ZooKeys 207: 1–10 (2012)
doi: 10.3897/zookeys.207.3339
www.zookeys.org

RESEARCH ARTICLE

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

A new genus and species of Metopiinae (Hymenoptera, Ichneumonidae) from Mexico

Andrey I. Khalaim[1,2,†], Enrique Ruíz-Cancino[1,‡], Juana M. Coronado-Blanco[1,§]

1 *División de Estudios de Postgrado e Investigación, Facultad de Ingeniería y Ciencias, Universidad Autónoma de Tamaulipas, Cd. Victoria 87149, México* **2** *Zoological Institute, Russian Academy of Sciences, Universitetskaya nab. 1, St. Petersburg 199034, Russia*

† *urn:lsid:zoobank.org:author:ACF2AF20-5723-4507-AABB-CC7445B7A44A*
‡ *urn:lsid:zoobank.org:author:81FACC41-6193-4C59-92E0-7AB89FCD037E*
§ *urn:lsid:zoobank.org:author:CB508630-E90E-42AD-B7CE-8AB40ED02AF7*

Corresponding author: *Andrey I. Khalaim* (ptera@mail.ru)

Academic editor: *Gavin Broad* | Received 6 May 2011 | Accepted 25 June 2012 | Published 11 July 2012

urn:lsid:zoobank.org:pub:1FFDF406-8FD6-4BDF-9292-3136AFE50BC4

Citation: Khalaim AI, Ruíz-Cancino E, Coronado-Blanco JM (2012) A new genus and species of Metopiinae (Hymenoptera, Ichneumonidae) from Mexico. ZooKeys 207: 1–10. doi: 10.3897/zookeys.207.3339

Abstract

A new genus of Metopiinae, *Ojuelos* Khalaim, **gen. n.**, with a single species, *Ojuelos juachicus* Khalaim & Ruíz-Cancino, **sp. n.**, is described from Jalisco Province in central Mexico. *Ojuelos* belongs to the group of three genera (*Cubus* Townes & Townes, *Colpotrochia* Holmgren and *Triclistus* Förster) having a high lamella separating the antennal sockets and reaching the median ocellus (this lamella possesses a dorsal groove in it, just below the median ocellus), but differs from these genera primarily by 1) face and clypeus not convex in lateral view, 2) face separated from clypeus by a shallow transverse impression, 3) mandible with lower tooth very strongly reduced, 4) flagellomeres of antenna strongly transverse, and 5) dorsal carinae of propodeum reduced. A portion of the key to the genera of Metopiinae is provided to distinguish the new genus.

Keywords

North America, *Ojuelos*, new genus, new species, taxonomy

Introduction

Metopiinae is a moderately large subfamily with over 750 described extant species distributed in 25 genera (Yu et al. 2005). The subfamily is well represented in all parts of the World, occurs from the Arctic to the tropics, and some large genera (e.g. *Exochus* Gravenhorst, *Metopius* Panzer) are almost worldwide. Species of Metopiinae can be collected in various habitats but generally are most abundant in forests. All known Metopiinae are solitary endoparasitoits of Lepidoptera. Oviposition is into the exposed or concealed host larva, and emergence is always from the pupa (Townes 1971; Gauld and Sithole 2002).

Most Metopiinae species are easily recognized by their face and clypeus which are confluent and not separated by a groove and moderately to strongly convex in lateral view (except that the face of *Metopius* is flat and with a large shield-shaped area bounded by a sharp carina). Most have the upper margin of the face produced dorsally between the antennal insertions into a triangular flange. The body and legs are usually robust, the metasoma is more or less cylindrical, and the ovipositor is thin and very short (not projecting beyond the apex of metasoma). Some Orthocentrinae [Orthocentrus group of genera sensu Wahl and Gauld (1998)] have a similar structure of the face and clypeus (confluent and strongly convex) but these may be distinguished from Metopiinae primarily by the long cylindrical scape of antenna and because the upper edge of the face lacks the triangular interantennal projection. In addition, Orthocentrinae parasitize Mycetophiloidea (Diptera) (Townes 1971).

A list of Mexican Metopiinae was prepared by Ruíz-Cancino et al. (2002) and included only 17 species from 7 genera. Some more metopiine species and genera were mentioned from Mexico in the book on Costa Rican Ichneumonidae published in the same year by Gauld and Sithole (2002). Five new records of metopiine species were recently recorded from southern Mexico by González-Moreno et al. (2011), and a review of the Mexican species of *Colpotrochia* Holmgren (five species of this genus are recorded for the first time) and *Cubus* Townes & Townes was published by Khalaim and Ruíz-Cancino (2011). Nevertheless at present, the Mexican Metopiinae are very poorly studied, and only a small part of the real Mexican metopiine fauna is described. For comparison, the fauna of America north of Mexico comprises about 145 species from 19 genera (Townes and Townes 1959), and 130 species from 14 genera were recorded from Costa Rica (Gauld and Sithole 2002). Here a new metopiine genus with a new species is described from central Mexico.

Material and methods

Wing venation and morphological terms predominantly follow Gauld and Sithole (2002). Photographs were taken at the Zoological Institute of the Russian Academy of Science (St. Petersburg, Russia) with a DFC 290 digital camera attached to a Leica MZ16 stereomicroscope, and images were combined using Helicon Focus software.

Generic identification was checked through the keys to world genera of Metopiinae (Townes 1971), genera of America north of Mexico (Townes and Townes 1959), genera of Costa Rica (Gauld and Sithole 2002) and genera of Australia (Fitton 1984). The only specimen of the new genus was collected on herbs in a dry area above 2200 m in central Mexico. The holotype of *O. juachicus* is deposited at the Insect Museum of Universidad Autónoma de Tamaulipas, Cd. Victoria, Mexico (UAT).

Results

Key to world genera of Metopiinae (modified from Gauld and Sithole 2002, Townes 1971)

1 Face with a large shield-shaped area bounded by a sharp carina. Tergites 1 and 2 fused (clearly visible in lateral view). Laterotergite 1 broad........................ ....***Metopius* Panzer**

– Face more or less convex, without a concave shield-shaped area. Tergites 1 and 2 separated by a flexible membrane **2**

2 Interantennal process of face produced dorsally into a high longitudinal lamella separating the antennal sockets; this lamella with a longitudinal groove in the dorsal surface, just below the median ocellus (Fig. 7) **3**

– Interantennal process of face not produced dorsally as a longitudinal lamella, or if a weak, short lamella present, it does not have groove in the dorsal surface ....**Other genera of Metopiinae**

3 Propleuron almost cubical in profile, resembling fore coxa in shape. Mesosternal region with a pair of flattened finger-like processes projecting backwards over bases of mid coxae. Upper half of mesopleuron strongly inflated . ...***Cubus* Townes & Townes**

– Propleuron not cubical in profile. Mesosternal region smooth or with a weak lamella before mid coxae, without finger-like processes. Mesopleuron laterally usually not strongly inflated...**4**

4 Face and clypeus not especially convex in lateral view, separated by weak and broad transverse impression. Mandible with lower tooth strongly reduced, represented as a small tubercle; upper tooth large, chisel-shaped (Fig. 5). Propodeum with only area posteroexterna bounded by carinae, otherwise ecarinate (Fig. 10). Flagellomeres of antenna very short, mid flagellomeres almost twice as broad as long (Fig. 2) ....***Ojuelos* Khalaim, gen. n.**

– Face and clypeus moderately to very strongly convex in lateral view; clypeus not separated from face. Mandible with lower tooth shorter, subequal to or longer than upper tooth, not especially reduced, and upper tooth more or less pointed, not chisel-shaped. Propodeum with carinae not as above. Flagellomeres of antenna more or less elongate **5**

5 First metasomal segment weakly to quite strongly tapered anteriorly, but always evenly so, thus the anterior 0.4 is not parallel sided; its spiracle near its anterior 0.3. Sternite 1 short, at most reaching about 0.3 of length of tergite. Mandible with lower tooth much shorter than upper tooth .... ***Triclistus* Foerster**

– First metasomal segment petiolate anteriorly, the anterior 0.4 slender and parallel sided; its spiracle near, at or behind the centre. Sternite 1 long, reaching more than 0.5 of length of tergite. Mandible with teeth subequal or with lower tooth longer than upper tooth .... ***Colpotrochia* Holmgren**

***Ojuelos* Khalaim, gen. n.**

urn:lsid:zoobank.org:act:6A8BDDD3-BF85-458A-A5F4-9850741A1819

http://species-id.net/wiki/Ojuelos

Figs 1–13

Type species: *Ojuelos juachicus* Khalaim & Ruíz-Cancino, sp. n.

Composition. The new genus contains only the type species, *O. juachicus*, described below.

Diagnosis. The new genus belongs to the group of three genera (*Cubus*, *Colpotrochia* and *Triclistus*) having a characteristic lamella separating the antennal sockets and reaching the median ocellus (this lamella possesses a longitudinal groove in it, just below the median ocellus) (Fig. 7), and can be distinguished from these genera by the characters given in the key above. Besides characters mentioned in the key, *Ojuelos* differs from *Colpotrochia* by the first metasomal segment not petiolate and evenly tapered anteriorly (Fig. 11), and lower tooth of mandible very small (Fig. 5), and from *Triclistus* by the subgenital plate of female without a deep V-shaped invagination posteriorly (Fig. 13) (some species of *Triclistus* also have hypopygium only weakly emarginate).

Ojuelos can be distinguished from all other genera of Metopiinae by combination of the following characters: 1) frons with a medial, longitudinal lamella that possesses a groove in dorsal surface (Fig. 3); 2) face very weakly convex in profile and separated from clypeus by a weak groove; 3) first metasomal tergite in dorsal view gradually widening posteriorly (Fig. 11) (not petiolate as in *Colpotrochia*); 4) mesosternum without a pair of flattened, finger-like processes projecting posteriorly over bases of mid coxa (projections present in *Cubus*); 5) propodeum lacks most carinae, only the area posteroexterna is bounded by carinae, whereas the longitudinal carinae are absent anteriorly.

Description. Fore wing length 9.5 mm, body length about 12.6 mm. Body and legs predominantly black, flagellum yellowish brown, wings yellow with distal margin broadly infuscate (Fig. 8).

Head: Mandibles stout, not twisted, with lower tooth strongly reduced (very small and inconspicuous) and upper tooth broad and chisel-shaped (Fig. 5). Labrum exposed, short and apically truncated (Fig. 6). Malar space half as long as basal width of mandible. Clypeus 3.0 times as broad as high, more or less flat in lateral view, separated from face by weak and broad transverse impression (Fig. 5). Face and upper 0.8 of clypeus very densely and coarsely punctate (punctures partly merging). Face very weakly convex, with upper part produced dorsomedially into a triangular projection that extends posteriorly as a thin, longitudinal lamella between bases of antennae; this lamella reaching to the median ocellus, and dorsally with a conspicuous groove (Fig. 7). Ocelli not enlarged. Back of head steeply declivous behind the posterior ocelli. Occipital carina dorsally close to foramen magnum, almost complete but obliterated ventrally before hypostomal carina (Fig. 4). Hypostomal carina strong, raised into a high flange (Fig. 4). Flagellum of antenna rather short and thick; all flagellomeres, excepting three basal and one apical flagellomere, distinctly transverse (Fig. 2).

Mesosoma: Propleuron not enlarged. Epomia very sharp and strongly raised, close to anterior margin and extending upwards (Fig. 7). Notauli completely absent. Mesopleuron strongly inflated (lateral sides of mesopleuron conspicuously protuberant in dorsal view). Epicnemial carina reaching almost margin of pleuron immediately below the subalar prominence, with a secondary carina extending from pleural margin near lower corner of pronotum, to join the subtegular ridge. Sternaulus absent. Posterior transverse carina of mesopleuron present laterally and absent ventrally. Propodeum rather short, convex, almost ecarinate, with only area posteroexterna clearly bounded by carinae, and with weak and short longitudinal carina extending anteriorly from anterior margin of area posteroexterna (Fig. 10). Propodeal spiracle large and oval (Fig. 10). Pleural carina between propodeum and metapleuron complete. Submetapleural carina complete, strongly raised anteriorly.

Wings: Fore wing with stalked rhombic areolet (Fig. 8), vein *cu-a* strongly inclivous and distad *Rs*&*M*. Vein 2*m-cu* slightly S-curved, with one long bulla. Hind wing with distal abscissa of *Cu*1 distinct, meeting cu-a much closer to 1*A* than to *M*.

Legs: Robust, all femora thickened. Fore tibia without apical tooth. Hind and mid tibiae with two spurs; inner spur of hind tibia longer than outer spur (Fig. 12). Apical tarsomeres not swollen. Tarsal claws large, simple but with long hairs.

Metasoma: Tergites 1 and 2 of metasoma separated. First tergite 1.6 times as long as posteriorly broad (length measured from hind margin of propodeum), evenly tapered anteriorly in dorsal view (Fig. 11), with spiracle near its anterior 0.35 (Fig. 9); dorsomedian carinae virtually absent, dorsolateral carinae distinct only at base of the tergite, completely absent behind spiracle; sternite 1 reaching about 0.33 of length of tergite. Tergites 2 and 3 with neither dorsal nor dorsolateral carinae. Laterotergites 2 and 3 narrow, separated by a sharp crease. Laterotergite 4 separated from tergite by weak crease only anteriorly. Subgenital plate of female roundly truncated and very weakly concave at apex (Fig. 13). Ovipositor thin and short, slightly upcurved, without dorsal subapical notch, slightly projecting beyond apex of subgenital plate (Fig. 12).

Etymology. Named after the type locality, Ojuelos de Jalisco. Gender masculine.

Ojuelos juachicus **Khalaim & Ruíz-Cancino, sp. n.**
urn:lsid:zoobank.org:act:2F287E7F-CF27-4383-BDF4-3DF74EA9EB43
http://species-id.net/wiki/Ojuelos_juachicus
Figs 1–13

Description. Female.

Head: Mandibles mostly densely and coarsely punctate, very finely shagreened at apex. Labrum 6.3 times as long as basally broad (Fig. 6). Maxillary and labial palpi slender and moderately long. Clypeus with lower margin truncated (Fig. 6), smooth in lower 0.2. Face with weak median tubercle in its upper part. Inner eye orbits moderately concave at level of antennal insertions. Vertex and genae with dense and sharp punctures (distance between punctures mostly equal to or slightly longer than diameter of puncture), smooth between punctures; punctures in lower part of genae sparser. Gena, in dorsal view, rounded, about as long as eye width (Fig. 3). Lateral ocellus separated from eye margin by distance equal to maximum diameter of ocellus. Flagellum of antenna with 46 flagellomeres; the basal flagellomere about 2.5 times as long as broad; flagellomeres 4+ distinctly transverse, mid flagellomeres almost twice as broad as long (Fig. 2).

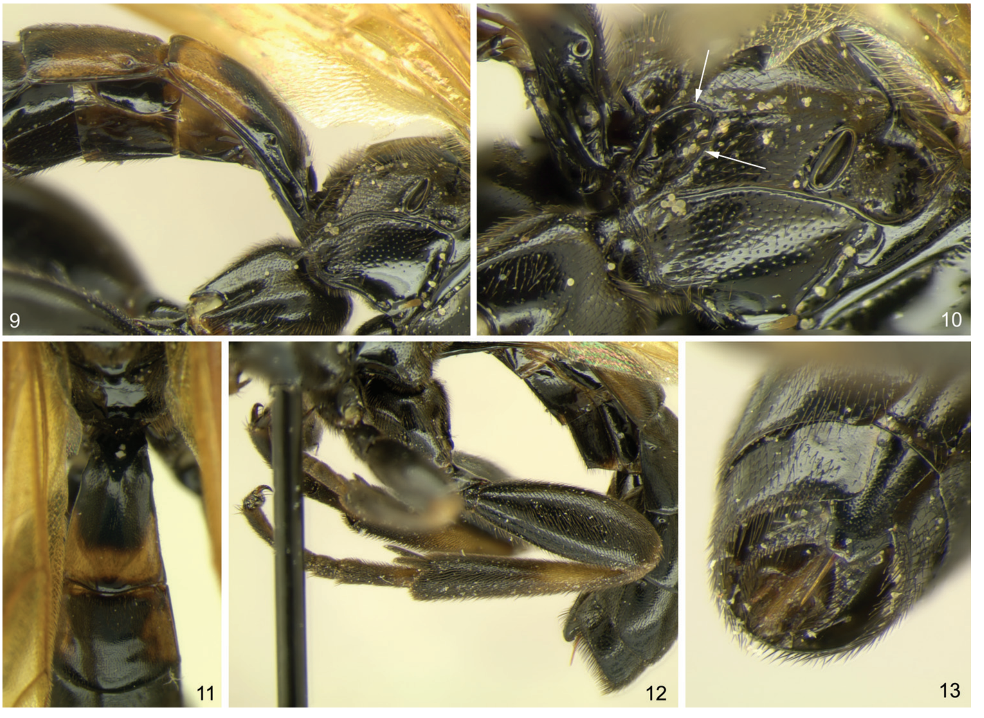
Mesosoma: Pronotum mediodorsally smooth, laterally deeply concave. Mesoscutum weakly convex, posterolaterally with a sharp flange, entirely densely and sharply punctate, smooth between punctures. Scutoscutellar groove deep and smooth. Scutel-

Figure 1. *Ojuelos juachicus* Khalaim & Ruíz-Cancino, **sp. n.**, habitus, female holotype.

lum moderately convex in lateral view, smooth, with sharp punctures and with lateral carinae only at its extreme base. Mesopleuron mostly densely and sharply punctate, smooth and impunctate only posteriorly. Propodeum dorsally polished, laterally and posteriorly finely punctate to coriaceous. Metapleuron smooth, in dorsoposterior 2/3 with sparp punctures, in ventroanterior 1/3 impunctate.

Metasoma: Tergite 2, in dorsal view, slightly transverse; laterotergite 2 parallel-sided, 3.8 times as long as broad. Tergite 3 with laterotergite rather narrow and parallel-

Figures 2–8. *Ojuelos juachicus* Khalaim & Ruíz-Cancino, **sp. n. 1** antenna, dorsal view **2** head, dorsal view **3** head, latero-ventro-posterior view (OC – occipital carina, HC – hypostomal carina) **5** head, latero-ventro-anterior view **6** head, frontal view **7** head and anterior part of mesosoma, dorsolateral view **8** fore wing, dorsal view.



Figures 9–13. *Ojuelos juachicus* Khalaim & Ruíz-Cancino, **sp. n. 9** propodeum, metapleuron and metasomal segments 1–2, lateral view **10** propodeum and metapleuron, lateral view **11** propodeum and metasomal segments 1–2, dorsal view **12** metasoma and hind leg, lateral view **13** apex of metasoma, latero-ventro-posterior view.

sided. Tergite 1 dorsally predominantly finely and densely punctate, smooth and shining between punctures. Tergites 2–6 dorsally mostly finely and very densely punctate, weakly polished between punctures. Subgenital plate finely punctate.

Coloration: Body and legs almost entirely black (Fig. 1). Flagellum yellowish brown with the basal and the apical flagellomeres fuscous (Fig. 2). Mouth parts blackish. Wings yellow with distal margin broadly infuscate, pterostigma and most of veins pale brown (Fig. 8). Legs predominantly black; fore leg with femur yellowish brown apically, tarsus yellowish brown, partly infuscate; mid leg with femur apically, tibia basally and basitarsus basally yellowish brown; hind leg with tibia with broad subbasal yellowish brown band and basitarsus basally yellowish brown. Tergite 1 with broad posterior brownish yellow band; tergite 2 laterally yellowish brown (Fig. 11).

Male unknown.

Material examined. Holotype female, México, Zacatecas Prov., 20 km S Ojuelos de Jalisco, Juachí, La Papa de Arriba, 21°42.104'N, 101°36.791'W, 2275 m, sweeping, 21.IX.2011, coll. A.I. Khalaim (UAT).

Distribution. Central Mexico (Jalisco).

Etymology. Named after the type locality, Juachí.

Discussion

Ojuelos is a distinct member of the Metopiinae as it has a characteristic stout body and legs, cylindrical metasoma with short first segment, face weakly separated from clypeus and with the dorsally projecting triangular interantennal flange, lack of sternaulus and tooth on apex of fore tibia, and having a short and very slender ovipositor.

We place *Ojuelos* to the group of three genera, *Cubus*, *Colpotrochia* and *Triclistus* (all occur in Mexico), based on the putative synapomorphy of the interantennal lamella that bears a dorsal, longitudinal groove. The genus is distinguished from other genera of the subfamily primarily by the rather unusual structure of the head which has the face and clypeus only slightly convex in lateral view and separated by a weak impression. Within the subfamily similar head present only in two small genera, the predominantly Holarctic *Periope* Haliday (Kusigemati 1968) and the Holarctic and Neotropical *Scolomus* Townes & Townes (= *Apolophys* Townes) (Gauld and Wahl 2006). *Ojuelos* differs from *Periope* by having a hind tibia with two robust spurs (one slender spur in *Periope*) and a strongly reduced lower tooth of the mandible, from *Scolomus* by having the triangular interantennal projection of face (in *Scolomus* face without triangular projection dorsally), a shorter malar space (1.2–1.8 times as long as basal width of mandible in *Scolomus*), a strongly transverse clypeus (subquadrate, about as broad as long in *Scolomus*), a fore wing with vein *cu-a* strongly distad *Rs&M* (opposite to slightly distad in *Scolomus*), and from both genera by having a reduced longitudinal carinae of the propodeum (Figs 10, 11) (propodeum with complete medial longitudinal carinae in *Periope* and more or less developed basal and apical transverse carinae in *Scolomus*).

Acknowledgements

We are thankful to Dmitry R. Kasparyan (Zoological Institute of Russian Academy of Sciences, St. Petersburg, Russia), Ilari E. Sääksjärvi (University of Turku, Finland) and Gavin R. Broad (Natural History Museum, London, UK) for their valuable comments and suggestions. We also wish to thank the anonymous referee for his important suggestions and language corrections. This work was supported by the Russian Foundation for Basic Research (grant no. 10-04-00265) and the PROMEP Project "Taxonomía y ecología de fauna y micobiota en comunidades forestales y cultivos".

References

Fitton MG (1984) Subfamily Metopiinae. In: Gauld ID (Ed) An introduction to the Ichneumonidae of Australia. Natural History Museum, London, 353–363.

Gauld ID, Sithole R (2002) Subfamily Metopiinae. In: Gauld ID, Sithole R, Ugalde-Gómez J, Godoy C (Eds) The Ichneumonidae of Costa Rica, 4. Memoirs of the American Entomological Institute 66, 11–262.

Gauld ID, Wahl DB (2006) The relationship and taxonomic position of the genera *Apolophus* and *Scolomus* (Hymenoptera: Ichneumonidae). Zootaxa 1130: 35–41.

González-Moreno A, Bordera S, Delfin-González H (2011) Metopiinae (Hymenoptera: Ichneumonidae) de la reserva especial de la biosphera Ríz Lagartos, México. Entomología mexicana 9 (2010): 212–215.

Khalaim AI, Ruíz-Cancino E (2011) Mexican species of *Colpotrochia* Holmgren, 1856 and *Cubus* Townes & Townes, 1959 (Hymenoptera: Ichneumonidae: Metopiinae). Russian Entomological Journal 20: 71–73.

Kusigemati K (1968) A revision of the genus *Periope* Haliday with description of a new species (Hymenoptera, Ichneumonidae). Insecta Matsumurana 31: 7–11.

Ruíz-Cancino E, Kasparyan DR, Coronado-Blanco JM (2002) 37. Ichneumonidae. In: Llorente-Bousquets J, Morrone JJ (Eds) Biodiversidad, Taxonomía y Biogeografía de Artrópodos de México: Hacia una síntesis de su conocimiento. Conabio-Ecosur-Bayer, México, 631–646.

Townes HK (1971) The genera of Ichneumonidae, Part 4. Memoirs of the American Entomological Institute 17: 1–372.

Townes HK, Townes M (1959) Ichneumon-flies of America north of Mexico: 1. Subfamily Metopiinae. United States National Museum Bulletin 216(1): 1–318. doi: 10.5479/si.03629236.216.1

Wahl DB, Gauld ID (1998) The cladistics and higher classification of the Pimpliformes (Hymenoptera: Ichneumonidae). Systematic Entomology 23: 265–298. doi: 10.1046/j.1365-3113.1998.00057.x

Yu DS, van Achterberg K, Horstmann K (2005) World Ichneumonoidea 2004. Taxonomy, biology, morphology and distribution. CD/DVD. TAXAPAD, Vancouver, Canada.

ZooKeys 207: 11–35 (2012)
doi: 10.3897/zookeys.207.3040
www.zookeys.org

RESEARCH ARTICLE

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

Taxonomic studies on genus *Tetramorium* Mayr (Hymenoptera, Formicidae) with report of two new species and three new records including a tramp species from India with a revised key

Himender Bharti[1,†], Rakesh Kumar[1,‡]

1 *Department of Zoology & Environmental Sciences, Punjabi University, Patiala, Punjab- 147002, India*

† *urn:lsid:zoobank.org:author:5CFEBC9B-3CA9-4459-83A6-6D7B61B984B7*
‡ *urn:lsid:zoobank.org:author:AA7C2937-B9E5-459D-BDB5-91B35350CE5E*

Corresponding author: *Himender Bharti* (himenderbharti@gmail.com)

Academic editor: *Brian Fisher* | Received 1 March 2012 | Accepted 28 June 2012 | Published 11 July 2012

urn:lsid:zoobank.org:pub:71A0BE2E-178C-4B69-A77F-1BD84ACA10CD

Citation: Bharti H, Kumar R (2012) Taxonomic studies on genus *Tetramorium* Mayr (Hymenoptera, Formicidae) with report of two new species and three new records including a tramp species from India with a revised key. ZooKeys 207: 11–35. doi: 10.3897/zookeys.207.3040

Abstract

Two new species of *Tetramorium* Mayr, namely *T. shivalikense* **sp. n.** and *T. triangulatum* **sp. n.** are described. *Tetramorium triangulatum* **sp. n.** belongs to the *inglebyi*-species group and is described based on worker, queen and male caste, while *T. shivalikense* **sp. n.** belongs to the *ciliatum*-species group and is described based on worker caste only. Three species viz., *T. caldarium* (Roger), *T. tonganum* Mayr and *T. urbanii* Bolton represent first records from India. The male caste is described for the first time in the case of *T. tonganum*. Among these, *T. caldarium* is a tramp species which extends its limit to India as well. A revised key to the Indian ants of this genus is also provided herewith.

Keywords

Tetramorium, Myrmicinae, new species, tramp species, India, key

Introduction

Tetramorium Mayr, 1855 is one of the largest genera within the tribe Tetramoriini and is one of the most species rich genera with 477 species (Bolton 2012). The genus has a worldwide distribution with varying species richness among different zoogeographical regions. The greatest number of species (230) has been reported from the Afrotropical region, whereas there are only very few (13) known from the New World. The genus has a good representation in the Palaearctic, Oriental, Malagasy and Indo-Australian regions, although much less compared to the Afrotropical region (Hita Garcia and Fisher 2011). Bolton (1976, 1977, 1979, 1980 and 1985) revised this genus for most of the above stated regions except the Palaearctic, and noteworthy contributions for the Palaearctic include Steiner et al. (2005), Schlick-Steiner et al. (2006), Csösz et al. (2007), Csösz and Schulz (2010), Steiner et al. (2010). Other significant contributions to this genus dealing with revision of species groups and complexes from the Palaearctic, Afrotropical and Malagasy regions are Csösz et al. (2007), Csösz and Schulz (2010), Hita Garcia et al. (2010), Hita Garcia and Fisher (2011).

In India, the genus *Tetramorium* is currently represented by 30 species (Bharti 2011). Most of the Indian species were treated by Bolton (1976, 1977) in his revisionary work dealing with the Oriental and Indo-Australian regions. Later, the contributions which reported new species included Mathew (1981), Sheela and Narendran (1998), Mathew and Tiwari (2000), and Bharti (2011) who provided a replacement name for *T. browni* Tiwari. Fourteen species out of 30 described hitherto have been reported from Southern India, 3 from North-eastern India, 2 from North India, 1 from Central India. Five Indian species *T. indicum* Forel, *T. obesum* Andre, *T. smithi* Mayr, *T. tortuosum* Roger and *T. walshi* (Forel) have wide distribution ranges in South-East Asia. Five tramp species namely *T. bicarinatum* (Nylander), *T. caespitum* (Linnaeus), *T. lanuginosum* Mayr, *T. pacificum* Mayr, *T. simillimum* (Smith) are widely distributed in India as well. Thus, the genus is mainly known from the southern region of the country. During the present study two new species *T. triangulatum* sp. n. and *T. shivalikense* sp. n. are described from the northern part of the country. The three species *T. caldarium* (Roger), *T. tonganum* Mayr and *T. urbanii* Bolton represent first records from India. Moreover, *T. caldarium* is a well established tramp species and *T. tonganum* a probable tramp species. Male caste of *T. tonganum* is described for the first time.

With the addition of 5 species, the genus *Tetramorium* is now represented by 35 species from India. These species are placed in the following 12 species groups except *Tetramorium beesoni (*Mukerjee) for which the group is unknown: *angulinode*-group: *smithi* Mayr; *bicarinatum*-group: *bicarinatum* (Nylander), *indicum* Forel, *pacificum* Mayr, *meghalayense* Bharti, *petiolatum* Sheela and Narendran; *caespitum*- group: *caespitum* (Linnaeus); *ciliatum*-group: *T. shivalikense* sp. n.; *fergusoni*-group: *fergusoni* Forel; *inglebyi*-group: *elisabethae* Forel, *inglebyi* Forel, *myops* Bolton, *T. triangulatum* sp. n.; *mixtum*-group: *mixtum* Forel, *rugigaster* Bolton, *malabarense* Sheela and Narendran, *sentosum* Sheela and Narendran; *obesum*-group: *coonoorense* Forel, *decamerum* (Forel), *lanuginosum* Mayr, *obesum* Andre, *rossi* (Bolton); *simillimum*-group: *simillimum* (Smith), *caldarium* (Roger); *tonganum*-group: *christiei* Forel, *salvatum* Forel, *tonganum* Mayr, *barryi* Mathew; *tortuosum*-group: *belgaense* Forel, *tortuosum* Roger, *urbanii* Bolton, *keralense* Sheela and Narendran; *walshi*-group: *cordatum* Sheela and Narendran, *walshi* (Forel). A revised key to the Indian ants of this genus is also provided herewith.

Materials and methods

The ants were collected by pitfall traps, hand picking, soil core sampling, beating vegetation, and from the leaf litter with Winkler's extractor. The digital images of these specimens were prepared on a Nikon SMZ-1500 stereo zoom microscope using Auto-Montage software. Later, images were cleaned with Adobe Photoshop CS5.

Abbreviations of the type depositories are as follows: BMNH, The Natural History Museum, London, U.K.; PUPAC, Punjabi University Patiala Ant Collection, Patiala, India. Two paratypes of each, *T. shivalikense* sp. n. and *T. triangulatum* sp. n., will be deposited in BMNH.

