</i>		
SL*	Scutellum length	From the base to the apex of the scutellum
SW*	Scutellum width	Across the base of the scutellum between the inner margins of the lateral scutellar carinae
<i>Metasoma</i>		
M1A*	Metasomal segment 1 apical width	The width of the first metasomal segment measured in dorsal view at the apex (Figure 2b)
M1B*	Metasomal segment 1 basal width	The width of the first metasomal segment measured in dorsal view at the base (Figure 2b)
M1S*	Metasomal segment 1 spiracle width	The width of the first metasomal segment measured in dorsal view at the level of the spiracles (Figure 2b)
<i>Legs</i>		
CL	Metacoxa length	Maximum length of metacoxa in lateral view
CW	Metacoxa width	Maximum width of metacoxa in lateral view
FL*	Metafemur length	Midpoint of the base of the hind femur to midpoint of the apex, in lateral view

Abbreviation	Character	Details
FW*	Metafemur width	Maximum lateral width of the hind femur
MT1	Metatarsomere 1 length	In lateral view at midpoint of tarsomere
MT2	Metatarsomere 2 length	In lateral view at midpoint of tarsomere
MTS	Mesotibial spur ratio	Length of shorter spur/Length of longer spur
<i>Wings</i>		
Wing L*	Length of the fore wing	For most specimens, this was measured in ImageJ from the photographs used in the wing geometric morphometric analysis; photographs were calibrated for size using the known size of the coverslip on the slide-mount; for those specimens not photographed for the wing analysis, wing length was measured using a calibrated ocular micrometer
cu-a*	cu-a index of hind wing	Length of <i>cu-a</i> above <i>Cu1</i> /length of <i>cu-a</i> below <i>Cu1</i> (=ab/bc in Figure 1). For most specimens this was measured in ImageJ 1.46r (Rasband 1997–2012) from the photographs taken for the wing geometric morphometric analysis. For those specimens not photographed (11 specimens), this was measured using an ocular micrometer
AI	Alar index of fore wing	Length of <i>1m-cu</i> between bulla and <i>2m-cu</i> /length of <i>3rs-m</i> (=xy/wz in Figure 1)
CI	Cubital index of fore wing	Length of <i>Cu1</i> between <i>1m-cu</i> and <i>Cu1a</i> /length of <i>Cu1b</i> (=ef/fh in Figure 1)
ICI	Intercubital index of fore wing	Length of <i>3rs-m</i> /length of <i>M</i> between <i>2m-cu</i> and <i>3rs-m</i> (=wz/wx in Figure 1)
SDI	Second discoidal index of fore wing	Length of <i>Cu1a</i> between <i>Cu1b</i> and <i>2m-cu</i> /length of <i>Cu1</i> between <i>Rs+M</i> and <i>1m-cu</i> (=fg/de in Figure 1)

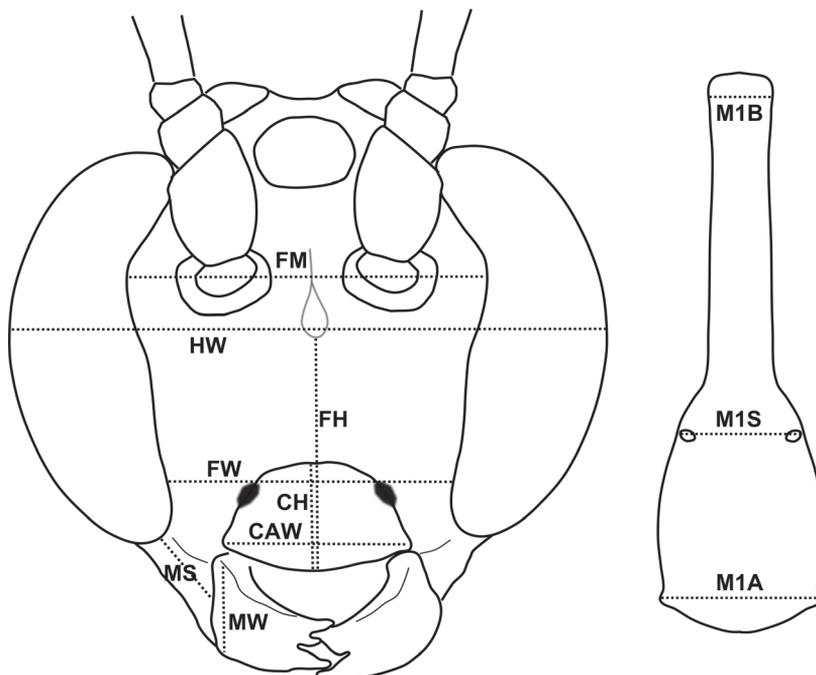


Figure 2. Measurements used in classical morphometric analysis and in species descriptions. **a** Face **b** Metasomal tergite 1, in dorsal view.

length was included since size did seem to be a potential useful discriminating character between species. We conducted Principal Components Analysis of the morphometric data in Ginkgo version 1.7 (Bouxin 2005), with sexes analyzed separately.

Data resources

The data underpinning the analyses reported in this paper are deposited at Canadensys (www.canadensys.net), and are available at <http://dx.doi.org/10.5886/y2bbsq5>.

Results

The *O. scutellaris* species group was well-supported by both molecular and morphological characters, and thus far includes seven Nearctic and potentially two Palearctic species (Figure 3). The Nearctic species are: *Ophion idoneus* Viereck, 1905, *O. clave* Schwarzfeld, sp. n., *O. aureus* Schwarzfeld, sp. n., *O. brevipunctatus* Schwarzfeld, sp. n., *O. dombroskii* Schwarzfeld, sp. n., *O. keala* Schwarzfeld, sp. n. and *O. importunus* Schwarzfeld, sp. n.. The Palearctic species have been tentatively labeled *O. scutellaris* A and *O. scutellaris* B. Briefly, the group can be characterized as early-flying, reddish specimens, lacking extensive yellow markings, with the mid-tibial spurs nearly equal in length. The complete diagnosis and description of the species group is provided in the Taxonomic Part below.

Summary of molecular analyses

Statistics from the molecular analyses are found in Table 2. Maximum likelihood and maximum parsimony analyses gave essentially equivalent results, and there was no conflict between the three genes. Despite the congruence between datasets, we did not include a combined analysis, since the phylogenetic signal from COI was much stronger than in the other two genes. The combined analysis was therefore nearly identical to the COI analysis. Uncorrected p-distances and distances calculated under the K2P model were very similar (Table 3). Throughout the paper we have reported the uncorrected value; if the K2P value differed, we included it in parentheses.

Monophyly of the *O. scutellaris* species group was strongly supported in almost all analyses, with bootstrap support ranging from 72% in the 28S ML analysis to 100% in the ITS2 MP analysis (Figure 3). Only the MP analysis of the 28S data lacked bootstrap support for the species group. Within the species group there was a further strongly supported division into two subgroups (A and B, Figure 3); these two subgroups were recovered by all genes and all analyses, with bootstrap support ranging from 72% (28S MP) to 100% (COI ML). The Palearctic species, *O. scutellaris*, was recovered within subgroup A. The five specimens identified as this species formed a well-supported clade in the COI analysis (ML bootstrap: 99, MP: 95). However there

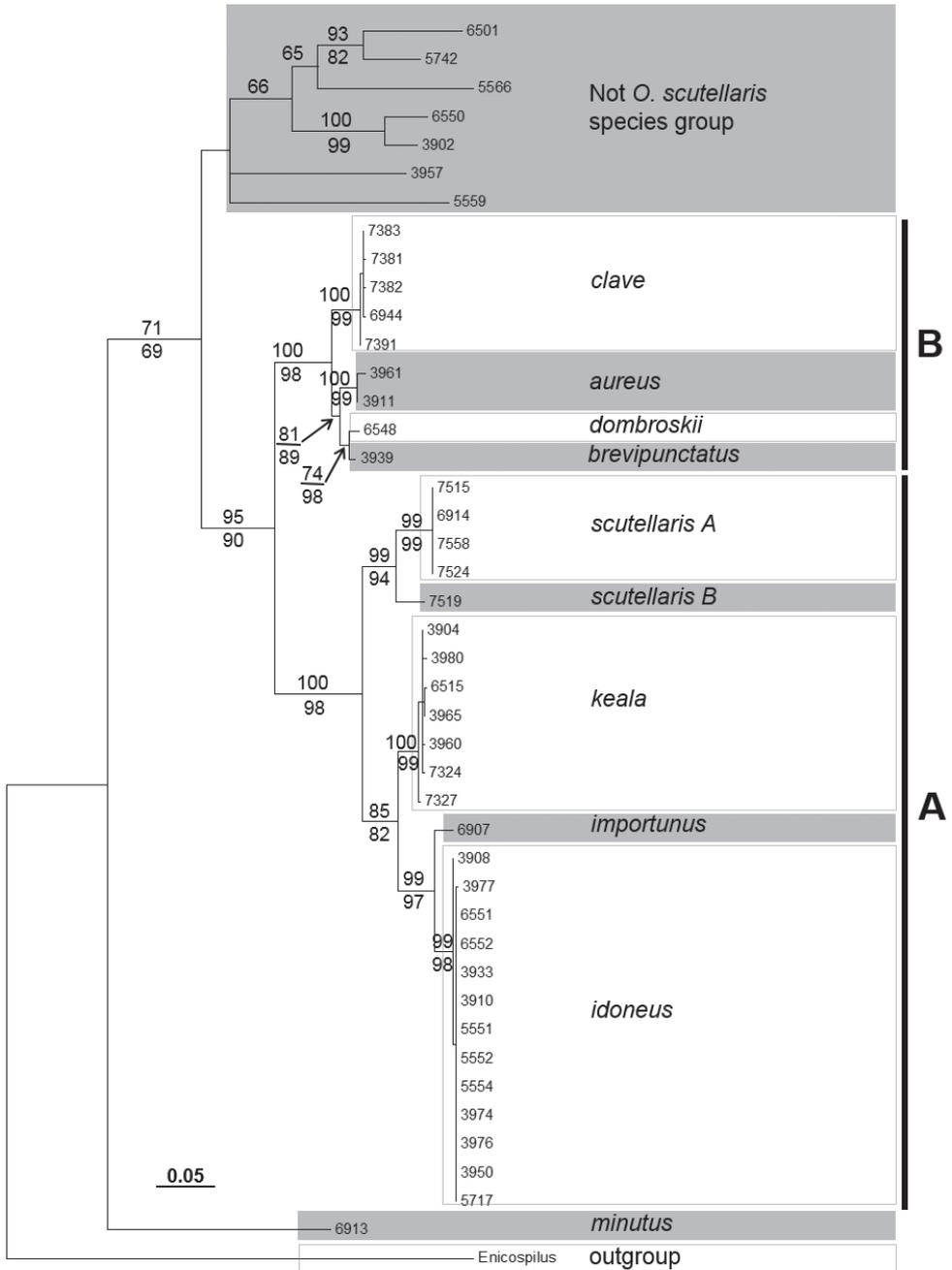


Figure 3a. Maximum likelihood tree of COI sequences. Maximum likelihood bootstrap support values are above branches and maximum parsimony bootstrap values are below branches.

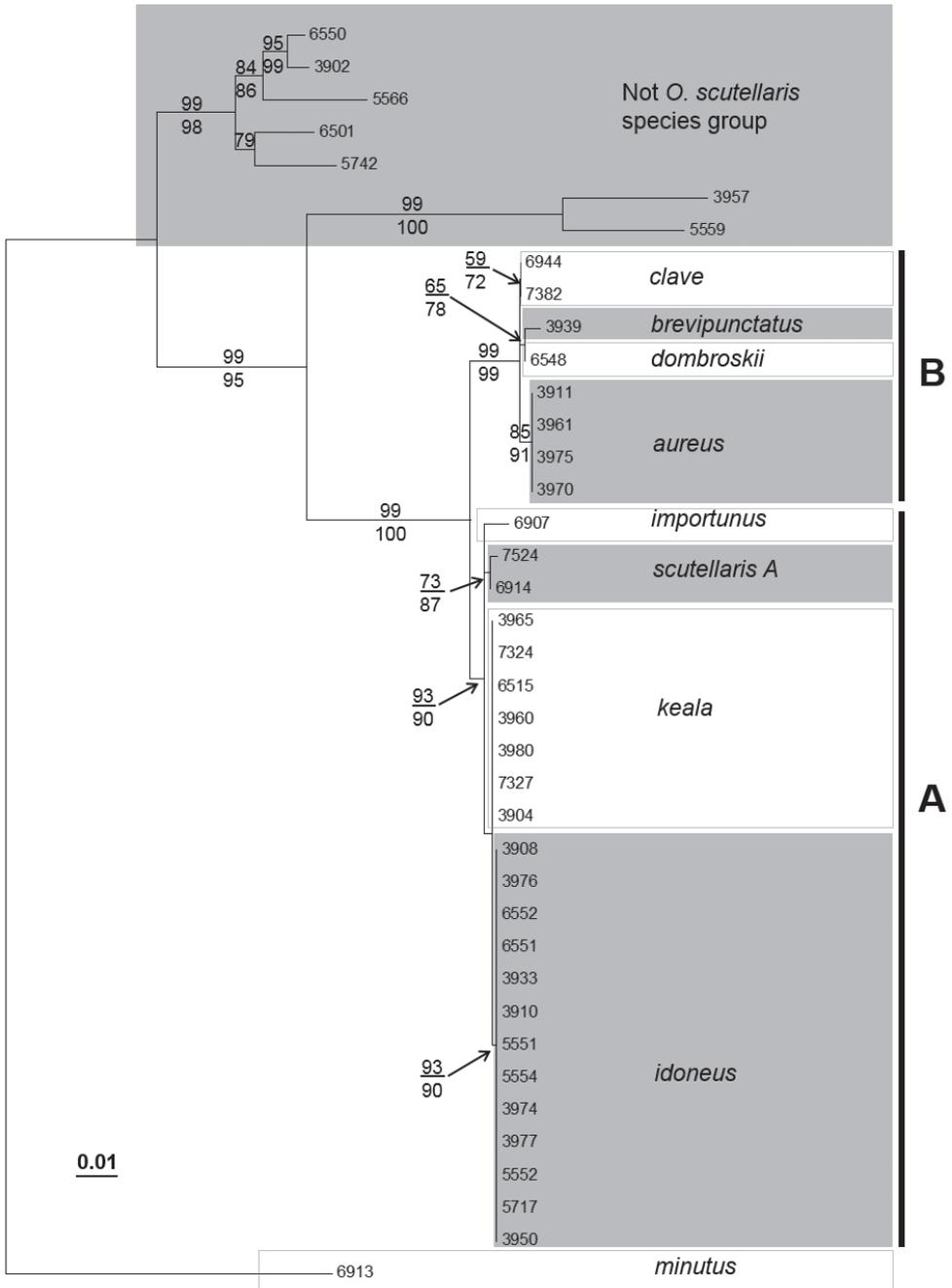


Figure 3b. Maximum likelihood tree of ITS2 sequences. Maximum likelihood bootstrap support values are above branches and maximum parsimony bootstrap values are below branches.

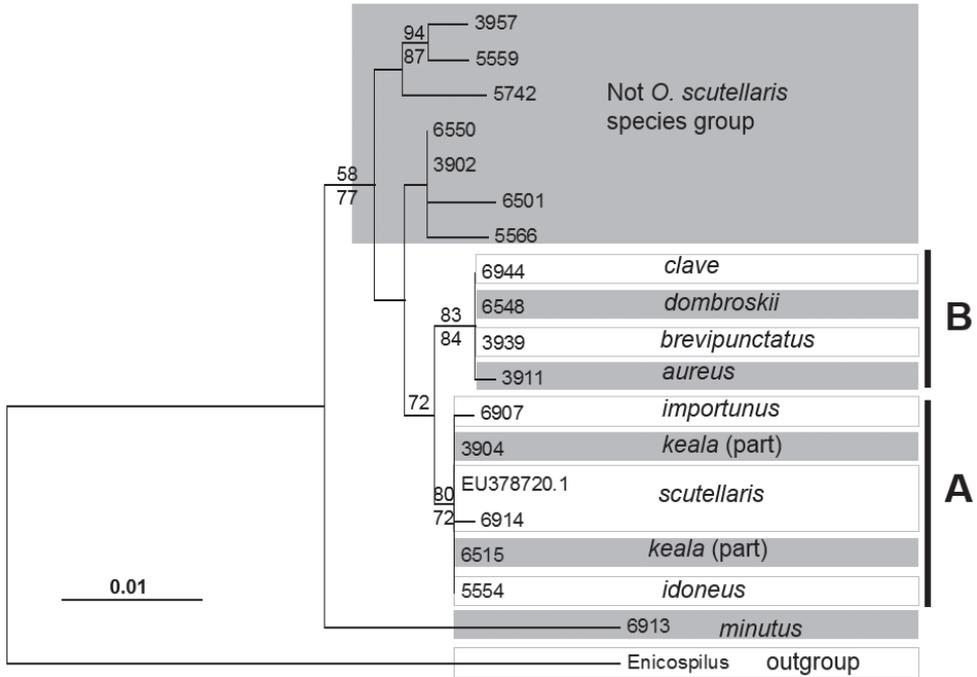


Figure 3c. Maximum likelihood tree of 28S sequences. Maximum likelihood bootstrap support values are above branches and maximum parsimony bootstrap values are below branches.

Table 2. Summary of statistics from maximum likelihood (ML) and maximum parsimony (MP) analyses of COI, ITS2 and 28S genetic markers.

Analysis	Statistics	COI	ITS2	28S
ML	Log likelihood	-3545.81	-4076.72	-1429.26
MP	Tree Length	579	467	75
	No. MP trees	8	10	10
	CI/RI	0.55/0.80	0.90/0.93	0.88/0.78

was also a divergence of 3.6% (K2P: 3.8%) between one specimen (*O. scutellaris* B) and the remaining *O. scutellaris* specimens, which may indicate a previously unrecognized species. Only one of these putative species was sequenced for ITS2.

Sequence divergence within the *O. scutellaris* group was highest in the COI dataset, with a maximum of 9.4% (K2P: 10.1%) sequence divergence within the species group, and 14.8% (K2P: 16.6%) within all included *Ophion*. While ITS2 had a higher sequence divergence overall (17.4%; K2P: 19.9%), the divergence within the *O. scutellaris* species group was only 2.6%. 28S was highly conserved, with a 2.8% (K2P: 2.9%) divergence within all *Ophion*, and 0.7% within the *O. scutellaris* group.

Table 3. Interspecific and intraspecific percent sequence divergence for three genetic markers within the *Ophion scutellaris* species group. Genetic distances calculated with the Kimura-2-parameter model are found above the diagonal, uncorrected p-distances are below the diagonal, and intraspecific distances are along the diagonal. Intraspecific distances and all 28S distances were identical using both models. *aur* = *areus*; *bre* = *brevipunctatus*; *cla* = *clavae*; *dom* = *dombroskii*; *ido* = *idoneus*; *imp* = *importunus*; *kea* = *keala*; *scuA* = *scutellaris* A; *scuB* = *scutellaris* B.

a. COI

	<i>aur</i>	<i>bre</i>	<i>cla</i>	<i>dom</i>	<i>ido</i>	<i>imp</i>	<i>kea</i>	<i>scuA</i>	<i>scuB</i>
<i>aur</i>	0.4	2.0–2.4	2.9–3.7	2.1–2.4	9.5–10.1	9.1–9.6	9.3–10.0	9.0–10.0	8.8–8.9
<i>bre</i>	1.9–2.4	n/a	3.0–3.4	1.0	8.3–8.5	7.7	8.3–8.7	8.8–9.3	8.5
<i>cla</i>	2.8–3.6	3.0–3.3	0.1–0.3	3.2–3.5	9.1–9.7	9.0–9.3	9.2–9.8	9.0–9.6	8.7–9.0
<i>dom</i>	2.1–2.4	1.0	3.1–3.4	n/a	9.5–9.7	8.8	9.2–8.8	9.4–9.8	8.8
<i>ido</i>	8.9–9.4	7.9–8.0	8.6–9.0	8.9–9.0	0–0.3	2.3–2.4	4.6–5.4	6.5–7.6	6.7–7.0
<i>imp</i>	8.6–9.0	7.3	8.4–8.7	8.3	2.2–2.4	n/a	4.8–5.3	6.7–7.6	7.0
<i>kea</i>	8.7–9.3	7.9–8.2	8.6–9.2	8.6–8.9	4.4–5.2	4.6–5.0	0.1–0.7	4.6–5.9	5.4–5.9
<i>scuA</i>	8.5–9.2	8.3–8.7	8.5–9.0	8.8–9.1	6.2–7.1	6.4–7.1	4.5–5.6	0	3.4–3.8
<i>scuB</i>	8.3–8.4	8.0	8.1–8.4	8.3	6.4–6.7	6.7	5.2–5.6	3.3–3.6	n/a

b. ITS2

	<i>aur</i>	<i>bre</i>	<i>cla</i>	<i>dom</i>	<i>ido</i>	<i>imp</i>	<i>kea</i>	<i>scu</i>
<i>aur</i>	0	0.6	0.2–0.3	0.3	2.0–2.1	2.3–2.4	1.9–2.0	1.8–1.9
<i>bre</i>	0.6	n/a	0.5	0.3	2.3	2.6	2.2	2.1
<i>cla</i>	0.2–0.3	0.5	0	0.1	1.8	2.1	1.7	1.6–1.7
<i>dom</i>	0.3	0.3	0.1	n/a	1.9	2.2	1.8	1.7
<i>ido</i>	1.9–2.1	2.2–2.3	1.7–1.8	1.8	0	0.9	0.1	0.4–0.5
<i>imp</i>	2.3–2.4	2.6	2.0–2.1	2.1	0.9	n/a	0.8	0.7–0.8
<i>kea</i>	1.8–1.9	2.1	1.6	1.7	0.1	0.8	0	0.3–0.4
<i>scu</i>	1.7–1.9	2.0–2.1	1.5–1.7	1.6–1.7	0.4–0.5	0.7–0.8	0.3–0.4	0.1

c. 28S; p-distances and K2P distances were identical, and are therefore only reported above the diagonal

	<i>aur</i>	<i>bre</i>	<i>cla</i>	<i>dom</i>	<i>ido</i>	<i>imp</i>	<i>kea</i>	<i>scu</i>
<i>aur</i>	n/a	0.1	0.1	0.1	0.6	0.7	0.6	0.6–0.7
<i>bre</i>	0.1	n/a	0	0	0.4	0.6	0.4	0.5–0.6
<i>cla</i>			n/a	0	0.4	0.6	0.4	0.5–0.6
<i>dom</i>				n/a	0.4	0.6	0.4	0.5–0.6
<i>ido</i>					n/a	0.1	0	0–0.1
<i>imp</i>						n/a	0.1	0.2–0.3
<i>kea</i>							0	0–0.1
<i>scu</i>								n/a

Summary of morphometric analyses

For the geometric morphometric (GM) analysis, approximately 60% of the variation in wing shape could be summarized in the first three principal components (PC). In

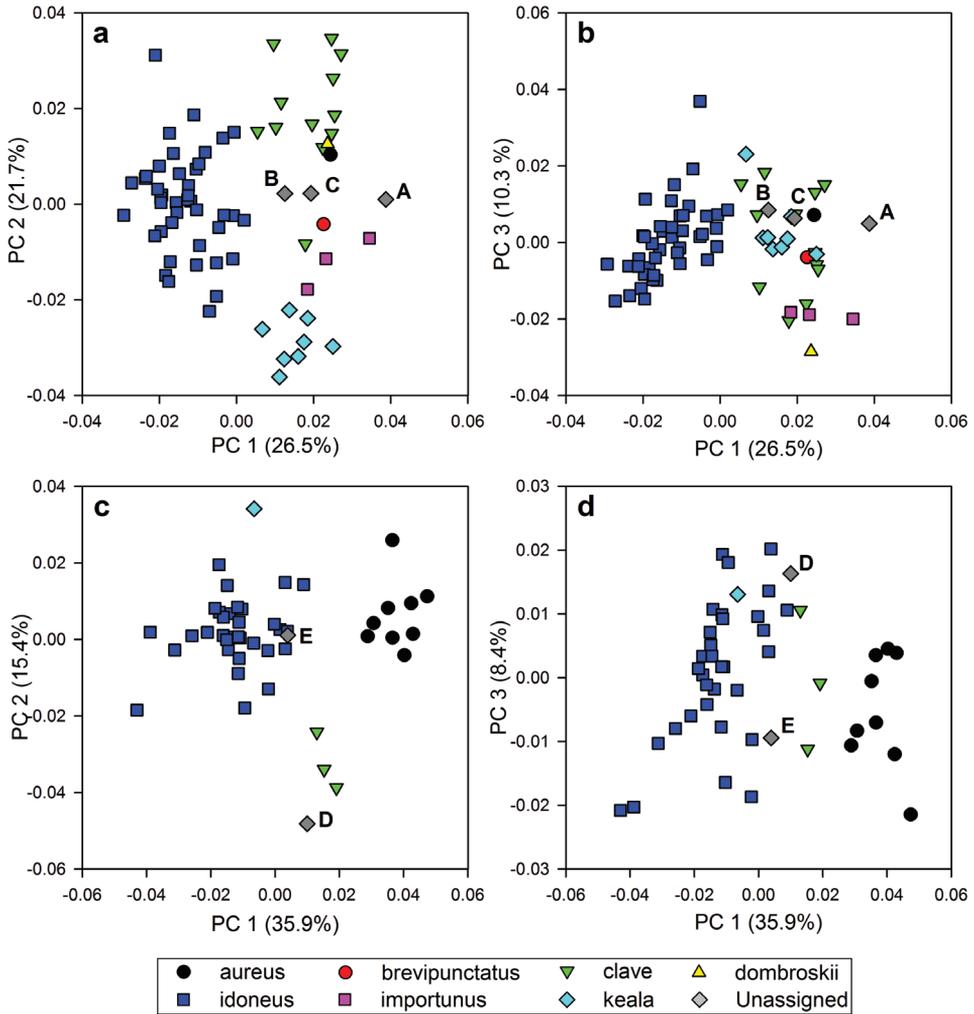


Figure 4. Principal Components Analysis of 23 fore wing landmarks from female (a, b) and male (c, d) specimens of the *O. scutellaris* species-group. Upper-case letters (A–E) refer to unassigned specimens (see text).

the analysis of females, the variation was quite evenly represented by the first two principal components (PC1: 26.5%, PC2: 21.7%, PC3: 10.3%; Figure 4a, b), while in the analysis of males, most of the variation was explained in the first PC (PC1: 35.9%, PC2: 15.4%, PC3: 8.4%; Figure 4c, d).

In the classical morphometric (CM) analysis, the first three principal components represented 77.9% of the total variation in the female dataset (PC1: 52.0%, PC2: 18.9%, PC3: 7.0%; Figure 5a, b). For the analysis of males, they represented 74.8% of the variation (PC1: 41.4%, PC2: 21.1%, PC3: 12.2%; Figure 5c, d). All measurements are summarized in Tables 4 and 5.

Table 4. Summary of measurements of 13 morphometric variables for females of the *O. scutellaris* species group. Morphometric variables are defined in Table 1. The mean ± standard deviation for each variable is given, followed by the range. *cla* = *clave*; *aur* = *aureus*; *bre* = *brevipunctatus*; *dom* = *dombroskii*; *kea* = *keala*; *imp* = *importunus*; *ido* = *idoneus*; A, B, C refer to unplaced specimens; the number of specimens measured for each species is in parentheses.

