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A new species of *Hemichela* Stock, 1954 from the South China Sea (Arthropoda, Pycnogonida, Ammotheidae)

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Abstract

A new species of pycnogonid collected by the Chinese research vessel, R/V HY IV, during deep sea cruises to the South China Sea in 2013, is described. The new species, *Hemichela nanhaiensis*, obtained from more than 1300 m depth, is distinguished from the other two species in the genus by the characters of the chela dactylus with 12 denticulations on the inner margin and by the presence of taller tubercles on the lateral processes.

Keywords

Deep sea, South China Sea, Pycnogonida, *Hemichela*

Introduction

Stock (1954) established the new genus *Hemichela* based on the presence of a single dactylus on the chela, segregating it from the closely-related genus *Paranymphon* and he then described *Hemichela micrasterias* the type species of the new genus. According to Bamber et al. (2015) the genus includes two named species to date, *H. micrasterias* Stock, 1954 and *Hemichela longiunguis* Staples, 1982, both from western Pacific localities only. *Hemichela micrasterias* has been found in Indonesia (Stock 1954; Nakamura and Child 1990), Philippines (Child 1988b) and Japan (Nakamura and Child 1991) at a depth range of 20–657 meters. *Hemichela longiunguis* is only known from Queensland, Australia, at depths shallower than 5.8 m (Staples 1982).

A re-examination of the types of both of these species by Stock (1985) corrected certain characteristics inadvertently overlooked in his initial description (Stock 1954). Nakamura and Child (1990) demonstrated differences between *H. micrasterias* from the Flores Sea and the holotype, and described the sub-adult and juvenile stages of this species. Bamber (1992) summarized the localities where these species have been found, and discovered evidence for Child's (1983, 1988a) zoogeographic 'corridor' from the Antipodes to Japan.

The Pycnogonida from the islands off the western Pacific coast of China have been summarized by Bamber (1992). Japanese collections were covered by Nakamura and Child (1988a, b, 1990), and Child produced a notable series on the pycnogonids from the western Pacific Islands (1982, 1983, 1988b, 1989, 1990, 1991, 1995, 1996a, b, 1998, 1999). However, despite the long coastlines and numerous islands, pycnogonids from China have been generally poorly studied. Lou (1936a, b) described the sea spiders taken from Yantai and Jiaozhou bays. Bamber (1992, 2004, 2008) and Bamber and Morton (1997) published on the pycnogonids of the South China Sea, Taiwan, and Hong Kong. Huang and Lin (2012) illustrated 13 species recorded in the seas adjacent to China. Compared with the work completed in neighboring seas as have, for example, Nakamura and Child (1991) in Japan, Hong and Kim (1987) in Korea, and Stock (1991) in the Philippines, research on the pycnogonids of China seas are still insufficient.

During 2013, research, including benthic surveying, water sampling, and grabbing for biological and geological specimens, was carried out by the Chinese research vessel R/V HY IV in a cruise to the South China Sea. At station DS06-13, one specimen of Pycnogonida was found representing a new species of *Hemichela* together with other benthic invertebrates such as *Chaetozone setosa* Malmgren, 1867 (Annelida: Polychaeta: Cirratulidae), *Pseudosphyrapus anomalus* (Sars, 1869) (Arthropoda: Malacostraca: Sphyrapodidae), *Asellus* sp. (Arthropoda: Malacostraca: Asellidae), *Eriopisella sechellensis* (Chevreux, 1901) (Arthropoda: Malacostraca: Eriopisidae) and *Grandidierella* sp. (Arthropoda: Malacostraca: Aoridae).

Material and methods

The specimen was collected by a box-core and sorted from the other benthic fauna and sediments from Station DS06-13 and it is conserved as the holotype at the Third Institute of Oceanography, State Oceanic Administration, China (No. DS06-13-01). The specimen was drawn using a *camera lucida* and photographs were made with an Automontage system on a Leica M205 FA stereomicroscope. Measurements were made axially, dorsally for the trunk, laterally for the palp, proboscis and leg, and are given in millimeters.

Systematics

Class Pycnogonida Latreille, 1810
Order Pantopoda Gerstäcker, 1863
Suborder Eupantopodida Fry, 1978
Superfamily Ascorhynchoidea Pocock, 1904
Family Ammotheidae Dohrn, 1881
Genus *Hemichela* Stock, 1954

***Hemichela nanhaiensis* sp. n.**
http://zoobank.org/8E0715B3-D42F-4CC1-8F4C-0FA3188A0ED8
Fig. 1

Material examined. One male, holotype (DS06-13-01), Station DS06-13, South China Sea, 21.95°N 118.81 °E, 1317.5 m depth, BC, 5 May 2013.

Diagnosis. Trunk slender, lateral processes with a single distal dorsal tubercle and armed with pedunculate asterisk-shaped setae. Ocular tubercle long with bifurcate tip (Fig. 1A, B). Chela dactylus bearing 12 denticulations on the inner margin (Fig. 1C). Palps seven-articled, second article with a conical outgrowth (Fig. 1A, G). Ovigers ten-articled, fifth article with a reversed spine located on the ventral surface near the proximal end (Fig. 1E arrow b), seventh to tenth articles with compound spines in formula 3: 2: 1: 1 (Fig. 1F). Legs slender, major articles with short lateral spines, main claw approximately 3/5 length of propodus, auxiliary claws absent (Fig. 1D).

Description of the holotype (male). Size large for genus. Trunk slender, intersegmental lines absent, with many tiny papillae (Fig. 1A, B). Lateral processes very long, widely separated, slightly dilated distally, armed with asterisk-shaped setae on tip of tiny outgrowth. A distal dorsal tubercle is present on each lateral processe. Each tubercle long and slender, length is nearly twice diameter of lateral processes, with several minute setae. Ocular tubercle long, erected obliquely, armed with many tiny papillae, tip bifurcate with two lateral tubercles, without obvious eyes (Fig. 1A, B). Proboscis short, like a circular cone with flat tip. Abdomen very tall, directed upwards (Fig. 1A, B).

Chelifore scape one-segmented, armed distally with long setae. Palm short, with several long setae. Chela with one dactylus only, curved and bearing 12 denticulations on inner margin (Fig. 1C).

Palps seven-articled (Fig. 1G, H). First article short, without spines or setae. Second and third articles with few distal long setae. Second article longest, with a conical outgrowth on the outer surface, located in the first third of the article. Fourth to seventh articles armed with fields of ventral and distal setae mostly little longer than their article diameter (Fig. 1H).

Ovigers ten-articled (Fig. 1E, F). First and second articles stout, without setae and spines. Fourth and fifth articles longest, bearing few short setae and spines. Fifth article with a reversed spine basally. Sixth article with two distal spines and few ventral setae.

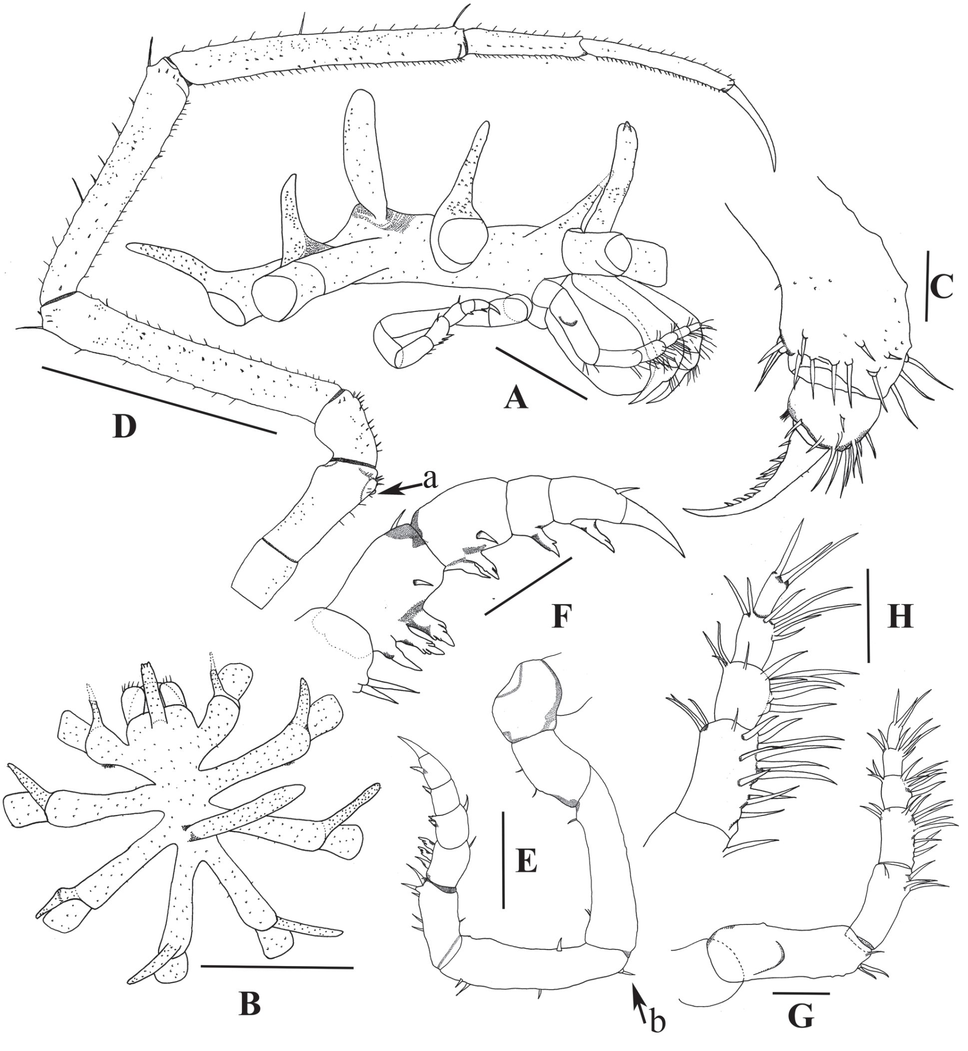

Figure 1. *Hemichela nanhaiensis* sp. n., DS06-13-01, male holotype: **A** trunk, lateral view **B** trunk, dorsal view **C** chela, enlarged **D** leg 3 **E** oviger **F** terminal articles of oviger, enlarged **G** palp **H** terminal articles of palp, enlarged; arrow a, position of genital pore; arrow b, reversed spine. Scale bars **A, B, D** = 1.0 mm; **C, F, H, G** = 0.1 mm; **E** = 0.2 mm.

Seventh to tenth articles with compound spines in formula 3: 2: 1: 1. Each spine bears one to three lateral denticulations. Terminal claw as long as tenth article (Fig. 1F).

Legs slender (Fig. 1D). Major articles with short lateral spines. First coxa short. Second coxa longest, distally swollen, with short ventral and distal seta. Genital pores present on ventral surface of second coxae of the third and fourth legs, borne on a spherical tubercle (Fig. 1D, arrow a). Third coxa short with short setae. Femur and tibiae with short ventral setae, lateral spines and long dorsal setae. Femur and second

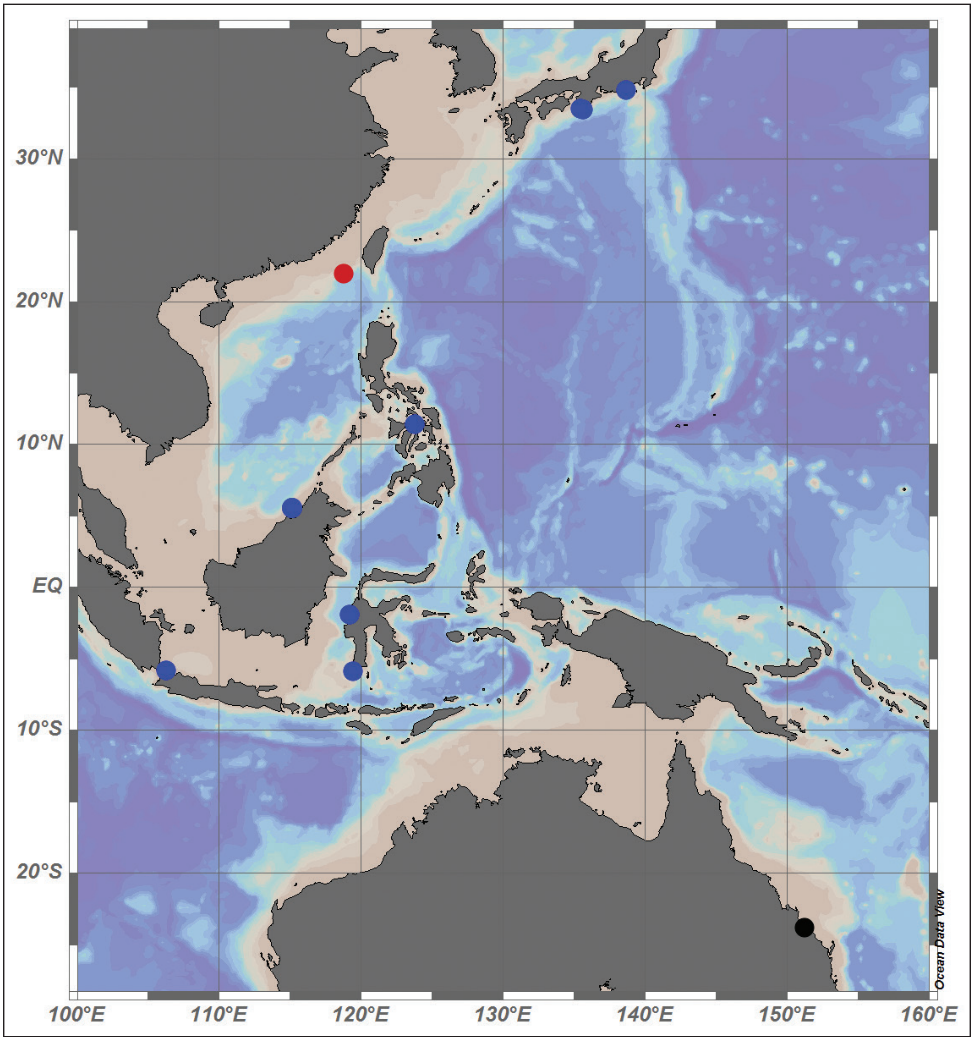

Figure 2. Distribution map of the three species of the genus *Hemichela*: ● *H. micrasterias* ● *H. nanhaiensis* ● *H. longiunguis* (modified from Bamber 1992).

tibia subequal, longer than first tibia. Cement gland not evident. Tarsus long with short setae and spines. Propodus without heel, with single row of sole spines. Main claw strong, approximately 3/5 length of propodus. Auxiliary claws absent.

Female and juvenile are unknown.

Measurements of holotype in mm: Trunk length (from chelifore insertion to tip of fourth lateral processes) 3.46; width across second lateral processes 3.49; proboscis length 0.63.

Lengths of palp articles 1 to 7 respectively: 0.09; 0.25; 0.14; 0.10; 0.06; 0.05; 0.04.

Lengths of oviger articles 1 to 10 respectively: 0.06; 0.13; 0.16; 0.33; 0.33; 0.15; 0.08; 0.08; 0.06; 0.07; 0.07 (claw).

Third leg, coxa 1, 0.24; coxa 2, 0.51; coxa 3, 0.30; femur, 1.24; tibia 1, 1.13; tibia 2, 1.23; tarsus, 0.53; propodus, 0.65; claw, 0.40.

Etymology. The species name, *nanhaiensis*, is derived from the Chinese language, Nanhai meaning South China Sea, referring to the location where the new species was found.

Remarks. The specimen is identified as belonging to the genus *Hemichela* by the absence of a movable chela finger. Compared with *H. longiunguis* and *H. micrasterias*, the body size of *H. nanhaiensis* is distinctly larger, length of lateral process tubercles are nearly twice diameter of lateral processes in *H. nanhaiensis*, and are much taller than those in the other two species, and the *H. nanhaiensis* palps are armed with more setae. The outgrowths with asterisk-shaped setae of *H. micrasterias* are branching and large while the ones of *H. longiunguis* and *H. nanhaiensis* are simple and not distinct. The length ratio of the terminal claw and propodus, 0.62, lies between that of the previous two species (1.06 in *H. longiunguis* and 0.46 in *H. micrasterias*), and the relative length of the oviger terminal claw is evidently shorter than the other species in the genus (the length ratio of terminal claw and tenth article: 1 in *H. nanhaiensis*, 2.33 in *H. longiunguis* and 1.88 in *H. micrasterias*). The chelifores are different from those of the other two species, with 12 denticulations on the inner margin of the dactylus compared to six in *H. micrasterias* and two in *H. longiunguis*; the chelifore scape and palm are armed with more seta than those of the other two species of the genus (Stock 1954, 1985; Staples 1982).

The records of this genus are from Japan to Queensland, Australia (Fig. 2) and the island systems of the western Pacific Ocean, with the deepest record of 657 m in the Flores Sea (Nakamura and Child 1990; Bamber 1992; Müller 1993). The new species was obtained from 1317.5 m, increasing the depth range of this genus. The occurrence of the new species fills a gap in the distribution ‘corridor’ of this genus, connecting the species in Japan with the Philippines and equatorial and Australian species.

The type habitat was sea floor predominantly composed of soft mud.

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Taxonomic studies on the ant genus *Ponera* Latreille, 1804 (Hymenoptera, Formicidae), with the description of a new species from India

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Abstract

Four species of the ant genus *Ponera* Latreille, 1804, are recorded from India. The present study reports one new species *P. sikkimensis* **sp. n.**, a divergent population of *P. indica* Bharti & Wachkoo, 2012 and one new record, *P. paedericera* Zhou, 2001 from India. An identification key and distributions for the four known Indian species of *Ponera* based on the worker caste are provided.

Keywords

Ponerinae, new record, new species, north-eastern Himalaya

Introduction

The ant genus *Ponera* belongs in subfamily Ponerinae, and is currently represented by 56 extant and five fossil-based species (Bolton 2014). The genus was revised worldwide by Taylor (1967) and since then a number of additional species have been described by various workers (Terayama 1986, 1996, 2009; Perrault 1993; Xu 2001a, b; Zhou 2001; Csősz and Seifert 2003; Dlussky 2009; Bharti and Wachkoo 2012). The worker caste of *Ponera* superficially resembles those of some other Ponerinae genera (*Hypo-*

ponera, *Cryptopone*, *Euponera*, and *Pseudoponera*) but can be distinguished from these due to the presence of an anterior fenestra in the subpetiolar process (a few species of *Hypoponera* apparently possess fenestrae, but lack paired posterior teeth on the subpetiolar process, which is a further character typifying *Ponera*). Additionally, *Ponera* has two maxillary palp segments, while *Hypoponera* has a one-segmented maxillary palp. Some other genera (*Belonopelta* and *Emeryopone*) also have an anterior fenestra in the subpetiolar process, but they have narrow mandibles with long attenuated teeth. *Ponera* differs from them on the basis of its typical triangular mandibles with only short teeth (Schmidt 2013; Schmidt and Shattuck 2014).

Ponera is currently represented by two species described from India: *P. indica* Bharti & Wachkoo, 2012 and *P. taylori* Bharti & Wachkoo, 2012. The present study reports one new species (*P. sikkimensis* sp. n.), a divergent population of *P. indica* Bharti & Wachkoo, 2012 and one new record (*P. paedericera* Zhou, 2001) from India. With the addition of these species, the genus is now represented by four species in India, which are distributed in Himalayan regions. A revised key is provided herewith. Two further species, *P. affinis* Jerdon, 1851 and *P. pumila* Jerdon, 1851 were described earlier from Malabar, India. Due to inadequate original descriptions and a lack of type material these have already been considered *incertae sedis* in the genus (Bharti 2008, 2011; Bharti and Wachkoo 2012).

Materials and methods

The specimens were collected using the Winkler extractor method. Taxonomic analysis was conducted on a Nikon SMZ 1500 stereo zoom microscope with maximum magnification of 112.5×. For digital images, an MP (Micro Publisher) digital camera was used on the same microscope with Auto-Montage software (Syncroscopy, Division of Synoptics, Ltd.). Later, images were cleaned with Adobe Photoshop CS5 and Helicon Filter 5. Holotype of new species has been deposited in PUAC (Punjabi University Patiala Ant Collection at Department of Zoology and Environmental Sciences, Punjabi University, Patiala, Punjab, India). Measurements were recorded in millimeters on a Nikon SMZ 1500 stereo zoom microscope. The comparative morphometric data of the species are listed in Table 1. Morphological terminology for measurements and indices is as follows:

Head Length (HL)	Maximum length of head in dorsal view, measured in as a straight line from the anterior most point of the median clypeal margin to the midpoint of the occipital margin.
Head Width (HW)	Maximum width of head in dorsal view.
Head Size (HS)	Head size, arithmetic mean of HL and HW.
Scape Length (SL)	Maximum length of the scape excluding the basal neck and condyle.

Pronotal Width (PrW)	Maximum width of pronotum in dorsal view.
Weber's Length (WL)	Mesosoma measured in lateral view from the anterior surface of the pronotum (excluding the collar) to the posterior margin of the propodeal lobes.
Petiole Height (PH)	Maximum height of the petiole in profile from the apex of subpetiolar process to dorsal most point.
Petiole Width (PW)	Maximum width of the petiole in dorsal view.
Petiole Length (PL)	In profile, the distance from the midpoints of the curves where the anterior and posterior faces of the node meet the anterior and posterior peduncles.
Cephalic Index (CI)	Cephalic index: HW × 100/HL.
Scape Index (SI)	Scape index: SL × 100/HW.
Petiole Node Index (PNI)	Petiolar node index: PW × 100/PrW.
Lateral Petiole Index (LPI)	Lateral petiolar index: PL × 100/PH.
Dorsal Petiole Index (DPI)	Dorsal petiole index: PW × 100/PL.
Ocular Index (OI)	(sexuals only) Maximum diameter of eye divided by head width.

Acronym of depository

PUAC	"Punjabi University Patiala Ant Collection" at Department of Zoology and Environmental Sciences, Punjabi University, Patiala, Punjab, India.

Results

***Ponera sikkimensis* sp. n.**
http://zoobank.org/FB59D7A2-D2D6-4B82-A1F9-3F2904D7256D
Figs 1–3

Type locality. India, Sikkim: Phadamchen, 27°12.75'N, 88°37.22'E, 1040 m, leaf litter, Winkler, 30 May 2012, Joginder Singh leg.

Type material. Holotype worker and two paratype workers with same data as of holotype [PUAC].

Holotype measurements. HL 0.42; HW 0.39; HS 0.40; SL 0.30; PrW 0.25; WL 0.52; PH 0.23; PL 0.17; PW 0.18; CI 92.85; SI 76.92; PNI 72; LPI 74; DPI 105.89.

Head: roughly oval in shape, distinctly longer than broad, sides convex, occipital margin concave, occipital corners rounded. Mandibles each with five well-developed teeth, Eyes small, composed of 3-4 indistinct facets. Anterior margin of clypeus concave. Apex of scape does not reach the midpoint of the occipital margin when laid straight back from its insertion in full-face view; funiculus incrassate toward apex; antennal club with four segments.

Figures 1–3. *Ponera sikkimensis* sp. n. worker **1** head in full-face view **2** body in profile view **3** body in dorsal view.

Mesosoma and petiole: In lateral view dorsum of mesosoma weakly convex, in dorsal view promesonotal suture distinct; metanotal groove indistinct. Dorsum of propodeum about as long as declivity, declivity flat, posterodorsal corner rounded. Petiole broader than long in dorsal view, dorsal face convex, in profile view, anterior and posterior faces straight, in dorsal view node roughly semicircular, anterior and lateral borders forming a single arc, posterior border weakly concave. Subpetiolar process with oval fenestra, anteroventral corner blunt, posteroventrally with enlarged teeth.

Gaster: Cinctus of second gastral tergite with cross ribs.

Sculpture: Head, mesosoma and gaster sparsely punctate, Petiolar dorsum more strongly punctate; propodeal declivity, posterior face of petiole and gastral apex smooth and shining. Mandibles shining with scattered punctures.

Pilosity: Dorsum of head, mesosoma, petiole and gaster with dense decument pubescence. Erect hairs present on anterior portion of head and posterior half of gaster.

Colour: Head brownish and dull; rest of body light brown and shining; mandibles, antennae and legs yellow.

Etymology. The species is named after the state of Sikkim.

Remarks. *P. sikkimensis* sp. n. is somewhat similar to *P. longlina* Xu, 2001, described from China. It can be distinguished from the latter by the following combination of characters: head roughly oval in shape; mandible with five well-developed teeth, eyes with 3-4 indistinct facets; fenestra in subpetiolar process oval in shape; propodeum and petiole with stronger punctures; petiolar node relatively low and narrow. In *P. longlina* the head is roughly square in shape; mandibles each with three well-developed teeth at the apical margin followed by small denticles; eyes with single facet; fenestra in subpetiolar process circular in shape; propodeum and petiole smooth; petiolar node higher and relatively broad.

Ponera indica Bharti & Wachkoo, 2012

Material examined. India, Sikkim: Phadamchen, 27°12.75'N, 88°37.22'E, 1040 m, leaf litter, Winkler, 1 June 2012, 13 workers and 1 queen, Joginder Singh leg. Holotype worker with labels, “India, Himachal Pradesh, Terrace, 31.9234°N, 75.9294°E, 430 m, 12 October, 2008, Winkler”. Paratypes: 5 workers with same data as of Holotype, 1 worker and 1 gyne, India, Himachal Pradesh, Andretta, 32.0744°N, 76.5856°E, 940 m, 11 June, 2010, hand picking; 5 workers, India, Himachal Pradesh, Mandi, 31.7080°N 76.9318°E?, 800 m, 27 June, 2010, soil core (PUAC).

Remarks. The *P. indica* material collected from Sikkim (north-eastern Himalaya) possibly represents a divergent population, as the species was originally described from north-western part of Himalaya. At present, the morphological differences outlined do not substantiate its status as a distinct species. The intraspecific variation includes: head rectangular in shape, occipital margin concave; mandibles each with three well-developed teeth followed by small denticles; fenestra in subpetiolar process circular; standing pilosity sparse; eyes composed of 1-2 indistinct facets; apex of scape does not reach the midpoint of posterior cephalic margin, CI 86.67–90.69; LPI 59.25–75; DPI 104.76–160. However, in the population representing type material of *P. indica*, the head is more oval in shape, the occipital margin straight; and the mandibles each with three well-developed teeth and without small denticles; the subpetiolar fenestra is oval in shape, and pilosity is abundant, eyes composed of 3-4 indistinct facets; apex of scape reaches the posterior cephalic margin, CI 91.3–97.8; LPI 34.5–40; DPI 200–266.7.

Ponera paedericera Zhou, 2001

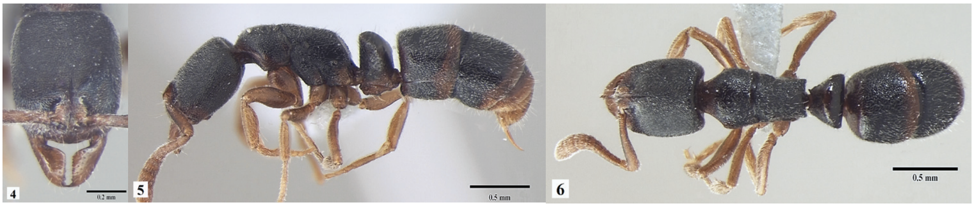
Figs 4–6

Material examined. India, Arunachal Pradesh: Dirang, 27°21.50'N, 92°14.46'E, 1634m, 29 September 2013, Winkler, 4 workers and 1queen, Joginder Singh leg.

For complete description see Zhou (2001).

Global distribution. China, India.

Remarks. The Chinese *P. paedericera* Zhou, 2001 is reported here for the first time from India. This species is remarkably different from the other known Indian species with following combination of characters: anterior margin of clypeus with a distinct blunt median tooth; antennal club with 3 segments; posterodorsal corners of propodeum rounded, declivity depressed, lateral sides of propodeum distinctly marginate; anterior face of petiole straight, dorsal and posterior faces form a single arched surface, anterodorsal corner blunt, dorsal surface smooth and shining, subpetiolar process with relatively large posteroventral teeth; head, mesosoma and the two basal segments of gaster densly and finely punctate; blackish in colour.



Figures 4–6. *Ponera paedericera* worker **4** head in full-face view **5** body in profile view **6** body in dorsal view.

Table 1. Average worker measurements with standard deviation and minimum and maximum values in brackets.

Species	HL	HW	HS	SL	PrW	WL	PH	PW	PL	CI	SI	PNI	LPI	DPI
P. indica (type material) (n=12)	0.445±0.009 [0.430,0.460]	0.418±0.0058 [0.410,0.430]	0.432±0.006 [0.420,0.440]	0.315±0.015 [0.280,0.330]	0.302±0.0096 [0.280,0.310]	0.585±0.0018 [0.560,0.610]	0.289±0.008 [0.270,0.300]	0.229±0.001 [0.210,0.240]	0.104±0.009 [0.90,0.120]	94.4±2.24 [91.3,97.8]	74.1±5.2 [65.1,80.5]	74.5±5.12 [67.7,79.3]	36.7±21.37 [34.5,40]	221.4±21.44 [200,266.7]
P. indica (divergent population from North-east Himalaya) (n=13)	0.448±0.0016 [0.43,0.49]	0.396±0.013 [0.37,0.43]	0.421±0.014 [0.41,0.46]	0.289±0.016 [0.27,0.33]	0.248±0.016 [0.22,0.28]	0.55±0.06 [0.51,0.66]	0.246±0.015 [0.22,0.28]	0.216±0.029 [0.18,0.25]	0.166±0.016 [0.15,0.21]	88.35±1.653 [86.67,90.69]	73±3.068 [69.23,76.74]	87.21±9.709 [72,96]	68.11±5.906 [59.25,75]	130.69±19.755 [104.76,160]
P. taylori (n=12)	0.650±0.0219 [0.600,0.670]	0.585±0.019 [0.550,0.610]	0.620±0.0150 [0.595,0.640]	0.440±0.001 [0.430,0.460]	0.390±0.008 [0.380,0.400]	0.843±0.042 [0.740,0.890]	0.372±0.016 [0.350,0.390]	0.241±0.011 [0.200,0.260]	0.183±0.015 [0.160,0.200]	89.3±2.81 [83.3,93.8]	75.5±2.56 [71.7,81.8]	62.8±2.11 [60.5, 65]	47.8±2.99 [44.7,52.6]	113.2±9.02 [120,144.4]
P. paedericera (n=4)	0.735±0.020 [0.71,0.76]	0.602±0.015 [0.59,0.62]	0.667±0.015 [0.65,0.68]	0.485±0.019 [0.47,0.51]	0.41±0.033 [0.37,0.45]	0.802±0.022 [0.78,0.83]	0.38±0.033 [0.34,0.42]	0.395±0.005 [0.39,0.40]	0.267±0.012 [0.25,0.28]	81.98±1.710 [80.26,83.78]	80.55±4.400 [75.80,86.44]	96.75±6.818 [88.89,105.40]	70.85±7.934 [64.28,82.35]	147.89±6.66 [139.28,156]
P. sikkimensis sp.n. (n=3)	0.433±0.011 [0.42,0.44]	0.396±0.005 [0.39,0.40]	0.415±0.008 [0.40,0.42]	0.286±0.011 [0.28,0.30]	0.243±0.011 [0.23,0.25]	0.516±0.005 [0.51,0.52]	0.236±0.011 [0.23,0.25]	0.18±0 [0.18]	0.17±0 [0.17]	91.55±1.120 [90.91,92.85]	72.30±3.995 [70,76.92]	74.08±3.614 [72,78.26]	80.75±11.853 [73.91,94.44]	105.89±0 [105.89]

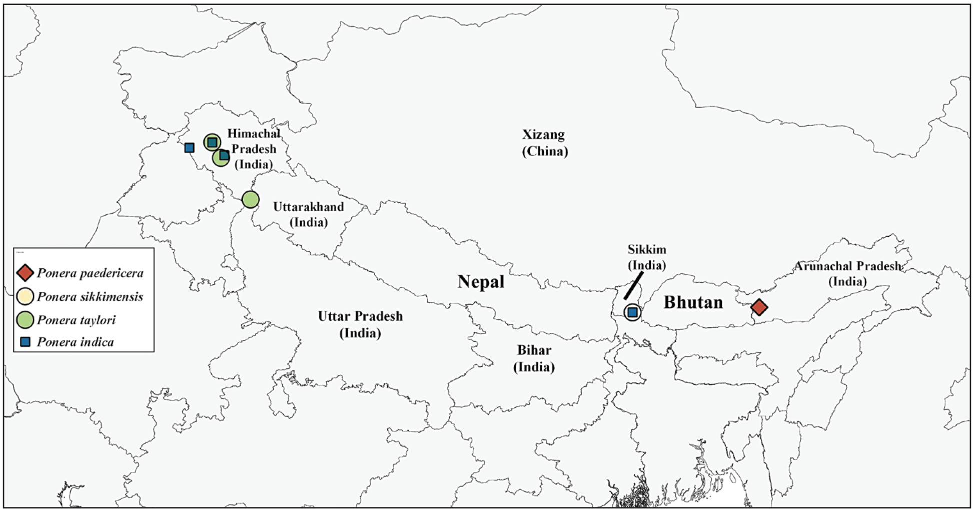
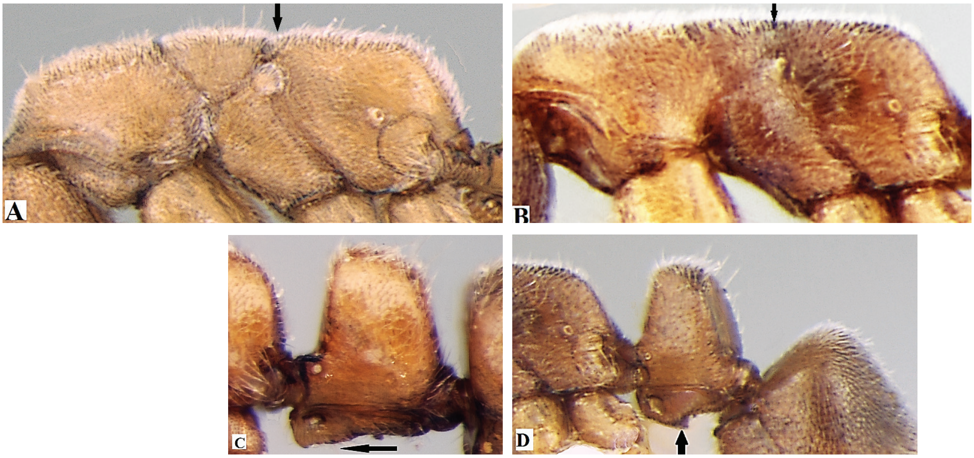


Figure 7. Map showing the localities from which Indian *Ponera* species have been recorded in Indian Himalaya.

Key to the known Indian species of *Ponera* based on worker caste

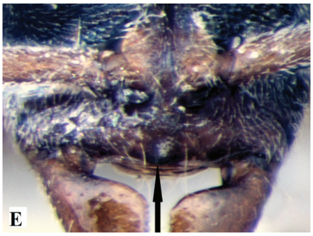
1 Eyes absent; metanotal groove distinct (Fig. A); posteroventral teeth of subpetiolar process absent (Fig. C)................ ***P. taylori*** **Bharti & Wachkoo, 2012**

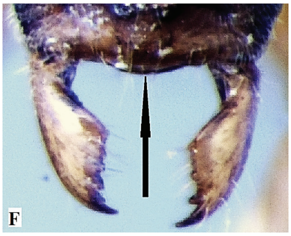
– Eyes present; metanotal groove indistinct (Fig. B); posteroventral teeth of subpetiolar process present (Fig. D) **2**

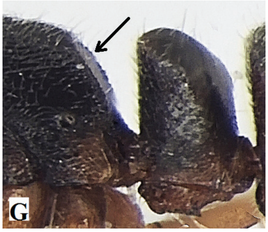


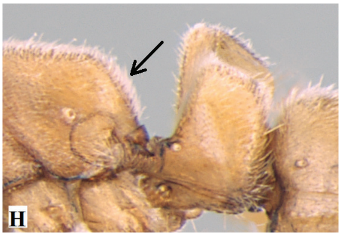
2 A blunt tooth on clypeal margin present (Fig. E), lateral sides of propodeum distinctly marginate (Fig. G), body blackish in colour... ***P. paedericera* Zhou, 2001**

– A blunt tooth on clypeus margin absent (Fig. F), lateral sides of propodeum not marginate (Fig. H), body reddish brown to dark brown in colour.........**3**



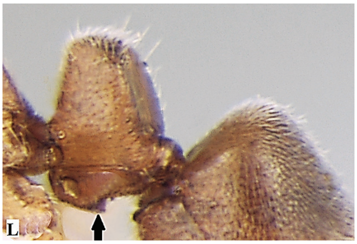






3 Mandible with 5 well-developed teeth; mesosoma, petiole, and gaster sparsely punctate (Fig. I), teeth on subpetiolar process directed downward; (Fig. K), DPI=106 .... ***P. sikkimensis* sp. n.**

– Mandible with 3 well-developed teeth; mesosoma, petiole, and gaster densely punctate (Fig. J), teeth on subpetiolar process directed backward (Fig. L), DPI: >131–221 ....***P. indica* Bharti & Wachkoo, 2012**



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Diagnostic survey of Malagasy *Nesomyrmex* species-groups and revision of *hafahafa* group species via morphology based cluster delimitation protocol

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Abstract

Madagascar and its surrounding islands are among the world's greatest biodiversity hotspots, harboring predominantly endemic and threatened communities meriting special attention from biodiversity scientists. Building on the considerable efforts in recent years to inventory the Malagasy ant fauna, the myrmicine genus *Nesomyrmex* is reviewed and (1) subdivided into four major groups based on salient morphological features corroborated by numeric morphology: *angulatus*-, *hafahafa*-, *madecassus*- and *sikorai*-groups, and (2) the *hafahafa* species-group endemic to Madagascar is revised. Diversity within *hafahafa* species-group was assessed via hypothesis-free *nest-centroid-clustering* combined with *gap statistic* to assess the number of clusters and to determine the most probable boundaries between them. This combination of methods provides a highly automatized, objective species delineation protocol based on continuous morphometric data. Delimitations of clusters recognized by these exploratory analyses were tested via confirmatory Linear Discriminant Analysis. These results suggest the existence of four morphologically distinct species, *Nesomyrmex capricornis* **sp. n.**, *N. hafahafa* **sp. n.**, *N. medusus* **sp. n.** and *N. spinosus* **sp. n.**; all are described and an identification key for their worker castes using morphometric data is provided. Two members of the newly outlined *hafahafa* species-group, *N. hafahafa* **sp. n.** and *N. medusus* **sp. n.**, are distributed along the southeastern coast Madagascar and occupy rather large ranges, but two other species, *N. capricornis* **sp. n.** and *N. spinosus* **sp. n.**, are only known to occur in small and isolated forest, highlighting the importance of small forest patches for conserving arthropod diversity.

Keywords

Taxonomy, morphometry, species delimitation, exploratory analyses, gap statistic, biogeography

Introduction

The Malagasy zoogeographical region, i.e. Madagascar and surrounding islands (Bolton 1994), is considered one of the world's hottest biodiversity hotspots (Myers et al. 2000) and harbors a unique and threatened biota (Ganzhorn et al. 2001). The recently recognized global biodiversity crisis has highlighted the need to explore the flora and fauna of tropical areas, where biodiversity remains largely unexplored, and is enduring the fastest rate of environmental transformation. Thanks to intensive ant systematic research in Madagascar over the last decade (e.g. Fisher 2009, Blaimer and Fisher 2013, Yoshimura and Fisher 2012, Hita-Garcia and Fisher 2014) our knowledge of Malagasy myrmecofauna has increased considerably, supporting earlier assumptions about the extreme species diversity of the region.