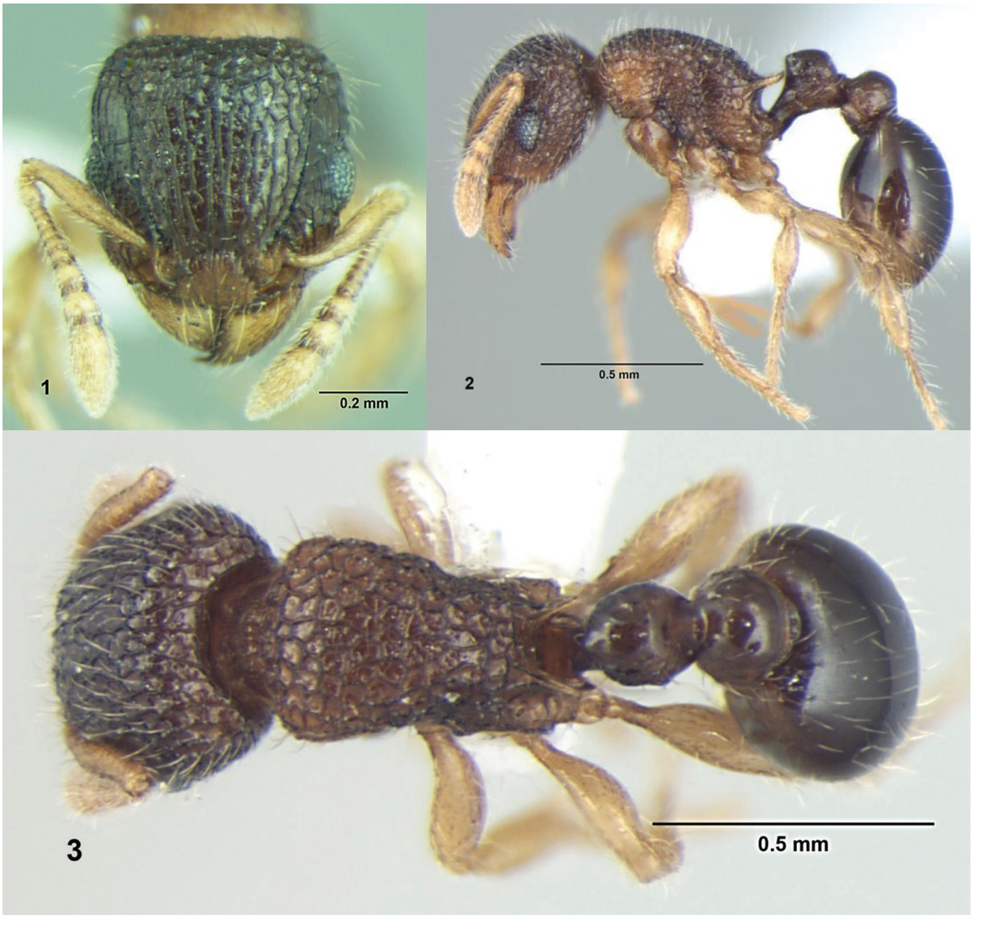
Measurements and indices follow Hita Garcia and Fisher (2011): head Length (HL), head Width (HW), scape Length (SL), eye length (EL), pronotal width (PW), weber's length (WL), propodeal spine Length (PSL), petiolar node height (PTH), petiolar node length (PTL), petiolar node width (PTW), postpetiole height (PPH), postpetiole length (PPL), postpetiole width (PPW), ocular index (OI), cephalic index (CI), scape index (SI), propodeal spine index (PSLI), petiolar node index (PeNI), lateral petiole index (LPeI), dorsal petiole index (DPeI), postpetiolar node index (PpNI) = PPW/PW*100, lateral postpetiole index (LPpI), dorsal postpetiole index (DPpI), postpetiole index (PPI).

Results

Tetramorium shivalikense **sp. n.**
urn:lsid:zoobank.org:act:C846D381-9691-4465-8098-FF44357F415C
http://species-id.net/wiki/Tetramorium_shivalikense
Figs 1–3

Holotype. Worker, India, Himachal Pradesh, Terrace, 31.928591°N, 75.931342°E, 420m alt., winkler, 11 October 2008, coll. R. Kumar, PUPAC.

Paratypes. 11(w), India, Himachal Pradesh, Terrace, 420m alt., winkler, 11 October 2008; 1(w), India, Punjab, Dharampur, 450m alt., beating, 14 October 2008; 18(w), India, Himachal Pradesh, Siholi, 550m alt., winkler, 19 October 2008; 1(w), India, Himachal Pradesh, Terrace, 420m alt., winkler, 25 May 2009; 1(w), India, Uttarakhand, Dehradun, Selaqui, 650m alt., 9 August 2009, winkler; 50(w), India, Uttarakhand, Dehradun, Forest Research Institute, 640m alt., hand picking, 14 August 2009; 1(w), India, Uttarakhand, Dehradun, Forest Research Institute, 640m alt., winkler, 17 August 2009; 1(w), India, Himachal Pradesh, Terrace, 420m alt., pitfall trap, 24 September 2009; 4(w), India, Himachal Pradesh, Ghati, 450m alt., winkler, 27 September 2009; 2(w), India, Himachal Pradesh, Chanaur, 600m alt., winkler, 3 October 2009; 2(w), India, Himachal Pradesh, Andretta, 940m alt., winkler, 11June 2010; 8(w), India, Himachal Pradesh, Palampur, 1140m alt., winkler, 14 June 2010;



Figures 1–3. *Tetramorium shivalikense* sp. n., Worker: **1** Head, full-face view **2** Body, lateral view **3** Body, dorsal view.

1(w), India, Himachal Pradesh, Dattal, 940m alt., winkler, 16 June 2010; coll. R. Kumar; PUPAC and two paratypes will be deposited in BMNH.

Worker description. Measurements: Holotype worker. HL 0.56, HW 0.52, SL 0.34, EL 0.13, WL 0.60, PW 0.38, PSL 0.13, PTL 0.14, PPL 0.19, PTW 0.20, PPW 0.23, PTH 0.20, PPH 0.20, CI 92.86, OI 25.00, SI 65.38, PSLI 23.21, PeNI 52.63, LPeI 70.00, DPeI 142.86, PpNI 60.53, LPpI 95.00, DPpI 121.05, PPI 115.00.

Paratype workers. HL 0.56-0.62, HW 0.52-0.56, SL 0.34-0.35, EL 0.13-0.14, WL 0.60-0.67, PW 0.38-0.42, PSL 0.13-0.14, PTL 0.13-0.14, PPL 0.19-0.23, PTW 0.20-0.23, PPW 0.23-0.25, PTH 0.20-0.21, PPH 0.20-0.21, CI 89.83-92.86, OI 24.53-25.00, SI 62.50-66.04, PSLI 22.03-23.21, PeNI 51.22-54.76, LPeI 61.90-70.00, DPeI 142.86-164.29, PpNI 59.52-60.98, LPpI 95.00-109.52, DPpI 108.70-125.00, PPI 108.70-119.05 (10 measured).

Head slightly longer than broad, sides almost straight with rounded posterolateral corners, slightly broader posteriorly than anteriorly; posterior head margin straight with shallow median notch; clypeus convex with steep apical half; anterior margin of clypeus entire without median notch; anterior margin of clypeus with a narrow transverse plate-like fringe and having convex anterior margin; mandibles triangular, masticatory margin of mandibles with large apical and preapical tooth; third tooth slightly smaller than the preapical tooth followed by 3–4 denticles; frontal lobes weakly developed and elevated laterally, frontal area indistinct; antennal scrobes shallow and broad; eye moderate in size, located laterally and at mid-length of head, composed of ca. 35–36 ommatidia; antennae slender, 12-segmented; scape short from posterior head margin by one fourth of its length; mesosoma slightly longer than head, broader anteriorly than posteriorly, dorsum convex; pro-mesonotal suture and metanotal groove indistinct; propodeal spine longer (PSL 0.13–0.14mm), acute, divergent, with tips upcurved; propodeal lobes roughly broadly triangular and acute; posterior declivity of propodeum short, concave; petiole with a short peduncle, node slightly broader than long in dorsal view; base of node longer than dorsal face in lateral view, weakly convex dorsum in lateral view; ventrally petiole downcurved along its length; postpetiole broader than long; base of first gastral tergite weakly concave behind the postpetiole, anterolateral corners rounded and not projecting forward as a pair of blunt teeth or horns which go round the sides of the posterior portion of the postpetiole, gaster oval.

Head longitudinally rugose with few cross-meshes up to vertex, posteriorly reticulate-rugose, interrugal space punctured and shiny; frontal carinae strongly developed and somewhat short to reach posterior head corners; mandibles longitudinally rugulose and interrugal space smooth and shiny; clypeus with a strong median carina continued to vertex and two weak lateral carinae; dorsum of mesosoma reticulate-rugose; sides of mesosoma rugo-reticulate but weaker sculptured than dorsum; dorsum of node with an unsculptured median longitudinal strip and sides with weak rugosity; dorsum of postpetiole smooth and shiny, sides with weak rugosity; propodeal declivity, gaster and legs smooth and shiny.

Body darker brown in most specimens and few specimens yellowish brown; Whole body covered with abundant, long, erect and short subdecumbent pilosity; antennal scapes and hind tibiae with short suberect hairs.

Etymology. The specific epithet refers to the collection area.

Ecology. This new species is widespread in the Shivalik range of the north-western Himalaya and was collected from soil and leaf litter.

Remarks. This new species belongs to the *ciliatum-* species group (Bolton 1977) which is distributed in the Oriental and Indo-Australian regions. The characteristics of this group are: antennae 12-segmented, sting appendage triangular or dentiform, anterior clypeal margin entire and not notched or indented medially, frontal carinae extending well beyond the level of the posterior margins of the eyes, propodeal spines long and usually strongly developed, never downcurved along their length, anterolateral gastral corners not projecting forward as a pair of blunt teeth or horns which go round the sides of the posterior portion of the postpetiole.

Tetramorium shivalikense sp. n. is somewhat allied to *T. zypidum* Bolton. However, it can be easily distinguished from *T. zypidum* by the following combination of characters: anterior margin of clypeus is entire and convex, petiolar node slightly broader than long in dorsal view while in *T. zypidum* the anterior clypeal margin is shallowly impressed medially and the petiolar node significantly longer than broad. Other significant characters of *T. shivalikense* sp. n. which differentiate it from *T. zypidum* include eyes located laterally at mid-length of the head, propodeal lobes broadly triangular and acute, SI 62.50-66.04, sides of postpetiole with weak rugosity, frontal carinae strongly developed and somewhat short to reach posterior head corners. In *T. zypidum* the eyes are situated in front of the middle of the sides of the head, the propodeal lobes narrowly triangular and acute, SI 69.00–75.00, sides of postpetiole smooth, and the frontal carinae extend to the posterior head corners and are weak behind the level of the eyes.

***Tetramorium triangulatum* sp. n.**
urn:lsid:zoobank.org:act:8552E147-02EF-4E82-B8FE-F95A80A2694D
http://species-id.net/wiki/Tetramorium_triangulatum
Figs 4–12

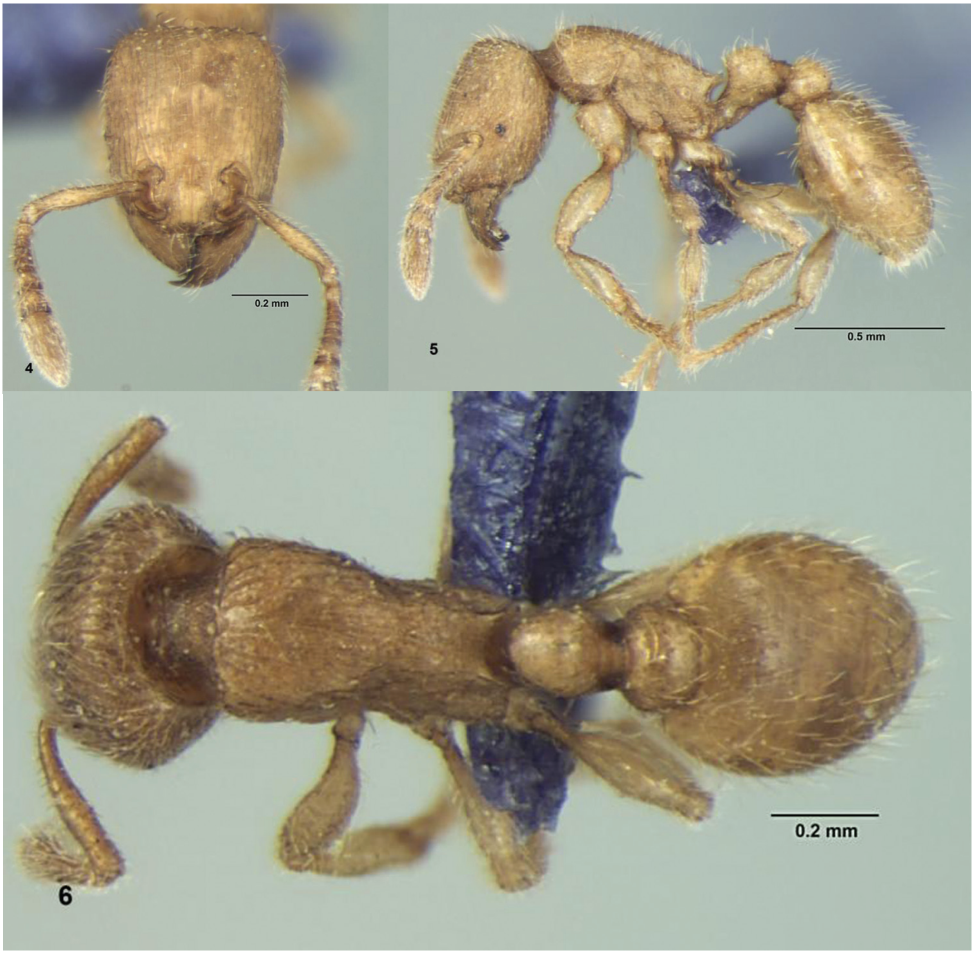
Holotype. Worker, India, Himachal Pradesh, Andretta, 32.036638°N, 76.566532°E, 940m alt., soil core, 19 June 2010, coll. R. Kumar, PUPAC.

Paratypes. 15(q), India, Punjab, Patiala, 250m alt., soil core, 13 July 1999, coll. H. Bharti; 25(m), India, Punjab, Patiala, 250m alt., soil core, 13 July 1999, coll. H. Bharti; 1(w), India, Uttarakhand, Assan Barrage, 440m alt., soil core, 10 May 2009, coll. R. Kumar; 46(w), India, Himachal Pradesh, Andretta, 940m alt., soil core, 19 June 2010, coll. R. Kumar; 7(m), India, Himachal Pradesh, Andretta, 940m alt., soil core, 19 June 2010, coll. R. Kumar; 10(q), India, Himachal Pradesh, Andretta, 940m alt., soil core, 19 June 2010; coll. R. Kumar; PUPAC and two paratype will be deposited in BMNH.

Worker description. Measurements. Holotype worker. HL 0.60, HW 0.52, SL 0.38, EL 0.03, WL 0.63, PW 0.37, PSL 0.07, PTL 0.14, PPL 0.20, PTW 0.19, PPW 0.21, PTH 0.21, PPH 0.19, CI 86.67, OI 5.77, SI 73.08, PSLI 11.67, PeNI 51.35, LPeI 66.67, DPeI 135.71, PpNI 56.76, LPpI 105.26, DPpI 105.00, PPI 110.53.

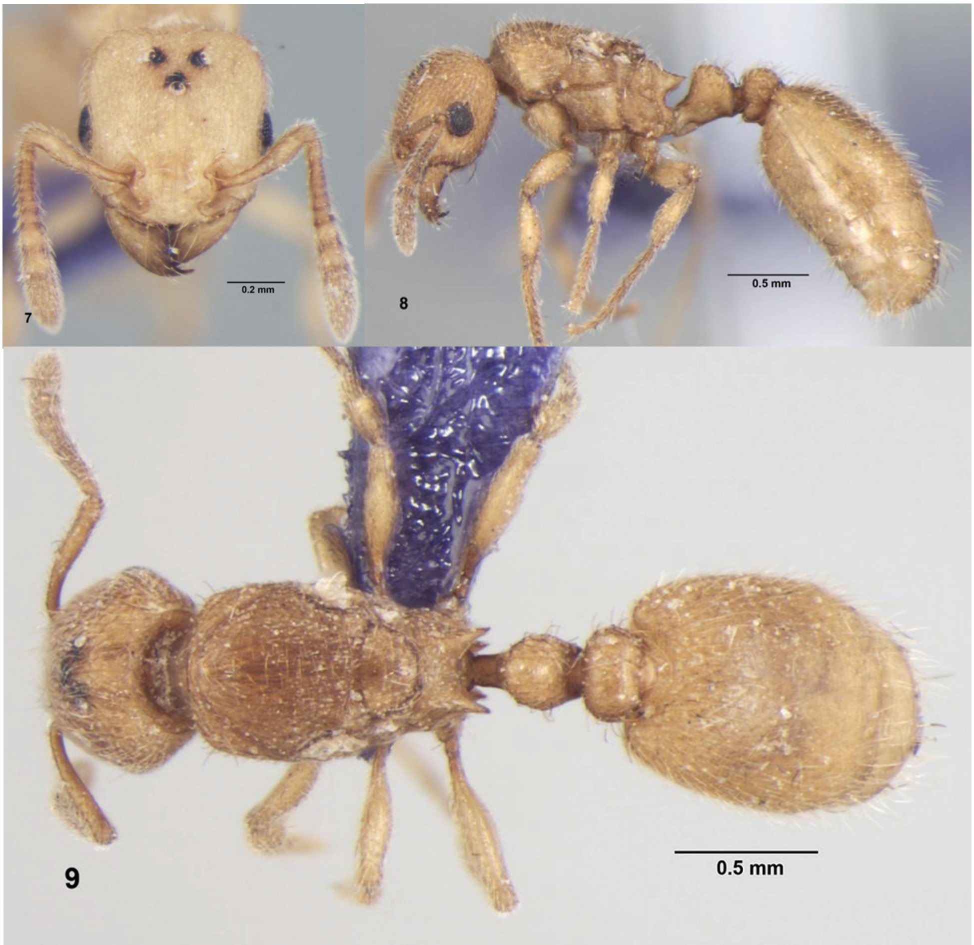
Paratype workers. HL 0.53-0.60, HW 0.45-0.52, SL 0.32-0.38, EL 0.03, WL 0.57-0.63, PW 0.31-0.37, PSL 0.07, PTL 0.12-0.14, PPL 0.17-0.20, PTW 0.16-0.19, PPW 0.19-0.21, PTH 0.19-0.21, PPH 0.16-0.19, CI 84.91-86.67, OI 5.77-6.67, SI 71.11-75.00, PSLI 11.67-13.21, PeNI 50.00-51.61, LPeI 63.16-70.00, DPeI 121.43-135.71, PpNI 56.76-61.76, LPpI 89.47-106.25, DPpI 105.00-123.53, PPI 110.53-123.53 (8 measured).

Head longer than broad, sides weakly convex or almost straight with rounded posterolateral corners, broader posteriorly than anteriorly; posterior head margin straight; clypeus convex with steep apical half; anterior margin of clypeus with a nar-



Figures 4–6. *Tetramorium triangulatum* sp. n., Worker: **4** Head, full-face view **5** Body, lateral view **6** Body, dorsal view.

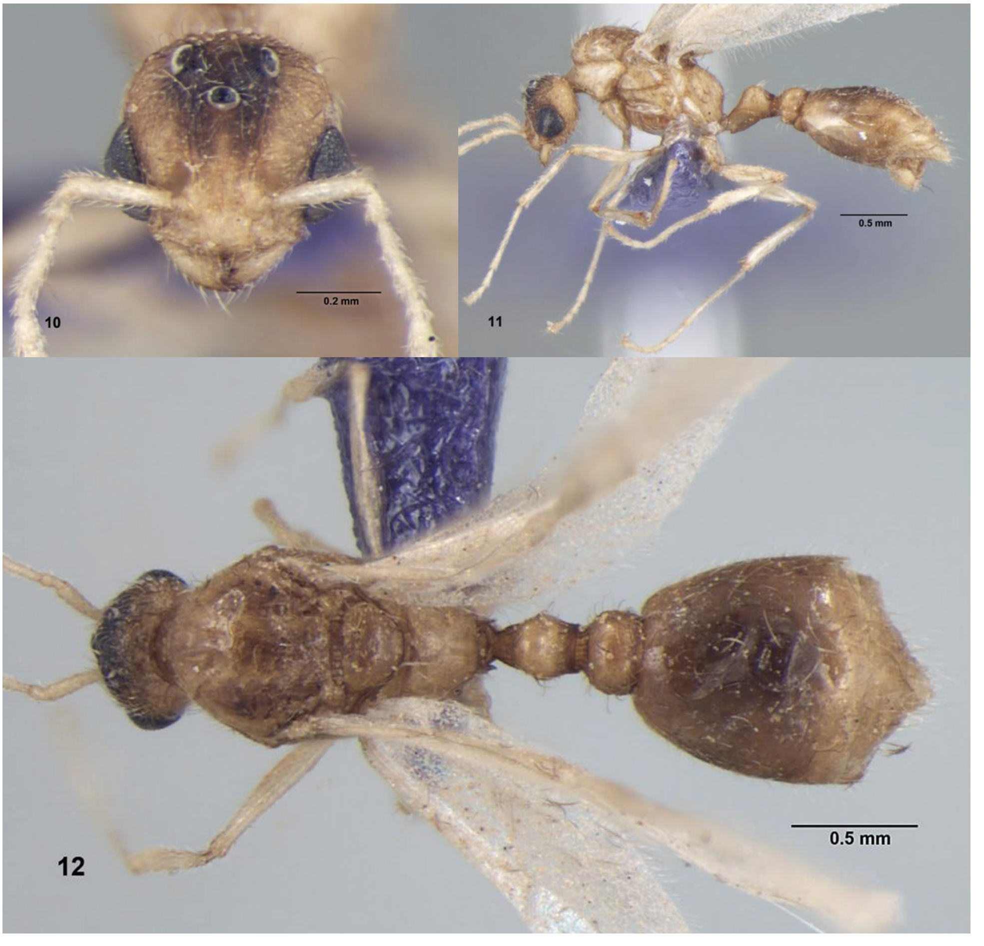
row transverse plate like fringe and somewhat impressed medially; mandibles triangular with 7 teeth, masticatory margin of mandibles with large apical and preapical tooth; third tooth slightly smaller than the preapical tooth followed by 4 denticles; frontal lobes weakly developed, frontal area indistinct; antennal scrobes absent; eye small in size, located laterally and below mid-length of head, composed of single ommatidium; antennae slender, 12-segmented; scape not reach to posterior head margin and 0.63× head length; mesosoma slightly longer than head, broader anteriorly than posteriorly, dorsum flat, tapering backwards; pro-mesonotal suture and metanotal groove indistinct; propodeal spine short (PSL 0.07mm), triangular, acute, divergent and slightly longer than propodeal lobes; propodeal lobes triangular and acute; posterior declivity of propodeum short, concave; petiolar node as broad as long in dorsal view; weakly convex dorsum in lateral view; peduncle short, with a



Figures 7–9. *Tetramorium triangulatum* sp. n., Queen: **7** Head, full-face view **8** Body, lateral view **9** Body, dorsal view.

large, straight lamella ventrally; postpetiole broader than long, base of first gastral tergite concave behind the postpetiole, anterolateral corners prominent and projecting forward as a pair of blunt teeth or horns which go round the sides of the posterior portion of the postpetiole, gaster oval.

Head longitudinally rugulose, interrugal space somewhat granular, punctured and shiny; frontal carinae very short, ending in front of the level of the eyes; mandibles longitudinally rugulose and finely punctured; clypeus longitudinally carinate and these carinae continued to head sculpture; dorsum of mesosoma longitudinally rugulose and interrugal space somewhat granular, punctured; sides of mesosoma finely rugoreticulate; petiole and postpetiole mostly smooth with traces of rugosity; propodeal declivity with traces of fine transverse rugosity, base of first gastral tergite longitudinally rugulose; legs smooth except coxae faintly punctured.



Figures 10–12. *Tetramorium triangulatum* sp. n., Male: **10** Head, full-face view **11** Body, lateral view **12** Body, dorsal view.

Body yellowish brown; whole body covered with long and short, erect and suberect pilosity; antennal scapes and hind tibiae with short suberect hairs.

Queen description. Measurements. HL 0.67-0.71, HW 0.62-0.63, SL 0.42-0.44, EL 0.17-0.19, WL 0.94-0.98, PW 0.57-0.59, PSL 0.13-0.14, PTL 0.14-0.19, PPL 0.24-0.25, PTW 0.23-0.27, PPW 0.30-0.32, PTH 0.28-0.30, PPH 0.27-0.30, CI 88.73-92.54, OI 26.98-30.16, SI 67.74-69.84, PSLI 18.31-19.72, PeNI 38.98-45.76, LPeI 50.00-63.33, DPeI 135.29-171.43, PpNI 50.85-54.24, LPpI 83.33-88.89, DPpI 125.00-128.00, PPI 118.52-130.43 (3 measured).

Similar to the worker in structure, sculpture and pilosity except the following characters (besides characters related to wings): eyes large in size, head with three ocelli.

Male description. Measurements. HL 0.50-0.52, HW 0.46-0.48, SL 0.23-0.24, EL 0.23, WL 1.02-1.05, PW 0.66-0.69, PTL 0.14-0.16, PPL 0.21-0.24, PTW 0.21-0.23, PPW 0.27-0.28, PTH 0.23-0.24, PPH 0.23-0.25, CI 92.00-92.31, OI 47.92-50.00, SI

50.00, PeNI 31.82-34.33, LPeI 58.33-69.57, DPeI 131.25-164.29, PpNI 39.13-42.42, LPpI 84.00-104.35, DPpI 112.50-133.33, PPI 117.39-133.33 (3 measured).

Head slightly longer than broad, sides convex, posterior head margin convex, with three ocelli; mandibles with well developed 5 pointed teeth but in few specimens large apical teeth followed by series of denticles; clypeus convex and its anterior margin entire, convex with a narrow transverse plate like fringe and not impressed medially; frontal lobes reduced; antennae 10-segmented; scape short and not reach to posterior head margin and almost 0.46× times head length; apical segment longer and twice of preapical segment, followed by 4 segments as long as broad; then followed by a segment slightly longer than broad; antennal segment attached to pedicel much longer and almost equal to apical segment which then followed by a small segment (smaller than all flagellar segments); antennal scrobes absent; eyes large, convex, situated laterally and more towards lower half of head; pronotum broader than head with rounded anterior lateral angles; mesoscutum and mesoscutellum flat; propodeal dorsal face flat and oblique with vertical declivitous part; propodeal spines absent; propodeal lobes almost rounded; petiole longer, almost 1.4× times its width, with a ventral lamella along its entire length; Postpetiole broader than long; gaster convex, elongate, oval; longer legs.

Head and clypeus longitudinally rugulose and spaces between them punctured; mandibles punctured, frontal carinae continued to the posterior ocelli; dorsum and sides of mesosoma smooth and shiny except propodeum; propodeum finely longitudinally rugulose and punctured; node of petiole, postpetiole, gaster and legs smooth and shiny except few trace of sculpture on sides of node of petiole; wings transparent.

Body yellowish brown with 1st gastral tergite much darker and area of ocelli blackish; body covered with short and long suberect pilosity.

Etymology. The specific epithet refers to the triangular propodeal spines.

Ecology. This species is uncommon in the Shivalik range of the north-western Himalaya and was collected from soil.

Remarks. *Tetramorium triangulatum* sp. n. belongs to the *inglebyi*-species group (Bolton 1977) which is apparently restricted to India and is easily characterized by antennae 12-segmented, appendage of sting triangular or dentiform, frontal carinae absent or very short, not reaching the level of the anterior margin of the eyes, eyes small, reduced to a single ommatidium in *myops,* antennal scrobes absent, base of first gastral tergite strongly concave in dorsal view, the anterolateral angles of the sclerite angular, produced as a short tubercles or tooth on each side of the posterolateral corners of the postpetiole.

This new species is close to *Tetramorium myops* Bolton as both species possess short frontal carinae, minute eyes, peduncle with ventral lamella and an medially impressed anterior clypeal margin. However, this new species can be easily distinguished from *T. myops* by the following combination of characters: *T. triangulatum* sp. n. has short propodeal spines (PSL 0.07mm), triangular and divergent, peduncle with a large and straight lamella ventrally, dorsum of mesosoma longitudinally rugulose, base of first gastral tergite longitudinally rugulose, while in case of *T. myops* the propodeal spines are long and upcurved along their length, the peduncle with a large rounded and convex lamella ventrally, dorsum of mesosoma with longitudinal rugulae and reticulation, base of first gastral tergite with vestiges of superficial sculpture. Some of the other significant characters of *T. triangulatum* sp. n. which differentiate it from *T. myops* are: head broader posteriorly with straight sides and SI 71.11-75.00 versus head with convex sides and SI 77.00-83.00 in *T. myops*.

Tetramorium caldarium (Roger, 1857), new record from India

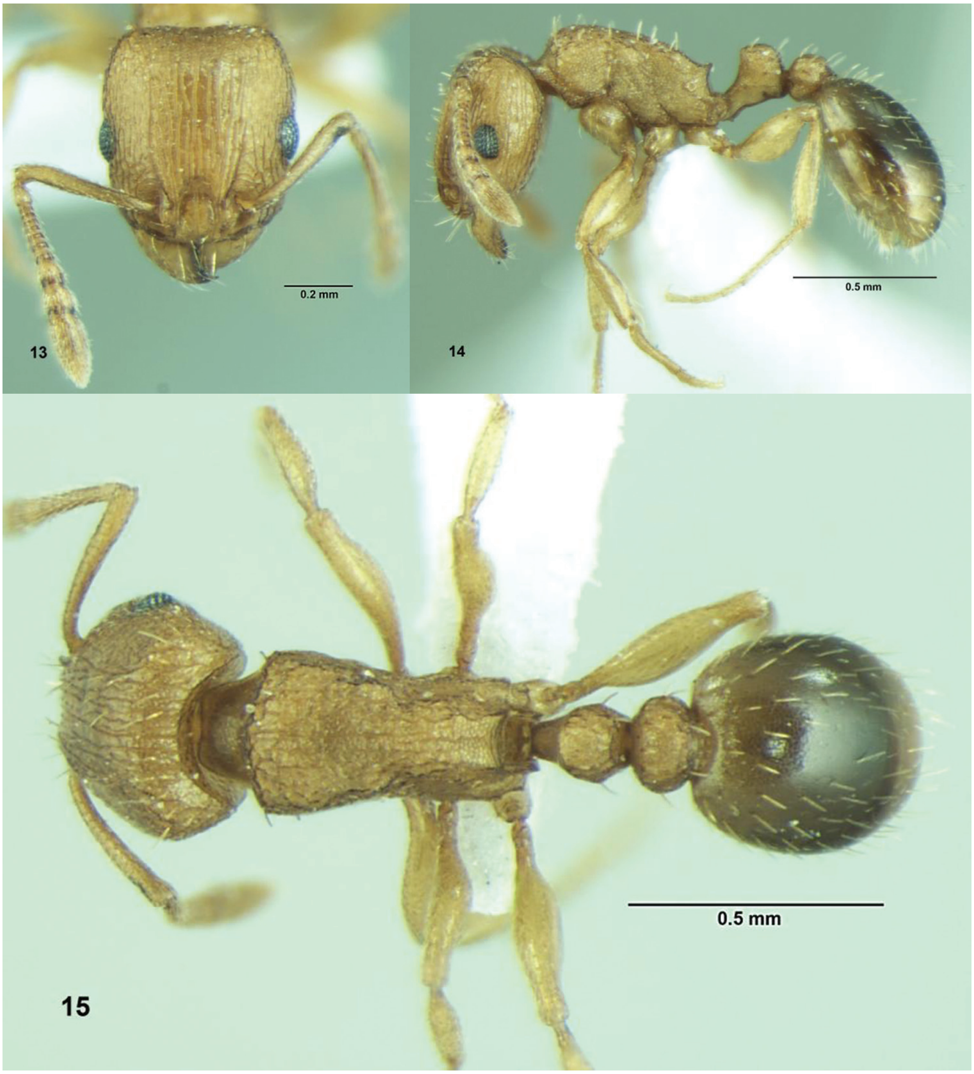
http://species-id.net/wiki/Tetramorium_caldarium
Figs 13–15

Material examined. 11(w), India, Punjab, Patiala, 250m alt., hand picking, 07 April 2011, coll. R. Kumar, PUPAC.