Variable	<i>cla</i> (13)	<i>aur</i> (1)	<i>bre</i> (1)	<i>dom</i> (1)	<i>kea</i> (8)	<i>imp</i> (3)	<i>ido</i> (21)	A (1)	B (1)	C (1)
FW/FM	0.83±0.02 <i>0.81–0.85</i>	0.83	0.79	0.84	0.81±0.02 <i>0.78–0.84</i>	0.82±0.01 <i>0.82–0.83</i>	0.86±0.01 <i>0.84–0.89</i>	0.88	0.87	0.83
FW/FH	1.23±0.08 <i>1.19–1.26</i>	1.37	1.27	1.34	1.33±0.09 <i>1.24–1.49</i>	1.26±0.02 <i>1.25–1.29</i>	1.37±0.05 <i>1.28–1.45</i>	1.30	1.29	1.29
FW/HW	0.52±0.02 <i>0.50–0.54</i>	0.51	0.47	0.53	0.48±0.01 <i>0.46–0.50</i>	0.50±0.00 <i>0.49–0.50</i>	0.53±0.01 <i>0.51–0.55</i>	0.54	0.54	0.51
MS/MW	0.51±0.10 <i>0.43–0.63</i>	0.60	0.50	0.58	0.40±0.04 <i>0.33–0.47</i>	0.51±0.06 <i>0.46–0.58</i>	0.59±0.04 <i>0.54–0.70</i>	0.60	0.58	0.54
IOD/OL	0.77±0.08 <i>0.53–1.00</i>	0.71	0.69	1.20	0.36±0.06 <i>0.27–0.44</i>	0.72±0.16 <i>0.53–0.85</i>	0.74±0.08 <i>0.61–0.86</i>	1.00	0.73	0.71
OOD/OL	0.22±0.05 <i>0.13–0.29</i>	0.29	0.13	0.45	0.16±0.04 <i>0.11–0.22</i>	0.19±0.04 <i>0.15–0.23</i>	0.33±0.04 <i>0.25–0.43</i>	0.32	0.20	0.21
SL/SW	1.43±0.17 <i>1.23–1.58</i>	1.18	1.48	1.76	1.63±0.10 <i>1.47–1.76</i>	1.58±0.03 <i>1.55–1.60</i>	1.52±0.09 <i>1.37–1.69</i>	1.39	1.52	1.45
M1B/M1S	0.80±0.11 <i>0.71–0.92</i>	0.70	0.80	0.78	0.63±0.06 <i>0.57–0.74</i>	0.78±0.04 <i>0.75–0.82</i>	0.80±0.06 <i>0.71–0.92</i>	0.82	0.88	0.63
M1S/M1A	0.61±0.07 <i>0.58–0.67</i>	0.69	0.60	0.64	0.76±0.06 <i>0.57–0.74</i>	0.66±0.02 <i>0.64–0.68</i>	0.67±0.06 <i>0.59–0.79</i>	0.64	0.53	0.70
FL/FW	7.82±0.95 <i>7.00–8.59</i>	7.95	9.50	7.24	10.26±1.09 <i>8.41–11.63</i>	8.58±0.31 <i>8.25–8.87</i>	6.87±0.26 <i>6.41–7.50</i>	7.56	7.89	7.79
Flag	55.08±5.82 <i>52–60</i>	65	67	51	70.63±1.30 <i>69–73</i>	55.00±1.73 <i>54–57</i>	54.05±1.93 <i>51–57</i>	52	59	59
cu-a	0.69±0.11 <i>0.60–0.84</i>	0.88	0.66	0.83	1.08±0.13 <i>0.89–1.26</i>	0.72±0.09 <i>0.66–0.83</i>	0.83±0.12 <i>0.68–1.13</i>	0.62	0.68	0.64
Wing L	11.83±2.76 <i>10.49–12.44</i>	16.69	14.04	10.80	19.06±0.45 <i>18.64–19.73</i>	12.92±0.38 <i>12.57–13.33</i>	10.13±0.64 <i>8.98–11.48</i>	10.70	12.86	12.70

Table 5. Summary of measurements of 13 morphometric variables for males of the *O. scutellaris* species group. Morphometric variables are defined in Table 1. The mean ± standard deviation for each variable is given, followed by the range. *cla* = *clave*; *aur* = *aureus*; *kea* = *keala*; *ido* = *idoneus*; D, E refer to unplaced specimens; the number of specimens measured for each species is in parentheses.

Variable	<i>cla</i> (3)	<i>aur</i> (9)	<i>kea</i> (1)	<i>ido</i> (17)	D (1)	E (1)
FW/FM	0.85±0.02 <i>0.83–0.87</i>	0.84±0.01 <i>0.82–0.89</i>	0.86	0.89±0.02 <i>0.85–0.91</i>	0.83	0.91
FW/FH	1.22±0.04 <i>1.18–1.26</i>	1.33±0.05 <i>1.25–1.41</i>	1.41	1.40±0.03 <i>1.32–1.45</i>	1.23	1.39
FW/HW	0.50±0.02 <i>0.49–0.52</i>	0.52±0.01 <i>0.50–0.54</i>	0.50	0.53±0.01 <i>0.51–0.56</i>	0.50	0.55
MS/MW	0.48±0.06 <i>0.43–0.54</i>	0.74±0.05 <i>0.65–0.80</i>	0.39	0.65±0.08 <i>0.50–0.82</i>	0.58	0.70

Variable	<i>cla</i> (3)	<i>aur</i> (9)	<i>kea</i> (1)	<i>ido</i> (17)	D (1)	E (1)
IOD/OL	0.79±0.13 <i>0.67–0.92</i>	0.74±0.05 <i>0.65–0.80</i>	0.44	0.87±0.16 <i>0.58–1.25</i>	1.04	0.90
OOD/OL	0.23±0.03 <i>0.20–0.27</i>	0.30±0.02 <i>0.26–0.33</i>	0.44	0.48±0.14 <i>0.35–0.92</i>	0.33	0.40
SL/SW	1.54±0.12 <i>1.43–1.67</i>	1.23±0.08 <i>1.13–1.38</i>	1.74	1.44±0.12 <i>1.21–1.68</i>	1.68	1.44
M1B/M1S	0.79±0.04 <i>0.76–0.84</i>	0.64±0.08 <i>0.54–0.78</i>	0.63	0.77±0.07 <i>0.61–0.87</i>	0.79	0.75
M1S/M1A	0.65±0.06 <i>0.61–0.71</i>	0.72±0.04 <i>0.67–0.78</i>	0.79	0.73±0.07 <i>0.62–0.90</i>	0.67	0.80
FL/FW	7.08±0.09 <i>7.00–7.18</i>	8.72±0.54 <i>8.11–9.63</i>	9.03	6.95±0.43 <i>6.31–7.85</i>	7.13	7.14
Flag	54.67±1.53 <i>53–56</i>	66.78±1.56 <i>65–69</i>	65	54.69±1.74 <i>51–57</i>	54	52
cu-a	0.69±0.09 <i>0.59–0.74</i>	0.69±0.10 <i>0.51–0.83</i>	1.43	0.97±0.22 <i>0.72–1.53</i>	0.76	0.96
Wing L	10.78±0.11 <i>10.65–10.85</i>	15.55±0.94 <i>14.37–17.07</i>	16.23	9.45±0.56 <i>8.42–10.74</i>	9.91	8.91

Morphological characterization of subgroups

Examination of specimens from the two strongly supported subgroups from the molecular analysis uncovered additional morphological characters distinguishing them. The most useful character to distinguish these subgroups can be found on the propodeum. All specimens in subgroup A have a weakly arched anterior transverse carina (Figure 6a), while subgroup B has this carina strongly arched centrally (Figure 6b). In addition, the clypeus of species in subgroup A tends to be more convex and more strongly separated from the face (i.e. with a more deeply impressed epistomal sulcus), with small regular punctures (Figure 7a–c). In comparison, species in subgroup B have a flatter clypeus that is more weakly separated from the face, with larger, irregularly spaced punctures (Figure 7d–f).

Species discovery and delimitation

Six Nearctic species are described, and one redescribed, based on the integrated results of these analyses (see Taxonomic Part below). Because of the nature of the iterative process, a single path was not followed in determining the species boundaries for all species.

Two species (*O. aureus* Schwarzfeld, sp. n. and *O. keala* Schwarzfeld, sp. n.) were easily recognizable as distinct based on gross morphology. In particular, they are both considerably larger than the remaining species in the group. *Ophion aureus* is only known from the Peace River region of Alberta, and was recognized based on its golden-orange colour and distinctive propodeal carinae (Plate 5). It formed a strongly

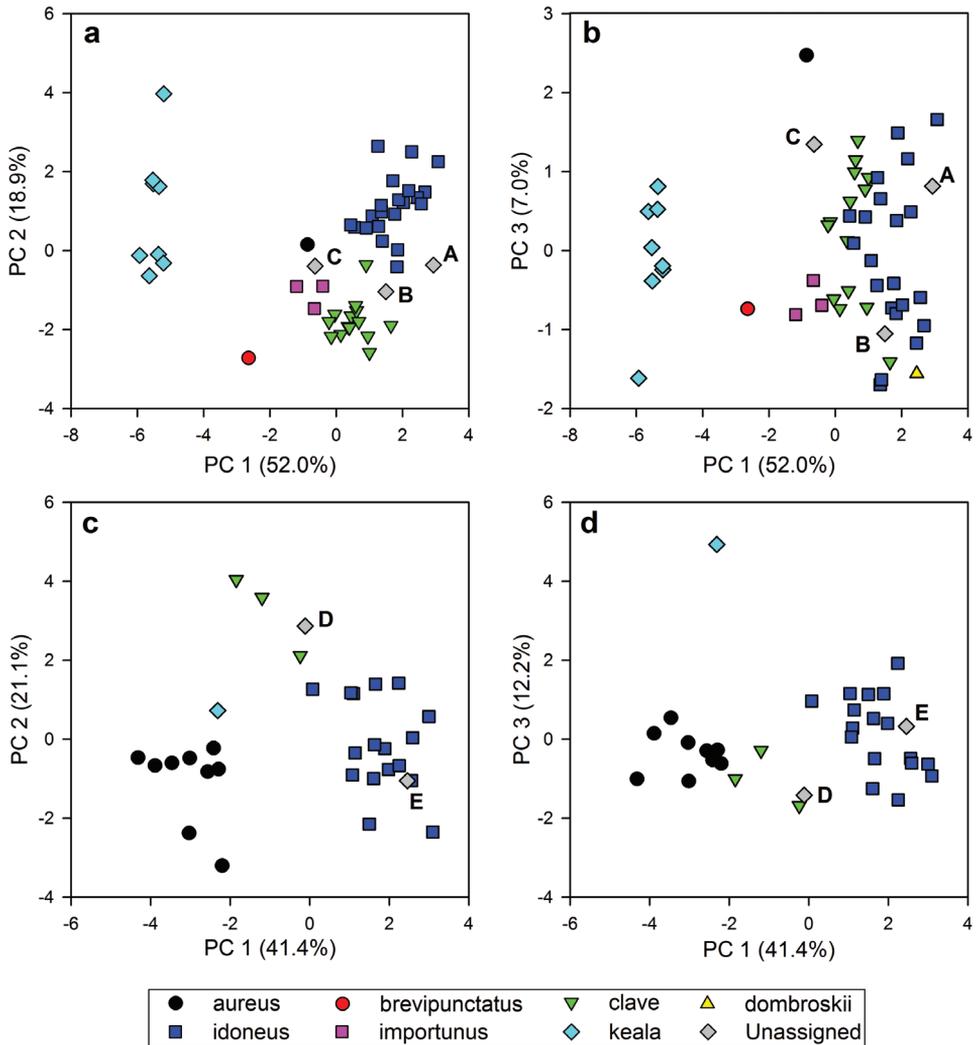


Figure 5. Principal Components Analysis of 13 morphometric characters for female (**a**, **b**) and male (**c**, **d**) specimens of the *O. scutellaris* species-group. Upper-case letters (**A–E**) refer to unassigned specimens (see text).

supported clade in both the COI and ITS2 analyses (Figure 3). The minimum inter-specific divergence was 1.9% (K2P: 2.0%) divergence for COI, and 0.2% for ITS2 (Table 3a). There was an intraspecific divergence of 0.4% for the two specimens that were successfully sequenced for COI, and the four specimens that were sequenced for ITS2 were invariant. *Ophion keala* is the largest species in this group (as well as being among the largest species of *Ophion* we have examined) and is a uniformly dark red colour (Plate 1). In the analysis of COI, it formed a strongly supported monophyletic clade, and was separated by a minimum of 4.4% sequence divergence (K2P: 4.6%)

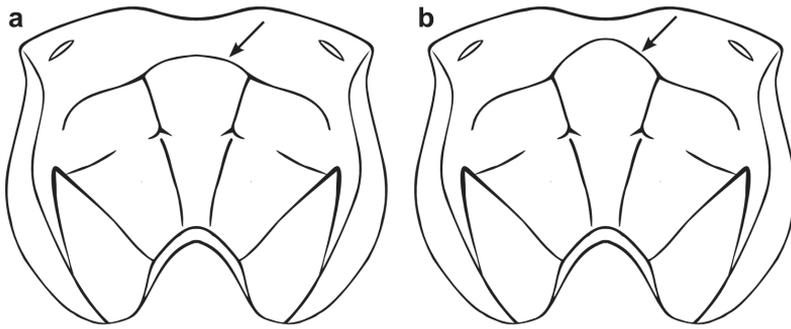


Figure 6. Generalized propodeum demonstrating the difference in the anterior transverse carina (ATC) between the two subgroups of the *O. scutellaris* species group. **a** Subgroup A, showing the weakly arched ATC **b** Subgroup B, showing the strongly arched ATC.

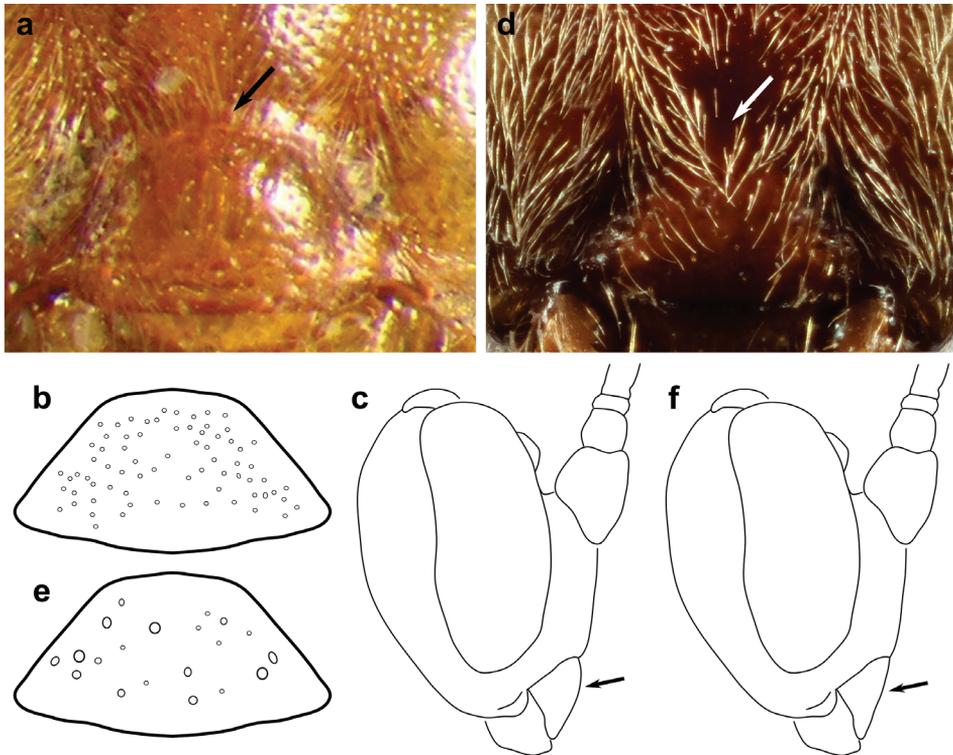


Figure 7. Clypeus of subgroup A (**a–c**) and subgroup B (**d–f**) within the *O. scutellaris* species group. **a, d** Clypeus in frontal view; arrow indicates epistomal sulcus **b, e** Clypeus in frontal view, showing representative clypeal punctures **c, f** Clypeus in lateral view; arrow indicates the more convex clypeus in subgroup A, compared to subgroup B.

from any other species. However, according to ITS2, it was recovered as a paraphyletic grade with respect to another species, *O. idoneus*, from which it differed by 0.1% sequence divergence. The molecular analyses recovered *O. aureus* within subgroup B

and *O. keala* within subgroup A, and the morphology of each is consistent with the respective subgroups.

There is a strong sex bias in the specimens available for each of these species. *Ophion aureus* was represented entirely by males, except for a single female specimen, while the opposite occurred in *O. keala*. They could therefore only be thoroughly assessed in the morphometric analyses of male or female specimens, respectively. Both species were successfully delimited by both GM and CM analyses, with essentially no overlap with other specimens (Figures 4, 5). Only the plot of PC1 vs PC3 in the GM analysis failed to recognize *O. keala* as distinct. The singleton specimens of the opposite sex were also included in the respective analyses. While PCA maximizes the spread of variation of all specimens, and therefore is less informative for singletons, these single specimens were also often recovered as distinct from all other clusters, particularly in the CM analysis.

O. idoneus Viereck, the only previously described Nearctic species within this species group, was also initially recognized on the basis of morphology, in particular the shape of the propodeal carinae, the lack of a ramellus in the fore wing and the small size (Plate 2). It was identified to species by comparison to the type specimen. The molecular analyses recovered it within subgroup A, and it was strongly supported by both COI and ITS2 (Figure 3). The minimum interspecific difference was 2.2% (K2P: 2.3%) for COI, and 0.1% for ITS2. It was almost invariant intraspecifically, with a maximum divergence of 0.3% according to COI (equivalent to two base pairs), while all ITS2 sequences were identical. It was also recovered as distinct in all morphometric analyses, with only the plot of PC1 vs PC3 in the CM study having significant overlap with any other group (Figures 4, 5). It was by far the most common species in this species group.

A single female specimen of *O. importunus* sp. n. was first noted as being very similar to *O. idoneus*, but differing slightly in the shape of the propodeal carinae, along with being slightly larger and having a longer ramellus (Plate 3, Figure 11c). Sequencing of this specimen confirmed it as being related to *O. idoneus*, with all analyses strongly supporting its inclusion within subgroup A. However it was separated from *O. idoneus* by a minimum of 2.2% (K2P: 2.3%) divergence according to COI and 0.9% divergence according to ITS2, compared to the almost invariant sequences within *O. idoneus* (Table 3). Two other female specimens were identified morphologically as belonging to subgroup A, and were hypothesized to be conspecific with *O. importunus*. Both GM and CM analyses supported this hypothesis, with the three specimens grouping closely together, while being distinct from the cluster of *O. idoneus* (Figures 4a,b; 5a,b).

O. clave Schwarzfeld, sp. n. was the only species other than *O. idoneus* that was represented by multiple male and female specimens, though female specimens were more common. It was first identified as a putative species based on the molecular analyses. It was recovered as part of subgroup B by all analyses, and formed a well-supported monophyletic clade in the analysis of COI (Figure 3a); only two specimens were successfully sequenced for ITS2, however these were also recovered as a clade, with moderate bootstrap support (Figure 3b). It had a minimum interspecific divergence of 2.8% (K2P: 2%) for COI, and a maximum intraspecific divergence of 0.3%.

For ITS2, there was a minimum interspecific divergence of 0.1% (a single base pair), while the two sequences within this species were invariant. Based on these results, the specimens were examined for morphological characters and a number of additional, unsequenced specimens were hypothesized to be part of this species.

The morphometric analyses generally recovered both males and females of this species as distinct clusters compared to other species. For the analysis of females, this result was strongest in the plots of PC1 vs PC2 of both GM and CM, whereas all plots from the analysis of males recovered this species as a distinct group (Figures 4, 5). In a few cases, female specimens that were originally unassigned to any species also clustered with this group in both GM and CM analyses. Based on a qualitative examination of these specimens, we further refined our morphological species concept for this species. In the GM analysis, a single female specimen was not recovered with the rest of the species. However, morphological examination of this specimen supports its assignment to *O. clave*, as does the CM analysis. This indicates that wing shape outliers can exist within species, though misidentification cannot be conclusively ruled out.

O. brevipunctatus Schwarzfeld, sp. n. and *O. dombroskii* Schwarzfeld, sp. n. are each represented by singletons in this study. *Ophion dombroskii* differs from all other members of the *scutellaris* species group, and from all other known Nearctic *Ophion*, by its distinctive black face and thorax (Plate 7). In comparison, *O. brevipunctatus* looks superficially very similar to *O. clave* (Plates 6, 4). However both ITS2 and COI recovered these two specimens as a monophyletic clade, with bootstrap support ranging from 65% (ITS2 ML) to 98% (COI MP). They were separated by only 1.0% sequence divergence according to COI, and by 0.3% divergence in ITS2 (Table 3). Neither morphometric analysis, however, showed any similarity between these two specimens, which supports the view that they are not merely colour morphs of the same species. Qualitatively, *O. dombroskii* has unusually short antennal segments, which, along with the black colouration, suggest this species is active diurnally (Gauld 1980). While PCA will not necessarily distinguish singletons, *O. brevipunctatus* was nevertheless recovered as distinct from all other clusters in the CM study, thus supporting the distinctiveness of this species. Further morphological examination uncovered additional characters. In particular, this species can be distinguished from the apparently more common *O. clave* by the larger size, extremely shallow and sparse facial punctures, and the lack of any yellow on the orbits (Plate 6).

Five specimens (3 female and 2 male) remain unassigned to any species. Based on the structure of the propodeal carinae, one of the female specimens can be assigned to subgroup A, while the other two are part of subgroup B. The former specimen (labeled as "A" in figures and tables) was initially identified as *O. idoneus*, but based on its divergent position in the morphometric analyses, particularly in the GM analysis, we re-examined this specimen, and concluded that it also differs from *O. idoneus* morphologically. The other two female specimens ("B" and "C") cluster near or within *O. clave* in both CM and GM analyses. However they were sufficiently morphologically divergent from *O. clave* and from each other that we suspect this does not indicate conspecificity.

One of the two unplaced male specimens (“D”) can be assigned to subgroup B, and the other (“E”) is in subgroup A. According to both the GM and CM analyses, these clustered with species from their respective subgroup, i.e. “D” was near *O. clave* and “E” was near *O. idoneus*. However, they are sufficiently different morphologically from these species that this is probably an artifact of the data. It is possible that specimen “E” represents the unknown male of *O. importunus*, whereas we are almost certain that specimen “D” is an additional undescribed species.

Discussion

The genus *Ophion* is often considered a particularly challenging taxonomic puzzle, due to high intraspecific and low interspecific morphological variation (Townes 1971, Brock 1982). We used an iterative analysis of multiple genetic markers, geometric morphometrics, classical morphometrics and morphology to define the *O. scutellaris* species group, and to assess and delimit species within the group. All analyses were broadly congruent, however each provided unique information to aid in understanding this group.

While 28S was useful in supporting the monophyly of the species group as a whole, and particularly of the two subgroups, it was too conserved to distinguish species within each subgroup. COI and ITS2 were both apparently effective at separating species, since most species, as defined through the integrated analysis, were recovered as well supported clades, with greater divergence between species than within species. However, few individuals over a limited geographical range were sequenced for the majority of species; further sequencing is needed to fully assess the ability of these markers to distinguish species across their range (Ekrem et al. 2007, Bergsten et al. 2012). Nevertheless, at least in the case of *O. idoneus* the haplotypes were almost invariant across Canada.

Despite the apparent utility of these molecular markers, morphology is an essential component of diagnosing species, since clusters of haplotypes are not necessarily equivalent to biological species (Sperling and Roe 2009, Dupuis et al. 2012). As well, DNA cannot be sequenced for all specimens, and without morphology these species would remain largely unknown (Schlick-Steiner et al. 2007). Finally at least two species in this study, *O. brevipunctatus* and *O. dombroskii*, would probably be considered a single species based on COI alone, yet were clearly distinct morphologically.

Qualitative morphology, geometric morphometrics and classical morphometrics provide three additional semi-independent datasets with which to evaluate species diagnoses. Each species in this study is distinguishable morphologically, though again small sample sizes and limited geographical sampling mean the morphological variability within each species has probably not been fully sampled. Four species (*O. clave*, *O. brevipunctatus*, *O. importunus*, and *O. idoneus*) look superficially very similar, however each has qualitative morphological characters that are sufficient to separate them. In comparison, *O. aureus*, *O. keala*, and *O. dombroskii* are very morphologically

distinctive species. Both *O. brevipunctatus* and *O. dombroskii* are described from single specimens. While some taxonomists argue that species should never be described from singletons (e.g. Dayrat 2005), Lim et al. (2012) counter that rarity is a fact of biodiversity, and that we will consistently underestimate diversity if we ignore singleton species. Finally, while beyond the scope of this study, initial examination of the two putative species of "*O. scutellaris*" supports their distinctiveness, with "*scutellaris* B" being larger and having coarser, denser facial punctures.

Principal Components Analysis is a one-group method for data exploration, meaning it does not include *a priori* group designations (Strauss 2010). As such, it will not definitely separate groups, even if they are distinct. Discriminant analysis is more effective for separating predefined clusters of species and assigning specimens to groups, but it requires known species, which have been identified based on other criteria (e.g. hosts, pheromones, genetic markers) (Marcus 1990, Mutanen and Pretorius 2007, Strauss 2010). In this case, sequenced specimens would be ideal, but sample sizes were too small for the analysis to be statistically valid. Basing the analysis on specimens that were identified morphologically would be circular, considering that some specimens were re-examined and re-classified based on the morphometric analyses. We have therefore restricted the analysis to exploratory PCA's. Future studies are needed to increase molecular sampling over a wider geographic range, which could then be used for discriminant analyses of morphometric data.

Both geometric and classical morphometrics were effective for clustering species, although the clusters were often not widely separated. In general, superficially similar species clustered more closely together than they did to morphologically divergent species, indicating congruence between quantitative measures of shape and subjective, qualitative analysis. Specimens that did not cluster with other members of their putative species were flagged for further examination. In some cases these were misidentifications, while in others morphology and the alternate morphometric analysis supported their placement within a given species. Conversely, inclusion within a cluster did not guarantee that the specimen was a member of that species. These examples further support the advantage of including multiple lines of evidence for accurate species delimitation.

Conclusion

This is a first attempt at describing species within this newly-defined species group; as such, it should be considered a work in progress. This study was almost entirely limited to Canadian material, most species were from only a few localities, and all species except *O. idoneus* were represented by small numbers of individuals. As well, there are almost certainly additional undescribed species in the material available. All of this indicates that we have just begun to sample the true diversity within this species group. Nonetheless, we have shown that by using an iterative analysis of morphology, molecular analysis and morphometrics, we can delimit and describe species within a genus that is so

morphologically challenging that no new species have been described in North America for more than a hundred years. Furthermore, molecular and morphological recognition of this species group will now allow more targeted specimen collection and museum research, supporting a global revision of the species group in its entirety.

Taxonomic part

Terminology

Morphological terms were matched as closely as possible to the Hymenoptera Anatomy Ontology (Yoder et al. 2010). Further information and images for the majority of terms can thus be found at <http://portal.hymao.org>. Some additional terms were included from the ophionine literature, primarily Brock (1982) and Gauld (1991); these terms are defined below and in Table 1.

Wing characters used in this study are illustrated in Figure 1. We have also included four indices of the fore wing that have been used in other treatments of Ophioninae (e.g. Gauld 1988). These indices are the alar index (AI), cubital index (CI), intercubital index (ICI), and the second discoidal index (SDI); these are defined in Table 1 and illustrated in Figure 1. The pleurosternal angle of the epicnemial carina is illustrated in Figure 8a (Brock 1982). The stemmaticum is the area containing the ocelli (Figure 8c). It is bounded by variously distinct sulci; when these sulci are strongly impressed and completely surround the stemmaticum, they are referred to as “complete” (Brock 1982).