However, questions of diversity, rate of endemism, and connections to the African continent for several genera such as Malagasy *Nesomyrmex* have never been the subject of focused research. To date, only four valid *Nesomyrmex* species have been recorded to occur in Madagascar (Mbanyana and Robertson 2008), Based on the recent inventories of Fisher and team, this paper reassesses the *Nesomyrmex* fauna and describes the species from one species group.

A novel approach was used to facilitate species delimitations using multivariate morphometric analyses. Morphological diversity is assessed via NC-clustering (Seifert et al. 2014). This exploratory data analysis technique has proved efficient at pattern recognition within large and complex datasets (Csősz et al. 2014, Guillem et al. 2014, Wachter et al. 2015). The estimation of the optimal number of clusters representing species within a morphological dataset is determined via gap statistic algorithm (Tibshirani et al. 2001). This algorithm helps to find statistically supported number of groups in normally distributed data such as continuous morphometric data based on intra-cluster variance. The combination of NC-clustering and gap statistic offers a highly automated, hypothesis-free protocol producing a statistically calculated goodness of clustering measure that minimizes opportunities for subjective interpretation.

In the present paper, the Malagasy *Nesomyrmex* fauna is subdivided into four clearly delimited species groups diagnosed here and a key to the species groups is provided. The first step of the current project, to inventory the entire Malagasy *Nesomyrmex* fauna, will involve providing a detailed description of the diversity of the *Nesomyrmex hafahafa* species-group. The three pairs of dorsal spines (pronotal spines, propodeal spines and antero-dorsal spines on petiolar node) makes the appearance of this group extremely unique; no similar species group has been found either in the Malagasy region or on the African continent. Multivariate evaluation of morphological data has revealed that the unique-looking *N. hafahafa* species-group comprises four well-outlined clusters, or species, that are endemic to Madagascar. The four new species outlined, *N. capricornis* sp. n., *N. hafahafa* sp. n., *N. medusus* sp. n., and *N. spinosus* sp. n., are described here based on worker caste, and both a key that includes both a numeric identification tool that helps readers to resolve the most problematic cases and a traditional character based key. Distribution maps are also provided. Our research has also revealed that two of the four species, *N. capricornis* sp. n. and *N. spinosus* sp. n., occur in small, highly isolated forests, leaving them at a high risk of extinction from continuing environmental destruction or climatic changes.

Material and methods

In the present study, 21 continuous morphometric traits were recorded in 177 worker individuals belonging to 100 nest samples collected in the Malagasy region (Table 1). The material is deposited in the California Academy of Sciences (CAS), San Francisco, USA. The full list of non-type material morphometrically examined in this revision is listed in Table 1 with unique specimen identifiers (e.g. CASENT0460666). Designation of type material with detailed label information is given in relevant sections *type material investigated* for each taxon. All images and specimens used in this study are available online on AntWeb (http://www.antweb.org). Images are linked to their specimens via their unique specimen code affixed to each pin (CASENT0002660). Online specimen identifiers follow this format: http://www.antweb.org/specimen/CASENT0002660.

Digital color montage images were created using a JVC KY-F75 digital camera and Syncroscopy Auto-Montage software (version 5.0), or a Leica DFC 425 camera in combination with the Leica Application Suite software (version 3.8). Distribution maps were generated by using QGIS 2.4.0 software (QGIS Development Team 2014).

The measurements were taken with a Leica MZ 12.5 stereomicroscope equipped with an ocular micrometer at a magnification of 100×. Measurements and indices are presented as arithmetic means with minimum and maximum values in parentheses. Body size dimensions are expressed in µm. Due to the abundance of worker individuals in contrast to the limited number of queen and male specimens available the present revision is based on worker caste only. Worker-based revision is further facilitated by the fact that name-bearing type specimens of the vast majority of existing ant taxa were designated from worker caste. All measurements were made by the first author. For the definition of morphometric characters, earlier protocols (Schlick-Steiner et al. 2006, Seifert 2006, Seifert and Csősz 2015) were considered. Explanations and abbreviations for measured characters are as follows:

CL	Maximum cephalic length in median line. The head must be carefully tilted to the position providing the true maximum. Excavations of hind vertex and/or clypeus reduce CL (Fig. 1).
CW	Maximum width of the head including compound eyes (Fig. 1).
CWb	Maximum width of head capsule without the compound eyes. Measured just posterior of the eyes (Fig. 1).
Cdep	Antero-median clypeal depression. Maximum depth of the median clypeal depression on its anterior contour line as it appears in fronto-dorsal view.
EL	Maximum diameter of the compound eye.

Table 1. List of morphometrically investigated samples. Unique CASENT number for pinned samples, locality, geographic coordinates (E, N) in decimal format altitude (ALT) in meters a.s.l., collector's name, date and number of specimens investigated bearing the given CASENT number are provided. Red row: holotype, yellow row: paratype(s). All samples collected in Toliara administrative region, Madagascar, and deposited at the California Academy of Sciences (CAS).

Species name	CASENT number	Locality	N	E	ALT	Collector	Date	Number of specimens
***capricornis* sp. n. HT**	**CASENT0452741**	**Forêt de Mahavelo, Isantoria River**	**-24,758**	**46,157**	**110 m**	**Fisher-Griswold Arthropod Team**	**1/28/2002**	**1w**
***capricornis* sp. n. PT**	**CASENT0452715**	**Forêt de Mahavelo, Isantoria River**	**-24,758**	**46,157**	**110 m**	**Fisher-Griswold Arthropod Team**	**1/28/2002**	**1w**
***capricornis* sp. n. PT**	**CASENT0452716**	**Forêt de Mahavelo, Isantoria River**	**-24,758**	**46,157**	**110 m**	**Fisher-Griswold Arthropod Team**	**1/28/2002**	**1w**
***capricornis* sp. n. PT**	**CASENT0452738**	**Forêt de Mahavelo, Isantoria River**	**-24,758**	**46,157**	**110 m**	**Fisher-Griswold Arthropod Team**	**1/28/2002**	**2w**
***capricornis* sp. n. PT**	**CASENT0452739**	**Forêt de Mahavelo, Isantoria River**	**-24,758**	**46,157**	**110 m**	**Fisher-Griswold Arthropod Team**	**1/28/2002**	**2w**
***capricornis* sp. n.**	CASENT0443010	Forêt de Mahavelo, Isantoria River	-24,758	46,157	110 m	Fisher-Griswold Arthropod Team	1/28/2002	1w
***capricornis* sp. n.**	CASENT0456949	Parc National d'Andohahela, Forêt de Manantalinjo, 33.6 km 63°ENE Amboasary, 7.6 km 99°E Hazofotsy	-24,817	46,61	150 m	Fisher-Griswold Arthropod Team	1/12/2002	2w
***capricornis* sp. n.**	CASENT0456950	Parc National d'Andohahela, Forêt de Manantalinjo, 33.6 km 63°ENE Amboasary, 7.6 km 99°E Hazofotsy	-24,817	46,61	150 m	Fisher-Griswold Arthropod Team	1/12/2002	2w
***capricornis* sp. n.**	CASENT0452881	Forêt de Mahavelo, Isantoria River	-24,758	46,157	110 m	Fisher-Griswold Arthropod Team	1/28/2002	1w
***capricornis* sp. n.**	CASENT0459109	Parc National d'Andohahela, Forêt de Manantalinjo, 33.6 km 63°ENE Amboasary, 7.6 km 99°E Hazofotsy	-24,817	46,61	150 m	Fisher-Griswold Arthropod Team	1/12/2002	1w
***capricornis* sp. n.**	CASENT0459110	Parc National d'Andohahela, Forêt de Manantalinjo, 33.6 km 63°ENE Amboasary, 7.6 km 99°E Hazofotsy	-24,817	46,61	150 m	Fisher-Griswold Arthropod Team	1/12/2002	1w
***capricornis* sp. n.**	CASENT0456620	Parc National d'Andohahela, Forêt de Manantalinjo, 33.6 km 63°ENE Amboasary, 7.6 km 99°E Hazofotsy	-24,817	46,61	150 m	Fisher-Griswold Arthropod Team	1/12/2002	1w
***capricornis* sp. n.**	CASENT0456621	Parc National d'Andohahela, Forêt de Manantalinjo, 33.6 km 63°ENE Amboasary, 7.6 km 99°E Hazofotsy	-24,817	46,61	150 m	Fisher-Griswold Arthropod Team	1/12/2002	1w

Species name	CASENT number	Locality	N	E	ALT	Collector	Date	Number of specimens
capricornis **sp. n.**	CASENT0452872	Forêt de Mahavelo, Isantoria River	-24,758	46,157	110 m	Fisher-Griswold Arthropod Team	1/28/2002	2w
capricornis **sp. n.**	CASENT0452175	Forêt de Mahavelo, Isantoria River	-24,758	46,157	110 m	Fisher-Griswold Arthropod Team	1/28/2002	2w
capricornis **sp. n.**	CASENT0452871	Forêt de Mahavelo, Isantoria River	-24,758	46,157	110 m	Fisher-Griswold Arthropod Team	1/28/2002	2w
capricornis **sp. n.**	CASENT0020707	Parc National d'Andohahela, Forêt de Manantalinjo, 33.6 km 63°ENE Amboasary, 7.6 km 99°E Hazofotsy	-24,817	46,61	150 m	Fisher-Griswold Arthropod Team	1/12/2002	1w
capricornis **sp. n.**	CASENT0079196	Parc National d'Andohahela, Forêt de Manantalinjo, 33.6 km 63°ENE Amboasary, 7.6 km 99°E Hazofotsy	-24,817	46,61	150 m	Fisher-Griswold Arthropod Team	1/12/2002	1w
capricornis **sp. n.**	CASENT0452754	Forêt de Mahavelo, Isantoria River	-24,758	46,157	110 m	Fisher-Griswold Arthropod Team	1/28/2002	3w
hafahafa **sp. n. HT**	**CASENT0460666**	**Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota**	**-22,802**	**43,421**	**70 m**	**Fisher-Griswold Arthropod Team**	**3/6/2002**	**1w**
hafahafa **sp. n. PT**	**CASENT0746771**	**Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota**	**-22,802**	**43,421**	**70 m**	**Fisher-Griswold Arthropod Team**	**3/6/2002**	**1w**
hafahafa **sp. n. PT**	**CASENT0460667**	**Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota**	**-22,802**	**43,421**	**70 m**	**Fisher-Griswold Arthropod Team**	**3/6/2002**	**2w**
hafahafa **sp. n.**	CASENT0430386	Parc National de Kirindy Mite, 16.3 km 127°SE Belo sur Mer	-20,795	44,147	80 m	Fisher-Griswold Arthropod Team	12/6/2001	2w
hafahafa **sp. n.**	CASENT0430386	Parc National de Kirindy Mite, 16.3 km 127°SE Belo sur Mer	-20,795	44,147	80 m	Fisher-Griswold Arthropod Team	12/6/2001	2w
hafahafa **sp. n.**	CASENT0430494	Parc National de Kirindy Mite, 16.3 km 127°SE Belo sur Mer	-20,795	44,147	80 m	Fisher-Griswold Arthropod Team	12/6/2001	2w
hafahafa **sp. n.**	CASENT0430390	Parc National de Kirindy Mite, 16.3 km 127°SE Belo sur Mer	-20,795	44,147	80 m	Fisher-Griswold Arthropod Team	12/6/2001	2w
hafahafa **sp. n.**	CASENT0451365	Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota	-22,802	43,421	70 m	Fisher-Griswold Arthropod Team	3/6/2002	2w
hafahafa **sp. n.**	CASENT0460712	Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota	-22,802	43,421	70 m	Fisher-Griswold Arthropod Team	3/6/2002	2w

Species name	CASENT number	Locality	N	E	ALT	Collector	Date	Number of specimens
***hafahafa* sp. n.**	CASENT0457087	Forêt de Beroboka, 5.9 km 131°SE Ankidranoka	-22,233	43,366	80 m	Fisher-Griswold Arthropod Team	3/12/2002	2w
***hafahafa* sp. n.**	CASENT0439492	Forêt de Beroboka, 5.9 km 131°SE Ankidranoka	-22,233	43,366	80 m	Fisher-Griswold Arthropod Team	3/12/2002	2w
***hafahafa* sp. n.**	CASENT0460679	Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota	-22,802	43,421	70 m	Fisher-Griswold Arthropod Team	3/6/2002	2w
***hafahafa* sp. n.**	CASENT0457090	Forêt de Beroboka, 5.9 km 131°SE Ankidranoka	-22,233	43,366	80 m	Fisher-Griswold Arthropod Team	3/12/2002	2w
***hafahafa* sp. n.**	CASENT0426075	3 km 50°NE Ifaty	-23,15	43,617	60 m	D.O.Burge	10/23/2001	2w
***hafahafa* sp. n.**	CASENT0426077	3 km 50°NE Ifaty	-23,15	43,617	60 m	D.O.Burge	10/23/2001	2w
***hafahafa* sp. n.**	CASENT0059254	Ranobe	-23,045	43,615	20 m	Frontier Wilderness Project	1/26/2004	1w
***hafahafa* sp. n.**	CASENT0446254	Parc National de Kirindy Mite, 16.3 km 127°SE Belo sur Mer	-20,795	44,147	80 m	Fisher-Griswold Arthropod Team	12/6/2001	1w
***hafahafa* sp. n.**	CASENT0066346	Mikea Forest, spiny forest, Tulear Province	-22,913	43,482	37 m	R. Harin'Hala	11/27/2001	1w
***hafahafa* sp. n.**	CASENT0427038	Forêt de Beroboka, 5.9 km 131°SE Ankidranoka	-22,233	43,366	80 m	Fisher-Griswold Arthropod Team	3/12/2002	1w
***hafahafa* sp. n.**	CASENT0447426	Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota	-22,802	43,421	70 m	Fisher-Griswold Arthropod Team	3/6/2002	2w
***hafahafa* sp. n.**	CASENT0447445	Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota	-22,802	43,421	70 m	Fisher-Griswold Arthropod Team	3/6/2002	2w
***hafahafa* sp. n.**	CASENT0447465	Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota	-22,802	43,421	70 m	Fisher-Griswold Arthropod Team	3/6/2002	1w
***hafahafa* sp. n.**	CASENT0127637	48 km ENE Morondava, Kirindy	-20,067	44,65	30 m	B.L.Fisher	4/18/1995	2w
***hafahafa* sp. n.**	CASENT0426078	3 km 50°NE Ifaty	-23,15	43,617	60 m	D.O.Burge	10/23/2001	2w
***hafahafa* sp. n.**	CASENT0430746	Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota	-22,802	43,421	70 m	Fisher-Griswold Arthropod Team	3/6/2002	2w
***hafahafa* sp. n.**	CASENT0459595	Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota	-22,802	43,421	70 m	Fisher-Griswold Arthropod Team	3/6/2002	2w
***hafahafa* sp. n.**	CASENT0004062	Forêt de Tsinjoriaky, 6.2 km 84°E Tsifota	-22,802	43,421	70 m	Fisher-Griswold Arthropod Team	3/6/2002	2w

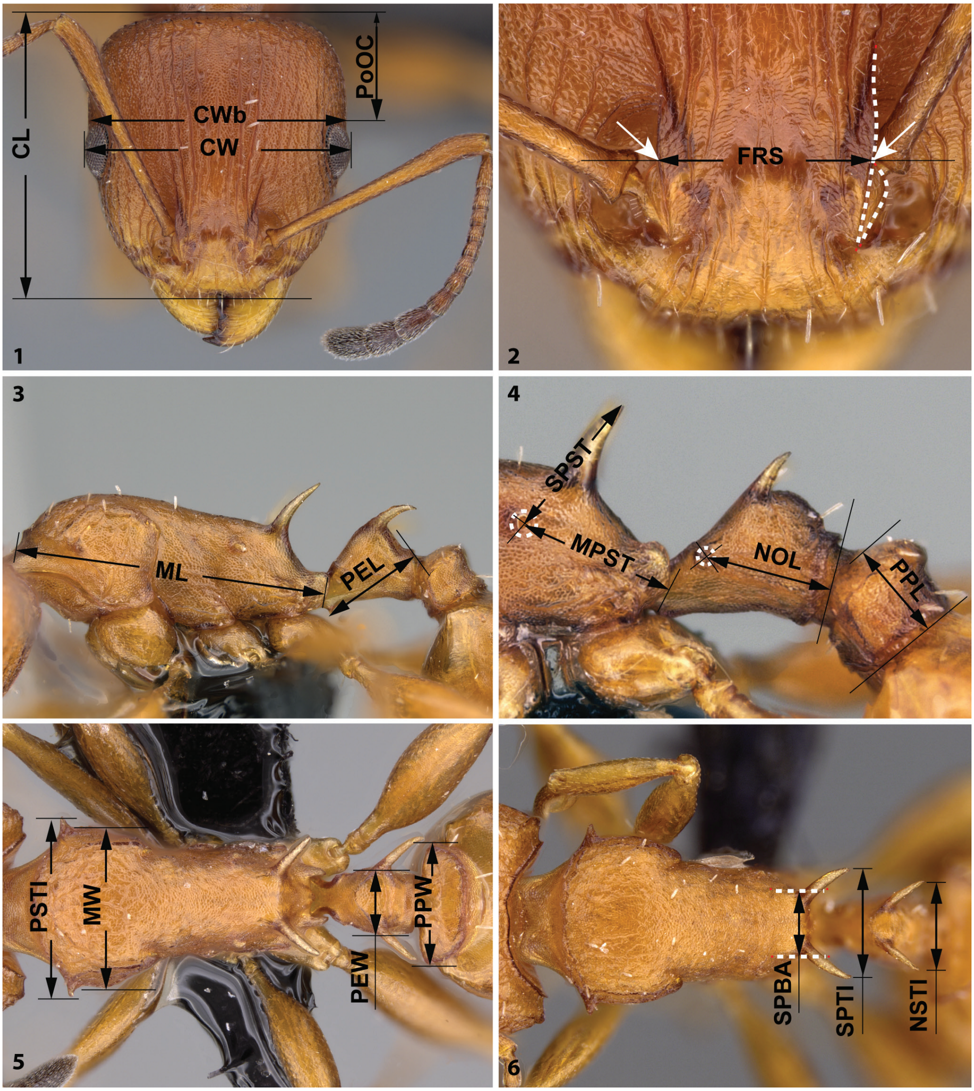
Species name	CASENT number	Locality	N	E	ALT	Collector	Date	Number of specimens
***hafahafa* sp. n.**	CASENT0457427	Forêt de Beroboka, 5.9 km 131°SE Ankidranoka	-22,233	43,366	80 m	Fisher-Griswold Arthropod Team	3/12/2002	1w
medusus sp. n. HT	**CASENT0455428**	**Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77°ENE Efoetse, 17.4 km 170°S Beheloka**	**-24,047**	**43,753**	**40 m**	**Fisher-Griswold Arthropod Team**	**3/18/2002**	**1w**
medusus sp. n. PT	**CASENT0746770**	**Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77°ENE Efoetse, 17.4 km 170°S Beheloka**	**-24,047**	**43,753**	**40 m**	**Fisher-Griswold Arthropod Team**	**3/18/2002**	**1w**
***medusus* sp. n.**	CASENT0448719	Mahafaly Plateau, 6.2 km 74°ENE Itampolo	-24,654	43,997	80 m	Fisher-Griswold Arthropod Team	2/21/2002	2w
***medusus* sp. n.**	CASENT0449033	Mahafaly Plateau, 6.2 km 74°ENE Itampolo	-24,654	43,997	80 m	Fisher-Griswold Arthropod Team	2/21/2002	2w
***medusus* sp. n.**	CASENT0449105	Mahafaly Plateau, 6.2 km 74°ENE Itampolo	-24,654	43,997	80 m	Fisher-Griswold Arthropod Team	2/21/2002	2w
***medusus* sp. n.**	CASENT0448791	Mahafaly Plateau, 6.2 km 74°ENE Itampolo	-24,654	43,997	80 m	Fisher-Griswold Arthropod Team	2/21/2002	2w
***medusus* sp. n.**	CASENT0448943	Mahafaly Plateau, 6.2 km 74°ENE Itampolo	-24,654	43,997	80 m	Fisher-Griswold Arthropod Team	37308	2w
***medusus* sp. n.**	CASENT0448945	Mahafaly Plateau, 6.2 km 74°ENE Itampolo	-24,654	43,997	80 m	Fisher-Griswold Arthropod Team	37308	2w
***medusus* sp. n.**	CASENT0451410	Mahafaly Plateau, 6.2 km 74°ENE Itampolo	-24,654	43,997	80 m	Fisher-Griswold Arthropod Team	37308	2w
***medusus* sp. n.**	CASENT0455001	Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77°ENE Efoetse, 17.4 km 170°S Beheloka	-24,047	43,753	40 m	Fisher-Griswold Arthropod Team	37333	2w
***medusus* sp. n.**	CASENT0448723	Mahafaly Plateau, 6.2 km 74°ENE Itampolo	-24,654	43,997	80 m	Fisher-Griswold Arthropod Team	37308	1w
***medusus* sp. n.**	CASENT0424306	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	37337	1w
***medusus* sp. n.**	CASENT0445085	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	37337	1w
***medusus* sp. n.**	CASENT0444985	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	37337	3w

Species name	CASENT number	Locality	N	E	ALT	Collector	Date	Number of specimens
***medusus* sp. n.**	CASENT0445705	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	3/22/2002	2w
***medusus* sp. n.**	CASENT0445292	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	3/22/2002	2w
***medusus* sp. n.**	CASENT0445591	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	3/22/2002	2w
***medusus* sp. n.**	CASENT0444997	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	3/22/2002	2w
***medusus* sp. n.**	CASENT0427243	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	3/22/2002	2w
***medusus* sp. n.**	CASENT0455177	Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77°ENE Efoetse, 17.4 km 170°S Beheloka	-24,047	43,753	40 m	Fisher-Griswold Arthropod Team	3/18/2002	2w
***medusus* sp. n.**	CASENT0445705	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	37337	2w
***medusus* sp. n.**	CASENT0445590	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	3/22/2002	2w
***medusus* sp. n.**	CASENT0445291	Parc National de Tsimanampetsotsa, Forêt de Bemanateza, 20.7 km 81°E Efoetse, 23.0 km 131°SE Beheloka	-23,992	43,881	90 m	Fisher-Griswold Arthropod Team	3/22/2002	4w
***medusus* sp. n.**	CASENT0004002	Mahafaly Plateau, 6.2 km 74°ENE Itampolo	-24,654	43,997	80 m	Fisher-Griswold Arthropod Team	2/21/2002	2w
***medusus* sp. n.**	CASENT0477179	Parc National de Tsimanampetsotsa, 6.7 km 130°SE Efoetse, 23.0 km 175°S Beheloka	-24,101	43,76	25 m	Fisher-Griswold Arthropod Team	3/18/2002	1w
***medusus* sp. n.**	CASENT0477180	Parc National de Tsimanampetsotsa, 6.7 km 130°SE Efoetse, 23.0 km 175°S Beheloka	-24,101	43,76	25 m	Fisher-Griswold Arthropod Team	3/18/2002	1w
***medusus* sp. n.**	CASENT0455436	Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77°ENE Efoetse, 17.4 km 170°S Beheloka	-24,047	43,753	40 m	Fisher-Griswold Arthropod Team	3/18/2002	2w
***medusus* sp. n.**	CASENT0454945	Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77°ENE Efoetse, 17.4 km 170°S Beheloka	-24,047	43,753	40 m	Fisher-Griswold Arthropod Team	3/18/2002	2w
***medusus* sp. n.**	CASENT0454890	Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77°ENE Efoetse, 17.4 km 170°S Beheloka	-24,047	43,753	40 m	Fisher-Griswold Arthropod Team	3/18/2002	2w

Species name	CASENT number	Locality	N	E	ALT	Collector	Date	Number of specimens
***medusus* sp. n.**	CASENT0455002	Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77°ENE Efoetse, 17.4 km 170°S Beheloka	-24,047	43,753	40 m	Fisher-Griswold Arthropod Team	3/18/2002	2w
spinosus* sp. n. *HT	**CASENT0443515**	**Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary**	**-24,930**	**46,210**	**65 m**	**Fisher-Griswold Arthropod Team**	**2/7/2002**	**1w**
spinosus* sp. n. *PT	**CASENT0443515**	**Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary**	**-24,930**	**46,210**	**65 m**	**Fisher-Griswold Arthropod Team**	**2/7/2002**	**1w**
spinosus* sp. n. *PT	**CASENT0443531**	**Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary**	**-24,930**	**46,210**	**65 m**	**Fisher-Griswold Arthropod Team**	**2/7/2002**	**1w**
***spinosus* sp. n.**	CASENT0454095	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	3w
***spinosus* sp. n.**	CASENT0454237	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	2w
***spinosus* sp. n.**	CASENT0454238	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	2w
***spinosus* sp. n.**	CASENT0454100	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	2w
***spinosus* sp. n.**	CASENT0001365	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	1w
***spinosus* sp. n.**	CASENT0001366	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	1w
***spinosus* sp. n.**	CASENT0003947	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	2w
***spinosus* sp. n.**	CASENT0001369	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	2w
***spinosus* sp. n.**	CASENT0454236	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	2w
***spinosus* sp. n.**	CASENT0057339	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	B.L.Fisher	4/16/2005	1w
***spinosus* sp. n.**	CASENT0454094	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	2w
***spinosus* sp. n.**	CASENT0443504	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	1w

Species name	CASENT number	Locality	N	E	ALT	Collector	Date	Number of specimens
***spinosus* sp. n.**	CASENT0443512	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	2w
***spinosus* sp. n.**	CASENT0443601	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	2w
***spinosus* sp. n.**	CASENT0442542	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	1w
***spinosus* sp. n.**	CASENT0443593	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	2w
***spinosus* sp. n.**	CASENT0443501	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	1w
***spinosus* sp. n.**	CASENT0443502	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	1w
***spinosus* sp. n.**	CASENT0442540	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	1w
***spinosus* sp. n.**	CASENT0442541	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	1w
***spinosus* sp. n.**	CASENT0443539	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	2w
***spinosus* sp. n.**	CASENT0443544	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	2w
***spinosus* sp. n.**	CASENT0443540	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	2w
***spinosus* sp. n.**	CASENT0001469	Parc National d'Andohahela, Forêt d'Ambohibory, 1.7 km 61°ENE Tsimelahy, 36.1 km 308°NW Tolagnaro	-24,93	46,646	300 m	Fisher-Griswold Arthropod Team	1/16/2002	2w
***spinosus* sp. n.**	CASENT0443605	Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325°NW Amboasary	-24,930	46,210	65 m	Fisher-Griswold Arthropod Team	2/7/2002	3w
***spinosus* sp. n.**	CASENT0108875	Anosy Region, Distric of Amboasary,58Km SW of Fort Dauphin, 08Km NW of Amboasary, Berenty Special Reserve	-25,021	46,306	36 m	Mike, Rin'ha	11/30/2003	1w

FRS	Frontal carina distance. Distance of the frontal carinae immediately caudal of the posterior intersection points between frontal carinae and the torular lamellae. If these dorsal lamellae do not laterally surpass the frontal carinae, the deepest point of scape corner pits may be taken as reference line. These pits take up the inner corner of scape base when the scape is fully directed caudally and produces a dark triangular shadow in the lateral frontal lobes immediately posterior to the dorsal lamellae of the scape joint capsule (Fig. 2).
ML (Weber length)	Mesosoma length from caudalmost point of propodeal lobe to transition point between anterior pronotal slope and anterior pronotal shield (preferentially measured in lateral view; if the transition point is not well defined, use dorsal view and take the centre of the dark-shaded borderline between pronotal slope and pronotal shield as anterior reference point). In gynes: length from caudalmost point of propodeal lobe to the most distant point of steep anterior pronotal face (Fig. 3).
MPST	Maximum distance from the center of the propodeal spiracle to the posteroventral corner of the ventrolateral margin of the metapleuron (Fig. 4).
MW	Mesosoma width. In workers MW is defined as the longest width of the pronotum in dorsal view excluding the pronotal spines (Fig. 5).
NOL	Length of the petiolar node. Measured in lateral view from the centre of petiolar spiracle to dorso-caudal corner of caudal cylinder. Do not erroneously take as the reference point the dorso-caudal corner of the helcium, which is sometimes visible (Fig. 4).
NSTI	Apical distance of the anterodorsal spines on the petiolar node in dorsal view; if spine tips are rounded or thick take the centers of spine tips as reference points (Fig. 6).
PEL	Diagonal petiolar length in lateral view; measured from anterior corner of subpetiolar process to dorso-caudal corner of caudal cylinder (Fig. 3).
PEW	Maximum width of petiole in dorsal view. Nodal spines are not considered (Fig. 5).
PoOC	Postocular distance. Use a cross-scaled ocular micrometer and adjust the head to the measuring position of CL. Caudal measuring point: median occipital margin; frontal measuring point: median head at the level of the posterior eye margin (Fig. 1).
PPL	Postpetiole length. The longest anatomical line that is perpendicular to the posterior margin of the postpetiole and is between the posterior postpetiolar margin and the anterior postpetiolar margin (Fig. 4).
PPW	Postpetiole width. Maximum width of postpetiole in dorsal view (Fig. 5).
PSTI	Apical distance of pronotal spines in dorsal view; if spine tips are rounded or thick take the centers of spine tips as reference points (Fig. 5).
SL	Scape length. Maximum straight line scape length excluding the articular condyle.
SPBA	Minimum propodeal spine distance. The smallest distance of the lateral margins of the propodeal spines at their base. This should be measured in dorsofrontal view, since the wider parts of the ventral propodeum do not interfere



Figures 1–6. Measurement lines for metric characters. Head in dorsal view (**1**) with measurement lines for CL, CW, CWB and PoOC; frontal region of the head dorsum (**2**) with measurement lines for FRS; dorsal view of mesosoma (**3**) with measurement lines for NSTI, SPBA and SPTI; dorsal view of mesosoma (**4**) with measurement lines for MW, PSTI, PEW and PPW; lateral view of mesosoma (**5**) with measurement lines for ML and PEL; lateral view of mesosoma petiole and postpetiole (**6**) with measurement lines for MPST, NOL, PPL and SPST.

with the measurement in this position. If the lateral margins of propodeal spines diverge continuously from the tip to the base, a smallest distance at base is not defined. In this case, SPBA is measured at the level of the bottom of the interspinal meniscus (Fig. 6).

SPST	Propodeal spine length. Distance between the centre of propodeal spiracle and spine tip. The spiracle centre refers to the midpoint defined by the outer cuticular ring but not to the centre of real spiracle opening that may be positioned eccentrically (Fig. 4).
SPTI	Apical propodeal spine distance. The distance of propodeal spine tips in dorsal view; if spine tips are rounded or truncated, the centres of spine tips are taken as reference points (Fig. 6).

Taxonomic nomenclature, OTU concepts and natural language (NL) phenotypes were compiled in mx (http://purl.org/NET/mx-database). Taxonomic history and descriptions of taxonomic treatments were rendered from this software. Hymenoptera-specific terminology of morphological statements used in descriptions, identification key, and diagnoses are mapped to classes in phenotype-relevant ontologies (Hymenoptera Anatomy Ontology (HAO) (Yoder et al. 2010) via a URI table (Table 2); see Seltmann et al. (2012), Mikó et al. (2014) for more information about this approach.

In verbal descriptions of taxa based on external morphological traits, recent taxonomic papers (Csősz et al. 2014, Seifert and Csősz 2015) were considered. Definitions of surface sculpturing are linked to Harris (1979). Body size is given in µm, means of morphometric ratios as well as minimum and maximum values are given in parentheses with up to three digits. Estimated inclination of pilosity and cuticular spines is given in degrees. Definitions of species-groups as well as descriptions of species are surveyed in alphabetic order.

Statistical analyses of continuous morphometric data

Hypothesis formation by exploratory analyses. Our hypothesis of the number of clusters and classification of samples was formulated by an exploratory data analysis technique, NC-clustering (Seifert et al. 2014) using continuous morphometric data. NC-clustering searches for discontinuities in data, sorting all similar cases into the same cluster by transforming morphological differences between nest samples into a distance matrix in a linear discriminant space. The linear discriminant scores for each nest sample are displayed in a dendrogram within Euclidean space via UPGMA (Unweighted Pair Group Method with Arithmetic Mean) distance method. This method is able to tackle large datasets with high dimensionality (Csősz et al. 2014, Guillem et al. 2014, Wachter et al. 2015), providing readily inferable patterns even for a high number of clusters. A bootstrap version of cluster analysis was applied to evaluate how consistently the same clusters appear with a sub-sampled dataset by running 1000 iterations (method = “average”, method.dist = “euclidean”, nboot = 1000) using package *pvclust* (Suzuki and Shimodaira 2014). Package *pvclust* returns two type of p values: the Approximately Unbiased P-value (AU) is computed by multiscale bootstrap resampling, and the raw Bootstrap Probabilities (BP) that is calculated before statistical adjustments by normal bootstrap resampling.

Table 2. URI table for morphometric characters and Hymenoptera-specific terminology of morphological statements used in descriptions, identification key, and diagnoses are mapped to classes in phenotype-relevant ontologies.

Abbr.	Label	Class genus differentia definition	Comments	uri
CL	maximum cephalic length in median view	The median anatomical line that extends between the posterior margin of the cranium and the distal margin of the clypeus in frontal view.	The maximum cephalic length in median view is not equivalent to the maximum cephalic size that extends between the posterior cranial margin and the distal clypeal line. The head must be carefully tilted to the position with the true maximum. Excavations of hind vertex and/or clypeus reduce CL (Fig. 1A).	http://purl.obolibrary.org/obo/HAO_0002331
CW	head width	The anatomical line that is the longest horizontal diameter of the cranium in frontal view.	The head width is the largest distance between the lateral margins of the compound eyes measured in frontal view (Fig. 1A).	http://purl.obolibrary.org/obo/HAO_0002268
CWb	dorsal head width	The anatomical line between the intersections of the cranium contour line and dorsal head line in frontal view.	The dorsal head width is the maximum width of head capsule without the compound eyes that is measured just posterior of the eyes in frontal view (Fig. 1A).	http://purl.obolibrary.org/obo/HAO_0002314
Cdep	median clypeal notch depth	The anatomical line that is between the distal clypeal line and the proximalmost point of the distal clypeal notch in frontal view.		http://purl.obolibrary.org/obo/HAO_0002333
EL	maximum diameter of compound eye	The longest diameter of the eye.		http://purl.obolibrary.org/obo/HAO_0002326
FRS	frontal carina line	The transverse torular line that extends between the frontal carinae.	Distance of the frontal carinae immediately caudal of the posterior intersection points between frontal carinae and the torular lamellae. If these dorsal lamellae do not laterally surpass the frontal carinae, the deepest point of scape corner pits may be taken as reference line. These pits take up the inner corner of scape base when the scape is fully switched caudad and produce a dark triangular shadow in the lateral frontal lobes immediately posterior of the dorsal lamellae of scape joint capsule (Fig. 1B).	http://purl.obolibrary.org/obo/HAO_0002323
ML	Weber length	The anatomical line that connects the global minima of the contour line of the pronotal slope in lateral view when the specimen is rotated until the contour line becames as symmetric as possible and the posteriormost point of the propodeal lobe.	Preferentially measured in lateral view; if the transition point is not well defined, use dorsal view and take the centre of the dark-shaded borderline between pronotal slope and pronotal shield as anterior reference point. In gynes: length from distalmost point of propodeal lobe to the most distant point of steep anterior pronotal face (Fig. 1E).	http://purl.obolibrary.org/obo/HAO_0002309
MPST	maximum spiracle distance of propodeum	The anatomical line that connects the center of the propodeal spiracle with the posteriormost point of the propodeal lobe in lateral view.	Maximum distance from the center of the propodeal stigma to the anterioventral corner of the ventrolateral margin of the metapleuron (Fig. 1F).	http://purl.obolibrary.org/obo/HAO_0002334

Abbr.	Label	Class genus differentia definition	Comments	uri
MW	mesosoma width	The longest width of the pronotum in dorsal view.	Mesosoma width. In workers MW is defined as the longest width of the pronotum in dorsal view excluding the pronotal spines (Fig. 1D).	http://purl.obolibrary.org/obo/HAO_0002335
NOL	length of petiolar node	The anatomical line that is the shortest between the center of the petiolar spiracle and the posterior margin of the petiole in lateral view.	Length of the petiolar node. Measured in lateral view from the centre of petiolar spiracle to posterodorsal corner of caudal cylinder. Do not erroneously take as reference point the dorso-caudal corner of the helcium, which is sometimes visible (Fig. 1F).	http://purl.obolibrary.org/obo/HAO_0002336
NOH	maximum height of petiolar node	The anatomical line that is the longest between the dorsal margin of the petiole and the posterior petiolar distance and perpendicular to the posterior petiolar distance.		http://purl.obolibrary.org/obo/HAO_0002327
NSTI	apical petiolar spine distance	The anatomical line between the distal ends of the anterodorsal spines of the petiolar node.	If spine tips are rounded or thick take the centers of spine tips as reference points (Fig. 1C).	http://purl.obolibrary.org/obo/HAO_0002338
PEH	maximum petiole height	The anatomical line that is the longest between the ventral margin of the petiole and the dorsal margin of the petiole and is perpendicular to the ventral margin of the petiole in lateral view.		http://purl.obolibrary.org/obo/HAO_0002328
PEL	diagonal petiolar length	The anatomical line that extends between the distalmost point of the subpetiolar process and the global minima of the contour line of the dorsal region of the posterior petiolar constriction in lateral view when the specimen is rotated until the contour line became as symmetric as possible.	Fig. 1E.	http://purl.obolibrary.org/obo/HAO_0002317
PEW	petiole width	The maximum width of the petiole in dorsal view.	Anterodorsal spines of the petiolar node are not considered (Fig. 1D).	http://purl.obolibrary.org/obo/HAO_0002339
PoOC	postocular distance	The median anatomical line of the cranium that is the longest between the dorsal margin of the cranium and the dorsal head width.	Use a cross-scaled ocular micrometer and adjust the head to the measuring position of CL. Caudal measuring point: median occipital margin; frontal measuring point: median head at the level of the posterior eye margin (Fig. 1A).	http://purl.obolibrary.org/obo/HAO_0002340
PPL	postpetiole length	The longest anatomical line that is perpendicular to the posterior margin of the postpetiole in lateral view and is between the posterior postpetiolar margin and the anterior postpetiolar margin.	Fig. 1F	http://purl.obolibrary.org/obo/HAO_0002341

Abbr.	Label	Class genus differentia definition	Comments	uri
PPW	postpetiole width	The maximum width of the postpetiole in dorsal view.	Fig. 1D	http://purl.obolibrary.org/obo/HAO_0002342
PSTI	apical distance of pronotal spines	The anatomical line between the distal ends of the pronotal spines.	If spine tips are rounded or thick take the centers of spine tips as reference points (Fig. 1D).	http://purl.obolibrary.org/obo/HAO_0002345
SL	scape length	The proximodistal anatomical line of the scapal area distal to the radicle.	Maximum straight line scape length excluding the radicle (Fig. 1A).	http://purl.obolibrary.org/obo/HAO_0002346
SPBA	minimum spine distance	The shortest anatomical line between the lateral margins of the propodeal spines.	This should be measured in anterodorsal view, since the wider parts of the ventral propodeum do not interfere with the measurement in this position. If the lateral margins of spines diverge continuously from the tip to the base, a smallest distance at base is not defined. In this case, SPBA is measured at the level of the bottom of the interspinal meniscus (Fig. 1C).	http://purl.obolibrary.org/obo/HAO_0002347
SPST	spine length	The anatomical line between the center of the propodeal spiracle and the distal end of the propodeal spine.	Spine length. Distance between the centre of propodeal stigma and spine tip. The stigma centre refers to the midpoint defined by the outer cuticular ring but not to the centre of real stigma opening that may be positioned eccentrically (Fig. 1F).	http://purl.obolibrary.org/obo/HAO_0002348
SPTI	apical spine distance	The anatomical line between the distal ends of the propodeal spines.	If spine tips are rounded or truncated, the centres of spine tips are taken as reference points (Fig. 1C).	http://purl.obolibrary.org/obo/HAO_0002319
	anterior pronotal slope	The concave area anteriorly on the mesosoma that accommodates the posterior area of the cranium.		http://purl.obolibrary.org/obo/HAO_0002311
	anterior setal pit	The anteriormost setal pit on the dorsal side of the petiole.		http://purl.obolibrary.org/obo/HAO_0002312
	caudal cylinder	The petiolar area posterior to the posterior petiolar constriction.		http://purl.obolibrary.org/obo/HAO_0002318
	cranial scrobe of the pronotum	The scrobe on the pronotum that accommodates the posterior surface of the cranium.		http://purl.obolibrary.org/obo/HAO_0002343
	distal clypeal line	The anatomical line that is perpendicular to the median anatomical line and is the tangent at the distalmost point(s) of the clypeus in frontal view.		http://purl.obolibrary.org/obo/HAO_0002316
	dorsal head line	The anatomical line between the posteriormost (dorsalmost) points of compound eyes in frontal view.		http://purl.obolibrary.org/obo/HAO_0002315

Abbr.	Label	Class genus differentia definition	Comments	uri
	dorsal petiolar scrobe	The scrobe that is dorsal to the propodeal foramen and accommodates the proximodorsal area of the petiole.		http://purl.obolibrary.org/obo/HAO_0002313
	external area of the scape	The area of the scape that faces away from the cranial surface in fully caudal scape position.		http://purl.obolibrary.org/obo/HAO_0002320
	eye	The compound organ that is composed of ommatidia.		http://purl.obolibrary.org/obo/HAO_0000217
	facial area of the scape	The area of the scape that faces the cranium surface when the scape is in fully flexed position.		http://purl.obolibrary.org/obo/HAO_0002321
	frontal carina	The carina that extends along the lateral margin of the intertorular area (median margin of the antennal foramen) towards the vertex.		http://purl.obolibrary.org/obo/HAO_0001533
	frontal carina line	The transverse torular line that extends between the frontal carinae.		http://purl.obolibrary.org/obo/HAO_0002323
	lateral carina of clypeus	The carina that extends between the ventral (anterior) margin of the antennal foramen to the apical clypeal margin.		http://purl.obolibrary.org/obo/HAO_0002324
	margin	The line that delimits the periphery of an area.		http://purl.obolibrary.org/obo/HAO_0000510
	median clypeal notch	The median notch that is on the distal clypeal margin.		http://purl.obolibrary.org/obo/HAO_0002332
	mesosoma	The anatomical cluster that is composed of the prothorax, mesothorax and the metapectal-propodeal complex.		http://purl.obolibrary.org/obo/HAO_0000576
	Weber length	The anatomical line that connects the global minima of the contour line of the pronotal slope in lateral view when the specimen is rotated until the contour line becames as symmetric as possible and the posteriormost point of the propodeal lobe.		http://purl.obolibrary.org/obo/HAO_0002309

Abbr.	Label	Class genus differentia definition	Comments	uri
	petiolar scrobe	The scrobe that is located ventrally of the propodeal foramen and accommodates the proximal area of the petiole.		http://purl.obolibrary.org/obo/HAO_0002265
	pronotal spine	The spine that is located at the dorsolateral edge of the cranial scrobe of the pronotum.		http://purl.obolibrary.org/obo/HAO_0002344
	pronotum	The notum that is located in the prothorax.		http://purl.obolibrary.org/obo/HAO_0000853
	scape	The antennal segment that is proximal to the pedicel and is connected to the head via the radicle.		http://purl.obolibrary.org/obo/HAO_0000908
	scrobe	The area that is impressed and is for the reception or concealment of another sclerite.		http://purl.obolibrary.org/obo/HAO_0000912
	setal angle	The angle of the proximodistal axis of the seta to the contour line of the bodypart where the seta is located.		http://purl.obolibrary.org/obo/HAO_0002330
	setal line	The row that is composed of setae.		http://purl.obolibrary.org/obo/HAO_0000903
	setal pit	The impression with a centered sensillum trichodeum.		http://purl.obolibrary.org/obo/HAO_0001958
	spine	The process that lacks non-sclerotised ring at the base.		http://purl.obolibrary.org/obo/HAO_0000949
	spiracle	The anatomical cluster that is composed of the distal end of the trachea and the margin of the sclerite or conjunctiva surrounding the spiracular opening.		http://purl.obolibrary.org/obo/HAO_0000950
	transverse torular line	The anatomical line that is tangential to the posteriormost points of the antennal rims.		http://purl.obolibrary.org/obo/HAO_0002322
	width	A 1-D extent quality which is equal to the distance from one side of an object to another side which is opposite.		http://purl.obolibrary.org/obo/HAO_0002308

The optimal number of clusters was determined via gap statistic using gap criterion introduced by Tibshirani et al. (2001). The gap statistic is a standard method for determining the number of clusters in a set of data (Mohajer et al. 2010). It clusters the observed data, varying the number of clusters and computes the corresponding within-cluster dispersion (i.e. the sum of the squared distances between the observations and the center of the cluster). For each number of clusters the gap statistic compares the standardized within-cluster dispersion to its expectation under an appropriate null reference distribution (i.e. each observation is assumed to fall in a single cluster). The optimal number of clusters is the value for which the observed within-cluster dispersion falls the farthest below this reference curve (Tibshirani et al. 2001).