Worker description. Measurements (worker). HL 0.63-0.64, HW 0.53-0.56, SL 0.42-0.45, EL 0.12-0.13, WL 0.66-0.69, PW 0.37-0.38, PSL 0.03-0.05, PTL 0.13-0.14, PPL 0.18-0.20, PTW 0.18-0.19, PPW 0.21-0.23, PTH 0.20-0.21, PPH 0.18-0.19, CI 84.13-87.50, OI 21.82-23.21, SI 76.36-83.02, PSLI 4.76-7.94, PeNI 47.37-51.35, LPeI 61.90-70.00, DPeI 128.57-146.15, PpNI 55.26-62.16, LPpI 94.74-105.56, DPpI 110.53-127.78, PPI 116.67-121.05 (9 measured).

Head longer than broad, sides almost straight, posterolateral corners rounded, posterior head margin shallowly emarginated; clypeus consisting of flat basal half and steep apical half; anterior margin of clypeus entire without median notch; mandibles triangular, with 6 teeth, masticatory margin of mandibles with large apical and preapical tooth; third tooth slightly smaller than the preapical tooth followed by three denticles; frontal lobes weakly developed and elevated laterally, frontal area indistinct; antennal scrobes feeble, indistinct, very little concave and not bordered posteriorly; eye moderate in size, located laterally and almost at mid-length of head, composed of ca. 8 ommatidia in a series along its maximum length; antennae slender, 12-segmented; scape short from posterior head margin by one fourth of its length; mesosoma longer than head, broader anteriorly than posteriorly, dorsum flat and tapers to backward in lateral view; pro-mesonotal suture and metanotal groove indistinct; propodeal teeth small (PSL 0.03-0.05mm), acute, triangular almost equal to its width and propodeal lobes; propodeal lobes broad and roughly triangular in shape; posterior declivity of propodeum short, concave; petiole with a short peduncle, its node as broad as long with anterior and posterior faces parallel, weakly convex dorsum in lateral view; ventrally petiole weakly downcurved along its length; peduncle with a small anteroventral lamella; postpetiole broader than long, gaster oval.

Head feebly longitudinally rugose, interrugal space weakly granular or punctulate; frontal carinae feeble and developed to the level of the midlength of the eye behind which fade out or broken; mandibles weakly longitudinally rugulose; clypeus with a strong mid and two lateral carinae; dorsum of mesosoma weakly granular or punctulate with traces of rugulose sculpture; sides of mesosoma reticulate; petiole and postpetiole faintly rugulose and punctulate; propodeal declivity reticulate, upper half finely transversely rugulose, gaster unsculptured; legs smooth and shiny.



Figures 13–15. *Tetramorium caldarium* (Roger), Worker: **13** Head, full-face view **14** Body, lateral view **15** Body, dorsal view.

Whole body yellowish brown with gaster darker brown; body with short, erect, stiff, blunt hairs and few scattered pubescence on gaster; antennal scapes and hind tibiae with very short, fine, appressed pubescence.

Remarks. Being tramp, it was collected from a disturbed area with high anthropogenic activities. It is widely distributed in the tropics and subtropics, associated with man and living in hothouses, zoos or other constantly heated buildings (Bolton 1980). It is uncommon in India and has been reported for the first time from India. It belongs to *simillimum*- species group (Bolton 1980, Hita Garcia and Fisher 2011) and is very close to *T. simillimum* (Smith). From the latter, it can be distinguished by the following combination of characters: frontal carinae developed to the level of the midlength of the eyes behind which they become very weak or broken, or gradually fade out posteriorly, ground sculpture of head is feeble with surfaces dully shiny; antennal scrobes vestigial.

Tetramorium tonganum Mayr, 1870, new record from India

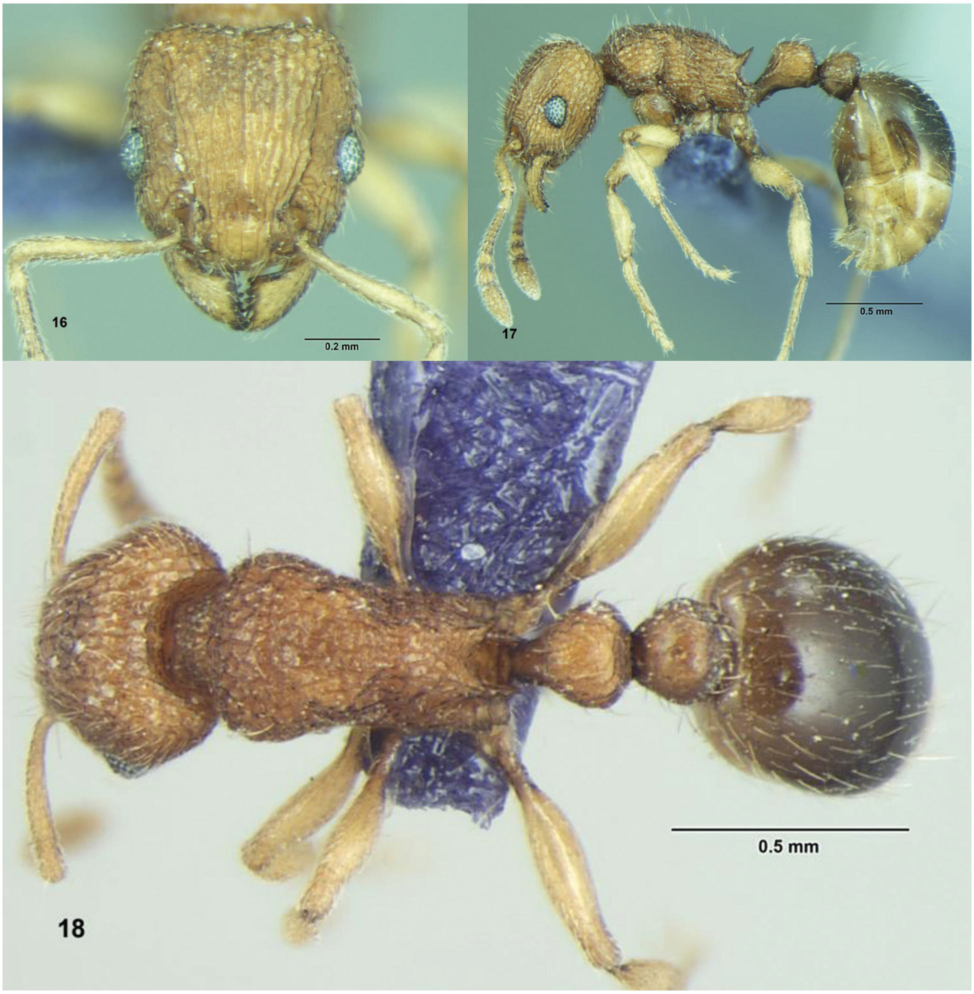
http://species-id.net/wiki/Tetramorium_tonganum
Figs 16–24

Material examined. 1(w), India, Himachal Pradesh, Lwasa, 1200m alt., soil core, 07 May 2009; 1(w), India, Uttarakhand, Dehradun, Forest Research Institute, 640m alt., soil core, 17 August 2009; 14(w), India, Himachal Pradesh, Baijnath, 1000m alt., soil core, 17 June 2010; 8(m), India, Himachal Pradesh, Baijnath, 1000m alt., soil core, 17 June 2010; 13(q), India, Himachal Pradesh, Baijnath, 1000m alt., soil core, 17 June 2010; 3(q), India, Himachal Pradesh, Andretta, 940m alt., soil core, 20 June 2010; 8(m), India, Himachal Pradesh, Andretta, 940m alt., soil core, 20 June 2010; 28(w), India, Himachal Pradesh, Andretta, 940m alt., soil core, 20 June 2010; 14(w), India, Mandi, Himachal Pradesh, 800m alt., soil core, 27 June 2010; coll. R.Kumar; PUPAC.

Worker description. Measurements (worker).HL 0.62-0.66, HW 0.56-0.60, SL 0.46-0.48, EL 0.14, WL 0.69-0.75, PW 0.42-0.46, PSL 0.07-0.10, PTL 0.16-0.17, PPL 0.20-0.23, PTW 0.21-0.26, PPW 0.23-0.26, PTH 0.20-0.21, PPH 0.20-0.23, CI 90.32-92.19, OI 23.33-25.00, SI 76.67-85.71, PSLI 11.29-15.63, PeNI 50.00-56.52, LPeI 80.00-85.00, DPeI 131.25-152.94, PpNI 52.27-56.52, LPpI 86.96-115.00, DPpI 100.00-130.00, PPI 100.00-109.52 (7 measured).

Head slightly longer than broad, sides almost straight with rounded posterolateral corners, slightly broader posteriorly than anteriorly; posterior head margin straight with shallow median notch; clypeus convex with steep apical half; anterior margin of clypeus entire without median notch; anterior margin of clypeus with a narrow transverse plate like fringe and having convex anterior margin; mandibles triangular, masticatory margin of mandibles with 7 teeth, large apical and preapical teeth; third tooth slightly smaller than the preapical tooth, fourth tooth smaller than the following teeths; frontal lobes weakly developed and slightly elevated laterally, frontal area distinct; antennal scrobes shallow; eye moderate in size, located laterally and almost at mid-length of head, composed of ca. 38-40 ommatidia; antennae slender, 12-segmented; scape long and just fail to reach posterior head margin; mesosoma longer than head, broader anteriorly than posteriorly, dorsum convex; pro-mesonotal suture and metanotal groove indistinct; propodeal spine longer (PSL 0.07-0.10mm) than propodeal lobes, acute, divergent, directed upwards; propodeal lobes broadly triangular; posterior declivity of propodeum short, concave; petiole with a long peduncle, node subglobular in dorsal view; ventrally petiole downcurved along its length, peduncle with an antero-ventral minute blunt teeth; petiole and postpetiole almost equally broader; gaster oval.

Head longitudinally rugose with few cross-meshes upto vertex, posteriorly reticulate, interrugal space punctured and shiny; frontal carinae more conspicuous than oth-

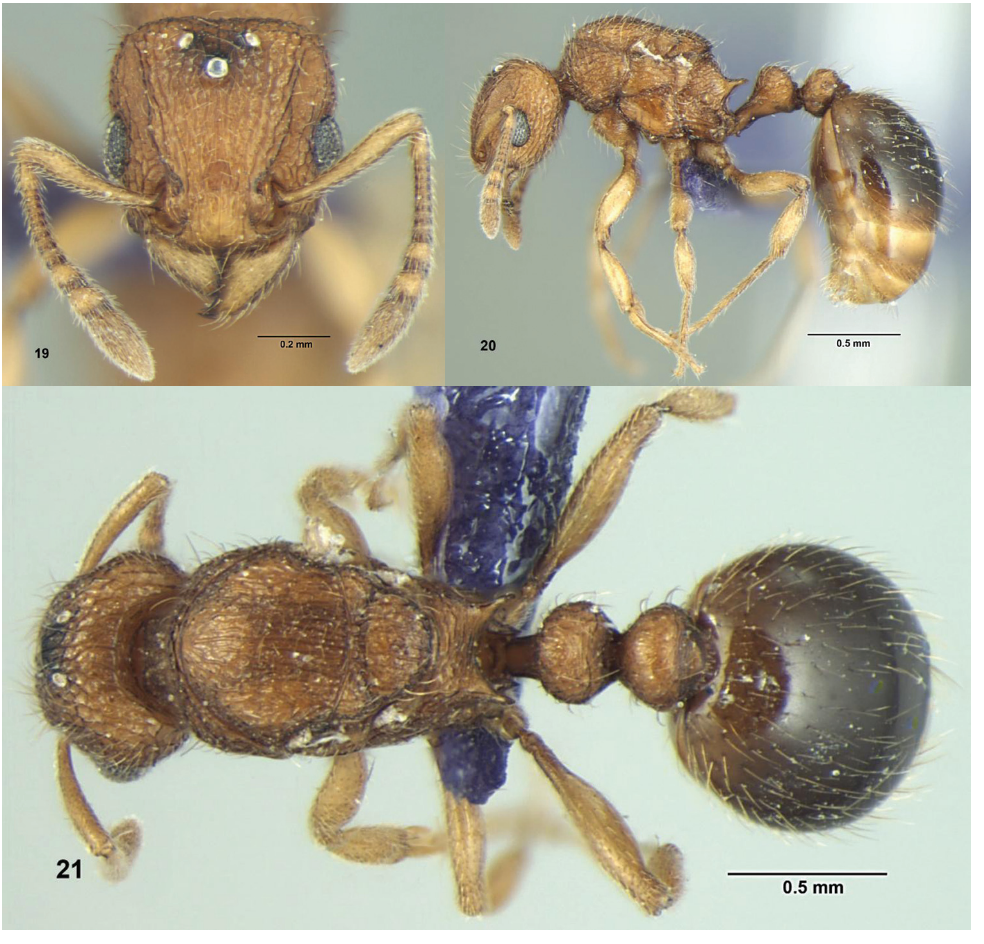


Figures 16–18. *Tetramorium tonganum* Mayr, Worker: **16** Head, full-face view **17** Body, lateral view **18** Body, dorsal view.

er cephalic sculpture and reaching to posterior head margin; mandibles longitudinally rugulose; clypeus longitudinally rugulose; dorsum and sides of mesosoma reticulate-rugulose; petiolar node with weak rugosity; postpetiole unsculptured; propodeal declivity and gaster smooth and shiny, legs smooth except coxae with punctures.

Body yellowish brown while gaster somewhat darker; body covered with suberect abundant hairs of varying length; antennal scapes and hind tibiae with decumbent short pubescence.

Queen description. Measurements (queen). HL 0.69-0.70, HW 0.64-0.66, SL 0.50-0.52, EL 0.20-0.21, WL 1.00-1.02, PW 0.64-0.66, PSL 0.12-0.13, PTL 0.16-0.17, PPL 0.27-0.28, PTW 0.31-0.32, PPW 0.31-0.32, PTH 0.27, PPH 0.27-0.28, CI 92.75-94.29, OI 30.77-31.82, SI 78.13-80.00, PSLI 17.14-18.84, PeNI 48.44-

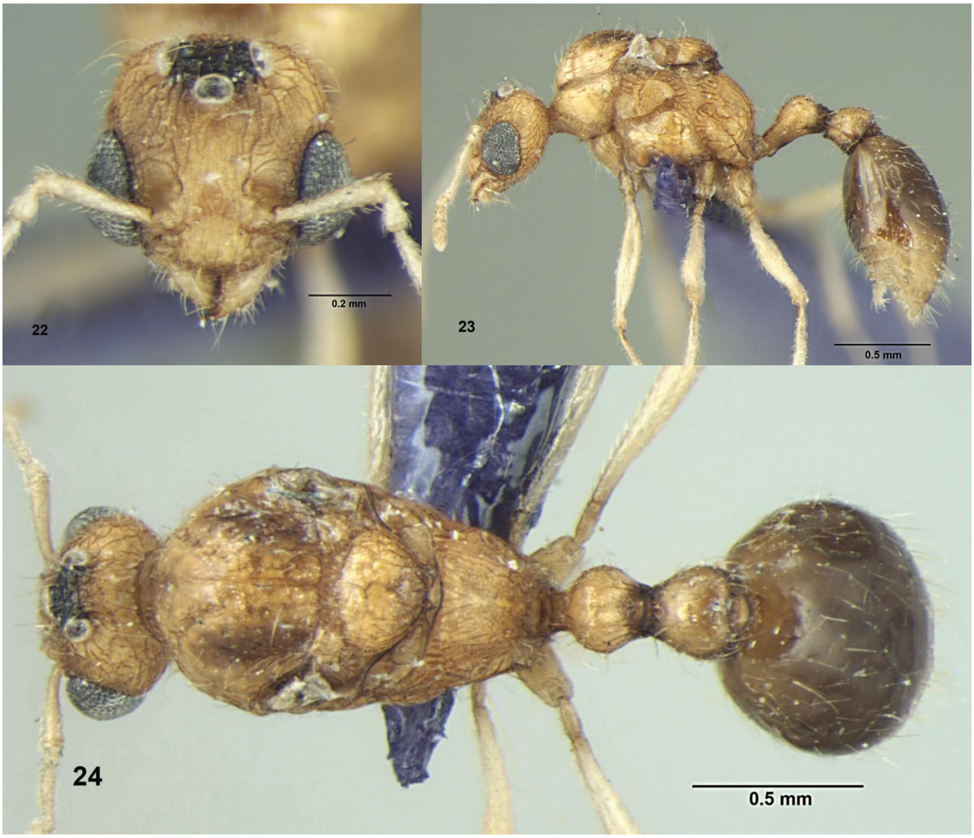


Figures 19–21. *Tetramorium tonganum* Mayr, Queen: **19** Head, full-face view; **20** Body, lateral view **21** Body, dorsal view.

48.48, LPeI 59.26-62.96, DPeI 182.35-193.75, PpNI 48.44-50.00, LPpI 96.43-103.70, DPpI 114.29-114.81, PPI 100-103.23 (3 measured).

Similar to the worker in structure, sculpture and pilosity except the following characters (besides characters related to wings): eyes large in size and with ca.10-12 ommatidia in a series along its maximum length, head with three ocelli, dorsum of mesosoma flat, propodeal spines slightly longer, petiolar node transverse, broad, pronotum reticulate; mesoscutum, mesoscutellum, anepisternum and sides of propodeum longitudinally rugulose; katepisternum smooth, base of propodeum transversally rugulose; petiolar node rugo-reticulate; postpetiole smooth with traces of sculpture on sides, coxae with faint transverse rugulae.

Male description. Measurements. HL 0.55-0.56, HW 0.52-0.53, SL 0.27-0.30, EL 0.28-0.31, WL 1.07-1.12, PW 0.69-0.74, PTL 0.16-0.19, PPL 0.25-0.27, PTW 0.24-0.27, PPW 0.25-0.28, PTH 0.20-0.21, PPH 0.23-0.27, CI 92.86-94.64, OI



Figures 22–24. *Tetramorium tonganum* Mayr, Male: **22** Head, full-face view; **23** Body, lateral view **24** Body, dorsal view.

53.85-59.62, SI 51.92-56.60, PeNI 34.78-36.99, LPeI 80.00-95.00, DPeI 142.11-158.82, PpNI 36.23-38.36, LPpI 100.00-117.39, DPpI 92.59-112.00, PPI 103.70-104.17 (3 measured).

Head slightly longer than broad, sides convex, posterior head margin straight or weakly convex, with three ocelli; mandibles with well developed 6 pointed teeth; apical tooth large followed by 5 short teeth; clypeus convex and its anterior margin entire, convex with a narrow transverse plate like fringe and not impressed medially; frontal lobes reduced; antennae 9-segmented; scape short and not reach to posterior head margin and almost 0.5x times head length; apical segment longer and more than twice of preapical segment; second flagellar segment longer than scape (0.34mm); antennal scrobes absent; eyes large, convex, situated laterally and more towards lower half of head; pronotum broader than head with rounded anterior lateral angles; mesoscutum convex and mesoscutellum flat; propodeal dorsal face flat and oblique with vertical declivitous part; propodeal spines absent; propodeal lobes almost rounded; petiole longer, almost 1.4× times its width, petiolar node subglobular and medially sulcate shallowly; Postpetiole slightly broader than long; gaster convex, broadly oval; longer legs.

Head and clypeus longitudinally rugulose and spaces between them punctured; mandibles smooth with traces of sculpture, frontal carinae continued to the each side of anterior ocellus; dorsum and sides of mesosoma mostly smooth with traces of sculpture and shiny except propodeum; propodeum finely longitudinally rugulose and punctured; node of petiole longitudinally rugulose except median sulcate region; postpetiole, gaster and legs smooth and shiny; wings transparent.

Body yellowish brown except 1st gastral tergite brownish and area between ocelli blackish; body covered with short and long suberect pilosity.

Remarks. This species has been found to be widespread in the Shivalik range of the north-western Himalaya and represents a new record for India. Its male caste has been described for the first time. This species belongs to the *tonganum*-species group (Bolton 1977) and resembles *T. difficile* Bolton. It can be distinguished from the latter due to larger size, relatively longer antennal scape, longer legs, broadly rounded pronotal corners and propodeum with long spine.

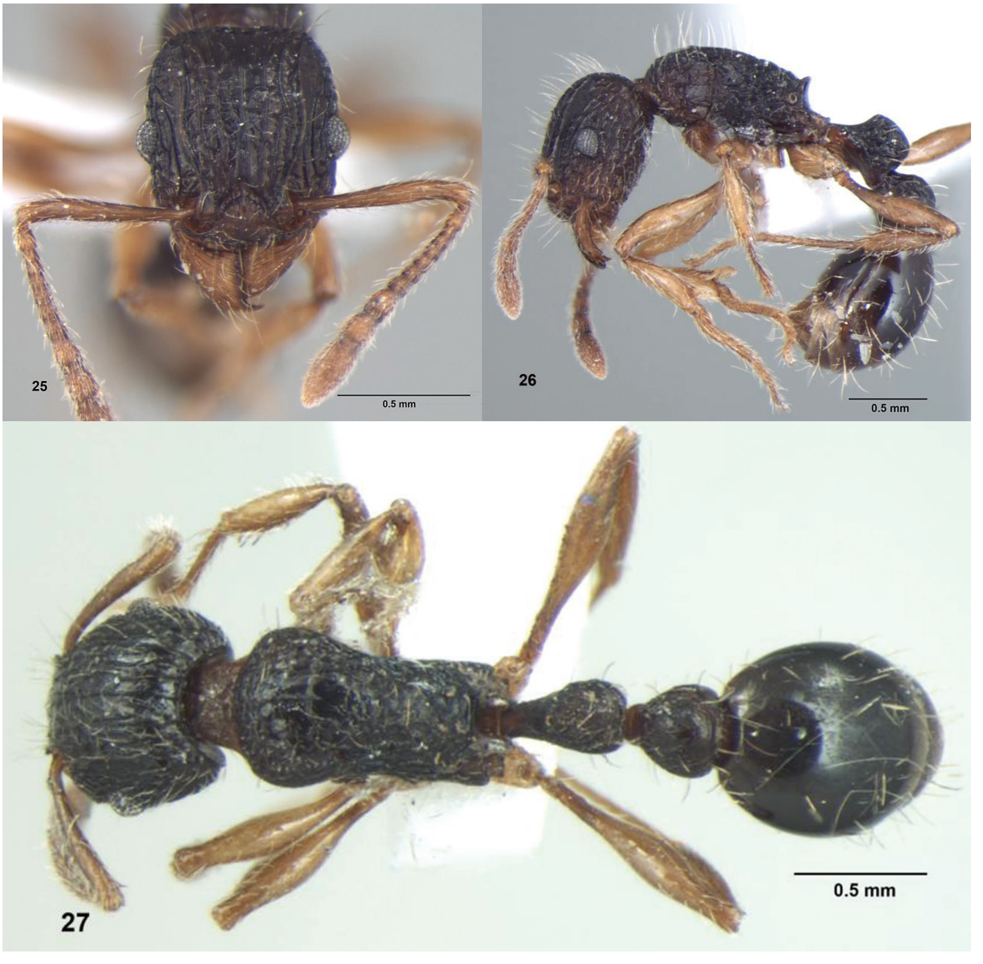
Tetramorium urbanii Bolton, 1977

http://species-id.net/wiki/Tetramorium_urbanii
Figs 25–27

Material examined. 2(w), India, Shillong, 20 May 2003, hand picking, coll. H. Bharti.

Worker description. Measurements (worker). HL 0.85-0.87, HW 0.74- 0.75, SL 0.70, EL 0.16, WL 1.05, PW 0.60, PSL 0.06, PTL 0.28-0.30, PPL 0.32-0.34, PTW 0.28, PPW 0.35-0.36, PTH 0.32-0.34, PPH 0.35, CI 85.06-88.24, OI 21.33-21.62, SI 93.33-94.59, PSLI 6.90-7.06, PeNI 46.67, LPeI 82.35-93.75, DPeI 93.33-100.00, PpNI 58.33-60.00, LPpI 91.43-97.14, DPpI 105.88-109.38, PPI 125.00-128.57 (2 measured).

Head longer than broad, sides almost straight, rounded posterolateral corners, posterior head margin straight, very feebly indented medially; clypeus consisting of slightly convex basal half and steep apical half, without anteromedian indentation; anterior margin of clypeus with a narrow transverse plate like fringe and having convex anterior margin; mandibles triangular, with 7 teeth, masticatory margin of mandibles with large apical and preapical tooth; third tooth slightly smaller than the preapical tooth followed by four denticles; frontal lobes weakly developed and elevated laterally; frontal area deep, forming concavity behind clypeus, broader than long; antennal scrobe distinct, strongly margined dorsally by the frontal carina; eye moderate in size, located laterally and at mid-length of head, composed of ca. 9-10 ommatidia in a series along its maximum length; antennae slender, 11-segmented; scape reaching to posterolateral corners of head; mesosoma longer than head, broader anteriorly than posteriorly, dorsum convex in lateral view; pro-mesonotal suture and metanotal groove indistinct; propodeal teeth small (PSL 0.06mm), triangular, almost



Figures 25–27. *Tetramorium urbanii* Bolton, Worker: **25** Head, full-face view; **26** Body, lateral view **27** Body, dorsal view.

equal to its width and propodeal lobes; propodeal lobes narrowly rounded; posterior declivity of propodeum short, slightly concave, separated from dorsum by a strong transverse carina; petiole with a short peduncle, its node longer than broad with convex dorsum, broader behind than front; ventrally petiole downcurved along its length; postpetiole slightly broader than long, gaster oval.

Head longitudinally rugose with few cross meshes; interrugal space punctured and somewhat shiny; frontal carinae strongly developed, almost straight, divergent at eye level, running back almost to the posterior head margin; antennal scrobes feebly sculptured; mandibles longitudinally striate; clypeus longitudinally rugulose; promesonotal dorsum mostly unsculptured smooth and shiny with traces of rugulose sculpture towards the sides and posteriorly; propodeum reticulate, sides of mesosoma longitudinally rugulose; petiole and postpetiole longitudinally rugulose; propodeal declivity and gaster smooth and shiny; legs smooth.

Whole body blackish brown except mandibles, antennae and legs yellowish brown. Whole body covered with abundant, long, erect and short subdecumbent pilosity; antennal scapes and hind tibiae with short subdecumbent hairs.

Remarks. *T. urbanii* belongs to the *tortuosum*- group (Bolton 1977). It has very short propodeal spines and moderately long scapes, these characters clearly separate it from the rest of the *tortuosum*- group species. This species was earlier reported from Bhutan and represents a first record from India.

Key to the Indian species of *Tetramorium* based on the worker caste (modified from Bolton 1976 and 1977)

1 The species with numerous branched hairs (bifid, trifid or quadrifid and in a few species a mixture of two or more of these may be present) **2**

– The species with only simple hairs... **9**

2 Antennae with 10 segments, propodeum unarmed .... ***decamerum* (Forel)**

– Antennae with 12 segments, propodeum with a pair of spines or teeth **3**

3 Gaster cordate (heart) in shape................. ***cordatum* Sheela and Narendran**

– Gaster non cordate... **4**

4 Basal one-quarter to two-thirds of first gastral tergite distinctly sculptured with striation, puncturation or a combination of both; node of petiole in dorsal view strongly antero-posteriorly compressed, transverse, distinctly broader than long .... ***walshi* (Forel) (part)**

– Basal portion of first gastral tergite not sculptured, the entire sclerite smooth and shiny; node of petiole variable in shape **5**

5 Node of petiole in dorsal view strongly antero-posteriorly compressed, transverse, distinctly broader than long............................... ***walshi* (Forel) (part)**

– Node of petiole in dorsal view not antero-posteriorly compressed, not transverse, generally as long as broad or very slightly broader than long.............. **6**

6 Dorsal surface of hind tibiae viewed from in front or behind with abundant short, curved hairs of approximately uniform length which are much shorter than the maximum tibial width; these hairs characteristically forming a close mat above the tibial surface. Antennal scrobes vestigial, without an acute dorsal margin .... ***rossi* (Bolton)**

– Dorsal surface of hind tibiae viewed from in front or behind with numerous long hairs of varying length, the longest of them at least subequal to the maximum tibial width; these hairs never forming a close mat above the tibial surface. Antennal scrobes developed with a marked dorsal margin **7**

7 First gastral tergite with all hairs simple........................... ***coonoorense* Forel**

– First gastral tergite with at least a few bifid or trifid hairs present **8**

8 Mandibles smooth with scattered punctures, not longitudinally striate; HW 0.76–0.82mm; first gastral tergite with trifid hairs on basal half......................... .... ***obesum* Andre**

– Mandibles longitudinally striate, the striation sometimes indistinct or absent in small specimens; HW 0.52–0.70mm; first gastral tergite basally with a mixture of simple and bifid hairs, trifid hairs usually completely absent .... ***lanuginosum*** **Mayr**

9 Antennae with 11 segments **10**

– Antennae with 12 segments **14**

10 Mandibles smooth with scattered pits, not striate. Small species, SL 0.42-0.46mm. .... ***smithi*** **Mayr**

– Mandibles longitudinally striate; usually this sculpture coarse and distinct but if faint then species much larger, SL 0.58mm.. **11**

11 Propodeum armed with a pair of short triangular teeth which are only slightly longer than their basal width and only marginally longer than the propodeal lobes .... ***urbanii*** **Bolton**

– Propodeum armed with a pair of long spines which are much longer than their basal width and considerably longer than the propodeal lobes **12**

12 Postpetiole punctulate propodeal lobes rounded, not acute at apex .... ***keralense*** **Sheela and Narendran**

– Dorsum of postpetiole unsculptured, smooth and shiny, propodeal lobes triangular and acute **13**

13 Dorsal mesosoma with rugulae tending to be effaced and replaced by shiny areas, HL 0.82–0.92mm, HW 0.78–0.86mm, SL 0.70–0.80mm, postpetiole unsculptured; entire body uniform dark brown or blackish brown ...... ***tortuosum*** **Roger**

– Dorsal mesosoma reticulate rugose, HL 0.74–0.80mm, HW 0.66–0.70mm, SL 0.58–0.64mm, sides of postpetiole with rugulose sculpture; colour light brown with gaster darker than head and mesosoma .... ***belgaense*** **Forel**

14 Species larger in size, body total length 5-6mm............. ***beesoni*** **(Mukerjee)**

– Species total length less than 5mm.. **15**

15 Posterior head margin emarginated .... ***meghalayense*** **Bharti**

– Posterior head margin either emarginated or non emarginated................. **16**

16 Lamelliform appendage of sting dentiform, triangular or pennant-shaped and projecting at an angle from the shaft, antennal scrobes either present or absent; frontal carinae either short or long.. **17**

– Lamelliform appendage of sting linear and spatulate, continuing the line of the shaft, antennal scrobes absent, frontal carinae short, ending before level of eyes.. ***fergusoni*** **Forel**

17 Frontal carinae short terminating at or in front of the level of the eyes; dorsum of head variably sculptured... **18**

– Frontal carinae long, projecting back beyond the level of the eyes. If the carinae fade out just behind the level of the eyes then the dorsum of the head is regularly, very densely longitudinally rugose or evenly sulcate **22**

18 Eyes minute with only a single ommatidium. Peduncle of petiole with large anteroventral lamella.. **19**

– Eyes large with five or more ommatidia. Peduncle of petiole without a large anteroventral lamella..**20**

19 Anterior clypeus with distinct median impression, dorsal mesosoma reticulate-rugose and propodeal spines relatively long upcurved along their length ....***myops* Bolton**

– Anterior clypeus without any median impression, dorsal mesosoma longitudinally rugulose, and propodeal spines relatively short (PSL 0.07mm), triangular .... ***triangulatum* sp. n.**