The carinae of the propodeum are often considered too highly variable to be of much use in species delimitation (Brock 1982, Gauld 1991). At least within this species group, however, we have found them to be quite useful. While they are certainly variable, particularly in the extent to which the various carinae are developed, there are usually at least a few essential elements that are consistent within species. Propodeal carinae and areas follow Gauld (1991) (Figure 9). The posterior area of the propodeum is the area posterior to the anterior transverse carina, while the spiracular area is anterior to the anterior transverse carina (Gauld 1988).

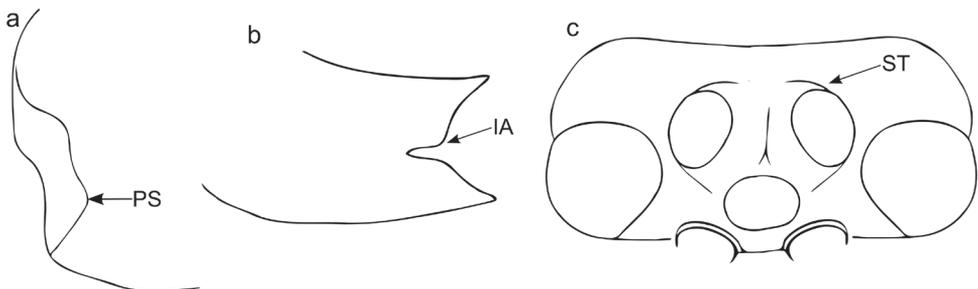


Figure 8. Morphological characters used in the species descriptions of the *O. scutellaris* species group that are not illustrated in the Hymenoptera Anatomy Ontology (portal.hymao.org). **a** Epicnemial carina; PS = Pleurosternal angle **b** Mandible; IA = internal angle of tooth **c** Stemmaticum.

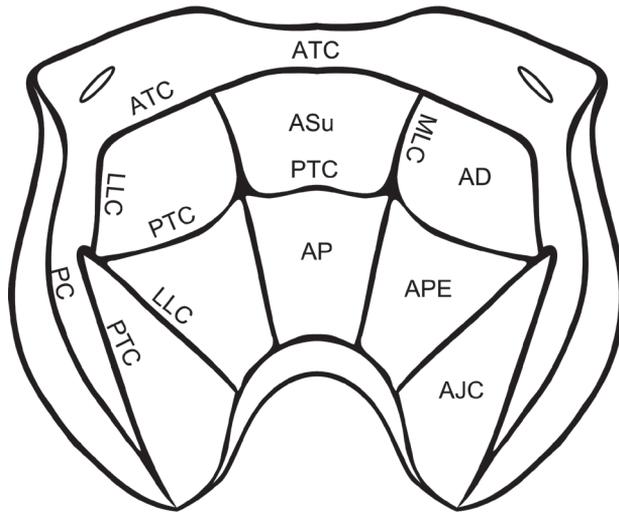


Figure 9. Propodeum of *Ophion* demonstrating propodeal carinae and areas. Carinae: ATC = anterior transverse carina; PTC = posterior transverse carina; MLC = median longitudinal carinae; LLC = lateral longitudinal carina; PC = pleural carina; Areas: ASu = area superomedia; AP = area petiolaris; AD = area dentiparis; APE = area postero-externa; AJC = area juxta-coxalis.

Other important characters are the sculpture of the face and clypeus, punctation of the metapleuron, number of flagellomeres, and overall size and colour.

Key to the known Canadian species of the *Ophion scutellaris* species group

- 1a Face and most of thorax black, central flagellomeres approximately quadrate (Plate 7)..... ***O. dombroskii* Schwarzfeld, sp. n.**
- 1b Body entirely orange or reddish, central flagellomeres distinctly longer than wide..... **2**
- 2a Anterior transverse carina weakly convex in centre (Figure 6a, 10a–c) **3**
- 2b Anterior transverse carina strongly convex in centre (Figure 6b, 10d–g)..... **5**
- 3a Fore wing length greater than 16 mm; antennae with at least 65 flagellomeres, more in female (Plate 1)..... ***O. keala* Schwarzfeld, sp. n.**
- 3b Fore wing length less than 14 mm; antennae with less than 58 flagellomeres **4**
- 4a Median longitudinal carinae of propodeum strongly convergent posterior to areola, usually arriving at apex of propodeum as a single carina (Figure 10b); ramellus almost always extremely short to absent (rarely longer) (Figure 11b; Plate 2) ***O. idoneus* Viereck**
- 4b Median longitudinal carinae of propodeum represented by wrinkles posterior to posterior transverse carina, convergent but not fusing into a single carina (Figure 10c); ramellus long (Figure 11c; Plate 3) ***O. importunus* Schwarzfeld, sp. n.**

- 5a Yellow-orange base colour, wing length greater than 14 mm, propodeal carinae generally reduced, greatly reduced in male, but apical part of lateral longitudinal carinae expanded as a flange (Figure 10e; Plate 5) *O. aureus* Schwarzfeld, sp. n.
- 5b Reddish-orange base colour, wing length 14 mm or less, propodeal carinae more developed, apical part of lateral longitudinal carinae strong but not expanded into a flange (Figure 10d, f) **6**
- 6a Facial punctures strong and separated by less than their diameter; orbits yellowish, stemmaticum and mesopleural fovea concolourous with base colour (Plate 4) *O. clave* Schwarzfeld, sp. n.
- 6b Facial punctures very shallow and separated by 2–3× their diameter; orbits lacking yellow, concolourous with reddish head, stemmaticum and mesopleural fovea darker than base colour (Plate 6) *O. brevipunctatus* Schwarzfeld, sp. n.

Species descriptions

Ophion scutellaris species group

Diagnosis. Most species are reddish-coloured, lacking yellow markings (except for narrowly on orbits, tegula, mesepimeron and rarely mandibles); early-season (most collected April to June); midtibial spurs nearly equal in length; eyes separated from posterior ocellus by 0.27–1.25× ocellar diameter; facial punctures more widely separated in centre of face than on sides; scutellum strongly carinate (at least partially); propodeum short, posterior area abruptly sloping so that it is nearly vertical at apex, anterior transverse carina (at least in centre) and lateral part of posterior transverse carina (along area juxta-coxalis) strong, otherwise carinae variable, but median longitudinal carinae always convergent apical of area superomedia; petiolar spiracle distinctly anterior to membrane of first metasomal segment.

Description. Head: Eyes convergent to nearly parallel, not strongly bulging (FW/HW: 0.46–0.56); eyes moderately indented (FW/FM: 0.69–0.91); face with minute to medium sized punctures, variously separated, but always closer together on sides and under toruli than in centre; clypeus coriaceous, variously punctate, CH/CAW: 0.49–0.70; mandible with internal angle well-defined (Figure 8b), punctate except for impunctate polished flange and tips; stemmaticum slightly to strongly raised, OC/OL: 0.42–1.2, OOD/OL: 0.11–0.92; IOD/OL: 0.27–1.25; ocellar carina rounded, in some species very slightly rippled or with a small peak at the apex; temple receding, usually approximately equal to width of eye in lateral view; antennae with 51–73 flagellomeres.

Mesosoma: Epicnemial carina with pleurosternal angle obtuse (rarely 90°); propodeum short, posterior area abruptly sloping so that it is nearly vertical at apex, ATC

strong and convex along ASu, usually entirely strong, but sometimes obsolete or absent laterally, lateral part of PTC (along AJC) strong, usually absent or obsolete along APE, obsolete to strong along ASu; MLC variously developed, but always convergent apical of ASu, LLC mostly absent except strong to absent along AJC; PC strong, rarely connected to spiracle by a very weak carina, but usually not connected.

Wings: Wing L: 8.4–19.7 mm; CI: 0.39–0.84, AI: 1.13–3.31, SDI: 1.03–1.31, ICI: 0.44–1.00, *R*_s sinuate, ramellus absent to somewhat long, fenestra not extending below prestigma, lacking glabrous area in discocubital cell along *R*_s+*M*.

Legs: CL/CW: 1.41–2.37; trochantellus dorsally shorter than width; FL/FW: 6.3–11.6; midtibial spurs nearly equal in length (MTS: 0.70–0.97, usually > 0.80).

Metasoma: First metasomal segment with spiracles distinctly anterior to membrane; first metasomal segment 1.3–1.6× as long as second; second metasomal segment 2.4–4.5× as long as high.

Colour: Uniformly reddish, without yellow markings except orbit (usually narrowly), tegula, mesepimeron and rarely mandibles; females with ovipositor sheath concolourous with apex of metasoma; one species with head and mesosoma predominately black.

Seasonality. Early-flying species, most dates of capture in Canada are May to mid-June. Unusual dates of captures are one specimen that was collected in July, and one collected in August. At least in the northern Nearctic region, most other early-flying species can be distinguished from this species group by their distinct yellow markings.

Biology. There is virtually nothing known about the biology or hosts of the Nearctic species. The one exception is that *O. idoneus* has been recorded from the noctuid, *Sunira bicolorago* (Guenée) (Crumb 1924). The Palearctic species, *O. scutellaris* Thomsen, is a parasitoid of noctuids that overwinter as feeding larvae and are fully grown by spring (Brock 1982, G. Broad, pers. comm.). Since the Nearctic species are also early season parasitoids, they may have similar life-histories.

Remarks. The *O. scutellaris* species group can be further divided into two monophyletic subgroups (see text). One group (A) includes *O. idoneus*, *O. scutellaris*, *O. keala* and *O. importunus*. It can be recognized by the weakly arched anterior transverse carina of the propodeum (so the base of the area superomedia is only slightly convex; Figure 6a) and the more convex clypeus, distinctly separated from the face by a relatively strongly impressed epistomal sulcus, with smaller, denser, more regularly distributed punctures (Figure 7a–c). The second group (B) includes *O. clava*, *O. aureus*, *O. brevipunctatus*, and *O. dombroskii*, and can be recognized by the strongly arched anterior transverse carina of the propodeum (so that the base of the area superomedia is U-shaped; Figure 6b) and the flatter clypeus, weakly separated from the face by a less distinct epistomal sulcus, usually with coarse, irregularly scattered clypeal punctures (Figure 7d–f).

Only a small proportion of collected *Ophion* will generally be from the *O. scutellaris* species group. Within the group, *O. idoneus* is by far the most common Nearctic species.

***Ophion keala* Schwarzfeld, sp. n.**

<http://zoobank.org/A4509217-2C71-4FB4-AED4-D81BF3344DA5>

Figures 10a, 11a; Plate 1

Type material. Holotype: ♀ (MS2249, DNA3965, GenBank KF594539, KF615948) CAN: AB: Porcupine Hills, Skyline Rd; 49.972 -114.087; 29 v 2008; UV trap; J.Dombroskie, J.Walker (CNC)

Paratypes: 7 ♀♀, 1 ♂. CAN: AB: 2 ♀♀ (MS2244, DNA3980, GenBank KF594552, KF615947; MS2238, DNA3960, GenBank KF594534, KF615950) Same data as holotype (CNC); 1 ♂, 1 ♀ (MS2235, DNA3904, GenBank KF594480, 615945; MS2237) Same data as holotype except date 28 v 2008 (CNC); 1 ♀ (MS8647, DNA6515, GenBank KF594730, KF615943, KF616332) Porcupine Hills, Skyline Rd, 49.972 -114.087, 15 vi 2009, UV trap J.Dombroskie, B.Brunet (CNC); 1 ♀ (MS7801, DNA7327, GenBank KF594917, KF615946) 62 km WNW of Dixonville, Mixedwood retention patch in clearcut, Site 7, 56.685 -118.641, 26 v 2008, UV trap, B.Bodeux (CNC); 1 ♀ (MS7912, DNA7324, GenBank KF594914, KF615944) 62 km WNW of Dixonville, Mixedwood retention patch in clearcut, Site 4, 56.684 -118.644, 7 vi 2008, UV trap, B.Bodeux (CNC); 1 ♀ (MS7746) 54 km NW of Dixonville, Mixedwood forest, 56.86 -118.31, 11 vi 2007, UV trap, B.Bodeux (CNC).

Etymology. The name for this species is derived from *keala*, the Hawaiian word for path, as this large and distinctive species presents a rare clear path within the morphologically homogeneous jungle that is *Ophion*. It is a noun in apposition - and is also the name of the species author's daughter.

Diagnosis. ♀: Wing L: 18.6–19.7 mm, Flag: 69–73; ♂: Wing L: 16.2 mm, Flag: 65; Very large species, uniformly dark reddish-orange with interocellar area often darker; hind femur long and slender (FW/FH: 8.4–11.6), scutellum strongly carinate.

Description. Head: *Female:* Eyes convergent in frontal view; stemmaticum weakly raised, sulci surrounding stemmaticum complete; IOD/OL: 0.27–0.44; OOD/OL: 0.11–0.22; occipital carina rounded, often very slightly wavy, with a very small peak in the centre; OC/OL: 0.42–0.68; temple receding, approximately equal to width of eye in lateral view; CH/CAW: 0.52–0.63, coriaceous with evenly distributed medium-sized punctures, separated by approximately 1–2× their diameter, punctures smaller basally; face weakly coriaceous, with small punctures separated by 1–2× their diameter, closer on sides than in centre; FW/FH: 1.24–1.49; antennae with 69–73 flagellomeres; F1: 3.56–4.50; F20: 1.54–2.24; MS/MW: 0.33–0.47; GI/MW: 0.46–0.69; *Male:* Same, except: Eyes more weakly convergent, OOD/OL: 0.44; OC/OL: 0.81; flagellomeres: 65.

Mesosoma: Mesoscutum polished, evenly punctate with minute punctures separated 1–2× their diameter; mesopleuron coriaceous, densely punctate with small to medium-sized relatively shallow punctures, separated by approximately their diameter; subpolished with minute punctures separated by 2–3× their diameter above mesopleural fovea; epicnemial carina with pleurosternal angle obtuse, distinctly so in male, rounded (see variation); SL/SW: 1.47–1.76, lateral carinae strong along almost entire length of scutellum, slightly weaker in male; metapleuron strongly coriaceous,

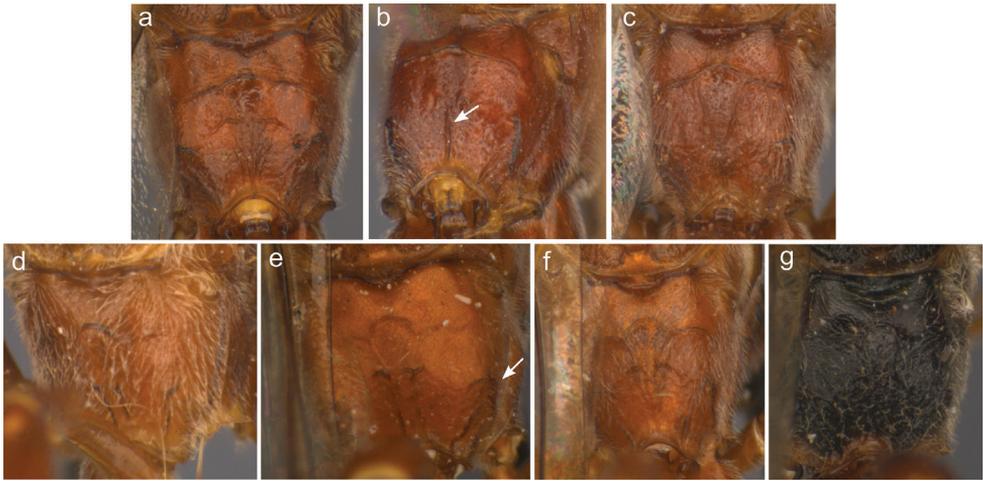


Figure 10. Propodeal carinae of species from the *O. scutellaris* species group. All images are of female specimens; male specimens have the same basic arrangement, but often with weaker carinae. **a** *keala* **b** *idoneus* (arrow indicates fused carinae) **c** *importunus* **d** *clave* **e** *aureus* (arrow indicates expanded, flange-like carina) **f** *brevipunctatus* **g** *dombroskii*.

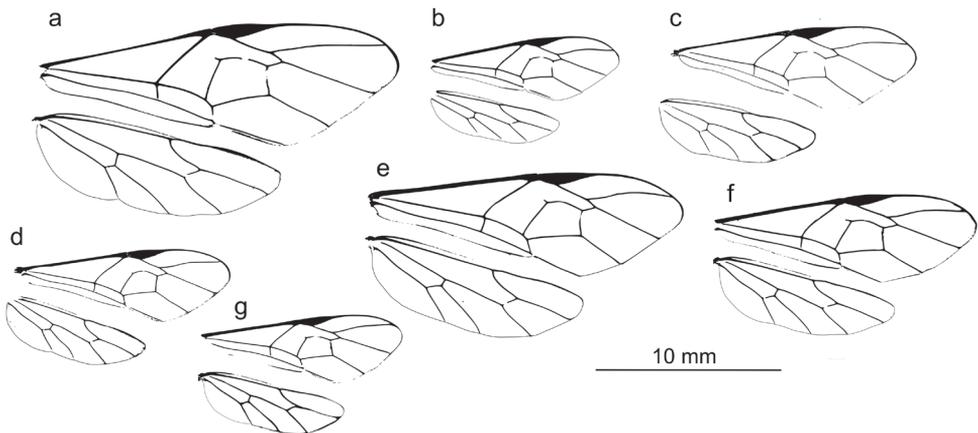


Figure 11. Representative fore wings and hind wings of species from the *O. scutellaris* species group. **a** *keala* **b** *idoneus* **c** *importunus* **d** *clave* **e** *aureus* **f** *brevipunctatus* **g** *dombroskii*.

punctures approximately equal to those of posterior corner of mesopleuron, equally or slightly less dense.

Propodeum: ATC strong, very slightly arched above ASu; PTC weak to absent along ASu, represented by small crests at MLC, obsolete to absent along AD, very strong along AJC where it is expanded as a flange; MLC obsolete, absent to very faintly represented by parallel or slightly convergent wrinkles along ASu, present as a series of stronger convergent wrinkles along AP; LLC weak to obsolete along AJC, otherwise absent; PC strong, connected to spiracle by a very weak to obsolete carina; spiracular area sloping, subpolished



Plate I. *Ophion keala* Schwarzfeld sp.n., type specimen; **a** habitus **b** propodeum and scutellum **c** mesothorax **d** head, dorsal **e** face.

with minute shallow punctures separated by 1–2× their diameter; posterior area weakly wavy-wrinkled with minute punctures to PTC, then more distinctly wrinkled to apex.

Wings: *Female:* Wing L: 18.6–19.7 mm, CI: 0.54–0.70, AI: 1.42–2.01, SDI: 1.13–1.27, ICI: 0.61–0.93; wings slightly brownish with black veins, stigma reddish-brown, ramellus very short to somewhat long, fenestra restricted to area under stigma; *Male:* Same, except wing L: 162 mm.

Legs: *Female:* CL/CW: 1.94–2.37; FL/FW: 8.41–11.63, MT1/MT2: 2.06–2.33; MTS: 0.78–0.88 (♀); *Male:* Same, except CL/CW: 1.83; MTS: 0.91.

Metasoma: First metasomal segment often abruptly (sometimes gradually) expanded from petiole to postpetiole, spiracles sometimes raised on tubercles.

Colour: Reddish-orange; stemmaticum often slightly darker, mandibles usually slightly paler; orbit (especially posterior to eye), tegula and dorsal part of mesepimeron yellowish; notauli and margins of mesocutum slightly darker.

Variation. One ♀ with all punctures slightly more sparsely distributed than in the remaining specimens; One ♀ with pleurosternal angle of epicnemial carina approximately 90° and somewhat sharp.

Seasonality. All collections have been from late May until mid-June.

Ophion idoneus Viereck, 1905

Figures 10b, 11b; Plate 2

Material examined. Holotype: ♂ USA: Kansas: Douglas Co. ft. 900; May; U. of K., Lot 878, 8ub (SEMC)

Other material: 109 ♀♀, 83 ♂♂, 2 unknown: CAN: AB: 2 ♀♀ (MS12403, MS12405) 11 km NE of Lacombe, J.J. Collett Natural Area, N-facing slope, *P. glauca*, *B. papyrifera*, 835m, 52.553 -113.641, 18 vi 2009, UV, C.D. Bird (CNC); 4 ♀♀, 1 ♂ (MS11824–28) 5km NEE of Dunstable, George Lake Research Station, aspen forest, MT-7, 53.957 -114.130, 25-29 v 2007, Malaise, M. Schwarzfeld (UASM); 11 ♀♀, 6 ♂♂ (MS13317, MS13319–20, MS13322–26, MS13328–36) same data except date is 29 v-6vi 2007 (CNC); 2 ♀♀, 6 ♂♂ (MS12920, MS12922–28) 5km NEE of Dunstable, George Lake Research Station; Black spruce forest; MT-8, 53.957 -114.128, 29 v-6 vi 2007, Malaise, M. Schwarzfeld (UASM); 4 ♀♀ (MS12433–35, MS12444) 8 km NW of Winfield, Bird East Poplar Creek quarter, mixed woods, 900m, 53.01 -114.50, 12 vi 2010, UV, C.D. Bird (CNC); 1 ♂ (MS12335) same data except date is 15 v 2010 (UASM); 1 ♂ (MS11457) same data except date is 16 v 2009 (UASM); 1 ♀ (MS13925) same data except date is 21 v 2011 (UASM); 1 ♀ (MS2261) 8 km SE Sherwood Park, aspen forest, 53.478 -113.229, 12-15 v 2008, MV light, G.R. Pohl (UASM); 1 ♀ (MS7373) Bragg Creek, 50.917 -114.533, 15 viii 2007, at light, F. Sperling (CNC); 1 ♀ (MS4026), Calgary, Edgemont, 51.115 -114.142, 18 v 2010, light, T. Pike (CNC); 3 ♀♀ (MS2275, DNA3910, GenBank KF594486, KF615953; MS2280; MS2274) Edmonton, nr. Fulton Ravine, 53.545 -113.439, 15-16 v 2008, light, G. Anweiler (CNC); 1 ♂ (MS2284) same data except date is 17 v 2008 (UASM); 1 ♀ (MS9688, DNA3974, GenBank KF594547, KF615956) same data except date is 23 v 2009 (CNC); 2 ♀♀ (MS2286, MS2290) same data except date is 24 v 2008 (UASM); 1 ♀, 1 ♂ (MS5632, DNA3933, GenBank KF594507, KF615951; MS4301) same data except date is 26 v 2011 (CNC); 9 ♀♀ (MS13809, MS13811, MS13815, MS13820-22, MS13826-28) same data except date is 27 v 2011 (UASM); 3 ♀♀ (MS12169, MS12171–72) same data except date is 31 v 2009 (UASM); 7 ♀♀ (MS13834–35, MS13842–43, MS13858, MS13862) same data except date is 6-8 vi 2011 (UASM); 5 ♀♀, 2 ♂♂ (MS13763–65, MS13767, MS13757, MS13774, MS13782) same data except date is 9-11 vi 2011 (UASM); 2 ♂♂ (MS78, MS80) same data except date is v 2007 (CNC); 2 ♀♀ (MS2879, MS2886) Edmonton, Edith Ravine, 53.510 -113.622, 12 v 2010, UV light, J. Acorn (UASM); 1 ♀ (MS2885) same



Plate 2. *Ophion idoneus* Viereck, type specimen; **a** habitus **b** face **c** head, dorsal **d** propodeum **e** labels.

data except date is 27 v 2010 (UASM); 1 ♀ (MS2234, DNA5552, GenBank KF594576, KF615958) Edmonton, inside building, 53.521 -113.521, J. Dombroskie (CNC); 3 ♂♂ (MS100, MS103, MS107) Edmonton, River Valley at U.Alberta, 53.529 -113.519, 28 v 2007, Sweep, M. Schwarzfeld (CNC); 1 ♀ (MS2770, DNA6551, GenBank KF594763, KF615949) EMEND site, 48 km NW of Dixonville; Decid. forest, uncut, 56.7525 -118.3282, 28 v-10 vi 2008, Malaise, 852-2, M. Schwarzfeld (CNC); 2 ♀♀ (MS12420, MS12423) Erskine, 5 Maple Close, backyard with aspen, 830m, 52.322 -112.883, 19 v 2010, UV, C.D. Bird (UASM); 1 ♀, 1 ♂ (MS9763–64) George Lake Research Site, 53.953 -114.120, 29 v 2007, Sweep, M. Schwarzfeld (UASM); 1 ♂ (MS39) George Lake Research Site, Aspen forest, 53.957 -114.125, 25 v 2007, Sweep, M. Schwarzfeld (UASM); 1 ♀ (MS3613) N. Wyndham-Carseland Provincial Park, 50.8366 -113.4347, 31 v 2008, light, T. Pike (UASM); 2 ♀♀ (MS5650, DNA3977, GenBank KF594549, KF615957; MS5651, DNA3950, GenBank KF594524, KF615952) Pigeon Lake, Itaska,

53.072 -114.072 3 vi 2008, UV light, F. Sperling (CNC); 1 ♀ Pigeon Lake, Itaska, May 28, 2006, F.A.H. Sperling coll.; 9 ♀♀ 14 ♂♂ (MS12460, MS12463, MS12472, MS12474–83, MS12485–93, MS12495) Rochon Sands Prov. Park, 15 km N Erskine, 720m, aspen, chokecherry, aspen, 52.46 -112.88, 2 vi 2010, UV, C.D. Bird (UASM); 1 ♂ (MS12197) Spruce Grove, 13 km South, 53.4 -113.9, 28 v-2 vi 1989, Malaise, A.T. Finnamore (CNC); 1 ♀ (MS12265) Summer Village of Gull Lake, 52.460 -113.947, 31 v 2009, UV trap, J.H. Acorn (UASM); 1 ♂ (MS13966) Wintering Hills West, 51.2552 -112.6261, 29 v 2011, net, J. Dupuis (UASM); BC: 1 ♂ (ENT008-002270) Robson, “?” v 1951, H.R. Foxlee, Ex. H.R. Foxlee Collection U.B.C. 1971 (RBCM); 1 ♂ (ENT008-005274) same data except date is 14 v 1954 (RBCM); 1 ♀ (ENT008-002250) same data except date is 15 v 1951 (RBCM); 1 ♂ (ENT008-002274) same data except date is 15 v 1954 (RBCM); 1 ♀, 1 ♂ (ENT008-002252, ENT008-002275) same data except date is 17 v 1954 (RBCM); 1 ♂ (ENT008-002230) same data except date is 29 v 53 (RBCM); 1 ♂ (ENT008-002239) same data except date is 3 v 51 (RBCM); 1 ♂ Robson, 8 v 1954, H.R. Foxlee (UBCZ); MB: 2 ♀♀ 10 mi. S. of Winnipeg, 1 vi 1973, coll. C. Starr, at UV light (SEM); 2 ♀♀ same data except date is 30 v 73 (SEM); 1 ♀ Brandon, 29 v 49, Light Trap (NFRC); ON: 4 ♀♀, 2 ♂♂ (MS2927, MS2932–34, MS2940, MS2943) Bells Corners, Monaghan Forest, 45.272 -75.808, 18 v 2010, Light, B.C. Schmidt (UASM); 1 ♀, 1 ♂ (MS8020, MS8039) Bells Corners, Stony Swamp, 45.295 -75.830, 25 v 2008, B.C. Schmidt (UASM); 1 ♂ (MS12164) Bells Corners, Stony Swamp, 45.295 -75.830, 3 v 2010, MV light, J. Dombroskie, B.C. Schmidt (UASM); 1 ♀, 1 unknown (MS10755, DNA5554, GenBank KF594578, KF615955; MS10754) Grenadier Is., St. Lawrence Islands Nat. Pk., *Carya* grove, 44.4 -75.9 10–21 vi 1994, YPT, Coll. CNC Hym Team (CNC); 1 ♀ (MS10710) same data except date is 24 v-9 vi 1994 (CNC); 7 ♂♂ (MS10713, DNA6552, GenBank KF594764, KF615960; MS10711; MS10716–17; MS10719–21) same data except trap is Malaise, date is 24 v-9 vi 1994 (CNC); 1 ♀ (MS10751) same data except trap is Malaise, date is 3–13 v 1994 (CNC); 1 ♀ (MS8007, DNA3976, GenBank KF594548, KF615961) Leeds Grenville Co., Long Mtn. 44.487 -76.008, 7 vi 2008, B.D. Schmidt (CNC); 2 ♀♀ (MS10807, MS10813) same data except date is 21 v 2009 (UASM); 5 ♀♀, 22 ♂♂ (MS10793, DNA5717, GenBank KF594635, KF615959; MS10794, DNA5552, GenBank KF594576, KF615958; MS10779, DNA5551, GenBank KF594575, KF615954; MS10768–78, MS10780–92) Ottawa, city garden, 45.356 -75.707, 5 v-5 vi 2008; Malaise, Coll. H. Goulet (CNC); 1 ♂ Waterloo Co., Cambridge, malaise, Skevington & Cannings (RBCM); SK: 1 ♀ S'toon, May 22, 1940, D.R. Foskett (RBCM); USA: MI: 1 ♀ Ag. Coll. Mich 5–23 93 22 (CUIC); 1 ♂ Ag. Coll. Mich 5-23 95 22 (CUIC); NY: 1 ♀, 1 ♂ Ithaca, v 23 1936 (CUIC); 1 unknown Orient, L.I. June 2, 1932, Roy Latham/ Roy Latham Collection (CUIC).