Statistical computing was done in R (R Core Team 2014). NC-clustering was done via package *cluster* (Maechler et al. 2014), *MASS* (Venables and Ripley 2002). Gap statistic and partitioning of samples was calculated based on recursive thresholding via the *clusterGenomics* package (Nilsen and Lingjaerde 2013) using functions 'gap' (with optional arguments Kmax=10, B=100, nstart=20) and 'part' (Kmax=10, minSize=5, Kmax.rec=5, B=100).

Hypothesis testing by confirmatory LDA. To increase the reliability of species delimitation, hypotheses on clusters and classifications of cases via two exploratory processes were tested by a confirmative LDA. Classification hypotheses were imposed for all samples congruently classified by exploratory methods while wild-card settings (i.e. no prior hypothesis imposed on its classification) were given to samples that were incongruently classified by the two methods. The confirmative LDA was run as an iterative process to achieve the lowest number of characters necessary to achieve the desired level (>97%) of classification success (Seifert 2014).

Results

Synopsis of Malagasy *Nesomyrmex* species

angulatus group
  angulatus (Mayr, 1862)
    = *angulatus ilgii* (Forel, 1894)
    = *latinodis* (Mayr, 1895)
    = *angulatus concolor* (Santschi, 1914)

hafahafa group
  capricornis Csősz & Fisher, sp. n.
  hafahafa Csősz & Fisher, sp. n.
  medusus Csősz & Fisher, sp. n.
  spinosus Csősz & Fisher, sp. n.

madecassus group
  gibber (Donisthorpe, 1946)
  madecassus (Forel, 1892)

sikorai group
  retusispinosus (Forel, 1892)
  sikorai (Emery, 1896)

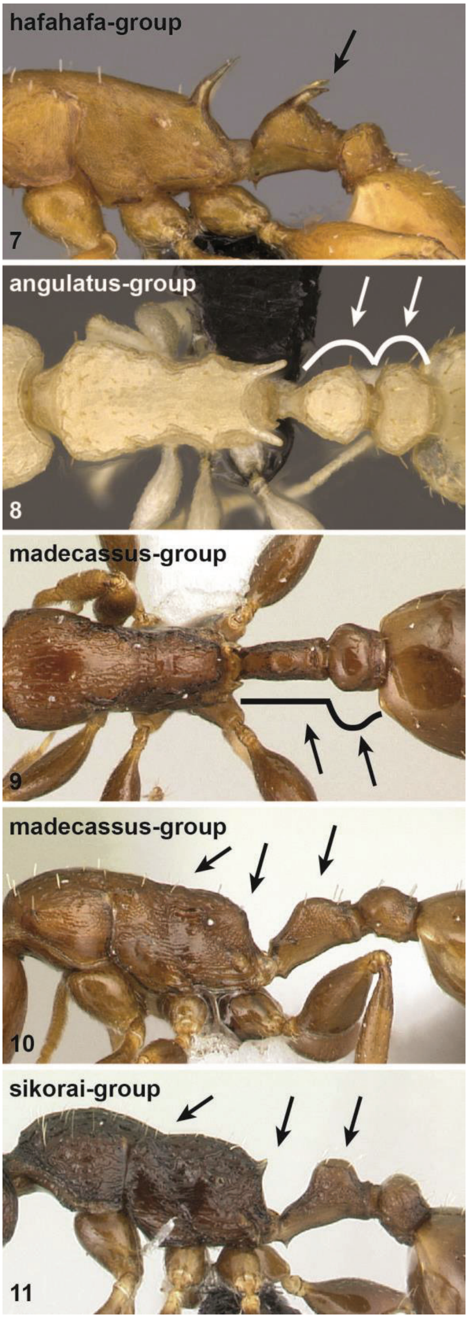
I. Definitions and diagnoses of groups

Key to species-groups

1 Anterodorsal spines on petiolar node present (Fig. 7)........... ***hafahafa* group**
– Anterodorsal spines on petiolar node absent (Figs 8–11)............................. **2**
2 Petiolar node globular in dorsal view (Fig. 8), postocular distance vs. petiole width (PoOc/PEW): 0.887 [0.723, 1.167] .... ***angulatus* group**
– Petiolar node long and narrow in dorsal view, sides are nearly parallel (Fig. 9). Postocular distance vs. petiole width (PoOc/PEW): (*sikorai*-group) 1.415 [1.198, 1.676], (*madecassus*-group) 1.610 [1.210, 2.090]............................ **3**
3 Petiolar node in lateral view lower, (MPST/NOH): 3.541 [2.714, 5.625], propodeal spines very short to absent, mesopropodeal depression absent to shallow (Fig. 10)... ***madecassus* group**
– Petiolar node in lateral view higher, (MPST/NOH): 2.409 [1.885, 2.869], propodeal spines moderately long, always present, mesopropodeal depression conspicuous, deep (Fig. 11) .... ***sikorai* group**

angulatus species-group

Pronotal spines present or absent. Anterodorsal spines on petiolar node absent. Propodeal spines short to long and acute. Vertex ground sculpture areolate. Main sculpture on vertex not defined. Metanotal depression present or absent. Median clypeal notch present or absent. Median clypeal notch shape/depth: 0–23 µm. Antennomere count: 12. Absolute cephalic size (CS): 591 µm [418, 946]. Cephalic length vs. maximum width of head capsule (CL/CWb): 1.218 [1.057, 1.490]. Postocular distance vs. cephalic length (PoOc/CL): 0.40 [0.359, 0.444]. Scape length vs. absolute cephalic size (SL/CS): 0.676 [0.519, 0.866]. Eye length vs. absolute cephalic size (EL/CS): 0.260 [0.193, 0.317]. Petiole width vs. absolute cephalic size (PEW/CS): 0.431 [0.330, 0.522]. Postpetiole width vs. absolute cephalic size (PPW/CS): 0.496 [0.361, 0.585]. Petiolar node height vs. absolute cephalic size (PEW/CS): 0.250 [0.185, 0.311]. *Nesomyrmex angulatus* (Mayr, 1862) and ca. four undescribed species belong to this group in the Malagasy zoogeographical region.



Figures 7–11. Diagnostic characters for workers of all species-groups outlined in this paper. Lateral view of mesosoma, petiole and postpetiole of a member of the *hafahafa* species-group (**7**), dorsal view of mesosoma, petiole and postpetiole of *angulatus* species-group (**8**), dorsal view of mesosoma, petiole and postpetiole of *madecassus* species-group (**9**), lateral view of mesosoma, petiole and postpetiole of *madecassus* species-group (**10**), lateral view of mesosoma, petiole and postpetiole of *sikorai* species-group (**11**). For details see main text.

hafahafa **species-group**

Pronotal spines present. Anterodorsal spines on petiolar node present. Propodeal spines long and acute. Vertex ground sculpture areolate. Vertex main sculpture rugulose. metanotal depression absent. Median clypeal notch present. Median clypeal notch shape/depth: 15–31 µm. Antennomere count: 12. Absolute cephalic size (CS): 1059 µm [930, 1200]. Cephalic length vs. maximum width of head capsule (CL/CWb): 1.074 [1.0, 1.143]. Postocular distance vs. cephalic length (PoOc/CL): 0.378 [0.342, 0.403]. Scape length vs. absolute cephalic size (SL/CS): 0.890 [0.835, 0.984]. Eye length vs. absolute cephalic size (EL/CS): 0.232 [0.210, 0.264]. Petiole width vs. absolute cephalic size (PEW/CS): 0.267 [0.203, 0.353]. Postpetiole width vs. absolute cephalic size (PPW/CS): 0.523 [0.430, 0.586]. Petiolar node height vs. absolute cephalic size (PEW/CS): 0.142 [0.107, 0.186]. Four species, *Nesomyrmex capricornis* sp. n., *N. hafahafa* sp. n., *N. medusus* sp. n. and *N. spinosus* sp. n. are known to constitute this species group in Madagascar.

madecassus **species-group**

Pronotal spines absent. Anterodorsal spines on petiolar node absent. Propodeal spines short, lamelliform to absent. Vertex ground sculpture smooth. Vertex main sculpture not defined. Metanotal depression present. Median clypeal notch present or absent. Median clypeal notch shape/depth 0–15 µm. Antennomere count: 12. Absolute cephalic size (CS): 571 µm [405, 785]. Cephalic length vs. maximum width of head capsule (CL/CWb): 1.231 [1.092, 1.567]. Postocular distance vs. cephalic length (PoOc/CL): 0.479 [0.407, 0.544]. Scape length vs. absolute cephalic size (SL/CS): 0.718 [0.492, 0.831]. Eye length vs. absolute cephalic size (EL/CS): 0.249 [0.1934, 0.279]. Petiole width vs. absolute cephalic size (PEW/CS): 0.217 [0.181, 0.256]. Postpetiole width vs. absolute cephalic size (PPW/CS): 0.331 [0.243, 0.398]. Petiolar node height vs. absolute cephalic size (PEW/CS): 0.122 [0.072, 0.158]. *Nesomyrmex madecassus* (Forel, 1892) and ca. seven other taxa from the Malagasy zoogeographical region will be revised in the forthcoming revisionary work.

sikorai **species-group**

Pronotal spines present or absent. Anterodorsal spines on petiolar node absent. Propodeal spines short to long and acute. Vertex ground sculpture not defined. Vertex main sculpture areolate. Metanotal depression present. Median clypeal notch present or absent. Median clypeal notch shape/depth 0–15 µm. Antennomere count: 12. Absolute cephalic size (CS): 750 µm [634, 890]. Cephalic length vs. maximum width of head capsule (CL/CWb): 1.218 [1.075, 1.382]. Postocular distance vs. cephalic length (PoOc/CL): 0.461 [0.411, 0.511]. Scape length vs. absolute cephalic size (SL/CS):

0.816 [0.761, 0.872]. Eye length vs. absolute cephalic size (EL/CS): 0.232 [0.201, 0.284]. Petiole width vs. absolute cephalic size (PEW/CS): 0.243 [0.206, 0.326]. Postpetiole width vs. absolute cephalic size (PPW/CS): 0.359 [0.306, 0.426]. Petiolar node height vs. absolute cephalic size (PEW/CS): 0.175 [0.149, 0.205]. *Nesomyrmex sikorai* (Emery, 1896), *Nesomyrmex retusispinosus* (Forel, 1892) plus ca. ten more Malagasy species will be revised in a forthcoming revisionary work.

II. Species delimitation

Multivariate Analyses of Numeric Morphology

Four clusters were revealed by gap statistic (Fig. 12) to be the most parsimonious solution corroborating the evaluation of the NC-clustering dendrogram (Fig. 13). The grouping hypotheses generated by hypothesis-free exploratory analyses is confirmed by Linear Discriminant Analysis (LDA) with 99.4% classification success. This pattern is also supported by the examination of external morphological traits (e.g. shape of petiolar node, length and deviation of anterodorsal spines on petiolar node), hence the four clusters can be defined as morphospecies based on descriptive morphology. The distinctive morphology of these species permits considerable character reduction, so that the four taxa can be separated based on the combination of four continuous morphometric traits (FRS, NSTI, PSTI and SPST see Table 3) with 99.4% classification success (Fig. 14). Synopses of species were defined based on multivariate analyses of morphological traits: *Nesomyrmex capricornis* sp. n., *Nesomyrmex hafahafa* sp. n., *Nesomyrmex medusus* sp. n., *Nesomyrmex spinosus* sp. n.

Coefficients of linear discriminants of LD1 and LD2 help to place every additional sample in the discriminant space illustrated in Fig. 14. These placements were calculated using the four most discriminative characters. The morphometric data are in micrometer. Classification functions based on linear discriminants LD1 and LD2 are as follows:

$$LD1= -(0.0324\times PEL)+(0.0121\times SPST)-(0.0023\times PSTI)+(0.0281\times NSTI) +1.6$$
$$LD2= +(0.0336\times PEL)+(0.0258\times SPST)-(0.0328\times PSTI)+(0.0049\times NSTI)-2.9$$

Discriminant scores (LD1, LD2) obtained here can either be compared to the values given in Table 3, or can also be used as coordinates in Fig. 14, if relevant scores are fitted on axes LD1 and LD2, and the position of every new sample can be readily identified visually.

Though all species defined in this revisionary work proved to be highly separable via descriptive morphology, or by using simple indices, the application of classification functions LD1 and LD2 provides a foolproof, numeric morphology-based identification tool when decisions based on conventional diagnostic traits fail.

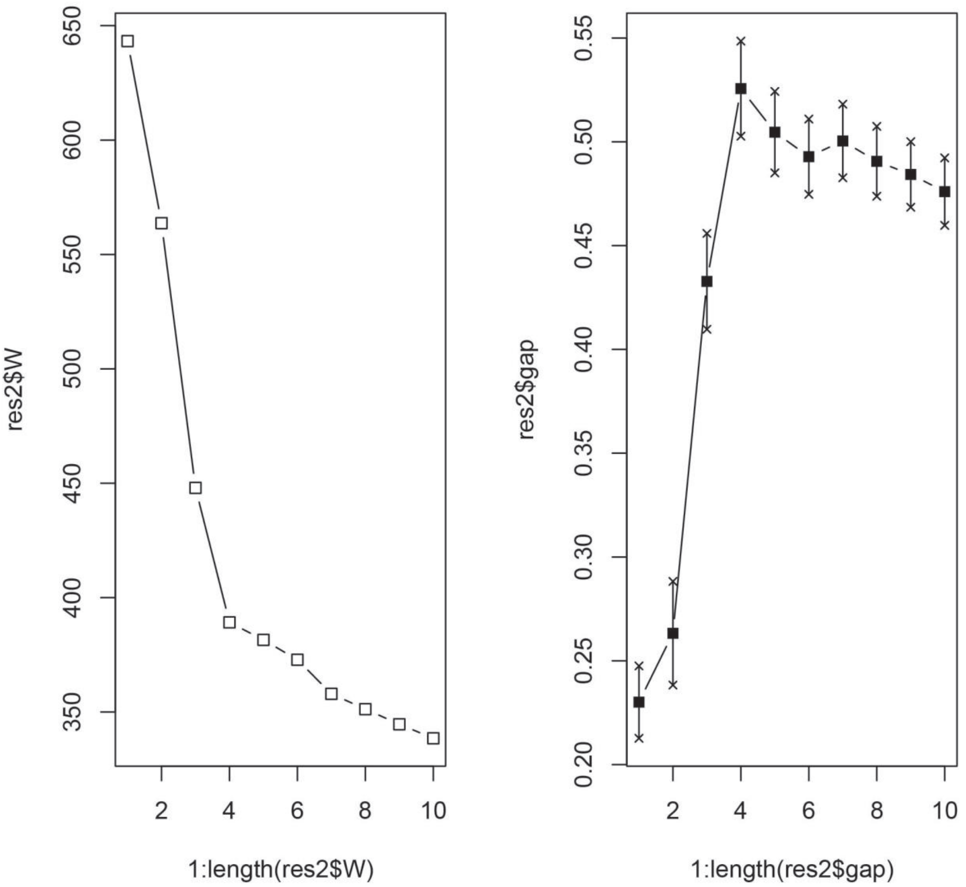


Figure 12. Gap statistic for dataset of *hafahafa* species-group. Four-cluster solution is highly supported by the elbow at 4 components by the dispersion curve (left) and by the peak at cluster number four by the gap curve (right). Number of clusters in the data (X axis), the total within-cluster dispersion for each evaluated partition (Y axis for the left plot) and the vector of length Kmax giving the Gap statistic for each evaluated partition (Y axix for the right plot) is illustrated.

Description of the species in the *Nesomyrmex hafahafa* species-group

In this section, four new species of the *N. hafahafa* species-group are described, and a key to these species is provided. Diagnoses are given in the key, the basic statistics of body size ratios are given in Table 4 for each species. The biogeography of the *hafahafa* group is detailed in the discussion. The diagnoses and a key to the four Malagasy *Nesomyrmex* species groups (*angulatus*-group, *hafahafa*-group, *madecassus*-group and *sikorai*-group) defined here are followed by the descriptions of species belonging to the *hafahafa* group.

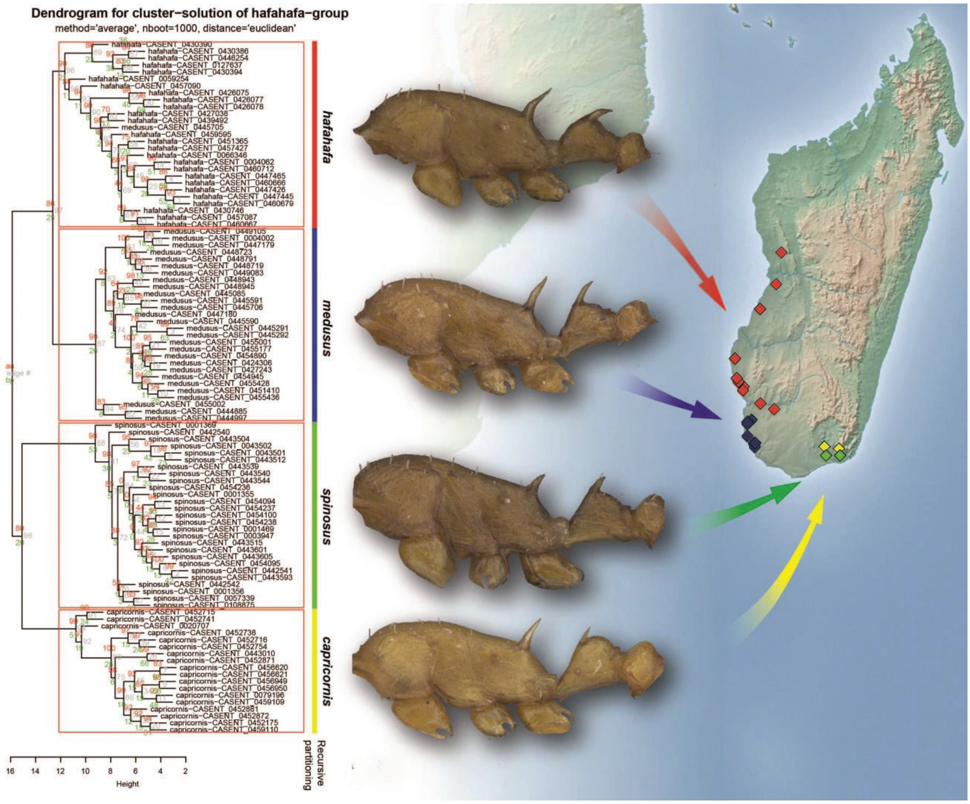


Figure 13. Dendrogram for NC-clustering scores with AU/BP values (%), classification of objects based on recursive partitioning with mesosomal profile of four species of *hafahafa* species-group is mapped on distributional map of Madagascar. Abbreviations: AU = approximately unbiased P-value, BP = bootstrap probabilities before statistical adjustments. Rectangles show the final species hypothesis. Color codes: *Nesomyrmex capricornis* sp. n. (yellow), *N. hafahafa* sp. n. (red), *N. medusus* sp. n. (blue), *N. spinosus* sp. n. (green).

Key to the species of *hafahafa* group

The species of the *Nesomyrmex hafahafa* group differ in body ratios. The following dichotomous identification key for the worker caste was generated based on ratios of morphological features that allow quick identification. Minimum and maximum values for each character is given in parentheses. The reliability of all characters has been tested and calculated classification success was always higher than 95% for each node. Where classification error was detected (i.e. the range of a given trait overlaps between two species) a percentile range 5–95% was also provided in brackets.

1 Propodeal spine very short (Fig. 15). Spine length vs. absolute cephalic size (SPST/CS): ≤ 0.330 (min. 0.258, max. 0.330) .... ***spinosus* sp. n.**

– Propodeal spine longer (Figs 16–18). Spine length vs. absolute cephalic size (SPST/CS): > 0.330 (min. 0.333, max. 0.437) **2**

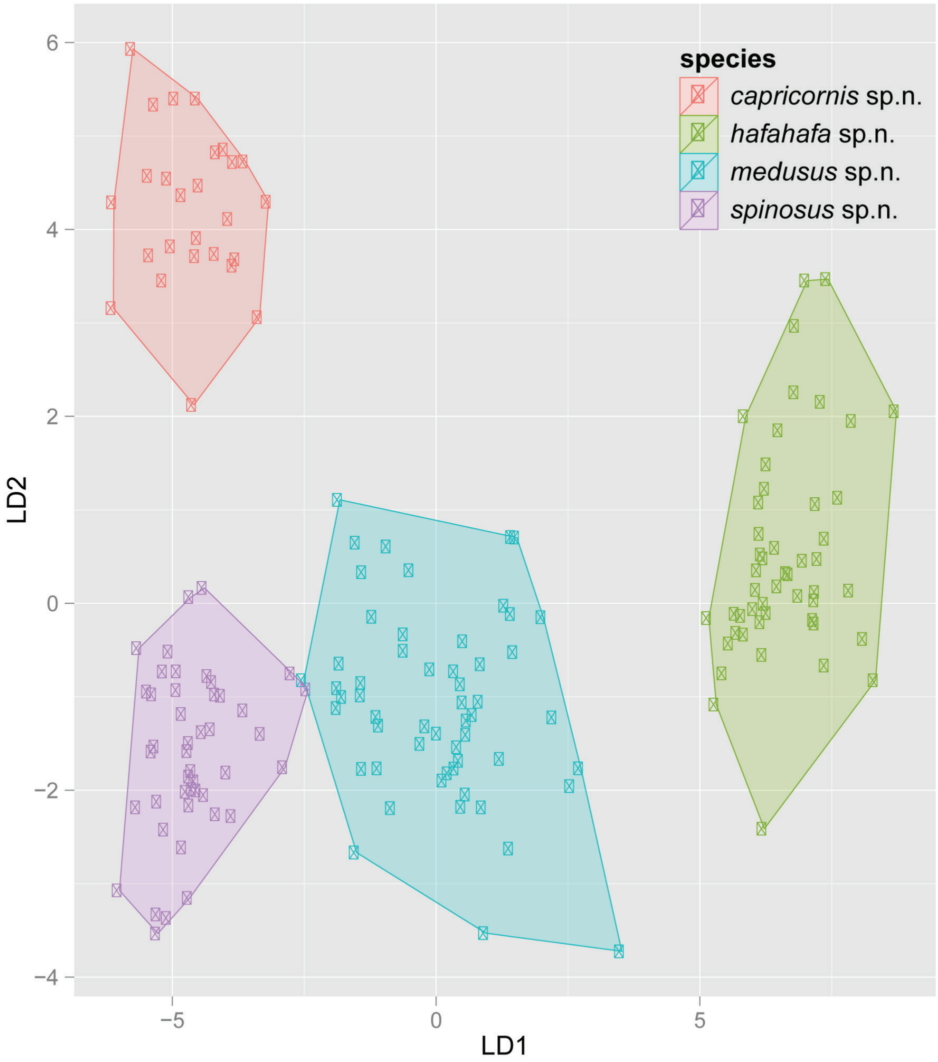
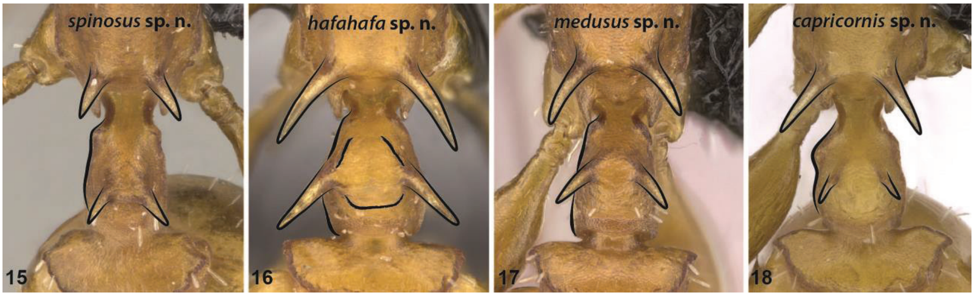


Figure 14. Scatterplot of discriminant scores DL1 and LD2 for *Nesomyrmex capricornis* sp. n. (red), *N. hafahafa* sp. n. (green), *N. medusus* sp. n. (blue), *N. spinosus* sp. n. (lilac) is illustrated. Convex hull graphically displays boundaries between sets of points forming different clusters. Classification functions for LD1 and LD2 are given in the text.

2 Bases of anterodorsal petiolar spines enclose a triangular truncate area on the dorsum of petiolar node delineated by a rim (Fig. 16). In dorsal view, anterodorsal petiolar spines distantly surpassing lateral margin of petiole (Fig. 16). Apical distance of the anterodorsal spines on the petiolar node vs. petiole width (NSTI/PEW): > 1.550 (min. 1.531, max. 1.948), [5–95% percentiles: min. 1.563, max. 1.873] ....***hafahafa* sp. n.**



Figures 15–18. Anterodorsal view of the propodeal spines and anterodorsal spines on the petiolar node of *Nesomyrmex spinosus* sp. n. (**15**), *N. hafahafa* sp. n. (**16**), *N. medusus* sp. n. (**17**), *N. capricornis* sp. n. (**18**). Contour lines of propodeal spines, anterodorsal petiolar spines and the left lateral margin of the petiole are drawn.

– There is no conspicuous truncate area on the dorsum of petiolar node (Figs 17–18). Apical distance of the anterodorsal spines on the petiolar node vs. petiole width (NSTI/PEW): < 1.550 (min. 0.795, max. 1.575), [5–95% percentiles: min. 0.823, max. 1.549]..**3**

3 In dorsal view, distance between tips of anterodorsal petiolar spines longer than petiole width, spines surpassing lateral margins of petiole (Fig. 17). Apical distance of the anterodorsal spines on the petiolar node vs. petiole width (NSTI/PEW): > 1.090 (min. 1.055, max. 1.575), [5–95% percentiles: min. 1.094, max. 1.549]. Pronotal spines wider; apical distance of pronotal spines vs. absolute cephalic size (PSTI/CS): > 0.700 (min. 0.711, max. 0.813) .... ***medusus* sp. n.**

– In dorsal view, distance between tips of anterodorsal petiolar spines shorter than petiole width (Fig. 18). Apical distance of the anterodorsal spines on the petiolar node vs. petiole width (NSTI/PEW): > 1.090 (min. 0.795, max. 1.220), [5–95% percentiles: min. 0.823, max. 1.083]. Apical distance of pronotal spines vs. absolute cephalic size (PSTI/CS): < 0.700 (min. 0.617, max. 0.690).. ***capricornis* sp. n.**

Table 3. Discriminant scores for each taxon calculated based on classification functions for discriminant roots LD1 and LD2. Scores calculated by classification functions are provided in the following order: mean, ±SD, and minimum, maximum values are given, the latter two in parentheses.

N. hafahafa sp. n. (n = 48)	LD1= 6.090±0.76 [4.650, 8.013]
	LD2= 0.547±1.17 [-2.401, 3.491]
N. medusus sp. n. (n = 56)	LD1= 0.063±1.27 [-2.299, 3.247]
	LD2= -1.089±1.02 [-3.750, 1.150]
N. spinosus sp. n. (n = 46)	LD1= -4.445±0.68 [-5.626, -2.443]
	LD2= -1.623±0.87 [-3.506, 0.170]
N. capricornis sp. n. (n = 27)	LD1= -4.373±0.75 [-5.830, -3.065]
	LD2= 4.249±0.84 [2.146, 5.950]

Table 4. Morphometric data of species calculated on individuals. Mean of indices, ±SD are provided in the upper row, minimum and maximum values are given in parentheses in the lower row.

Species:	***N. capricornis* sp. n.**	***N. hafahafa* sp. n.**	***N. medusus* sp. n.**	***N. spinosus* sp. n.**
nr. of individulals:	(n = 27)	(n = 48)	(n = 56)	(n = 46)
CS	**1024±38**	**1062±41**	**1069±52**	**1021±43**
	[919, 1115]	[974, 1142]	[958, 1189]	[935, 1121]
CL/CWb	**1.079±0.020**	**1.038±0.020**	**1.046±0.025**	**1.056±0.024**
	[1.037, 1.111]	[0.993, 1.075]	[0.990, 1.097]	[0.980, 1.113]
PoOC/CL	**0.390±0.006**	**0.388±0.010**	**0.391±0.008**	**0.374±0.011**
	[0.381, 0.403]	[0.361, 0.406]	[0.371, 0.413]	[0.342, 0.393]
FRS/CS	**0.315±0.007**	**0.316±0.008**	**0.313±0.008**	**0.315±0.009**
	[0.297, 0.326]	[0.289, 0.333]	[0.295, 0.331]	[0.291, 0.335]
SL/CS	**0.927±0.012**	**0.895±0.017**	**0.907±0.028**	**0.880±0.016**
	[0.907, 0.948]	[0.861, 0.927]	[0.849, 0.997]	[0.844, 0.919]
EL/CS	**0.241±0.011**	**0.230±0.007**	**0.232±0.007**	**0.239±0.008**
	[0.225, 0.267]	[0.212, 0.248]	[0.219, 0.249]	[0.220, 0.265]
MW/CS	**0.652±0.012**	**0.657±0.019**	**0.682±0.018**	**0.650±0.014**
	[0.632, 0.685]	[0.631, 0.712]	[0.633, 0.740]	[0.618, 0.679]
PEW/CS	**0.265±0.017**	**0.307±0.021**	**0.268±0.011**	**0.237±0.009**
	[0.238, 0.312]	[0.275, 0.357]	[0.246, 0.295]	[0.206, 0.259]
PPW/CS	**0.558±0.025**	**0.538±0.022**	**0.543±0.021**	**0.491±0.022**
	[0.516, 0.613]	[0.494, 0.576]	[0.496, 0.585]	[0.435, 0.529]
SPBA/CS	**0.260±0.014**	**0.287±0.014**	**0.266±0.018**	**0.212±0.010**
	[0.238, 0.292]	[0.257, 0.311]	[0.234, 0.308]	[0.184, 0.235]
SPTI/CS	**0.455±0.039**	**0.543±0.032**	**0.443±0.034**	**0.307±0.027**
	[0.386, 0.569]	[0.463, 0.607]	[0.354, 0.504]	[0.221, 0.361]
ML/CS	**1.290±0.026**	**1.266±0.029**	**1.319±0.031**	**1.270±0.023**
	[1.234, 1.335]	[1.201, 1.323]	[1.181, 1.376]	[1.218, 1.313]
PEL/CS	**0.506±0.015**	**0.420±0.014**	**0.441±0.018**	**0.435±0.010**
	[0.468, 0.526]	[0.399, 0.453]	[0.392, 0.500]	[0.397, 0.459]
NOL/CS	**0.303±0.017**	**0.278±0.015**	**0.290±0.012**	**0.299±0.012**
	[0.258, 0.338]	[0.229, 0.307]	[0.243, 0.319]	[0.265, 0.321]
PPL/CS	**0.216±0.007**	**0.202±0.010**	**0.211±0.009**	**0.206±0.011**
	[0.204, 0.228]	[0.181, 0.223]	[0.190, 0.233]	[0.164, 0.231]
SPST/CS	**0.397±0.017**	**0.398±0.019**	**0.385±0.019**	**0.300±0.018**
	[0.367, 0.432]	[0.355, 0.427]	[0.333, 0.437]	[0.258, 0.330]
MPST/CS	**0.411±0.011**	**0.409±0.013**	**0.400±0.010**	**0.404±0.012**
	[0.386, 0.432]	[0.383, 0.442]	[0.379, 0.426]	[0.370, 0.433]
PSTI/CS	**0.658±0.017**	**0.724±0.028**	**0.757±0.020**	**0.677±0.021**
	[0.617, 0.690]	[0.631, 0.776]	[0.711, 0.813]	[0.624, 0.723]
NSTI/CS	**0.265±0.035**	**0.514±0.052**	**0.354±0.039**	**0.216±0.018**
	[0.203, 0.364]	[0.473, 0.563]	[0.278, 0.464]	[0.194, 0.276]
Cdep/CS	**0.023±0.003**	**0.022±0.003**	**0.022±0.003**	**0.021±0.005**
	[0.018, 0.030]	[0.015, 0.029]	[0.017, 0.029]	[0.015, 0.027]

Nesomyrmex capricornis **Csősz & Fisher, sp. n.**

http://zoobank.org/EC84BA51-2D96-4084-AB2B-8B19AF1DEEDC
Figs 19–21, Table 4

Type material investigated. Holotype worker. CASENT0452741, collection code: BLF05245; MADGAGASCAR: Prov. Toliara, Forêt Mahavelo, Isantoria Riv., 5.2 km 44°NE Ifotaka, 24°46'S, 46°09'E [-24.75833N, 46.15717E], 110 m, 28.iii.2002 Fisher et al. (CAS);

Paratypes. Ten workers, a single gyne and two males with the same label data with the holotype under CASENT codes: CASENT0452715, "5245", (1w, CAS); CASENT0452716, "5245", (1w, CAS); CASENT0452717, "5245", (1w, CAS); CASENT0452720, BLF05245, (1w, CAS); CASENT0452721, BLF05245, (1w, CAS); CASENT0452722, BLF05245, (1w, CAS); CASENT0452725, BLF05245, (1w, CAS); CASENT0452726, BLF05245, (1w, CAS); CASENT0452726, BLF05245, (1w, CAS); CASENT0452727, BLF05245, (1w, CAS); CASENT0452728, BLF05245, (1w, CAS); CASENT0452729, BLF05245, (1w, CAS); CASENT0452730, BLF05245, (1w, CAS); CASENT0452731, BLF05245, (1w, CAS); CASENT0452732, BLF05245, (1w, CAS); CASENT0452733, BLF05245, (1w, CAS); CASENT0452734, BLF05245, (1w, CAS); CASENT0452735, BLF05245, (1w, CAS); CASENT0452736, BLF05245, (1w, CAS); CASENT0452737, BLF05245, (1w, CAS); CASENT0452738, BLF05245, (1w, CAS); CASENT0452739, BLF05245, (1w, CAS); CASENT0452742, BLF05245, (1w, CAS); CASENT0452743, BLF05245, (1w, CAS); CASENT0452744, BLF05245, (1w, CAS); CASENT0452745, BLF05245, (1w, CAS); CASENT0452746, BLF05245, (1w, CAS); CASENT0452747, BLF05245, (1w, CAS); CASENT0452748, BLF05245, (1w, CAS); CASENT0452750, BLF05245, (1w, CAS); CASENT0452751, BLF05245, (1w, CAS); CASENT0452752, BLF05245, (1w, CAS); CASENT0452753, BLF05245, (1w, CAS);

The list of 21 non-type individuals belonging to 14 nest samples of other material investigated is given in Table 1.