20 Head without any reticulate or rugoreticulate structure, petiole and postpetiole finely sculptured with a smooth median area or smooth median longitudinal strip on dorsum, propodeal spines not upcurved .... ***caespitum*** (Linnaeus)

– Head with reticulate sculpture on its posterior region or sides, petiole and postpetiole mostly unsculptured, propodeal spines upcurved **21**

21 Petiole node in dorsal view about as long as broad. Median portion of clypeus abruptly downcurved so that its anterior one-third is vertical and separated by a marked angle from the more posterior portion.....................***inglebyi* Forel**

– Petiole node in dorsal view much broader than long. Median portion of clypeus evenly convex in its anterior half ....***elisabethae* Forel**

22 Basal half or more of first gastral tergite sculptured, usually strongly so, with rugosity, dense striation, dense puncturation or a combination of these **23**

– Basal half of first gastral tergite unsculptured or at most with sparse, short, regular basigastral costulae or a few pits from which hairs arise **24**

23 Anterolateral angles of first gastral tergite projecting forward as a pair of blunt teeth or tubercles; basal half of first gastral tergite and sternite strongly rugulose .... ***rugigaster* Bolton**

– Anterolateral angles of first gastral tergite angular but not produced into teeth or tubercles, first gastral tergite and sternite entirely finely reticulate .... ***malabarense* Sheela and Narendran**

24 With the gaster in dorsal view the lateral corners of the base extended forward as a pair of horns which surround the posterior portion of the postpetiole........**25**

– With the gaster in dorsal view the lateral corners of the base rounded or sometimes bluntly angular, but never extended forward as a pair of horns which surround the posterior portion of the postpetiole........................... **26**

25 Anterolateral angles of first gastral tergite projecting forward as a pair of blunt teeth or horns which go round the sides of the posterior portion of the postpetiole; propodeal lobes elongate triangular and acute............***mixtum* Forel**

– Anterolateral angles of first gastral tergite projecting forward as a pair of acute teeth which go round the sides of the posterior portion of the postpetiole; propodeal lobes subtriangular with rounded tip ....***sentosum* Sheela and Narendran**

26 Anterior clypeal margin with the median portion convex and notched or sharply indented medially **27**

– Anterior clypeal margin with the median portion entire, varying from convex to broadly and shallowly concave, but never notched or sharply indented medially **31**

27 Mandibles sculptured with fine, dense striation or shagreening, occasionally the striation faint **28**

– Mandibles completely smooth and shiny except for scattered hair-pits **30**

28 Colour uniform dark brown to blackish brown. Petiole in profile with a narrow anterior peduncle, a short anterior face which curves into the long convex dorsum and a posterior face which is much higher than the anterior. In dorsal view the node is usually slightly longer than broad .... ***pacificum* Mayr (part)**

– Colour yellow brown to orange-brown, sometimes with the gaster darker brown. Rarely entirely coloured dark brown approaching that of *pacificum,* but in this case the petiole of different shape **29**

29 Longest hairs projecting dorsally from frontal carinae behind the level of the antennal insertions shorter than the maximum diameter of the eye. Gaster always much darker in colour than alitrunk and head, contrasting strongly with them. Petiole node in profile roughly square, the dorsum not sloping upwards posteriorly, the anterodorsal and posterodorsal angles approximately on a level. Propodeal spines moderately long, varying from more or less straight to slightly upcurved along their length .... ***bicarinatum* (Nylander)**

– Longest hairs projecting dorsally from frontal carinae behind the level of the antennal insertions longer than the maximum diameter of the eye. Gaster usually same colour as alitrunk and head, only rarely noticeably darker. Petiole node in profile with the dorsum sloping upwards posteriorly, so that the posterodorsal angles is on a slightly higher level than the anterodorsal. Propodeal spines usually short, elevated but more or less straight, not upcurved along their entire length .... ***indicum* Forel**

30 Petiole in profile with a short anterior face which curves into the long convex dorsum and a posterior face which is slightly higher than the anterior, OI 25.81(eyes comparatively larger in size 0.24mm), CI 100, SI 67 .... ***petiolatum* Sheela and Narendran**

– Petiole in profile with a short anterior face which curves into the long convex dorsum and a posterior face which is much higher than the anterior, OI 20.59–25 (eyes comparatively smaller 0.18-0.21mm), CI 83-90, SI 79-87 .... ***pacificum* Mayr (part)**

31 Spaces between rugulose sculpture on entire dorsum of head (and often dorsal alitrunk) completely filled by a dense and very conspicuous reticulate-puncturation so that the surface appears dull, mat and very granular, the punctulate sculpture often as conspicuous as the rugulae **32**

– Spaces between rugulose sculpture on dorsum of head either smooth or with superficial faint or vestigial sculpture so that the surface appears mostly or entirely shiny and largely or partially smooth, the punctulate sculpture never as conspicuous as the rugulae **33**

32 Frontal carinae strongly developed throughout their length, sinuate, running unbroken almost to the posterior head margin and surmounted throughout their length ba a narrow raised rim or flange. The whole of the frontal carinae much more strongly developed than the remaining cephalic rugulae. Ground sculpture of head between frontal carinae strongly granular or reticulate- punctulate, the surface matt. Antennal scrobes shallow but broad and conspicuous .... ***simillimum*** **(Smith)**

– Frontal carinae feebly developed, weakly or not sinuate, most strongly developed to level of midlength of eye behind which they become very weak or broken, or gradually fade out posteriorly; not surmounted by a raised rim or flange beyond the level of the midlength of the eye, behind which the carinae are no stronger than the remaining cephalic rugulae. Ground sculpture of head more feeble than above, the surfaces dully shiny. Antennal scrobes vestigial .... ***caldarium*** **(Roger)**

33 Dorsal surface of hind tibiae with decumbent or appressed pubescence only or with very short hairs which are curved through 90° at the base so that the apical portion of the hairs are nearly flush with the surface; erect or suberect hairs or erect pubescence completely absent from the outer tibial surface, SI ≥ 74 .... **34**

– Dorsal surface of hind tibiae with conspicuous suberect hairs, SI ≤ 67.00 .... ***shivalikense*** **sp. n.**

34 Antennal scapes relatively longer, SI 87-91, colour uniform black................ .... ***christiei*** **Forel**

– Antennal scapes relatively shorter, SI 74-86, colour yellowish brown or dark brown **35**

35 Peduncle of petiole in profile short and straight, not downcurved along its length from node to insertion nor passing through a rounded angle at about its midlength. Propodeal lobes bluntly rounded.................... ***salvatum*** **Forel**

– Peduncle of petiole downcurved along its length. Propodeal lobes triangular **36**

36 Propodeal spines short and about the size of triangular propodeal lobes, SI 74-79; EL 0.09mm and body dark brown with a reddish tinge.................... .... ***barryi*** **Mathew**

– Propodeal spines longer than the broadly triangular propodeal lobes, SI 80-87, EL 0.14–0.16mm, colour varying from yellowish brown to mid brown.. .... ***tonganum*** **Mayr**

Acknowledgements

Sincere thanks are due to Dr. Francisco Hita Garcia for suggestions and critically examining the manuscript. Financial assistance rendered by Ministry of Environment and Forests (Grant No. 14/10/2007-ERS/RE), Govt. of India, New Delhi is gratefully acknowledged.

References

Bharti H (2011) List of Indian Ants (Hymenoptera: Formicidae). Halteres 3: 79–87.

Bolton B (1976) The ant tribe Tetramoriini (Hymenoptera: Formicidae). Constituent genera, review of smaller genera and revision of *Triglyphothrix* Forel. Bulletin of the British Museum (Natural History) Entomology 34: 281–379.

Bolton B (1977) The ant tribe Tetramoriini (Hymenoptera: Formicidae). The genus *Tetramorium* Mayr in the Oriental and Indo-Australian regions, and in Australia. Bulletin of the British Museum (Natural History) Entomology 36: 67–151.

Bolton B (1979) The ant tribe Tetramoriini (Hymenoptera: Formicidae). The genus *Tetramorium* Mayr in the Malagasy region and in the New World. Bulletin of the British Museum (Natural History) Entomology 38: 129–181.

Bolton B (1980) The ant tribe Tetramoriini (Hymenoptera: Formicidae). The genus *Tetramorium* Mayr in the Ethiopian zoogeographical region. Bulletin of the British Museum (Natural History) Entomology 40: 193–384.

Bolton B (1985) The ant genus *Triglyphothrix* Forel a synonym of *Tetramorium* Mayr. (Hymenoptera: Formicidae). Journal of Natural History 19: 243–248. doi: 10.1080/00222938500770191

Bolton B (2012) An Online Catalog of the Ants of the World. AntCat. http://www.antcat.org/

Csösz S, Radchenko A, Schulz A (2007) Taxonomic revision of the Palaearctic *Tetramorium chefketi* species complex (Hymenoptera: Formicidae). Zootaxa 1405: 1–38.

Csösz S, Schulz A (2010) A taxonomic review of the Palaearctic *Tetramorium ferox* species-complex. Zootaxa 2401: 1–29.

Forel A (1902) Myrmicinae nouveaux de l'Inde et de Ceylan. Revue Suisse de Zoologie 10: 165–249.

Hita Garcia F, Fischer G, Peters MK (2010) Taxonomy of the *Tetramorium weitzeckeri* species group (Hymenoptera: Formicidae) in the Afrotropical zoogeographical region. Zootaxa 2704: 1–90.

Hita Garcia F, Fisher BL (2011) The ant genus *Tetramorium* Mayr (Hymenoptera: Formicidae) in the Malagasy region—introduction, definition of species groups, and revision of the *T. bicarinatum*, T. *obesum*, *T. sericeiventre* and *T. tosii* species groups. Zootaxa 3039: 1–72.

Mathew R (1981) Description of new species of ant (Hymenoptera: Formicidae) from the Khasi Hills, Meghalaya. Oriental Insects 14: 425–427. doi: 10.1080/00305316.1980.10434826

Mathew R, Tiwari RN (2000) Insecta: Hymenoptera: Formicidae. Zoological Survey of India. Fauna of of Meghalaya 7: 251–409.

Mayr G (1855) Formicina austriaca. Beschreibung der bisher im oesterreichischen Kaiserstaate aufgefundenen Ameisen nebst Hinzufügung jener in Deutschland, in der Schweiz und in Italien vorkommenden Ameisen. Verhandlungen des Zoologisch-Botanischen Vereins in Wien 5: 273–478.

Mayr G (1870) Neue Formiciden. Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien 20: 939–996.

Mukerjee D (1934) Entomological investigations on the spike disease of sandal (22). Formicidae (Hymen.). Indian Forest Records 20(5): 1–15.

Roger J (1857) Einiges über Ameisen. Berliner Entomologische Zeitschrift 1: 10–20. doi: 10.1002/mmnd.18570010106

Schlick-Steiner BC, Steiner FM, Zettel H (2006) *Tetramorium pacificum* Mayr, 1870, *T. scabrum* Mayr, 1879 sp. rev., *T. manobo* (Calilung, 2000) – three good species. Myrmecological News 8: 181–191.

Sheela S, Narendran TC (1998) On five new species of *Tetramorium* (Hymenoptera: Formicidae: Myrmicinae) from India. Entomon 23: 37–44.

Steiner FM, Schlick-Steiner BC, Sanetra M, Ljubomirov T, Antonova V, Christian E, Stauffer C (2005) Towards DNA- aided biogeography: An example from *Tetramorium* ants (Hymenoptera: Formicidae). Annales Zoologici Fennici 42: 23–35.

Steiner FM, Seifert B, Moder K, Schlick-Steiner BC (2010) A multisource solution for a complex problem in biodiversity research: Description of the cryptic ant species *Tetramorium alpestre* sp.n. (Hymenoptera: Formicidae). Zoologischer Anzeiger 249: 223–254. doi: 10.1016/j.jcz.2010.09.003

ZooKeys 207: 37–47 (2012)
doi: 10.3897/zookeys.207.3237
www.zookeys.org

RESEARCH ARTICLE

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

White-toothed shrews (Mammalia, Soricomorpha, *Crocidura*) of coastal islands of Vietnam

Alexei V. Abramov[1,4], Anna A. Bannikova[2], Viatcheslav V. Rozhnov[3,4]

1 *Zoological Institute, Russian Academy of Sciences, Universitetskaya nab. 1, Saint Petersburg 199034, Russia* **2** *Lomonosov Moscow State University, Vorobievy Gory, Moscow 119992, Russia* **3** *A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences, Leninskii pr. 33, Moscow 119071, Russia* **4** *Joint Vietnam-Russian Tropical Research and Technological Centre, Nguyen Van Huyen, Nghia Do, Cau Giay, Hanoi, Vietnam*

Corresponding author: *Alexei V. Abramov* (a.abramov@mail.ru)

Academic editor: *Kristofer M. Helgen* | Received 15 April 2012 | Accepted 2 July 2012 | Published 11 July 2012

Citation: Abramov AV, Bannikova AA, Rozhnov VV (2012) White-toothed shrews (Mammalia, Soricomorpha, *Crocidura*) of coastal islands of Vietnam. ZooKeys 207: 37–47. doi: 10.3897/zookeys.207.3237

Abstract

New findings of the white-toothed shrews (*Crocidura* spp.) from offshore islands of Vietnam are reported. The species identifications have been confirmed by the analysis of complete mitochondrial cytochrome *b* gene (1140 bp). *Crocidura phuquocensis* is the only species found in the Phu Quoc Island. *Crocidura fuliginosa* has been recorded from two islands of the Con Dao Archipelago (Con Son and Bai Canh). The occurrence of *C. fuliginosa* in Vietnam has been genetically confirmed for the first time. *Crocidura attenuata* has been collected from the Cat Ba Island for the first time, and this finding corresponds well with the proposal that the species' distribution is confined to the north and east of the Red River only.

Keywords

Crocidura fuliginosa, *Crocidura attenuata*, *Crocidura phuquocensis*, biogeography, Cat Ba, Con Dao, Phu Quoc, SE Asia

Introduction

Biodiversity of Southeast Asian islands has often been the focus of intensive studies by systematists, evolutionary biologists and biogeographers (Meijaard 2003; Esselstyn and Brown 2009; Esselstyn et al. 2009; Esselstyn and Oliveros 2010). Such studies of insular faunas of terrestrial mammals make it possible to examine geographic and temporal processes of diversification. The species distribution and richness of island faunas are determined by colonization and extinction events and are largely dependent on geographical characteristics of the islands, particularly their size and isolation.

Despite its small size, Vietnam has a very long coastline (near 3500 km) and is surrounded by more than 3000 islands. The majority of Vietnamese coastal islands are situated within a shallow shelf. Two main stages of the geological history of this area can be recognized (Korotky et al. 1995). At the first stage, most parts of the modern South China Sea shelf were continental. During following transgressions the continent was submerged and many coastal islands developed. These islands were from time to time connected to the continent during repeated sea level fluctuations in the Pleistocene. Island communities off mainland Vietnam may reflect dispersal and vicariance events initiated by climate change.

Most mammal surveys of Vietnamese islands have been devoted to the study of rodents and large mammals (Van Peenen et al. 1970, Kuznetsov and Anh 1992, Kuznetsov 2000). Shrews remain poorly studied in these areas. A few biodiversity surveys were conducted by the Joint Vietnam-Russian Tropical Research and Technological Centre (VRTC) on coastal islands of Vietnam (Fig. 1) during 2003-2011. In this paper, we have summarized the results of the study of white-toothed shrews resulting from these surveys.

Studied area

Phu Quoc is the largest Vietnamese island (it covers ca. 562 km^2) lying in the Gulf of Thailand, ca. 15 km south of the coast of mainland Cambodia. Primary lowland tropical forests still cover the northeastern part of the island. The first mammalogical survey of Phu Quoc was carried out of the VRTC (Abramov et al. 2007a) in the period of 25 November - 20 December, 2003. In total, 105 trap-nights were conducted using pitfall traps (plastic buckets 40×30 cm) located in a few different biotopes.

The Con Dao Archipelago is situated in the monsoon belt of the South China Sea at about 90 km off mainland Vietnam. Con Son, formerly known as Pulo Condor, consists of the largest (ca. 52 km^2) island of archipelago, surrounded by 14 smaller islets. The topography of Con Son Island is mountainous, and is dominated by the granite ridge running from south-west to north-east and is covered by primary tropical forest. A biodiversity survey of Con Son was conducted by the VRTC from 26 May to 12 June, 2010. Small mammal trapping was conducted using plastic buckets (25×20 cm) and glasses (13×9 cm) as pitfall traps. Trapping took place for a total of 1237 trap-nights, distributed unequally between 13 survey sites.

Cat Ba is the largest of hundreds of islands that comprise the Cat Ba Archipelago and is located at the southeastern edge of Ha Long Bay in northern Vietnam. Cat Ba Island lies approximately 30 km east of Hai Phong city in northern Vietnam and has a surface area of 285 km^2. The landscape of Cat Ba is dominated by limestone karst with alternating narrow valleys running along the northeast-southwest line. The main natural vegetation type on Cat Ba consists of moist tropical forest on limestone karst,

Figure 1. Map of Vietnam. Location of islands studied is shown.

however, in large areas it is now replaced by limestone scrub or bare rocks. Fieldworks were carried out by the VRTC in the central part of Cat Ba Island from 10 to 25 October, 2011. In total, 650 trap-nights were conducted using pitfall traps (plastic glasses of 13×9 cm) located in five different biotopes.

Material and methods

A total of thirteen *Crocidura* specimens were collected during the three aforementioned island surveys. Specimens were fixed in 70% ethanol. Tissue samples were preserved in 96% ethanol. Skulls were extracted and cleaned from many specimens. Standard external body measurements (head and body length, tail length, hind foot length) were taken in the field. Weight was measured in grams. Voucher specimens are kept in the Zoological Institute of the Russian Academy of Sciences (Saint-Petersburg, Russia).

Genomic DNA was isolated from ethanol-fixed kidney or muscles by proteinase K digestion, phenol-chloroform deproteinization and isopropanol precipitation (Sambrook et al. 1989).

The complete mitochondrial cytochrome *b* gene (*cytb*, 1140 bp) was amplified by PCR with the primer combination and conditions for *cytb* amplification as in Bannikova et al. (2011). Primers L14728_Cr (5`-GACATGAAAAATCATCGTTGTTCTTCAAC-3`) and H1310_Cr (5`-GAATATCAGCTTTGGGTGYTGATGGTGG-3`) were used for amplification of the whole *cytb* gene (1140 bp), and primers Cro_481b (5`-ACGGAAAAGCCTCCTCAGATTCATTCTAC-3`) and L363A (5`-CGCAGTTATAGCCACCGCCTTTATAGG-3`) were used for sequencing and amplification of short parts of the gene if necessary. Sequencing with each primer was performed by the ABI 3100-Avant autosequencing system using ABI PRISM®BigDyeTM Terminator v. 3.1. *Cytb* gene sequences were aligned by eye using BioEdit v.7.0.5.3 (Hall 1999). The final alignment of the mitochondrial gene included 1140 bp. Diversity patterns of *cytb* sequences were assessed using maximum parsimony (MP) and neighbour joining (NJ) methods with the help of PAUP* version 4.0b10 (Swofford 1998) based on pairwise *p*-distance matrix. To assess clade support, 1000 bootstrap pseudoreplicates were analyzed.

GenBank accession numbers for the original sequences used in the study are JX181934-JX181941.

We also included *cytb* sequence data from several earlier studies (Ruedi et al. 1998; Bannikova et al. 2006, 2011; Dubey et al. 2008; Esselstyn et al. 2009; Lavrenchenko et al. 2009) to place the shrews from Vietnam into a regional phylogeographic and phylogenetic context.

Results

Crocidura fuliginosa (Blyth, 1855)

http://species-id.net/wiki/Crocidura_fuliginosa

Remarks. We have found this species on Con Son Island only. A single specimen was collected near Nui Nha Ban on the north slope of Nui Chua Mt. in the central part of island. The pitfall traps (08°42'49"N, 106°37'13"E) were set in moist primary forest at an elevation of 250 m asl. Despite considerable trapping efforts (more than 1200 trap-nights) we collected only one specimen. This species was firstly reported from Con Son by Van Peenen et al. (1970). A single adult male (USNM 357348, Smithsonian Institution) was caught in a small Sherman trap at the side of a trail leading to Nui Nha Ban, at the elevation of 80 m asl. Another specimen (ZMMU S-144368, Zoological Museum of Moscow University) was collected in 1987 in the forest of Bai Canh Islet located just 1 km eastward of the Con Son Island.

This is a large, long-tailed *Crocidura*; tail 79% of head and body length, on average. Means and extremes of measurements (in mm) from 3 adults are: head and body length, 87.0 (83–90); tail length, 68.3 (67–71); hind foot length, 15.7 (15–17); weight (n=1), 16.7 g.

The mtDNA analysis suggests that specimen from the Con Son Island belongs to *C. fuliginosa* (Fig. 2).

Many papers listed *C. fuliginosa* as being widespread in mainland Vietnam (Heaney and Timm 1983; Huynh et al. 1994; Kuznetsov 2006; Can et al. 2008; Jenkins et al. 2009). A recent comparative study of mtDNA (Bannikova et al. 2011) did not confirm its occurrence in Vietnam. Specimens from northern Vietnam (Ha Giang Province) are very different from the shrews taken from the Cameron Highlands (Peninsular Malaysia) assigned to this species. Moreover, the northern Vietnamese specimens are close to the shrews from Yunnan, southern China. A major distinction between Yunnan specimens and *C. fuliginosa* from Peninsular Malaysia was also found by Dubey et al. (2008) in the analysis of nuclear genes. Bannikova et al. (2011) proposed to re-establish the name *C. dracula* for the large white-toothed shrews from northern Vietnam and southern China. This taxon was described by Thomas (1912) from southern Yunnan. According to Allen (1938) and Ellerman and Morrison-Scott (1951), this species is distributed across southern China and adjacent Indochina. Jenkins (1976) considered *dracula* a subspecies of *C. fuliginosa*, and was followed in this opinion by various authors (Heaney and Timm 1983; Jiang and Hoffmann 2001; Hutterer 2005). Based on the data from mitochondrial DNA, the name *fuliginosa* was provisionally restricted to the shrews from the southern part of Southeast Asia, including Malaysia and southern Myanmar (Bannikova et al. 2011). A comparison of *cytb* sequences suggests that specimen from the Con Son Island belongs to this haplogroup (Fig. 2). This is a first genetically confirmed record of *C. fuliginosa* from Vietnam.

The occurrence of *C. fuliginosa* sensu stricto in mainland Vietnam is still questionable (see also Heaney and Timm 1983). Jenkins et al. (2009) have mentioned museum specimens of *C. fuliginosa* (= *dracula* sensu Bannikova et al. 2011) from Lao Cai in northern Vietnam and Yunnan in southern China only. Two other records mentioned by Jenkins et al. (2009) were based on survey reports, not on museum voucher specimens. One of them (Trai et al. 1999), reporting *C. fuliginosa* from Ngoc Linh Mt. in Kon Tum Province, central Vietnam, was based on a visual observation only. Another location mentioned (see Jenkins et al. 2009) is Nui Bi Doup, Lam Dong Province, southern Vietnam. In 2004 and 2006, during mammal surveys in Ngoc Linh Mt. conducted by the VRTC, we collected 116 shrews of three *Crocidura* species (Abramov et al. 2007b; Rozhnov and Abramov 2009). Two of these species, *C. sokolovi* and *C.*

zaitsevi, were new to science (Jenkins et al. 2007); the third one was *C. tanakae* (see Bannikova et al. 2011). Several biodiversity surveys conducted by the VRTC in Nui Bi Doup area in 2002-2009 (Abramov et al. 2010) yielded more than 100 shrews of three *Crocidura* species, including *C. tanakae*, *C. indochinensis* and *C. zaitsevi* (see Bannikova et al. 2011). However, we documented no specimens of *C. fuliginosa*, neither in the Ngoc Linh nor in the Bi Doup areas.

Crocidura phuquocensis Abramov, Jenkins, Rozhnov et Kalinin, 2008

http://species-id.net/wiki/Crocidura_phuquocensis

Remarks. Five adult white-toothed shrews were collected in the northern part of Phu Quoc Island (10°22'53"N, 104°00'19"E), 5 km west of Bai Thom Village, near the road Duong Dong-Bai Thom, close to the northern slope of Mount Chua area, at the elevation of about 30 m asl. Pitfall traps were set up in the dipterocarp forest, near tumbled down trees, at the bottom of a mountain. On the basis on these specimens, *C. phuquocensis* was described by Abramov et al. (2008).

This is a medium-sized *Crocidura*, with a moderately long tail; tail 75% of head and body length, on average. Means and extremes of measurements (in mm) from 5 adults are: head and body length, 76.2 (68–72); tail length, 52.4 (49–59); hind foot length, 12.1 (12–12.5).

The validity of this species was recently confirmed by comparison of *cytb* and COI sequences with available reference data (Bannikova et al. 2011). On the *cytb* tree, the *C. phuquocensis* haplogroup is the nearest neighbour to the *C. fuliginosa* – *C. dracula* group, although with low bootstrap support (Fig. 2).

Phu Quoc lies very close to mainland Cambodia. The Phu Quoc rainforests belong to the Cardamom Mountain rain forests ecoregion (MacKinnon 1997). Overall, the small mammal fauna of Phu Quoc is similar to that of the Cardamom Mountains (Swan and Kry 2000; Abramov et al. 2007a). Presumably, *C. phuquocensis* (currently known from Phu Quoc only) may also be found in the adjacent mainland.

Crocidura attenuata Milne-Edwards, 1872

http://species-id.net/wiki/Crocidura_attenuata

Remakrs. We collected seven specimens of this species from Cat Ba Island. The trapping line (20°48'N, 106°59'E) was located along the west part of tourist trail from the Cat Ba National Park Headquarters to Viet Hai Village. All specimens were caught in pitfall traps set in mixed forest near limestone bare rocks. It is the first record of *Crocidura* from Cat Ba Island.

This is a medium-sized *Crocidura*, with a moderately long tail; tail 79.8% of head and body length, in average. Means and extremes of measurements (in mm) from 5 adults are: head and body length, 74.6 (71–79); tail length, 59.2 (57–62); hind foot length, 13.2 (12–14); weight (n=4), 9.8 (7.3–11.5) g.

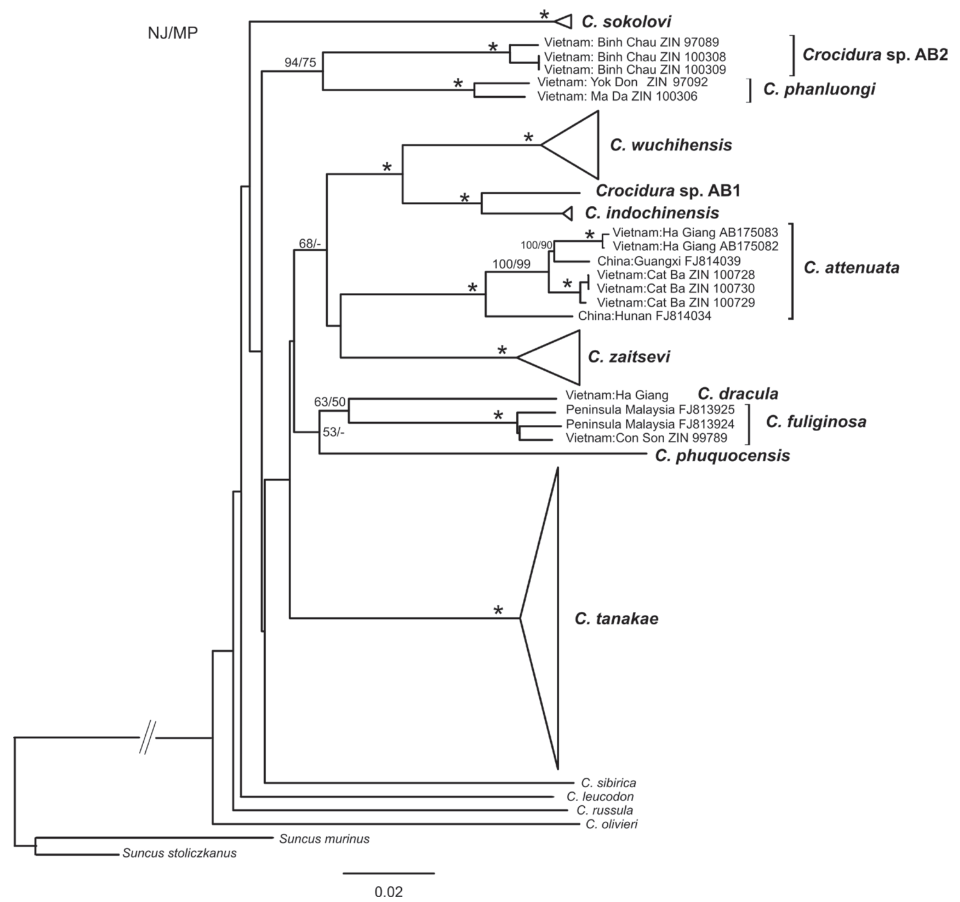


Figure 2. The NJ tree for the *cytb* gene. The bootstrap values (≥50%) obtained from 1000 replications in NJ/MP analyses are presented above the branches. «*» denotes bootstrap support of 100% in both NJ and MP analyses; «-» indicates support values of less than 50%. *Suncus murinus* and *S. stoliczkanus* are used as outgroup.

Analysis of mitochondrial DNA confirmed that the specimens from Cat Ba belong to *C. attenuata* proper. All the analyzed specimens from Cat Ba (see Fig. 2) formed a single cluster closely related to the group of specimens from northern Vietnam (Ha Giang Province) and southeastern China (Guangxi Province). The genetic distance (*p*-distance) between specimens from Cat Ba/Ha Giang as well as Cat Ba/Guangxi is about 2.1%. The specimen of *C. attenuata* from the more north-eastern region of China (Hunan Province) appears basal among all samples of *C. attenuata* from China and Vietnam. Thus, the genetic distance between two specimens from China (Hunan/Guangxi) is 4.3%, which is nearly the same as the distance between *C. indochinensis*/*C.* sp. AB1. Thus, genetic differentiation of *C. attenuata* is notable and reveals a phylogeographic structure with four haplogroups.

Most authors (Heaney and Timm 1983; Huynh et al. 1994; Hutterer 2005; Kuznetsov 2006; Can et al. 2008; Jenkins et al. 2009) have suggested a wide geographic distribution for *C. attenuata* in Vietnam. However, the recent study of mitochondrial DNA (Bannikova et al. 2011) restricted the distribution of *C. attenuata* proper to the northernmost part of Vietnam. Elsewhere in mainland Vietnam, it is replaced by *C. tanakae*. The latter species was previously considered an endemic of Taiwan (Motokawa et al. 1997, 2001; Hutterer 2005). However, based on mtDNA data analyses, the name *C. tanakae* has been applied to all white-toothed shrews that are genetically similar to the Taiwanese haplogroup. This haplogroup is widely distributed across mainland Asia, including in southern China, Vietnam and Laos (Esselstyn et al. 2009, 2010; Bannikova et al. 2011).

Documentation of *C. attenuata* on Cat Ba Island well corresponds to the proposed species' distribution confined to the north and east of the Red River (see Bannikova et al. 2011).

Conclusion

Current distributions and phylogenetic relationships of *Crocidura* species from Vietnamese offshore islands support the hypothesis that shrews may have colonized the islands relatively recently. It is known that the non-volant mammal fauna of these islands was formed during the period when most parts of the modern South China Sea shelf were continental (see also Kuznetsov and Anh 1992; Kuznetsov 2000).

Cat Ba Island is a part of the extended region of the Viet Bac Karst zone, stretching from southeastern China to northeastern Vietnam (Tuyet 1998), and its mammal fauna is similar to that of the adjacent mainland (Abramov and Kruskop 2012). The low level of divergence between mainland populations of *C. attenuata* and that from Cat Ba seem to correspond to recent faunal exchanges in northeastern Vietnam, including Cat Ba Island. *Crocidura phuquocensis*, the only endemic species of white-toothed shrew from coastal islands of Vietnam, is very likely to be found in the Cardamom Mountains of the adjacent mainland, if targeted small mammals surveys are undertaken there.