Diagnosis. Smallest species within the species group; MLC fused immediately apically of ASu, therefore appears Y-shaped; ramellus usually absent or extremely short; Wing L: 8.4–11.5 mm, Flag: 51–57.

Description. Head: Eyes weakly convergent in frontal view; stemmaticum very weakly raised, sulci not complete; IOD/OL: 0.58–1.25, OOD/OL: 0.25–0.43 (♀), 0.35–0.92 (♂); occipital carina rounded, often very slightly rippled or wavy, usually

with a small peak at centre, OC/OL: 0.58–0.95; temple receding, approximately equal to eye width in lateral view; clypeus convex in lateral view and distinctly separated from face, coriaceous, with small regular shallow punctures only slightly larger than on face, separated by approximately their diameter, CH/CAW: 0.57–0.70; face subpolished to very weakly coriaceous, with small shallow punctures separated by approximately their diameter, slightly more dense on sides; FW/FH: 1.28–1.45; antennae with 51–57 flagellomeres, F1: 2.93–4.00; F20: 1.33–2.00; MS/MW: 0.50–0.82; GI/MW: 0.46–0.73.

Mesosoma: Mesoscutum subpolished with very small to minute regular punctures separated by approximately $2\times$ their diameter; mesopleuron weakly coriaceous, strongly closely punctate, punctures separated by their diameter or less, above mesopleural fovea subpolished with small punctures separated by $1\text{--}3\times$ their diameter; metapleuron slightly more coriaceous, punctures similar in size to those of mesopleuron, only slightly less dense; epicnemial carina with pleurosternal angle obtuse; scutellum with lateral carina strong along most of length, SL/SW: 1.21–1.69.

Propodeum: ATC strong, weakly arched above ASu; PTC weak to obsolete along ASu, raised into small crests where intersects with MLC, absent along AD, strong along AJC; MLC obsolete and weakly convergent along ASu, strongly convergent just apical to ASu, so that the carinae fuse into one stronger carina for most of AP; LLC almost absent, short carina in AJC may be remnant of this carina; PC strong, not connected to spiracle; spiracular area slightly sloping, nearly horizontal, subpolished with shallow minute indistinct punctures, separated by $2\text{--}3\times$ their diameter; posterior area wavy-wrinkled with very shallow indistinct punctures basally, more wrinkled apically.

Wings: Wing L: 8.4–11.5 mm, CI: 0.48–0.84, AI: 1.95–3.31, SDI: 1.03–1.29, ICI: 0.44–0.80; wings with veins dark brown, stigma light brown with apex whitish-gray, ramellus completely absent or represented by a minute vestigial stub, rarely somewhat long, fenestra not extending below prestigma.

Legs: CL/CW: 1.41–1.85, FL/FW: 6.31–7.85, MT1/MT2: 2.09–2.50; MTS: 0.71–0.89.

Metasoma: Expansion from petiole to postpetiole gradual.

Colour: Reddish-orange, mandibles, palps and legs slightly paler; orbits, tegula and dorsal part of mesepimeron yellowish.

Seasonality. All collection records are from May and June, with the exception of a single specimen collected on Aug 15 from Bragg Creek, Alberta.

Remarks. Common and wide-spread early-season species. Most small dark reddish individuals, lacking yellow notauli, collected in May will be this species, at least in the northern Nearctic region. The original description (Viereck 1905) for this species is quite detailed, and is sufficient to identify this species; I have re-described it here so that the description is consistent with the other members of the species group. I excluded characters from the original description that apply to the species group as a whole, and focused on characters that distinguish it from other species within the group.

***Ophion importunus* Schwarzfeld, sp. n.**

<http://zoobank.org/284591E3-6786-44DB-AF14-CDC0767ACF9C>

Figures 10c, 11c; Plate 3

Type material. Holotype: ♀ (MS12343, DNA6907, GenBank KF594814, KF615963, KF616346) CAN: AB: 8 km NW of Winfield, Bird East Poplar Creek quarter, mixed woods, 900m; 53.01 -114.5; 15 v 2010; UV; C.D.Bird (CNC).

Paratypes: 2 ♀♀. CAN: AB: 1 ♀ (MS13904) 8 km NW of Winfield, Bird East Poplar Creek quarter, mixed woods, 900m, 53.01 -114.5, 21 v 2011, UV, C.D.Bird (CNC). ON: 1 ♀ (MS12153) Bells Corners, Stony Swamp, 45.295 -75.83, 3 v 2010, MV light, J.Dombroskie, B.C.Schmidt (CNC).

Etymology. This species is most similar to *O. idoneus*. Since *idoneus* is the Latin word for “suitable” or “proper”, the name for this species is derived from the Latin word *importunus*, meaning “unsuitable”.

Diagnosis. Similar to *O. idoneus*, but can be recognized by the larger size, LMC convergent but not meeting (thus propodeum lacks Y-shaped carinae), and the long ramellus. Wing L: 12.6–13.3 mm, Flag: 54–57.

Description. Head: Eyes weakly convergent in frontal view; stemmaticum weakly raised, sulci not complete; IOD/OL: 0.53–0.85, OOD: 0.15–0.23; occipital carina rounded, very slightly rippled or wavy, OC/OL: 0.80–1.00; temple receding, approximately equal to eye width in lateral view; clypeus convex, weakly coriaceous, with small regular punctures only slightly larger than on face, separated by approximately their diameter, CH/CAW: 50–0.60; face subpolished with very small punctures separated by slightly more than their diameter in the centre and slightly less on the sides; FW/FH: 1.25–1.29; antennae with 54–57 flagellomeres, F1: 3.43–3.69; F20: 1.54–1.83; MS/MS: 0.46–0.58; GI/MW: 0.46–0.54.

Mesosoma: Mesoscutum subpolished with very small regular punctures separated by 1–2× their diameter; mesopleuron and metapleuron coriaceous, strongly closely punctate, punctures separated by less than their diameter; area of mesopleuron above mesopleural fovea subpolished with minute punctures separated by 1–3× their diameter; epicnemial carina: pleurosternal angle obtuse, rounded; scutellum with lateral carina strong along most of length, SL/SW: 1.55–1.60; **Propodeum:** ATC strong, moderately arched above ASu; PTC present along AJC, otherwise absent; MLC very weak and weakly convergent along ASu, stronger at apex of ASu, obsolete and represented by strongly convergent wrinkles along AP; LLC represented by indistinct wrinkles along AJC, otherwise absent; PC strong, sometimes weakly connected to spiracle by an obsolete carina; spiracular area sloping, subpolished with small punctures separated by less than their diameter; posterior area wavy-wrinkled with very shallow punctures basally, more wrinkled apically.

Wings: Wing L: 12.6–13.3 mm, CI: 0.60–0.67, AI: 1.58–1.89, SDI: 1.06–1.22, ICI: 0.62–0.80, wings with veins black, stigma reddish-brown with apex whitish-gray, ramellus long, fenestra not extending below prestigma.



Plate 3. *Ophion importunus* Schwarzfeld sp.n., type specimen; **a** habitus **b** propodeum and scutellum **c** mesothorax and head **d** face.

Legs: CL/CW: 1.61–2.00, FL/FW: 8.25–8.87, MT1/MT2: 2.19–2.26; MTS: 0.79–0.87.

Metasoma: Expansion from petiole to postpetiole somewhat abrupt.

Colour: Reddish-orange, orbits and sometimes mandibles yellow, tegula and dorsal part of mesepimeron yellowish, scutellum slightly paler than base colour.

Seasonality. All three collection records are in May.

***Ophion clave* Schwarzfeld, sp. n.**

<http://zoobank.org/59F09AD9-0EDE-490F-BA1A-A84128CB9ED4>

Figures 10d, 11d; Plate 4

Type material. Holotype: ♀ (MS12193, DNA6944, GenBank KF594831, KF615972, KF616352): CAN: AB: Spruce Grove, 13 km South, 53.4 -113.9, 28 v-2 vi 1989, Malaise, A.T.Finnamore (CNC)

Paratypes: 13 ♀♀, 3 ♂♂. CAN: AB: 2 ♀♀(MS12198-99) Same data as holotype (CNC); 1 ♂, 3 ♀♀ (MS13746, DNA7383, GenBank KF594963; MS13749, DNA7381, GenBank KF594961; MS13748; MS13752) Jenner Bridge, S. Jenner, riparian willow/sagebrush shrub, 50.844 -111.154, 2 vi 2010, UV trap, G.Anweiler (CNC); 1 ♀ (MS1689, DNA7391, GenBank KF594970) Jenner rodeo grounds, 50.842 -111.151, 07 vi 2007, Light, G.Anweiler (CNC); 1 ♂, 1 ♀ (MS71, DNA7382, GenBank KF594962; MS72) Jenner rodeo grounds, 50.842 -111.151, 09 v 2007, UV trap, M.Schwarzfeld (CNC); 1 ♀ (MS1434) Jenner rodeo grounds, 50.842 -111.151, 26 v 2007, UV trap, J.Dombroskie & G.Anweiler (CNC); 1 ♀ (MS12386) 17 km S of Stettler, Lowden Springs Conserv. Area, aspen/buckbrush/grassland, 822m, 52.154 -112.713; 26 v 2010; UV; C.D.Bird (CNC); 1 ♂ (MS11578) 17 km S of Stettler, Lowden Springs Conserv. Area, native prairie, 825m, 52.154 -112.712, 24 v 2009, UV, C.D.Bird (CNC). MB: 1 ♀ Brandon, 29.v.49, light trap (NFRC); ON: 2 ♀♀ (MS10758, MS10763) Leeds, Grenville Co. Long Mtn, 44.487 -76.008, 27 iv 2009, B.C.Schmidt (CNC); 1 ♀ Waterloo Co., Cambridge, malaise, 18-21.v.1992, Skevington & Cannings (RBCM)

Etymology. “*Clave*” is the Spanish word for key, and refers to the arrangement of the propodeal carinae, which resemble an old-fashioned keyhole. It is also the fundamental rhythm in salsa music, which was undoubtedly playing as this species was being described. It is a noun in apposition.

Diagnosis. ATC of propodeum U-shaped above ASu; stemmaticum raised; occipital carina rounded; face coarsely densely punctate (most punctures separated by less than their diameter), and punctures connected by strong microreticulation; Wing L: 10.5–12.4 mm; Flag: 52–60. This species is most similar to *O. brevipunctatus*, but can be distinguished by the sculpture of the face, the more extensive yellow orbits and the smaller size. This species is also similar to *O. idoneus* and *O. importunus*, but can be most easily distinguished by the strongly convex ATC.

Description. Head: Eyes slightly convergent to nearly parallel in frontal view; stemmaticum raised, sulci surrounding stemmaticum complete or nearly so; IOD/OL: 0.53–1.00; OOD/OL: 0.13–0.29; occipital carina rounded, OC/OL: 0.67–0.92; temple receding, approximately equal to width of eye in lateral view; clypeus weakly convex in lateral view and very weakly separated from face, coriaceous with irregularly scattered coarse punctures, often interspersed with at least a few minute punctures, smaller and denser towards lateral and dorsal margins, less dense than on face (see variation), CH/CAW: 0.49–0.67; face evenly coarsely punctate, most punctures separated

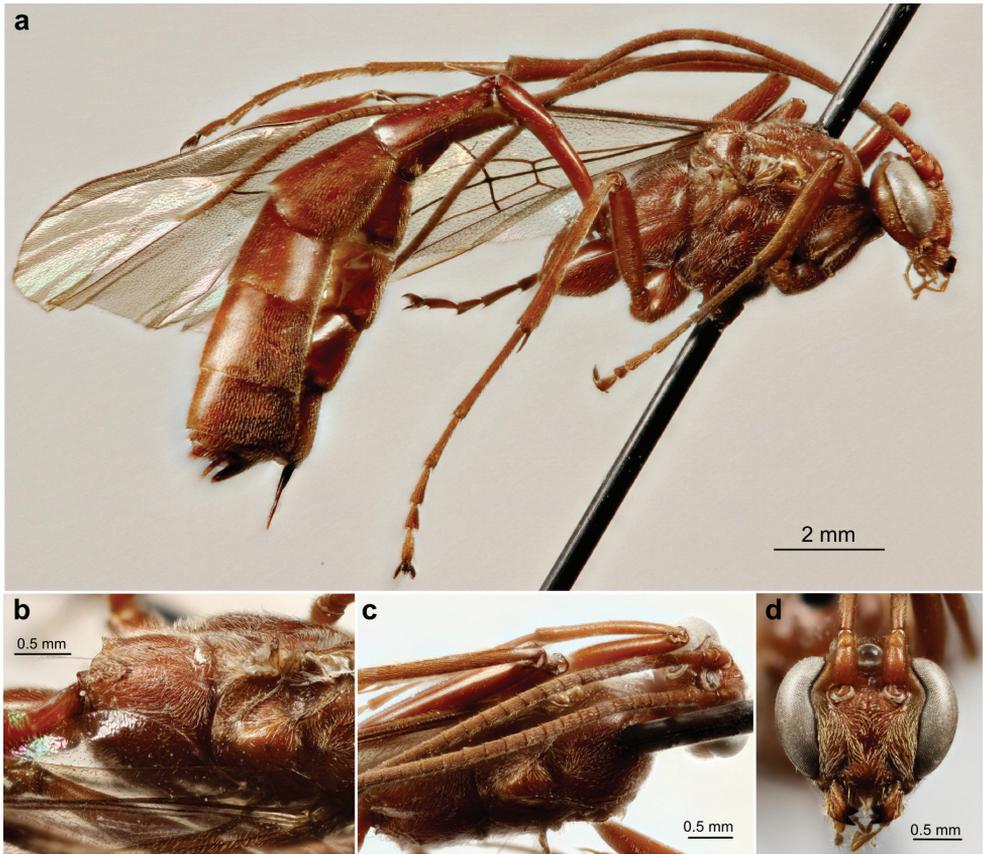


Plate 4. *Ophion clave* Schwarzfeld sp.n., type specimen; **a** habitus **b** propodeum and scutellum **c** mesothorax and head **d** face.

by less than their diameter and connected by strong microreticulation, smaller on sides than in centre (see variation); FW/FH: 1.18–1.26; antennae with 52–60 flagellomeres, F1: 3.00–4.17, F20: 1.36–1.83; MS/MW: 0.43–0.63; GI/MW: 0.36–0.67

Mesosoma: *Female:* Mesoscutum polished to subpolished (see variation), evenly, shallowly punctate with small to minute punctures; mesopleuron coriaceous with strong punctures separated by approximately their diameter, polished with sparse minute punctures above mesopleural fovea; epicnemial carina of females with pleurosternal angle approximately 90° , and more or less sharp, varying from slightly acute to slightly obtuse; SL/SW: 1.23–1.58; lateral carina strong along anterior third to two-thirds of scutellum; metapleuron coriaceous with strong punctures separated by approximately their diameter; *Male:* Same, except SL/SW: 1.43–1.67; pleurosternal angle of epicnemial carina rounded and slightly obtuse.

Propodeum: *Female:* ATC strong, strongly arched above ASu (so anterior margin of ASu is highly convex), occasionally weak to obsolete along AE; PTC present (occasionally obsolete) along ASu, usually produced as small crests where intersects with

MLC, obsolete to absent between AD and APE, strong along AJC; MLC weak and slightly convergent along ASu, strong (occasionally weak) and distinctly convergent (but not meeting) along AP; LLC weak to strong along AJC, otherwise absent; PC strong, not connected to spiracle; spiracular area slightly to strongly sloping, closely punctate, subpolished to coriaceous; posterior area rugulopunctate basally, strongly wrinkled apically; *Male*: Same pattern but all carinae tending to be weaker.

Wings: Wing L: 10.5–12.4 mm, CI: 0.39–0.59, AI: 1.13–2.16, SDI: 1.16–1.30, ICI: 0.52–0.93; veins dark brown to black, stigma light brown; fore wing with ramellus absent or present, discocubital cell entirely trichiose except for well-defined fenestra under stigma (not extending below prestigma).

Legs: *Female*: CL/CW: 1.58–1.93; FL/FW: 7.00–8.59 (♀), 7.00–7.18 (♂), MT1/MT2: 2.01–2.26 (♀); MTS: 0.72–0.88; *Male*: Same, except MT1/MT2: 1.69–2.02.

Metasoma: Sides of petiole gently divergent from spiracles to apex in females, more abruptly expanded at spiracles in males.

Colour: Reddish-orange; palps, mandibles and/or scutellum sometimes slightly paler; orbits narrowly yellowish; tegula and mesepimeron yellowish.

Variation. There is some geographic variation in this species, with less morphological variation in specimens from within each locality than there is between localities.

2 ♀♀ have clypeal punctures more densely and regularly spaced than in remaining specimens; 2 ♀♀ have facial punctures slightly smaller and facial microreticulation slightly weaker than in the remaining specimens; 1 ♂, 1 ♀ (from same locality) with mesoscutum coriaceous.

Seasonality. This species has been collected from late April until early June.

Ophion aureus Schwarzfeld, sp. n.

<http://zoobank.org/A6525116-194C-42DC-B454-FC927FF00AB1>

Figures 10e, 11e; Plate 5

Type material. Holotype ♀ (MS7632, DNA3970, GenBank KF615968) CAN: AB: Machesis Lk Forest Prov. Rec. Area, 32 km W Fort Vermilion, 318m, Jack pine forest, 58.325 -116.578, 10 vi 2008, UV trap, D.&S. Macaulay (CNC).

Paratypes 9 ♂♂ (MS2318, DNA3961, GenBank KF594535, KF645966; MS2324, DNA3911, GenBank KF594487, KF615965; MS2310, DNA3975, GenBank KF615969; MS2311, MS2313–16, MS2320) nr. Tangent Park Campgrnd, 23km S of Peace River, meadow in spruce/aspens, 56.092 -117.542; 7 v 2008, UV trap, D.Macaulay (CNC).

Etymology. The name *aureus* is the Latin word for golden, referring to the golden-orange colour of this species.

Diagnosis. Wing L: 14.3–17.1 mm, Flag: 65–69. Largest species in subgroup B; stemmaticum raised with sulci complete; reduced propodeal carinae with posterior area strongly wrinkled; more golden-orange (less reddish) than the other species in this species group.



Plate 5. *Ophion aureus* Schwarzfeld sp.n., type specimen; **a** habitus **b** propodeum **c** mesothorax and head **d** face.

Description. Head: Eyes weakly convergent in frontal view; stemmaticum distinctly raised, sulci surrounding stemmaticum complete and deeply impressed; IOD/OL: 0.65–0.80, OOD/OL 0.26–0.33; occipital carina rounded, OC/OL: 0.73–1.00; temple receding, approximately equal to width of eye in lateral view; clypeus moderately convex in lateral view and weakly separated from face, slightly more convex in males, coriaceous, sparsely punctate in males, very sparsely punctate in female, with irregularly sized (minute to coarse) punctures, punctures denser basally and especially laterally, CH/CAW: 0.0.53–0.64; face coriaceous with small punctures separated by slightly more than their diameter, smaller and denser on orbits than in centre, FW/

FH: 1.25–1.41; antennae with 65–69 flagellomeres, F1: 3.25–4.00; F20: 1.47–2.38; MS/MW: 0.52–0.76; GI/MW: 0.32–0.66.

Mesosoma: Mesoscutum densely evenly punctate, subpolished with minute punctures in males, weakly coriaceous with slightly larger punctures in female; mesopleuron coriaceous with strong punctures separated by approximately their diameter in female, punctures smaller and separated by approximately 2× their diameter in males, subpolished with smaller sparser punctures above mesopleural fovea, epicnemial carina with pleurosternal angle 90° to slightly obtuse, rounded (occasionally somewhat sharp); scutellum with lateral carina strong at base, present along basal third to half; SL/SW: 1.13–1.38; metapleuron coriaceous (strongly coriaceous in female), punctures smaller and sparser than on mesopleuron.

Propodeum: *Female:* ATC strong along ASu, strongly arched (so anterior margin of ASu is highly convex), otherwise absent; PTC present along ASu, raised into crests where intersects with MLC, absent along APE, extremely strong (raised as a flange) along AJC; MLC very weak and slightly convergent along ASu, stronger and nearly parallel along AP; LLC absent; two strong longitudinal wrinkles in AJC, one of which probably represents remnant of LLC; PC strong, not connected to spiracle; propodeum short, spiracular area sloping, punctate, strongly coriaceous, posterior area rugose; *Male:* similar, but with all carinae much less developed: ATC present as vestige in centre; PTC present only as slight crests where intersects with MLC and as a flange along AJC, but much less raised than in female; MLC convergent, weak to obsolete, often reduced to longitudinal wrinkles; punctures on spiracular area very shallow.

Wings: Wing L: 14.3–17.1 mm, CI: 0.41–0.60, AI: 1.57–2.36, SDI: 1.17–1.31, ICI: 0.70–1.00; veins brown to dark brown, stigma light brown with an apical white spot, fenestra mostly confined to area below stigma, in several specimens indistinctly extending below prestigma; trichiae more or less sparse along Rs+M; ramellus long

Legs: *Female:* CL/CW: 1.67, FL/FW: 7.95; MT1/MT2: 1.22; MTS: 0.86; *Male:* CL/CW: 1.69–2.08; FL/FW: 8.11–9.63; MT1/MT2: 1.22–2.19; MTS: 0.70–0.90.

Metasoma: Sides of petiole gently divergent from spiracles to apex, some males with more abrupt expansion at spiracles

Colour: Uniformly golden-orange, males less reddish than other members of the species group, female distinctly less reddish. Orbits narrowly and indistinctly yellow, more yellow posterior to eye; tegula and extreme dorsal part of mesepimeron yellowish.

Seasonality. This species had been collected in only two collection events, the males in mid-May and the one female in mid-June.

***Ophion brevipunctatus* Schwarzfeld, sp. n.**

<http://zoobank.org/88A11622-15EA-40E9-B988-1EAC4AF972E2>

Figures 10f, 11f; Plate 6

Material examined. Holotype ♀ (MS7990, DNA3939, GenBank KF594513, KF615967, KF616314) CAN: ON: Carleton Co., Carp Ridge, nr. Carp; 45.385–76.008; 13 v 2008; UV light; B.C. Schmidt (CNC).

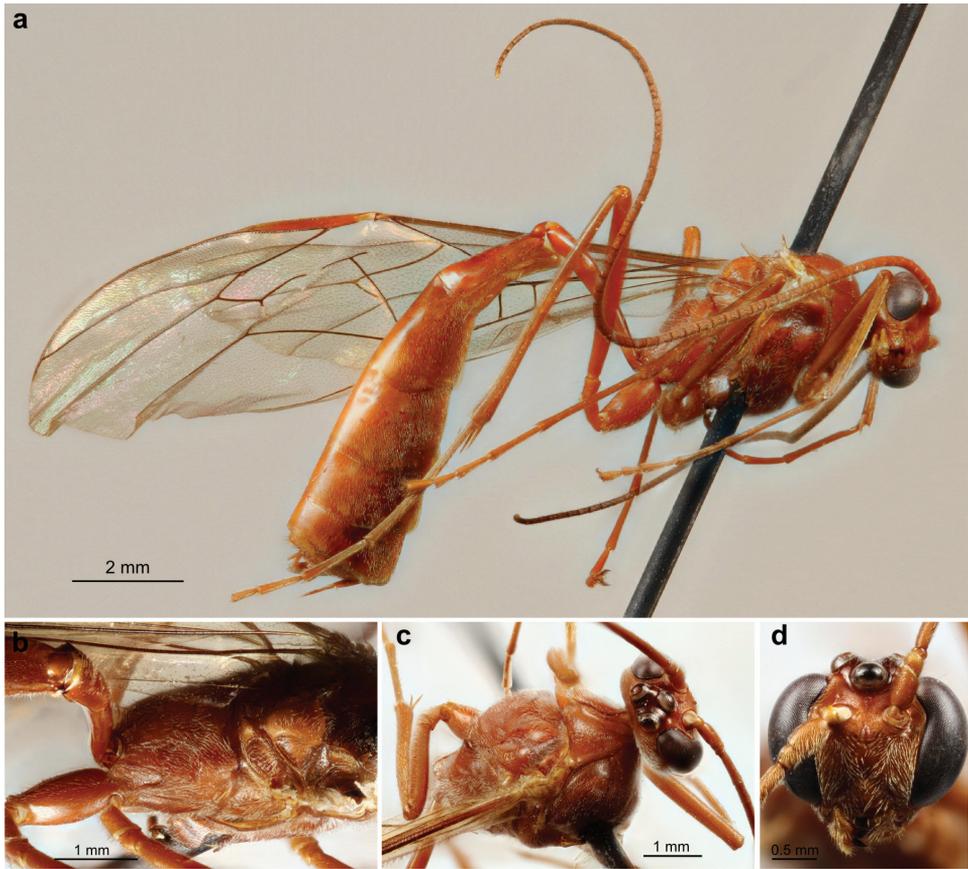


Plate 6. *Ophion brevipunctatus* Schwarzfeld sp.n., type specimen; **a** habitus **b** propodeum and scutellum **c** mesothorax and head **d** face.

Etymology. The name is derived from the Latin words *brevis* and *punctatus*, referring to the unusually shallow punctures of the face.

Diagnosis. Wing L: 14.0 mm; Flag: 67; ATC strongly arched above ASu; stemmaticum raised with sulci complete; facial punctures small, very shallow, widely separated but connected with strong microreticulation; temple strongly receding, 0.6× eye width (other species in this group with temple approximately equal to eye width); stemmaticum dark, no yellow on orbits.