Diagnosis. In key.

Description of workers. Body color: yellow. Body color pattern: Body concolorous, only clava darker. Absolute cephalic size: 1024 [919, 1115] µm (n=27). Cephalic length vs. maximum width of head capsule (CL/CWb): 1.079 [1.037, 1.111]. Postocular distance vs. cephalic length (PoOc/CL): 0.390 [0.381, 0.403]. Postocular sides of cranium contour frontal view orientation: converging posteriorly. Postocular sides of cranium contour frontal view shape: broadly convex. Vertex contour line in frontal view shape: straight. Vertex sculpture: main sculpture rugose, ground sculpture areolate. Gena contour line in frontal view shape: convex. Genae contour from anterior view orientation: converging. Gena sculpture: rugo-reticulate with areolate ground sculpture. Concentric carinae laterally surrounding antennal foramen count: absent; present. Eye length vs. absolute cephalic size (EL/CS): 0.241 [0.225, 0.267]. Frontal carina distance vs. absolute cephalic size (FRS/CS): 0.315 [0.297, 0.326]. Longitudi-

Figures 19–21. *Nesomyrmex capricornis* sp. n. holotype worker (CASENT0452741). Lateral view of the body (**19**), head of the holotype worker in full-face view (**20**), dorsal view of the body (**21**). Scale 0.5 mm.

nal carinae on median region of frons count: present. Longitudinal carinae on medial region of frons shape: forked. Smooth median region on frons count: absent. Antennomere count: 12. Scape length vs. absolute cephalic size (SL/CS): 0.927 [0.907, 0.948]. Facial area of the scape absolute setal angle: setae absent, pubescence only. Median clypeal notch count: present. Median clypeal notch depth vs. absolute cephalic size (Cdep/CS): 0.023 [0.018, 0.030]. Ground sculpture of submedian area of clypeus: smooth. Median carina of clypeus count: present. Lateral carinae of clypeus count: present. Median anatomical line of propodeal spine angle value to Weber length in lateral view: 65–70°. Spine length vs. absolute cephalic size (SPST/CS): 0.397 [0.367, 0.432]. Minimum spine distance vs. absolute cephalic size (SPBA/CS): 0.260 [0.238, 0.292]. Apical spine distance vs. absolute cephalic size (SPTI/CS): 0.455 [0.386, 0.569]. Propodeal spine shape: straight; slightly bent. Apical distance of pronotal spines vs. absolute cephalic size (PSTI/CS): 0.658 [0.617, 0.690]. Metanotal depression count: absent. Dorsal region of mesosoma sculpture: areolate ground sculpture, superimposed by dispersed rugae. Lateral region of pronotum sculpture: areolate ground sculpture, superimposed by dispersed rugae. Mesopleuron sculpture: areolate ground sculpture, superimposed by dispersed rugae. Metapleuron sculpture: areolate ground sculpture, superimposed by dispersed rugae. Petiole width vs. absolute cephalic size (PEW/CS): 0.265 [0.238, 0.312]. Anterodorsal spines on petiolar node angle of deviation from each other: 60°. Apical distance of anterodorsal spines on petiolar node vs. absolute cephalic size (NSTI/CS): 0.265 [0.203, 0.364]. Frontal profile of petiolar node contour line in lateral view shape: straight; concave. Dorso-caudal petiolar profile contour line in lateral view shape: strongly convex. Dorsal region of petiole sculpture: ground sculpture areolate, main sculpture dispersed rugose; ground sculpture areolate, main sculpture absent. Postpetiole width vs. absolute cephalic size (PPW/CS): 0.558 [0.516, 0.613]. Dorsal region of postpetiole sculpture: ground sculpture areolate, main sculpture absent; ground sculpture areolate, main sculpture dispersed rugose.

Etymology. This species is named for the shape of the anterodorsal spines on the petiolar node, which resemble goat horns.

Distribution. This species is known to occur in small, highly isolated forests (Toliara, Forêt Mahavelo and Parc National d'Andohahela, Forêt de Manantalinjo) in the southern part of Madagascar (Fig. 13).

Nesomyrmex hafahafa **Csősz & Fisher, sp. n.**

http://zoobank.org/C2249F7A-0FFE-4C76-A2E8-905A4B1EA754
Figs 22–24, Table 4

Etymology. This Malagasy word "hafahafa" means weird, and refers to the unusual morphology of this species.

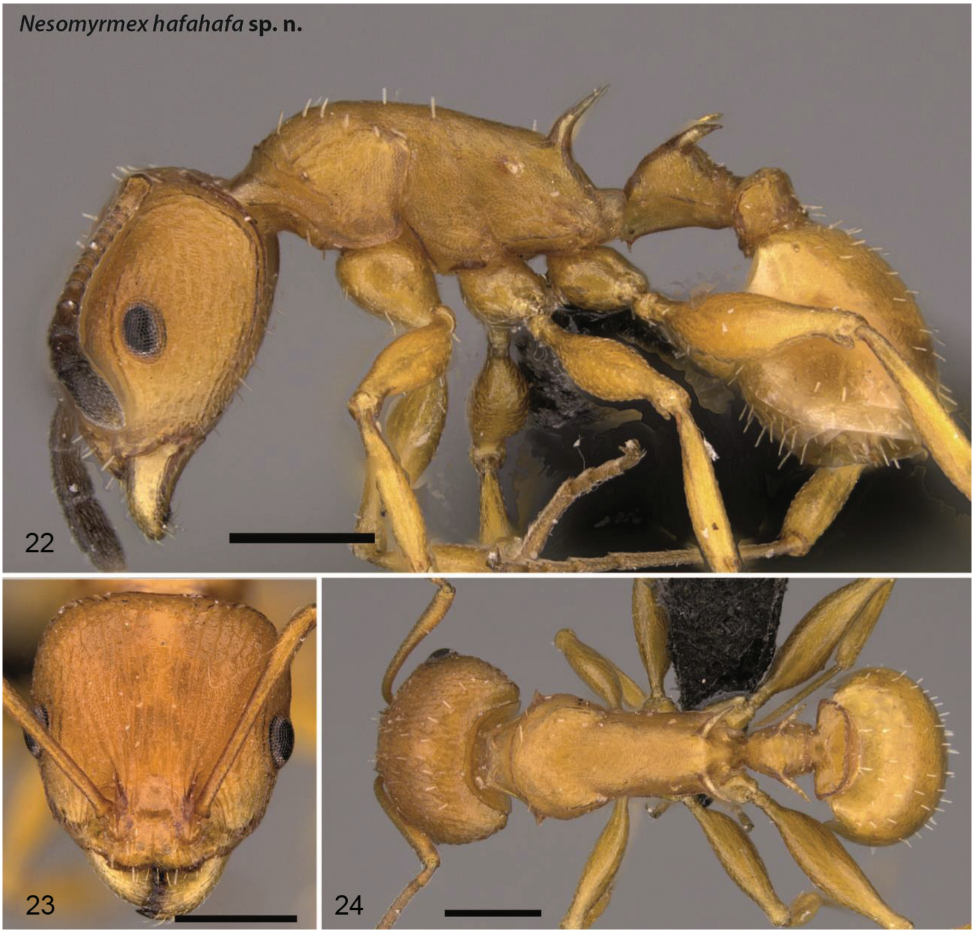
Type material investigated. Holotype worker. CASENT0460666, collection code: BLF06010; MADG'R: Prov. Toliara, Forêt de Tsinjoriaky, 6.2 km 84° E Tsifota, 22°48'S, 43°25'E [-22.80222N, 43.42067E], 70 m, 6–10.iii.2002 Fisher et al. (CAS)

Paratypes. Ten workers, a single gyne and two males with the same label data as the holotype under CASENT codes: CASENT0746771, BLF06010, (2w, CAS); CASENT0460667, BLF06010, (3w, CAS); CASENT0460668, BLF06010, (3w, CAS); CASENT0460669, BLF06010, (1q, CAS); CASENT0451364, "6019", (2w, CAS); CASENT0451364, "6019", (2m, CAS);

The list of 44 non-type individuals belonging to 25 nest samples of other material investigated is given in Table 1.

Diagnosis. In key.

Description of workers. Body color: yellow; brown. Body color pattern: body concolorous, only clava darker. Absolute cephalic size: 1062 [974, 1142] µm (n = 48). Cephalic length vs. maximum width of head capsule (CL/CWb): 1.224 [1.193-1.254]. Postocular distance vs. cephalic length (PoOc/CL): 0.388 [0.361, 0.406]. Postocular sides of cranium contour frontal view orientation: converging posteriorly. Postocular sides of cranium contour frontal view shape: broadly convex. Vertex contour line in frontal view shape: straight; slightly concave. Vertex sculpture: main sculpture



Figures 22–24. *Nesomyrmex hafahafa* sp. n. holotype worker (CASENT0460666). Lateral view of the body (**22**) head of the holotype worker in full-face view (**23**), dorsal view of the body (**24**). Scale 0.5 mm.

rugose, ground sculpture areolate. Gena contour line in frontal view shape: feebly convex. Genae contour from anterior view orientation: converging. Gena sculpture: rugo-reticulate with areolate ground sculpture. Concentric carinae laterally surrounding antennal foramen count: present. Eye length vs. absolute cephalic size (EL/CS): 0.230 [0.212, 0.248]. Frontal carina distance vs. absolute cephalic size (FRS/CS): 0.316 [0.289, 0.333]. Longitudinal carinae on median region of frons count: present. Longitudinal carinae on medial region of frons shape: forked. Smooth median region on frons count: absent. Antennomere count: 12. Scape length vs. absolute cephalic size (SL/CS): 0.895 [0.861, 0.927]. Facial area of the scape absolute setal angle: setae absent, pubescence only. Median clypeal notch count: present. Median clypeal notch depth vs. absolute cephalic size (Cdep/CS): 0.022 [0.015, 0.029]. Ground sculpture of submedian area of clypeus: smooth. Median carina of clypeus count: present. Lateral carinae of clypeus count: present. Median anatomical line of propodeal spine angle value to Weber length in lateral view: 55–60°. Spine length vs. absolute cephalic size (SPST/CS): 0.398 [0.355, 0.427]. Minimum spine distance vs. absolute cephalic size (SPBA/CS): 0.287 [0.257, 0.311]. Apical spine distance vs. absolute cephalic size (SPTI/CS): 0.543 [0.463, 0.607]. Propodeal spine shape: strongly bent. Apical distance of pronotal spines vs. absolute cephalic size (PSTI/CS): 0.724 [0.631, 0.776]. Metanotal depression count: absent. Dorsal region of mesosoma sculpture: areolate ground sculpture, superimposed by dispersed rugae. Lateral region of pronotum sculpture: areolate ground sculpture, superimposed by dispersed rugae. Mesopleuron sculpture: areolate ground sculpture superimposed by dispersed rugulae; areolate ground sculpture, superimposed by dispersed rugae. Metapleuron sculpture: areolate ground sculpture, superimposed by dispersed rugae. Petiole width vs. absolute cephalic size (PEW/CS): 0.307 [0.275, 0.357]. Anterodorsal spines on petiolar node angle of deviation from each other: 80°. Apical distance of anterodorsal spines on petiolar node vs. absolute cephalic size (NSTI/CS): 0.514 [0.473, 0.563]. Frontal profile of petiolar node contour line in lateral view shape: convex. Dorso-caudal petiolar profile contour line in lateral view shape: convex. Dorsal region of petiole sculpture: ground sculpture areolate, main sculpture dispersed rugose. Postpetiole width vs. absolute cephalic size (PPW/CS): 0.538 [0.494, 0.576]. Dorsal region of postpetiole sculpture: ground sculpture areolate, main sculpture dispersed rugose.

Distribution. This species is widely distributed along the western forests of Madagascar (Fig. 13) between the 23rd and 20th southern latitudes.

Nesomyrmex medusus Csősz & Fisher, sp. n.

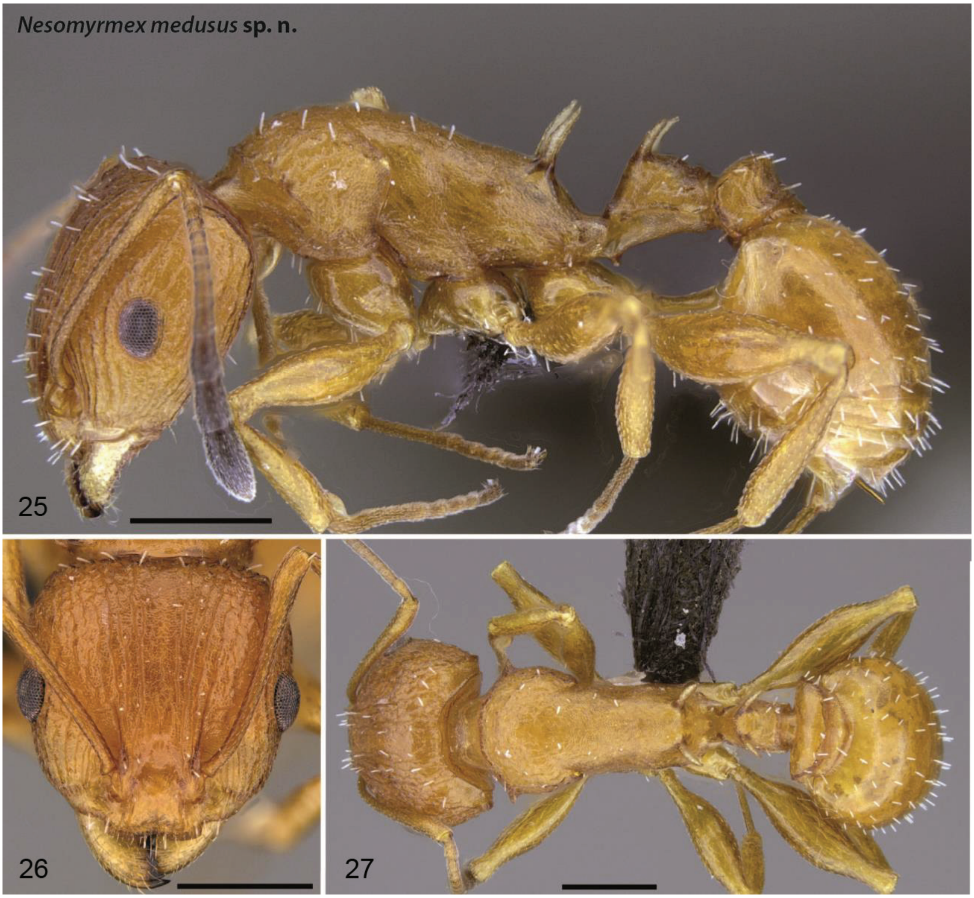
http://zoobank.org/EC3DCF85-8648-4FD2-90D5-113C8FA30099
Figs 25–27, Table 4

Etymology. The numerous long spines on the dorsal body make the workers reminiscent of Medusa of the Greek mythology who has snakes on her head in place of hair.

Type material investigated. Holotype worker. CASENT0455428, collection code: BLF06201; MADGAGASCAR: Prov. Toliara, Parc National de Tsimanampetsotsa, Mitoho Cave, 6.4 km 77° ENE Efoetse, 17.4 km 170°S Beheloka, 24°03'S, 43°46'E [-24.04722 N, 43.75317 E], 65 m, 18–22.iii.2002 Fisher et al. (CAS);

Paratypes. Ten workers, a single gyne and two males with the same label data as the holotype under CASENT codes: CASENT0746770, BLF06201, (2w, CAS); CASENT0455429, BLF06201, (3w, CAS); CASENT0455430, BLF06201, (3w, CAS); CASENT0455431, BLF06201, (2w, CAS); CASENT0455432, BLF06201, (2w, CAS); CASENT0455433, BLF06201, (1q, CAS); CASENT0455434, BLF06201, (1w, CAS); CASENT0455435, BLF06201, (1w, CAS); CASENT0455437, BLF06201, (1w, CAS); CASENT0455438, BLF06201, (1w, CAS); CASENT0455439, BLF06201, (1w, CAS); CASENT0455440, BLF06201, (3m, CAS);

The list of 54 non-type individuals belonging to 28 nest samples of other material investigated is given in Table 1.



Figures 25–27. *Nesomyrmex medusus* sp. n. holotype worker (CASENT0455428). Lateral view of the body (**25**), head of the holotype worker in full-face view (**26**), dorsal view of the body (**27**). Scale 0.5 mm.

Diagnosis. In key.

Description of workers. Body color: brown. Body color pattern: body concolorous, only clava darker. Absolute cephalic size: 1069 [958, 1189] µm (n=56). Cephalic length vs. maximum width of head capsule (CL/CWb): 1.046 [0.990, 1.097]. Postocular distance vs. cephalic length (PoOc/CL): 0.391 [0.371, 0.413]. Postocular sides of cranium contour frontal view orientation: converging posteriorly. Postocular sides of cranium contour frontal view shape: broadly convex. Vertex contour line in frontal view shape: straight; slightly concave. Vertex sculpture: main sculpture rugose, ground sculpture areolate. Gena contour line in frontal view shape: feebly convex. Genae contour from anterior view orientation: converging. Gena sculpture: rugo-reticulate with areolate ground sculpture. Concentric carinae laterally surrounding antennal foramen count: present. Eye length vs. absolute cephalic size (EL/CS): 0.232 [0.219, 0.249]. Frontal carina distance vs. absolute cephalic size (FRS/CS): 0.313 [0.295, 0.331]. Longitudinal carinae on median region of frons count: present. Longitudinal carinae on medial region of frons shape: forked. Smooth median region on frons count: absent. Antennomere count: 12. Scape length vs. absolute cephalic size (SL/CS): 0.907 [0.849, 0.997]. Facial area of the scape absolute setal angle: setae absent, pubescence only. Median clypeal notch count: present. Median clypeal notch depth vs. absolute cephalic size (Cdep/CS): 0.022 [0.017, 0.029]. Ground sculpture of submedian area of clypeus: smooth. Median carina of clypeus count: present. Lateral carinae of clypeus count: present. Median anatomical line of propodeal spine angle value to Weber length in lateral view: 65–72°. Spine length vs. absolute cephalic size (SPST/CS): 0.385 [0.333, 0.437]. Minimum spine distance vs. absolute cephalic size (SPBA/CS): 0.266 [0.234, 0.308]. Apical spine distance vs. absolute cephalic size (SPTI/CS): 0.443 [0.354, 0.504]. Propodeal spine shape: straight; slightly bent. Apical distance of pronotal spines vs. absolute cephalic size (PSTI/CS): 0.757 [0.711, 0.813]. Metanotal depression count: absent. Dorsal region of mesosoma sculpture: areolate ground sculpture, superimposed by dispersed rugae. Lateral region of pronotum sculpture: areolate ground sculpture, superimposed by dispersed rugae. Mesopleuron sculpture: areolate ground sculpture, superimposed by dispersed rugae. Metapleuron sculpture: areolate ground sculpture, superimposed by dispersed rugae. Petiole width vs. absolute cephalic size (PEW/CS): 0.268 [0.246, 0.295]. Anterodorsal spines on petiolar node angle of deviation from each other: 70°. Apical distance of anterodorsal spines on petiolar node vs. absolute cephalic size (NSTI/CS): 0.354 [0.278, 0.464]. Frontal profile of petiolar node contour line in lateral view shape: straight. Dorso-caudal petiolar profile contour line in lateral view shape: straight; convex. Dorsal region of petiole sculpture: ground sculpture areolate, main sculpture dispersed rugose; ground sculpture areolate, main sculpture absent. Postpetiole width vs. absolute cephalic size (PPW/CS): 0.543 [0.496, 0.585]. Dorsal region of postpetiole sculpture: ground sculpture areolate, main sculpture absent; ground sculpture areolate, main sculpture dispersed rugose.

Distribution. This species occurs in the south-western forests (Parc National de Tsimanampetsotsa, Forêt de Bemanateza and Mahafaly Plateau) of Madagascar (Fig. 13) between the southern latitudes S 24° and S 24.65°.

Nesomyrmex spinosus **Csősz & Fisher, sp. n.**

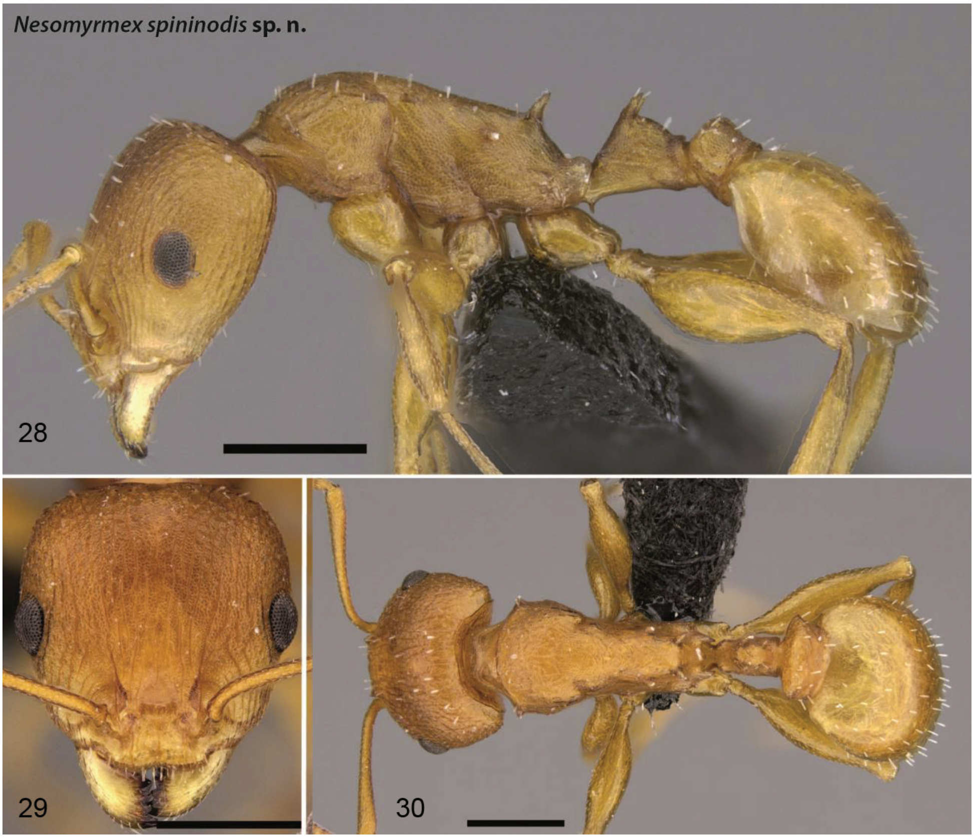
http://zoobank.org/D3643DB1-75EB-415A-9220-9F255A5FCB21

Figs 28–30, Table 4

Etymology. Name "spinosus" refers to the short, strong antero-dorsal spines on the petiolar node.

Type material investigated. Holotype worker. CASENT0443515, BLF05489; MADGAGASCAR: Prov. Toliara, Réserve Privé Berenty, Forêt d'Anjapolo, 21.4 km 325° NW Amboasary, 24°56'S, 46°13'E [-24.92972 N, 46.20967 E], 65 m, 7.iii.2002 Fisher et al. (CAS CASENT0443515);

Paratypes. 24 workers and three males with the same label data with the holotype under CASENT codes: CASENT0443515, BLF05489, (2w, CAS);



Figures 28–30. *Nesomyrmex spinosus* sp. n. paratype worker (CASENT0443532). Lateral view of the body (**28**), head of the holotype worker in full-face view (**29**), dorsal view of the body (**30**). Scale 0.5 mm.

CASENT0443516, BLF05489, (3w, CAS); CASENT0443517, BLF05489, (3w, CAS); CASENT0443518, BLF05489, (1w, CAS); CASENT0443519, BLF05489, (1w, CAS); CASENT0443520, BLF05489, (1w, CAS); CASENT0443521, BLF05489, (1w, CAS); CASENT0443522, BLF05489, (1w, CAS); CASENT0443523, BLF05489, (1w, CAS); CASENT0443524, BLF05489, (1w, CAS); CASENT0443525, BLF05489, (1w, CAS); CASENT0443526, BLF05489, (1w, CAS); CASENT0443527, BLF05489, (1w, CAS); CASENT0443530, BLF05489, (1w, CAS); CASENT0443531, BLF05489, (1w, CAS); CASENT0443532, BLF05489, (1w, CAS CASENT0443532); CASENT0443533, BLF05489, (1w, CAS); CASENT0443534, BLF05489, (1w, CAS); CASENT0443535, BLF05489, (1w, CAS); CASENT0443536, BLF05489, (1m, CAS); CASENT0443537, BLF05489, (2m, CAS);

The list of 44 non-type individuals belonging to 26 nest samples of other material investigated is given in Table 1.

Diagnosis. In key.

Description of workers. Body color: brown. Body color pattern: body concolorous, only clava darker. Absolute cephalic size: 1021 [935, 1121] µm (n=46). Cephalic length vs. maximum width of head capsule (CL/CWb): 1.056 [0.980, 1.113]. Postocular distance vs. cephalic length (PoOc/CL): 0.374 [0.342, 0.393]. Postocular sides of cranium contour frontal view orientation: converging posteriorly. Postocular sides of cranium contour frontal view shape: broadly convex. Vertex contour line in frontal view shape: slightly concave. Vertex sculpture: main sculpture rugose, ground sculpture areolate. Gena contour line in frontal view shape: feebly convex. Genae contour from anterior view orientation: converging. Gena sculpture: rugo-reticulate with areolate ground sculpture. Concentric carinae laterally surrounding antennal foramen count: present. Eye length vs. absolute cephalic size (EL/CS): 0.239 [0.220, 0.265]. Frontal carina distance vs. absolute cephalic size (FRS/CS): 0.315 [0.291, 0.335]. Longitudinal carinae on median region of frons count: present. Longitudinal carinae on medial region of frons shape: forked. Smooth median region on frons count: absent. Antennomere count: 12. Scape length vs. absolute cephalic size (SL/CS): 0.880 [0.844, 0.919]. Facial area of the scape absolute setal angle: setae absent, pubescence only. Median clypeal notch count: present. Median clypeal notch depth vs. absolute cephalic size (Cdep/CS): 0.021 [0.015, 0.027]. Ground sculpture of submedian area of clypeus: smooth. Median carina of clypeus count: present. Lateral carinae of clypeus count: present. Median anatomical line of propodeal spine angle value to Weber length in lateral view: 65°. Spine length vs. absolute cephalic size (SPST/CS): 0.300 [0.258, 0.330]. Minimum spine distance vs. absolute cephalic size (SPBA/CS): 0.212 [0.184, 0.235]. Apical spine distance vs. absolute cephalic size (SPTI/CS): 0.307 [0.221, 0.361]. Propodeal spine shape: straight; slightly bent. Apical distance of pronotal spines vs. absolute cephalic size (PSTI/CS): 0.677 [0.624, 0.723]. Metanotal depression count: absent. Dorsal region of mesosoma sculpture: rugose with areolate ground sculpture. Lateral region of pronotum sculpture: areolate ground sculpture, superimposed by dispersed rugae. Mesopleuron sculpture: areolate ground sculpture, superimposed by dispersed rugae. Metapleuron sculpture: areolate ground sculpture, superimposed by dispersed rugae. Petiole width vs. absolute cephalic size (PEW/CS): 0.237 [0.206, 0.259]. Anterodorsal spines on petiolar node angle of deviation from each other: 60°. Apical distance of anterodorsal spines on petiolar node vs. absolute cephalic size (NSTI/CS): 0.216 [0.194, 0.276]. Frontal profile of petiolar node contour line in lateral view shape: straight. Dorso-caudal petiolar profile contour line in lateral view shape: convex. Dorsal region of petiole sculpture: ground sculpture areolate, main sculpture absent; ground sculpture areolate, main sculpture dispersed rugose. Postpetiole width vs. absolute cephalic size (PPW/CS): 0.491 [0.435, 0.529]. Dorsal region of postpetiole sculpture: ground sculpture areolate, main sculpture absent; ground sculpture areolate, main sculpture dispersed rugose.

Distribution. This species is known to occur in small, highly isolated forests (Réserve Privé Berenty, Forêt d'Anjapolo and Parc National d'Andohahela, Forêt d'Ambohibory) in the southern part of Madagascar (Fig. 13).

Discussion

In this paper we placed the Malagasy *Nesomyrmex* fauna into four species-groups delimited based on morphological features corroborated by morphometric data (see definition and diagnoses of groups). The within-group diversity of one of these new groups, *Nesomyrmex hafahafa* group, was revealed by an enhanced hypothesis-free approach. The exploratory NC-clustering (Seifert et al. 2014) technique was combined with a gap statistic (Tibshirani et al. 2001) in order to address the central problem of taxonomic workflow on estimating the number of optimal clusters (i.e. how many species).

A gap statistic algorithm (function '*gap*') implemented in the package *clusterGenomics* (Nilsen and Lingjaerde 2013) was employed to determine the optimal number of cluster within data that were transformed into discriminant space by the NC-clustering and recursive partitioning (function '*part*') assigned observations (i.e. specimens, or samples) into partitions. Gap statistic is a global method, determines the number of clusters based on gap criterion described by Tibshirani et al. (2001), while recursive partitioning searches for sub-clusters by running 'gap' recursively (Nilsen et al. 2013).

Our research demonstrates that combination of NC-clustering with gap statistics and recursive partitioning algorithms performs well in distinguishing partitions in the present data based on morphological distances among nest sample means. Four-cluster hypothesis was returned by both gap statistic (Fig. 12) and recursive partitioning (Fig. 14) as the most parsimonious solution for the diversity of the *hafahafa*-group. This classification was confirmed by multiple lines of evidence. The error rate between the exploratory procedure and the results of the confirmatory Linear Discriminant Analysis was 0.6%. Moreover the pattern recognized by the exploratory process was also corroborated by both the examination of diagnostic morphological traits (e.g. shape of petiolar node, length and deviation of anterodorsal spines on petiolar node) and the known biogeographic patterns (Fig. 14).

We highlight the importance and advantages of the combination of NC-clustering with algorithms to statistically infer gaps and create array of clusters. This protocol also has the potential at accelerate and improve taxonomic decision making process considerably by enabling taxonomists to objectively interpret results based on quantitative morphometric data even in a largely underexplored or poorly understood group such as the Malagasy genus *Nesomyrmex*.

Combination of these approaches allows researchers to recognize cryptic species, but also prevent users from inferring overly diverse pattern in the data. A taxonomist without long-term training in a given group can evaluate new specimens and potential new species by repeating the analysis with measurements from new specimens. This method is best included with an integrated approach that includes conventional morphological characters, biogeography, ecology or molecular data.

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SHORT COMMUNICATION

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How small is the smallest? New record and remeasuring of *Scydosella musawasensis* Hall, 1999 (Coleoptera, Ptiliidae), the smallest known free-living insect

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Abstract

The smallest known beetle *Scydosella musawasensis* Hall is recorded for the second time. Precise measurements of its body size are given, and it is shown that the smallest examined representative of this species has a length of 325 µm.

Keywords

Smallest beetle, body size, SEM, Colombia

Introduction

The smallest insects have recently attracted considerable attention as models for studying animal miniaturization, since they are among the smallest metazoans and since many morphological features unique to them and resulting from their extremely small size have been described (Polilov 2015). The size of the smallest known parasitoid insect, male *Dicopomorpha eschmepterigis* (139 µm) is known rather precisely, and has been determined by using modern equipment (Mockford 1997; Huber and Noyes 2013). On the other hand, it is not quite clear which free-living insect is the smallest. It is stated in a great number of scientific and popular publications that the body length of the smallest beetles is 0.25 mm, but this statement is incorrect, although it has a long history. LeConte (1863) described *Ptilium fungi*, specifying its length as 'scarcely more than 1-100 of an inch,' i.e., 254 µm. Motschoulsky (1868) almost simultaneously described *Nanosella fungi* from Georgia, North America, specifying its length 1/10 l., i.e., 212 µm (1 line = 2.116 mm). Sörensson (1997), who re-examined the type material, indicated that the length given in earlier studies resulted from error of measurement and undescribed *nanosellines* remained the smallest, having a body length of about 0.3 mm (Dybas 1990). Therefore, it was still unclear which known beetle was the smallest. Hall (1999) described several new genera and species; as a result, *Scydosella musawasensis* Hall, 1999, which has a body length of 0.30 mm, became the smallest described beetle. This species was known up to date only from several specimens of the type series collected by B. Malkin in Nicaragua. *Scydosella musawasensis* was measured only from cleared specimens embedded in preparations for microscopy studies, which makes it difficult to measure length precisely.

Methods

Adults of *Scydosella musawasensis* Hall, 1999 were collected in Chicaque National Park, Colombia, 10 km west of Bogotá, on 8 February 2015 (coordinates 4.619, -74.312), 2200 m above sea level, on the fungus *Steccherinum* sp. (Meruliaceae), 85 specimens. The material was fixed in FAA (formaldehyde—alcohol—acetic acid) and preserved in 70% ethanol. It was subsequently examined under a Jeol JSM-6380 scanning electron microscope (SEM) after drying of the specimens at the critical point (Hitachi HCP-2) and sputter coating with gold (Giko JSM-6380). The measurements were made using the program Meazure (C Thing Software) from digital micrographs obtained under SEM.

Results and discussion

Measuring of ten specimens of *S. musawasensis* has shown that the smallest of them has a length of 325 µm, the largest has a length of 352 µm, and the average length is 338 µm (Fig. 1). The body width (maximum width of both elytra at rest) is 98 to 104 µm (M = 99 µm, n = 10). Thus, the smallest beetle and the smallest known free-living insect has a body length of 325 µm.

The record of *S. musawasensis* in Colombia considerably broadens the known range of this genus and species, known previously only from one site in Nicaragua (Hall 1999), where the type series was collected: Musawas, Waspuc River, Nicaragua, 14 October 1955. This record also broadens the known range of fungi colonized by *S. musawasensis*, which was known previously only from *Rigidoporus lineatus* (Meripilaceae, given as *Polyporus zonalis* in the original description) (Hall 1999); I have collected it on *Steccherinum* sp. (Meruliaceae).

This genus and the only described species it includes differ from the other Nanosellini in the following combination of characters. Body elongate-oval (Fig. 1A–C), yellowish-

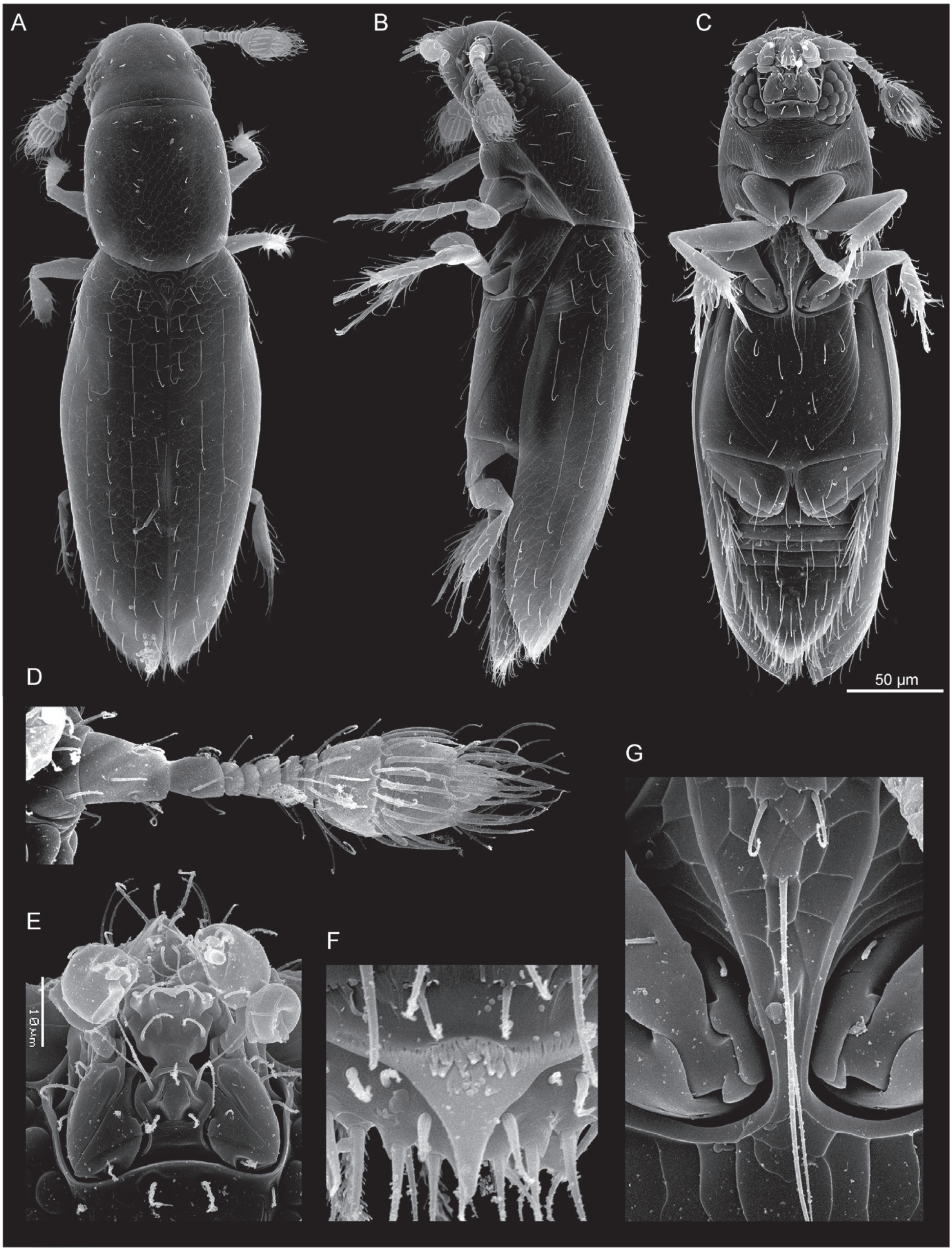

Figure 1. Habitus and diagnostic characters of *Scydosella musawasensis*, SEM: **A** dorsal view **B** lateral view **C** ventral view **D** antenna **C** mouthparts **F** pygidial tooth **G** mesosternal process.

brown, surface generally glabrous, punctation sparse. Antennae 10-segmented (Fig. 1D). Mentum setal formula 2+2+1 (Fig. 1E). Pronotum widest at middle. Procoxal pockets absent, prothoracic glands absent. Mesosternal process evenly narrowing anteriad, with obtuse apex, not extending onto metasternum (Fig. 1G). Mesosternal lines ending near process; metasternal lines complete. Elytral venter with stridulatory file. Femoral line ending in 2 setae. Pygidial tooth acute (Fig. 1F). Spermatheca rounded, as described earlier (Hall 1999: p. 123, no. 147).

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Description of *Trichophoromyia ruifreitasi*, a new phlebotomine species (Diptera, Psychodidae) from Acre State, Brazilian Amazon

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Abstract

Trichophoromyia ruifreitasi **sp. n.** is described as a new species of sand fly from the genus *Trichophoromyia* Barretto. This description is supported with illustrations and photographs that detail the morphological characteristics of male specimens collected in the municipality of Assis Brasil, Acre State, Brazilian Amazon. This species is similar to *T. auraensis* (Mangabeira), but the two species can be easily differentiated by the distribution of setae on their parameres, and by the presence of a dorsal lobe in the parameres of the new species.