Sister relationships between the Con Son and Malaysian populations of *C. fuliginosa* suggest that its distribution might have been more extensive in the past. However, data on this species' occurrence in Southeast Asia are very scarce and doubtful. Morphological characters and genetic variation of the populations from Thailand, Laos, Cambodia and Myanmar referred to as *C. fuliginosa* (Corbet and Hill 1992; Ruedi 1995; Francis 2008) need to be examined in detail.

Acknowledgements

We thank the administration of the Joint Vietnam-Russian Tropical Research and Technological Centre, and notably Dr. A.N. Kuznetsov for talented organization of field work. We are grateful to the administrations of the Phu Quoc, Con Dao, and

Cat Ba National Parks for providing us with an opportunity to carry out field surveys. AA thanks Dr. A.A. Kalinin and A.V. Shchinov who helped out with field collecting. We are obliged to Dr. D.V. Logunov (Manchester, UK) for linguistic help. We are very grateful to Dr. Manuel Ruedi and two anonymous reviewers for their helpful and constructive comments on the early version of the manuscript. This work was supported in part by the Ministry of Education and Science of Russian Federation and by the Russian Foundation for Basic Research (projects 11-04-00020, 12-04-93005).

References

Abramov AV, Kruskop SV (2012) The mammal fauna of Cat Ba Island, northern Vietnam. Russian Journal of Theriology 11: 57–72.

Abramov AV, Kalinin AA, Morozov PN (2007a) Mammal survey on Phu Quoc Island, southern Vietnam. Mammalia 71: 40–46. doi: 10.1515/MAMM.2007.001

Abramov AV, Rozhnov VV, Morozov PN (2007b) Notes on mammals of the Ngoc Linh Nature Reserve (Vietnam, Kon Tum Province). Russian Journal of Theriology 5: 85–92.

Abramov AV, Jenkins PD, Rozhnov VV, Kalinin AA (2008) Description of a new species of *Crocidura* (Soricomorpha: Soricidae) from the island of Phu Quoc, Vietnam. Mammalia 72: 269–272. doi: 10.1515/MAMM.2008.033

Abramov AV, Kruskop SV, Shchinov AV (2010) Small mammals of the Dalat Plateau, southern Vietnam. Russian Journal of Theriology 8: 61–73.

Allen GM (1938) The Mammals of China and Mongolia. American Museum of Natural History, New York, 620 pp. doi: 10.5962/bhl.title.12195

Bannikova AA, Abramov AV, Borisenko AV, Lebedev VS, Rozhnov VV (2011) Mitochondrial diversity of the white-toothed shrews (Mammalia, Eulipotyphla, *Crocidura*) in Vietnam. Zootaxa 2812: 1–20.

Bannikova AA, Lebedev VS, Kramerov DA, Zaitsev MV (2006) Phylogeny and systematics of *Crocidura suaveolens* species group: corroboration and controversy between nuclear and mitochondrial DNA markers. Mammalia 70: 106–119. doi: 10.1515/MAMM.2006.011

Can DN, Endo H, Son NT, Oshida T, Canh LX, Phuong DH, Lunde DP, Kawada S-I, Hayashida A, Sasaki M (2008) Checklist of Wild Mammal Species of Vietnam. Institute of Ecology and Biological Resources, Hanoi, 400 pp.

Corbet GB, Hill JE (1992) The Mammals of the Indomalayan Region. Oxford University Press, Oxford, 488 pp.

Dubey S, Salamin N, Ruedi M, Barriere P, Colyn M, Vogel P (2008) Biogeographic origin and radiation of the Old World crocidurine shrews (Mammalia: Soricidae) inferred from mitochondrial and nuclear genes. Molecular Phylogenetics and Evolution 48: 953–963.

Ellerman JR, Morrison-Scott TCS (1951) Checklist of Palaearctic and Indian Mammals, 1758 to 1946. Trustees of the British Museum (Natural History), London, 810 pp.

Esselstyn JA, Brown RM (2009) The role of repeated sea-level fluctuations in the generation of shrew (Soricidae: *Crocidura*) diversity in the Philippine Archipelago. Molecular Phylogenetics and Evolution 53: 171–181. doi: 10.1111/j.1558-5646.2009.00743.x

Esselstyn JA, Oliveros CH (2010) Colonization of the Philippines from Taiwan: a multi-locus test of the biogeographic and phylogenetic relationships of isolated populations of shrews. Journal of Biogeography 37: 1504–1514.

Esselstyn JA, Timm RM, Brown RM (2009) Do geological or climatic processes drive speciation in dynamic archipelagos? The tempo and mode of diversification in Southeast Asian shrews. Evolution 63: 2595–2610.

Francis CM (2008) A Field Guide to the Mammals of South-East Asia. New Holland, London, 392 pp.

Hall TA (1999) BioEdit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. Nucleic Acids Symposium Series 41: 95–98.

Heaney LR, Timm RM (1983) Systematics and distribution of shrews of the genus *Crocidura* (Mammalia: Insectivora) in Vietnam. Proceedings of the Biological Society of Washington 96: 115–120.

Huynh DH, Tien DV, Sung CV, Anh PT, Khien HM (1994) Checklist of Mammals in Vietnam. Publ. House "Science & Technics", Hanoi, 168 pp.

Hutterer R. (2005) Order Soricomorpha. In: Wilson DE, Reeder DM (Eds) Mammal Species of the World. A Taxonomic and Geographic Reference. Third edition. Johns Hopkins University Press, Baltimore, 220–311.

Jenkins PD (1976) Variation in Eurasian shrews of the genus *Crocidura* (Insectivora: Soricidae). Bulletin of the British Museum (Natural History), Zoology 30: 271–309.

Jenkins PD, Abramov AV, Rozhnov VV, Makarova OV (2007) Description of two new species of white-toothed shrews belonging to the genus *Crocidura* (Soricomorpha: Soricidae) from the Ngoc Linh Mountain, Vietnam. Zootaxa 1589: 57–68.

Jenkins PD, Lunde DP, Moncrieff CB (2009) Chapter 10. Descriptions of new species of *Crocidura* (Soricomorpha: Soricidae) from mainland Southeast Asia, with synopses of previously described species and remarks on biogeography. In: Voss RS, Carleton MC (Eds) Systematic mammalogy: contributions in honour of Guy G. Musser. Bulletin of the American Museum of Natural History 331: 356–405.

Jiang X, Hoffmann RS (2001) A revision of the white-toothed shrews (*Crocidura*) of southern China. Journal of Mammalogy 82: 1059–1079. doi: 10.1644/1545-1542(2001)082<1059:AROTWT>2.0.CO;2

Korotky AM, Razjigaeva NG, Ganzey LA, Volkov VG, Grebennikova TA, Bazarova VB, Kovalukh NN (1995). Late Pleistocene-Holocene coastal development of islands off Vietnam. Journal of Southeast Asian Earth Sciences 11: 301–308. doi: 10.1016/0743-9547(94)E0016-7

Kuznetsov GV (2000) Mammals of coastal islands of Vietnam: zoogeographical and ecological aspects. Bonner Zoologische Monographien 4: 357–366.

Kuznetsov GV (2006) Mammals of Vietnam. KMK Scientific Press, Moscow, 420 pp. [in Russian]

Kuznetsov GV, Anh PT (1992) Mammals of coastal islands of Vietnam (biogeographical and ecological aspects). In: Sokolov VE (Ed) Zoological Studies in Vietnam. Nauka, Moscow, 182–197. [in Russian]

Lavrenchenko LA, Bannikova AA, Lebedev VS (2009) Shrews (*Crocidura* spp.) endemic to Ethiopia: recent adaptive radiation of an ancient lineage. Doklady Biological Sciences 424: 57–60. doi: 10.1134/S0012496609010177

MacKinnon J (1997) Protected Areas Systems Review of the Indo-Malayan Realm. The Asian Bureau for Conservation, Canterbury, 198 pp.

Meijaard E (2003) Mammals of south-east Asian islands and their Late Pleistocene environments. Journal of Biogeography 30: 1245–1257. doi: 10.1046/j.1365-2699.2003.00890.x

Motokawa M, Harada M, Lin LK, Koyasu K, Hattori S (1997) Karyological study of the gray shrew *Crocidura attenuata* (Mammalia: Insectivora) from Taiwan. Zoological Studies 36: 70–73.

Motokawa M, Harada M, Wu Y, Lin LK, Suzuki H (2001) Chromosomal polymorphism in the gray shrew *Crocidura attenuata* (Mammalia: Insectivora). Zoological Science 18: 1153–1160. doi: 10.2108/zsj.18.1153

Rozhnov VV, Abramov AV (2009) Insectivorous mammals of Ngoc Linh Mt., Vietnam. In: Rozhnov VV et al. (Eds) Fauna of Mountain Territories. KMK Scientific Press, Moscow, 455–459. [in Russian]

Ruedi M (1995) Taxonomic revision of shrews of the genus *Crocidura* from the Sunda Shelf and Sulawesi with description of two new species (Mammalia: Soricidae). Zoological Journal of the Linnean Society 115: 211–265. doi: 10.1111/j.1096-3642.1995.tb02461.x

Ruedi M, Auberson M, Savolainen V (1998) Biogeography of Sulawesian shrews: testing for their origin with a parametric bootstrap on molecular data. Molecular Phylogenetics and Evolution 9: 567–571. doi: 10.1006/mpev.1998.0487

Sambrook J, Fritsch EF, Maniatis T (1989) Molecular Cloning: a Laboratory Manual. Cold Spring Harbor Lab. Press, Cold Spring Harbor, New York, 398 pp.

Swofford DL (1998) PAUP*. Phylogenetic Analysis Using Parsimony (*and Other Methods). Version 4. Sinauer Associates, Sunderland, MA.

Swan SR, Kry M (2000) Small mammals. In: Daltry JC, Momberg F (Eds) Cardamom Mountains Survey 2000. Fauna & Flora International, Cambridge, UK, 69–78.

Thomas O (1912) New species of *Crocidura* and *Petaurista* from Yunnan. Annals and Magazine of Natural History 8: 686–688. doi: 10.1080/00222931208693186

Trai LT, Richardson WJ, Tuyen BD, Cham LV, Dung NH, Hoach HV, Monastyrskii AL, Eames JC (1999) An Investment Plan for Ngoc Linh Nature Reserve, Kon Tum Province, Vietnam: A Contribution to the Management Plan. BirdLife International Vietnam Programme, Hanoi, 106 pp.

Tuyet D (1998) Overview on karst of Vietnam. In: Yuan D, Liu Z (Eds) Global Karst Correlation. Science Press, Beijing, 179–191.

Van Peenen PFD, Cunningham ML, Duncan JF (1970) A collection of mammals from Con Son Island, Vietnam. Journal of Mammalogy 51: 419–424. doi: 10.2307/1378509

ZooKeys 207: 49–63 (2012)
doi: 10.3897/zookeys.207.3334
www.zookeys.org

RESEARCH ARTICLE

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

A new species of *Orobdella* (Hirudinida, Arhynchobdellida, Orobdellidae) from Taipei, Taiwan

Takafumi Nakano[1,†], Yi-Te Lai[2,3,‡]

1 *Department of Zoology, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan* **2** *Institute of Zoology, National Taiwan University, No. 1, Roosevelt Road, Section 4, Taipei 106, Taiwan* **3** *Department of Biology, University of Eastern Finland, P. O. Box 111, FI 80101 Joensuu, Finland*

† *urn:lsid:zoobank.org:author:FE6B9521-5C9E-43C5-B492-08B0D0590E1B*
‡ *urn:lsid:zoobank.org:author:17BD9035-2FC9-4E38-998A-2F42D5239ECA*

Corresponding author: *Takafumi Nakano* (nakano@zoo.zool.kyoto-u.ac.jp)

Academic editor: *F. Govedich* | Received 6 May 2012 | Accepted 4 July 2012 | Published 11 June 2012

urn:lsid:zoobank.org:pub:D10C419D-4FB1-406D-B805-2B65A193E1C3

Citation: Nakano T, Lai Y-T (2012) A new species of *Orobdella* (Hirudinida, Arhynchobdellida, Orobdellidae) from Taipei, Taiwan. ZooKeys 207: 49–63. doi: 10.3897/zookeys.207.3334

Abstract

A new quadrannulate species of *Orobdella*, *Orobdella ketagalan* **sp. n.**, from Taipei, Taiwan, is described. This is the first record of *Orobdella* and the family Orobdellidae from Taiwan. This new species possesses small, paired sperm duct bulbs in the male reproductive system. In addition to these bulbs, the following combination of characters distinguishes this new species from other quadrannulate species: somite IV uniannulate, male gonopore at XI b6, female gonopore at XIII a1, 1/2 + 4 + 1/2 between gonopores, simple tubular gastroporal duct, lacking epididymides, and undeveloped atrial cornua. Phylogenetic analyses using nuclear 18S rDNA and histone H3 as well as mitochondrial COI, 12S rDNA, $tRNA^{Val}$, and 16S rDNA markers showed that *O. ketagalan* is related to the two Ryukyu Archipelago species *Orobdella dolichopharynx* Nakano, 2011 and *Orobdella shimadae* Nakano, 2011.

Keywords

Hirudinida, Orobdellidae, *Orobdella*, new species, first record, gastroporous, Taiwan

Introduction

Species of the genus *Orobdella* Oka, 1895 are large annelids that feed on earthworms. They are usually 10–20 cm in length (except for *O. koikei* Nakano, 2012, approx. 5 cm) and they inhabit the banks of mountain streams in East Asia (Nakano 2012a, Oka 1895). The systematic position of the genus *Orobdella* has been contentious. *Orobdella* was initially included in the family Gastrostomobdellidae along with the Southeast Asian terrestrial macrophagous leech genus *Gastrostomobdella* Moore, 1929 (Richardson 1971, Sawyer 1986). Although Sawyer (1986) placed Gastrostomobdellidae under Hirudiniformes, recent molecular phylogenetic studies reclassified the family under Erpobdelliformes (Nakano et al. 2012, Oceguera-Figueroa et al. 2011). Nakano et al. (2012) split Gastrostomobdellidae into two families based on phylogenetic analyses as well as morphological discontinuity, and the monotypic family Orobdellidae was erected for *Orobdella*.

Taxonomic and inventory studies on *Orobdella* have progressed recently, and this genus now includes ten species (Nakano 2010, 2011a, b, 2012a, b, in press, Oka 1895, Richardson 1975). *Orobdella* leeches exhibit various types of mid-body somite annulation; three types have been documented thus far: quadrannulate, sexannulate, and octannulate (Sawyer 1986). The quadrannulate mid-body somite is a plesiomorphy of this genus, and the sexannulate form is considered to have evolved in parallel (Nakano 2012a, b, Nakano et al. 2012).

All of the known *Orobdella* species have been described based on specimens collected from Japan, and eight of the ten species have been reported only from Japanese islands (Sawyer 1986). Outside Japan, *O. whitmani* Oka, 1895, which is the type species of the genus, has been recorded from Primorsky Krai, Russia (Gilyarov et al. 1969). However, Nakano (2012a) noted that this specimen from Russia was misidentified as *O. whitmani*, and that it should be considered a new, undescribed species. In addition, *O. tsushimensis* Nakano, 2011 was recently collected from Gageodo Island, Korea (Nakano and Seo in press). In Taiwan, no studies have investigated the species diversity of terrestrial macrophagous leeches. Taiwanese leech species were catalogued by Lai and Chen (2010), but *Orobdella* leeches were not included. Recently, quadrannulate *Orobdella* specimens were collected from Taipei, Taiwan. These materials clearly differ from the other known quadrannulate *Orobdella* species. Therefore, in the present study, *Orobdella* leeches from Taipei are described as a new species. This is the first record of orobdellid leeches from Taiwan. In addition, their phylogenetic position is estimated using nuclear 18S and histone H3 (H3) and mitochondrial COI, 12S, $tRNA^{Val}$, and 16S rDNA (12S–16S) sequence data.

Materials and methods

Leeches were collected from Taipei, Taiwan (Fig. 1). Botryoidal tissue was taken from specimens, which were fixed in ethanol, for DNA extraction. All of the specimens were preserved in 70% ethanol. Two measurements were taken: body length (BL) from the

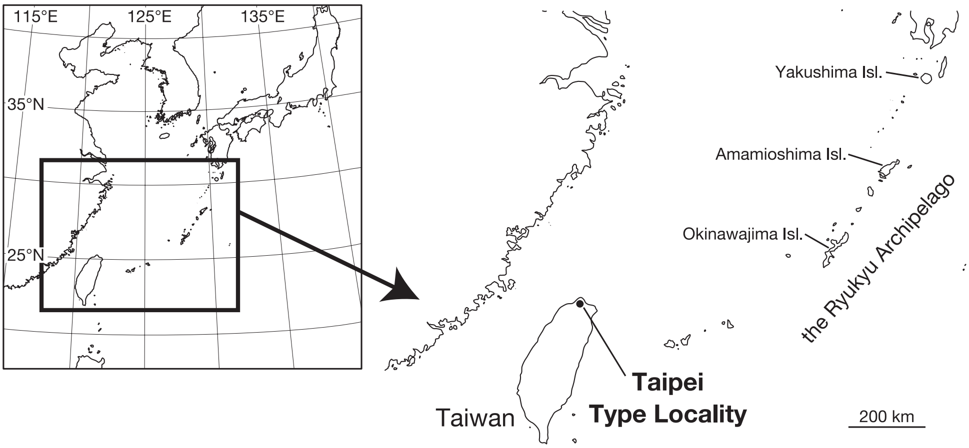


Figure 1. Map showing the collection localities in this study.

anterior margin of the oral sucker to the posterior margin of the caudal sucker, and maximum body width (BW). Examination, dissection, and drawings of the specimens were accomplished under a stereoscopic microscope with a drawing tube (Leica M125). The specimens have been deposited in the Zoological Collection of Kyoto University (KUZ).

We used the numbering convention of Moore (1927): body somites are denoted by Roman numerals, and annuli in each somite are given alphanumeric designations.

The extraction of genomic DNA followed (Nakano 2012a). The primer sets used in this study are listed in Table 1: for 18S, A and L, C and Y, and O and B (Apakupakul et al. 1999) were used; for H3, H3aF and H3bR (Colgan et al. 1998); for COI, LCO 1490 and HCO 2198 (Folmer et al. 1994), and LCO-in and HCO-out (Nakano 2012a); for 12S–16S, 12SA-in and 12SB-out (Nakano 2012a). The DNA sequencing methods for the above four markers followed Nakano (2012a). The following DNA sequences were newly obtained and deposited in GenBank (Table 2): 18S and H3 sequences from the holotype (KUZ Z208) of the new species, and COI and 12S–16S sequences from the holotype (KUZ Z208) and three paratypes (KUZ Z209–Z211) of the new species. The DNA sequences of the holotype (KUZ Z208) were analyzed in the following phylogenetic analyses. The other sequences were taken from GenBank (Table 2). For the outgroup, three Erpobdelliformes leeches were included in the phylogenetic analyses: *Erpobdella japonica* Pawłowski, 1962 (Erpobdellidae), *Gastrostomobdella monticola* Moore, 1929 (Gastrostomobdellidae), and *Mimobdella japonica* Blanchard, 1897 (Salifidae).

H3 and COI sequences were aligned by eye because there were no indels. Nuclear 18S and mitochondrial 12S–16S sequences were aligned using MAFFT X-INS-I (Hofacker et al. 2002, Katoh and Toh 2008, McCaskill 1990, Tabei et al. 2008) taking into account RNA secondary structure information, and then refined with GBLOCKS (Castresana 2000). Aligned sequences of 18S was 1787 bp in length; those of H3, COI, and 12S–16S were 327, 1266, and 410 bp, respectively. The concatenated sequences thus yielded a total of 3790 bp positions.

Table 1. PCR and cycle sequencing (CS) primers used in this study. Sources: [a]Apakupakul et al. (1999), [b]Colgan et al. (1998), [c]Folmer et al. (1994), [d]Nakano (2012a).

Gene	Primer name	Reaction	Primer sequence (5' → 3')
18S			
1	A[a]	PCR & CS	AACCTGGTTGATCCTGCCAGT
	L[a]	PCR & CS	CCAACTACGAGCTTTTTAACTG
2	C[a]	PCR & CS	CGGTAATTCCAGCTCCAATAG
	Y[a]	PCR & CS	CAGACAAATCGCTCCACCAAC
3	O[a]	PCR & CS	AAGGGCACCACCAGGAGTGGAG
	B[a]	PCR & CS	TGATCCTTCCGCAGGTTCACCT
Histone H3			
	H3aF[b]	PCR & CS	ATGGCTCGTACCAAGCAGACVGC
	H3bR[b]	PCR & CS	ATATCCTTRGGCATRATRGTGAC
COI			
1	LCO1490[c]	PCR & CS	GGTCAACAAATCATAAAGATATTGG
	HCO2198[c]	CS	TAAACTTCAGGGTGACCAAAAAATCA
2	LCO-in[d]	CS	TCCAGAACGTATTCCATTATTTG
	HCO-out[d]	PCR & CS	TCTGGGTAGTCAGAATATCG
12S–16S			
	12SA-in[d]	PCR & CS	AATTAAAACAAGGATTAGATACCC
	12SB-out[d]	PCR & CS	AACCCATAATGCAAAAGGTAC

Phylogenetic trees were constructed using maximum likelihood (ML) and Bayesian inference (BI). ML phylogenies were calculated using TREEFINDER v October 2008 (Jobb et al. 2004) with the tool package Phylogears v 2.0 (Tanabe 2008), and then non-parametric bootstrapping (Felsenstein 1985) was conducted with 500 replicates. The best-fit models for each partition were selected using the Akaike information criterion (Akaike 1974) by using Kakusan 4 (Tanabe 2011): for 18S, the Jobb 2008 model (J2) with gamma distribution (+G) and proportion of invariant sites (+I) was selected; for H3 1st position, the Tamura-Nei model (TN93); for H3 2nd position, the Jukes-Cantor model (JC69); for H3 3rd position, J2+G; for COI 1st position, TN93+G+I; for COI 2nd position, the transversion model (TVM)+I; for COI 3rd position, TN93+G; for 12S, the general time reversal model (GTR)+G; for tRNA^{Val}, the Hasegawa-Kishino-Yano model (HKY85)+G; and for 16S, the transition model (TIM)+G. BI and Bayesian posterior probabilities (BPPs) were estimated using the MPI version of MrBayes v 3.1.2 (Altekar et al. 2004, Huelsenbeck et al. 2001, Ronquist and Huelsenbeck 2003). The best-fit models for each partition were identified using the Bayesian information criterion (Schwarz 1978) also by using Kakusan 4: for 18S, the Kimura 1980 model (K80)+I; for H3 1st and 2nd positions, JC69; for H3 3rd position, HKY85+G; for COI 1st position, GTR+G+I; for COI 2nd position, the Felsenstein 1981 (F81) model+I; for COI 3rd position, HKY85+G; for 12S, GTR+G; and for tRNA^{Val} and 16S, HKY85+G. Two independent runs of four Markov chains were conducted for 20 million generations and the tree was sampled every 100 generations. The parameter

Table 2. Samples used for the phylogenetic analyses. Information on vouchers, collection localities, and GenBank accession numbers is provided.UNIMAS, the Universiti Malaysia Sarawak. Sources: [a]Nakano (2012a), [b]Nakano (2012b), [c]Nakano et al. (2012).

Species	Voucher	18S	Histone H3	COI	12S–16S
Orobdella ketagalan sp. n.	KUZ Z208 Holotype	AB704785	AB704786	AB704787	AB704788
Orobdella ketagalan sp. n.	KUZ Z209 Paratype			AB704789	AB704790
Orobdella ketagalan sp. n.	KUZ Z210 Paratype			AB704791	AB704792
Orobdella ketagalan sp. n.	KUZ Z211 Paratype			AB704793	AB704794
Orobdella esulcata	KUZ Z29 Holotype	AB663655[c]	AB698873[b]	AB679664[a]	AB679665[a]
Orobdella dolichopharynx	KUZ Z120 Holotype	AB663665[c]	AB698876[b]	AB679680[a]	AB679681[a]
Orobdella ijimai	KUZ Z110 Topotype	AB663659[c]	AB698877[b]	AB679672[a]	AB679673[a]
Orobdella kawakatsuorum	KUZ Z167 Topotype	AB663661[c]	AB698878[b]	AB679704[a]	AB679705[a]
Orobdella koikei	KUZ Z156 Holotype	AB698883[b]	AB698882[b]	AB679688[a]	AB679689[a]
Orobdella mononoke	KUZ Z224 Holotype	AB698868[b]	AB698869[b]	AB698866[b]	AB698867[b]
Orobdella octonaria	KUZ Z181 Topotype	AB698870[b]	AB698871[b]	AB679708[a]	AB679709[a]
Orobdella shimadae	KUZ Z128 Holotype	AB663663[c]	AB698875[b]	AB679676[a]	AB679677[a]
Orobdella tsushimensis	KUZ Z134 Holotype	AB663653[c]	AB698872[b]	AB679662[a]	AB679663[a]
Orobdella whitmani	KUZ Z45 Topotype	AB663657[c]	AB698874[b]	AB679668[a]	AB679669[a]
Erpobdella japonica	KUZ Z178	AB663648[c]	AB698879[b]	AB679654[a]	AB679655[a]
Gastrostomobdella monticola	UNIMAS/A3/ BH01/10	AB663649[c]	AB698880[b]	AB679656[a]	AB679657[a]
Mimobdella japonica	KUZ Z179	AB663650[c]	AB698881[b]	AB679658[a]	AB679659[a]

estimates and convergence were checked using Tracer v 1.5 (Rambaut and Drummond 2009), and based on the results the first 50,001 trees were discarded.

Nodes with bootstrap (BS) values higher than 70% were considered sufficiently resolved (Hillis and Bull 1993). Nodes with BPPs higher than 95% were considered statistically significant (Leaché and Reeder 2002).

Taxonomy

Family Orobdellidae Nakano, Ramlah & Hikida, 2012
urn:lsid:zoobank.org:act:5F5BABE8-BD26-4FC7-9593-F73E62E26122
Genus *Orobdella* Oka, 1895
urn:lsid:zoobank.org:act:FA8333ED-8C17-41FD-AFC1-62A4F98D4AC1

Orobdella ketagalan **sp. n.**
urn:lsid:zoobank.org:act:AFF291DF-E13F-46A3-A965-14B92E23F520
http://species-id.net/wiki/Orobdella_ketagalan
Figs 2–4

Diagnosis. Somite IV uniannulate, somites VIII–XXV quadrannulate. Pharynx reaching to posterior of XIV to anterior of XV. Gastropore conspicuous at XIII a1. Gas-

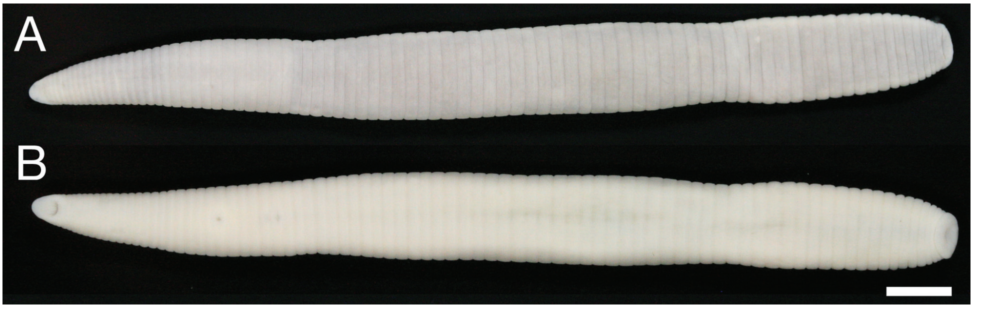


Figure 2. *Orobdella ketagalan* sp. n., holotype, KUZ Z208. **A** Dorsal and **B** ventral views. Scale bar, 5 mm.

troporal duct simple, tubular. Male gonopore at XI b6, female gonopore at XIII a1, gonopores separated by 1/2 + 4 + 1/2 annuli. Small paired sperm duct bulbs in XV. Epididymis absent. Atrial cornua, coniform, undeveloped.

Materials examined. Holotype. KUZ Z208, mature specimen of 70.9 mm length, dissected, collected from Yangmingshan National Park (alt. 779 m, 25°11'07"N, 121°31'10"E), Taipei City, Taiwan, by Win-Je Chi on March 24, 2011. Paratypes (a total of five specimens collected from Taiwan in 2005–2011): KUZ Z197, from Jinsan Township, Taipei County (alt. 739 m, 25°11'01"N, 121°30'54"E), on March 18, 2005; KUZ Z207, from the type locality (alt. 776 m, 25°09'49"N, 121°33'10"E) by Chi-Lun Lee and Win-Je Chi on July 30, 2010; KUZ Z209 (alt. 779 m, 25°11'07"N, 121°31'10"E), dissected, KUZ Z210 (alt. 600 m, 25°11'11"N, 121°31'10"E), dissected, from the type locality by Win-Je Chi on March 24, 2011; and KUZ Z211 from the type locality (alt. 737 m, 25°10'55"N, 121°30'50"E) by Win-Je Chi on April 24, 2011.

Etymology. The specific name is taken from the native Taiwanese tribe Ketagalan. The type locality of this new species is in an area settled by this aboriginal tribe. The specific name is a native word, not a Latin or Latinized word.

Description of holotype. Body firm, muscular, elongated, gaining regularly in width in caudal direction, dorso-ventral depressed, sides nearly parallel from mid-length to point just anterior to caudal sucker, BL 70.9 mm, BW 6.4 mm (Fig. 2). Caudal sucker ventral, oval, diameter smaller than BW (Figs 2B, 3D). Color faded in preservative (Fig. 2).

Somite I completely merged with prostomium (Fig. 3A). Somite II uniannulate, not separated from I (Fig. 3A). Somites III and IV uniannulate (Fig. 3A). Somite V biannulate, (a1 + a2) = a3, a3 forming posterior margin of oral sucker (Fig. 3A, B). Somites VI and VII triannulate, a1 = a2 = a3 (Fig. 3A, B). Somites VIII–XXV quadrannulate, a1 = a2 = b5 = b6 (Fig. 3A–E); b5 of X being first annulus on clitellum, a2 of XIII being last annulus of clitellum (Fig. 3E). Somite XXVI triannulate, a1 > a2 > a3, a3 being last complete annulus on venter (Fig. 3C, D). Somite XXVII incomplete uniannulate with slight furrow (Fig. 3C); anus behind it with no post-anal annulus (Fig. 3C).