Description. Head: Eyes convergent in frontal view; stemmaticum raised, sulci complete; IOD/OL: 0.69, OOD/OL: 0.13; occipital carina rounded, OC/OL: 0.78; temple strongly receding, 0.6× as long as eye width in lateral view; CH/CAW 0.58× apical width, only slightly convex in lateral view, weakly separated from face; clypeal punctures irregularly sized, sparsely, irregularly distributed across coriaceous clypeus; punctures of face small, very shallow, separated by 2–3× their diameter, connected by strong microreticulation; FW/FH: 1.27; antennae with 67 flagellomeres; F1: 3.6; F20: 1.8; MS/MW: 0.5; GI/MW: 0.5.

Mesosoma: Mesoscutum subpolished, evenly punctate with minute punctures; mesopleuron coriaceous with strong punctures separated by approximately their diameter, varying to subpolished with smaller punctures anteriodorsally; subpolished with minute punctures above mesopleural fovea; epicnemial carina with pleurosternal angle slightly obtuse; SL/SW: 1.5, strongly carinate along the anterior third; metapleuron coriaceous with shallow medium-sized punctures, more sparsely distributed than on mesopleuron.

Propodeum: ATC strong, strongly arched along ASu (so anterior margin of ASu strongly convex); PTC obsolete in centre, strong at intersection with MLC and for a short distance along AD, otherwise obsolete along AD, very strong along AJC; MLC obsolete and slightly convergent along ASu, obsolete (represented by wrinkles) and strongly convergent along AP; LLC present along AJC, very weakly represented at intersection with ATC, otherwise absent; PC strong, not connected to spiracle; spiracular area sloping, coriaceous with small shallow punctures; posterior area weakly rugopunctate, becoming wrinkled apically.

Wings: Wing L: 14.0 mm, CI: 0.62, AI: 1.73, SDI: 1.29, ICI: 0.80, wing veins dark brown, stigma reddish-brown, fenestra restricted to area below stigma, trichiae slightly sparser below prestigma, ramellus long.

Legs: CL/CW: 2.0; FL/FW: 9.5, MT1/MT2: 2.1; MTS: 0.78.

Metasoma: Sides of petiole gradually expanding at spiracles.

Colour: Uniformly reddish-orange; stemmaticum distinctly darker, dark reddish-brown; palps and scutellum very slightly paler than base colour, tegula and extreme dorsal part of mesepimeron dark yellowish, mesopleural fovea slightly darker than base colour.

Seasonality. The one collection record is from May 13.

***Ophion dombroskii* Schwarzfeld, sp. n.**

<http://zoobank.org/E1B81D98-14D3-4B7B-959B-01E9873B93DA>

Figures 10g, 11g; Plate 7

Type material. Holotype ♀ (MS13975, DNA6548, GenBank KF594760, KF615971, KF616341) CAN: SK: nr. Newton L., 49.301 -107.764, 20 v 2011, UV trap, J. Dombroskie (CNC).

Etymology. This species is named for Jason Dombroskie, who was kind enough to collect the only known specimen of this species on an otherwise rainy and utterly unsuccessful moth-collecting trip.

Diagnosis. Wing L: 10.8 mm, Flag: 51; The head and thorax of this species are almost entirely black, making this species easily recognizable. It also has unusually short antennal segments, widely separated ocelli and a long, narrow scutellum.

Description. Head: Eyes slightly convergent in frontal view; stemmaticum slightly raised, sulci surrounding stemmaticum complete; IOD/OL: 1.20, OOD/OL: 0.45; occipital carina rounded, OC/OL: 1.20; temple receding, approximately equal to width of eye in lateral view; clypeus 0.5× as high as apical width, coriaceous, punctures



Plate 7. *Ophion dombroskii* Schwarzfeld sp.n., type specimen; **a** habitus **b** propodeum and scutellum **c** mesothorax and head **d** face.

irregularly sized (coarse to very small) and sparsely, irregularly distributed, denser on sides, CH/CAW: 0.50; face with medium-sized punctures, approximately separated by their diameter and connected with strong microreticulation, smaller on sides of face; FW/FH: 1.34; antennae short, 51 flagellomeres, F1: 2.7, F20: 1.1; MS/MW: 0.6; GI/MW: 0.8.

Mesosoma: Mesoscutum coriaceous, evenly punctate with minute punctures, separated by several times their diameter; mesopleuron and metapleuron strongly coriaceous, evenly, coarsely punctate with punctures separated by their diameter or less; mesopleuron above mesopleural fovea subpolished, punctures minute, separated by

2-3× their diameter; epicnemial carina pleurosternal angle obtuse; scutellum with lateral carina strong along anterior half, SL/SW: 1.8.

Propodeum: ATC strong and strongly arched along ASu (so anterior margin of ASu strongly convex), weak to obsolete along AD; PTC mostly obsolete, represented by wrinkles, forming small crests where intersects with MLC, strong along AJC, especially strong at propodeal apophysis; MLC obsolete, faintly represented by wrinkles along ASu and even more indistinctly along AP; LLC present as a wrinkle along AJC, otherwise absent; PC strong, not connected to spiracle; spiracular area sloping, coriaceous with numerous small punctures; posterior area weakly wrinkled and punctate, more wrinkled apically.

Wings: Wing L=10.8 mm, CI: 0.49, AI: 1.39, SDI: 1.15, ICI: 0.83; wings with veins dark brown, stigma light brown, fenestra not extending below prestigma, ramellus short.

Legs: CL/CW: 1.5, FL/FW: 7.2, MT1/MT2: 3; MTS: 0.85.

Colour: Head: black; orbits, temple, vertex, mandibles, palps and clypeus except for extreme base reddish-orange; Mesosoma: black; mesocutum (except margins and base of notauli), scutellum, anterior margin and an indistinct area in the centre of mesopleuron, apical margin of propodeum, apical half of coxae and legs reddish-orange; mesepimeron reddish-orange ventrally and yellowish dorsally; metasoma reddish-orange; ovipositor sheath same colour as metasoma.

Seasonality. The one collection record is from May 20.

Remarks. This species is unusual because of its extensive black markings. The unusually short antennae and black markings indicate that this species may be diurnally active (Gauld 1980). Gauld (1985) mentions a few undescribed deserticolous species with short antennae and quadrate central flagellomeres; we have not seen these specimens, so it is unknown whether this species should be considered among them.

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Appendix I

List of all specimens included in molecular and morphometric analyses.

Accession ¹	Provenance ²	Lat-long	Date	Coll. ³	Species ⁴	Sex	GenBank		
							COI	ITS2	28S
<i>O. scutellaris</i> species group									
DNA3970	AB: Machesis Lake PRA	58.325 -116.578	10 vi 2008	DM	<i>aureus</i> ^{CG}	F		KF615968	
DNA3911	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>aureus</i> ^{CG}	M	KF594487	KF615965	KF616311
DNA3961	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>aureus</i> ^{CG}	M	KF594535	KF615966	
DNA3975	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>aureus</i> ^{CG}	M		KF615969	
MS2313	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>aureus</i> ^{CG}	M			
MS2315	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>aureus</i> ^{CG}	M			
MS2316	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>aureus</i> ^{CG}	M			
MS2314	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>aureus</i> ^{CG}	M			
MS2311	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>aureus</i> ^{CG}	M			
MS2320	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>aureus</i> ^{CG}	M			
DNA3939	ON: nr. Carp	45.385 -76.008	13 v 2008	BCS	<i>brevipunctatus</i> ^{CG}	F	KF594513	KF615967	KF616314
DNA7381	AB: Jenner	50.844 -111.154	2 vi 2010	GGA	<i>clane</i> ^{CG}	M	KF594961		
DNA7382	AB: Jenner	50.842 -111.151	09 v 2007	MDS	<i>clane</i> ^{CG}	M	KF594962	KF615970	
DNA7383	AB: Jenner	50.844 -111.154	2 vi 2010	GGA	<i>clane</i> ^{CG}	F	KF594963		
DNA7391	AB: Jenner	50.842 -111.151	07 vi 2007	GGA	<i>clane</i> ^{CG}	F	KF594970		
MS72	AB: Jenner	50.842 -111.151	9 v 2007	MDS	<i>clane</i> ^{CG}	F			
MS1434	AB: Jenner	50.842 -111.151	26 v 2007	JJD	<i>clane</i> ^{CG}	F			
MS13752	AB: Jenner	50.844 -111.154	2 vi 2010	GGA	<i>clane</i> ^{CG}	F			
MS13748	AB: Jenner	50.844 -111.154	2 vi 2010	GGA	<i>clane</i> ^{CG}	F			
DNA6944	AB: Spruce Grove	53.4 -113.9	28 v-2 vi 1989	ATF	<i>clane</i> ^{CG}	F	KF594831	KF615972	KF616352
MS12198	AB: Spruce Grove	53.4 -113.9	28 v-2 vi 1989	ATF	<i>clane</i> ^{CG}	F			
MS12199	AB: Spruce Grove	53.4 -113.9	28 v-2 vi 1989	ATF	<i>clane</i> ^{CG}	F			
MS12386	AB: Stettler Co.	52.154 -112.713	26 v 2010	CDB	<i>clane</i> ^{CG}	F			
MS11578	AB: Stettler Co.	52.154 -112.713	24 v 2009	CDB	<i>clane</i> ^{CG}	M			

Accession ¹	Provenance ²	Lat-long	Date	Coll. ³	Species ⁴	Sex	GenBank		
							COI	ITS2	28S
n/a	MB: Brandon	49.83 -99.96	29 v 1949	?	<i>clava</i> ^C	F			
n/a	ON: Cambridge	43.46 -80.52	18–21 v 1992	S&C	<i>clava</i> ^C	F			
MS10758	ON: Leeds	44.487 -76.008	27 iv 2009	BCS	<i>clava</i> ^{C,G}	F			
MS10763	ON: Leeds	44.487 -76.008	27 iv 2009	BCS	<i>clava</i> ^{C,G}	F			
DNA6548	SK: nr. Newton Lake	49.301 -107.764	20 v 2011	JJD	<i>dombroskii</i> ^{C,G}	F	KF594760	KF615971	KF616341
ENT008-002252	BC: Robson	49.34 -117.70	17 v 1954	HRF	<i>idoneus</i> ^C	F			
ENT008-002250	BC: Robson	49.34 -117.70	15 v 1951	HRF	<i>idoneus</i> ^C	F			
ENT008-005274	BC: Robson	49.34 -117.70	14 v 1954	HRF	<i>idoneus</i> ^C	M			
ENT008-002230	BC: Robson	49.34 -117.70	29 v 1953	HRF	<i>idoneus</i> ^C	M			
DNA6551	AB: 48 km NW Dixonville	56.753 -118.328	28 v–10 vi 2008	MDS	<i>idoneus</i> ^{C,G}	F	KF594763	KF615949	
MS7373	AB: Bragg Cr.	50.917 -114.533	15 viii 2007	FAHS	<i>idoneus</i> ^{C,G}	F			
MS4026	AB: Calgary	51.115 -114.142	18 v 2010	TP	<i>idoneus</i> ^{C,G}	F			
DNA3908	AB: Edmonton	53.521 -113.521	20 v 2008	JJD	<i>idoneus</i> ^{C,G}	F	KF594484	KF615962	
MS100	AB: Edmonton	53.527 -113.519	28 v 2007	MDS	<i>idoneus</i> ^{C,G}	M			
MS107	AB: Edmonton	53.527 -113.519	28 v 2007	MDS	<i>idoneus</i> ^{C,G}	M			
MS103	AB: Edmonton	53.527 -113.519	28 v 2007	MDS	<i>idoneus</i> ^G	M			
DNA3933	AB: Edmonton	53.545 -113.439	15 vi 2008	GGA	<i>idoneus</i> ^{C,G}	M	KF594507	KF615951	
DNA3910	AB: Edmonton	53.545 -113.439	15–16 v 2008	GGA	<i>idoneus</i> ^{C,G}	F	KF594486	KF615953	
MS2274	AB: Edmonton	53.545 -113.439	15–16 v 2008	GGA	<i>idoneus</i> ^G	F			
MS2280	AB: Edmonton	53.545 -113.439	15–16 v 2008	GGA	<i>idoneus</i> ^G	F			
MS2284	AB: Edmonton	53.545 -113.439	17 v 2008	GGA	<i>idoneus</i> ^G	M			
DNA3974	AB: Edmonton	53.545 -113.439	23 v 2009	GGA	<i>idoneus</i> ^{C,G}	F	KF594547	KF615956	
MS2286	AB: Edmonton	53.545 -113.439	24 v 2008	GGA	<i>idoneus</i> ^G	F			
MS12169	AB: Edmonton	53.545 -113.439	31 v 2009	GGA	<i>idoneus</i> ^G	F			
MS12171	AB: Edmonton	53.545 -113.439	31 v 2009	GGA	<i>idoneus</i> ^G	F			
MS12172	AB: Edmonton	53.545 -113.439	31 v 2009	GGA	<i>idoneus</i> ^G	F			
MS78	AB: Edmonton	53.545 -113.439	v 2007	GGA	<i>idoneus</i> ^{C,G}	M			
MS80	AB: Edmonton	53.545 -113.439	v 2007	GGA	<i>idoneus</i> ^G	M			

Accession ¹	Provenance ²	Lat-long	Date	Coll. ³	Species ⁴	Sex	GenBank		
							COI	ITS2	28S
MS12420	AB: Erskine	52.322-112.883	19 v 2010	CDB	<i>idoneus</i> ^{G,G}	F			
MS9764	AB: George L	53.953-114.120	29 v 2007	MDS	<i>idoneus</i> ^G	F			
MS9763	AB: George L	53.953-114.120	29 v 2007	MDS	<i>idoneus</i> ^G	M			
MS39	AB: George L	53.957-114.125	25 v 2007	MDS	<i>idoneus</i> ^G	M			
MS11824	AB: George L	53.957-114.125	25-29 v 2007	MDS	<i>idoneus</i> ^G	F			
MS11825	AB: George L	53.957-114.125	25-29 v 2007	MDS	<i>idoneus</i> ^G	F			
MS11826	AB: George L	53.957-114.125	25-29 v 2007	MDS	<i>idoneus</i> ^G	F			
MS11827	AB: George L	53.957-114.125	25-29 v 2007	MDS	<i>idoneus</i> ^G	F			
MS11828	AB: George L	53.957-114.125	25-29 v 2007	MDS	<i>idoneus</i> ^G	M			
MS13334	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^{G,G}	M			
MS13333	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^{G,G}	M			
MS13319	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			
MS13330	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			
MS13331	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			
MS13332	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			
MS13336	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^{G,G}	F			
MS13320	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS13322	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS13324	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS13325	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS13326	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS13328	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS13329	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS13335	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS13317	AB: George L	53.957-114.125	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS12920	AB: George L	53.957-114.128	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			
MS12922	AB: George L	53.957-114.128	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			
MS12924	AB: George L	53.957-114.128	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			

Accession ¹	Provenance ²	Lat-long	Date	Coll. ³	Species ⁴	Sex	GenBank		
							COI	ITS2	28S
MS12926	AB: George L	53.957-114.128	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			
MS12927	AB: George L	53.957-114.128	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			
MS12928	AB: George L	53.957-114.128	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	M			
MS12923	AB: George L	53.957-114.128	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
MS12925	AB: George L	53.957-114.128	29 v-6 vi 2007	MDS	<i>idoneus</i> ^G	F			
n/a	AB: Pigeon Lake	53.072-114.072	38 v 2006	FAHS	<i>idoneus</i> ^{G,G}	M			
DNA3977	AB: Pigeon Lake	53.072-114.072	3 vi 2008	FAHS	<i>idoneus</i> ^{G,G}	F	KF594549	KF615957	
DNA3950	AB: Pigeon Lake	53.072-114.072	3 vi 2008	FAHS	<i>idoneus</i> ^{G,G}	F	KF594524	KF615952	
MS12475	AB: Rochon Sands PP	52.46-112.88	2 vi 2010	CDB	<i>idoneus</i> ^{G,G}	F			
MS12491	AB: Rochon Sands PP	52.46-112.88	2 vi 2010	CDB	<i>idoneus</i> ^{G,G}	M			
MS2261	AB: Sherwood Park	53.478-113.229	12-15 v 2008	GRP	<i>idoneus</i> ^G	F			
MS12197	AB: Spruce Grove	53.4-113.9	28 v-2 vi 1989	ATF	<i>idoneus</i> ^{G,G}	M			
MS12444	AB: Winfield	53.01-114.50	12 vi 2010	CDB	<i>idoneus</i> ^{G,G}	F			
MS12434	AB: Winfield	53.01-114.50	12 vi 2010	CDB	<i>idoneus</i> ^G	F			
MS12433	AB: Winfield	53.01-114.50	12 vi 2010	CDB	<i>idoneus</i> ^G	F			
MS12435	AB: Winfield	53.01-114.50	12 vi 2010	CDB	<i>idoneus</i> ^G	F			
MS12335	AB: Winfield	53.01-114.50	15 v 2010	CDB	<i>idoneus</i> ^{G,G}	M			
MS11457	AB: Winfield	53.01-114.50	16 v 2009	CDB	<i>idoneus</i> ^G	M			
	MB: Brandon	49.83-99.96	29 v 1949	?	<i>idoneus</i> ^C	F			
	MB: Winnipeg	49.74-97.13	1 vi 1973	CS	<i>idoneus</i> ^C	F			
MS2933	ON: Bells Corners	45.272-75.808	18 v 2010	BCS	<i>idoneus</i> ^{G,G}	F			
MS2927	ON: Bells Corners	45.272-75.808	18 v 2010	BCS	<i>idoneus</i> ^{G,G}	M			
MS2932	ON: Bells Corners	45.272-75.808	18 v 2010	BCS	<i>idoneus</i> ^{G,G}	M			
DNA5554	ON: Grenadier Is.	44.4-75.9	10-21 vi 1994	CNC	<i>idoneus</i>	?	KF594578	KF615955	KF616320
DNA6552	ON: Grenadier Is.	44.4-75.9	24 v-9 vi 1994	CNC	<i>idoneus</i> ^{G,G}	M	KF594764	KF615960	
DNA3976	ON: Leeds	44.487-76.008	7 vi 2008	BCS	<i>idoneus</i> ^{G,G}	F	KF594548	KF615961	
MS10780	ON: Ottawa	45.356-75.707	5 v-5 vi 2008	HG	<i>idoneus</i> ^{G,G}	M			
DNA5551	ON: Ottawa	45.356-75.707	5 v-5 vi 2008	HG	<i>idoneus</i> ^{G,G}	M	KF594575	KF615954	

Accession ¹	Provenance ²	Lat-long	Date	Coll. ³	Species ⁴	Sex	GenBank		
							COI	ITS2	28S
DNA5552	ON: Ottawa	45.356 -75.707	5 v-5 vi 2008	HG	<i>idoneus</i> ^{C,G}	F	KF594576	KF615958	
DNA5717	ON: Ottawa	45.356 -75.707	5 v-5 vi 2008	HG	<i>idoneus</i> ^{C,G}	F	KF594635	KF615959	
n/a	SK: Saskatoon	52.1 -106.6	22 v 1940	DRF	<i>idoneus</i> ^C	F			
DNA6907	AB: 8 km NW Winfield	53.01 -114.50	15 v 2010	CDB	<i>importunus</i> ^{C,G}	F	KF594814	KF615963	KF616346
MS13904	AB: 8 km NW Winfield	53.01 -114.50	15 v 2010	CDB	<i>importunus</i> ^{C,G}	F			
MS12153	ON: Bells Corners	45.295 -75.830	3 v 2010	BCS	<i>importunus</i> ^{C,G}	F			
MS7746	AB: 54 km NW Dixonville	56.86 -118.31	11 vi 2007	BBB	<i>keala</i> ^{C,G}	F			
DNA7324	AB: 62 km WNW Dixonville	56.684 -118.644	7 vi 2008	BBB	<i>keala</i> ^{C,G}	F	KF594914	KF615944	
DNA7327	AB: 62 km WNW Dixonville	56.685 -118.641	26 v 2008	BBB	<i>keala</i> ^{C,G}	F	KF594917	KF615946	
DNA3904	AB: Porcupine Hills	49.972 -114.087	28 v 2008	JJD	<i>keala</i> ^{C,G}	M	KF594480	KF615945	KF616307
DNA3960	AB: Porcupine Hills	49.972 -114.087	28 v 2008	JJD	<i>keala</i> ^{C,G}	F	KF594534	KF615950	
DNA3965	AB: Porcupine Hills	49.972 -114.087	29 v 2008	JJD	<i>keala</i> ^{C,G}	F	KF594539	KF615948	
DNA3980	AB: Porcupine Hills	49.972 -114.087	29 v 2008	JJD	<i>keala</i> ^{C,G}	F	KF594552	KF615947	
DNA6515	AB: Porcupine Hills	49.972 -114.087	15 vi 2009	JJD	<i>keala</i> ^{C,G}	F	KF594730	KF615943	KF616332
MS2237	AB: Porcupine Hills	49.972 -114.087	28 v 2008	JJD	<i>keala</i> ^{C,G}	F			
MS11464	AB: Winfield	53.01 -114.50	16 v 2009	CDB	<i>A</i> ^{C,G}	F			
MS4024	AB: Calgary	51.115 -114.142	18 v 2010	TP	<i>B</i> ^{C,G}	F			
MS4310	AB: Beaver Mines Lake	49.371 -114.295	16 vii 2009	TP	<i>C</i> ^{C,G}	F			
MS2322	AB: nr. Tangent Park	56.092 -117.542	7 v 2008	DM	<i>D</i> ^{C,G}	M			
MS11823	AB: George Lake	53.957 -114.125	25-29 v 2007	MDS	<i>E</i> ^{C,G}	M			
n/a	UK	not listed	not listed		<i>scutellaris</i>				EU378720
DNA7524	UK	?	?	GRB	<i>scutellaris A</i>		KF595042	KM982696	
DNA6914	UK: Pritstone Commons	51.81 -0.593	22 iv-7 v 2011	GRB	<i>scutellaris A</i>		KF594819	KF615964	KF616305
DNA7515	UK: Radnage	51.659 -0.858	3 v 2008	AMG	<i>scutellaris A</i>		KF594993		
DNA7558	UK: Radnage	51.659 -0.858	21 vii 2011	AMG	<i>scutellaris A</i>		KF595030		
DNA7519	UK: Westcott	51.848 -0.962	20 iii 2009	DW	<i>scutellaris B</i>		KF594995		

Accession ¹	Provenance ²	Lat-long	Date	Coll. ³	Species ⁴	Sex	GenBank		
							COI	ITS2	28S
Not <i>O. scutellaris</i> species group									
DNA6501	AB: 6 km N Guy	55.607 -117.161	22 vii–16 viii	BAM	<i>Ophion</i> sp.		KF594717	KF616256	KF616362
DNA6913	UK: Aldbury	51.799 -0.601	9 v 2011	GRB	<i>minutus</i>		KF594818	KF616300	KF616360
DNA3902	AB: Kootenay Plains PRA	52.064 -116.422	14 vii 2007	MDS	<i>Ophion</i> sp.		KF594478	KF615984	KF616308
DNA6550	SK: nr. Newton Lake	49.301 -107.764	20 v 2011	JJD	<i>Ophion</i> sp.		KF594762	KF616150	KF616343
DNA5559	BC: Vancouver	49.2 -123.2	3–17 ix 1997	IK	<i>Ophion</i> sp.		KF594583	KF615978	KF616371
DNA5742	BC: Glacier NP	51.26 -117.57	8 vii 2010	MDS	<i>Ophion</i> sp.		KF594660	KF615911	KF616337
DNA3957	AB: 21 km S Whitelaw	55.928 -117.995	29 vi 2008	DM	<i>Ophion</i> sp.		KF594531	KF615930	KF616381
DNA5566	MB: Winnipegosis	51.651 -99.945	16 vi 2007	HG	<i>Ophion</i> sp.		KF594589	KF616242	KF616321
DNA3901	AB: Kootenay Plains PRA	52.064 -116.422	14 vii 2007	MDS	<i>Enicospilus</i> sp.		KF594477		KF594477

1. Specimen accession numbers: DNA = Sperling lab (University of Alberta) DNA voucher number for newly sequenced specimens; MS = M. Schwarzfeld specimen number; ENT = RBCM database number

2. Abbreviations: NP = National Park; PP = Provincial Park; PRA = Provincial Recreation Area

3. Collectors: AMG = A.M. George; ATF = A.T. Finnamore; BAM = B.A. Mori; BBB = B.B. Bodeux; BCS = B.C. Schmidt; CDB = C.D. Bird; CNC = Canadian National Collection Hym team; CS = C. Starr; DM = D. Macaulay; DRF = D.R. Foskell; DW = D. Wilton; FAHS = F.A.H. Sperling; GGA = G.G. Anweiler; GRB = G.R. Broad; HG = H. Goulet; HRF = H.R. Foxlee; IK = I. Klimeszewski; JJD = J.J. Dombroskie; MDS = M.D. Schwarzfeld; S&C = Skevington & Cannings; TP = T. Pike

4. Species: All Nearctic species were determined by MDS; all newly sequenced Palearctic species were determined by GRB; C = specimen included in classical morphometric study; G = specimen included in geometric morphometric study

Eucharitidae (Hymenoptera, Chalcidoidea), a family new to the fauna of Saudi Arabia, with the description of the previously unknown male of *Eucharis (Psilogastrellus) affinis* Bouček

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Abstract

The family Eucharitidae (Hymenoptera: Chalcidoidea) is recorded for the first time for the fauna of Saudi Arabia based on *Hydrorhoa caffra* (Westwood) and *Eucharis (Psilogastrellus) affinis* Bouček. The record of *H. caffra* suggests that Al-Baha and Asir provinces should be considered as part of the Afrotropical rather than the Palearctic region. The previously unknown male of *E. affinis* Bouček is described and figured. Macrophotographs of the species are provided.

Keywords

Eucharitidae, *Eucharis*, *Hydrorhoa*, new records, Baha City, Asir province, Saudi Arabia

Introduction

The Eucharitidae (Hymenoptera: Chalcidoidea) are a monophyletic family of solitary parasitoids of ant pupae (Clausen 1940, Heraty 2002). They are the largest and most diverse group of hymenopteran parasitoids of eusocial insects. Members are distributed in almost every zoogeographic region of the world but are most abundant in the tropics (Heraty 2002). The family includes 54 genera and about 420 species worldwide (Heraty 2002, Torr ns 2013, Torr ns and Heraty 2013) classified in the three subfamilies Gollumiellinae, Oraseminae and Eucharitinae (Munro et al. 2011, Heraty et al. 2013, Murray et al. 2013).

The family is poorly represented in the Arabian Peninsula, with only two species of *Stilbula* Spinola (Narendran and Kumar 2004) and a single species of *Orasema* Cameron (Heraty 1994) reported from Yemen.

The Eucharitidae are here reported from the Arabian Peninsula, from Saudi Arabia (Al-Mekhwah, Baha Province; Raydah, Abha, Asir Province) based on *Eucharis* (*Psilogastrellus*) *affinis* Bou ek, for which we describe and figure the male for the first time, and *Hydrorhoa caffra* (Westwood).

Al-Baha and Asir provinces are situated in the south-western part of the kingdom of Saudi Arabia and are characterized by a natural tree cover and agricultural plateaus. Both are similarly divided into two main sectors. A lowland in the west forms a part of the coastal plain that extends from north to south, which is known as “Tihama”. There is also a mountainous area in the east with an elevation of about 1500–3000 m above sea level, known as “Al-Sarat or Al-Sarah” which forms part of the Al-Sarawat mountain range (Alahmed et al. 2010, Ibrahim and Abdoon 2005, El-Hawagry et al. 2013).