Keywords

Sand fly, taxonomy, Neotropical region, leishmaniasis, Psychodidae, Phlebotominae

Introduction

Phlebotomine sand flies are small, dipteran, hematophagous insects. They are vectors of etiological agents such as *Leishmania* Ross, a protozoan that causes leishmaniases (Young and Duncan 1994). These diseases occur throughout the world, and infection can result in mutilations and death. Sand fly diversity is higher in the Amazon basin than it is in other biomes (Barret et al. 1996, Alves et al. 2012).

The genus *Trichophoromyia* Barretto is of medical importance because some species are involved in the life cycle of *Leishmania* (*Viannia*) *lainsoni* Silveira, Shaw, Braga and Ishikawa, and *L.* (*V.*) *braziliensis* Vianna (Silveira et al. 1991, Martinez et al. 2001, Valdivia et al. 2012, Pereira Junior et al. 2015). To date, 41 species have been described of this diverse genus (Ladeia-Andrade et al. 2014, Fernandez et al. 2015). Most descriptions are based on male specimens, because the females of this genus are morphologically similar in most cases.

A study of phlebotomine sand fly diversity was undertaken in the region where Brazil borders Peru and Bolivia. A list of collected species was previously presented in Teles et al. (2013). These authors reported that *T. auraensis* (Mangabeira) is a known vector in that area (Valdivia et al. 2012; Araújo-Pereira et al. 2014). After reexamining the sand flies collected and identified as *T. auraensis*, it was discovered that the specimens belonged to a similar, but distinct species. The present paper describes this new species based on male specimens.

Material and methods

Forest fragments were sampled in the municipality of Assis Brasil, located approximately 330 km south west of Rio Branco, Acre, Brazil, on the east bank of the Acre river, bordering Bolivia and Peru. Sand flies were captured between November 2009 and October 2010, using CDC light traps placed approximately 100 meters from domestic habitats. Details of the collection methods can be found in Teles et al. (2013). Insects were individually slide-mounted in synthetic Canada balsam. Specimens were identified and measured using a Zeiss microscope calibrated with a micrometer scale, and specimens were drawn using a camera lucida. All measurements are in micrometers (µm); measurements of the holotype are followed in parentheses by the measurement range of the paratypes, and the number of specimens observed. Morphological characteristics are also illustrated by photomicrographs that were made using a Leica DM 1000 optical microscope coupled to a JVC - 3 CCD digital camera and a computer imaging system.

Nomenclature and morphological terminology is according to Galati (2003).

Taxonomy

Trichophoromyia ruifreitasi sp. n.

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Figs 1, 2, 3

Type-material and depository. Holotype male and 7 paratype males collected using CDC light traps in Assis Brasil, São Francisco road, 10°56'29"S 69°34'01"W, 5 -11. XII.2009, coll. L.M.A. Camargo. The holotype and paratypes are deposited in the entomological collection of the National Institute of Amazonian Research (INPA), and some paratypes are deposited at the Leônidas and Maria Deane Institute.

Diagnosis. The new species is included in the genus *Trichophoromyia* due the male characters, the fifth palpomere slightly longer to the third, genitalia longer than or equal to the thorax, gonostyli with four spines (Santos et al. 2014). The new species is distinct from the others members of *Trichophoromyia* due the subtriangular paramere with a discrete dorsal lobe, and approximately 30 long, recurved setae distributed in the lobe, digital area after the dorsal proximal lobe is around 2× longer than it is broad, without distinct setose.

Description. Male (n = 8) Holotype (male) small, measuring approximately 2040 (2000–2080, n = 8) from thorax to the end of the gonostylus. Head, thorax and abdomen brown, contrasting markedly with lower pleura and femora; paratergite, upper anepisternum, anepimeron and metepisternon pale.

Head length 340 (325–340; n = 8) from post-occiput to clypeus apex, and maximum width 325 (300–325; n = 8). Eyes measuring 190 (190–195; n = 8) long by 100 (90–105; n = 8) wide, with incomplete interocular suture. Interocular distance 120 (105–120; n = 8) and ommatidia with a diameter of 18 (16–18; n = 8); interocular distance six times greater than the diameter of the ommatidia (Fig. 1a). Clypeus 101 (93–101; n = 8) long. Cibarium (Fig. 1b) with eight to ten acute posterior teeth equally spaced and clearly visible with a 40x objective; chitinous arc complete, pigmented spot weakly marked. Pharynx (Fig. 1c) 162 (160–173; n = 8) long, posterior third armed with transverse rows of denticles arranged in eight pairs and teeth clearly visible in immersion. Labrum-epipharynx 213 (200–216; n = 8) long. Antenna with simple, elongated ascoids (Fig. 1d) inserted nearly at the same level on antennomere AIII, reaching or exceeding the base of subsequent antennomeres, and present on all antennmoreres except XV and XVI (Fig. 1e). Length of antennomeres: AIII = 224 (213–224; n = 8), AIV = 125 (120–128; n = 8), AV = 122 (117–128; n = 8), AXV = 64 (64–69; n = 8) and AXVI = 56 (56–66; n = 8). Antennal formula = AIII–AXIV.2, AXV–AXVI.0. Palpus 445 (415–445; n = 8) long. Palpomeres: P1 = 35 (35–40; n = 8), P2 = 90 (80–90; n = 8), P3 = 130 (110–130; n = 8), P4 = 55 (50–60; n = 8), P5 = 135 (130–145; n = 7). Palpal formula: 1:4:2:3:5. Newstead's spines distributed solely along the median inner face of palpomere III (Fig. 1f). Labial suture united in furca.

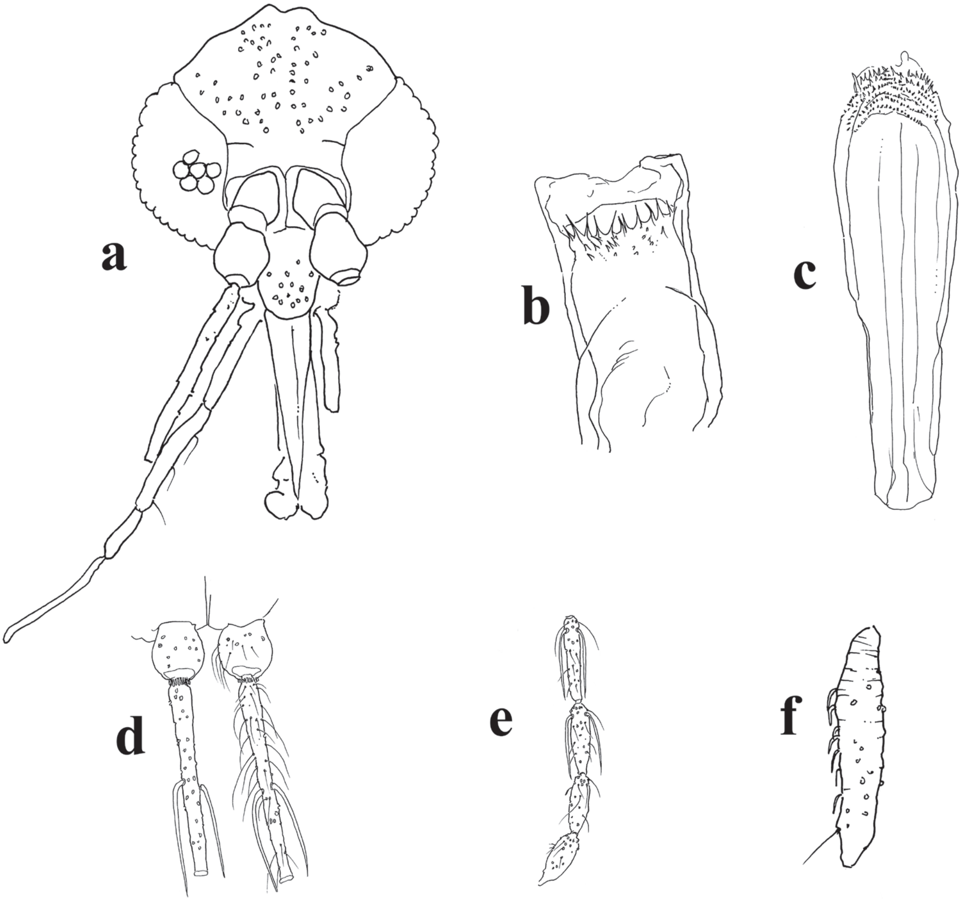

Figure 1. A–F *Trichophoromyia ruifreitasi* sp. n. **A** head, dorsal view **B** cibarium, dorsal view **C** pharynx, dorsal view **D–E** part of antenna, showing ascoids, dorsal view **F** palpomere III, dorsal view.

Thorax length 500 (480–580; n = 8) from anterior margin of pronotum to posterior margin of metanotum. Ventrocervical sensillae absent. Anepisternum with upper bristles 10 (10–13; n = 8) long, and lower bristles 5 (4–6; n = 8) long. Wing (Fig. 2a): length 1900 (1880–1900; n = 8) from insertion point to apex; maximum width 580 (580–600; n = 8). Venation: R5 = 1160 (1160–1222; n = 8) long; alpha = 520 (520–580; n = 8); beta = 260 (240–280; n = 8); delta = 340 (340–420; n = 8); gamma = 240 (220–240; n = 8); pi = 200 (200–220; n = 8); alpha twice the length of beta. Length of femora, tibiae, basitarsi and tarsomeres of fore, mid and hind legs: Fore: femora = 780 (720–800; n = 8); tibiae = 980 (940–1060; n = 8); basitarsi= 600 (580–620; n = 8); tarsomeres: I = 260 (260; n = 8), II = 180 (160–180; n = 8), III = 140 (140; n = 8), IV = 100 (100; n = 8). Mid: femora = 720 (680–740; n = 8); tibiae = 1220 (1140–1240; n = 8); basitarsi = 720 (680–720; n = 8), tarsomeres: I = 280 (280–300; n = 8), II = 180 (180–260; n = 8), III = 160 (140–160; n = 8), IV = 100 (100; n = 8). Hind: femora =

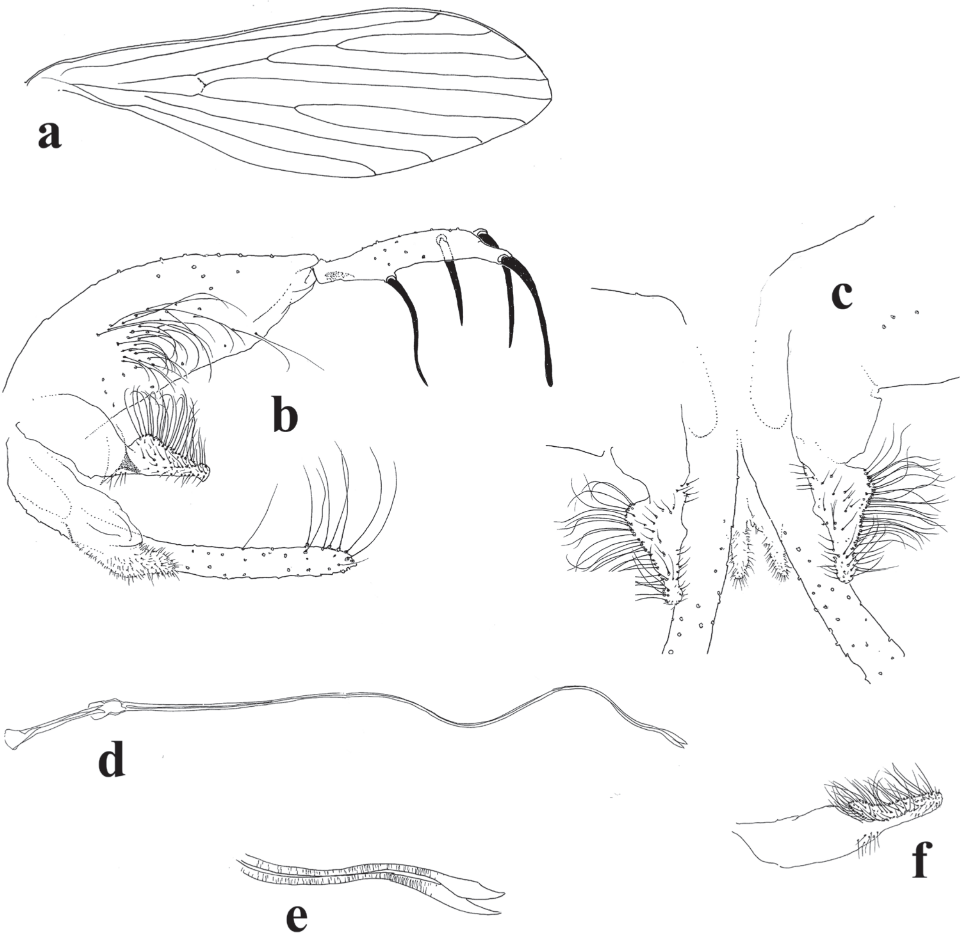

Figure 2. A–F *Trichophoromyia ruifreitasi* sp. n. **A** wing **B** lateral view of genitalia **C** dorsal view of parameres **D–E** genital filaments **F** paramere of *T. auraensis*, lateral view.

820 (780–840; n = 8); tibiae = 1400 (1320–1480; n = 8); basitarsi = 800 (740–820; n = 8); tarsomeres: I = 300 (260–300; n = 8), II = 200 (180–200; n = 8), III = 160 (160–180; n = 8), IV = 100 (100; n = 8). Hind femora without spines.

Abdomen length 2010 (1960–2110; n = 8) from first tergite to gonostylus apex. Genitalia (Fig. 2b): Gonostylus 185 (180–190; n = 8) long and 30 (30; n = 8) wide, presenting four strong spines distributed as follows: one apical, one subapical, one external implanted just below the subapical spine and equidistant from the apical and subapical spines, and one internal at the distal end of the gonostylus basal third; subterminal setae absent. Gonocoxite 320 (300–320; n = 8) long; maximum width 110 (80–120; n = 8), ornamented in the median area with a sparse group of approximately 30 bristles, some thin and long on the distal portion of the gonocoxite, but much shorter on the basal portion. Paramere (Figs 2b–c, 3a) 210 (200–210; n = 8) long, and

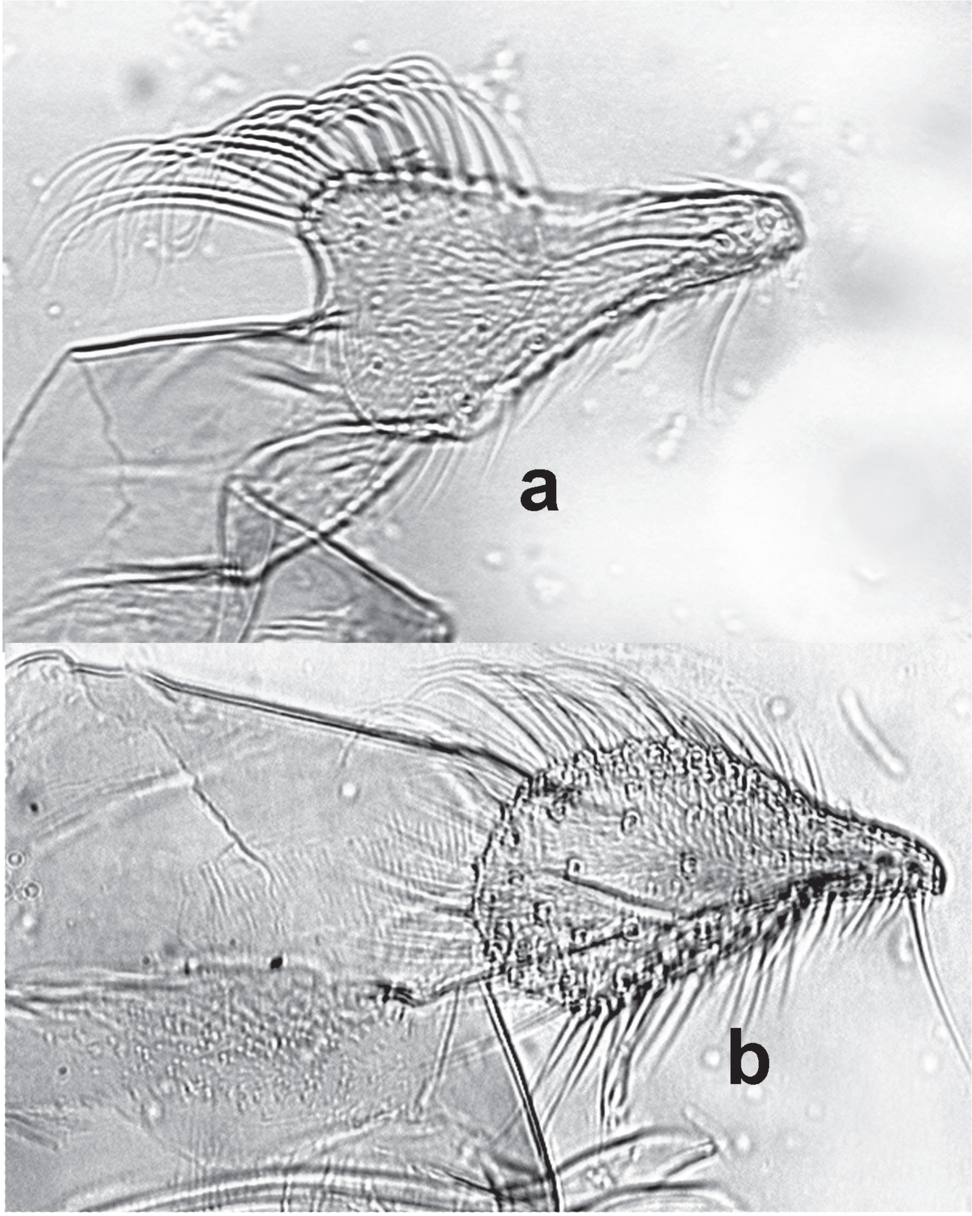

Figure 3. Lateral view of paramere of **A** *Trichophoromyia ruifreitasi* sp. n. **B** *T. auraensis*.

40 (35–45) wide, simple, subtriangular, proximal half part with a convex dorsal lobe, that is recovered with 28–30 long setae recurved at the apex; some setae running along the dorsal margin narrow at the rounded end of paramere, approximately ten (10) setae; apical margin with 4–5 much thicker setae. Proximal portion of paramere with a discrete translucid ventral lobe. Aedeagus conical and pigmented. Lateral lobe 350

(350–360; n = 8) long, cylindrical, not inflated, with a group of long slender setae that run along the back of the apex and spread throughout the distal half. Genital pump 180 (170–180; n = 8) long, and genital piston 150 (140–150; n = 8) long (Fig. 2d–e). Genital filaments (Fig. 2d–e) long and narrow with a striated surface; 900 (860–900; n = 8) long, thus approximately 5× longer than the pump. Apex of the filaments broad-bladed in shape and slightly recurved.

Etymology. *Trichophoromyia ruifreitasi* is named in honor of our friend, mentor and fellow-researcher, Rui Alves de Freitas, who has made an immense and unparalleled contribution to the taxonomy of these small flies in Amazonas State.

Female. Unknown.

Discussion

Trichophoromyia ruifreitasi sp. n. and two other species of its genus share the same type locality. These species have distinct parameres: *T. auraensis* has a paramere (Figs 2f and 3b) that is completely covered with long setae, lacks a dorsal lobe, and is digitiform in the apical half. *T. ruifreitasi* has a subtriangular paramere with a discrete dorsal lobe, and approximately 30 long, recurved setae. *T. melloi* (Causey and Damasceno) has a paramere with a very pronounced dorsal lobe in the tip, with setae present solely within the apical region.

Two new *Trichophoromyia* species have recently been described in the Amazon basin: *T. nautaensis* in Loreto State, Peru, described by Fernandez, Lopez, Roldan and Requena; and, *T. adelsonsouzai* in Pará State, described by Santos, Silva, Barata, Andrade and Galati. Both species have parameres with dorsal lobes; however, in *T. nautaensis* the lobe is located in the median part of the paramere, while in *T. adelsonsouzai* the paramere has a relatively broad hump, exhibiting dorsal curvature in the apical region (Fernandez et al. 2015; Santos et al. 2014).

In comparison with other known species from the genus *Trichophoromyia*, the parameres of the new species, *T. napoensis* and *T.* sp.1 of Araracuara are similar. The digital area after the dorsal proximal lobe is approximately twice as long as it is broad in the new species compared with the other two species. However, *T. napoensis* is distinct from the others in that it possesses 2–3 long recurved setae at paramere apex, and a tuft of setae concentrated at the tip of dorsal lobe (Young and Duncan 1994). The parameres of *T. ruifreitasi* and *T.* sp.1 of Araracuara are covered by setae. *Trichophoromyia* sp.1. of Araracuara species possesses 4–6 long setae near its lateral ventral margin of the paramere apex (Young and Duncan 1994). Additionally, *T.* sp.1 of Araracuara also possesses other setae that are smaller than the width of the dorsal lobe, while *T. ruifreitasi* possess long setae that are distributed in the dorsal lobe. Santos et al. (2014) recently gave a brief review of the genus *Trichophoromyia*, and described *T. adelsonsouzai*, differentiating between the majority of species in the genus, except by the *T. napoensis* and *T.* sp.1 of Araracuara, not included in their analysis, and more closely related with the paramere of *T. ruifreitasi*. The new species described here raises the number of *Trichophoromyia* species worldwide to 42, and 21 in Brazil.

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RESEARCH ARTICLE

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Revised generic placement of *Brachypelma embrithes* (Chamberlin & Ivie, 1936) and *Brachypelma angustum* Valerio, 1980, with definition of the taxonomic features for identification of female *Sericopelma* Ausserer, 1875 (Araneae, Theraphosidae)

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Abstract

The tarantula genus *Sericopelma* was originally defined based on male specimens, most notably lacking tibial spurs on leg I. Early female specimens were unrecognised as *Sericopelma,* and typically placed in *Eurypelma* – a dumping ground for problem specimens. The first females were only later recognised, but authors failed to adequately define female *Sericopelma*. Here, the holotypes of the Southern-most alleged *Brachypelma* species, *B. embrithes* (Chamberlin & Ivie, 1936) and *B. angustum* Valerio, 1980 were examined, and finding both to possess defining characteristics of *Sericopelma* were transferred. The taxonomic attributes to define *Sericopelma* relative to *Brachypelma* and select other Neotropical genera are discussed, especially for females. As important diagnostic characters for *Sericopelma*, the single (unilobar) spermathecae swollen at the apex forming a P-shaped cross-section, metatarsus IV with trace scopula, femur IV with a dense retrolateral pad of plumose hair, plus other attributes. Some past confusion in these characters are clarified and *Sericopelma* relative to *Brachypelma* and *Megaphobema mesomelas* are discussed. Finally recommendations are given about these taxonomic changes for CITES regulations.

Keywords

Spider taxonomy, Theraphosidae, *Brachypelma,* transfer, *Sericopelma*

Introduction

Sericopelma Ausserer, 1875 was established for a male tarantula from an unspecified location in Panama without leg I tibial apophyses, named *S. rubronitens* Ausserer, 1875. *Sericopelma* was originally a subgenus of *Eurypelma* Koch, 1851, but later given full generic status (Simon 1892). Karsch (1880) also described an early male tarantula from Chiriquí Panama without leg I tibial apophyses as *Theraphosa panamana* Karsch, 1880. In revision, Simon (1892) synonymized *T. panamana* into Ausserer's *Sericopelma rubronitens*, emphasizing the lack of male tibial apophyses. He also considered that another male in the Paris collection from Chiriquí, Panama, might be the same. Like Karsch, he drew on similarities to the genus *Theraphosa*, where males of *T. blondi* (Latreille, 1804) also lack tibial apophyses, but distinguished the genera by several other features such as bulb shape, eye ratios, and cephalothorax dimensions. Soon after, Pickard-Cambridge (1897) described another species from four males also collected around Chiriquí province in Panama, which he named *Sericopelma commune* F.O.P.-Cambridge, 1897. He distinguished *Sericopelma* by femur IV "*with a thick scopuliform pad on inner side*", male tibia I without spurs, and emphasized the lack of scopulae on protarsus (metatarsus) of leg IV "*with no thick scopulae on the inner side*". Pocock (1901) again treated *Sericopelma* as congeneric with *Theraphosa*, but was not subsequently accepted.

Throughout the early twentieth century, only male *Sericopelma* were formally known and females remained unrecognised. Simon had described *Eurypelma panamense* Simon (1891) from a female with the vague locality of "Panama, Guatemala" emphasising conspicuous scopulae on femural leg IV, but failed to recognize it as *Sericopelma* (see Gabriel 2009). Schiapelli and Gerschman de Pikelin (1967) then evaluated both sexes of a *Sericopelma* sp. from "Rio Grande, Nicaragua" (? = Río Grande de Matagalpa) and illustrated the first female spermathecae. Next, Valerio (1980) described seven new Costa Rican species including three from both sexes, namely *Sericopelma generala*, *S. immensum* and *S. silvicola*, but only males for *S. dota*, *S. ferrugineum*, *S. melanotarsum* and *S. upala*. Following Schiapelli and Gerschman (1967), *Sericopelma* was characterized in Valerio (1980) by the "*presence of a thick scopula on the inner side of femur IV, and by the absence of spurs on tibia I [of males], and by the absence of stridulatory setae on trochanter I, and [absence of] scopula on metatarsus IV*". Smith (1991b) then re-described a syntype male of *S. commune* and illustrated the spermathecae of a female *Sericopelma* sp. in the BMNH collection. He suggested the latter was the un-described female of *S. commune*, and although stating "not a species description", it has been subsequently treated as such (*i.e.* World Spider Catalog 2015). We deduce that Smith (1991b) was referring to a female from Pozo Azul de Pirrís, Costa Rica, assigned by Valerio to *S. immensum* [see discussion]. Schmidt (1994) described the exuvia of a female as *S. melanotarsum*, illustrating the spermathecae, but did not give collection locality nor list any museum deposit. Most recently, Gabriel (2009) transferred the Panamanian *Sericopelma panamense* (Simon, 1891) from *Eurypelma*, illustrating the holotype spermathecae plus of another Panamanian *Sericopelma* sp. from Boquete, Chiriquí province, whilst Gabriel and Longhorn (2011) illustrated the spermathecae of a *Sericopelma* sp. from Bocas del Toro province, Panama. Finally Andre and

Esche (2011) showed the spermathecae of *S. melanotarsum* alongside other morphological data, plus substantial ecological, behavioural, and captive breeding data. However, despite these studies, *Sericopelma* as a whole remains poorly defined.

The genus *Brachypelma* Simon, 1891 was created for *Mygale emilia* White, 1856, originally listed from Panama. However, this location is erroneous, as the natural distribution of the type species and allies is South-western México (*i.e.* Smith 1994, Locht et al. 1999, Schmidt 2003). *Brachypelma* is currently said to range from México to Panama, though the southern-most species have not been revised until now. Pickard-Cambridge (1897) could not distinguish *Brachypelma* from *Eurypelma*, and considered the genera synonymous, describing other species such as *B. smithi* (F.O.P.-Cambridge, 1897), which has become a flagship for conservation efforts under the Convention on International Trade in Endangered Species (CITES). *Eurypelma* was partly dismembered by Pocock (1903), who recognised the importance of plumose hairs on leg I and palp to define *Brachypelma*, whilst Simon (1903) admitted *Eurypelma* was previously insufficiently characterised. *Brachypelma* was considered valid by Valerio (1980) who described three new species from Costa Rica, *B. albopilosum* Valerio, 1980, *B. fossorium* Valerio, 1980 and *B. angustum* Valerio, 1980. Soon after, Smith (1986) formalised additional transfers from *Eurypelma* to *Brachypelma*. Valerio (1980) had previously also transferred the Costa Rican *Eurypelma mesomelas* O.P.-Cambridge, 1892 into *Brachypelma* and described the female. Smith (1986, 1987) agreed, but not Schmidt (1991a/b), who further transferred it to *Megaphobema* despite objections by Smith (1991a/b). Schmidt (1993, 2003) continued to list this as *Megaphobema mesomelas*, as does the current World Spider Catalog (World Spider Catalog 2015).

Here taxonomic placement of some Costa Rican and Panamanian species is re-evaluated. Petrunkevitch (1925) had previously recorded several alleged *Eurypelma* from Panama, listing some as species now placed in *Brachypelma* (namely *emilia*, *sabulosum* and *vagans*) since known only from México, Guatemala and Belize (Smith 1994, Locht et al. 1999). Chamberlin and Ivie (1936) went further and described a species from Barro Colorado Island [Panama] as *Eurypelma embrithes*, placing it in that genus without explanation. Already, the robustness of *Eurypelma* should have been suspicious, as many species had been placed there without justification. Petrunkevitch (1939) later considered *Eurypelma* as "*genus incertum* and *invalidum*", although was treated as valid by Roewer (1942). Raven (1985) went on to regard *Eurypelma* as a junior synonym of the arboreal *Avicularia* Lamarck, 1818. Consequently several species were transferred to *Avicularia* that clearly did not belong there. Schmidt (1993) instead transferred several former *Eurypelma* into *Aphonopelma*, leading to the new combination *Aphonopelma embrithes* (Chamberlin & Ivie, 1936) although gave no justification, nor apparently examined any relevant types. Smith (1994) relocated *embrithes* to *Brachypelma* after reviewing many historical specimens, but did not explain his placement of this Panamanian species, thereby becoming the southern-most representative of *Brachypelma*. However, *B. embrithes* has since been listed as such (*e.g.* World Spider Catalog 2015) and receives legal protection under CITES legislation. However, much taxonomic revision is necessary for this protected genus in the context of others genera such as *Sericopelma*, although Smith (1994), Locht et al. (1999) and West (2005) have each made valuable contributions. Here, type material of *B. embrithes* and *B. angustum* are re-examined and their taxonomic placement is reconsidered in a modern context.

Methods

Specimens were examined under a binocular microscope, photographs of spermathecae and other structures were typically made using a Leica M135 auto-montage system, other photographs with a Fujipix S5000. All measurements are given in millimetres (mm). *Abbreviations, Institutes:* AMNH = American Museum of Natural History; BMNH = British Museum of Natural History; CNAN = Colección Nacional de Arácnidos, Instituto de Biología, Universidad Nacional Autónoma de México; LAAHFC = Laboratorio de Acarología "Anita Hoffmann", Facultad de Ciencias, Universidad Nacional Autónoma de México; MCZ = Museum of Comparative Zoology Harvard; MIUCR = Museo de Invertebrados University Costa Rica, MIUP = Museo de Invertebrados G.B. Fairchild, Universidad de Panama; MNHN = Muséum National d'Histoire Naturelle, Paris; OUMNH = Oxford University Museum of Natural History, UK; PMY = Peabody Museum of Natural History, Yale, Connecticut; SJLC = Private collection Stuart J. Longhorn; STRI = Smithsonian Tropical Research Institute; NHMV = Natural History Museum Vienna (Naturhistorisches Museum Wien), Austria; ZMB = Museum für Naturkunde, Berlin, Germany. *Others:* CITES = Convention on International Trade in Endangered Species; ANAM = Autoridad Nacional del Ambiente; B.C.I. = Barro Colorado Island; Imm = immature specimen; Ident. = indeterminate; det. = determined as; ALE = Anterior Lateral Eyes; PLE = Posterior Lateral Eyes; AME = Anterior Medial Eyes, PLE = Posterior Lateral Eyes; LHS = Left Hand side (from above); RHS = Right Hand Side. DMS = Degrees, Minutes, Seconds. Authors comments/emphases in[ ].

Type material examined: 1 ♀ holotype & 1 imm ♀ paratype *Aphonopelma seemanni* F.O.P-Cambridge 1897, BMNH [unknown accession], Puerto Culebra, Costa Rica, leg. Dr. B. Seemann; 1 ♀ holotype *Brachypelma angustum* Valerio 1980, UCR-433; 1 ♂ holotype *Brachypelma baumgarteni* Smith 1993, BMNH 1999-122, Sierra Madre del Sur, Mexico, leg. M. Baumgarten; 1 ♀ holotype *Brachypelma embrithes* (Chamberlin and Ivie 1936), AMNH [No accession], Barro Colorado Island (B.C.I), Panama, leg. unknown; 1 ♂ neotype *Brachypelma emilia* (White 1856), BMNH 98-12-24-32, Ciudad (Durango, Mexico) leg. Mr. Forrer (See Smith 1994); 1 ♂ paraneotype *B. emilia* (labeled as paratype), OUNMH Jar 106, Ciudad, Mex (Durango, Mexico) leg. Forrer; 1 ♂ holotype *Brachypelma fossorium* Valerio 1980, UCR-238 Guanacaste, Gte Filadelfia, leg. 24 jul.1973, Eddie Herrera & 1 ♀ allotype UCR-126, Guanacaste, Finca Santo Tomás, leg. 9 Apr. 1966, C.E. Valerio; 1 ♀ holotype *Brachypelma sabulosum* (F.O.P.-Cambridge 1897) BMNH 1898.12.24.54, Tikal Petten (=Peten), Guatemala, leg. A.P.Maudslay; 1 j♂ holotype (originally listed as ♀) *Brachypelma smithi* (F.O.P.-Cambridge 1897), BMNH 1898.12.24.33 (1143), Dos Arroyos, Mexico (=Guerrero), leg. H.H. Smith; 1 ♂ holotype & 1 ♀ paratype

Brachypelma vagans (Ausserer 1875), BMNH 1890-7-1-380-282, Yucatan (Keyserling collection), leg. Unknown; 1 ♂ holotype *Megaphobema mesomelas* (O.P.-Cambridge 1892), BMNH 1898.12.24.55, Caché, Costa Rica, leg. H. Rogers, Goodman and Salvin collection [ex-dried]; 1 ♂ holotype, 1 ♂ paratype (=syntype) *Megaphobema robustum* (Ausserer 1875), BMNH 1890.7.1.369-371, Bogotá [=Colombia] (Keyserling collection), leg. unknown; 1 ♂ holotype *Megaphobema peterklaasi* Schmidt 1994, SMF 38028 Costa Rica, leg. P. Klaas, det G. Schmidt 1994 & 1 ♂ paratype SMF 38030, same data; 1 ♂ holotype & 1 ♀ allotype *Megaphobema velvetosoma* Schmidt 1995, SMF 57910, Ecuador, area around Tena, leg. D.Antonelli; 3 ♂ 'syntypes' (lectotype and paralectotypes) *Sericopelma commune* F.O.P.-Cambridge 1897, BMNH 1898.12.24 19-21, Panama, Chiriquí, leg. G.C. Champion; 1 ♂ paralectotype (fourth syntype) *S. commune* OUMNH Jar 106, Chiriquí, leg G. Champion.; 1 ♂ holotype *Sericopelma immensum* Valerio 1980, UCR-237, San José, Cantón Dota, Finca El Cedral 2100 m, leg. 28 Oct. 1972, Guillermo Solís & 1 ♀ allotype UCR-288, San José, Cantón Puriscal, Naranjal de Guarumal, 480 m, leg. 5 Apr. 1972, Luis E. Jirón; 1 ♀ holotype *Sericopelma panamense* (Simon 1891), AR 4850 MNHN (Simon Collection), 'Panama and Guatemala' leg. unknown; 1 ♂ holotype *Sericopelma panamana/um* (Karsch 1880), ZMB 2394 BERLIN = Junior synonym of *S. rubronitens* by Simon (1892), Panama, Chiriquí, leg. Unknown; 1 ♂ holotype *Sericopelma rubronitens* Ausserer 1875, NHMV Nr.1874.III.1, WIEN, Panama, leg. unknown.

Other material examined: See supplement for full listing of examined Nicaraguan, Costa Rican and Panamanian *Sericopelma* spp. in the collections at BMNH, MCZ, MNHN, MIUP, OUMNH, PMY, SJLC. Specimens of various *Brachypelma* sp. from BMNH, CNAN, MCZ, OUMNH, LAAHCF, SJLC, *Megaphobema* sp. from MCZ, OUMNH, SJLC and *Theraphosa* sp. from OUMNH and SJLC.

Results

Taxonomy

Family Theraphosidae Thorell, 1869
Genus *Sericopelma* Ausserer, 1875

Sericopelma embrithes (Chamberlin & Ivie, 1936), comb. n.

Eurypelma embrithes Chamberlin & Ivie, 1936: 7 (D female)
Avicularia embrithes Raven, 1985: 146, 148, 151 (T f from *Eurypelma*).
Aphonopelma embrithes Schmidt, 1993: 78 (T f from *Eurypelma = Avicularia*).
Brachypelma embrithes Smith, 1994: 160 (T f from *Eurypelma = Avicularia*).

Description. *Female* (Holotype AMNH): Total length including chelicerae 58.6. Carapace, length 27.6, width 23.2. Caput, high. Ocular tubercle, length 2.6, width 3. An-

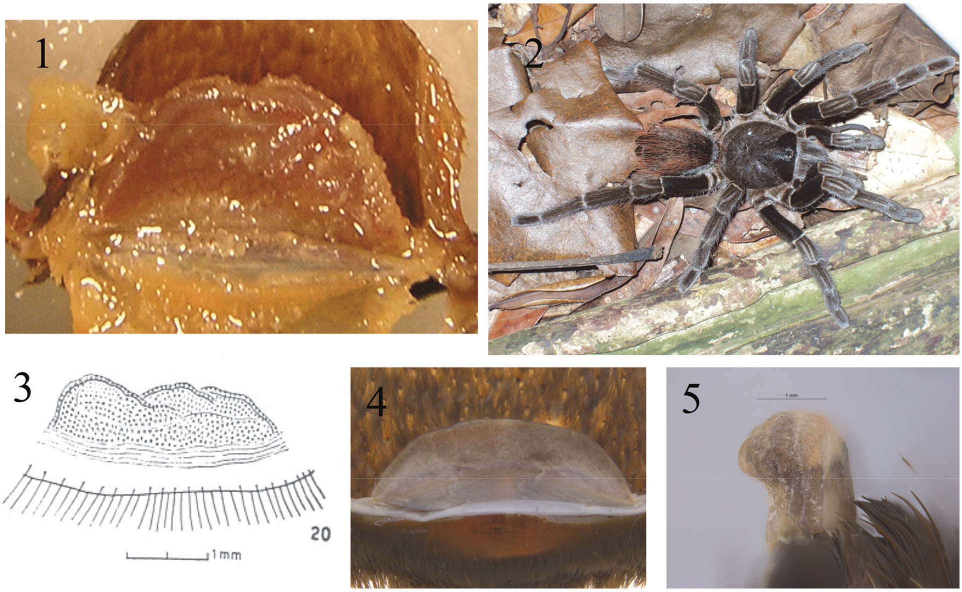

Figure 1–5. 1 Spermathecae from holotype of *S. embrithes* in dorsal view **2** Live specimen *in situ* of *Sericopelma* cf. *embrithes* at type locality on Barro Colorado Island, probable adult Female [Photo: Insa Wagner, STRI] **3** Spermatheca drawing of female Nicaraguan *Sericopelma* sp. in dorsal from Schiapelli and Gerschman (1967), their figure 20 **4** Spermatheca of mature female *Sericopelma* sp. Boquete (8.78°N, 82.43°W), Districto Boquete, Chiriquí Province, Panama, dorsal view lacking any distinct median notch **5** Same spermatheca (as 4) in lateral view with diagnostic 'P-shape' (of seen in reverse).

terior row procurved, posterior row recurved. Eyes ALE > AME, AME > PLE, PLE > PME. Clypeus; 0.9, clypeal fringe long. Fovea, deep transverse. Maxillae, with 100–120 cuspules, covering approximately 60% of proximal edge. Labium, length 3.2, width 4.4, with 40–60 labial cuspules most separated by less than 0.5 - 1 times the width of a single cuspule. Labio-sternal mounds separate. Sternum, damaged with three pairs of sigilla. Femur IV with a dense pad of plumose hair on retro-lateral surface, pro-lateral surfaces of trochanter/femur of anterior legs lacking stridulatory setae. Tarsi I–IV densely scopulate. Metatarsal scopulae, I 88%, II 83%, III 64%, IV 15% of the length of the segment, IV divided. Lengths of leg and palpal segments see Table 2. Spination: femurs I, III, IV, 0-0-2 palp d 0-0-1, patella I, palp, II, III 0-2-0, IV 0-3-0, tibia 1 d 0-2-0, v 0-0-3, II d 1-2-0, v 1-1-3, III d 2-2-2, v 0-2-3 (apical), tibia IV d 4-3-2, v 2-1-2, palp d 0-1-2, metatarsus I 0-0-1, II v 0-0-2 (apical), III d 2-3-2, v 4-0-5 (apical), IV d 3-2-2, v 5-5-9 (5 apical). Posterior lateral spinnerets, with three segments, basal 4.4, medial 3.7, digitiform apical 6.1.Lateral median spinnerets, with one segment. Spermathecae, single domed receptacle apically swollen (Fig. 1). Urticating hairs (not from holotype) type I and III.