Anterior ganglionic mass in VI a2 and a3. Ganglia VIII–XXI in a2 of each somite (Fig. 4A). Ganglion XIII in a2 and b5 (Fig. 4A). Ganglia XIV–XXIII in a2 of each

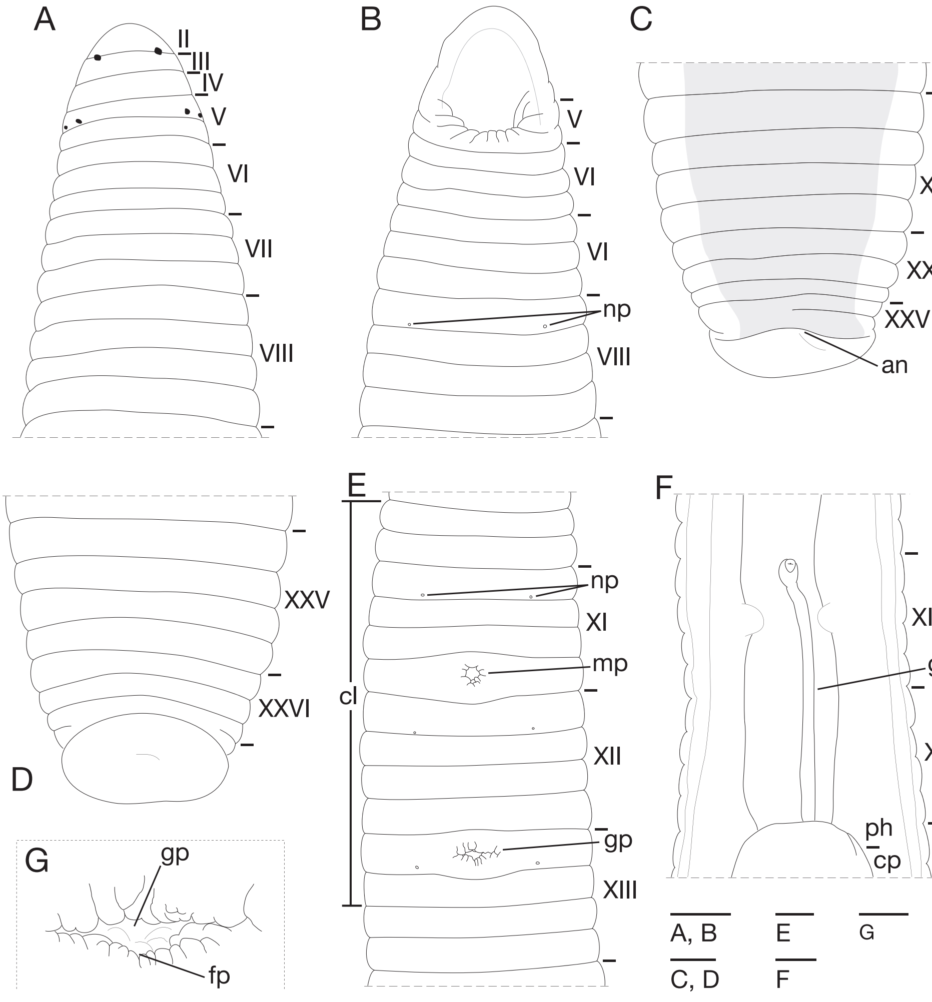


Figure 3. *Orobdella ketagalan* sp. n., holotype, KUZ Z208. **A** Dorsal and **B** ventral views of somites I–VIII **C** dorsal and **D** ventral views of somites XXV–XXVII and caudal sucker **E** ventral view of somites X b5–XIII **F** ventral view of gastroporal duct; and **G** ventral view of gastropore and female gonopore. Scale bars, 1 mm (**A–F**) and 0.25 mm (**G**). Abbreviations: an, anus; cl, clitellum; cp, crop; fp, female gonopore; gd, gastroporal duct; gp, gastropore; mp, male gonopore; np, nephridiopore; and ph, pharynx.

somite (Fig. 4A). Ganglia XXIV and XXV in a1 and a2 of each somite. Ganglion XXVI in b6 of somite XXV. Posterior ganglionic mass in XXVI a1–a3.

Eyes, three pairs, first pair dorsally in furrow of II/III, second and third pairs dorsolaterally on posterior margin of V (a1 + a2) (Fig. 3A). Nephridiopores, 17 pairs, ventrally at posterior margin of a1 of each somite of VIII–XXIV (Fig. 3B, E). Papillae numerous, minute, hardly visible, one row on every annulus.

Pharynx agnathous, euthylaematous, reaching to XV a1 (Fig. 3F). Crop tubular, acecate, in XV a1 to XXI a2. Gastropore conspicuous, ventral, located middle of XIII a1 (Fig.

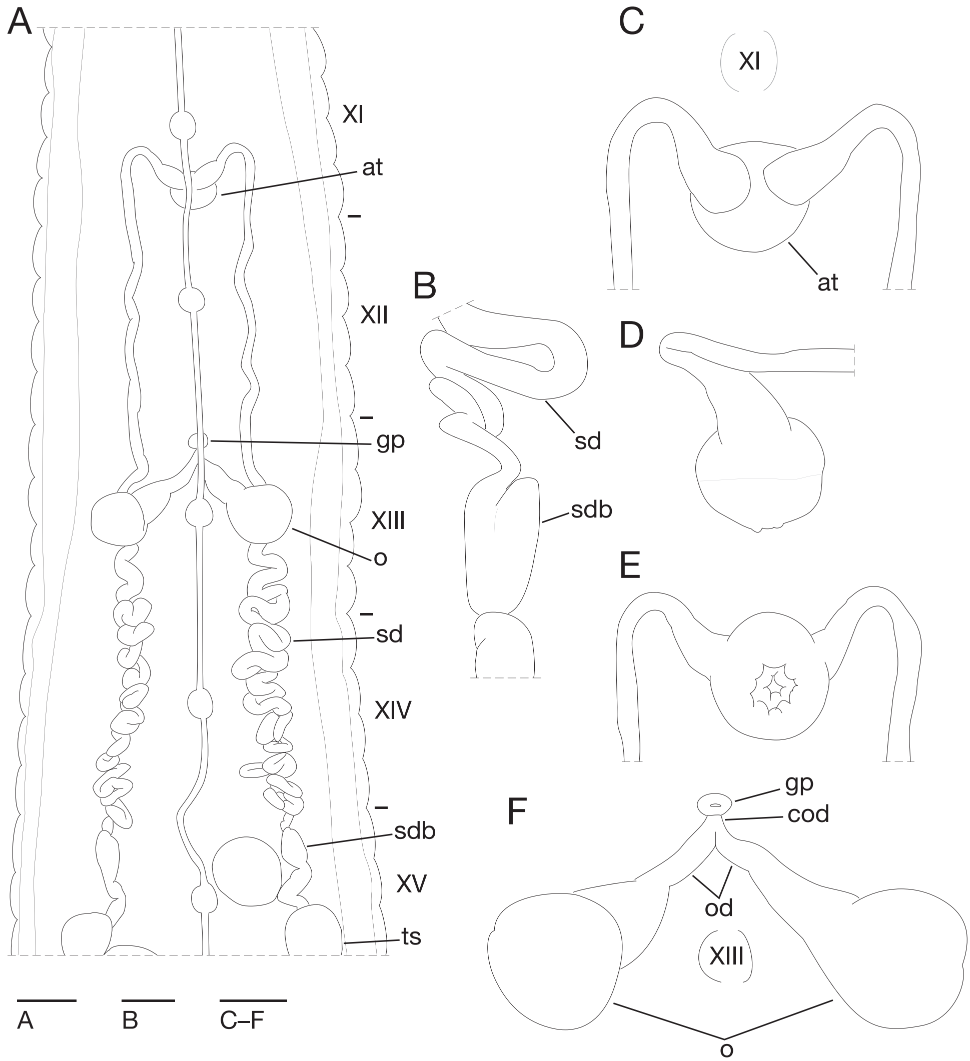


Figure 4. *Orobdella ketagalan* sp. n., holotype, KUZ Z208. **A** Dorsal view of reproductive system including ventral nervous system **B** lateral view of bulb of right sperm duct **C** dorsal **D** lateral, and **E** ventral views of male atrium: **C** including position of ganglion XI; and **F** dorsal view of female reproductive system including position of ganglion III. Scale bars, 1 mm (**A**), 0.5 mm (**C–F**), and 0.25 mm (**B**). Abbreviations: at, atrium; cod, common oviduct; gp, gastropore; o, ovisac; od, oviduct; sd, sperm duct; sdb, sperm duct bulb; and ts, testisacs.

3E, G). Gastroporal duct narrow, simple tubular, joining with crop in XIV/XV (Fig. 3F). Intestine tubular, acecate, in XXI a2 to XXIV b5/b6. Rectum tubular, thin-walled.

Male gonopore located at middle of XI b6 (Fig. 3E). Female gonopore at middle of XIII a1, inconspicuous, located behind gastropore (Fig. 3E, G). Gonopores separated by 1/2 + 4 + 1/2 annuli (Fig. 3E). Testisacs multiple, one or two testisacs on each side in each annulus, in XV a2 to XXV b5 (Fig. 4A). Sperm ducts in XI b5 to XV a2, coiled in XIII b5 to XV a1 (Fig. 4A): small paired sperm duct bulbs in XV a1 (Fig. 4A, B). Epididymides absent. Ejaculatory bulbs absent. Paired atrial cornua in XI b5 and b6, undeveloped, coniform (Fig. 4A, C). Atrium body short, muscular, globular in XI b5 and b6 (Fig. 4A, C–E). Penis sheath and penis absent. Ovisacs, one pair, thin-walled, globular, in XIII a2 and b5 (Fig. 4A, F). Oviducts thin-walled, right oviduct crossing ventrally beneath nerve cord, both oviducts converging into common oviduct in XIII a1/a2 (Fig. 4A, F). Common oviduct thin-walled, very short, directly ascending to female gonopore (Fig. 4F).

Variation. Maximum BL 111.7 mm, maximum BW 10.3 mm (KUZ Z210). In life, dorsal surface grayish, slightly darker in first third of dorsum, ventral surface whitish. Somite XXVI dorsally quadrannulate, ventrally triannulate (KUZ Z197, Z207, Z211) or quadrannulate (KUZ Z210). Somite XXVII incomplete biannulate. Pharynx reaching to XIV a1/b5–b6. Crop reaching to XXI a2/b5–XXI/XXII. Gastroporal duct joining with crop in XIV b5–XIV b5/b6. Intestine reaching to XXIV a2/b5–XXV a2. Testisacs in XV a2–XVI b6 to XXIII a1–XXV a2. Paired sperm duct bulbs in XV a1 and a2 (KUZ Z209), in XV b5 (KUZ Z210). Right or left oviducts crossing ventrally beneath nerve cord.

Distribution. Known from Yangmingshan National Park and adjacent areas in northern Taipei City, Taiwan (Fig. 1).

Remarks. *Orobdella ketagalan* differs from the five other quadrannulate *Orobdella* species (i.e., *O. esulcata* Nakano, 2010, *O. kawakatsuorum* Richardson, 1975, *O. koikei*, *O. tsushimensis*, and *O. whitmani*) in the following combination of characteristics (Table 3): IV uniannulate, gonopores separated by 1/2 + 4 + 1/2 annuli, XXV quadrannulate, gastroporal duct simple and tubular, paired sperm duct bulbs in XV, epididymides absent, and atrial cornua undeveloped. Because *O. ketagalan* possesses

Table 3. Comparison of morphological characters between *Orobdella ketagalan* sp. n. and five quadrannulate congeneric species.

Character	*O. ketagalan* sp. n.	*O. esulcata*	*O. kawakatsuorum*	*O. koikei*	*O. tsushimensis*	*O. whitmani*
Annulation of IV	uniannulate	uniannulate	biannulate	uniannulate	uniannulate	uni- or biannulate
Number of annuli between gonopores	1/2 + 4 + 1/2	2/3 + 4 + 1/3	6	1/2 + 4 + 1/2	1/2 + 5	1/2 + 4 +1/2
Annulation of XXV	quadrannulate	quadrannulate	quadrannulate	triannulate	quadrannulate	quadrannulate
Gastroporal duct	simple tubular	tubular, but bulbous at junction with gastropore	simple tubular	tubular, but bulbous at junctions with gastropore and crop	bottle-shaped	bulbiform
Paired sperm duct bulbs	in XV	absent	absent	absent	absent	absent
Epididymides	absent	XVI to XX	XVI to XVII	XVII to XIX	XVI to XIX	XVI to XVIII
Atrial cornua	undeveloped	ovate	undeveloped	ovate	coniform	ovate

quadrannulate mid-body somites, this new species is easily distinguishable from the four sexannulate species (i.e., *O. dolichopharynx* Nakano, 2011, *O. ijimai* Oka, 1895, *O. mononoke* Nakano, 2012, and *O. shimadae* Nakano, 2011) and one octannulate species, *O. octonaria* Oka, 1895.

Phylogenetic analyses

The BI tree (Fig. 5) was nearly identical to the ML tree with ln *L* = -12357.61 (not shown). Monophyly of the genus *Orobdella* was well supported (BS = 97%, BPP = 100%). *Orobdella* then divided into two clades: clade A (BS = 100%, BPP = 100%) consisted of two species from Hokkaido, Japan, *O. kawakatsuorum* and *O. koikei*; and clade B (BS = 94%, BPP = 100%) included the other nine *Orobdella* species. Clade B was split into three subclades: subclade B1 included only *O. tsushimensis* (from Tsushima Island, Japan); subclade B2 (BS = 83%, BPP = 100%) included *O. esulcata* (from Kyushu, Japan), *O. mononoke* (from Yakushima Island, Japan), *O. dolichopharynx* (from Amamioshima Island, Japan), *O. shimadae* (from Okinawajima Island, Japan), and *O. ketagalan* (from Taipei, Taiwan); and subclade B3 (BS = 69%, BPP = 99%) consisted of three species (from Honshu, Japan), *O. whitmani*, *O. ijimai*, and *O. octonaria*. Subclades B2 and B3 formed a monophyletic clade in both analyses, but with low support (BS = 67%, BPP = 89%).

In subclade B2, three species from the Ryukyu Archipelago, *O. mononoke*, *O. dolichopharynx*, and *O. shimadae,* and the Taiwanese *O. ketagalan* formed a monophyletic clade, but this clade was also not sufficiently supported (BS = 55%, BPP = 82%).

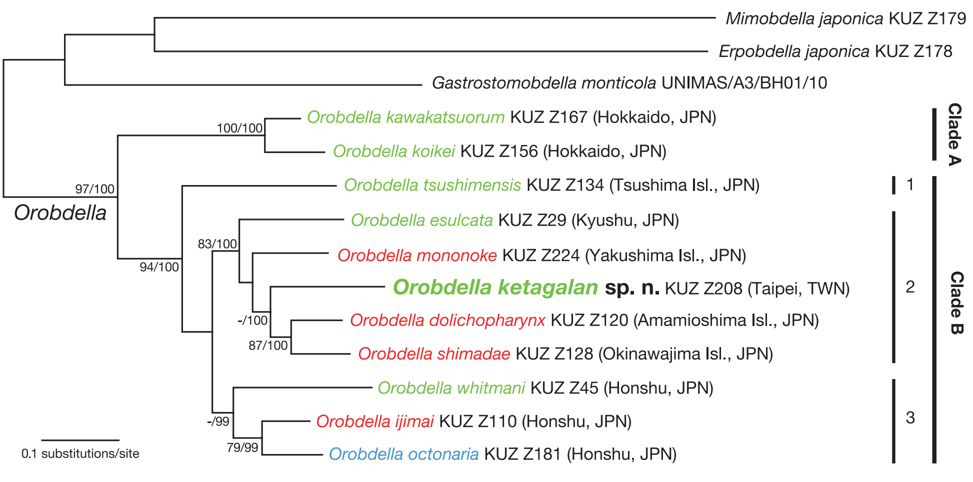


Figure 5. The BI tree of 3790 bp of nuclear 18S rDNA and histone H3, and mitochondrial COI, 12S rDNA, tRNA^{Val}, 16S rDNA. A species name in green indicates a quadrannulate species; in red, sexannulate; and in blue, octannulate. The numbers associated with the nodes represent the bootstrap values for ML (BS) and Bayesian posterior probabilities (BPPs). BSs higher than 70 % and/or BPPs higher than 95 % are indicated. Abbreviations: JPN, Japan; and TWN, Taiwan.

Monophyly of *O. ketagalan*, *O. dolichopharynx*, and *O. shimadae* was supported in the BI analyses (BPP = 100%), but was not recovered in the ML analyses (BS = 46%). Monophyly of *O. dolichopharynx* and *O. shimadae* was confirmed (BS = 87%, BPP = 100%).

Discussion

The phylogenies obtained in this study are nearly identical to those obtained in other phylogenetic analyses of the genus *Orobdella* (Nakano 2012a, b, Nakano et al. 2012). The most ancestral clade of *Orobdella* (clade A in Fig. 5) is distributed in Hokkaido, Japan. The other species inhabit islands south of Hokkaido (clade B in Fig. 5) and are divided into three subclades (B1–3 in Fig. 5). In our analyses, however, the phylogenetic relationships of these subclades were not sufficiently resolved. Our phylogenetic trees clearly indicated that the quadrannulate mid-body somite annulation is a plesiomorphic character of *Orobdella*, and that sexannulate mid-body somites had evolved in parallel. This result was also mentioned in previous studies (Nakano 2012a, b, Nakano et al. 2012). Even in subclade B2, the sexannulate character was considered to have evolved in parallel. In this subclade, three sexannulate species from the Ryukyu Archipelago were included: *O. mononoke* is from Yakushima Island, which is located in the northern part of the Ryukyu Archipelago; *O. dolichopharynx* is from Amamioshima Island, which is located in the middle region of the Archipelago; and *O. shimadae* is from Okinawajima Island, which is also located in the middle region of the Archipelago, but south of Amamioshima Island. Our analyses showed that these three sexannulate species did not form a monophyletic clade. In contrast, two sexannulate species, *O. dolichopharynx* and *O. shimadae*, and the Taiwanese quadrannulate *O. ketagalan* formed a monophyletic clade. The other sexannulate species, *O. mononoke*, was not closely related to *O. dolichopharynx* and *O. shimadae*. This is in agreement with findings by (Nakano 2012b), who mentioned that *O. mononoke* was probably not very close to those two species. Our phylogenetic analyses supported his phylogenetic conclusion. According to the topologies of the ML and BI trees, *O. mononoke* is a sister taxon of a clade including *O. ketagalan*, *O. dolichopharynx*, and *O. shimadae*, but this phylogenetic position was not well resolved in either tree. To better understand the biogeographical history of *Orobdella* leeches, more robust trees for this genus based on either more DNA markers or specimens should be obtained.

Orobdella ketagalan possesses small, paired sperm duct bulbs in XV (Fig. 4A, B). Such small bulbs have never before been reported in *Orobdella*. Hence, small sperm duct bulbs could be considered an apomorphy of the Taiwanese *O. ketagalan*. *Orobdella* species generally possess eipididymides in their male reproductive systems (Nakano 2010, 2011a, b, 2012a, b, in press). However, only *O. ketagalan*, *O. dolichopharynx*, and *O. shimadae* do not bear epididymides (Nakano 2011b). These three species formed a monophyletic clade in our phylogenetic analyses (Fig. 5). Therefore, lacking epididymides could be considered a synapomorphy within *O. ketagalan*, *O. dolichopharynx*, and *O. shimadae*. *Orobdella ketagalan* also possesses a simple, tubular gastroporal duct, which is similar to that of *O. kawakatsuorum* (Nakano 2012a, Richardson 1975). This morphological similarity is clearly due to convergence, according to our phylogenetic analyses.

This is the first record of the genus *Orobdella* from Taiwan. Moreover, we collected several other specimens that appear to be undescribed species of *Orobdella* (Nakano and Lai, unpublished observation). Further faunal and systematic studies will reveal the species diversity of Taiwanese *Orobdella* and further elucidate the biogeographical and evolutionary history of these macrophagous leeches.

Key to the known species of the genus *Orobdella*

1	Mid-body somites more than quadrannulate	**2**
–	Mid-body somites quadrannulate	**6**
2	Mid-body somites sexannulate	**3**
–	Mid-body somites octannulate	***Orobdella octonaria* Oka, 1895**
3	Pharynx reaching to XIV	**4**
–	Pharynx reaching to XVI	**5**
4	Gonopores separated by 1/2 + 7 + 1/2 annuli	***Orobdella ijimai* Oka, 1895**
–	Gonopores separated by 8 + 1/2 annuli	***Orobdella mononoke* Nakano, 2012**
5	Gonopores separated by 8 annuli	***Orobdella dolichopharynx* Nakano, 2011**
–	Gonopores separated by 9 annuli	***Orobdella shimadae* Nakano, 2011**
6	Color yellowish	**7**
–	Color grayish blue or brown	**9**
7	Gonopores separated by 1/2 + 4 + 1/2 annuli	**8**
–	Gonopores separated by 1/2 + 5 annuli, gastroporal duct bottle-shaped	***Orobdella tsushimensis* Nakano, 2011**
8	Gastroporal duct bulbiform, epididymides in XVI to XVIII	***Orobdella whitmani* Oka, 1895**
–	Gastroporal duct simple tubular, epididymides absent, small paired sperm duct bulbs in XV	***Orobdella ketagalan* sp. n.**
9	Color grayish blue	**10**
–	Color brown, gonopores separated by 1/2 + 4 + 1/2 annuli	***Orobdella koikei* Nakano, 2012**
10	Gonopores separated by 2/3 + 4 + 1/3, gastroporal duct simple tubular but bulbous at junction with gastropore	***Orobdella esulcata* Nakano, 2010**
–	Gonopores separated by 6 annuli, gastroporal duct simple tubular	***Orobdella kawakatsuorum* Richardson, 1975**

Acknowledgments

The authors are grateful to Professor Tsutomu Hikida (Kyoto University; KU) for his helpful comments and suggestions to improve this manuscript. We are also grateful to

Win-Je Chi (National Taiwan University; NTU) and Chi-Lun Lee (NTU) for providing type specimens of the new species, to two anonymous reviewers and Dr Fredric R. Govedich (Southern Utah University) for their constructive comments on this manuscript, and to Hiroshi Noda (KU) and Eri Kawaguchi (KU) for their technical support. This study was financially supported in part by a Grant-in-Aid for Biodiversity and Evolutionary Research of Global COE (A06) from the Ministry of Education, Culture, Sports Science and Technology (MEXT), Japan, to Kyoto University.

References

Akaike H (1974) A new look at the statistical model identification. IEEE Transactions on Automatic Control 19: 716–723. doi: 10.1109/TAC.1974.1100705

Altekar G, Dwarkadas S, Huelsenbeck JP, Ronquist F (2004) Parallel Metropolis coupled Markov chain Monte Carlo for Bayesian phylogenetic inference. Bioinformatics 20: 407–415. doi: 10.1093/bioinformatics/btg427

Apakupakul K, Siddall ME, Burreson EM (1999) Higher level relationships of leeches (Annelida: Clitellata: Euhirudinea) based on morphology and gene sequences. Molecular Phylogenetics and Evolution 12: 350–359. doi: 10.1006/mpev.1999.0639

Blanchard R (1897) Hirudinées du Musée de Leyde. Notes from the Leyden Museum 19: 73–113.

Castresana J (2000) Selection of conserved blocks from multiple alignments for their use in phylogenetic analysis. Molecular Biology and Evolution 17: 540–552. doi: 10.1093/oxfordjournals.molbev.a026334

Colgan DJ, McLauchlan A, Wilson GDF, Livingston SP, Edgecombe GD, Macaranas J, Cassis G, Gray MR (1998) Histone H3 and U2 snRNA DNA sequences and arthropod molecular evolution. Australian Journal of Zoology 46: 419–437. doi: 10.1071/ZO98048

Felsenstein J (1985) Confidence limits on phylogenies: an approach using the bootstrap. Evolution 39: 783–791. doi: 10.2307/2408678

Folmer O, Black M, Hoeh W, Lutz R, Vrijenhoek R (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3: 294–299.

Gilyarov MS, Lukin EI, Perel TS (1969) The first terrestrial leech—*Orobdella whitmani* Oka (Hirudinel, Herpobdellidae)—in the fauna of the USSR: A Tertiary relict of forests of the southern Maritime Territory. Doklady Akademii Nauk SSSR 188: 235–237.

Hillis DM, Bull JJ (1993) An empirical test of bootstrapping as a method for assessing confidence in phylogenetic analysis. Systematic Biology 42: 182–192. doi: 10.1093/sysbio/42.2.182

Hofacker IL, Fekete M, Stadler PF (2002) Secondary structure prediction for aligned RNA sequences. Journal of Molecular Biology 319: 1059–1066. doi: 10.1016/S0022-2836(02)00308-X

Huelsenbeck JP, Ronquist F, Nielsen R, Bollback JP (2001) Bayesian inference of phylogeny and its impact on evolutionary biology. Science 294: 2310–2314. doi: 10.1126/science.1065889

Jobb G, von Haeseler A, Strimmer K (2004) TREEFINDER: a powerful graphical analysis environment for molecular phylogenetics. BMC Evolutionary Biology 4: 18. doi: 10.1186/1471-2148-4-18

Katoh K, Toh H (2008) Improved accuracy of multiple ncRNA alignment by incorporating structural information into a MAFFT-based framework. BMC Bioinformatics 9: 212. doi: 10.1186/1471-2105-9-212

Lai Y-T, Chen J-H (2010) Leech Fauna of Taiwan. National Taiwan University Press, Taipei, 118 pp.

Leaché AD, Reeder TW (2002) Molecular systematics of the eastern fence lizard (*Sceloporus undulatus*): a comparison of parsimony, likelihood, and Bayesian approaches. Systematic Biology 51: 44–68. doi: 10.1080/106351502753475871

McCaskill JS (1990) The equilibrium partition function and base pair binding probabilities for RNA secondary structure. Biopolymers 29: 1105–1119. doi: 10.1002/bip.360290621

Moore JP (1927) The segmentation (metamerism and annulation) of the Hirudinea. In: Harding WA, Moore JP. The Fauna of British India, including Ceylon and Burma Hirudinea. Taylor and Francis, London, 1–12.

Moore JP (1929) Leeches from Borneo with descriptions of new species. Proceedings of the Academy of Natural Sciences of Philadelphia 81: 267–295.

Nakano T (2010) A new species of the genus *Orobdella* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from Kumamoto, Japan, and a redescription of *O. whitmani* with the designation of the lectotype. Zoological Science 27: 880–887. doi: 10.2108/zsj.27.880

Nakano T (2011a) A new species of *Orobdella* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae) from Tsushima Island, Japan. Species Diversity 16: 39–47.

Nakano T (2011b) Redescription of *Orobdella ijimai* (Hirudinida: Arhynchobdellida: Gastrostomobdellidae), and two new species of *Orobdella* from the Ryukyu Archipelago, Japan. Zootaxa 2998: 1–15.

Nakano T (2012a) A new species of *Orobdella* (Hirudinida, Arhynchobdellida, Gastrostomobdellidae) and redescription of *O. kawakatsuorum* from Hokkaido, Japan with the phylogenetic position of the new species. ZooKeys 169: 9–30. doi: 10.3897/zookeys.169.2425

Nakano T (2012b) A new sexannulate species of *Orobdella* (Hirudinida, Arhynchobdellida, Orobdellidae) from Yakushima Island, Japan. ZooKeys 181: 79–93. doi: 10.3897/zookeys.181.2932

Nakano T (in press) Redescription of *Orobdella octonaria* (Hirudinida: Arhynchobdellida: Orobdellidae) with designation of a lectotype. Species Diversity.

Nakano T, Ramlah Z, Hikida T (2012) Phylogenetic position of gastrostomobdellid leeches (Hirudinida, Arhynchobdellida, Erpobdelliformes) and a new family for the genus *Orobdella*. Zoologica Scripta 41: 177–185. doi: 10.1111/j.1463-6409.2011.00506.x

Nakano T, Seo H-Y (in press) First record of *Orobdella tsushimensis* (Hirudinida: Arhynchobdellida: Orobdellidae) from Korea (Gageodo Island) and its molecular phylogenetic position within the genus. Species Diversity.

Oceguera-Figueroa A, Phillips AJ, Pacheco-Chaves B, Reeves WK, Siddall ME (2011) Phylogeny of macrophagous leeches (Hirudinea, Clitellata) based on molecular data and evaluation of the barcoding locus. Zoologica Scripta 40: 194–203. doi: 10.1111/j.1463-6409.2010.00465.x

Oka A (1895) On some new Japanese land leeches. (*Orobdella* nov. gen.). The Journal of the College of Science, Imperial University, Japan 8: 275–306.

Pawłowski LK (1962) O występowaniu pijawki *Erpobdella octoculata* (L.) w Japonii. Zeszyty Naukowe Uniwersytetu Łódzkiego Nauki Matematiczno-przyrodnicze Seria II 12: 127–136.

Rambaut A, Drummond AJ (2009) Tracer. 1.5: http://tree.bio.ed.ac.uk/software/tracer/

Richardson LR (1971) Gastrostomobdellidae f. nov. and a new genus for the gastroporous *Orobdella octonaria* Oka, 1895, of Japan (Hirudinoidea: Arhynchobdellae). Bulletin of the National Science Museum (Tokyo) 14: 585–602.

Richardson LR (1975) A new species of terricolous leeches in Japan (Gastrostomobdellidae, *Orobdella*). Bulletin of the National Science Museum Series A (Zoology) 1: 39–56.

Ronquist F, Huelsenbeck JP (2003) MrBayes 3: Bayesian phylogenetic inference under mixed models. Bioinformatics 19: 1572–1574. doi: 10.1093/bioinformatics/btg180

Sawyer RT (1986) Leech Biology and Behaviour. Clarendon Press, Oxford, 1065 pp.

Schwarz G (1978) Estimating the dimension of a model. The Annals of Statistics 6: 461–464. doi: 10.1214/aos/1176344136

Tabei Y, Kiryu H, Kin T, Asai K (2008) A fast structural multiple alignment method for long RNA sequences. BMC Bioinformatics 9: 33. doi: 10.1186/1471-2105-9-33

Tanabe AS (2008) Phylogears. 2.0: http://www.fifthdimension.jp/

Tanabe AS (2011) Kakusan4 and Aminosan: two programs for comparing nonpartitioned, proportional and separate models for combined molecular phylogenetic analyses of multilocus sequence data. Molecular Ecology Resources 11: 914–921. doi: 10.1111/j.1755-0998.2011.03021.x

ZooKeys 207: 65–78 (2012)
doi: 10.3897/zookeys.207.3419
www.zookeys.org

RESEARCH ARTICLE

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

Three new species of *Atopsyche* Banks (Trichoptera, Hydrobiosidae) from Brazil

Allan P. M. Santos[1,2,3,†], Ralph W. Holzenthal[3,‡]

1 *Departamento de Zoologia, Instituto de Biologia, Universidade Federal do Rio de Janeiro, P.O. box 68044, Rio de Janeiro, RJ 21941-971, Brazil* **2** *CAPES Foundation, Ministry of Education of Brazil, Brasília, DF 70040-020, Brazil* **3** *Department of Entomology, University of Minnesota, 219 Hodson Hall, 1980 Folwell Ave., St. Paul, Minnesota, 55108, USA*

† *urn:lsid:zoobank.org:author:FDBB2390-430F-4769-A3A3-E8DD1CF36EBC*
‡ *urn:lsid:zoobank.org:author:C27A1C49-F372-4232-A49C-B8B5F753CC70*

Corresponding author: *Allan P. M. Santos* (a.santos@ufrj.br)

Academic editor: *Christy Geraci* | Received 25 May 2012 | Accepted 20 June 2012 | Published 11 July 2012

urn:lsid:zoobank.org:pub:F391D3A7-0F39-4818-87D7-5AFD9D920C3B

Citation: Santos APM, Holzenthal RW (2012) Three new species of *Atopsyche* Banks (Trichoptera, Hydrobiosidae) from Brazil. ZooKeys 207: 65–78. doi: 10.3897/zookeys.207.3419

Abstract

Three new species of *Atopsyche* Banks (Hydrobiosidae) from Brazil are described and illustrated: *Atopscyhe* (*Atopsaura*) *blahniki* **sp. n.**, *Atopsyche* (*Atopsyche*) *parauna* **sp. n.**, and *Atopsyche* (*Atopsaura*) *galharada* **sp. n.** Additional illustrations of the male genitalia of *A. urumarca* Schmid are provided, including its populational variation. Also, we provide new state records for 2 species: *A.* (*Atopsyche*) *urumarca* from São Paulo, and *A.* (*Atopsaura*) *plancki* Marlier from Santa Catarina.