Sclater (1858) and Wallace (1876) were the first to propose many of the classical zoogeographic regions, and they placed the northern border of the Afrotropical region along the Tropic of Cancer. Consequently, Al-Baha and Asir Provinces were included in the Afrotropical region (H lzel 1998). However, according to Uvarov (1938), Greathead (1980), and Larsen (1984) this area should be united with the central Arabian deserts which are either considered as a part of the Palaearctic or, by some authors, as an autonomous Eremic zone (also called the Saharo-Sindian faunal region).

Material and methods

This study is based on specimens collected by sweep net in Saudi Arabia, from Al-Mekhwah (Baha City) and Raydah, Abha (Asir province). The male of *H. caffra* is deposited in Museum of Arthropods, Plant Protection Department, Faculty of Food and Agriculture Sciences, King Saud University, KSA (KSMA), while that of *E. (Psilogastrellus) affinis* is deposited in the Efflatoun Bey collection, Entomology Department, Faculty of Science, Cairo University (CUE). Morphological terms are based on Gibson (1997) and Heraty (1992, 2002, 2004). Terminology for body sculpture follows Harris

(1979). Photos were taken with a Canon camera (G12) attached to an Optech trinocular zoom stereomicroscope (LFZT). Measurements of the different parts were made with the help of an ocular micrometer.

Abbreviations used in the text are:

F = flagellomere; GS9 = last male sternite; OOL = ocellular line; POL = posterior ocellar line; T = metasomal tergite.

Insect depositories mentioned in the text:

CUE = Efflatoun Bey collection (Entomology Department, Faculty of Science, Cairo University, Egypt); KSMA = Museum of Arthropods, Plant Protection Department, Faculty of Food and Agriculture Sciences, King Saud University, Saudi Arabia; NMPC = National Museum, Prague, Czech Republic; SAMC = South African Museum, Cape Town; UMOX = Hope Entomological Collections, Oxford University Museum of Natural History, Oxford, England.

***Hydrorhoa caffra* (Westwood, 1874)**

Figs 1–3

Schizaspidia caffra Westwood, 1874: 152. Type data: Africa, Caffraria [South Africa].

Holotype ♂, by monotypy. Type depository: UMOX.

Sibulaspis fortistriata Cameron, 1907: 221. Type data: South Africa, KwaZulu-Natal,

Estcourt. Lectotype ♀, designation by Heraty 2002 for nomenclatural stability.

Type depository: SAMC.

Sibulaspis atropurpurea Cameron, 1907: 221–222. Type data: South Africa: KwaZulu-

Natal, Durban. Lectotype ♂, designated by Heraty 2002 for nomenclatural stability.

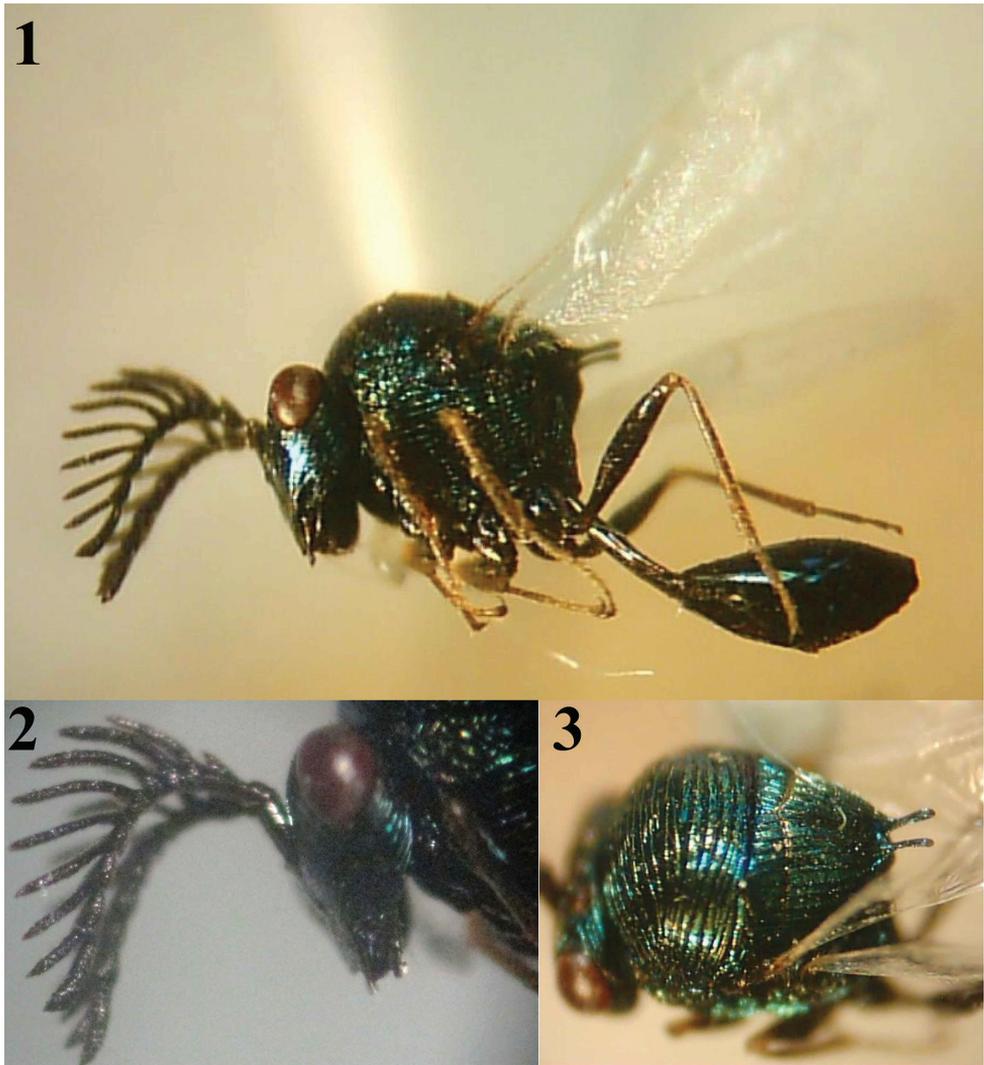
Type depository: SAMC.

Hydrorhoa caffra; Heraty 2002: 162.

Material examined. Raydah (Abha, Asir province), 18° 11.88'N; 42° 24.44'E, 2387 m, 7.vi.2014, leg. El-Hawagry [1♂, KSMA].

Diagnosis. Both sexes of this species are characterized within the genus by the form of the scutellar spines (Heraty 2002). The male is characterized by the following: metallic bluish-green color (Fig. 1); flagellomeres with long pectination; malar space long (about 2× longitudinal diameter of eye), transversely striated (Fig. 2); mesoscutum with coarse transverse striations and scutellum with coarse longitudinal striations (Fig. 3); posterior margin of scutellum with two long, slender processes, the distance between them less than half length of either (Fig. 3).

Distribution. Afrotropical: Kenya, Zimbabwe (Heraty 2002), South Africa (Westwood 1874, Cameron 1907, Heraty 2002), new to the Arabian Peninsula.



Figures 1–3. *Hydrorhoa caffra* (Westwood) (♂): **1** General habitus **2** Lateral view of head **3** Dorso-lateral aspect of mesosoma.

Remarks. *Hydrorhoa caffra* has Afrotropical affinities, previously being recorded only from Kenya, Zimbabwe and South Africa. The present record in Saudi Arabia is significant because it supports studies which consider that parts of the Arabian Peninsula, including Al-Baha and Asir Provinces, should be included in the Afrotropical rather than in the Palearctic region or the Eremic zone, and that the northern limit of the Afrotropical region should be placed in the Taif area, about 200 km north of Al-Baha (El-Hawagry et al. 2013, Hölzel 1998, Sclater 1858, Wallace 1876).

***Eucharis (Psilogastrillus) affinis* Bouček, 1956 (male)**

Figs 4–9

Eucharis (Pachyeucharis) affinis Bouček, 1956: 255–256. Type data: Israel: Bat Yam.

Holotype ♀, by original designation. Type depository: NMPC. Description of female, with illustrations.

Psilogastrillus affinis; Bouček 1977: 124. Change of combination (by inference).

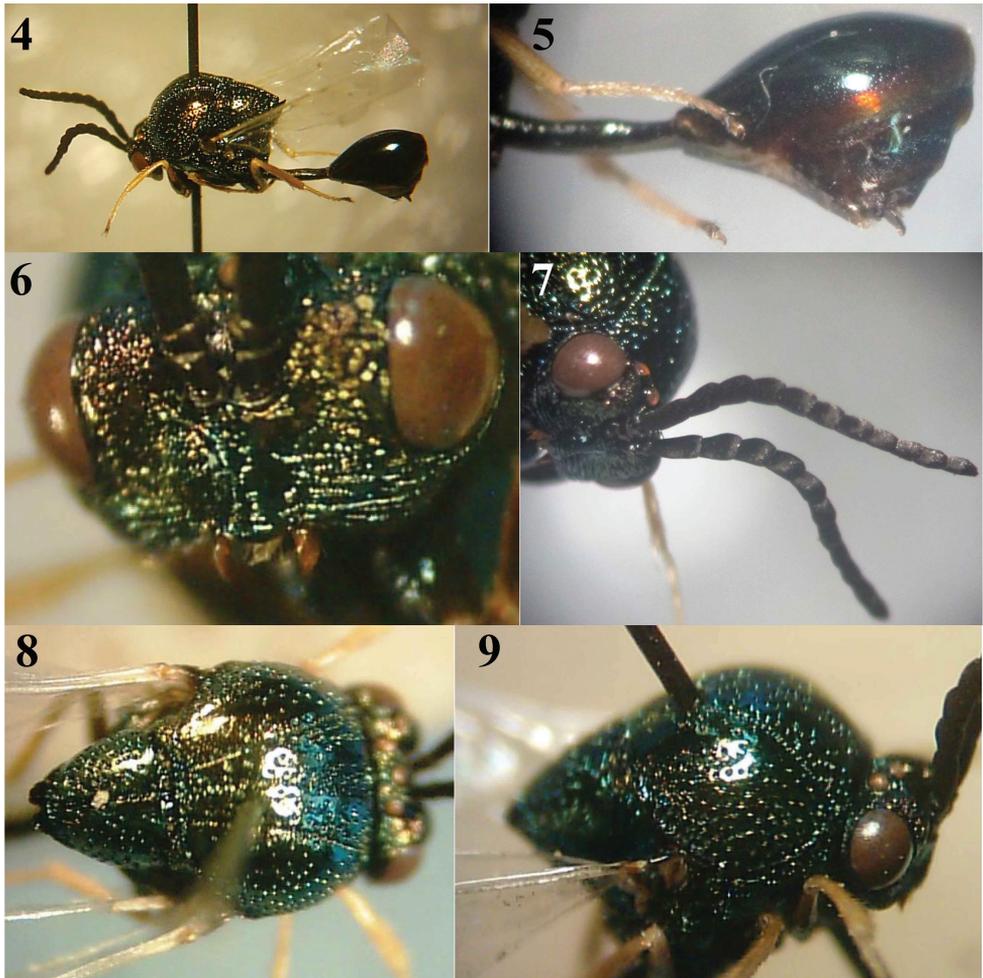
Eucharis (Psilogastrillus) affinis; Heraty 2002: 144.

Material examined. Saudi Arabia (Al-Mekhwah, Baha Province), 19°48.81'N; 41°26.45'E, 455m, 6.vii.2012, leg. El-Hawagry [1♂, CUE].

Description. Male: Body length: 6.1 mm. *Coloration* (Fig. 4). Head metallic dark green (except for upper face between eyes to lateral ocelli, antennal scape and pedicel which are metallic purple, flagellum dark brown to black, mandible reddish to orange, with black tip); mesosoma dark bluish green with reddish reflections especially lateral lobes; legs yellow except coxae which are metallic dark green; trochanters, basal two thirds of front and hind femora, middle femur (except distally), last tarsomeres and claws dark brown to black; metasoma brilliant metallic green, with a broad fulvous apical band on T1 as well as narrower bands on posterior margins of remaining tergites (Fig. 5); metasomal sternites mostly fulvous. Wings hyaline, with inconspicuous pale brown veins.

Head: In dorsal view semiglobular to transverse, 1.6× as broad as high and narrower than mesosoma (8:10). POL 1.7× OOL. Lower face, malar space and clypeus coarsely transversely striate. Clypeus not separated from supraclypeal area (Fig. 6), clypeal margin rounded. Eyes separated by 2.2× their height. Malar space 0.4× height of eye. Ocelli on uppermost part of head, equal in size, arranged in a broadly obtuse ocellar triangle forming an almost straight transverse line, interocular area with very thin transverse striations. Antenna (Fig. 7) 13-segmented, flagellomeres closely appressed; scape length 0.8× distance between torulus and upper margin of median ocellus; all flagellomeres longer than broad and cylindrical, F1 1.5× as long as F2 and F3 equal, F6-8 slightly longer than broad, last flagellomere rhomboidal, acuminate distally. Mandible relatively short, sickle-shaped ventrally and lacking subapical teeth.

Mesosoma (Figs 8, 9): Glabrous, with irregularly dispersed fine punctures, denser anteriorly and laterally. Mesoscutum with notauli well developed as foveolate lines, extending along its whole length, becoming thin anteriorly and more distinct, thicker and converging posteriorly; with a longitudinal foveolate sulcus between notauli, this sulcus indistinct on anterior half of mesoscutum, deeper and more distinct on posterior half, extending through scutellum along longitudinal mid line where it is deeper than on mesoscutum. Scutellar disc relatively large, hardly longer than broad, with closer and deeper puncturations dorsally, and with two close sub-triangular posterior processes, the distance between them less than length of either. Propodeum conical, medially depressed, with dense thick transverse striations laterally. Prepectus densely finely punctate. Mesopleuron shiny but superficially micropunctate, and smooth and



Figures 4–9. *Eucharis (Psilogastrellus) affinis* Bouček (♂): **4** General habitus **5** Lateral aspect of metasoma **6** Frontal view of head **7** Antenna **8** Dorsal view of mesosoma **9** Lateral aspect of mesosoma.

shiny ventrally; metapleuron with dense thick transverse striations. Front coxa coarsely sculptured, mid and hind coxae smooth and shiny. Wings with inconspicuous veins.

Metasoma (Fig. 5). Petiole relatively long, 2.1× as long as hind coxa and 5.9× as long as broad, straight in profile, with a fine irregular sculpture, dorsally with a narrow median sulcus that becomes broader posteriorly. Metasomal T1 smooth, shagreened along posterior margin; T2–4 with dense fine, shallow punctures; epipygium very small, whitish; GS9 spoon-shaped, distinctly concave ventrally, pointed apically.

Distribution. Israel (female, Bouček 1956), new for Arabian Peninsula.

Remarks. The male resembles the female (Figs 10–15) described by Bouček (1956) except for the following: wings of male entirely hyaline without any infuscation (apical two thirds of wings infuscated in female); F6–8 slightly longer than broad (F7–12



Figures 10–15. *Eucharis (Psilogastrellus) affinis* Bouček (♀ holotype): **10** Female holotype habitus **11** Dorsal view of mesosoma **12** Label (holotype ♀) **13** Lateral aspect of mesosoma **14** Posterior view of body **15** Frontal view of head.

subquadrate in female); metasoma mostly bright metallic green, with fulvous bands on posterior margin of tergites (metasoma mostly fulvous in female); unlike female, upper face metallic purplish; clypeus transversely striated (nearly smooth in female).

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***Circanota*: a new genus of Sparganothini from the Neotropics, and its two new species (Lepidoptera, Tortricidae)**

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Abstract

Circanota, new genus, and its two new species, *C. undulata* **sp. n.** (type species), from Costa Rica and Panama, and *C. simplex* **sp. n.**, from Panama and Ecuador, are described and illustrated. Although superficially similar to some species of *Platynota* Clemens, 1860, *Circanota* appears to be more closely related to members of a putative clade within Sparganothini defined by a slender crescent-shaped signum in the corpus bursae of the female genitalia. The most conspicuous autapomorphy for *Circanota* is the strongly undulate costa of the male and female forewing. Barcode sequence data (i.e., cytochrome oxidase I) from *Circanota undulata* (n = 12) form a tight cluster with exceedingly limited genetic divergence (less than 0.1%); specimens of *C. simplex* have not been sequenced. In neighbor-joining trees based on COI, *Circanota* is portrayed nearest *Sparganothoides*, which is consistent with morphological evidence.

Keywords

Costa Rica, Ecuador, morphology, Panama, *Platynota*, *Sparganothoides*, systematics

Introduction

Sparganothini is one of the smallest and most well-defined tribes in the family Tortricidae, with approximately 350 described species restricted almost exclusively to the New World; only a handful of species is recorded from the Palearctic (Powell and Brown 2012). The

tribe has been the subject of considerable contemporary systematic work (e.g., Landry and Powell 2001, Phillips-Rodriguez and Powell 2007, Kruse and Powell 2009, Kruse 2011, Powell and Brown 2012, Brown et al. 2013, Brown 2014), and its hypothesized phylogenetic position as sister to Atteriini has been demonstrated fairly convincingly (Regier et al. 2012). Nonetheless, new species and new genera continue to be discovered, primarily from the Neotropics. The purpose of this contribution is to describe a new genus and its two new species, one from Costa Rica and Panama, the other from Panama and Ecuador.

Methods

Dissection methods follow those presented in Brown and Powell (1991). Images of adults and genitalia were captured using a Canon EOS 40D digital SLR (Canon U.S.A., Lake Success, NY) mounted on a Visionary Digital BK Lab System (Visionary Digital, Palmyra, VA). Terminology for genitalia structures and forewing pattern elements follows Powell and Brown (2012). In descriptions of the forewing, “dorsum” refers to hind margin of the wing, i.e., the dorsal most edge of the wings when the live moth is in resting posture.

Tissue samples (i.e., one leg from a preserved adult) were used to amplify 650bp of the mitochondrial gene cytochrome oxidase 1 (COI), commonly referred to as the DNA “barcode,” using standard procedures employed at the Biodiversity Institute of Ontario, University of Guelph (e.g., Craft et al. 2010, Wilson 2012). Barcode data, along with images of the vouchers, are stored in BOLD (Barcode of Life Database).

Specimen depositories are abbreviated as follows: INBio, Instituto Nacional de Biodiversidad, Santa Domingo de Heredia, Costa Rica; MEM, Mississippi Entomological Museum, Mississippi State, MS, U.S.A.; and USNM, National Museum of Natural History, Washington, D.C., U.S.A.

Results

***Circanota* Brown, gen. n.**

<http://zoobank.org/B5C859DD-C5B1-4C49-8742-FF0E93BFF688>

Type species. *Circanota undulata* Brown, sp. n.

Diagnosis. *Circanota* is superficially most similar to *Platynota* Clemens, 1860, with a comparable forewing length and pattern, and long porrect labial palpi. *Circanota* can be distinguished from *Platynota* and all other sparganothine genera by the strongly undulate costa of the forewing in both sexes. Although females of a few species of *Platynota* (e.g., *P. flavendana* Clemens, 1860, *P. rostrana* (Walker, 1863)) have a slightly undulate costa, males typically have an evenly arched costa. Males of *Circanota* lack the complex scaling of the frons typical of many, but not all, *Platynota*, and the

labial palpi of *Circanota* lack pronounced sexual dimorphism; the palpi are conspicuously longer in the female in most Neotropical *Platynota*.

The female genitalia of *Circanota* are represented by two distinct types. In the type species, *C. undulata* sp. n., the anterior (typically cup-shaped) part of the sterigma, possibly homologous with the antrum, is broad and asymmetrical, unique within Sparganothini. In contrast, in *C. simplex* the structure is unmodified and similar to that of *Aesiocopa* Zeller, 1877. The signum is long, narrow, and somewhat slender crescent-shaped, most likely homologous with that of *Aesiocopa* Zeller, 1877, *Amorbia* Clemens, 1860, *Amorbimorpha* Kruse, 2011, *Coelostathma* Clemens, 1860, *Lambertiodes* Diakonoff, 1959, *Paramorbia* Powell & Lambert, 1986, *Rhynchophyllus* Meyrick, 1932, *Sparganocosma* Brown, 2013, *Sparganopseustis* Powell & Lambert, 1986, *Sparganothina* Powell, 1986, and *Sparganothoides* Lambert & Powell, 1986. *Circanota* lacks abdominal dorsal pits, which are present in *Aesiocopa*, many species of *Amorbia*, *Coelostathma*, and *Sparganopseustis*. In the male genitalia of *Circanota*, the uncus is long and slender, as in many other sparganothine genera (e.g., *Sparganothis* Hübner, 1825, *Cenopis* Zeller, 1875) and in contrast to the spindle-shaped (i.e., broadened subbasally) uncus of *Platynota*. The secondary arms of the socii are long and slender, more similar to those of males of genera whose females lack the crescent-shape signum (e.g., *Sparganothis*, *Cenopis*, *Platynota*). The valvae of *C. undulata* are highly modified, whereas those of *C. simplex* are less so, although in both species the distal edge of the valva (the area between the termination of the sacculus and the termination of the costa) is membranous and somewhat lobed (much more pronounced in *C. undulata*).

Description. Head: Vertex relatively smooth scaled, upper frons with large, flat tuft of scales overhanging lower frons, lower frons smooth scaled without complex hood. Antennal scaling in two bands per segment, sensory setae 0.7–0.9 times flagellomere width in male, shorter, sparser in female; labial palpus moderate in length, segment II about 2.0 times horizontal diameter of compound eye in male, only slightly longer in female, weakly upcurved; ocellus well developed in both sexes. Thorax: Notum smooth scaled throughout; legs unmodified. Forewing length 4.9–6.1 mm, slightly greater in females; costa undulate in both sexes; costal fold present in male, broad and pronounced in *undulata*, reduced and narrow in *simplex*; forewing without raised scales; R_4 and R_5 stalked in basal 0.6. Hindwing with R_s and M_1 approximate at base, CuA_1 and M_3 connate, and M_2 and M_3 approximate at base; cubital hair pecten present in both sexes, slightly less developed in males. Abdomen: Dorsal pits absent. Female lacking enlarged corethropyne scaling. Male genitalia with uncus long, slender, uniform in width throughout, curved ventrad apically; socius rather short, narrow, with slender line of sclerotization along inner edge, bearing long dense scales, secondary arm long, slender, not expanded apically; gnathos absent; transtilla slightly arched mesially, with few (*undulata*) or many (*simplex*) stout spines; pulvinus weakly developed; valva broad, short, with expanded “notch” subapically (in *undulata*); sacculus narrow, confined to basal edge of valva, either simple, without free distal process (*simplex*) or undulate with a long, free, weakly curved spine at termination (*undulata*). Phallus long, slender and curved in *undulata*, shorter, more pistol shaped in *simplex*; vesica with a field of about

25–30 short, slender, deciduous, asciculate cornuti. Female genitalia with papillae anales oblong-ovoid, slightly narrower anteriorly, densely covered with papillate setae throughout; apophyses about as long as papillae anales, posteriores slightly shorter than anteriores; sterigma a strongly sclerotized plate, flat along posterior margin, slightly rounded anteriorly, in *undulata* with a conspicuous, angulate-rhomboidal mesal portion immediately before junction with ductus bursae (typically the cup-shaped portion of the sterigma), in *simplex* simple, flat, unmodified; colliculum inconspicuous; ductus bursae uniformly narrow throughout, equal to or slightly longer than corpus bursae; corpus bursae round, entire surface with fine faint rounded punctations; signum a ribbon-like, crescent-shaped sclerite in posterior portion of corpus bursae; a tiny, membranous, pocket-like external evagination near signum.

Distribution and biology. *Circanota* includes two species: *C. undulata* from Costa Rica and Panama, and *C. simplex* from Panama and Ecuador. Hence, the documented range extends from southern Central America to northern South America. *Circanota undulata* has been collected from about 50–500 m in elevation, with a single individual from 900 m; and *C. simplex* is known from below 600 m.

Although the early stages of *Circanota* are unknown, circumstantial evidence suggests that larvae may feed in leaf litter, as was hypothesized for the related *Sparganothoides* (Kruse and Powell 2009). *Circanota undulata* is not among the species reared during the extensive survey of the caterpillars of Area de Conservación Guanacaste in northwestern Costa Rica (Janzen and Hallwachs 2014); however, it has been collected at light ($n = 8$ specimens) within the same study area. Because most Sparganothini are polyphagous leaf-rollers (Powell and Brown 2012), it is assumed that larvae of this species would have been encountered if it was feeding externally on living vegetation. Although leaf-litter feeding is unusual within Tortricidae, it is the main feeding mode in the Australian Epitymbiini (Tortricinae) (Powell and Common 1985) and has been implicated as the feeding strategy in the Nearctic genus *Anopina* Obratzsov, 1962 (Tortricinae: Euliini) (Brown and Powell 2000) and the Neotropical genus *Sparganothoides* (Kruse and Powell 2009).

Barcodes. BOLD (Barcode of Life Database, Biodiversity Institute of Ontario, University of Guelph) includes sequence data for 12 specimens of *Circanota undulata* but no specimens of *C. simplex*. Of the 12 specimens, I have examined four from the ALAS Project (The Arthropods of La Selva) (Colwell and Longino 2006) (INBio) and three from Area de Conservación Guanacaste (Janzen and Hallwachs 2014) (USNM). Five specimens from Area de Conservación Guanacaste could not be located. The 12 specimens show genetic divergence of less than 0.1% among the samples. In neighbor-joining trees (based on COI) for all Sparganothini, *Circanota* is portrayed nearest *Sparganothoides*, consistent with many morphological features (e.g., the crescent-shaped signum, the presence of secondary arms of the gnathos, the absence of dorsal pits, minimal sexual dimorphism).

Remarks. The male genitalia of the two included species are divergent in several features, in particular the shapes of the valva and the phallus, casting some doubt on their putative congeneric status. However, the two species are virtually indistinguishable in facies, including the most compelling synapomorphy of the genus (i.e., undulate

costa in both sexes), and the male genitalia share a unique combination of characters: a long, slender uncus; short socii with long, slender secondary arms (not expanded distally); and a membranous lobelike process at the outer margin of the valva. Both species also lack modified scaling on the frons in the male (which is present in many *Platynota*) and dorsal pits (which are present in many *Amorbia* and *Sparganopseustis* and nearly all *Coelostathma*, *Aesiocopa*, and *Sparganopseustis*). On the basis of these characters, the two species are assigned to *Circanota*.

Etymology. The generic name is from the Latin “circum”, meaning around, and the Latin “nota,” meaning mark. It is interpreted as masculine.