Colour. Type specimen alcohol faded brown. Live freshly moulted specimens from type locality are an overall blackish with longer red hairs on the abdomen, with grayish hairs on the dorsal trochanter, coxae and edges of the carapace, and two converging stripes on patella in older specimens (Fig. 2). These colours fade to overall

Table 1. *S. embrithes* female holotype lengths of legs and palp.

	I	II	III	IV	Palp
Femur	17.9	17.5	14.8	19.9	14.5
Patella	10.8	9.7	8.7	10.6	9.0
Tibia	12.7	13.2	11.3	15.5	9.8
Metatarsus	12.7	12.2	14.6	21.3	-
Tarsus	9.9	9.8	9.8	11.0	11.1
Total	64.0	62.4	59.2	78.3	44.4

brown with subdued russet abdominal hairs after a few months and the first dry season (RG pers.obs.).

Distribution. Only known from type locality Barro Colorado Island, = Lake Gatun/ Canal Zone, Districto La Chorrera, Provincia de Panamá, República de Panamá [DMS = 9°09'00"N, 79°50'41"W].

Remarks. Originally, this species was described by "Carapace is decidedly longer than wide. Median depression transverse; deep" and "barely a trace of scopula on metatarsus IV". Our examination confirmed these features, but lead us to conclude identification as *Sericopelma* as defined here, including presence of an apically swollen unilobar spermathecae (Fig. 1, see also Figs 3–5, 7–9, contrast 13–16). The type locality of Barro Colorado Island is the site of a Smithsonian Institute field-centre; hence there is a large series of specimens from type locality assignable to *Sericopelma embrithes* (Fig. 2) in the MCZ, MIUP and PMY (supplementary material). It is possible that *S. embrithes* (Chamberlin and Ivie 1936) is a junior synonym of another *Sericopelma* sp. such as *S. commune* Pickard-Cambridge, 1897 or *S. panamanum* (Karsch, 1880). Unfortunately, the mature male of *S. embrithes* remains unknown. However, geographic considerations can be vital to make confident decisions about both generic and species identities as many tarantulas have narrow distributions, and we contend these older named Panamanian species were collected in distant western Panama, namely 'Chiriquí', likely the cool highlands near Volcán Baru and Boquete (Prov. de Chiriquí) where Europeans would acclimatize (rather than the small modern village of Chiriquí, Prov. de Chiriquí). Conversely, *S. embrithes* from Barro Colorado Island (Prov. de Panamá) is within the central Canal Zone, a distance of over 300 km from 'Chiriquí' (Specifically *ca.* 320 km from Panama City to Boquete).

Sericopelma angustum (Valerio, 1980), comb. n.

Brachypelma angusta Valerio, 1980: 269, f. 19. (D female)
Euathlus angustus: Raven 1985: 150 (T f from *Brachypelma*).
Brachypelma angustum: Schmidt 1992: 10, f. 8 (T f from *Euathlus*).
Brachypelma angustum: Schmidt 1993: 82, f. 192. (misidentification*)
[*Note: The figure 'Abb. 192' in Schmidt 1993 shows a spermathecae of an alleged *B. angustum*, but does not conform to either the Valerio's (1980) drawing of the

holotype spermathecae, nor our examination of the type. We suggest the material of Schmidt (1993) was likely misidentified pet trade *Brachypelma* sp. as with discussion and figures in Peters (2000, 2003), also misidentified pet trade *Brachypelma* sp.]

Description. *Female* (Holotype UCR 433): Total length including chelicerae 58.9. Carapace, length 22.9, width 19.2.Caput, high. Ocular tubercle, length 2.6, width 3.1. Anterior row procurved, posterior row recurved. Eyes, ALE > PLE, PLE > AME, AME > PME. Clypeus, 0.5, clypeal fringe long. Fovea, deep transverse. Maxillae, with 80–100 cuspules, covering approximately 60% of proximal edge. Labium, length 2.9, width 3.7, with 21 labial cuspules (a bald area in the centre of the labium lacks sockets for cuspules and may indicate previous damage, this cannot be confirmed until further specimens are examined) most separated by less than 0.5–1 times the width of a single cuspule. Labio-sternal mounds separate. Sternum damaged, narrow, length 10.2 (approx), width 8.4 with three pairs of sigilla. Femur IV with a dense pad of plumose hair on retro-lateral surface, pro-lateral surfaces of trochanter/femur of anterior legs lacking stridulatory setae. Tarsi I–IV densely scopulate, tarsus IV with spines along central axis. Metatarsal scopulae, I 84%, II 78%, III 35%, of the length of the segment, IV lacking scopulae. Lengths of leg and palpal segments see Table 1. Spination: femurs I, II, IV d 0-0-1, III 0-0-4, palp 0-0-2 (no spines on LHS palp only on RHS palp), patella II, palp 0-1-0, III 1-1-0, tibia I d 0-2-0, v 4-3-3, II d 1-1-1, v 2-4-3, III d 2-2-2, v 3-5-3, tibia IV d 2-0-4, v 4-4-3, palpal tibia d 0-2-1, v 2-2-4 (apical), metatarsus I v 2-0-3, II d 0-1-1, v 2-1-3(apical), III d 3-3-2, v 3-5-10 (6 apical), IV d 6-5-4, v 8-11-16 (6 apical). Posterior lateral spinnerets with three segments, basal 3.9, medial 3.2, digitiform apical 5.1.Lateral median spinnerets with one segment. Spermathecae, single domed receptacle apically swollen with slight medial indentation. Urticating hairs, type I and type III present.

Colour. Alcohol faded brown, posterior legs III and IV with longer reddish setae.

Distribution. Only known from type locality San Pedro de Arenal, Cantón San Carlos, Provincia de Alajuela, Costa Rica. [Likely DMS = 10°22'30"N, 84°34'47"W].

Remarks. The holotype is now fragmented (Figs 6–11) and right legs II and III both appear to have been lost in life as coxal stumps are blackened indicating wound healing. Accession data from UCR and jar labels specify the holotype was collected on 01-Oct.-1974 by Edgar Vargas, but this information was not given by Valerio 1980. In the holotype jar of *S. angustum* a label "iqual a *Sericopelma upala* (?) CEV 13 julio 83" (Fig. 6) shows Valerio himself (= CEV) had doubts about placement in *Brachypelma*, also considering it conspecific to the male he described as *S. upala*. The type localities are close, less than 50 km apart in Alajuela with similar ecotypes of lowland tropical forest, now largely fragmented to sugarcane plantation and cattle pasture (S. Longhorn pers. obs). However, until further specimens of *Sericopelma upala* and/or *S. angustum* are examined, we are not prepared to place them into synonymy at this time. We suspect Valerio (1980) lacked sufficient access to *Brachypelma* material to make a more informed decision about the genus, failing to recognise defining characteristics (as outlined below).

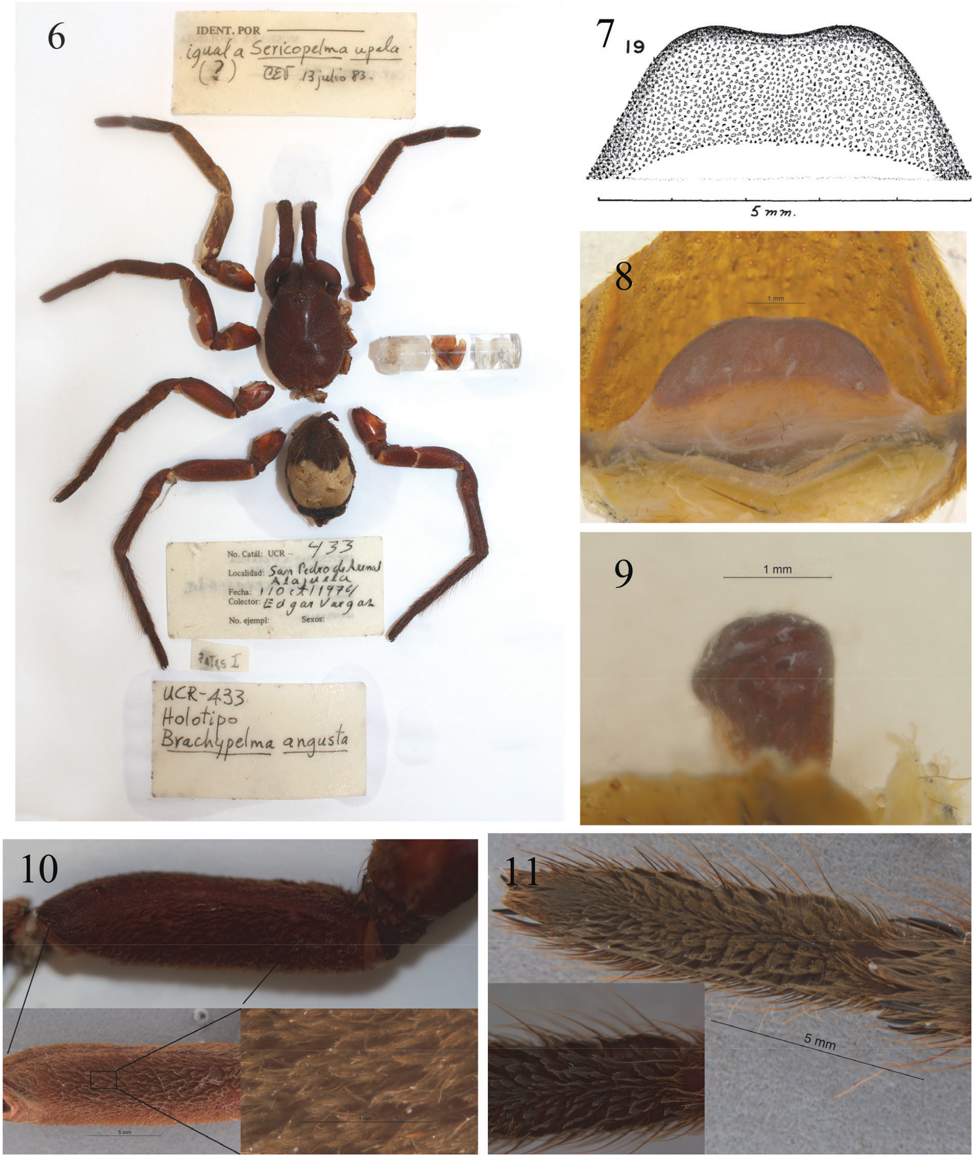

Figure 6–11. Holotype of *S. angustum*. **6** Habitus and labels **7** Valerio (1980) figure 19, drawing spermathecae **8** Spermathecae, dorsal view **9** Spermathecaee, lateral view showing (reversed) 'P-shape' diagnostic of *Sericopelma* **10** Dense pad of plumose hairs on femur IV not present in *Brachypelma*, upper with alcohol wet, bottom left inset same dried, bottom right inset closeup of plumose hairs **11** tarsus leg IV showing unusual spines along central axis, bottom left inset closer image.

Table 2. *S. angustum* female holotype lengths of legs and palp.

	I	II	III	IV	Palp
Femur	16.3	15.2	14.6	18.9	11.9
Patella	9.5	8.9	8.3	9.7	7.1
Tibia	14.0	12.0	11.2	15.1	9.4
Metatarsus	12.0	12.0	15.0	22.0	-
Tarsus	9.6	9.4	9.1	9.6	9.8
Total	61.4	57.5	58.2	75.3	38.2

Sericopelma commue F.O.P.-Cambridge, 1897

Sericopelma communis F.O.P-Cambridge: 15 (D male).
Sericopelma commune Smith, 1991b: 18 (f), here considered misplaced in this species.

Type. *Male* (3 male syntypes, BMNH 1898-12-24-19-21, male syntype OUMNH O.P.-Cambridge Coll. Jar 106):

Remarks. Smith (1991b) refers to three of four male syntypes from Chiriquí as *S. commune*, specifically BMNH 1898-12-24-19-21 (*i.e.* accessioned 24th-Dec-1898, coded ‘19-21’), then described a female, saying “Female BMNH 98-12-24-22. Assigned to the species by Valerio”. The only female BMNH specimen with this accession has the oldest label “*Museo Nacional de Costa Rica, Pozo Azul de Pirrís, José C. Zeldón*”, naming a collector from the 1890s. A later label “*Sericopelma immensa* n. sp. Det. C. E. Valerio, Jan 10, 1979” matches his paper (Valerio 1980) referring to a BMNH specimen from this same locality as *S. immensum*. However, the species on the Valerio label has been physically scored out, but likely reads *immensa*. Another pen-written label says “*Sericopelma commune* F.O Pick–Cambr.” (in handwriting of curator Doug Clark, died 1972), apparently present when both Valerio and Smith examined the specimen. We suspect this label misled Smith (1991b) to reconsider the specimen as the un-described female *S. commune,* even though collected at a Costa Rican locality (Parrita Cantón, Puntarenas), approx. 250 km from the Chiriquí type site. However Smith only records the distribution (indicating both sexes) from Chiriquí, Panama. Further confusion occurs with another mature male in BMNH with an old pencil-written label “Panama”, then two pen labels in Clark’s handwriting, “*S. commune* PDA Costa Rica BMNH 1898-12-24-22” and “*Sericopelma commune* det. Clark 1960”. We suspect these latter labels were an attempt by Clark to wrongly allocate this “Panama” male to both the Pozo Azul de Pirrís accession, and as a ‘missing’ fourth male syntype of *S. commune*. Clark perhaps did not realise that fourth male is in the Pickard-Cambridge collection at OUMNH, where a male labelled ‘syntype’ had the unequivocal label “*Sericopelma communis* Fopc Chiriqui – Champion”. In a BMNH accessions book, 1898-12-24-22 corresponds to “*Sericopelma* sp? Pozo Azul de Pirrís (Costa Rica). Pres. by F.D. Godman, Esq., Costa Rica Mus, F.O.P.-Cambridge”. However, although F.O. Pickard-Cambridge apparently recognised it as a possible female *Sericopelma* sp, the lack of accounts before Valerio (1980) indicate it was ignored, perhaps due to uncertainty about matching it with known males. We consider this female to be the same listed by both Valerio (1980) and Smith (1991b) and suggest its unsecure designation as the first described female of *S. commune* be suspended, instead to favour topotypic specimens from Chiriquí, such as the region of Volcán where G. Champion likely collected the four male syntypes.

Distribution. Only known from type locality, Chiriquí = Chiriquí, Provincia de Chiriquí, República de Panamá.

Sericopelma panamanum (Karsch, 1880), stat. rev.

Theraphosa panamana Karsch, 1880: 84 (D male).
Sericopelma panamana F. O. Pickard-Cambridge, 1897a: 16.
Sericopelma rubronitens Simon, 1892: 159 (S, here considered misplaced in this species).

Type. *Male* (1 male holotype, ZMB 2394 BERLIN):

Remarks. Simon (1892) makes no clear justification why Karsh's *T. panamana* from Chiriquí should be synonymous with *S. rubronitens,* only referring to similarities in eye pattern and absence of tibial spurs in Karsh's description against another non-type male specimen in the Paris collection, which he had assigned as *S. rubronitens*. Our re-examination of the type specimen confirmed its designation as a *Sericopelma* sp., but not its synonymy with *S. rubronitens*, which is here reversed.

Distribution. Only known from type locality, Chiriquí = Chiriquí, Provincia de Chiriquí, República de Panamá.

Geographic distribution, and generic limits

We believe it is important to re-clarify the characteristics of *Brachypelma* in this context. The type of *Brachypelma* is *B. emilia*, originally suggested in the paper's title to be from Panama (White 1856). A later male from México: Ventanas, Prov. de Durango (leg. Forrier) was described by Simon (1891) as generic type. Smith (1994) incorrectly says "Simon lists his specimen as coming from Panama" (p.166). We suspect this stems from a mis-listing by F.O.P-Cambridge (1897) of "PANAMA (coll. Simon: Male)" where locality was confused with the original type. While the original specimen appears lost (Smith 1994) or 'non-existent' (Pickard-Cambridge 1897), an excellent illustration in White's paper allows identification, showing an adult male with tibial spurs. The route of the collector (Berthold Seemann) is well known (Seemann 1852), joining his ship in Panama and voyaging north along the Pacific, docking in México both at San Blas (Estado Nayarit) and Mazatlán (Sinaloa). The original type taken to the BMNH was most likely collected during the second inland foray in 1849/50 to Ciudad de Durango (modern Victoria de Durango, Durango) and Tepic (Nayarit). However, another male deposited in MNHN was used as generic type of *Brachypel-*

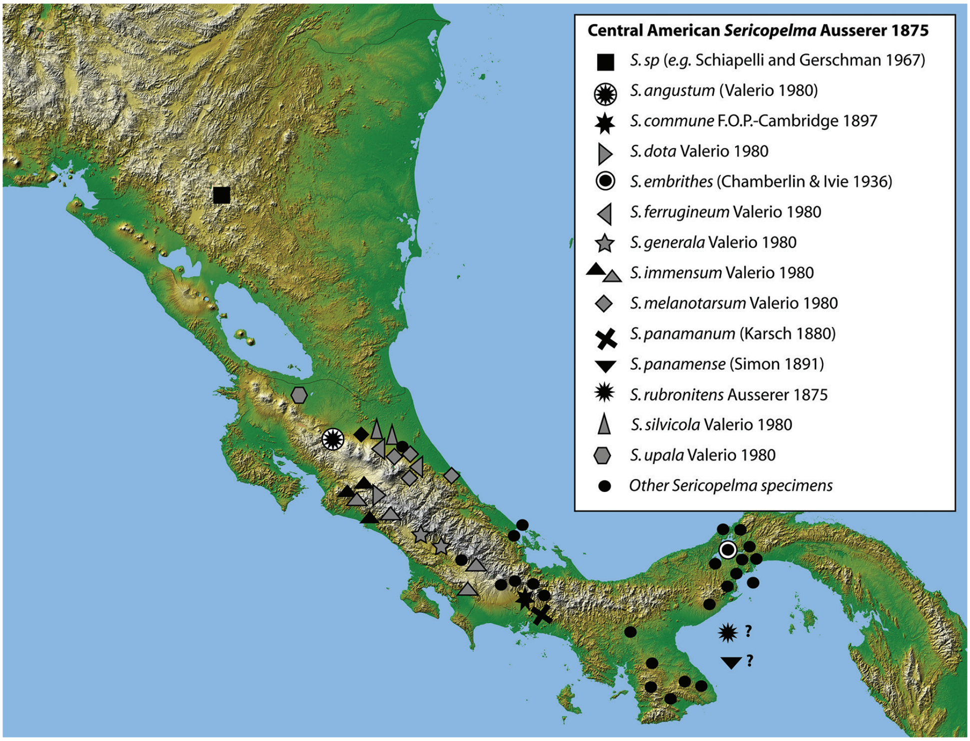

Figure 12. Geographic distribution of the genus *Sericopelma* from published records (including this study), where complete black-centred shapes are for specimens examined during this study, whilst gray shapes [outlined in black] are further specimens listed by Valerio (1980), accordingly data for *S. immensum* has black shapes (for the holotype, allotype and further female from Pozo Azul de Pirrís examined here), and gray shapes for further sites of Valerio. *S. rubronitens* and *S. panamense* are of unspecific location, but canal-zone seems likely.

ma, from Ventanas (leg. Forrer). This is likely modern Villa Corona, Estado Durango (DMS = 23°52'51"N, 105°46'19"W) (Selander and Vaurie 1962), but concurs both with the route of Seemann (within 15 km from Mazatlán to Ciudad de Durango) and with modern understanding of the species distribution across Sinaloa, Durango and Nayarit (Locht et al. 1999). Pickard-Cambridge (1897) mentions two males by Mr. Forrer from Ciudad [modern Victoria de Durango] plus Simon's male from Ventanas, but none specifically as neotype. One adult male which Smith (1994) refers to as neotype was accessioned in NHM as BMNH 98-12-24-32 where it is labelled 'leg. Forrer' plus 'Ciudad'. The second adult male is in the Pickard-Cambridge collection at OUNMH (Jar 65), with the same collection details of 'Ciudad. Mex, Forrer', plus labelled 'paratype A.M. Smith'. However, we argue preference could have been given to the generic type of Simon from Ventanas. Simon (1891) also referred to a female specimen, though Pickard-Cambridge (1897) stated the female is unknown. However Smith (1994) gives a comprehensive description of both sexes, using a later female BMNH 1962-2-28-1, and as a result the taxonomic identity of this species is clear. Simon (1891) originally emphasized several characters for *Brachypelma*, including presence of distinct scopula on the metatarsus, and femur IV without inner scopula (i.e. no dense pad of plumose hairs), instead long and simple hairs ("*metatarsus paris scopula crassa medium articulum fere attingente munitus, femora postica haud scopulata intus longe et simpliciter pilosa*", Simon 1890). The genus is also characterised by plumose hairs on the prolateral face of leg I trochanter/femur and retrolateral face of the palp (Pocock 1903). These features have been supported by subsequent authors as diagnostic for *Brachypelma* (*e.g.* Smith 1994), such as both sexes without a plumose pad on leg IV femur, the metatarsus IV distally one-third to one-fifth scopulate, and no tarsal division by stiffened setae, along with male palpal bulb distally wide and flattened (spoon-shaped), two unequal spurs on male tibia of leg I, females with a simple undivided/fused spermathecae (Figs 13–14) which we further clarify have a flat cross-section. Despite some earlier confusion about the types, the type species *B. emilia* is well defined, and the genus is easily separated from *Sericopelma*. The geographic range of *Brachypelma* is securely centred in south-western Mexico, now with *B. albopilosum* and *B. fossorium* at its southern-most limit in Northern Costa Rica. Due to the generic transfers here of *S. angustum* and *S. embrithes* (and comments below on other specimens), there are now no reliable records of the genus *Brachypelma* in Panama. The transfers proposed here verify that the *Brachypelma* as currently defined ranges from Mexico to north Costa Rica, and is not native in Panama or further south.

Geographic distribution of *Sericopelma*. From examination of specimens (see methods and supplement), combined with data we consider reliable in Schiapelli and Gerschman (1967) and Valerio (1980), we consider that *Sericopelma* ranges from Nicaragua to Panama (Fig. 2), with the northern-most report from Nicaragua. This was confirmed by examination of a single male specimen from Matagalpa, Nicaragua held in MCZ.

We regard the inclusion of 'Guatemala' in the original type locality of *S. panamense* from 'Panama, Guatemala' as an error, and suggest that 'Guatemala' instead refers to the locality for a second specimen (actually from another genus, and seemingly not of a taxon from Panama) which we found in the same jar from the Paris collection.

Panama [Provincia]: *Sericopelma commune* Pickard-Cambridge 1897 [Chiriquí]; *S. embrithes* (Chamberlin & Ivie, 1936) [Panamá]; *S. panamense* (Simon 1891) [Unspecified*]; *S. rubronitens* Ausserer 1875 [Unspecified**] (including as junior synonym *S. panamanum* (Karsch 1880) [Chiriquí]). **Costa Rica [Provincia]:** *Sericopelma angustum* (Valerio 1980) [Alajuela]; *S. dota* Valerio 1980 [San José]; *S. ferrugineum* Valerio 1980 [Cartiago, Heredia]; *S. generala* Valerio 1980 [San José]; *S. immensum* Valerio 1980 [San José, Puntarenas]; *S. melanotarsum* Valerio 1980 [Alajuela, Cartiago, Heredia; Limón]; *S. silvicola* Valerio 1980 [Cartiago, Heredia, Limón]; *S. upala* Valerio 1980 [Alajuela, Cartiago]. **Nicaragua [Departmento]:** *Sericopelma sp. indet.* [Matagalpa] (*e.g.* Schiapelli and Gerschman 1967).

Note: The extralimital Brazilian *Sericopelma fallax* Mello-Leitão, 1923 is considered misplaced (see Gabriel and Longhorn 2011). * Originally listed as Panama and Guatemala, though the latter is unlikely. ** Originally simply listed as Panama.

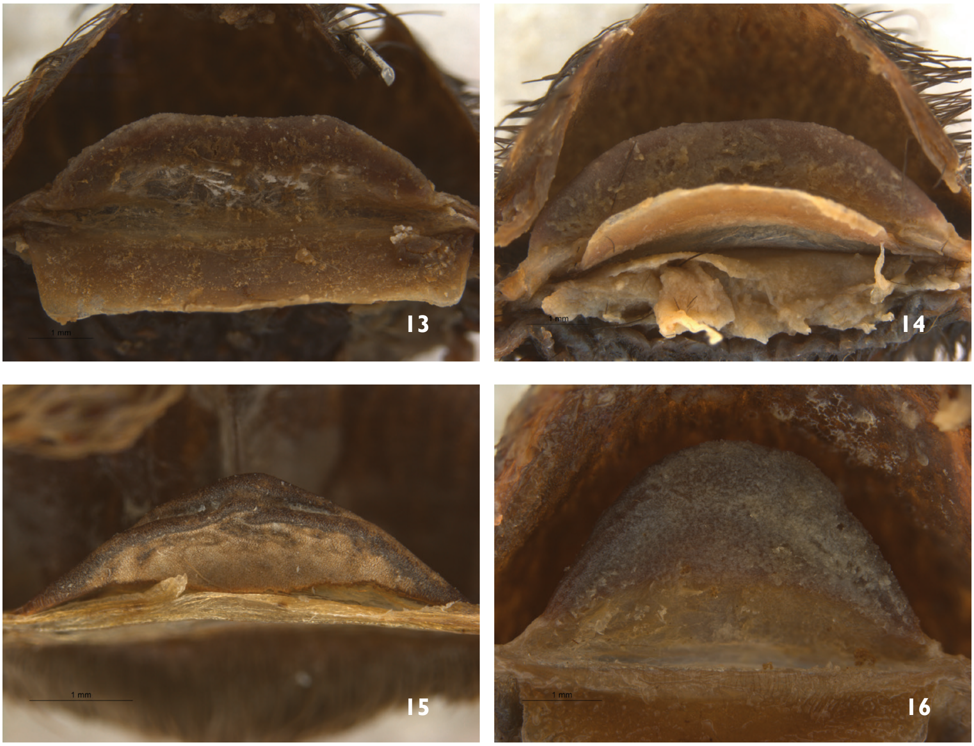

Figure 13–16. Selected taxa with similar spermathecae to *Sericopelma*. **13** *Brachypelma emilia*, type species of the genus from México, specimen EME10 in SJLC **14** *Brachypelma verdezi* from México, PAL4 in SJLC **15** *Megaphobema robustum* type species of the genus from Colombia, OUMNH 2008 072 (ROB3); and **16** *Megaphobema mesomelas* from Costa Rica as MES4 in SJLC.

Discussion

Prior to Valerio (1980) the diagnostic features for *Sericopelma* were poorly known, with males primarily recognised by the palpal bulb shape and absence of tibial apophyses (Ausserer 1875, Karsch 1880, Simon 1891/82), while females were unrecognized until Schiapelli and Gerschman (1967). Over-reliance on the lack of male tibial apophyses led many museum specimens to be mislabelled and misplaced. In actuality, Simon (1891) had described the first female *Sericopelma* as *Eurypelma panamense*, but unrecognized until Gabriel (2009) rediscovered it as a former *Eurypelma*, a genus that Raven (1985) had described as a taxonomic "dumping ground". We now confirm that Chamberlin and Ivie (1936) misplaced another female into *Eurypelma,* here transferred to *Sericopelma embrithes* (Chamberlin & Ivie, 1936). As the female characteristics of *Sericopelma* have long been uncertain, the female description by Smith (1991b) was valuable to resolve uncertainty about spermathecae characteristics. Schiapelli and Gerschman (1967) illustrated the first spermatheca of a probable *Sericopelma* from Nicaragua (Fig. 3) [Nb. specimen not seen]. Their relatively poor illustration shows possible indentations or notches on the apex, which appears atypical of the genus. However, we confirm that *Sericopelma* indeed exists in that region from another examined male *Sericopelma* sp. in MCZ with the label "Matagalpa, Nicaragua". Valerio (1980) described seven species from Costa Rica, only illustrating the spermathecae of both *S. immensum* and *S. silvicola* as simple domes, and neither shows any such notches. Neither do spermathecae of Smith (1991b) nor Schmidt (1994) show any such notches. Perez-Miles et al. (1996) reproduced the Schiapelli and Gerschman (1967) illustration, stating female *Sericopelma* have "a single spermathecae receptaculum with a median notch", plus key "19. Female with notched spermathecae". Schmidt (2003) also referred to the *Sericopelma* spermathecae as "*Einteilige flache*" (*i.e.* single flat) using the same illustration, not mentioning any apical notches or indentations. We regard the 'notched spermathecae' of Schiapelli and Gerschman (1967) as misleading, and its use to define female *Sericopelma* as erroneous. We find that mature female *Sericopelma* spermathecae lack any distinct median notch (Fig. 4) and furthermore, are distinctly swollen on the apex producing a diagnostic P-shape when viewed in profile (Fig. 5), which is also diagnostic for most immature *Sericopelma* females. We suggest this apical swelling probably expands with age (*i.e.* ontogenetic modification). Although the holotype spermathecae of *S. angustum* does have a slight medial concaved indentation, we consider this unique. It also shows the diagnostic swollen apex with P-shaped profile diagnostic for *Sericopelma*. The swollen apex is not found in the other Neotropical theraphosid genera where females have a single unilobar spermathecae, instead flattened or apically narrowed cross-section, such as *Brachypelma* Simon, 1890, *Megaphobema* Pocock, 1901 and *Theraphosa* Thorell, 1870. Female *Sericopelma* can be distinguished from *Eupalaestrus* Pocock, 1901, *Vitalius* Lucas, Silva & Bertani, 1993, *Nhandu* Lucas, 1983, *Pamphobeteus* Pocock, 1901 and *Xenesthis* Simon, 1891 by the unilobar spermathecae lacking two separated apical projections (Bertani 2001), and from *Mygalarachnae* Ausserer, 1871, by the unilobar structure lacking a broad median notch (Gabriel and Longhorn 2011).

Along with spermathecae attributes, *Sericopelma* can now be defined by; Carapace longer than wide (Ausserer 1875, Karsch 1880, Simon 1892, Pickard-Cambridge 1897, Schiapelli and Gerschman 1967), deep transverse fovea (Ausserer 1875, Karsch 1880, Pickard-Cambridge 1897) and distinct radiating sulci (Ausserer 1875). We confirm these attributes as useful for both sexes, although carapace is more rounded in mature males than females. Another useful diagnostic is few/weak metatarsal scopulae on distal leg IV forming two distinct pads, elsewhere defined as "barely a trace of scopula on metatarsus IV" (Chamberlin and Ivie 1936), "not scopulate, or very slightly so at the apex" (Pickard-Cambridge 1897), or absent (Ausserer 1875, Simon 1892, Valerio 1980, Schiapelli and Gerschman 1967). Here we confirm that almost every examined specimen of *Sericopelma* actually does have trace of scopulae on the distal leg IV metatarsus, most forming two small distinct pads when viewed ventrally (Fig. 17, in most extensive form). Such 'trace scopulae' are typically present on in both mature sexes, but in some specimens are distinct while in others greatly reduced. The fresh specimens that lacked trace scopulae were smaller juveniles, suggesting the feature may become

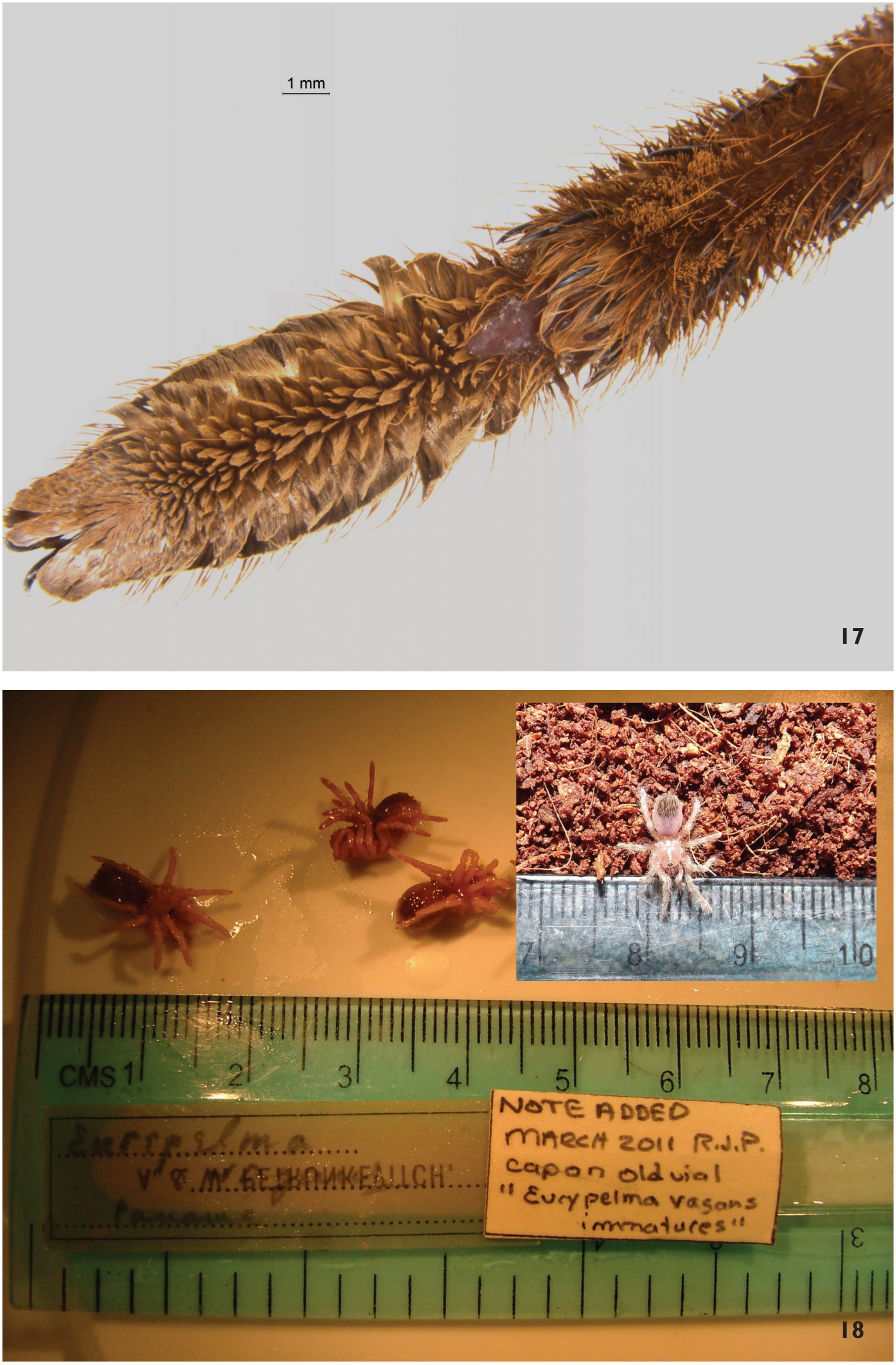

Figure 17–18. 17 Leg IV tarsus and metatarsus of *Sericopelma immensum*, allotype female (Naranjal de Guarumal, Cantón Puriscal, San José, Costa Rica), showing most extensive metatarsal 'trace' scopula **18** Nymphal (pre-dispersal) young misidentified by Petrunkevitch as *Brachypelma vagans* Panama, and inset, older yet smaller (post-dispersal) young of *Brachypelma* cf. *vagans* (pettrade, from Mexico).

more conspicuous through development. Trace scopulae were absent on some larger specimens, but only when eroded through wear or damage. Our examination of *S. angustum* confirmed trace scopulae on leg IV metatarsus as with other *Sericopelma*, unlike the one-third to one-fifth scopulae present in *Brachypelma*. From a large array of specimens (see Supplement), female *Sericopelma* may be robustly defined by: Spermathecae single (unilobar), swollen at the apex to form a P-shaped cross-section, femur IV with a dense retrolateral pad of plumose hair, trochanter/femur of leg I lacking stridulatory setae, carapace longer than wide, deep transverse fovea and distinct radiating sulci, ventral metatarsus IV with a divided and reduced trace of scopulate hairs at the distal end. Apart from spermathecae attributes, these remaining features also define mature males along with the absence of tibial spurs and characteristic embolus shape.

The dense retrolateral pad of plumose hair on femur IV is another useful character to separate *Sericopelma* from *Brachypelma*. We clarify the term 'femoral scopula/e' in *Sericopelma* as a broad pad of plumose hairs. Valerio (1980) defined *Brachypelma* with "Scopula in femur IV inconspicuous or absent", as did subsequent authors (Smith 1994, Schmidt 2003). Yet Valerio (1980) had previously confirmed that femur IV of *B. angustum* does indeed have a modified patch of hairs, by "*Femur IV con cojinete medial*" (p. 270), and elsewhere confirmed *Sericopelma* indeed posses such. Our examination of the *S. angustum* holotype (Figs 6–11) showed a broad pad of plumose hair on retrolateral femur IV (Fig. 10) as in other *Sericopelma* spp., but not *Brachypelma*. Schmidt and Krause (1994) reported that *Brachypelma klaasi* is exceptional with a "thin pad of plumose hairs on femur IV", used to support a new genus *Brachypelmides*, since rejected. They gave no indication of which sex was examined nor where femoral hairs were found. We therefore also examined mature *B. klaasi* specimens of both sexes and found no distinct pad on retrolateral femur IV, just a few sporadic fine-hairs slightly plumose basally, near the distal femur. We suggest these conform to the diagnostic 'short weak-feathered hairs (= kurze schwachgefiederte Haare) of Schmidt and Krause (1994), but do not form any distinctive pad as in *Sericopelma* (as *S. angustum* and *S. embrithes*). Instead in *B. klaasi*, these modified hairs are interspersed among more numerous long-fine hairs and thicker bristle-like hairs. Further, there is a baldline forming a longitudinal strip along the axis in *B. klaasi*, observable in both fresh and alcohol preserved specimens, contrasting with the dense pad of plumose hairs in *Sericopelma*. Modified hairs of *B. klaasi* hind-femurs were difficult to distinguish on alcohol-preserved specimens, so we also examined dried exuvia as Schmidt and Krause (1994), where fine-basally plumose hairs were more easily detected. Other examined *Brachypelma* spp. only showed fine hairs and bristle like hairs on femur IV, as reported for *B. albiceps* by Locht et al. (1999).