Keywords

Atlantic forest, *Atopsyche*, Brazil, caddisfly, Hydrobiosidae, Neotropics

Introduction

Atopsyche Banks constitutes the most diverse genus in the family Hydrobiosidae, with over 120 described species (Holzenthal and Cressa 2002, Holzenthal et al. 2007). The genus occurs from the southwestern United States to northern Argentina, but it is replaced by other genera of Hydrobiosidae in the Chilean subregion (Holzenthal and Cressa 2002). Schimd (1989) provided a world revision of the family Hydrobiosidae, including comments on the classification and phylogeny of *Atopsyche* and descriptions of several new species. Currently, 19 species are recorded from Brazil, of which only 2 were recorded after Schmid (1989): *A. chirihuana* Schmid, originally described from Ecuador; and *A. erigia* Ross, originally described from Mexico (Blahnik et al. 2004). Following Schmid (1989), *Atopsyche* species are divided into three subgenera, based on features of the male genitalia: *Atopsaura* Ross, *Atopsyche* Banks, and *Dolochorema* Banks.

In this paper, we describe 3 new species of *Atopsyche* from southeastern Brazil. These additional species bring the number of known caddisflies species from Brazil to 569, but many species of this and other genera remain undescribed. In addition, we illustrate variations in the male genitalia of *A. urumarca* Schmid, and provide new state distributional records of *A. urumarca* from São Paulo and *A. plancki* Marlier from Santa Catarina.

Material and methods

Morphological terminology used in this paper follows that presented by Schmid (1989). The lactic acid method (Blahnik et al. 2007) was used for specimen preparation. Genital structures were observed and illustrated with a compound microscope, equipped with a drawing tube. Pencil sketches were scanned and placed into an Adobe Illustrator (v. 13.0.0, Adobe Systems Inc.) document to produce a digital illustration. Descriptions provided for new species were made using the software DELTA (Dallwitz et al. 1999). Holotypes are deposited in the Museu de Zoologia, Universidade de São Paulo, São Paulo, Brazil (MZSP). Paratypes and other material examined are deposited in the MZSP and also in the University of Minnesota Insect Collection, St. Paul, Minnesota, USA (UMSP), the National Museum of Natural History, Smithsonian Institution, Washington DC, USA (NMNH), and the Coleção Entomológica Prof. José Alfredo Pinheiro Dutra, Universidade Federal do Rio de Janeiro, Rio de Janeiro, Brazil (DZRJ).

Taxonomy

***Atopsyche* (*Atopsaura*) *blahniki* sp. n.**
urn:lsid:zoobank.org:act:17398E47-24AC-45A6-8FEF-CF2B3A9BBFE2
http://species-id.net/wiki/Atopsyche_blahniki
Figs 1, 4, 7

Diagnosis. This new species is most similar to *Atopsyche zernyi* Flint, also described from Brazil. Both species have an apical process on the first article of the inferior append-

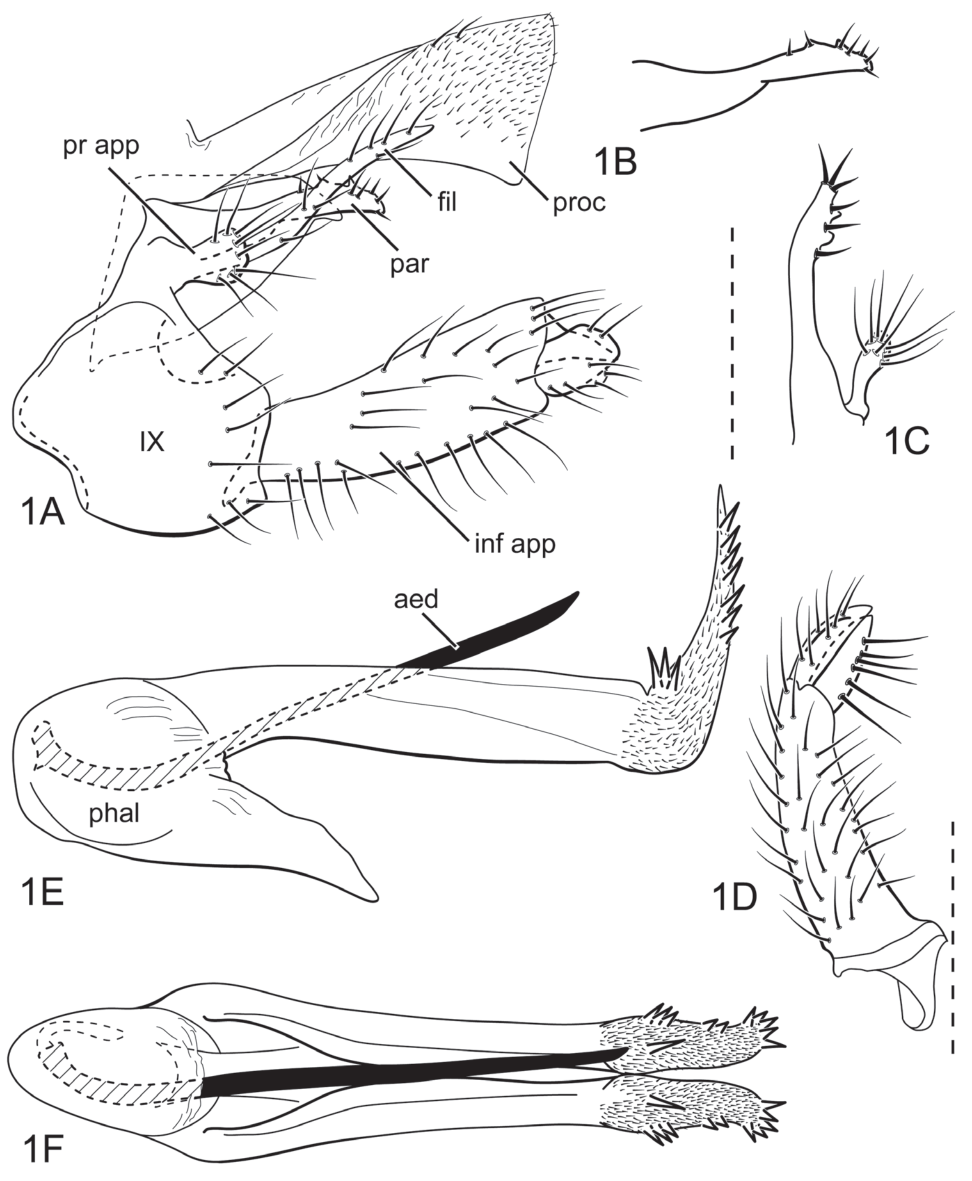


Figure 1. *Atopsyche* (*Atopsaura*) *blahniki* sp. n. Male genitalia: **A** lateral **B** parapod, lateral **C** parapod and preanal appendage, dorsal **D** inferior appendage, ventral **E** phallic apparatus, lateral **F** phallic apparatus, dorsal. Abbreviations: **aed** aedeagus **fil** filipod **inf app** inferior appendage **par** parapod **phal** phallotheca **pr app** preanal appendage **proc** proctiger **IX** abdominal segment IX.

age as long as the second article, and a phallotheca with long paired processes, apically upturned and narrow. However, *Atopsyche blahniki* sp. n. differs from *A. zernyi* by the narrower parapod, longer filipod (exceeding length of parapod), and in the apices of the paired processes from the phallotheca, which bear several spines on their lateral edges.

Male. Forewing length 5.5 mm (n=1). Overall body color brown; antennal scape brown, with long brown setae, pedicel brown, basal flagellomeres yellow, apical flagellomeres brown; setae of palps yellow; frons and vertex of head with long, erect brown and whitish setae; legs yellowish brown, coxae and femora of forelegs darker brown. Forewings brown; erect setae on veins forming irregular pattern of alternate dark brown and yellow setae; apex of wing with fringe of alternating patches of dark brown and yellow setae. Forewing venation complete (Fig. 4A); R1 branched; stem of fork I about twice its length; fork II long, sessile; stem of fork III equal to its length; fork IV long, sessile; stem of M almost straight between m-cu crossvein and first fork of M; fork V long, narrow; Cu2 long, converging near fused anal veins; apex of fused anal veins very short. Hind wing (Fig. 4B) with Sc and R1 fused apically; forks I, III, and V present, the first with a short stem, the last long with a short stem, stem of fork III equal to its length; forks II and IV absent; M3+4 not reaching wing margin; Cu2 long and almost straight; 1A long and sinuate. Nygmas indistinct in both wings. Tergum II with pair of prominent glands at posterolateral margin (Fig. 7A); tergum III with pair of prominent gland at anterolateral margin, lined at opening with minute setae (Figs 7A, 7B). Sternum V with pair of small, rounded glands on anterolateral margins (Fig. 7C). Sterna VI and VII with prominent spine-like ventral processes on posteromesal margins.

Male genitalia. Segment IX, in lateral view, long (Fig. 1A). Parapod narrow, simple, with small dorsolaterally directed tooth-like projections and short, stout setae (Figs 1A, 1B, 1C). Filipod long, slender, with elongate setae along length, apex attenuate (Fig. 1A). Preanal appendage short, rounded, setose (Figs 1A, 1C). Inferior appendage, first article long, slightly widened apically, otherwise relatively narrow and of uniform width, with subtriangular apical process, nearly equaling second article in length (Figs 1A, 1D); second article small, with subacute apex and small rounded carina ventrally (Figs 1A, 1D). Proctiger, in lateral view, broadly widened apically, with truncate apical margin, covered with minute setae, apicodorsal margin with long setae (Fig. 1A). Phallic apparatus complex (Fig. 1E, 1F); phallotheca broadly rounded basally, with narrow ventral process articulating with inferior appendages (Fig. 1E); posteriorly divided into long, paired processes (Fig. 1F); processes apically upturned and narrow, covered with minute setae and bearing spines on lateral edges (Figs 1E, 1F); aedeagus an elongate, stout, spine-like structure, with slight ventral curvature near base (Fig. 1E).

Holotype male. BRAZIL: Rio de Janeiro: Cachoeiras de Macacu, Rio Souza, 16°26.567'S, 42°37.957'W, 150 m, 16.iii.1996, Holzenthal, Rochetti & Oliveira (pinned) (UMSP000031906) (MZSP).

Paratypes. BRAZIL: Rio de Janeiro: same data as holotype, 23 females (pinned) (17 females, UMSP; 2 females, NMNH; 2 females, MZSP; 2 females, DZRJ).

Etymology. This new species is named in honor of Dr. Roger Blahnik, who identified this new species.

***Atopsyche* (*Atopsyche*) *parauna* sp. n.**
urn:lsid:zoobank.org:act:D90947CD-CF4E-44EA-9819-D47E65CCF7F6
http://species-id.net/wiki/Atopsyche_parauna
Figs 2, 5, 8

Diagnosis. This new species is most similar to *A. jaba* Blahnik and Gottschalk, described from Costa Rica. These two species share a similar mesal process on the first article of the inferior appendage and the complex phallotheca, with paired processes posteriorly. *Atopsyche parauna* sp. n. can be distinguished from *A. jaba* and other *Atopsyche* species by the broad parapod, in lateral view, with the dorsolateral margin serrate and with a midlateral spinose projection, whereas in *A. jaba*, the parapod has 2 prominent spines. In addition, the second article of the inferior appendage is shorter and slightly hooked in the new species, and the phallotheca is posteriorly divided into 2 long, paired processes, the dorsal one birfucate apically and the ventral one curved mesally.

Male. Forewing length 5.0–5.5 mm (n=10). Overall body color brown; antennal scape brown, with long stramineous setae, pedicel brown, basal flagellomeres yellow, apical flagellomeres brown; setae of palps yellow; frons and vertex of head with long, erect brown and whitish setae; legs yellowish brown, coxae of all legs darker brown. Forewings brown; erect setae on veins forming distinct mottled pattern of alternate dark brown and yellow setae, with dark brown setae along costal margin; apex of wing with fringe of alternating patches of dark brown and yellow setae. Forewing venation complete (Fig. 5A); R1 branched; stem of fork I equal to its length; fork II long, sessile; stem of fork III equal to its length; fork IV long, sessile; stem of M slightly curved between m-cu crossvein and first fork of M; fork V long, narrow; Cu2 long, converging near fused anal veins, crossvein near apex forming small cell on posterior margin of wing; apex of fused anal veins very short. Hind wing (Fig. 5B) with Sc and R1 fused apically; forks I, III, and V present, the first with a short stem, the last long with a short stem, stem of fork III longer than its length; forks II and IV absent; M3+4 reaching wing margin; Cu2 long and almost straight; 1A long and strongly curved, with row of elongate setae along its length. Nygmas indistinct in both wings. Terga III and IV with pair of prominent rounded glands at anterolateral margin, lined internally with minute setae (Fig. 8A). Sternum V with pair of small rounded glands on anterolateral margins, with a keel-like projection (Fig. 8B). Sterna VI and VII with prominent spine-like ventral processes on posteromesal margins.

Male genitalia. Segment IX, in lateral view, short (Fig. 2A). Parapod broad, with dorsolateral margin serrate, setose, and with small, midlateral spinose projection (Figs 2A, 2B). Filipod long, slender, with elongate setae along length, apex somewhat capitate (Fig. 2A). Preanal appendage short, rounded, setose (Figs 2A, 2B). Inferior appendage, first article long, slightly constricted mesally, otherwise relatively narrow and of uniform width, without apical process, but mesally with small process at midlength, bearing short spines (Figs 2A, 2C); second article small, slightly hooked apically (Figs 2A, 2C). Proctiger, in lateral view, broadly widened apically, with angulate apical mar-

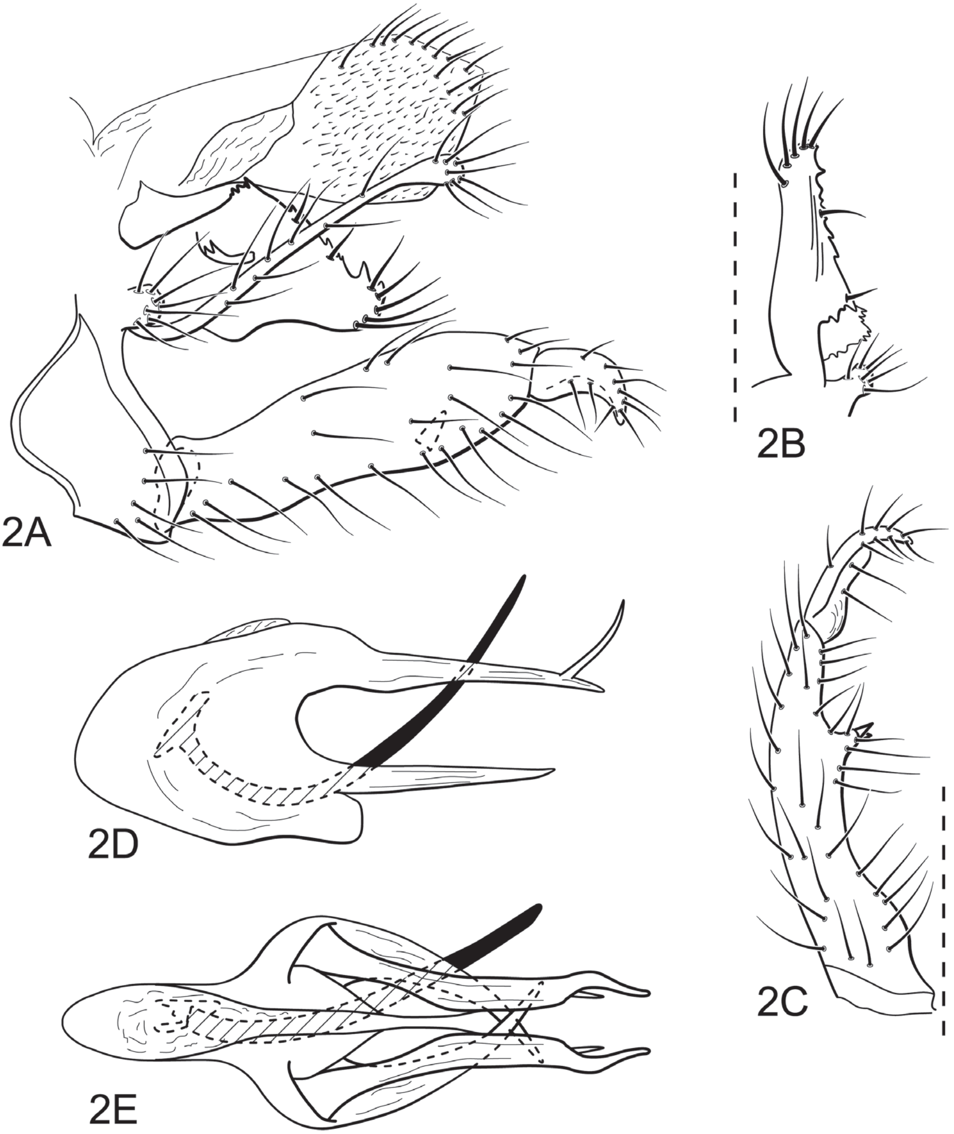


Figure 2. *Atopsyche* (*Atopsyche*) *parauna* sp. n. Male genitalia: **A** lateral **B** parapod and preanal appendage, dorsal **C** inferior appendage, ventral **D** phallic apparatus, lateral **E** phallic apparatus, dorsal.

gin, covered with minute setae, apicodorsal margin with long setae (Fig. 2A). Phallic apparatus complex (Figs 2D, 2E); phallotheca broadly rounded basally, with short rounded ventral process articulating with inferior appendages (Fig. 2D); posteriorly divided into two long, paired processes, dorsal one longer and bifurcate apically, ventral one curved mesally (Figs 2D, 2E); aedeagus an elongate, stout, spine-like structure, with ventral curvature near base (Fig. 2D).

Holotype male. BRAZIL: Minas Gerais: Rio Paraúna, 3 km S Santana do Riacho, 19°10.986'S, 43°43.485'W, 650 m, 11.xi.2001, Holzenthal, Paprocki, Blahnik & Amarante (pinned) (UMSP000080716) (MZSP).

Paratypes. BRAZIL: Minas Gerais: same data as holotype, 2 males, 3 females (pinned) (UMSP); Cardeal Mota, Cachoeira Véu da Noiva, 19°18.912'S, 43°36.260'W, 800 m, 12.xi.2001, Holzenthal, Paprocki, Blahnik & Amarante, 2 males (pinned) (DZRJ); Rio Cipó, Cachoeira de Baixo, 19°20.553'S, 43°38.531'W, 750 m, 10.xi.2001, Holzenthal, Paprocki, Blahnik & Amarante, 3 males (pinned) (2 males, NMNH; 1 male, UMSP).

Etymology. This species is named after the river where the holotype was collected, that means "black river" in the Tupi-guarani language.

***Atopsyche* (*Atopsaura*) *galharada* sp. n.**

urn:lsid:zoobank.org:act:4664284A-65D7-4F52-8ADB-8E66C1EAF4C2
http://species-id.net/wiki/Atopsyche_galharada
Figs 3, 6, 9

Diagnosis. This is a distinctive new species in the genus, belonging to the *A. longipennis* Ulmer group of the subgenus *Atopsaura*. *Atopsyche galharada* sp. n. resembles *A. ayahuaca* Schmid and *A. plancki* Marlier in the absence of filipods and in the simple phallotheca. The new species can be distinguished from the others by the broader parapod with 2 carinas bearing tooth-like processes. The new species and *A. plancki* are similar in the short and broad first article of the inferior appendage, with an apical process, but in the new species this process is longer and the second article of the inferior appendage is broad in ventral view, and slightly hooked in lateral view. Also, *A. galharada* has the proctiger with a broad lateral sclerotized projection, and the phallotheca posteriorly divided into long, paired flangelike processes, broadest subapically, in dorsal view.

Male. Forewing length 6.5–7.5 mm (n=23). Overall body color brown; antennal scape light brown, with long stramineous setae, pedicel brown, basal flagellomeres yellow, apical flagellomeres brown; setae of palps dark brown; frons and vertex of head with long, erect stramineous setae; legs yellowish brown, coxae of all legs darker brown. Forewings brown; erect setae on veins forming irregular pattern of alternate dark brown and yellow setae, with dark brown setae along costal margin; apex of wing with fringe of alternating patches of dark brown and yellow setae. Forewing venation complete (Fig. 6A); R1 branched; stem of fork I equal to its length; fork II long, sessile; stem of fork III equal in length to stem of fork I; fork IV long, sessile; stem of M slightly curved between m-cu crossvein and first fork of M; fork V long, narrow; Cu2 long, converging near fused anal veins, crossvein near apex forming small cell on posterior margin of wing; apex of fused anal veins very short. Hind wing (Fig. 6B) with Sc and R1 fused apically; forks I, III, and V present, the first with a short stem, the last long with a short stem, stem of fork III equal to its length; forks II and IV absent; M3+4 reaching wing margin; Cu2 long and almost straight; 1A long and sinuate. Nygmas

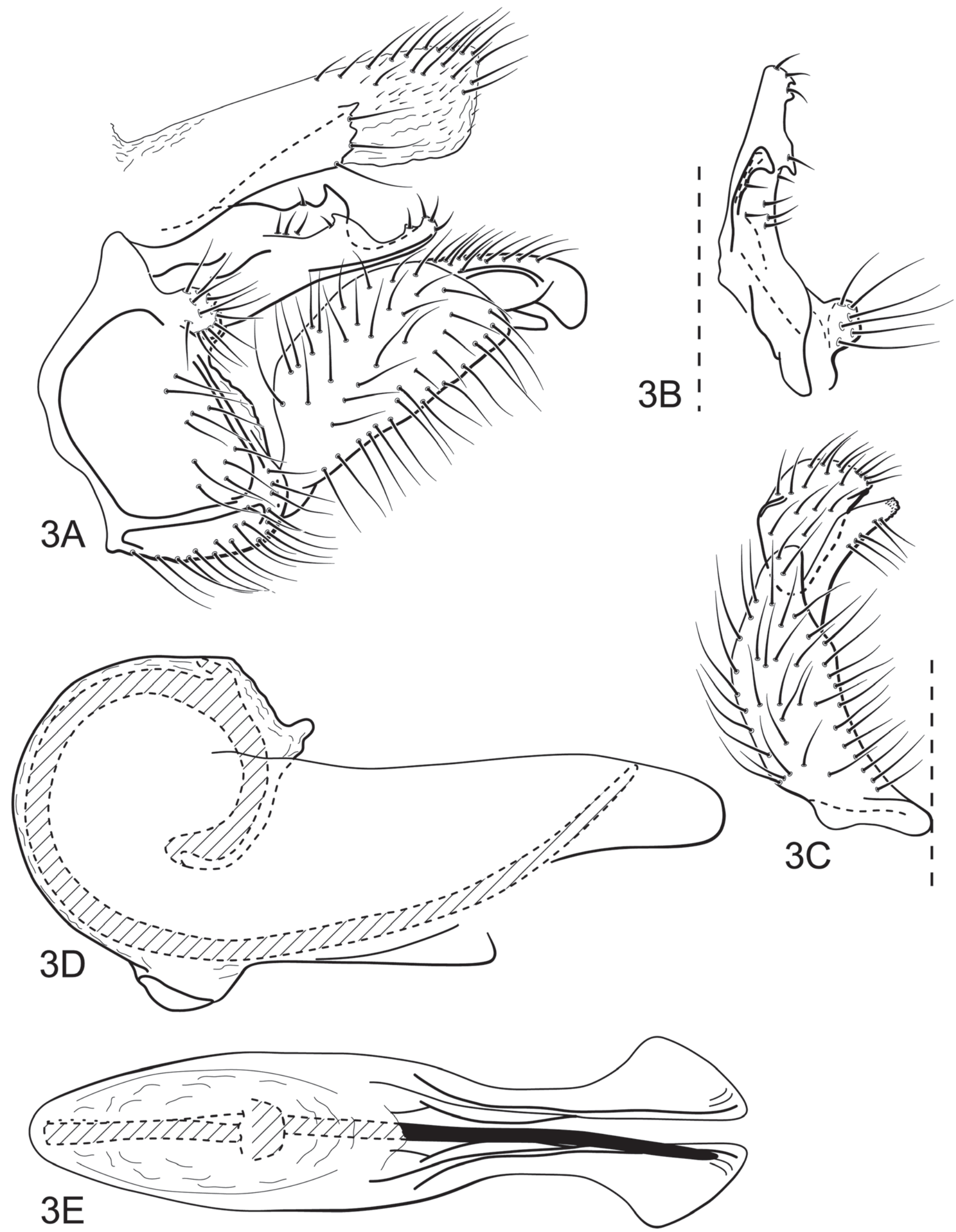
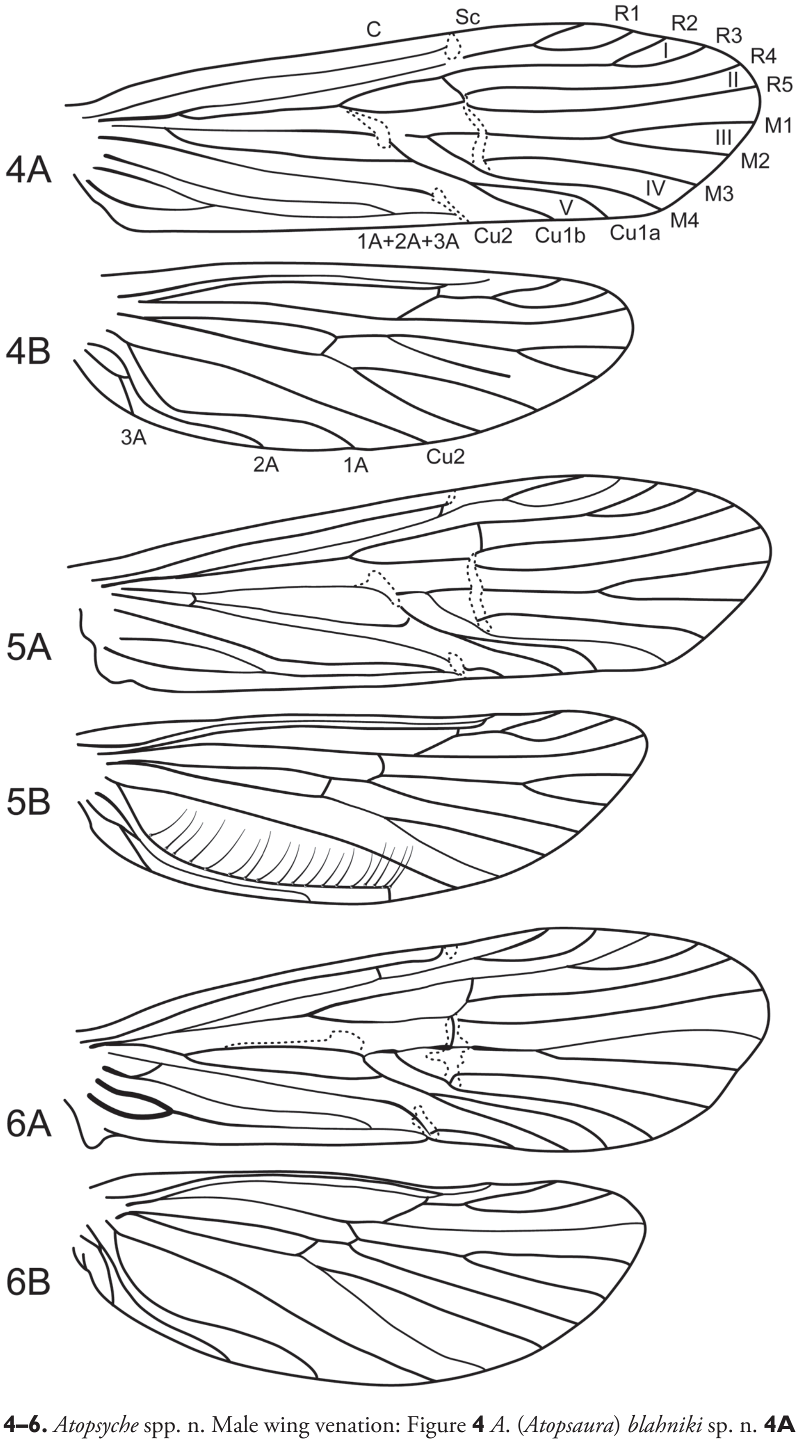
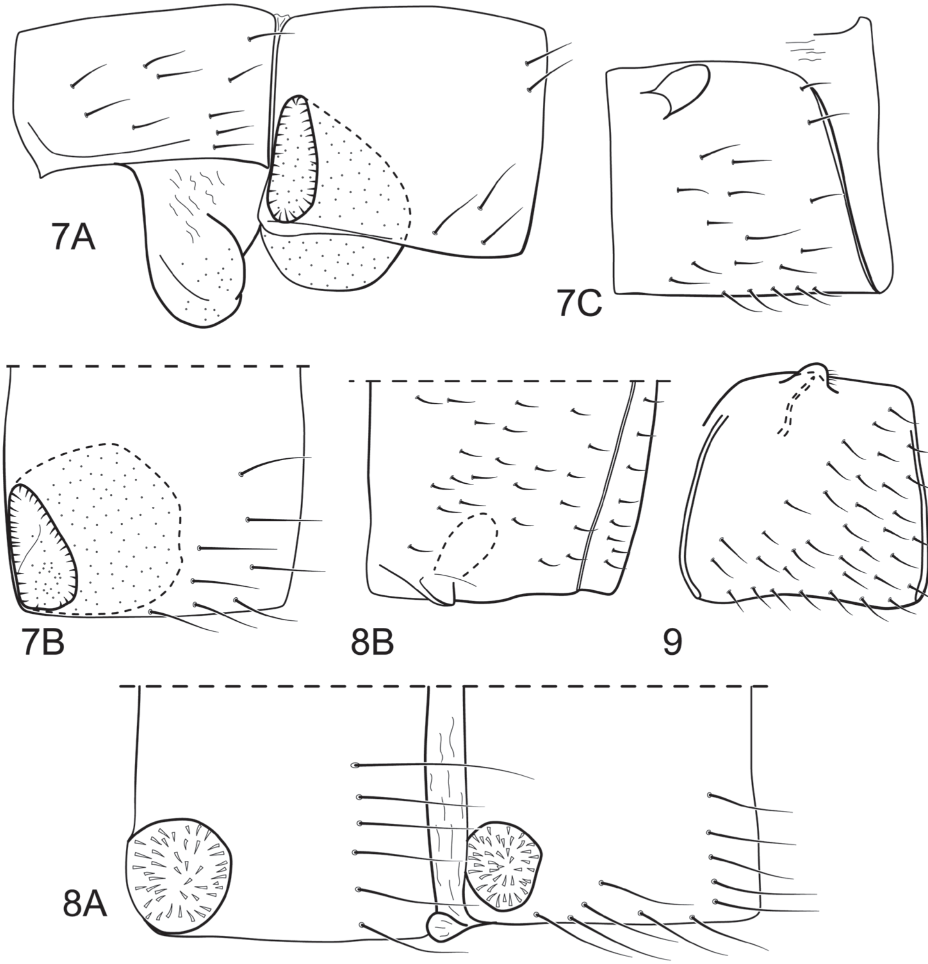


Figure 3. *Atopsyche* (*Atopsaura*) *galharada* sp. n. Male genitalia: **A** lateral **B** parapod and preanal appendage, dorsal **C** inferior appendage, ventral **D** phallic apparatus, lateral **E** phallic apparatus, dorsal.

indistinct in both wings. Sternum V with pair of small rounded glands on anterolateral margins, with a keel-like projection (Fig. 9). Sterna VI and VII with prominent spine-like ventral processes on posteromesal margins.



Figures 4–6. *Atopsyche* spp. n. Male wing venation: Figure **4** *A.* (*Atopsaura*) *blahniki* sp. n. **4A** forewing **4B** hind wing. Figure **5** *A.* (*Atopsyche*) *parauna* sp. n. **5A** forewing **5B** hind wing. Figure **6** *A.* (*Atopsaura*) *galharada* sp. n. **6A** forewing **6B** hind wing.