***Circanota undulata* Brown, sp. n.**

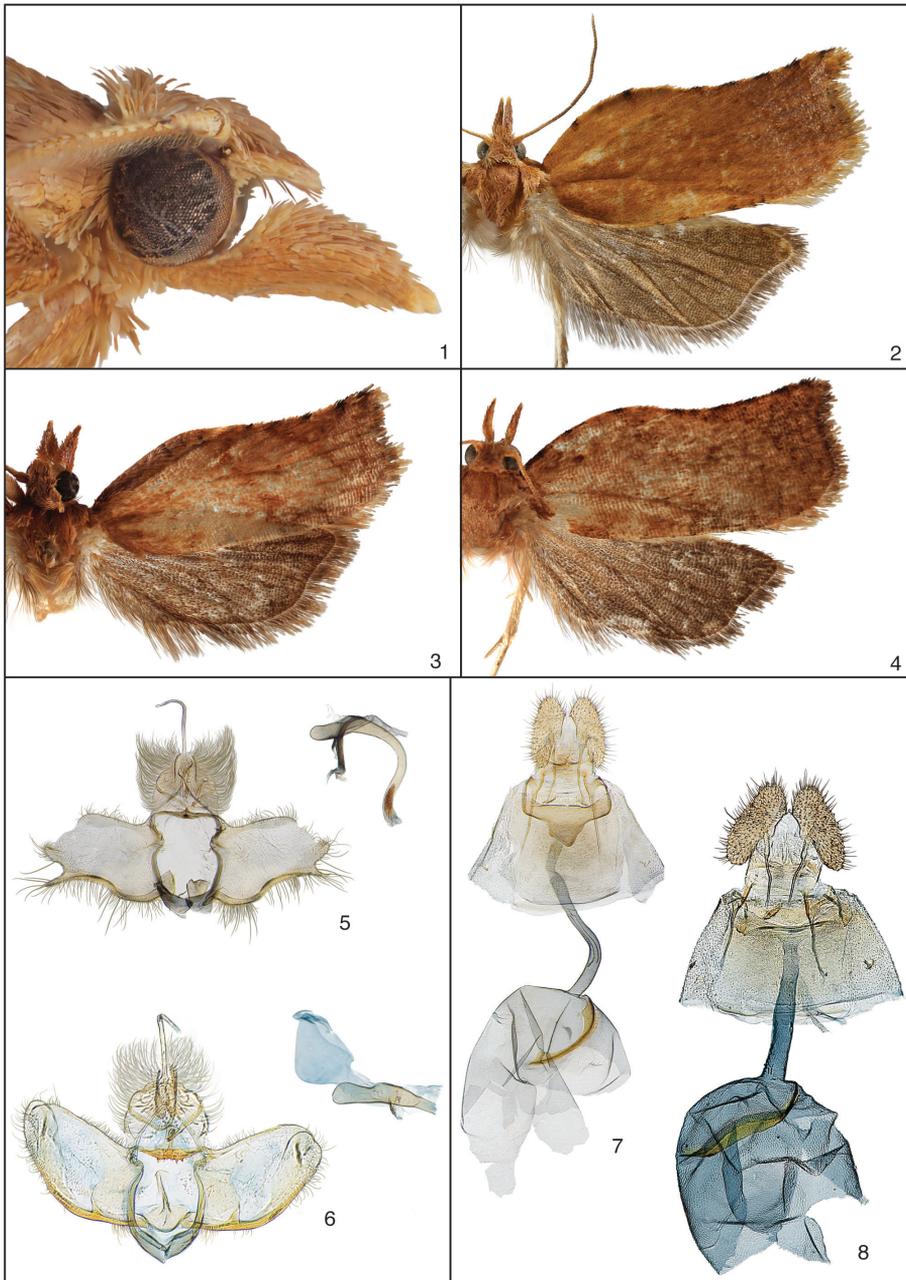
<http://zoobank.org/363BF9EF-58B2-4C09-9067-9B4400939B41>

Figs 1, 2, 3, 5, 7

Diagnosis. In *C. undulata* the valvae are short and broad, the membranous distal edge of the valva between the termination of the costa and the median lobe of the outer margin is exceedingly long, and the shape of the sacculus is unique - long and undulate, ending in a slender free spinelike process. All of these features are in strong contrast to their condition in *C. simplex*, which has a rounded valva that is bilobed distally, and a short, narrow sacculus lacking a free distal tip. The female genitalia of *C. undulata* have an asymmetrical anterior projection of the sterigma (= antrum) that is lacking in *C. simplex*.

Description. Male. Head: Vertex and upper frons uniform fawn brown, lower frons pale cream. Labial palpus fawn brown, paler on inner surface. Antenna pale fawn brown, slightly darker on scape. Thorax: Tegula and notum fawn brown. Forewing length 4.9–5.5 mm (mean 5.1; n = 6), fawn brown mixed throughout with pale orange brown, with faint, narrow, variable traces of slightly darker post-median and subterminal faciae, and a few short darker strigulae along costa; well developed costal fold occupying straight basal 0.4 of costa. Hindwing uniform dark gray brown. Abdomen: Genitalia (Fig. 5) with uncus long, slender, uniform in width throughout, hooked ventrad in apical 0.25; socius rather short, narrow, with slender line of sclerotization along inner edge, bearing long dense scales, secondary arm long, slender, not expanded apically; transtilla weakly expanded mesially with a single small median spine; valva broad, short, with costa short, well defined; an irregular “notch” extending from distal end of costa to lobe-like process near middle of outer margin of valva; sacculus well-defined, confined to basal edge of valva, undulate with a long, free, weakly curved spine at termination, a rounded excavation between tip of sacculus and lobe at middle of outer margin of valva. Phallus long, slender, undulate, nearly uniform in width throughout, with phallobase slightly expanded; vesica with a field of about 25–30 short, slender, deciduous (based on presence in female ductus bursae), asciculate cornuti.

Female. Head and Thorax: Essentially as described for male, except forewing length 5.0–5.9 mm (mean 5.5; n = 6) and forewing slightly darker overall. Abdomen:



Figures 1–8. Features of the adult of *Circanota*. **1** Head of male paratype of *C. undulata* from Turrialba, Costa Rica **2** Adult female paratype of *C. undulata* from Estación Biología La Selva, Costa Rica **3** Adult male holotype of *C. undulata* from Estación Biología La Selva, Costa Rica **4** Adult male paratype of *C. simplex* from Tinalandia, Ecuador **5** Male genitalia of holotype of *C. undulata* (USNM slide 118,864) **6** Male genitalia of paratype of *C. simplex* from Ecuador (USNM slide 142,059) **7** Female genitalia of paratype of *C. undulata* from 11 km ESE La Virgen, Costa Rica (USNM slide 118,863) **8** Female of paratype of *C. simplex* from Barro Colorado Island, Panama (USNM slide 144,903).

Genitalia (Fig. 7) as described for genus; sterigma a sclerotized plate, flat along posterior margin, slightly rounded anteriorly, confluent with an angulate-rhomboidal mesal portion at junction of sterigma and ductus bursae (typically the cup-shaped portion of the sterigma); ductus bursae uniformly narrow throughout, slightly longer than corpus bursae; ductus seminalis arising from ductus bursae ca. 0.33 distance from ostium to junction with corpus bursae; corpus bursae round, signum a ribbon-like, crescent-shaped sclerite, nearly uniform in width.

Holotype. Male, Costa Rica, Heredia, Estación Biología La Selva, 50–150 m, 10°26'N, 84°01'W, 12 May 1999, INBio-OET [BOLD: TONA407-08; JWB-08-0133]. Deposited in INBio.

Paratypes (11♂, 11♀). COSTA RICA: Alajuela: Area de Conservación, 09-SRNP-101007 (1♂) [BOLD: BLPDF403-09], 10-SRNP-106423 (1♂) [BOLD: BLPDR798-10], 10-SRNP-106757 (1♀) [BOLD: BLPDS133-10], D. Janzen & W. Hallwachs (USNM). Cartago: Turrialba, 17–21 Feb 1965 (1♂, 1♀), 13–17 Mar 1965 (1♂), S. S. & W. D. Duckworth (USNM). Heredia: Estación Biología La Selva, 50–150 m, 10°26'N, 84°01'W, 10 Jan 1993 (1♀), 12 Mar 1998 (1♀), 14 May 1998 (1♀), 21 Apr 1999 (1♂), INBio-OET, 26 Feb 2003 (1♂), 23–29 Feb 2004 (1♀) [BOLD: TONA408-08; JWB-08-0134], D. Wagner (INBio). 11 km ESE La Virgen, 250–350 m, 10°21'N, 84°03'W, 16 Mar 2004 (1♂), 18 Mar 2004 (1♂), 20 Mar 2004 (1♀), 21 Mar 2004 (1♂), 7 Apr 2004 (1♀) [BOLD: TONA409-08; JWB-08-0135], INBio-OET-ALAS transect (INBio). 10 km SE La Virgen, El Ciebo Ranger Station, 450–550 m, 10°20'N, 84°05'W, 11–12 Feb 2003 (1♂) [BOLD: TONA406-08; JWB-08-0132], D. Wagner (INBio), 17–23 Mar 2003 (1♀), 21 May 2003 (1♂), INBio-OET (INBio). Puntarenas: Golfito, 25–28 Apr 1965 (1♀), S. S. & W. D. Duckworth (USNM). PAMANA: Cabima, May 1911 (1♂), A. Busck (USNM). Cocle, El Valle, 800–900 m, 3–5 Jan 1988 (1♀), MacDonald & Schiefer (MEM).

Barcodes. In neighbor-joining trees, barcode sequence data from *Circanota undulata* (n = 12 field collected adults) form a tight cluster with genetic divergence of less than 0.1% among the individuals.

Distribution and biology. *C. undulata* is recorded from Costa Rica and Panama below about 900 m elevation. All the specimens were collected between January and May.

Etymology. The specific epithet refers to the undulate costa of the forewing.

***Circanota simplex* Brown, sp. n.**

<http://zoobank.org/1DDED0AC-8C88-4D62-BB55-261003E92F35>

Figs 4, 6, 8

Diagnosis. *Circanota simplex* can be distinguished superficially from *C. undulata* by the much narrower costal fold of the male forewing, which is broad and well defined in the latter. Otherwise, the two species are indistinguishable. In contrast, the male genitalia are extremely dissimilar between the two: those of *C. simplex* are much less modified than those of *C. undulata*, with a simple sacculus, a more elongate-rounded,

somewhat bilobed valva, and a phallus that is much shorter and more pistol shaped. The female genitalia of *C. simplex* likewise are dissimilar to those of *C. undulata*, with a symmetrical sterigma compared to the asymmetrical anterior extension of the sterigma (= antrum) in *C. undulata*.

Description. Male. Head: Vertex and upper frons uniform fawn brown, lower frons pale cream. Labial palpus fawn brown, paler on inner surface. Antenna pale fawn brown, slightly darker on scape. Thorax: Tegula and notum fawn brown. Forewing (Fig. 4) length 6.0 mm ($n = 1$); fawn brown mixed throughout with pale orange brown, with faint, narrow, variable traces of slightly darker post-median and subterminal fascia, and a few short darker markings along costa; male with costal fold weakly developed, occupying straight basal 0.4 of costa. Hindwing uniform dark gray brown. Abdomen: Genitalia (Fig. 6) with uncus long, slender, uniform in width throughout, curved in distal 0.2; socius rather short, narrow, with slender line of sclerotization along inner edge, bearing long dense scales, secondary arm long, slender, not expanded apically; transtilla slightly arched mesially, with several stout spines; valva short, broad, bilobed rounded distally; sacculus narrow, simple, confined to basal edge of valva, lacking free distal process. Phallus short, pistol shaped; vesica with a field of about 25–30 aciculate, presumably deciduous cornuti.

Female: Head and Thorax: Essentially as described for male, except forewing length 7.0–8.0 mm (mean 7.5; $n = 3$) and forewing with pattern elements less defined. Abdomen: Genitalia (Fig. 8) with sterigma a narrow sclerotized plate; colliculum weakly developed; ductus bursae uniformly narrow throughout, about as long as corpus bursae; ductus seminalis arising from ductus bursae ca. 0.2 length from ostium to junction with corpus bursae; corpus bursae round, signum weakly curved, ribbon-like.

Holotype. Male, Panama, [Canal Zone], Barro Colorado Island, 1–9 May 1964, W. D. & S. S. Duckworth. Deposited in USNM.

Paratypes (1♂, 3♀). PANAMA: Canal Zone: Barro Colorado Island, 1–9 May 1964 (3♀), W. D. & S. S. Duckworth (USNM). ECUADOR: Pichincha, Tinalandia, 16 km E Santo Domingo de los Colorados, 600 m, 5–11 May 1990 (1♂), R. H. Leuschner (USNM).

Distribution and biology. *Circanota simplex* is known from Panama and Ecuador, from about sea level to 600 m elevation. Specimens have been collected only in May, but that likely reflects sampling bias rather than a narrow flight period.

Etymology. The specific epithet refers to the simple, unmodified features of the genitalia as compared with those of *C. undulata*.

Remarks. The single male from Ecuador agrees well with the holotype of *C. simplex*, but the ventral lobe of the valva is slightly broader in the former. Until additional evidence becomes available, this slight difference is assumed to represent geographic variation.

Discussion

The slender crescent-shaped signum of the female genitalia of *Circanota* represents a putative synapomorphy for a sparganothine clade that includes *Aesiocopa*, *Amorbia*,

Amorbimorpha, *Circanota*, *Coelostathma*, *Lambertiodes*, *Paramorbia*, *Rhynchophyllus*, *Sparganocosma*, *Sparganopseustis*, *Sparganothina*, and *Sparganothoides* (Brown et al. 2013, Brown 2014). Within this clade, *Circanota* shares the presence of secondary arms of the socii with *Aesiocopa*, *Amorbimorpha*, *Sparganopseustis*, and *Sparganothoides*, but the arms are much more slender throughout in *Circanota*. In neighbor-joining trees that include all of the BOLD data for Sparganothini (Brown et al. in preparation), *Circanota* is portrayed nearest *Sparganothoides*, and *Aesiocopa* nearest *Sparganopseustis*; there are no sequence data for *Amorbimorpha*. *Circanota* is one of five genera (i.e., *Aesiocopa*, *Amorbimorpha*, *Circanota*, *Sparganopseustis*, and *Sparganothoides*) that possess both a crescent-shaped signum and secondary arms of the gnathos. Among these genera, *Circanota* shares the absence of dorsal pits and minimal sexual dimorphism with *Amorbimorpha* and *Sparganothoides*. All described *Amorbimorpha* and many *Sparganothoides* have a distally bifurcate uncus, remarkably different from the slender, curved uncus of *Circanota*. Hence, although many features suggest a strong affinity between *Sparganothoides* and *Circanota*, the two genera are divergent based on several conspicuous features of the adult morphology.

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Salmo kottelati, a new species of trout from Alakır Stream, draining to the Mediterranean in southern Anatolia, Turkey (Teleostei, Salmonidae)

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Abstract

Salmo kottelati **sp. n.**, is described from Alakır Stream (Mediterranean basin) in Turkey. It is distinguished from other Anatolian *Salmo* species by a combination of the following characters (none unique to the species): general body colour greenish to silvery in life; 7–9 parr marks along lateral line; four dark bands on flank absent in both sexes; black ocellated spots few, present only on upper part of flank in individuals smaller than 160 mm SL but in larger both males and females black spots numerous and located on back and middle and upper part of flank; red spots few to numerous, scattered on median, and half of lower and upper part of flank; head long (length 29–33% SL in males, 26–32 in females); mouth large (length of mouth gape 13–19% SL in males, 12–15 in females); maxilla long (length 10–13% SL in males, 8–12 in females); 105–113 lateral line scales; 24–29 scale rows between lateral line and dorsal-fin origin, 17–19 scale rows between lateral line and anal-fin origin; 13–15 scales between lateral line and adipose-fin insertion.

Keywords

Anatolia, fish distribution, taxonomy, *Salmo*, new species

Introduction

Salmo trutta Linnaeus, 1758 has long been considered to be a polymorphic species widely distributed throughout Europe and the Middle East reaching in south and south-east to the Atlas Range (Morocco, Algeria) and to the upper Amu-Darya drainage in Afghanistan (Kottelat 1997). Since many years, a number of subspecies of *S. trutta* or distinct species then assigned to *S. trutta* have been described. Most authors considered *S. trutta* to be a very variable species forming three major ecotypes (sea migratory, lacustrine, and riverine or brook).

Some forms or subspecies of *S. trutta* distributed in Europe and Asia were resurrected to the species level by Kottelat (1997). Later, species status of some North African species was discussed by Delling and Doadrio (2005) and of Balkan ones by Delling (2003, 2011). Kottelat and Freyhof (2007) tentatively recognised 29 species from European waters and mentioned that the status of several populations and nominal species was still not clear.

Tortonese (1955) reviewed the trouts of Anatolia and reported four subspecies of *Salmo trutta*: *S. trutta labrax* Pallas, 1814 from the Çoruh River (Black Sea basin), Lake Çıldır in the Kura drainage (Caspian Sea basin), and Uludağ mountains (Marmara Sea basin); *S. trutta caspius* Kessler, 1877 from the Kura River (Caspian Sea basin); *S. trutta macrostigma* (Duméril, 1858) from the Çoruh River (Black Sea basin), and the Çatak Stream (the Tigris system) and described *S. trutta abanticus* Tortonese, 1955, as a new subspecies, from Lake Abant (a closed lake in northwest Anatolia). Distribution area of *S. trutta macrostigma* was later considered as including, besides the Çoruh River, the Aegean Sea basin, the Marmara Sea basin, the Trace region, the Mediterranean basin, and the Tigris-Euphrates drainage (Geldiay and Kähnsbauer 1967; Kelle 1978; Kuru 1975, 2004; Balık 1984; Bardakçı et al. 1994; Küçük 1997). *Salmo trutta labrax* was commonly reported from the streams and rivers flowing to the southeastern shore of the Black Sea, and *S. trutta caspius* from the Kura drainage (Aras 1974; Kuru 1975, 2004; Kutrup 1994; Geldiay and Balık 2007, Tabak et al. 2002; Turan 2003). In addition, *S. platycephalus* Behnke, 1968 was described from the upper Seyhan drainage (Behnke 1968; Kuru 2004; Schöffmann 2004).

Turan et al. (2010) surveyed all rivers and streams draining to the Black Sea coast in Anatolia, and recognised three morphologically distinct groups of *Salmo* populations. These groups were identified by earlier authors as *S. trutta labrax* (drainages of south-eastern Black Sea coast), *S. trutta macrostigma* (Çoruh River drainage), and *S. trutta abanticus* (the outlet of the Abant Lake in the Bolu Province). Turan et al. (2010) compared the samples from the Black Sea coast of Anatolia with a sample of true *Salmo labrax* from the Ulu-Uzen River in Crimea (geographically close to one of the sites of the type locality of *S. labrax*, Biyuk-ozen River in Kacha River upper reaches in Crimea) and a sample from the Khosta River in Krasnodar Krai in Russia (north-eastern Black Sea coast). The comparison revealed that the *Salmo* populations from the Black Sea coast of Anatolia are different from *S. labrax* from the Crimea Peninsula and the Caucasian coast in Russia. *Salmo trutta abanticus* was evaluated at species level;

the two other populations were asserted morphologically distinct, diagnosable, and described as new species: *S. coruhensis* Turan, Kottelat & Engin, 2010 and *S. rizeensis* Turan, Kottelat & Engin, 2010. They also suggested that both species in several streams are present in sympatry, although rarely in syntopy. An opinion was proposed by Turan et al. (2010) that the trouts of the Black Sea basin in northeastern Turkey may represent distinct species as upstream resident trouts of different river drainages are genetically closer to each other than to migratory trouts in respective drainages. Tortonese (1955) reported both *S. trutta labrax* and *S. trutta macrostigma* from the Çoruh drainage. Turan et al. (2010) concluded that these apparently correspond to *S. coruhensis* and *S. rizeensis* respectively. The two species were also recorded from other streams and rivers draining to south-eastern Black Sea coast (see Turan et al. 2010: 336) (Fig. 1). *Salmo labrax* is distributed in the northern drainages of the Black Sea coast (undoubtedly from the northwest Caucasia in Russia to the Danube River) but the exact border between the ranges of *S. labrax* and *S. coruhensis* is still not known and the trout from rivers in Georgia still needs a taxonomic study. As to *S. coruhensis*, it is distributed in the drainages of south-eastern Black Sea coast from the Çoruh River in the north to the Kızılırmak River.

Distribution of *S. macrostigma* is restricted to Algeria (Kottelat 1997; Delling and Doadrio 2005). The other peri-Mediterranean populations referred to as *S. macrostigma* belong to several species (e.g. *S. cettii* in Italy and *S. farioides* in the eastern Adriatic drainages) (Kottelat 1997). In Turkey, besides *S. rizeensis*, some populations earlier misidentified as *S. trutta macrostigma* were described as *S. tigridis* Turan, Kottelat & Bektaş, 2011 (Tigris-Euphrates drainage, Persian Gulf basin), *S. labecula* Turan, Kottelat & Engin, 2012 (Ecemiş Stream in the lower Seyhan River, east Mediterranean basin), Kartoz and Zindan streams (tributaries of Köprü Stream, a Mediterranean coastal drainage), *S. opimus* Turan, Kottelat & Engin, 2012 (Tekir, Fırınz and Göçüksu streams in lower reaches of the Ceyhan River) and Alara Stream (a Mediterranean coastal drainage), *S. chilo* Turan, Kottelat & Engin, 2012 (Akdere Stream in the upper Ceyhan River), *S. okumusi* Turan, Kottelat & Engin, 2014 (western Euphrates drainage), and *S. euphrataeus* Turan, Kottelat & Engin, 2014 (northeastern Euphrates drainage).

The taxonomic status of *Salmo* populations found in the southern Marmara Sea coast and the Trace Region will be discuss in forthcoming papers.

The present paper reports our data on the identity of the resident trout inhabiting Alakır, a small stream draining to the Mediterranean Sea. We conclude that it is an unnamed species. Here, it is described as a new species *Salmo kottelati*.

Material and methods

Fish were caught with pulsed DC electro fishing equipment. Material is deposited in: FFR, Zoology Museum of the Faculty of Fisheries, Recep Tayyip Erdoğan University, Rize, and CMK, the collection of Maurice Kottelat, Cornol. Measurements and counts were all obtained on wild caught specimens, well preserved, in a straight position. Speci-

mens not fixed straight or damaged were excluded. Most samples include both sexes, juveniles and mature specimens. Most *Salmo* populations are small, geographically restricted and under great threat because of overfishing and habitat destruction, and it is not advisable to collect and preserve large series of individuals. Colour pattern and variation in shape were observed in the field on additional individuals which were not preserved. Measurements were taken with digital calipers (0.1 mm accuracy). Counts and measurements follow Hubbs and Lagler (1947), except as follows. Head depth 1: through eye; head depth 2: head depth at occiput; body depth 1: body depth at dorsal-fin origin; body depth 2: body depth at anal-fin origin; body width: body width at level of anal-fin origin; adipose-fin height: measured at middle of fin base; length of adipose-fin base: measured from origin to insertion; length of caudal peduncle: measured from anal fin insertion to middle of caudal-fin base; distance between adipose fin and caudal fin: measured from adipose-fin insertion to middle of caudal-fin base; length of maxilla: from anterior end to posterior end of upper margin of exposed part; length of mouth gape: maximum depth of combined maxilla and supramaxilla; width of mouth gape: measured between corners of mouth gape; length of mouth gape: distance from tip of snout to corner of mouth gape. Lateral-line scales were counted until the posterior extremity of the hypural complex. Scale rows between the adipose fin and the lateral line were counted at the adipose fin insertion. The last two branched dorsal and anal fin rays articulating on a single pterygiophore were counted as 1½. Vertebrae counts were obtained from radiographs and were counted separately as abdominal and caudal vertebrae. Abdominal vertebrae were counted from the first vertebra. The first caudal vertebra is that with its haemal spine fully developed. The count of caudal vertebrae includes the hypural complex. Sex was determined by examination of the gonads. In the description of colour pattern, we use *bands* to refer to the broad blackish vertical marks on the body, typically positioned behind the gill opening, below the dorsal fin, above the anal fin, and on the caudal peduncle. In some species these bands are known in well preserved specimens only, or in stressed individuals only, and in other species they are visible in situ in undisturbed individuals. A spot is called ocellated when surrounded by a white or very pale ring.

The morphometric and meristic data for *S. coruhensis*, *S. rizeensis*, *S. abanticus*, *S. caspius*, *S. tigridis*, *S. platycephalus*, *S. labecula*, *S. opimus*, *S. chilo*, *S. okumusi*, and *S. euphrataeus* are from Turan et al. (2010, 2011, 2012, 2014).

Results

Salmo kottelati sp. n.

<http://zoobank.org/A1CED992-9A64-4369-B88C-918DFB12BBDC>

Fig. 1

Holotype. FFR 03180, 205 mm SL, male; Turkey: Antalya Province: Altınyaka village; Alakır Stream (40°35.32'N, 40°51.50'E); D. Turan, E. Doğan and C. Kaya. 21 September 2014.



Figure 1. *Salmo kottelati*; Turkey: Antalya Province: Alakır stream **a** FFR 03180, holotype, 205 mm SL, male **b** FFR 03181, paratype, 207 mm SL, male **c** FFR 03181, paratype, 208 mm SL, female **d** FFR 03181, paratype, 175 mm SL, female **e** FFR 03181, paratype, 98 mm SL, Juvenile.

Paratypes. FFR 03181, 21, 98–210 mm SL; same data as holotype. FFR 03182, 16, 98–176 mm SL; CMK 22405, 4, 97–143 mm SL; Turkey: Antalya Province: Altınyaka village; Alakır Stream (40°35.32'N, 40°51.50'E); M. Kanyılmaz, 15 September 2008.

Diagnosis. *Salmo kottelati* is distinguished from all the described species of *Salmo* in Turkey by the combination of the following characters: 7–9 parr marks along lateral line distinct in males up to at least 176 mm SL and in females up to at least 208 mm SL; absence of four dark bands on flank in males and females; black spots on body numerous, ocellated, scattered on back, middle and upper part of flank (sometimes lower part of flank) in males larger than about 160 mm SL, and females between about 160–190 mm SL; in males and females smaller than about 160 mm SL, black spots few, present only on upper part of flank; few to numerous ocellated red spots on back and half of upper and lower flank; number of both black or red spots commonly increasing with size and age in males while number of both black and red spots decreasing with size and age in females; head long (29–33% SL in males, 26–32 in females); mouth large (length of mouth gape 13–19% SL in males, 12–15 in females), slightly subterminal; maxilla long (10–13% SL in males, 8–12 in females), reaching beyond eye in males longer than about 120 mm SL and in females longer than about 170 mm SL; 105–113 lateral-line scales (until posterior hypural margin); 24–29 scale rows between lateral line and dorsal-fin origin; 17–19 scale rows between lateral line and anal-fin origin; 13–15 scale rows between lateral line and adipose-fin insertion; gill rakers 18–20 on outer side of first gill arch.

Description. General appearance shown in Fig. 1, morphometric and meristic data given in Tables 1 and 2. Dorsal profile of body behind head markedly convex, ventral profile less arched than dorsal profile in both sexes. Body moderately deep. Head long, 1.2–1.4 times body depth at dorsal-fin origin in males, 1.0–1.2 in females, slightly flattened dorso-ventrally in males longer than about 190 mm SL, not flattened in males smaller than about 180 mm SL, and in females. Head shape sexually dimorphic: upper profile slightly convex in interorbital area and convex on snout slightly behind level of nostrils in males, straight in interorbital area and markedly convex on snout in females. Mouth large, terminal or slightly subterminal in males larger than about 190 mm SL, subterminal in males smaller than about 180 mm SL and in females, conspicuously subterminal in juveniles. Upper jaw equal or slightly longer than lower jaw in males larger than about 190 mm SL, longer in females and juvenile, and in males smaller than about 180 mm SL. Tip of lower jaw slightly curved upward in males larger than about 190 mm SL and but in contrast, not curved in females of all sizes. Maxilla long, reaching beyond eye in males larger than about 120 mm SL and in females longer than about 170 mm SL, upper edge convex posteriorly in males, straight or slightly convex in females. Snout pointed in males and slightly pointed in females.

Lateral line with 105–113 scales; 24–29 scale rows between lateral line and dorsal-fin origin; 17–19 scale rows between lateral line and anal-fin origin; 13–15 scale rows between lateral line and adipose-fin insertion (Table 2). Dorsal fin with 3–4 simple and 9½–10½ branched rays, outer margin straight or slightly concave. Adipose fin small in males smaller than about 170 mm SL with upper edge straight or slightly

Table 1. Morphometric characters of *Salmo kottelati*. Number in parentheses: mean.