With a more robust definition of *Sericopelma* (including female characteristics), we can be increasingly certain about generic boundaries. Valerio (1980) defined *Sericopelma* by "the presence of a thick scopula in the inner side of femur IV, the absence of spurs on tibia I, [absence of] stridulatory setae on trochanter I, and [absence of] scopula on metatarsus IV". Also "One spermathecae, semicircular, sometimes with lateral extensions, covered with fine spinules", or as "*Receptaculum seminis* opens on dorsal side of apical region, communicating with distal tip of bulb by and open groove." This may be alluding to the apically swollen P-shaped cross-section that we consider diagnostic for *Sericopelma*. Valerio appears to have been misled by the central depression he characterised as "Spermathecae with a shallow notch in anterior edge (Fig. 7 [his figure 19])", leading him to recognise similarity with *B. albopilosum*, and misdiagnosing them both as *Brachypelma* by shared "Spermathecae with a conspicuous depression on the anterior edge". Our examination of *S. angustum* showed the spermathecae indeed possesses a slight medial indentation, but less defined than Valerio suggested, and we further recognise the apical swelling with a P-shape cross-section (Figs 8, 9) as diagnostic of *Sericopelma.* Spermathecae of other genera like *Brachypelma* (Figs 13–16) are flat throughout in cross-section. Further, *S. angustum* does not have any plumose hairs on the prolateral trochanter or femur of leg I (or II), nor the retrolateral palpal trochanter (*i.e.* Smith 1994, Schmidt 2003), but does have a distinctive pad of plumose hairs on femur IV (Fig. 10), together confirming it as *Sericopelma*, representing a unique species due in part to distinctive spines on tarsus IV (Fig. 11).

During this study, we found many historical museum specimens with mistaken identities, most importantly several wrongly reported as Panamanian *Brachypelma*. Petrunkevitch (1925) listed *Sericopelma commune*, 1 male and 1 female from the Canal zone. *Sericopelma rubronitens* from 2 females from Culebra (probably Pacific Canal Zone, 'Gaillard Cut'), and 2 females from Bocas del Toro. As discussed above, *S. commune* was described from males collected in distant Chiriquí, hence the identity of his Canal Zone species is dubious. Petrunkevitch did not compare his specimens to the earlier male types (nor could he with females), so his determination of various females as *S. rubronitens* cannot be regarded as reliable descriptions. Our confidence in Petrunkevitch determinations is greatly reduced as he also misidentified other geographically diverse specimens as *S. rubronitens*, all from outside the geographic range of the genus *Sericopelma*, such as from México, Haiti, and Ecuador (see supplement for re-evaluation), probably as all were similarly coloured with dark bodies and reddish abdominal hairs. He also inconsistently referred to specimens from Barro Colorado Island as either *S. rubronitens* or *S. commune* (see supplement), despite being the type locality for *S. embrithes*. Petrunkevitch (1925) mistakenly reported several *Brachypelma* from Panama, namely *B. emilia*, 1 female of *B. sabulosum* from Culebra, 1 female of *B. vagans* from Culebra, plus 4 young *B. vagans* specimens without locality. For *B. emilia*, Petrunkevitch (1925) merely repeated the erroneous location from the original description. Interestingly, some male *Sericopelma* from Chiriquí do superficially resemble *B. emilia* by light pinkish lower legs and carapace, plus black triangle on the carapace, perhaps leading to early confusion. On re-examination of the Petrunkevitch specimens in PMY, his alleged *B. sabulosum* was a *Sericopelma* sp, as likely are the 4 immatures of alleged *B. vagans*. The immatures are pre-dispersal nymphs, with the wrong proportions for *B. vagans* – where nymphs are almost one fifth of this size. In *B. vagans,* the legs remain proportionally shorter even when older post-dispersal 'spiderlings' of equivalent size (Fig. 18). The most likely genus for these large nymphs is *Sericopelma*. The alleged female *B. vagans* was not located, but we also expect to be a misidentified

Sericopelma, which can be similarly coloured and often confused by non-specialists. Distribution of *B. sabulosum* and *B. vagans* from Panama should be regarded as mistaken, *B. sabulosum* is only validly recorded from Guatemala, whilst *B. vagans* is recorded from México, Belize and Guatemala.

Finally, another allied Costa Rican species with long ambiguous placement is *Megaphobema mesomelas* (O.P.-Cambridge, 1892), again originally placed in the poorly defined *Eurypelma*. Valerio (1980) described the first female and transferred it to *Brachypelma* before Schmidt (1991a/b) transferred to *Megaphobema*. Smith (1991b) also re-evaluated the species, drawing tarsus IV with twin central lines of modified setae (his figure 6), which Valerio had recognised as "*Cojinete del tarso IV dividido por varias filas de espinas*". Against this, we considered *S. angustum* where scopulae are interspersed by thickened spines (Fig. 11), which we consider species specific - as not observed in other *Sericopelma*, nor mature specimens of other candidate genera. However, our inspection of various recent (both sexes) and historical specimens of *M. mesomelas* (including the male holotype and another male from same collector in the O.P.-Cambridge collection), each revealed only few long soft hairs on tarsus IV, not thickened spines. Our re-examination of *M. mesomelas* lead us to agree it does not belong in *Brachypelma*, nor *Sericopelma,* but neither do we agree with placement in *Megaphobema* (Gabriel and Longhorn, in prep). Female *Sericopelma* can be distinguished from *Megaphobema* by the form of the spermathecae, in the latter by greater ventral surface sculpturation with striated grooves more evenly spaced and extending to lateral edges, or a more cerebriform pattern, plus flatter cross-section (Fig. 15). Mature males of *Sericopelma* lack tibial apophyses (as do some other genera), but are present in *Megaphobema* (and other genera). Both sexes of *Megaphobema* also can be distinguished from *Sericopelma* by more extensive scopulae on metatarsus IV. For *M. mesomelas* the sternum is especially narrow and elongate, which Smith (1987) says "over twice as long as wide". We agree, observing the *M. mesomelas* sternum is more extremely narrowed than *S. angustum.* The narrowed form in both conflicts with *Brachypelma*, defined by a broad sternum (*i.e.* Simon 1891, "*Sternum aeque longum ae latum*"). *S. angustum* was diagnosed by Valerio (1980) by "Carapace longer than 18.0 mm" or "Carapace very narrow (1.6 times longer than broad)", and his specific epithet '*angust*' (= narrow) refers to both the narrow cephalothorax and sternum. We suggest the narrowed sternum can be indicative of close evolutionary affinities of *M. mesomelas* with *Sericopelma*, particularly *S. angustum*.

Consequences for conservation, including CITES

Currently, all *Brachypelma* species are protected by international commercial trade regulation (CITES, Appendix II). Transfer of *S. embrithes* and *S. angustum* into *Sericopelma* means that consequently these species may now only be protected by national wildlife laws. However, there does not appear to be a current need to regulate trade in *S. embrithes* and *S. angustum*, so we assert both species should indeed be removed from CITES listing. As with most theraphosids, the major threat appears to be habitat destruction. For *S. angustum*, much of its probable habitat in northern Costa Rica has already been disrupted by human activity, often for sugar cane plantations. However, its conservation status within Costa Rica must be urgently evaluated. For *S. embrithes*, much of its original range was likely destroyed during the damming of the Chagres River for the Panama canal, isolating Barro Colorado Island. A more deserving candidate for CITES regulation is *Megaphobema mesomelas*; a large brightly coloured species which has regularly been targeted by illegal collection for commercial gain, and traded internationally. We also point out there remains need for continued regulation of all *Brachypelma* sp. traded as exotic pets, including those in the pet-markets still exchanged under the former name '*Brachypelma angustum*', which would retain their CITES protected status under the aegis of *Brachypelma* sp.

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Appendix

Additional non-type material for comparison. Note – SJLC are mainly pet-trade, often of unclear providence unless otherwise stated, plus exuvia of other immatures and adults]

***Sericopelma* specimens:**

***S. embrithes* [Panama, Canal zone = Prov. Colón, Panamá and Panamá Oeste] - MCZ:** 2 ♀ 2 Imm, *Sericopelma embrithes* 74344 July 1936, B.C.I; 1 Imm ♂*S. embrithes* 74335 22/10/1954 B.C.I; 1 Imm ♂*S. embrithes* 74637 20/10/1950 B.C.I; 1 Imm ♂*S. embrithes* 74612 7/12/50 B.C.I; 3 Imm ♂*S. embrithes* 74338 B.C.I; 2 Imm ♂*S. embrithes* 74345 June – July 1950, B.C.I; 1 Imm ♂*S. embrithes* 74634 23/07/1950, B.C.I; 1 Imm ♂*S. embrithes* 74348 06/08/39, B.C.I; 7 Imm *S. embrithes* unsexed, 74340 16/08/1954, B.C.I; 1 Imm ♀ 1 Imm ♂*S. embrithes* 74343 B.C.I; 2 Imm ♂ 3 Imm ♀*S. embrithes* 74342 July 1936 B.C.I; 1 Imm ♀*S. embrithes* 74635 summer 1939 B.C.I; 1 Imm ♂*S. embrithes* 74336 summer 1939, B.C.I; 1 ♀ 74373, [no data], 1 Imm ♂ *S. embrithes* B.C.I., Canal Zone, Sept, coll. Phil Raw; **PMY:** 1 ♀ *S. embrithes* B.C.I. Canal Zone, Panama, July 1938, Coll. and Ident. (as *S. rubronitens*) by A. Petrunkevitch, from burrows on the lawn by the laboratory; 2 ♀ *S. embrithes* B.C.I. Panama, 04.viii.1938. coll. and Ident. (as *S. rubronitens)* by A. Petrunkevitch, [reverse reads 'in life with red abdomen]; 1 Imm ♂ *S. embrithes* (as *S. rubronitens*) B.C.I. Panama, July 1938, Coll. and Ident. by A. Petrunkevitch [mis-sexed ♀]; 1 ♂ *S. embrithes* B.C.I. Canal Zone, Panama, Coll. and Ident. (as S. *communis*) by A. Petrunkevitch, 1 Imm ♂ *S. embrithes* B.C.I. Panama, July 1938, coll. and Ident. by A. Petrunkevitch, [mis-sexed as ♀];1 ♀ 4 larvae *S. embrithes* 7 Imm, B.C.I., Canal Zone, A.M. Chickering, 1 ♀ 5 imm *S. embrithes*, B.C.I., Canal Zone, A.M. Chickering, July 12 1934.

***Sericopelma* spp. *[Panama, Canal zone = Prov. Colón, Panamá and Panamá Oeste]* - BMNH**: 1 ♀ *Sericopelma* sp. 1926.1.27.14 Taboga Island, Panama, 12/09/24, coll. G.I. Collenette. **MCZ:** 1 Imm ♀ 2 Imm ♂ *Sericopelma* sp. 74341 Ft. Clayton, IPAC. Side Panama, coll. Shropshire; 1 ♂ *Sericopelma* sp. 74346 Fort Davis, C.Z. 1924-1925 coll. Major D.R. Chase; 1 ♂ *Sericopelma* sp.74638 Bouia Point 1927,

J. Barbour Don, I.B. Shropshire, collection; 1 ♀ *Sericopelma* sp. Fort Sherman C. Z. [Canal Zone], Feb 1924, det, N. Banks; 2 ♂ *Sericopelma* sp. Ancón, Canal Zone, Mar-April 1922, T. Barbour and W.J. Brooks, det, N. Banks; 1 ♀ 2 ♂ *Sericopelma* sp. Corogae, Canal Zone, Atl.[Atlantic] Side, det. N. Banks. **MUIP:** 1 ♂ *Sericopelma* sp. Panama, Province Panama, Arraijan, San Jose de Bernardino 26.08.2003 coll. M. Barahona; 1 ♂ *Sericopelma* sp. Arraijan Panama 08.1995; 2 ♀ 1 Imm ♂ Vista Bella, Arraijan Panama Rep Panama 08 04 1990 coll. David Maruaga; 2 ♂ *Sericopelma* sp. Huili Arraijan, Panama R.D. Pan 8 November 86 coll. Daniel Holnes; 1 ♀ *Sericopelma* sp. Villalobos, Pedregal. Panama R.D. Pan 05.09.85 coll. Ramito Pinzon, Diana Moreno; 1 ♂ *Sericopelma* sp. Imprenta de la Universidad de Panama. Panamá 17.08.1981 coll. H. Martinez; 1 ♂ *Sericopelma* sp. Ciudad Panama, Republic de Panama, 26.08.1988 coll. Jasmin (sec. esc) Fistica; 1 ♂ *Sericopelma* sp. Panamá province, Panama Campana, L. Ortega 12.09.02; 1 ♂ *Sericopelma* sp. Profomsamilla 13, via Bolivar Panama 16 Oct 1980 coll. Alfonso Chong; 1 ♀ *Sericopelma* sp. Samaria, San Miguelito, Province Panama, Republic of Panama, coll. R. Navarro 16.12.94; 1 ♂ *Sericopelma* sp. Ciudad de Panama, Province Panama, Puerto Nuevo, Republic of Panama, 17.Dic.1977, coll. D. Quintero jnr; 1 ♂ *Sericopelma* sp. Isla Bagano, near bridge wet more, on forest litter, Province Panama, Republic of Panama, 31.01.76, coll. Claudia de Peralta; 1 ♂ *Sericopelma* sp. Province Panamá, Chilibre Carretera Puente de Chilibre, 25m despues del Puente, 15.Oct.1977, coll. D. Quintero jnr; 1 ♂ *Sericopelma* sp. Ciudad de Panama Ivan Diaz de rajo de tronco caido, Republic of Panama, 09.Dec.1977, coll. D. Quintero jnr; 1 ♀ *Sericopelma* sp. Panama, Province Panamá, area del canal, Howard Hecia Ferfan, 7-8.Feb. 2009, coll. S. Ortaga; 1 ♀ *Sericopelma* sp. Republic of Panama, Panamá Oeste Province, Bejuco, Sora, 21.Julio. 2007, coll. R. Carranzo. **PMY:** 1 ♀ *Sericopelma* sp. Culebra, Panama [was misidentified as *B. sabulosum*]; 4 Imm *Sericopelma* sp. Panama, [were misidentified as *B. vagans*], 1 ♀ *Sericopelma* sp. Culebra, Panama (described as *S. rubronitens* in the "Arachnida of Panama"), A. Petrunkevitch; 1 Imm ♂ *S.* cf. *rubronitens* Culebra, Panama; 1 ♀ *S.* cf. *rubronitens* Culebra, Panama, Dr. B.H. Buxton. ***[Panama, Central zone = Prov. Coclé, Herrera, Los Santos, Veraguas]*** **- MCZ:** 1 ♂ *Sericopelma* sp. El Valle, Panama, August 1936 (likely El Valle de Antón, Coclé; 1 ♂ 1 ♀ *Sericopelma* sp. 74371, San Pablo, Panama, Serly (possibly Rio San Pablo, Soná). **MUIP:** 1 ♂ *Sericopelma* sp. Altos de El Valle, Finca el Naranjal, Panama (Coclé), 22 Julio 1979, coll. Elisa De Fuentes; 2 ♂ *Sericopelma* sp. Rio Hato as Pollas Clano Bonito, Farallon el Plastanoc, Las Guias y El Rincon, Coclé, Panama 10.6.85, 24.7.85; 1 ♀ *Sericopelma* sp. Panama, Province Coclé, Río Hato (Las Guias – Farallon), Sept – Oct 1983, coll. A. Parra; 1 Imm ♀ *Sericopelma* sp. Panama, Province Herrera, District Las Minas, R.F. [=Refugio Forestal] El Monteuso - Estacion,13-15.Dic 2002 coll. P. Gonzales; 2 ♀ *Sericopelma* sp. Panama, Province Herrera, R.F. El Montueso, 3 Mayo 2007, coll. R.J. Miranda & A. Santor; 2 ♂ *Sericopelma* sp. Theraphosidae *S. commune* F.O.P.C. 1897 Det R.J. Miranda 2004

Panama, Province Los Santos, Cerro Canajagua 830m alt 11.12.02 coll. D. Gonzalez; 1 ♂ *Sericopelma* sp. Panama, Prov. Los Santos, Honantial 19. Augusto. 2000 L. Shamix; 1 ♂ *Sericopelma* sp. Panama, Province Herrera, San José, Oct 24 de Leo 1989, coll. K.F. Ponce; 1 ♀ *Sericopelma* sp. Panama Province Los Santos, R.F. La Trondsa, La Trondsa, 14-17 Augusto 2007, coll. R.J. Miranda. 1 ♂ *Sericopelma* sp. San Juan, Rio Cañazas, Province Veraguas, Panama, 22.Agusto.1987, coll. D. Quintero. ***[Panama, West Zone = Prov. Chiriquí, Bocas del Toro]* - MCZ:** 1 ♂ 74632 Boquete R.P. 23.03.1941; 1 ♀*Sericopelma* sp. Panama, Chiriquí, Volcán, 1200m el [elevation], 9/viii/1983, H.+L. Levi, in hole in low stone wall. **MUIP:** 1 ♂ *Sericopelma* sp. Finca del las Flores/Fleurs, Boquete Chiriquí Prov. Panama 07 Junio 1968 coll. Jorge Tovan; 1 ♂ *Sericopelma* sp. Boquete, Chiriquí Provence Panama 21.07.1992, coll. Miguel Bogante; 1 ♀ *Sericopelma* sp. Nueva California, Volcan, Chiriqui Province Republic of Panama coll. Leonardo Yanguez, Ríos de Unas Matas de Caña? debajo de las hojas secas suelo humedo; 1 Imm ♂ *Sericopelma* sp. Isla Colon Bocas del Toro Province, Panama 24.10.82 coll Astenid Araiz; 1 ♀ *Sericopelma* sp. Volcán, Province Chiriquí, Republic of Panama, 9.Sept.1987, coll. Arsenio Araug; 1 ♀ *Sericopelma* sp. Isla Taboga, Republic of Panama, Augusto 1985, coll. Kyle Summers. **OUMNH:** 1 ♂ *S. commune* Panama, Jar 106 Chiriquí, Champion, syntype. ***[Panamá, Unknown Prov.]* - MNHN:** 1 ♂ *Sericopelma rubronitens* Ausserer 1875. (Simon det) AR4803 PARIS. **MCZ:** 1 ♂ *Sericopelma* sp.74369, Panama; 2 ♂ *Sericopelma* sp. 74370, Prob[ably] Panama; 1 ♀ 1 Imm ♂*Sericopelma* sp. 74372, Panama.. **MUIP:** 1 ♂ *Sericopelma* sp. Panama 06.12.02 coll. G. Lover; 1 ♂ *Sericopelma* sp. [labeled Theraphosidae] Mulio 9 de Mayo 1994, ?Estuooeucauterisis, Disele el 15 Sept 1993 total 176 dias; 1 ♀ No Data, Panama; 1 Imm ♂ *Sericopelma* sp. San Cristobal ?Verani(S) Sanmig Velito Panama, 10.05.93; 1 ♂ *Sericopelma* sp. Poblado ?Irhe en la Hibrochet, de Banyo 10.00am, Panama, Republic of Panama, 29.12.88 coll. Abraham Beauville.. **OUMNH:** 1 ♀ *Sericopelma* sp. Panama, Jar 82 S. Tinter, Roger, O.P. Cambridge coll. ***[Unknown – likely Panama]:*** 1 ♂ *Sericopelma* sp. Central America ex London Zoo. ***[Costa Rica]* - BMNH:** 1 ♀ *Sericopelma* sp. 1906.11.3.1, Banana River 15 miles from Coast, July 1905, Costa Rica, Jose (?Río Banano, Cantón Limón, Prov. Limón]; 1 ♀ *Sericopelma* sp. 98-12-24-22 Pozo Azul de Pirrís, Prov. San José, Costa Rica, coll. C. Zeledon [Modern Cantón Parrita, Prov. Puntarenas]; **OUMNH:** 1 ♂ *Sericopelma* sp. Guápiles, Pococi, Prov. Limón, Costa Rica. coll. 2006 Viteslav Honsa SERGU1, died n.11.10, ex Benoit Menart; 1 ♀ *Sericopelma* sp. Sabanilla, Puntarenas Sud, Coto Brus, Costa Rica Coll. 2006 leg. Viteslav Honsa SERSB1 died 25.08.10; 1 ♂ as prev. leg. Viteslav Honsa SERSB2 died n.11.10, ex Benoit Menart; 1 ♂ *S. immensum* 2009 007, pet trade, K Matzen, 1 ♀ *Sericopelma* sp. 2009 007, Costa Rica, ex pet trade w/c 1997; 1 ♂ *S. melanotarsum* 2009 007, ex pet trade, K Matzen; 1 ♀ *S. melanotarsum* 2009 007, Costa Rica, w/c died 2000, donated anon. ***[Nicaragua]* - MCZ:** 1 ♂ *Sericopelma* sp. 74625 Matagalpa Nicaragua 1073, Richardson Dec 1907, R.C. Feb 12-1909.

***Brachypelma* specimens:**

***B. albiceps* - BMNH:** 1 ♀ *B. albiceps* (CB from German import as *B. ruhnaui*) RUHZ, died VIII.03, Ex E. Hijmensen/ S. Longhorn. **CNAN:** 1 ♂ *B. albiceps* n79. Teloloapan, Mpio. de Teloloapan. Edo. Guerrero, México. 15.IX.52, coll. Leonila Vazquez; 1 ♂ *B. albiceps* Presa Vicente Guerrero, Edo. Guerrero, México. 23.XI.96, coll. A. Castido Octavio; 1 ♀ *B. albiceps* Ref.3094. Presa Vicente Guerrero, Edo. Guerrero, México. 5.X.76. coll. No data. **LAAHFC:** 1 ♂ *Brachypelma albiceps* Sur Morelos. Edo. Morelos 1996. coll. A. Locht. **SJLC** [all pet-trade of unknown providence unless otherwise stated]**:** 1 Imm *Brachypelma albiceps* RUH2, died 11.IV.09, Ex unknown; 1 ♂ *B. albiceps* RUH3, died 2008, Ex Mark Davies.

***B. auratum* - BMNH:** 1 ♀ *B. auratum* Ref.27. Entre Hermiltepec y Río Pungarancho, Edo. Guerrero, México. 02.XI.2002. coll. E. Gonzalez y C. Duran. **OUMNH:** 4♀ *B. auratum* 2007 064 pet trade, Lee Arden (spidershop UK) died 2007. **SJLC:** 1 ♀ *B. auratum* AUR7 died 11.V.08, Ex unknown; 1 ♀ *B. auratum* AUR9, died VI.03, Ex Paul Herbert; 1 ♂ *B. auratum* AUR10, died I.04, Ex Stephen Copley; 1 ♂ *B. auratum* AUR11, died VI.04, Ex Ian Metcalfe; 1 ♂ *B. auratum* AUR12, died 25.VI.08, Ex Andy Fischer; 1 ♂ 1 ♀ *B. auratum* AUR13/AUR14, died 2008, Ex Mike Fletcher; 1 ♀ *B. auratum* AUR15, died 2010, Ex Becky Norris.

***B. albopilosum* – OUMNH:** 1♀ *B. albopilosum* 2007 064, pet trade, C/B. **MCZ:** 2 ♀ *B.* cf. *albopilosum* 74614, Georgia Fruit Company, Honduras, 20.v.1932; 1 ♀ *B.* cf. *albopilosum*, 74624, With Fruit Honduras; 1 ♀ *B.* cf. *albopilosum* 74615, Leon River Valley, East of Río Ulúa, Honduras, 1924, Donor, United Fruit Company, 1 ♀ *B.* cf. *albopilosum* Río Ulúa, Tela, Honduras, Fruit Company. **SJLC:** 1 ♂ *B.* cf. *albopilosum* ALB1, died 17.II.01, Ex Ronald Baxter; 1 ♂ *B.* cf. *albopilosum* ALB9, died 03.V.01, Ex Mark Dean; 1 ♂ *B.* cf. *albopilosum* died 01.XII.07, Ex Stuart Longhorn CB; 1 ♂ *B.* cf. *albopilosum* ALB12, died V.08, Ex Andy Matthews. (Plus several further specimens collected across Honduras to be detailed elsewhere).

***B. baumgarteni* – OUMNH:** 1♀ *B. baumgarteni* 2007 064 pet trade, Ex Boris Striffler from first import; 1♂ *B. baumgarteni* 2007 064, pet trade, Ex Boris Striffler from first import - remains of male eaten by female. **SJLC:** 1 imm *B. baumgarteni* BAU7, died XII.01, Ex Ronald Baxter; 1 ♀ *B. baumgarteni* BAU8, died I.03, Ex Ronald Baxter; 1 ♀ *B. baumgarteni* BAU12, died V.08, Ex Paul Herbert; 1 ♂ BAU13, died 2008, Ex Mark Pennell. ***Known hybrid* -** 1 ♂ imm *B.* sp. *baumgarteni* × *boehmei*, BAU10, died 2008, Ex Eddy Hijmensen.

***B. boehmei* – SJLC**: 1 ♂ *B. boehmei* BOH9, died 16.X.03, Ex Ronald Baxter; 1♀ *B. boehmei* BOH10, died 07.VI.12, Ex Ronald Baxter; 1 ♂ *B. boehmei* BOH11, died 25.V.08, Ex Mark Kent; 1 ♂ *B. boehmei* BOH12, died 2001, Ex Mark Dean; 1 imm ♂ *B. boehmei* BO13, died 2004, Ex Ray Gabriel.

***B. emilia* – CNAN:** 1 ♀ *B. emilia* Ref.3121. Sinaloa, Edo. Sinaloa, México. 30.I.65, coll. Ent 46; 1 ♀ *B. emilia* Ref.3080/No.80. Mazatlán, Mpio. Mazatlán, Edo. Sinaloa, México. VII.1959. coll. Ent 5. **OUMNH:** 2♀ *B. emilia* 2007 064, pet trade, imported Lee Arden Spidershop UK died 2007; 1♂ 2007 064, *B. emilia*, pet trade; 1♂ *B. emilia*, Jar 65, Cambridge coll. (discussed in text). **SJLC:** 1 ♀

B. emilia EME8, died 12.08.09; 1 ♂ *B. emilia* EME9, died 26.04.09, Ex Andy Fisher; 1 ♀ *B. emilia* EME10, died 19.05.09, Ex Becky Norris [spermathecae shown in figure 13]; 1 ♂ *B. emilia* EME11, died 2009, Ex Becky Norris; 1 imm, *B. emilia* EME12, died 2009, Ex Becky Norris.

***B. klaasi* – CNAN:** 1 ♂ *B. klaasi*. Reserva Biosfera Chamela - Cuixmala. Edo. Jalisco, México. 18.V.81. coll. A. Pescador. **LAAHFC:** 1 ♂ *B. klaasi* Ref.1714.23 Reserva Biosfera Chamela - Cuixmala. Edo. Jalisco, México. 3.IV.98. coll. A. Locht. **OUMNH:** 1♂ *B. klaasi* 2007 064; 1♂ *B. klaasi* 2008 071, Eddy Hijmensen. **SJLC**: 1 ♂ *B. klaas*i KLA1, died IV.01, Ex Mark Pennell; 1 ♂ *B. klaasi* KLA4, died 08.XII.98, Ex Ray Gabriel; 1 ♂ *B. klaasi* KLA5, died 2002; 1 ♀ *B. klaasi* died 2005, Ex Paul Herbert, 1 imm, *B. klaasi* died 2009, Ex Becky Norris; 1 ♀ *B. klaasi* died 20.II.10, Ex Mark Pennell.

***B. schroederi* – SJLC:** 1 ♂ *B. schroederi* SHR3, died VII.08, Ex Steffan Schroeder; 1 ♂ *B. schroederi* SHR4, died 01.I.10, Ex Andy Hood; 1 ♂ *B. schroederi*, SHR6, died 20.IX.15, Ex Peter Roach; 1 ♀ *B.* cf. *schroederi*, SHR5, died 19.V.09, Ex James Box.

***B.* aff. '*smithi*' – CNAN:** 1 ♀ *B.* aff. *smithi* Entre Tepames y Rio Coahuayana, Frontera, Edo. Colima, México. 8.VII.2005, coll A. Cervantes y M. Olson. **LAAHFC:** 1 ♂ *B.* aff. *smithi* Colima. Edo. Colima, México. 23.Oct. coll. A. Locht; 1 ♂ *B. smithi* Acapulco, Mpio. Acapulco de Juárez, Edo. Guerrero, México. 20.III.97. coll. A. Locht. **OUMNH:** 1♂ *B.* aff. *smithi*, 2007 064, C/B, 1♂ *B.* aff. *smithi* 2009 001, pet trade, 24/09/08, Yinnon Dolev; **SJLC:** 1 ♀ *B.* cf. *smithi* (traded as *annitha*), ANN1, died 25.III.02, Ex Tony Packer C/B; 1 Imm *B.* cf. *smithi* (traded as *annitha*) ANN2, died 2004, Ex Eddy Hijmensen C/B; 1 ♂ *B.* cf. *smithi* (trade as *annitha*), ANN3, died 2007, Ex Eddy Hijmensen C/B; 1 ♂ *B.* aff. *smithi* SMI1, died IV.01, ex Jean-Michel Verdez; 1 ♂ *B.* aff. *smithi* SMI8, died 03.V.07, Ex Stuart Longhorn; 1 ♂ *B.* aff. *smithi* SMI13, died unk.II.02, Ex Alan Smith; 1 ♂ *B.* aff. *smithi* SMI16, died 2008, Ex Ray Gabriel; 1 ♂ *B.* aff. *smithi* SMI17, died 2008, Ex anon; 1 ♂ *B.* aff. *smithi* SMI18, died 18.V.11, Ex Nicola Dolby; 1 ♀ *B.* aff. *smithi* SMI9, died 31.I.15, Ex Stuart Longhorn; 1 ♀ *B.* aff. *smithi* SMI12, died X.01, Ex Paul Herbert; 1 imm *B.* aff. *smithi* SMI14, died 2004, Ex Ray Gabriel; 1 imm *B.* aff. *smithi* SMI15, died 20.07.07, ex Lee Arden; 1 ♂ *B.* aff. *smithi* × (?) *klaasi* hybrid, HYBAXB, died II.10, Ex S.Longhorn.

***B.* aff. '*vagans*' – BMNH:** 1 ♀ *B.* sp (*vagans*-complex) 2003-148 Las Cuevas Research Station. Chiquibul National Park, Cayo District, Belize. 27.05.01. leg. Stuart Longhorn, Julie Chuter, Martin Nicholas. 1 ♀ *B.* sp (*vagans*-complex), 2003-148 Pooks Hill Lodge, near Teakettle, Cayo District, Belize, 05.06.01, leg. Stuart Longhorn, Julie Chuter, Martin Nicholas. Plus several other specimens to be detailed elsewhere. **CNAN:** 1 ♂ *B.* cf. *vagans* Celestún, Edo. Yucatán, México. 26.X.00. coll. Tila M.P; 1 ♂ *B.* sp. (*vagans*-complex) Valerio Trujano, Mpio. Cuicatlan, Edo. Oaxaca, México. 31.XII.04. coll. B. Chavez; 1 ♂ *B.* sp. (*vagans*-complex) Sierra de Sta. Martha. Los Tuxtlas. Edo. Veracruz, México. 17-XII-76. coll. H. Perez; 1 ♀*B.* sp. (*vagans*-complex) Área Protegida del Selva Lacandona, Mpio. Ocosingo, México. 7-IV-05. coll. O. Francke, A. Ballesteros, A. Valdez; 2 ♂ *B.* sp. (*vagans*-complex) Locale as previous. 6.VIII.2005. coll. As previous. **MCZ:** 1 ♀ *Brachypelma* sp. (*vagans*-complex) 74611, Stann Creek, Belize, under rock, 26.vi.1975, W. Sedgewick. 4 Imm *B.* sp. (*vagans*-complex) 74627, El Cayo, British Honduras [Belize], under rock, Feb.-Mar. 1931; 1 ♀ 3 Imm *B.* sp. (*vagans*-complex) 74620, Uaxactun, Petén, Guatemala, Mar.-April 1931, H.H. Bartlett. **LAAHFC:** 1 ♀ *Brachypelma* sp. (*vagans*-complex), Los Tuxtlas. Edo. Veracruz, México. No data. coll Unknown; 1 ♂ *Brachypelma* cf. *vagans* Merida, Edo. Yucatán, México. XI.1996. coll. H. Lopez; 1 ♂ *Brachypelma* sp. (*vagans*-complex) Playa el Arroyito. Mpio. Santa María de Huatulco, Edo. Oaxaca, México. 28.XII.98. coll. A. Locht. **OUMNH:** 1♀ *Brachypelma* sp. (*vagans*-complex) 2007 064; 1♀ imm *Brachypelma* sp, Jar 61 1905, Cambridge coll; 1♀ Imm *Brachypelma* sp., Cambridge coll, 1♀ *Brachypelma* sp., "Honduras", Jar 63 Boston* Nr Belize, O. Pickard-Cambridge colln (perhaps New Boston); 1♂ *B.* aff. *vagans* 2007 064, pet trade, C/B; 1♀ *B.* aff. *vagans* 2008 071, pet trade, C/B; 1♂ & 1♀ *B. vagans*, Jar 69 Guatemala, Cahabón, F. Sarg, Cambridge coll. **PMY:** 2 ♀ *Brachypelma* sp. (*vagans*-group), Tampico, México, Bis;hop Coll. 1940, in life with red abdomen, colour fades before moulting [were misidentified as *S. rubronitens*]. **SJLC**: 1 ♀ *B.* sp. '*sabulosum*', Aldea El Remate (casa Don David), nr Flores, Petén, Guatemala. Collected 19.V.08, David Ortiz; 1 ♂ *B.* sp. '*sabulosum*', SAB1, died VII.03; 1 ♂ *B.* sp. '*sabulosum*', SAB2, died 01.III.08, Ex Guatemala, Ronald Baxter; 1 ♀ *B.* sp. '*sabulosum*', SAB3, died 12.VI.11, Ex Guatemala, Ronald Baxter; 1 ♀ *B.* cf. *sabulosum* Parque Nacional Yaxha, Petén, Guatemala, 21.V.08. Coll. David Ortiz and Eduard Hijmensen; 1 ♀ *Brachypelma* sp. '*vagans*' VAG3, died 25.XI.00; 1 ♂ *B.* sp. '*vagans*', VAG4, died VII.01; 1 ♂ *B.* sp. '*vagans'* VAG7, died 13.VIII.97, Ex Richard Gallon; 1 ♂ *B.* sp. *'vagans'* died pre 2001, Ex Richard Gallon; 1 ♀ *B. albopilosum* × *B.* '*vagans*' (maternally purebred *albopilosum*) HYB4, died 2005, Ex S. Longhorn; 1 ♂ *B.* sp. '*angustum*' ANG2, died III.01, Ex Tony Davies; 1 ♂ *B.* sp. '*angustum*' ANG3, died VI.01, Ex unknown; 1 ♀ *B.* sp. '*angustum*' ANG4, died 2003, Ex unknown; 1 ♀ *B.* sp. '*angustum*' ANG5, died 2004, Ex Unknown; 1 ♂ *B.* sp. '*angustum*' ANG6, died 10.01, Ex Guy Tansley; 1 ♂ *B.* sp. '*angustum*', ANG7, died 20.X.04, Ex Unknown.

***B. verdezi* – LAAHFC:** 1 ♀ *B. verdezi* (labelled *B. vagans*) Acapulco, Mpio. Acapulco de Juárez, Edo. Guerrero, México. 1990. coll A. Locht,. **SJLC:** 1 ♀ *B. verdezi* (traded as *pallidum*), PAL2, died 2005; 1 ♀ *B. verdezi* (traded as pallidum), PAL4, died 26.X.09, Ex David James [see fig. 14]; 1 ♂ *B. verdezi* PAL5, died 27.IV.09, 1 ♂ *B. verdezi* PAL6, died 24.09.08, Ex Yinnon Dolev.

***Megaphobema* specimens:**

***M. mesomelas* - BMNH:** 2 ♂ *M. mesomelas* (18)96.3.20.3-4, El Azahar, (Canton Cartago, Dept.) Cartago, Costa Rica. J.F. Tristán (Museo Nacional de Costa Rica). 1 ♂ *M. mesomelas* 1898.12.24.56, La Palma (Prov. Cartago), Costa Rica. J.F. Tristán (Museo Nacional de Costa Rica). [note, this specimen was mislisted as type by Smith 1991b, also has additional label 'Visto por de Pikelin y Schiapelli, mayo 1968'); 1 ♀ *M. mesomelas* (18)96.10.25.1 La Palma (Prov. Cartago), Costa Rica.

[incl. dissected spermathecae labeled A.M.Smith]; 2 ♂ *M. mesomelas* 1905.3.29.14-15, Cariblanco (San Carlos, Prov. Alajuela), Costa Rica. Charles H. Lankester [both ex dried/pinned]; 2 ♂ *M. mesomelas* Dried/pinned collection (possibly additional specimens from H. Rogers, Caché listed by FOPC 1897, Costa rica). **OUMNH:** 1 ♂ *M. mesomelas* O. Pickard-Cambridge coll, Dried - drawer 46, Costa Rica (possibly syntype examined by FOPC); 2 ♀ *Megaphobema mesomelas* 2007 064, pet trade, Eddy Hijmensen; 1♀ *M. mesomelas* 2009 001, Costa Rica, Dutch Pet trade; 1 ♂ *M. mesomelas* 2009 001, Costa Rica, pet trade; 1 ♂ *M. mesomelas* 2008 072, Costa Rica, 01/12/97, w/c. **SJLC:** 1 ♀ *M. mesomelas* MES4, died 12.12.01 [see fig. 16].

M. peterklaasi **– OUMNH:** 1 ♀ *M. peterklaasi* 2008 072, pet trade, Ex A Mathews; 1♂ *M. peterklaasi* 2009 001, Costa Rica, Holland previously dried; 1 ♂ *M. peterklaasi* 2008 072, Costa Rica, 01/12/97, w/c Costa Rica. **SJLC:** 1 ♀ *Megaphobema peterklaasi* PEK2, died approx 2006, Ex Eddy Hijmensen.

M. robustum **– MCZ:** 1 ♂ *M. robustum* 74298 Colombia, Dept. Meta, Carimagua, 370m, 18 May 1973, Mary Corn, in cow pasture Savannah. **OUMNH:** 4 ♀ *M. robustum* 2008 072, Colombia, w/c 1997 [see fig. 15 for spermathecae of ROB3, 1 ♀ *M. robustum* O.P. Cambridge coll, Drawer 9; 1 ♀ *M. robustum*, Hope / Westwood coll, Drawer 23; 1♀ *M. robustum*, O.P. Cambridge coll, Drawer 46. **SJLC**: 1 ♂ *M. robustum*, Colombia, pet trade, died 2013 don. Craig Mackay; 1 ♀ *M. robustum* ROB5, died n.II.2014, Ex Stuart Longhorn; 1 Juv. *M. robustum* ROB5, died n.XI.2001, Ex Stuart Longhorn.

M. teceae **– OUMNH:** 1 ♂ *M. teceae* 2008 072, Brazil, Manaus, died 01/01/08 Ex Ken Matzen; 1 ♀*M. teceae*, 2009 001, Brazil, Manaus, died 01/01/09, Ex K. Matzen 2008.

M. velvetosoma **– OUMNH:** 1 ♂ *M. velvetosoma* VEL7, died 12.06.09, Ex Ray Gabriel; 1 ♀ *M. velvetosoma* 2008 072, W/c Ecuador (importer Erato Holland) 1997 w/c., 1 ♀ *M. velvetosoma*, VEL6, died 18.04.12 Ecuador, Ex John Chambers. **SJLC:** 1 ♀ *M. velvetosoma* VEL5, died 25.IX.15, Ex Stuart Longhorn; 1 imm *M. velvetosoma* VEL1, died 15.07.01, Ex WC import Paul Stevens, Tena, Ecuador.