Figures 7–9. *Atopsyche* spp. n. Abdominal glands: Figure **7** *A.* (*Atopsaura*) *blahniki* sp. n. **7A** terga II and III, lateral **7B** tergum III, dorsal **C** sternum V, lateral. Figure **8** *A.* (*Atopsyche*) *parauna* sp. n. **8A** terga III and IV, dorsal **8B** sternum V, ventral. Figure **9** *A.* (*Atopsaura*) *galharada* sp. n., sternum V, lateral.

Male genitalia. Segment IX, in lateral view, long (Fig. 3A). Parapod broad basally, narrow apically, with two carinas bearing tooth-like processes along dorsolateral edges and short, stout setae (Figs 3A, 3B). Filipod absent (Fig. 3A). Preanal appendage short, rounded, setose (Figs 3A, 3B). Inferior appendage, first article short, uniformly broad, with narrow apical process, nearly equaling second article in length (Figs 3A, 3C); second article large, bulging basally and downturned apically, in ventral view, broad (Figs 3A, 3C). Proctiger, in lateral view, uniformly wide, with broad lateral sclerotized projection and truncate apical margin, covered with minute setae, apicodorsal margin with long setae (Fig. 3A). Phallic apparatus simple (Figs 3D, 3E); phallotheca broadly rounded basally, not articulating with inferior appendages (Fig. 3D); posteriorly divided into long, paired flangelike processes, broadest subapically, in dorsal view (Fig. 3E); aedeagus an elongate, stout, spine-like structure, with strong basal loop (Fig. 3D).

Holotype male. BRAZIL: São Paulo: Campos do Jordão, Parque Estadual de Campos do Jordão, Rio Galharada, 22°41.662'S, 45°27.783'W, 1530 m, 4–5.iii.1996, Holzenthal & Guahyba (pinned) (UMSP000031880) (MZSP).

Paratypes. BRAZIL: São Paulo: same data as holotype, 2 females (pinned) (MZSP); same data, except 22.i.1998, Holzenthal, Froehlich & Paprocki,17 females (pinned) (UMSP); same data, except 13–15.ix.2002, Blahnik, Prather, Melo, Huamantinco, 1 male, 3 females (alcohol) (UMSP); Parque Estadual de Campos do Jordão, Campo do Meio, 22°41.750'S, 45°29.448'W, 1500 m, 21.i.1998, Holzenthal, Froehlich & Paprocki, 2 females (pinned) (UMSP); same data, except 6.iii.1996, Holzenthal & Guahyba, 1 male, 2 females (pinned) (NMNH); Rio Casquilho, 3.4 km NE Parque Estadual de Campos do Jordão, 22°40.29'S, 45°27.87'W, 1550 m, 23.1.1998, Holzenthal, Froehlich & Paprocki, 18 males, 39 females (pinned) (15 males, 34 females, UMSP; 3 males, 5 females, DZRJ); Ribeirão do Casquilho, Bosque Vermelho, ca. 5 km Parque Estadual de Campos do Jordão, 22°40'S, 45°27.5'W, 1435 m, 16.ix.2002, Blahnik, Prather, Melo & Huamantinco, 3 males (UMSP).

Etymology. This species is named after the river where holotype was collected.

***Atopsyche* (*Atopsyche*) *urumarca* Schmid**

http://species-id.net/wiki/Atopsyche_urumarca
Figs 10

Atopsyche (*Atopsaura*) *urumarca* Schmid, 1989: 131 [type locality: Brazil, Serra do Cipó, Rio Capivara; MZSP; male].

Diagnosis. *Atopsyche urumarca* Schmid was described from Minas Gerais state, Brazil, and placed in the *A. bolivari* Banks group. According to Schimid (1989), *A. urumarca* is most similar to *A. pachacutec* Schmid, especially in the form of the parapod and the apex of the phallotheca, but they differ in the structure of the second article of the inferior appendage. We have examined material from southeastern Brazil, including the type locality, and we found an interesting populational variation in the male genitalia structure. This variation is noticeable in the shape of the parapod and the apex of phallotheca. In all specimens, the parapod, in lateral view, is broad basally, with an oblique, mesal U-shaped incision, but this incision is deepest in specimens collected in Ipoema, Minas Gerais state, and shallow in specimens from São Paulo state; the parapod also can end in a narrow and rounded apex or bear a small, dorsal spine. The phallotheca is broadly rounded basally, with 3 paired processes posteriorly, the dorsal one long and broad, with small dorsal and ventral projections at its apex. Some specimens have a small, additional spine-like process on the posterior margin of this dorsal process, and the ventral margin can be rounded, slightly pointed, or pointed and hooked apically.

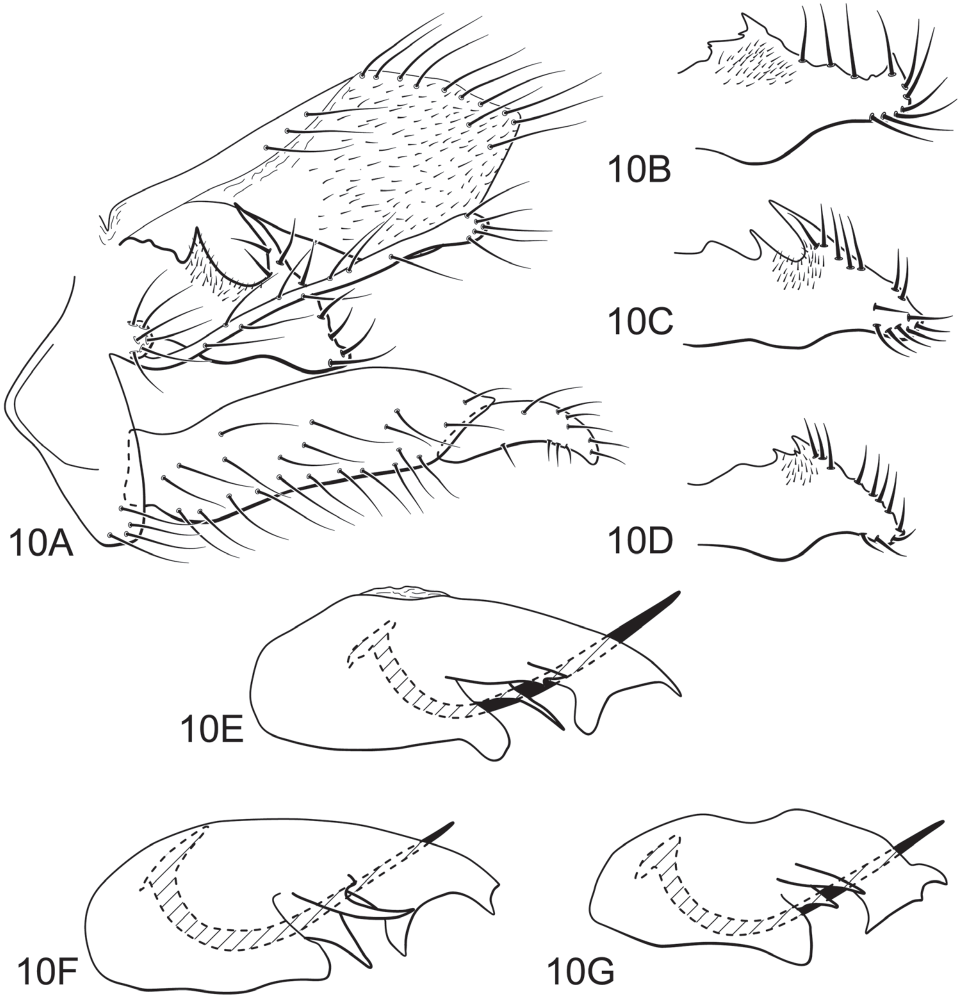


Figure 10. *Atopsyche* (*Atopsyche*) *urumarca* Schmd. Variation in male genitalia. **A** lateral, specimen from Ipoema, Minas Gerais **B–D** parapod, lateral **B** specimen from Serra do Cipó, Minas Gerais **C** specimen from Morro do Pilar, Minas Gerais **D** specimen from Altinópolis, São Paulo **E–G** phallic apparatus, lateral **E** specimen from Ipoema **F** specimen from Morro do Pilar **G** specimen from Altinópolis.

Material examined. BRAZIL: Minas Gerais: Serra do Cipó, Rio Capivara, 19°20.553'S, 43°38.531'W, 950 m, 11.ii.1998, Holzenthal & Paprocki, 2 males (pinned) (UMSP); Serra do Cipó, trib. to Rio Capivara, 19°14.396'S, 43°34.939'W, 1000 m, 18.ii.1998, Holzenthal & Paprocki, 3 males (pinned) (MZSP); Rio Tanque, ca. 12 km (rd) from Ipoema, 19°32.208'S, 43°26.878'W, 750 m, 16.v.1998, Holzenthal & Paprocki, 2 males, 1 female (pinned) (DZRJ); Rio Santo Antônio, downstream from Morro do Pilar, 19°08.134'S, 43°21.256'W, 530 m, 17.x.2000, Paprocki & Ferreira, 1 male (pinned) (UMSP); P.E. de São Gonçalo do Rio Preto, Rio Preto, 18°07.841'S, 43°20.246'W, 791 m, 12.x.2000, Paprocki, Amarante, Salgado, 1 male (alcohol) (UMSP); **São Paulo:** Altinópolis, Cachoeira dos Macacos, 20°55.390'S, 47°22.758'W, 758 m, 18.xi.2003, Holzenthal, Paprocki & Calor, 27 males, 15 females (pinned) (UMSP), 9 males, 1 female (alcohol) (DZRJ); Altinópolis, Fazenda São João da Mata, Rio Baguassu, 21°00.588'S, 47°28.900'W, 745 m, 19–21.xi.2003, Holzenthal, Paprocki & Calor, 8 male, 17 females (pinned) (3 males, 5 females, NMNH; 5 males, 12 females, UMSP), 28 males (alcohol) (UMSP); Pedregulho, Sítio Bruninho, 20°09.240'S, 47°30.704'W, 630 m, 17.xi.2003, Holzenthal, Paprocki & Calor, 1 male, 1 female (pinned) (UMSP); Pedregulho, Ribeirão São Pedro, 20°09.113'S, 47°30.626'W, 617 m, 16.ix.2003, Holzenthal, Paprocki, Calor, 1 male (alcohol) (UMSP).

***Atopsyche* (*Atopsaura*) *plancki* Marlier**
http://species-id.net/wiki/Atopsyche_plancki

Atopsyche (*Atopsaura*) *plancki* Marlier 1964: 2 [type locality: Brazil, São Paulo; IRSNB; male] - Blahnik et al. 2004: 4 [distribution; Brazil: Minas Gerais and Rio de Janeiro states]

Material examined. BRAZIL: Santa Catarina: Parque Ecológico Spitzkopf, confl. Rio Ouro & Rio Caeté, 27°00.352'S, 49°06.693'W, 140 m, 25.xi.2003, Holzenthal, Paprocki, Calor, 1 male (alcohol) (UMSP).

Acknowledgments

We are grateful to Dr. Roger Blahnik for assistance in the laboratory and important comments on this manuscript. We also are grateful to Adolfo Calor, Adriano Melo, Claudio Froehlich, and Henrique Paprocki for field assistance. APMS was supported by fellowship (PDSE 0085/12-0) from CAPES Foundation (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior), Ministry of Education of Brazil. This material is based on work supported by National Science Foundation grant no. DEB 9971885.

References

Blahnik RJ, Paprocki H, Holzenthal RW (2004) New distributional and species records of Trichoptera from southern and southeastern Brazil. Biota Neotropica 4: 1–6.

Blahnik RJ, Holzenthal RW, Prather A (2007) The lactic acid method for clearing Trichoptera genitalia. In: Bueno-Soria J, Barba-Alvarez R, Armitage B (Eds) Proceedings of the XIIth International Symposium on Trichoptera. The Caddis Press, Columbus, Ohio, 9–14.

Dallwitz MJ, Paine TA, Zurcher EJ (1999) User's guide to the DELTA Editor. http://deltaintkey.com/ [accessed 4 May 2012]

Flint OS Jr (1970) Studies of Neotropical caddisflies, X: *Leucotrichia* and related genera from North and Central America (Trichoptera: Hydroptilidae). Smithsonian Contributions to Zoology 60: 1–64. doi: 10.5479/si.00810282.60

Holzenthal RW, Cressa C (2002) The Trichoptera, caddisflies, of Venezuela: three new species and records of *Atopsyche* Banks (Hydrobiosidae). Studies on Neotropical Fauna and Environment 37: 133-143. doi: 10.1076/snfe.37.2.133.8578

Holzenthal RW, Blahnik RJ, Prather AL, Kjer KM (2007) Order Trichoptera Kirby, 1813 (Insecta), Caddisflies. Zootaxa 1668: 639–698.

Marlier G (1964) Sur trois Trichopteres nouveaux recueillis en Amerique du Sud par le Professeur J. Illies. Bulletin de l'Institut Royal des Sciences Naturelles de Belgique 40: 1–15.

Schmid F (1989) Les Hydrobiosides (Trichoptera, Annulipalpia). Bulletin de l'Institut Royal des Sciences Naturelles de Belgique 59 (supplement): 1–54.

ZooKeys 207: 79–84 (2012)
doi: 10.3897/zookeys.207.3522
www.zookeys.org

SHORT COMMUNICATION

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

A new combination expands the range of the African araneid spider *Singafrotypa* (Araneae, Araneidae)

Anna Šestáková[1,2], Mikhail M. Omelko[3,4]

1 *Zoological Museum, University of Turku, FI-20014, Turku, Finland* **2** *Department of Zoology, Faculty of Natural Sciences, Comenius University, Mlynská dolina, 84215 Bratislava, Slovakia* **3** *Far Eastern Federal University, Sukhanova, 8, Vladivostok 690950 Russia* **4** *Gornotaezhnaya Station FEB RAS, Gornotaezhnoe Vil., Ussuriyski Dist., Primorski Krai 692533 Russia*

Corresponding author: *Anna Šestáková* (asestakova@gmail.com)

Academic editor: *Yuri Marusik* | Received 13 June 2012 | Accepted 4 July 2012 | Published 11 July 2012

Citation: Šestáková A, Omelko MM (2012) A new combination expands the range of the African araneid spider *Singafrotypa* (Araneae, Araneidae). ZooKeys 207: 79–84. doi: 10.3897/zookeys.207.3522

Abstract

Study of the syntype of *Larinioides subinermis*, a species known from Ethiopia only, revealed that it actually belongs to *Singafrotypa* Benoit, 1962. We redescribe *Singafrotypa subinermis* (Caporiacco, 1940), **comb. n.**, and provide a key to females of four species belonging to *Singafrotypa*. A distribution map for all species is provided.

Keywords

Larinioides subinermis, *Singafrotypa*, redescription, taxonomy, spider, Africa

Introduction

The small African orb-weaver genus *Singafrotypa* was found to be restricted to western, southern and central Africa (Fig. 14). It presently contains 3 species: *S. acanthopus* (Simon, 1907), *S. mandela* Kuntner & Hormiga, 2002 and *S. okavango* Kuntner & Hormiga, 2002 (Kuntner and Hormiga 2002). Examination of syntypes of *Larinioides subinermis* revealed its generic affinity to *Singafrotypa* and therefore expands the known diversity of this genus. Except for the original description based on a female, it was considered in two further taxonomic publications by Grasshoff (1970, 1983) who examined the types. Grasshoff (1970) indicated that *L. subinermis* belonged to Cyclosini, although *Larinioides* is a member of Araneini (Grasshoff 1983) he did not make any formal transfer. When Grasshoff returned the types to MZUF he noted that the species actually belonged to *Singafrotypa* Benoit, 1962 and considered it as a junior synonym of *S. acanthopus* (Simon, 1907) (Berdondini and Whitman 2002).

Our study of a syntype of *Larinioides subinermis* showed that Grasshoff's informal synonymy was not correct. This became evident after studying the recently published revision of *Singafrotypa* by Kuntner and Hormiga (2002). Although *L. subinermis* is rather similar to *S. acanthopus*, the type species of the genus, it has clear differences.

In this paper we redescribe *Larinioides subinermis* and propose a new combination as *Singafrotypa subinermis* (= *Larinioides s.*), comb.n.

Material and methods.

Photographs were made with an Olympus Camedia E-520 camera attached to an Olympus SZX16 stereomicroscope at the Zoological Museum, University of Turku. Digital images were montaged using "CombineZP" image stacking software. Examined material is deposited in Museo Zoologico "La Specola" dell'Universita di Firenze, Florence, Italy (MZUF). The terminology of epigynal morphology follows Kuntner & Hormiga (2002). All measurements are in millimetres.

Abbreviations: BL – basal lamella of epigyne; CO – copulatory openings; EB – epigynal base; LL – lateral lamella of epigyne; MP – median plate of epigyne; SC – scapus.

Taxonomy

Singafrotypa Benoit, 1962

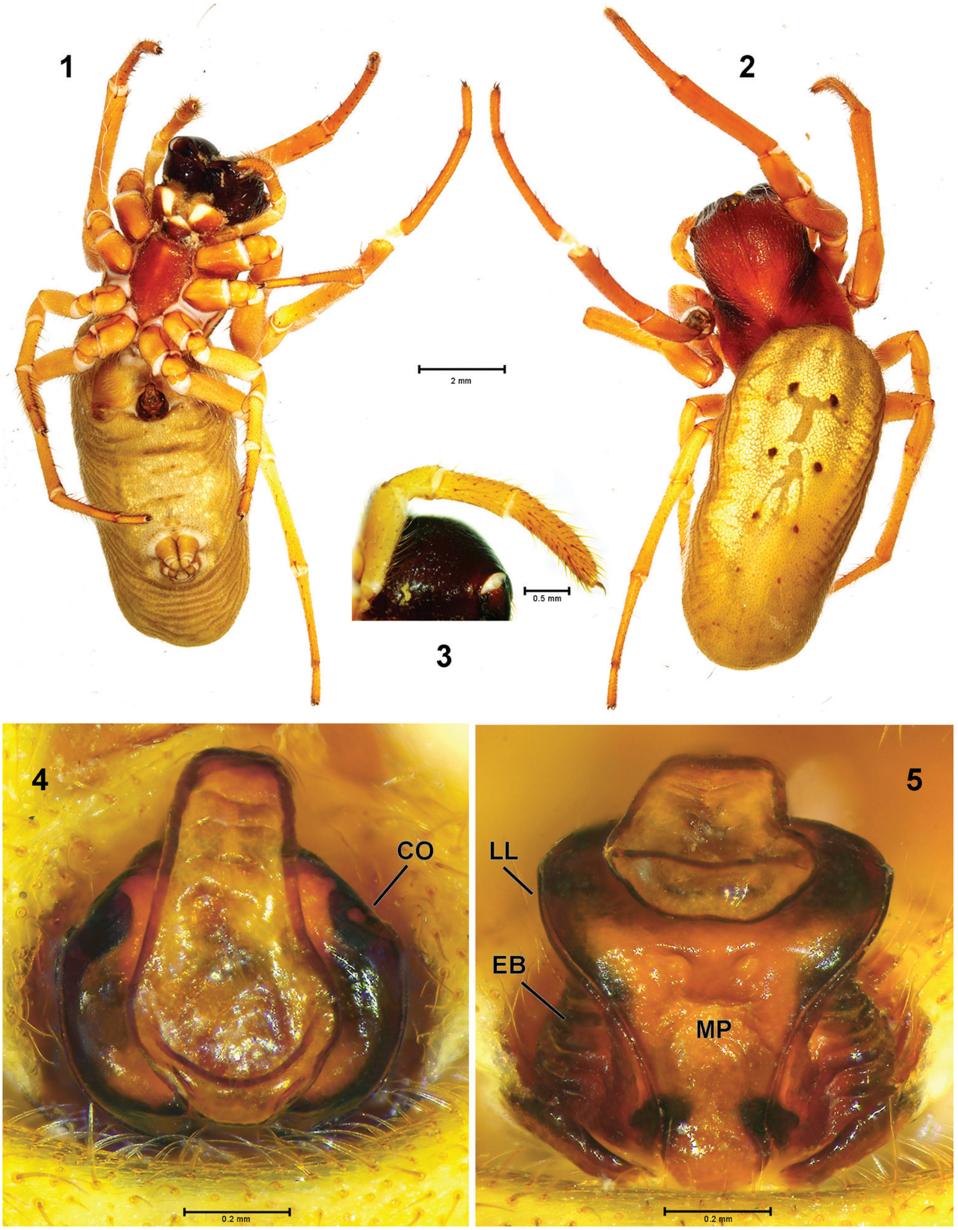
Singafrotypa subinermis (Di Caporiacco, 1940), comb. n.

http://species-id.net/wiki/Singafrotypa_subinermis
Figs 1–5, 9, 13

Larinioides s. Di Caporiacco 1940: 821, f. 28 (♀).

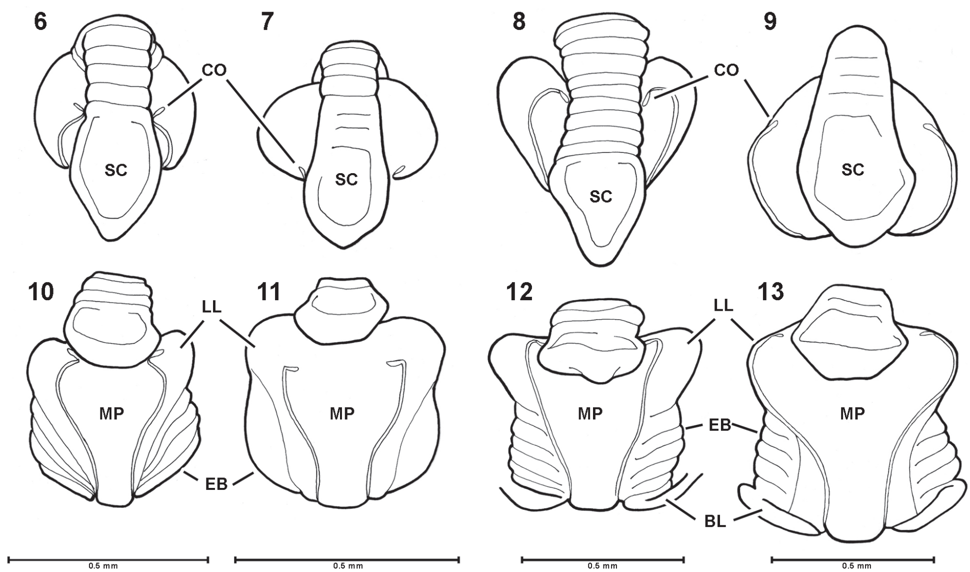
Material. 1♀ Syntype, Coll N°72, Mag. N°2581, Ethiopia, Lago Regina Margherita on island, 16.1,1938 (L. Di Capporiacco)

Diagnosis. *Singafrotypa subinermis* can be recognized from other females of *Singafrotypa* by the relative proportion of the scapus to the epigynal base (ventral view) – tip of the scapus only slightly protruding over the base of the epigyne, and position of copulatory openings on the edge of the epigynal base (Figs 6–9). Unlike *S. oka-*



Figures 1–5. Female of *Singafrotypa subinermis*. **1** ventral **2** dorsal **3** pedipalp, retrolateral **4** epigyne, dorsal **5** ibid., posterior.

vango, it does not have a heart-shaped epigynal base and a long, distinctly wrinkled scapus (Figs 8, 12). It differs from *S. mandela* by the absence of stout macrosetae on the palpal tarsus and paturon, a conical palpal tarsus (Kuntner and Hormiga 2002),



Figures 6–13. Epigynes of *Singafrotypa*. **6, 10** *S. acanthopus* **7, 11** *S. mandela* **8, 12** *S. okavango* **9, 13** *S. subinermis* **6–9** epigyne, dorsal **7–13**, ibid., posterior (Figs **6–8, 7–12** redrawn with permission, after Kuntner and Hormiga 2002).

and in the shape of the epigynal base (Figs 7, 11). The epigyne of *S. subinermis* is the most similar to *S. acanthopus* (Figs 6, 10), but it differs from latter by having fewer wrinkles on the scapus with a round tip (triangular in *S. acanthopus*), and the shallow depression of the median plate without protruding lateral lamellae (Figs 9, 13).

Description. Female. Total length 11.6. Carapace 4.2 long, 3.2 wide. Length of patella + tibia I 3.8. Carapace uniform red-brown, covered with small white hairs; cephalon protruding. Diameter of AME is 1.3 times larger than PME. Distance between AME 2 times longer than between PME. Chelicerae dark brown; 4 promarginal teeth, 3 retromarginal teeth. Sternum, brown, anteriorly in the middle with short, indistinct pale stripe; longer than wide (Fig. 1). Abdomen elongated, yellowish with two longitudinal brown stripes (Fig. 2), ventrally yellow, paler between epigastric furrow and spinnerets (Fig. 1). Legs yellow. Palp normal, no conical tarsus (Fig. 3). Femur I with 1 prolateral spine; 3 small, dorsal spines; no retrolateral spines.

Epigyne as in Figs 4, 5, 9, 13. Epigyne well sclerotized, protruding, with well developed scapus; epigynal base as wide as long, narrowing anteriorly (dorsal view); basal lamella thin, poorly developed; median plate with shallow depression (under scapus); copulatory openings located anteriorly on the edge of the base; flexible scapus almost as long as epigynal base, indistinctly wrinkled with a round tip (Figs 4, 9).

Distribution. Only known from the type locality, islands of Lake Abaya in Ethiopia (Fig. 14). *Singafrotypa subinermis* is the easternmost species of the genus.

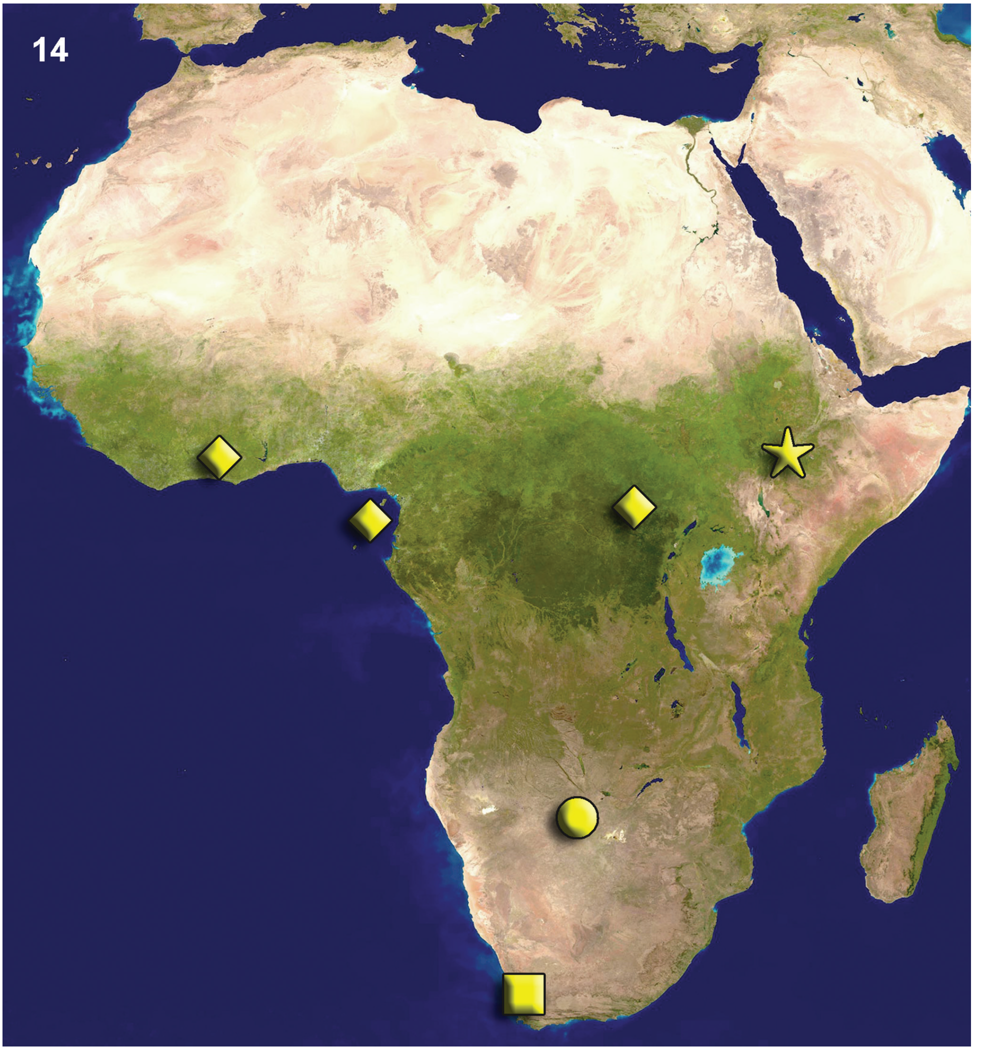


Figure 14. Distribution of the species of *Singafrotypa* (after Kuntner & Hormiga 2002 with additional locality of *S. subinermis*). (http://upload.wikimedia.org/wikipedia/en/2/21/Africa_satellite_orthographic.jpg) ♦ *S. acanthopus* ■ *S. mandela* ● *S. okavango* ★ *S. subinermis*.

Key for females of *Singafrotypa*

1	Epigynal base (ventral) oval or round	**2**
–	Epigynal base heart-shaped; long wrinkled scapus (Figs 8, 12)	***S. okavango***
2	Copulatory openings in the middle or more anteriorly on epigynal base (ventral); epigynal base (ventral) as wide as long; palpal tarsus not conical; chelicerae and palpal tarsus without stout macrosetae	**3**

– Copulatory openings posteriorly on epigynal base; epigynal base wider than long (Figs 7, 11); stout short macrosetae on palpal tarsus, and laterally on paturon..***S. mandela***

3 Scapus with many wrinkles, protrudes over epigynal base (ventral); copulatory openings in the middle of epigynal base (ventral); deep depression of median plate anteriorly with protruding lateral lamellae (posterior) (Figs 6, 10) .... ***S. acanthopus***

– Scapus with few wrinkles, does not protrude over epigynal base; copulatory openings anteriorly on epigynal base (ventral); shallow depression of median plate without protruding lateral lamellae (posterior) (Figs 9, 13)................... ....***S. subinermis***

Acknowledgements

We thank Sarah Whitman and MZUF for loaning the type material, Matjaž Kuntner for his help in confirming material and permission to redraw figures of epigynes. Special thanks go to Seppo Koponen who allowed us to use equipment in the Zoological Museum of the University of Turku. Last but not least, we thank Yuri M. Marusik who edited the manuscript and supported the visit of Anna Šestáková to Turku, reviewers for their valuable comments, Victor Fet who checked the English of an earlier draft and David Penney for the final correction of this manuscript.

References

Berdondini I, Whitman S (2002) Cataloghi del Museo di Storia Naturale dell'Università di Firenze – sezione di zoologia "La Specola". XVI. Arachnida, Araneae: Tipi. Atti della Società Toscana di Scienze Naturali. Memorie. Serie B. 109: 119–156.

Grasshoff M (1970) Die Tribus Mangorini. I. Die Gattungen *Eustala*, *Larinia* s. str., *Larinopa* n. gen. (Arachnida: Araneae: Araneidae-Araneinae). Senckenbergiana biologica 51: 209–234.

Grasshoff M (1983) *Larinioides* Caporiacco 1934, der korrekte Name für die sogenannte *Araneus cornutus*-Gruppe (Arachnida: Araneidae). Seckenbergiana biologica 64: 225–229.

Kuntner M, Hormiga G (2002) The African spider genus *Singafrotypa* (Araneae, Araneidae). Journal of Arachnology 30: 129–139. doi: 10.1636/0161-8202(2002)030[0129:TASGSA]2.0.CO;2

Platnick NI (2012) The world spider catalog, Version 12.5. American Museum of Natural History, New York. http://research.amnh.org/iz/spiders/catalog/ [accessed 30 May 2012]