	<i>Salmo kottelati</i>				
	Mediterranean Sea				
Basin	Alakir Stream				
Drainage	Alakir Stream				
Province	Antalya				holotype
Sex and number of specimens	Males, n=20		Females, n=20		Male
	Range	SD	Range	SD	
Standard length (mm)	122–210		98–208		205
In percentage of standard length					
Head length	29.2–32.7 (30.9)	0.90	26.2–31.5 (28.7)	1.46	31.8
Predorsal length	48.9–52.4 (50.1)	1.13	46.7–50.7 (49.4)	1.34	52.3
Prepelvic length	53.9–60.3 (55.7)	1.43	50.1–56.7 (54.7)	1.31	57.6
Preanal length	72.8–83.1 (75.5)	2.07	73.2–82.8 (76.0)	1.93	75.6
Body depth at dorsal-fin origin	21.6–26.7 (24.4)	1.32	23.0–27.0 (25.4)	1.13	24.0
Body depth at anal-fin origin	15.8–20.6 (18.0)	1.16	17.6–20.5 (18.8)	0.82	18.9
Depth of caudal peduncle	10.1–13.3 (11.3)	0.80	10.5–12.9 (11.5)	0.76	12.0
Length of caudal peduncle	15.3–19.3 (16.7)	0.99	14.8–18.4 (17.0)	0.93	16.2
Distance between adipose and caudal fins	14.1–17.0 (15.0)	0.78	13.8–16.2 (14.9)	0.64	14.2
Body width at anal-fin origin	5.7–11.8 (8.7)	1.86	6.9–11.6 (9.2)	1.83	10.3
Length of dorsal-fin base	13.4–19.6 (14.7)	1.44	11.4–15.3 (14.0)	0.99	15.2
Depth of dorsal fin	15.0–22.4 (19.1)	2.06	17.3–22.4 (19.6)	1.56	19.6
Length of pectoral fin	19.8–24.5 (22.2)	1.35	19.8–25.2 (22.5)	1.55	20.2
Length of adipose-fin base	2.7–4.6 (3.8)	0.57	2.3–4.4 (3.6)	0.50	3.4
Depth of adipose fin	7.4–10.5 (8.7)	0.73	5.6–9.4 (8.0)	0.82	9.1
Length of pelvic fin	15.2–19.4 (16.9)	1.12	15.9–18.9 (17.2)	0.94	16.2
Depth of anal fin	17.3–20.6 (19.1)	0.89	17.7–21.3 (19.1)	1.03	19.1
Length of anal fin-base	7.7–11.7 (10.0)	0.86	8.9–14.1 (10.5)	1.36	9.8
Length of upper caudal-fin lobe	17.7–22.4 (19.8)	1.28	16.8–22.0 (19.3)	1.50	18.1
Length of median caudal-fin rays	13.3–16.9 (15.2)	0.89	13.6–17.6 (14.6)	0.87	14.6
Length of lower caudal-fin lobe	17.1–22.2 (19.8)	1.56	17.5–21.9 (20.1)	1.30	18.5
Snout length	6.7–9.9 (8.1)	0.83	6.3–8.9 (7.6)	0.77	9.9
Distance between nasal openings	4.5–6.3 (5.0)	0.49	4.4–6.1 (4.7)	0.65	5.9
Eye diameter	6.5–9.1 (7.6)	0.81	5.9–8.2 (7.1)	0.73	6.5
Interorbital width	6.5–9.6 (8.0)	0.93	6.3–9.0 (7.5)	0.74	6.8
Head depth through eye	13.7–16.8 (14.8)	0.73	11.9–14.9 (13.6)	0.90	16.8
Head depth at nape	18.4–20.3 (19.2)	0.54	16.3–19.7 (18.4)	0.92	18.6
Length of maxilla	10.1–13.3 (11.8)	0.87	8.2–11.7 (9.8)	0.91	12.6
Maximum height of maxilla	3.0–3.9 (3.4)	0.30	2.6–4.0 (3.3)	0.46	3.4
Width of mouth gape	10.6–12.9 (11.6)	0.69	9.3–12.6 (10.4)	0.89	12.6
Length of mouth gape	13.2–18.9 (15.6)	1.35	11.8–14.5 (13.1)	0.76	18.9

convex anteriorly and convex posteriorly or large, almost reaching caudal-fin base in males larger than about 190–200 mm SL, upper margin markedly convex. In females, adipose fin small to medium, upper edge markedly convex both anteriorly and posteriorly. Pectoral fin long, with 1 simple, 10–13 branched rays, outer margin slightly concave. Pelvic fin with 1 simple and 7–9 branched rays, outer margin slightly convex.

Anal fin with 3 simple and $6\frac{1}{2}$ – $8\frac{1}{2}$ branched rays, outer margin straight or slightly convex anteriorly, concave posteriorly. Caudal fin long and emarginate in small to large size specimens, lobes slightly pointed. Gill rakers 6–7 + 12–13 = 18–20 on outer side of first gill arch. Total vertebrae 55(2), 56(12), 57(5), and 58(1); predorsal vertebrae 13–15 with mode of 14; number of abdominal vertebrae 33–35 with mode of 34, and that of caudal vertebrae 21–23 with mode of 22. Abdominal region longer than caudal region, rarely regions equal, and difference between abdominal and caudal counts 11–14; most common vertebral formula 34+22.

Sexual dimorphism. Males of *S. kottelati* having longer head and maxilla and greater mouth gape than females.

Colouration. General body colour greenish to silvery in life. Body dark brown on back and upper part of flank, brownish to yellowish on lower part of flank and belly yellowish in preserved specimens (Fig. 1). A large black spot (larger than pupil but smaller than eye) and one to five small black spots (smaller than pupil) behind eye (on cheek and preopercle), and 4–15 on opercle (smaller than pupil). Three to 21 black spots on top of head, smaller than pupil. Black spots on body, numerous, ocellated, medium to large (equal to or smaller than pupil), scattered on back (sometimes present in predorsal area), middle and upper part of flank (sometimes lower part of flank) in males larger than about 160 mm SL. Black spots few, present only on upper part of flank in both sexes smaller than about 160 mm SL, and in females over about 190 mm SL. Red spots few to numerous, ocellated, scattered on median, and half of lower and upper part of flank. Number of both black or red spots increasing with size and age in males except for one male (Fig. 1B) but, in contrast, number of both black and red spots decreasing with size and age in females. Dorsal fin greyish, with three or four rows of red spots posteriorly on lower part, 6–7 rows of black spots on middle, lower and upper part, boldly marked. Caudal fin dark grey, outer margin blackish. Pectoral, pelvic and anal fins yellowish. Leading edge of anal fin white in specimens larger than about 170 mm SL. Adipose fin greyish. Seven to nine parr marks distinct in males up to at least 176 mm SL and in females up to at least 208 mm SL, broad and large (Fig. 1), slightly rounded.

Distribution and habitat. *Salmo kottelati* is only known from Alakır Stream in which located about 96 km southwest of the city of Antalya, a drainage of Mediterranean Sea in southern Anatolia (Fig. 2). It inhabits in cold and clear water and moderate current, with gravel and pebble substrate.

Etymology. The species is named for Maurice Kottelat, who contributed to the knowledge of the fish fauna of Europe and Asia.

Discussion and comparisons

Salmo kottelati is immediately distinguished from all other species of *Salmo* in Turkey and *S. labrax* (from the northern Black Sea basin) by having fewer parr marks on the flank (7–9, vs. 10–13). It is further distinguished from *S. platycephalus*, *S. opimus*, *S.*

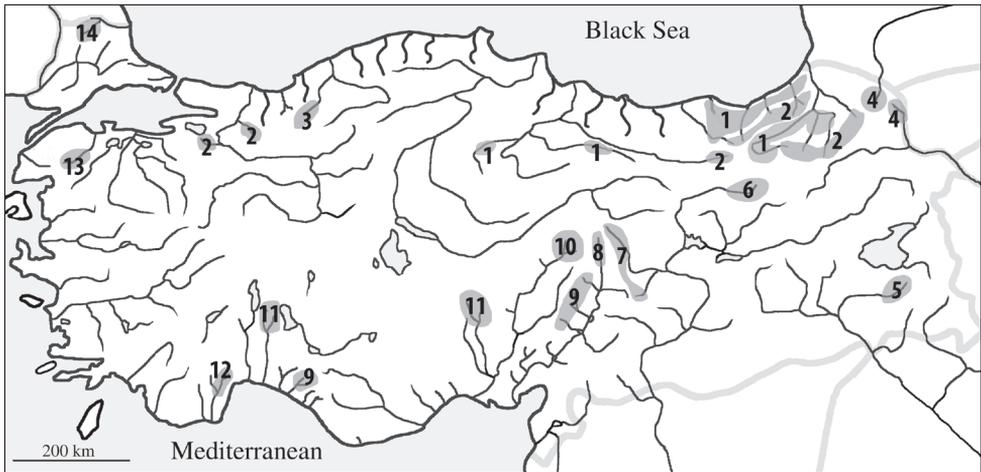


Figure 2. Distribution of *Salmo* species in Anatolia: *S. coruhensis* (1) *S. rizeensis* (2) *S. abanticus* (3) *S. caspius* (4) *S. tigridis* (5) *S. euphrataeus* (6) *S. okumusi* (7) *S. chilo* (8) *S. opimus* (9) *S. platycephalus* (10) *S. labecula* (11) *S. kottelati* (12) *S. cf. coruhensis* (13) *S. cf. rizeensis* (14).

chilo, and *S. labecula* by the absence of four dark bands on the flank in males and females (vs. presence).

Besides the above differences, *S. kottelati* is distinguished from *S. platycephalus* by the presence of red spots on the flank in individuals of all sizes (vs. absence in specimens larger than about 70 mm SL) and the presence of black spots in individuals of all sizes (vs. absence in specimens larger than about 170 mm SL). The new species has fewer gill rakers on the outer side of the first gill arch (18–20, vs. 23–25), a longer head in males (29–33% SL vs. 27–29), a deeper head (depth through eye 14–17% SL in males, 12–15 in females, vs. 12–13 in males, 11–12 in females), and a longer maxilla (10–13% SL in males, 8–12 in females, vs. 8–10 in males, 7–8 in females).

Besides the differences listed above, *S. kottelati* differs from *S. opimus* in having fewer lateral-line scales (105–113, vs. 112–120) and by the number and location of the black and red spots on the body in males and in females larger than about 160 mm SL. In *S. kottelati*, the black spots are numerous in males larger than about 160 mm SL and in females between about 160–190 mm SL, present on median, and half of upper and lower of part flank, and the number of both red and black spots increases with increasing size and age in males. In *S. opimus*, black spots are few (less than 50), present on back and upper part of flank, and their number does not increase with increasing size and age in males. There are also other differences between males of *S. kottelati* and *S. opimus*: males of *S. kottelati* have a deeper head (head depth through eye 14–17% SL, vs. 12–13), a longer maxilla (10–13% SL, vs. 9–10), and a greater mouth gape (length of gape 13–19% SL, mean 16, vs. 11–14, mean 13).

In addition to the differences mentioned above, *S. kottelati* is distinguished from *S. chilo* by the following characters: a slightly convex dorsal profile of head (vs. strongly convex), a pointed snout (vs. blunt), a slightly subterminal mouth (vs. conspicuously

subterminal), non-flesh maxilla and lower lip (vs. flesh), length of the maxilla markedly sexually dimorphic (the length in males markedly longer than that in females, vs. not sexually dimorphic); black spots on the body roundish (vs. irregularly shaped). The new species also differs from *S. chilo* by having more numerous scale rows between the lateral line and the anal-fin origin (17–19, vs. 15–17). When compared to males of *S. chilo*, males of *S. kottelati* have a deeper head (depth through eye 14–17% SL, vs. 12–13), and a longer maxilla (length 10–13% SL, mean 12, vs. 9–10, mean 9).

Besides the differences mentioned above, *S. kottelati* differs from *S. labecula* by the presence of red spots on the flank (vs. absence in specimens larger than about 70 mm SL) and the black spots on body roundish (vs. irregularly shaped). *Salmo kottelati* has more numerous scale rows between the lateral line and the anal-fin origin (17–19, vs. 16–17) and fewer gill rakers (18–20, vs. 21–23). It also differs from *S. labecula* by having a greater predorsal distance (49–52% SL, mean 50 in males, 47–51, mean 49 in females, vs. 45–48% SL, mean 46 in males, 44–47, mean 45 in females). Moreover, *S. kottelati* has a longer head in males (29–33% SL, mean 31, vs. 27–29, mean 28) and a deeper head in males (depth through eye 14–17% SL, mean 15, vs. 11–14, mean 13).

Salmo kottelati is further distinguished from *S. tigridis* by the number and locations of black spots on the body in specimens larger than about 160 mm SL. In *S. kottelati*, black spots are numerous in males larger than about 160 mm SL and in females between about 160–190 mm SL, present on median and half of upper and lower part of flank, and the number of both red and black spots increases with increasing size and age in males. In *S. tigridis*, black spots are few (less than 50), present on back and the upper part of flank and their number does not increase with increasing size and age. The new species also differs from *S. tigridis* by having fewer scale rows between the lateral line and the dorsal-fin origin (24–29, vs. 32–35), fewer scale rows between the lateral line and the anal-fin origin (17–19, vs. 22–26), and fewer scale rows between the adipose fin insertion and the lateral line (13–15, vs. 19–20). Besides the above listed differences, *S. kottelati* males are distinguished from *S. tigridis* males by a longer (29–33% SL, mean 31, vs. 25–28, mean 27) and deeper head (depth at nape 18–20% SL, mean 19, vs. 17–18, mean 17), a longer maxilla (10–13% SL, mean 12, vs. 8–9, mean 9), and a wider mouth gape (11–13% SL, mean 12, vs. 9–10, mean 10).

Salmo kottelati is further distinguished from *S. abanticus* by the presence of red spots on the body in specimens larger than about 210 mm SL (vs. absent), the shape of the black spots on the flank (round, vs. polygonal), the shape of the ring around black spots (circular, vs. polygonal), and the size of the black spots (about equal to the pupil, vs. markedly larger than the pupil). It has fewer lateral line scales than *S. abanticus* (105–113, vs. 113–121). Besides the differences mentioned above, it also differs from *S. abanticus* in having a longer head (29–33% SL, mean 31 in males, 26–32, mean 29 in females, vs. 26–29, mean 27 in males, 24–26, mean 26 in females). Males of *S. kottelati* differ from males of *S. abanticus* in having a greater predorsal distance (49–52% SL, vs. 47–48), a longer maxilla (10–13% SL, mean 12, vs. 9–10, mean 10), a greater eye diameter (7–9% SL, mean 8, vs. 6–7, mean 6), and a deeper head at nape (18–20% SL, mean 19, vs. 17–19, mean 17).

Salmo kottelati is further distinguished from *S. coruhensis* by fewer scale rows between the anal-fin origin and the lateral line (17–19, vs. 19–23), fewer scale rows between the adipose fin insertion and the lateral line (13–15, vs. 15–17), a longer (29–33% SL, mean 30.9, vs. 26–28, mean 27.3) and deeper head in males (depth through eye 14–17% SL, mean 15, vs. 12–14, mean 13).

Salmo kottelati is further distinguished from *S. rizeensis* by the number and location of black spots on the body. In *S. kottelati*, black spots are numerous (60 and more) in males larger than about 160 mm SL and in females between about 160–190 mm SL, present on median, and half of upper and lower of part flank, and the number of both red and black spots increases with increasing size and age in males. In *S. rizeensis*, black spots are few (less than 40), present on back and upper part of flank, and their number does not increase with increasing size and age. The new species also differs from *S. rizeensis* by the general body colour (greenish to silvery in life, vs. brownish), the adipose fin almost reaching the base of the caudal fin in males larger than 200 mm SL (vs. not reaching in all-sized specimens), and fewer lateral-line scales (105–113, vs. 114–120).

Salmo kottelati is further distinguished from *S. caspius* from the upper Kura drainage by having fewer lateral line scales (105–113, vs. 112–119), fewer scale rows between the lateral line and the anal-fin origin (17–19, vs. 19–22) and fewer scale rows between the insertion of the adipose fin and the lateral line (13–15, vs. 15–17). In *Salmo kottelati*, the general body colour is greenish to silvery in life (vs. brownish). Moreover, males of *S. kottelati* have a deeper head than that of *S. caspius* (head depth at nape 18–20% SL, vs. 17–18).

Salmo kottelati is further distinguished from *S. okumusi* by the absence of four dark bands on the flank in males and females (vs. very faintly marked or indistinct in small specimens but distinct in specimens larger than about 230 mm SL); the parr marks vertically oblong (vs. vertically elongate); the black spots circular (vs. irregularly shaped), bigger black spots on dorsal fin (slightly smaller than pupil, vs. smaller than half pupil). *Salmo kottelati* has a longer head than *S. okumusi* (29–33% SL in males, 26–32 in females, vs. 26–27 in males, 25–26 in females). Males of *S. kottelati* differs from males of *S. okumusi* by having a longer maxilla (10–13% SL, vs. 9–10) and a deeper head (at nape 18–20% SL, vs. 16–17).

Salmo kottelati is further distinguished from *S. euphrataeus* by the general body colour and the number and position of the black spots on the body: in *S. kottelati*, black spots are commonly numerous in males and increasing the number with size (vs. few and not increasing the number) and located on median, and half of upper and lower parts of the flank (vs. restricted to the upper part of the flank, mostly in its anterior area). The new species also differs from *S. euphrataeus* in having fewer lateral-line scales (105–113, vs. 112–120), fewer scale rows between the dorsal-fin origin and the lateral line (24–29, mean 26, vs. 28–31, mean 29), and fewer scale rows between the anal-fin origin and the lateral line (17–19, vs. 19–23).

Salmo kottelati differs from resident *S. labrax* by a large black spot behind the head (larger than the pupil but smaller than the eye, vs. equal or smaller than the pupil), black spots on the body smaller than the pupil (vs. larger), more numerous red spots

on the body (red spots few to numerous, scattered on median, and half of lower and upper part of the flank, vs. few, one or two irregularly rows of spots, scattered along the lateral line or, sometimes, below it). *Salmo kottelati* has fewer lateral line scales (105–113, vs. 112–121), fewer scale rows between the dorsal-fin origin and the lateral line (24–29, vs. 28–32), fewer scale rows between the lateral line and the anal-fin origin (17–19, vs. 19–23), fewer scale rows between the adipose fin insertion and the lateral-line (13–15, vs. 15–16), and more numerous gill rakers (18–20, vs. 16–18). Males of *S. kottelati* are further distinguished from males of *S. labrax* by having a longer head (29–33% SL, vs. 25–28), a greater predorsal length in males (49–52% SL, vs. 46–47), a deeper head (depth through eye 14–17% SL, vs. 11–13), a longer maxilla (10–13% SL, vs. 9–10), a wider mouth gape (11–13% SL, vs. 8–10), and a longer mouth gape (13–19% SL, mean 16, vs. 12–14, mean 13).

Salmo kottelati can be further distinguished from *S. cf. coruhensis* from the Gönen Stream (southern Marmara Sea) by fewer lateral-line scales (105–113, vs. 115–121), fewer scale rows between the lateral line and the anal-fin origin (17–19, vs. 20–23), fewer scales between the adipose fin insertion and the lateral line (13–15, vs. 15–17), a larger adipose fin (depth 7–11% SL, vs. 4–7), and a deeper caudal peduncle (depth 10–13% SL, vs. 8–10). Males of *S. kottelati* differs from males of *S. cf. coruhensis* by a longer head (29–33% SL, vs. 24–28), a greater predorsal distance (49–52% SL, 45–47), a longer mouth gape (13–19% SL, mean 16, vs. 11–14, mean 12), a narrower mouth gape (width 11–13% SL, vs. 8–10), a longer maxilla (10–13% SL, vs. 8–10), and a deeper head (depth through eye 14–17% SL, vs. 11–14).

Salmo kottelati is further distinguished from *S. cf. rizeensis* from the Rezova Stream (Trace Region) by fewer lateral-line scales (105–113, vs. 114–121), fewer scale rows between the dorsal-fin origin and the lateral line (24–29, vs. 29–34), fewer scale rows between the lateral line and anal-fin origin (17–19, vs. 20–23), fewer scales between the adipose fin insertion and the lateral line (13–15, vs. 16–17), a larger adipose fin (depth 7–11% SL, vs. 5–7), and a deeper caudal peduncle (depth 10–13% SL, vs. 9–10). Males of *S. kottelati* differs from males of *S. cf. rizeensis* by a longer (29–33% SL, vs. 26–29) and deeper head (depth through eye 14–17% SL, vs. 12–14).

Comparison material

Salmo platycephalus: 34, 75–550 mm SL; Turkey: Kayseri Prov.: Pınarbaşı Stream in Pınarbaşı district, Seyhan River drainage.

Salmo chilo: 33, 65–235 mm SL; Turkey: Sivas Prov.: Akdere Stream at Gürün county, Ceyhan River drainage.

Salmo labecula: 19, 85–400 mm SL, male; Turkey: Niğde Prov.: Ecemiş Stream at Çamardı county, Seyhan River drainage. 10, 140–241 mm SL; Turkey: Isparta prov.: Kartoz Köprüçay.

Salmo opimus: 13, 118–180 mm SL; Turkey: Antalya Prov.: Alara Stream at Gündoğmuş. 25, 115, 147–186 mm SL; mm SL; Turkey: Kahramanmaraş prov.:

Göçüksu Stream at Kömürköy, Ceyhan River drainage. 4, 175–210 mm SL; Turkey: Kahramanmaraş Prov.: Tekir Stream at Tekir, Ceyhan River drainage. 9, 90–300 mm SL; Turkey: Kahramanmaraş Prov.: Fırnız Stream at Fırnız, Ceyhan River drainage.

Salmo tigridis: 13, 136–227 mm SL; Turkey: Van Prov.: Çatak Stream, Tigris River drainage. 7, 15–18 mm SL, Turkey: Van Prov.: Müküs Stream, Tigris River drainage.

Salmo rizeensis: 16, 88–237 mm SL; Turkey: Erzurum Prov.: Ovit(2) [Kan] Stream at Ovit mountain, Çoruh River drainage. 7, 88–237 mm SL; Turkey: Artvin Prov.: Dörtkilise Stream at Tekkale Village, Çoruh River drainage. 12, 75–167 mm SL; Turkey: Artvin Prov.: Çiftköprü Stream at Cankurtaran mountain, Çoruh River drainage. 11, 113–221 mm SL; Turkey: Erzurum Prov.: Yağlı Stream at Yağlı village, Çoruh River drainage. 16, 145–224 mm SL; Turkey: Giresun Prov.: Akbulak stream at Akbulak village, Yeşilirmak River drainage. 10, 122–221 mm SL; Turkey: Kütahya Prov.: Sefaköy Stream at Domaniç, Sakarya River drainage. 10, 111–119 mm SL; Turkey: Kütahya Prov.: Çatalalç Stream at Domaniç, Sakarya River drainage. 13, 111–220 mm SL; Turkey: Rize Prov.: Çağlayan Stream at Gürcüdüzu plateau. 18, 95–226 mm SL; Turkey: Rize Prov.: Şehitlik Stream at Şehitlik village. 12, 90–118 mm SL; Turkey: Rize Prov.: Çayeli Stream at Kaptanpaşa village. 10, 90–238 mm SL; Turkey: Rize Prov.: Ovit Stream at Ovit mountain, İyidere drainage. 14, 120–200 mm SL; Turkey: Rize Prov.: Fırtına Stream on Elevit Plateau. 10, 114–245 mm SL; Turkey: Trabzon Prov.: Değirmen Stream at Çoşandere village. 12, 112–230 mm SL; Turkey: Trabzon Prov.: Solaklı Stream at Demirkapı village.

Salmo coruhensis: 13, 90–380 mm SL; Turkey: Erzurum Prov.: Uzundere district; Pehlivanlı Stream at Pehlivanlı village [tributary of Tortum], Çoruh River drainage. 13, 115–330 mm SL; Turkey: Artvin Prov.: Dörtkilise Stream at Tekkale village, Çoruh River drainage. 5, 130–229 mm SL; Turkey: Artvin Prov.: Barhal Stream at Sarıgöl village, Çoruh River drainage. 16, 190–465 mm SL; Turkey: Bayburt Prov.: Ölçer Stream at Ölçer village, Çoruh River drainage. 17, 80–550 mm SL; Turkey: Erzurum Prov.: Çayırbaşı (Kırık) Stream at Kırık village, Çoruh River drainage. 6, 160–290 mm SL; Turkey: Erzurum Prov.: Madenköprübaşı district; Büyük Stream at Büyükköy village, Çoruh River drainage. 17, 70–210 mm SL; Turkey: Gümüşhane Prov.: Harşut Stream at Yağmurdere village. 6, 95–117 mm SL; Turkey: Rize Prov.: Sarayköy Stream at Sarayköy village. 6, 100–250 mm SL; Turkey: Rize Prov.: İyidere Stream in İyidere district. 7, 150–450 mm SL; Turkey: Rize Prov.: Fırtına Stream at Çamlıhemşin. 5, 10–280 mm SL; Türkiye: Rize Prov.: Limanköy Stream at Limanköy village. 25, 90–520 mm SL; Türkiye: Rize Prov.: Fırtına Stream at Çat village. 11, 95–228 mm SL; Turkey: Rize Prov.: Kendirli Stream at Kalkandere District on road to Kendirli village, İyidere drainage. 13, 120–450 mm SL; Turkey: Rize Prov.: İyidere Stream (İkizder) at Güneyce. 6, 130–420 mm SL; Turkey: Rize Prov., Veliköy Stream at Veliköy village. 9, 160–450 mm SL; Turkey: Sivas Prov.: Gemin country, Yeşilirmak River drainage on road of Sivas.

Salmo abanticus: 20, 113–300 mm SL; Turkey: Bolu Prov.: outlet of Lake Abant.

Salmo caspius: 10, 126–222 mm. SL; Turkey: Ardahan Prov.: Çataldere Stream at Ardahan, Kura River drainage. 30, 110–250 mm. SL; Turkey: Ardahan Prov.: Tora Stream at Ardicdere village, Kura River drainage. 8, 135–240 mm SL; Turkey: Ardahan Prov.: Aşıkzülal Stream at Aşıkzülal village, Kura River drainage.

Salmo labrax: 6, 107–147 mm SL; Ukraine: Ula-Uzen River. 6, 102–160 mm SL; Russia: Krasnodar Prov.: Khosta River.

Salmo okumusi: 11, 75–213 mm SL; Turkey: Malatya Prov.: Sürgü Stream, Euphrates River drainage. 33, 68–28 mm SL; Turkey: Sivas Prov.: Gökpınar Stream (tributary of Tohma Stream), Euphrates River drainage.

Salmo euphrataeus: 36, 80–226 mm SL; Turkey: Erzurum Prov.: Kuzgun Stream (tributary of Karasu Stream), Euphrates River drainage. 18, 88–230 mm SL; Turkey: Erzurum prov.: Şenyurt Stream (tributary of Karasu Stream), Euphrates River drainage. 10, 160–250 mm SL; Turkey: Erzurum Prov.: Ağırcık Stream at Ağırcık Village (tributary of Karasu Stream), Euphrates River drainage. 12, 95–300 mm SL; Turkey: Erzurum Prov.: Sırlı Stream at Sırlı Village (tributary of Karasu Stream), Euphrates River drainage.

Salmo cf. coruhensis: 28, 95–228 mm SL; Turkey: Çanakkale Province: Çelebi Stream, drainage of Gönen Stream. 12, 108–160 mm SL; Turkey: Çanakkale Province: Kilise Stream; drainage of Gönen River.

Salmo cf. rizeensis: 50, 90–220 mm SL; Turkey: Kırklareli Province: Rezova Stream.

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