Theraphosa **specimens:**

T. apophysis **– BMNH:** 5 ♀& 1 ♂ *T. apophysis* Venezuela, Roraima. Coll. Ian Wallace. 13.11.90, det. A.M. Smith. **OUMNH:** 3 ♂ *T. apophysis*, 2007 064, pet trade, c/b.

T. stirmi **– BMNH:** 1 ♀ *T. stirmi* [labelled *T. blondi*] 1939.3.24.42 British Guiana (=Guyana), New River (East Berbice-Corentyne). Jan-March 1938, Purch. C.A.Hudeson; 1 ♂ & 1 ♀ *T. stirmi* [labelled *T. blondi*] Carl Davis. No data; 1 ♂ *T. stirmi* [labelled *T. blondi*] British Guiana (=Guyana). 2°19’05.0”N 59°22’33.5”W (=Upper Takutu-Upper Essequibo, Region of Isherton, south Rupununi), G.McDonnell 1933; 1 ♀ *T. stirmi* [labelled *T. blondi*] Guyana, Cuyuni-Mazaruni, Upper Waruma. 11.8.1971. M.Lyes Coll. (=British Roraima Expedition), det as *T. blondi* by W.Bücherl; 1 ♀ *T. stirmi* [labelled *T. blondi*] Guyana, (Cuyuni-Mazaruni), Upper Mazaruni, wet trail after rain 3500 ft. British Roraima Expedition 27.8.1971. M.Lyes Coll. det as *T. blondi* by W.Bücherl; 1 juv. British

Roraima Expedition, M.Lyes coll. det. *T. blondi* by W.Bücherl; 1 ♀ *Theraphosa* cf. *strimi* [labelled *T. blondi*] Brazil, State of Amazonas, Environs of Yanomami village of Watoriki, close to (Rio) Demini, FUNAI post. 1°31'N 62°49'W. **OUMNH:** 1 ♂ Imm *T. stirmi* (accessioned as sp., Guyana) 2007 064, 10/03/09, Imported Lee Arden (Spidershop UK); 1 ♀ *T. stirmi* [sold as sp. burgundy] 2009 007, Guyana, 10/03/09, Imported Lee Arden (Spidershop UK); 1 ♀ Imm *T. stirmi* (as *Theraphosa* sp, Guyana) 2009 007, 10/03/09, Imported Lee Arden Spidershop UK; 1 ♀ Imm *T. stirmi* [sold as sp. burgundy], 2009 051, Guyana, Imported Lee Arden (Spidershop UK).

***T. blondi* – OUMNH:** 1 ♂ *T. blondi* 2009 007, pet trade, Guy Tansley; 1 ♀ *T. blondi* 2009 001, pet trade, c/b 1996 died 01/10/08 K Halsey; 1 ♀ *T. blondi,* Hope coll; 1 ♂ *T. blondi* O.P.Cambridge coll, Drawer 48; 1 ♂ Imm *T. blondi* 2007 064, pet trade, M Walters stuck in moult. **SJLC:** 1 ♀ *T. blondi,* died 2013. W/c French Guiana, ExJ.M. Verdez.

***T.* sp. (indet). – BMNH:** ♀ *Theraphosa* sp. indet. [labelled *T. leblondi*] 1968.2.27.10. British Guiana (=Guyana). Coll. J.W Lester; 1 ♀ *Theraphosa* indet. [labelled as *T. blondi*] Brazil, St. Paulo (?). S.Roburn. No further data; 1 ♂ *Theraphosa* indet. [labelled *T. blondi*] No further data.

Other specimens:

PMY: 1 Imm ♂ *Pamphobeteus*? sp. Guayaquil, Ecuador, Banana Distribution Company, New Haven, 30.iii.1951 [was misidentified by Petrunkevitch as *S. rubronitens*]; 1 ♀ *Phormictopus* sp, Yale-Fla. Haiti Exped. Feb., March, April 1959 P. S. Humphrey, [was misidentified by Petrunkevitch as *S. rubronitens*].

MNHN: 1 ♀ Theraphosinae indet, AR 4850 MNHN (Simon Collection), 'Panama and Guatemala' leg. unknown (same jar as holotype for *S. panamense*).

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RESEARCH ARTICLE

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Description of a new species of *Julolaelaps* (Acari, Mesostigmata, Laelapidae) from Iran

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Abstract

Julolaelaps hallidayi **sp. n.**, was collected from soil of river verge in Brujen, Chaharmahal va Bakhtiari province, Iran. Description and illustrations of this new species based on adult females are presented. Some entries are added to the key of Moraza and Kazemi (2012) to include the new species.

Keywords

Laelapidae, Taxonomy, *Julolaelaps*, Iran

Introduction

Evolutionary relationships between mites and other arthropods date back to approximately 100 million years ago (Southwood 1973). As more niches became available, mites developed a wide variety of well-known symbiotic relationships with many arthropods (Lindquist 1975) including many species in the insect orders Coleoptera, Diptera, Hymenoptera, and Lepidoptera, and also with other arthropods such as myriapods (Farfan and Klompen 2012). The laelapid subfamily Iphiopsidinae *sensu* Evans (1955) was promoted to family level (Iphiopsididae) by Casanueva (1993) based on phylogenetic studies. The main character differentiating this family and Laelapidae is the lack of seta *pl2* on genu IV in iphiopsidids (Casanueva 1993). The Iphiopsididae includes three subfamilies and ten genera of mites that are associated with millipedes, centipedes, spiders, and terrestrial crustaceans. There is little information on the biology of iphiopsidids, although based on the regressive nature of the characters it seems that they have a paraphagic or parasitic mode of life on their terrestrial arthropod hosts (Lindquist et al. 2009).

Julolaelaps was erected by Berlese (1916) for a small group of mites living on Julids. In the definition of the genus he states that the species resemble very closely those of the genus *Hypoaspis* but lack claws on all legs (Evans 1955). Vitzthum (1941) referred to *Hypoaspis* Canestrini, and *Julolaelaps* Berlese as members of the subfamily Hypoaspidinae and *Iphiopsis* Berlese and *Jacobsonia* Berlese as members of the Iphiopsinae. Evans (1955) noted the possible absence of claws in all legs of *Julolaelaps* (present in most *Hypoaspis*) as a generic character. Ryke (1959) introduced *Julolaelaps* as a subgenus of *Hypoaspis*, and described three new species while referring to the presence of small claws on leg I ambulacra. Maes (1983) described four additional species of *Julolaelaps*, as a separate genus, and confirmed the presence of reduced claws on leg I.

Most *Julolaelaps* species that have been reported until now are associated with small millipedes (Berlese 1916, Maes 1983, Fain 1987, Uppstrom and Klompen 2005, Kontschan 2005, Salmane and Telnov 2007, Moraza and Kazemi 2012), and a few associated with Polydesmida (Ishikawa 1986). The feeding habitats (parasitism or paraphagy) of *Julolaelaps* are not confirmed (Salmane and Telnov 2007). Moraza and Kazemi (2012) presented a key for this genus based on known females and males, agreed the idea of Ryke (1959) to consider *Laelaps* (*Hypoaspis*) *indicus* Vitzthum as a synonym of *J. luctator* Berlese, 1916. The present paper is devoted to the description of a new species of *Julolaelaps*, found in the soil of a river verge in Brujen, Chaharmahal va Bakhtiari province, Iran, followed by a short discussion regarding the status of correct family for this genus.

Materials and methods

Mites were collected in soil from Brujen, Chaharmahal va Bakhtiari province in Iran, extracted from samples using Berlese-Tullgren funnels, placed in lactic acid at 55 °C for clearing and then mounted in Hoyer's medium on permanent microslides for microscopic examination. Line drawings were made by use of a drawing tube and figures were performed with Corel X-draw software, based on the scanned line drawings. Measurements of structures are expressed as minimum-maximum ranges in micrometers (µm). The dorsal setae notation followed that of Lindquist and Evans (1965). Leg and pedipalp setal notation and chaetotactic formulae are based on Evans (1963a, b respectively). Terminology for idiosomal glands and lyrifissures follows Johnston and Moraza (1991). We have attempted to identify all pore-like structures, but acknowledge that some might have been overlooked. Length of the dorsal shield is the distance from its antero-median edge anterior to bases of setae *j1* to its postero-median edge posterior to bases of setae *Z5*; width of dorsal shield was measured at widest part; length of the sternal shield was measured along midline from anterior edge to its posterior margin, width measured between coxae II-III (widest point) and slightly above the insertion of *st2* (narrowest point); the length of anal shield is midline from the anterior margin to the posterior edge of the cribrum, and width was measured at widest point. Setae were measured at level of insertions to their tips and distance between setae as the distance between their insertions. Length of leg segments was measured dorso-medially, and tarsi were measured excluding the stalk and its appendages.

Description

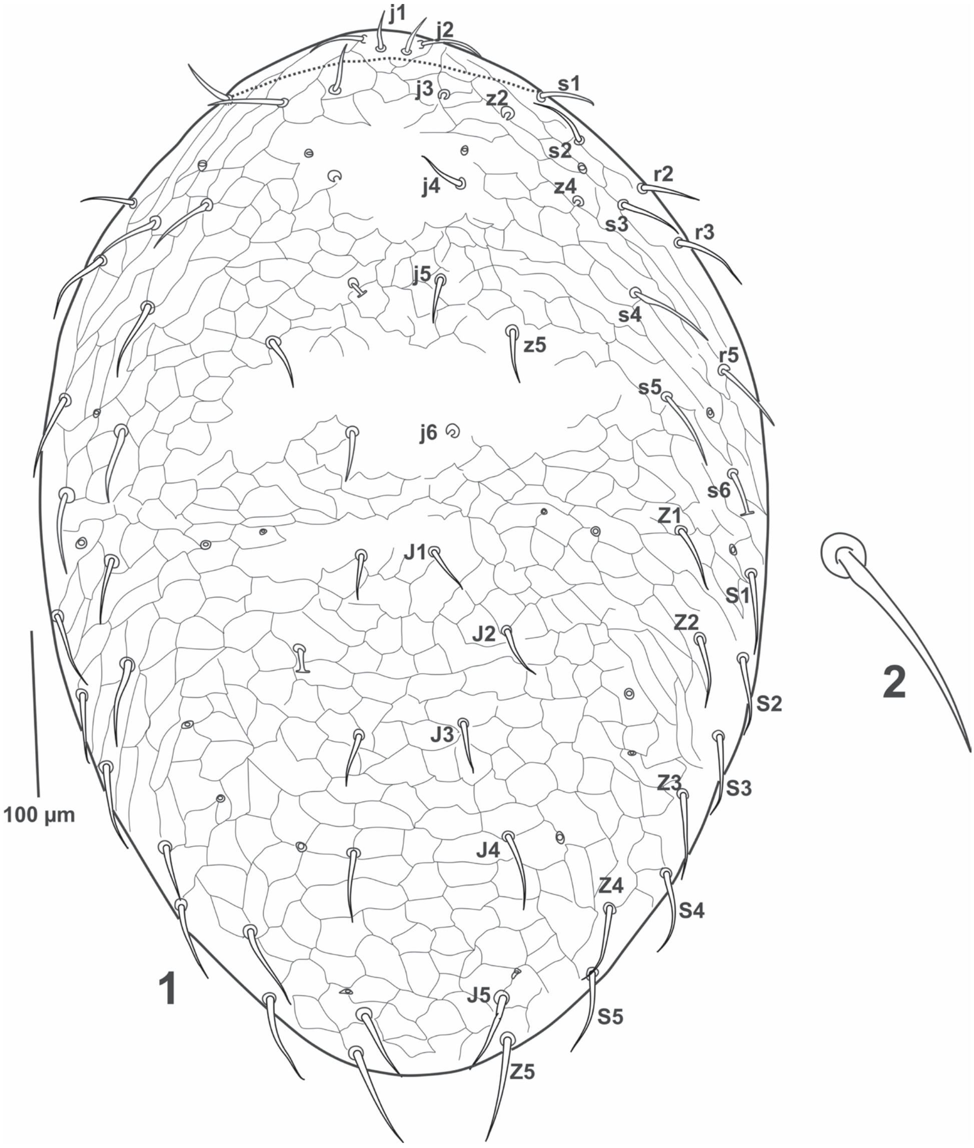
***Julolaelaps hallidayi* sp. n.**
http://zoobank.org/98513061-C2DA-41B3-80DF-E0A373F2053A
Figures 1–13

Specimens examined. Holotype, female, Brujen region, Chaharmahal va Bakhtiari province, Iran, soil, coll., B. Jalili, 2011; paratype, female (same data as holotype): deposited in Acarological Laboratory of Shahrekord University, Chaharmahal va Bakhtiari province, Iran; paratype, female collected from soil, Shahreza, Esfahan province, coll., F. Shameli, 2014: deposited in the Senckenberg Museum fur Naturkunde Görlitz, Germany.

Note. Some unknown arthropods species such as members of Thysanura, Microcoryphia, Diplopoda and Chilopoda were separated associated with the soil which contained specimens of *Julolaelaps* species.

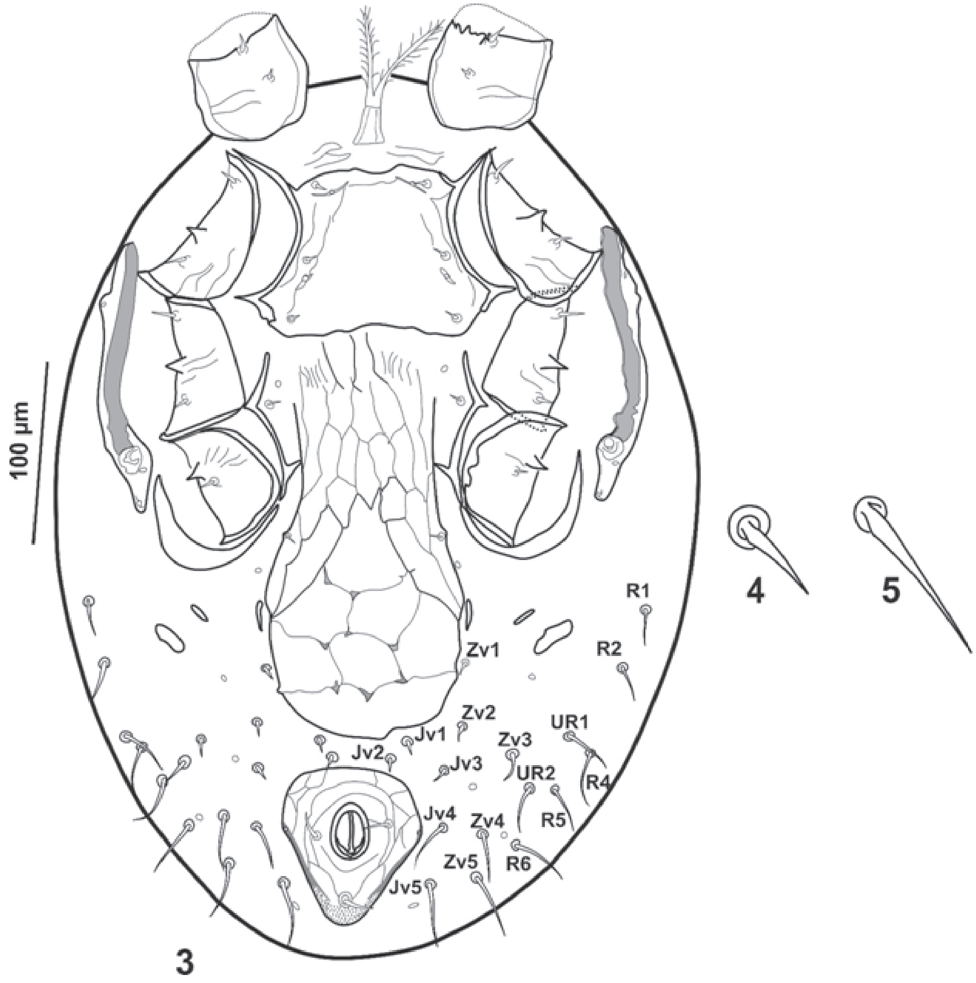
Diagnosis. Medium sized laelapid mite; with 33 pairs of simple acicular setae on dorsal shield, setae *z1, z3, z6, r4,* and *r6* missing in podonotal part, without extra setae between *J* and *Z* series; pre-sternal area not sclerotized; genital shield with reticulated pattern possess seven closed cells with eight small indentations at their margins, cells surrounded antero-laterally by inverse V shaped lines; peritremes short, extending to posterior margin of coxae II; tibia I and III with two *pl* and one *al* respectively.

Dorsal idiosoma. Dorsal idiosoma oval-shaped (Fig. 1), dorsal shield covered all dorsal surface, polygonal reticulation distinct on whole dorsum except of small area around *j4* and area between *z5* and *j6*. Dorsal shield 489-567 long, 341-348 wide between of setae *r3-5* (n = 3), with 33 pairs of simple acicular setae (Fig. 2), 18 pairs (*j1-6, z2, z4-5, s1-6* and *r2-3, r5*) located on podonotum, *z1, z3, z6, r4,* and *r6* missing on dorsal shield in podonotal part, and 15 pairs on opisthonotum (*J1-5*, *Z1-5* and *S1-5*) without extra setae between *J* and *Z* series. Dorsal setae length: *j1* (16-18), *j2-6* (20-31), *z2* and *z4* (34-39), *z5* (26), *s1-6* (29-39), *r2-3, r5* (29-36), *J1-5* (20-34), *Z1-5* (29- 42), *S1-5* (34-39). Cuticle between dorsal and ventral side of body bent down on ventral side, and bearing *R1* (18-21), *R2* (21-23), *R4* (23-29), *R5* (23-26), *R6* (26-29), and *UR1-2* (23-26). Podonotal part with three and opisthonotal region with seven pairs of discernible pore-like structures, as shown in figure 1; however, it is acknowledged that some might have been overlooked.



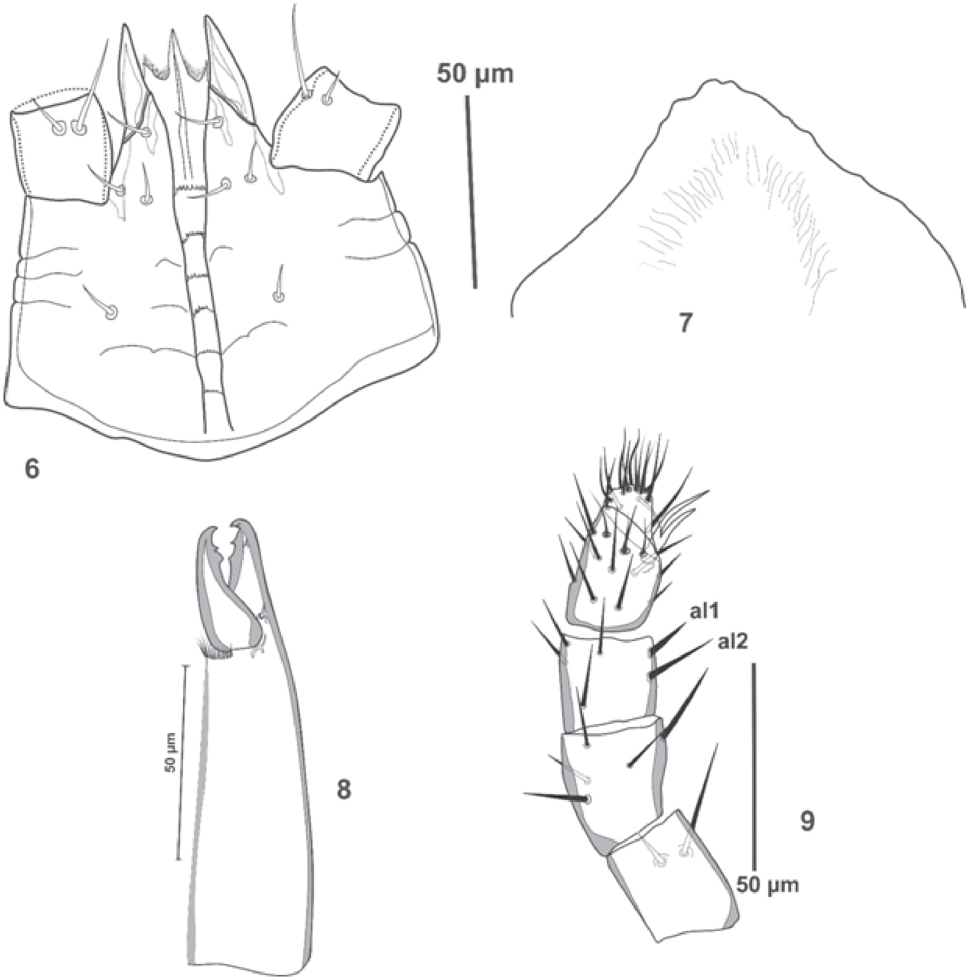
Figures 1–2. *Julolaelaps hallidayi* sp. n. (female): **1** Dorsal idiosoma **2** Example of dorsal setae.

Ventral idiosoma (Fig. 3). Tritosternum with columnar base, 18–21 long, and pilose laciniae (62). Pre-sternal area not sclerotized, with lines striation. Sternal shield with thin line reticulation in lateral surfaces, 96–99 long, 148–151 wide (at level of projection between coxae II-III) and 99 slightly above the insertion of *st2* (narrowest point), antero-medially slightly concave, posterior margin irregular. Sternal setae very short, *st1-3* (4), smooth, with conspicuous alveoli, *iv1* slit-like, located slightly behind *st1*, *iv2* slit-like, between *st2-st3*. Metasternal plates absent. Setae *st4* (5) and pore-like



Figures 3–5. *Julolaelaps hallidayi* sp. n. (female): **3** Ventral idiosoma **4–5** Examples of ventral setae.

iv3 located on integument posterior to sternal shield and interior to endopodal plates III/IV. Tongue-shaped genital shield 205–211 µm long (excluding hyaline flap at base of posterior margin of sternal shield), 83-88 wide at level of *st5*, and 101 at widest part near para-genital platelets, the ratio of length to width (L/W) is 2.32 /2.53 (width at level of *st5*), bearing one pair of setae (*st5* = 4-5) and reticulated pattern with seven closed cells with eight small indentations at their margins, cells surrounded antero-laterally by inverse V shaped lines (Fig. 3), genital shield separated from anal shield by about the length of the anal opening, paragenital pore-like opening on soft integument between genital seta and coxa IV. Subtriangular anal shield reticulated, anterior margin semi-circular, 78–83 long, and 73–75 wide, with one pair of minute adanal gland pores (*gv3*) on lateral margins, paranal setae (10) slightly smaller than post-anal seta (13). Cribrum extending laterally slightly upper than the level of post-anal seta



Figures 6–9. *Julolaelaps hallidayi* sp. n. (female): **6** Subcapitulum **7** Epistome **8** Chelicera **9** Palp.

insertion. Opisthogastric surface with one pair of suboval metapodal plates, one pairs of minute platelets (between metapodal plate and para-genital platelet), one pair of narrow, slightly elongate para-genital platelets, smooth setae *Jv1-3* (6-8), *Jv4* (18-23), *Jv5* (26), *Zv1* (5-7), *Zv2* (8-10), *Zv3* (13-16), *Zv4* (23-26), *Zv5* (26-29), (Figs. 4-5), and five pairs of pore-like structures. Stigmata located in anterior level of coxa IV surrounded by nearly narrow stigmatal plate. Peritremes short, extending to posterior margin of coxae II, peritrematal plate wider in anterior part, and with one glandular poroid *gp* (Fig. 3), separated from exopodal shield. Small poststigmatal plate with two pores. Exopodal plates like a narrow crescent-shape strip expanded posteriad coxae IV. Endopodal plates II/III fused to lateral margins of sternal shield, and III-IV elongate, narrow and angular.

Gnathosoma. Hypostome (Fig. 6) with three pairs of smooth simple setae; *h1-3* (8-10), palpcoxal setae 8-9 long. Deutosternal groove with six rows of multi-dentate (6-8 teeth), the denticles tend to be smaller from anterior to posterior rows. Corniculi normal (30-32), horn-like. Epistome with nearly smooth rounded anterior margin (Fig. 7). Cheliceral arthrodial processes crownet-like (Fig. 8), movable digit (26-29) with two teeth in addition to apical tooth, middle article 75-78 long, ending in fixed digit (29-31), bearing two teeth in addition to terminal tooth and very short setaceous pilus dentilis. Palp chaetotaxy normal for the free-living forms (sensu Evans and Till 1965), with simple and thin setae except *al* on femur, and *al1* and *al2* on genu slightly thickened; palp-tarsal claw two-tined, basal tine smaller (Fig. 9).

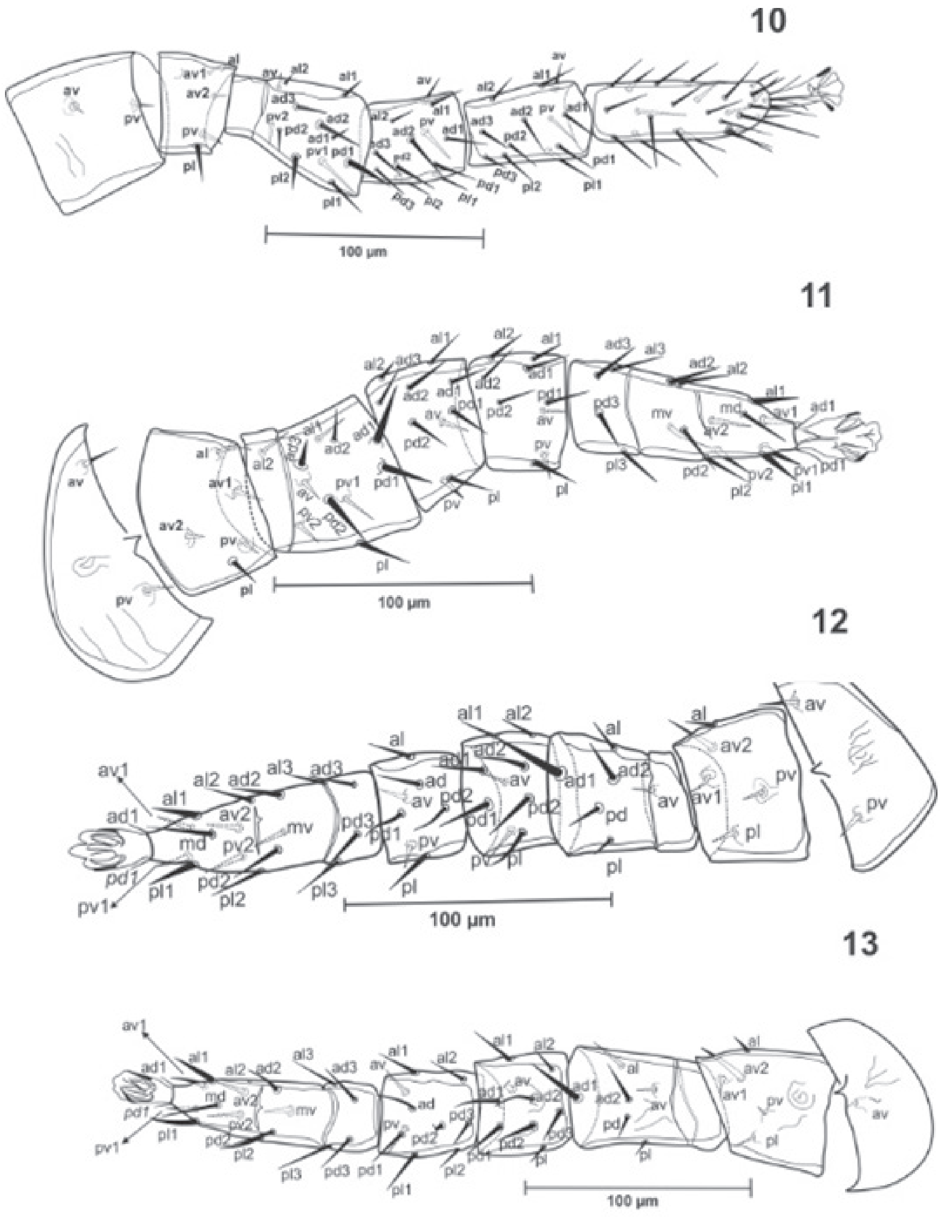
Legs. Tarsi I-IV with small and not well sclerotized claws, the sclerotization status is more distinct in their tips (Figs. 10-13). **Leg I** 374, coxa (70-73), trochanter (29-34), basi-femur (18-21), telo-femur (42), genu (42-47), tibia (55-60), tarsus (107-112); **leg II** 278-302 coxa (34-47), trochanter (31-39), basi-femur (16), telo-femur (34-39), genu (36-44), tibia (39), tarsus (75-91); **leg III** 307, coxa (36-39), trochanter (52), basi-femur (23), telo-femur (34), genu (31-36), tibia (34-36), tarsus (91); **leg IV** 359-385, coxa (39-47), trochanter (65-70), basi-femur (18-23), telo-femur (47-52), genu (39), tibia (44), tarsus (107-109). Legs I and IV longer than legs II and III. All leg setae smooth and pointed. Chaetotaxy of legs is as follows: **Leg I**: coxa 0 0/1 0/1 0; trochanter 1 0/2 1/1 1 (*pl* and *pv* slightly thickened); femur 2 3/12/2 2 (*ad2*, *pd1* and *pl2* slightly thickened); genu 2 3/1 3/1 2; tibia 2 3/1 3/1 2 (Fig. 10). **Leg II**: coxa 0 0/1 0/1 0; trochanter 1 0/2 0/1 1; femur 2 3/1 2/2 1 (*ad1*, *ad3*, *pd1-2* and *pl* slightly thickened); genu 2 3/1 2/1 1; tibia 2 2/1 2/1 1; tarsus 3,3/2,3/2,3 + *mv*, *md* (*al1*, *av1-2*, *pl1* and *pv1*-2 more thickened than the others) (Fig. 11). **Leg III**: coxa 0 0/1 0/1 0; trochanter 1 0/2 0/1 1; femur 1 2/1 1/0 1(*ad1* thickened and *ad2* slightly thickened); genu 2 2/1 2/1 1; tibia 1 1/1 2/1 1; tarsus 3 3/2 3/2 3 + *mv*, *md* (*al1*, *pv1* and *pl1* thickened). **Leg IV**: coxa 0 0/1 0/0 0; trochanter 1 0/2 0/1 1 (*av2* slightly thickened); femur 1 2/1 1/0 1 (*ad1* slightly thickened) (Fig. 13); genu 2 2/1 3/0 1; tibia 2 1/1 3/1 2; tarsus 33/23/23 + *mv*, *md* (*al1* and *pl1* slightly thickened).

Insemination structures. Not discernible.

Male. Unknown.

Etymology. This species is named in honour of Dr. Bruce Halliday (CSIRO Ecosystem Sciences, Canberra, Australia).

Remarks. The species of the genus *Julolaelaps* having been reported so far can be divided into two groups: the first group consisting of 14 species with reduced number of setae on dorsal shield than *J. hallidayi* sp. n. (9–23 pairs), and the other with more than 29 pairs of dorsal setae (*sensu* Moraza and Kazemi 2012), which comprises seven species including *J. luctator* Berlese, 1916, *J. dispar* Berlese, 1916, *J. pararotundatus* Ryke, 1959, *J. spirostrepti* Oudemans, 1914, *J. tritosternalis* Moraza and Kazemi 2012, *J. moseri* Hunter & Rosario, 1986, and *J. hallidayi* sp. n. Except for *J. tritosternalis*, the number of dorsal setae in the above-mentioned species is higher than in *J. hallidayi* sp. n. The two latter species are different from each other in that the former has 32 pairs of dorsal setae, while the latter has 33 pairs. Furthermore, the main discrepancy between them refers to the presence of *S1* in *J. hallidayi* sp. n., and absence of these structures



Figures 10–13. *Julolaelaps hallidayi* sp. n. (female): **10** Leg I **11** Leg II **12** Leg III **13** Leg IV.

in *J. tritosternalis*. In addition, *J. tritosternalis* has a disc-like structure on the base of tritosternum, while that structure is not present in *J. hallidayi* sp. n. Leg chaetotaxy of *J. hallidayi* sp. n., is different from that of *J. tritosternalis* Moraza & Kazemi, 2012: tibia I and III in *J. hallidayi* sp. n. bears two *pl* and one *al* while in *J. tritosternalis* tibia I and III are with one *pl* and two *al*.

Discussion

The loss of seta *pl2* on genu IV in iphiopsidids phylogenetically defines the family as an entity separate from the Laelapidae (Casanueva 1993), but its laelapid roots may clearly be seen in the genus *Julolaelaps*, an assemblage of iphiopsidine millipede associates that had long been considered a subgenus of the broadly defined laelapid genus *Hypoaspis* (Lindquist et al. 2009, Ryke 1959).

Based on Casanueva (1993) study, Iphiopsididae was recognized as a separate family from Laelapidae by considering two phylogenetic attributes: lack of seta *av-2* on tibia I in the Iphiopsididae, and lack of seta *pl-2* on genu IV in the Laelapidae. Assigning the new species to the family Iphiopsididae does not fit properly based on the above-mentioned attributes. In the first instance, *J. hallidayi* sp. n. is defined by one apomorphic character (lack of postero-lateral seta *pl2* on genu II), which has also evolved in group I (Pseudoparasitini) of the Laelapidae. Furthermore, *J. hallidayi* sp. n. presents one synapomorphic character, which is a regressive autapomorphy, supporting groups I and II of the Laelapidae: lack of setae *pv1* on genu IV. In addition, two synapomorphic characters of *J. hallidayi* sp. n., the loss of setae *pl2* on genu IV and the absence of podonotal setae *r6*, are shared with groups I-II and IV of Laelapidae, respectively. Finally *J. hallidayi* sp. n., along with some other species of the genus *Julolaelaps,* emerges from the subfamily Iphiopsidinae Kramer (Casanueva 1993) by lacking two synapomorphic characters: a reduced hypostomal process and the presence of additional setae (*px*) between *J* and *Z* series, as well as two apomorphic characters (loss of hypostomal setae *h1* or *h3* on the gnathosoma and absent peritreme).

On the other hand, Lindquist et al. (2009) accepted the idea of Casanueva (1993) to consider iphiopsidids as members of a separate family from laelapid mites by referring to some characters: tibia I usually with one ventral seta, lacking seta *av2*; genu IV usually with one postero-lateral seta, lacking seta *p12*; subcapitulum with internal malae usually weakly developed, with nearly smooth lateral margins and shorter than corniculi, which is discussed below. However species of laelapid mites usually possess setae *av2* on tibia I (Beaulieu 2009, Faraji and Halliday 2009, Evans and Till 1965, 1966, Kavianpour et al. 2013, Lindquist et al. 2009, Nemati and Kavianpour 2013, Nemati and Mohseni 2013), but Moraza and Kazemi (2012) considered different groups in *Julolaelaps* species assemblage. Within species with edentate chelicerae in males, one group includes species with largely complete dorsal complement of setae and usually with strong neotrichy in dorsal setae on soft cuticle, a well-developed genital shield, wider than anal shield (except *J. luctator*), usually long peritremes (extending at least to anterior margin of coxa II), and seta *av-2* present in tibia I. So, some species of *Julolaelaps* possess seta *av2* on tibia I and this character cannot be considered as an apomorphic feature for iphiopsidids. Furthermore, loss of seta *pl2* on genua IV is a character for laelapid mites and iphiopsidids mites also exhibit this character (Beaulieu 2009, Faraji and Halliday 2009, Kavianpour et al. 2013, Moraza et al. 2009, Nemati and Kavianpour 2013, Nemati and Mohseni 2013, see also above explanations). In addition, Moraza and Kazemi (2012) described *J. tritosternalis* with subcapitular internal malae well developed, with lateral margins fimbriated and longer than corniculi.

In this research we are following Maes (1983) and Moraza and Kazemi (2012) in keeping the *Julolaelaps* as a separate genus of the family Laelapidae Berlese, 1882, subfamily Iphiopsidinae Kramer, 1886.

This research has posed questions which are in need of further investigation, and considerably more work is needed to determine the level of Iphiopsididae or Iphiopsidinae as well as the name of genera that will be categorized within that level.

Modified key couplet to the species of *Julolaelaps* (after Moraza and Kazemi 2012), with emendations to add *J. hallidayi* sp. n.

6 Dorsal shield with 36 pairs of setae; setae *z1*, *z6* and *S1* present; setae *Z5* twice as long as *j1*; strong neotrichia on series *R*.......... ***J. moseri* Hunter & Rosario**

– Dorsal shield with 32-33 pairs of setae; setae z1, z6, r4, r6 absent and *S1* present or absent... 7

7 With 32 pairs of dorsal shield setae; *S1* absent; tritosternal base with ventral disc-like structure.................................. ***J. tritosternalis* Moraza & Kazemi**

– With 33 pairs of dorsal shield setae; *S1* present; tritosternal base normal and lacks ventral disc-like structure.. ***J. hallidayi* sp. n.**

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Two new species of *Xestoblatta* Hebard, 1916 from Brazil, a redescription of *Xestoblatta roppai* Rocha e Silva Albuquerque & Fraga, 1975 and a key for the species of the *buscki* group (Blattodea, Ectobiidae, Blattellinae)

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Abstract

Two new species of *Xestoblatta* from northern Brazil are described, *Xestoblatta buhrnheimi* **sp. n.** and *Xestoblatta rondonensis* **sp. n.**, included in the *buscki* group Gurney (1939), and new characters are added to the description of *X. mamorensis* Lopes & Oliveira, 2006. *Xestoblatta roppai* Rocha e Albuquerque-Silva & Fraga, 1975, from midwestern Brazil is redescribed, including its genital characters which were not previously described. Additionally, a key for the species of this group is provided, and photographs are given of the species in the habitus, of tergal modifications, and of the genitalia.

Keywords

Key, morphology, new species, taxonomy, *Xestoblatta*

Introduction

Xestoblatta was described by Hebard (1916) with *Xestoblatta carrikeri* designated as the type species. He placed the new genus in the *Ischnopteroides* (with *Symploce* Hebard, 1916, *Ischnoptera* Burmeister, 1838, and *Pseudomops* Serville, 1831). *Xestoblatta* is characterized by morphological characters of the head, the pronotum being ample and without sulci, a widened body, a pale yellow marginal field of the tegmen, and with a neotropical geographical distribution but absent in the West Indies (Hebard 1916). The etymological origin for the generic name *Xestoblatta* is Greek for "polished roach" (Hebard 1916).

Gurney (1939) noted that *Xestoblatta* included a very diverse group of cockroaches and that the 7th abdominal tergites differ in shape among the species. He described eight new species and the males of two species that had been previously described, stressing that male genitalia characters and tergal modifications are important for the generic diagnosis. Additionally, Gurney (1939) described the biology of the species of the genus, documented their geographical distributions, and provided a key to distinguish them. Based on characters such as coloration, number of rami in the ulnar vein, male subgenital plate, paraproct, and male tergal modifications, Gurney split *Xestoblatta* into eight groups based on the shape of the subgenital plate and tergal modifications (Gurney, 1939). One group he described was the *buscki* group, which included *X. festae* (Griffini, 1896), *X. ramona* Gurney (1939), and *X. braziliae* Gurney (1939).

Bruijning (1959) later compiled a key to separate *Xestoblatta*. He distinguished *Xestoblatta* from *Ischnoptera* based on the convex pronotal disk without sulci, tegmina and wings completely developed, and wings widened between discoidal field and anterior surface, with apical triangle wide. He also described a new species (*X. surinamensis* Bruijning, 1959) from Suriname.

Rocha e Silva-Albuquerque (1962) described a new species named *X. bananae* Rocha e Silva Albuquerque (1962), from Ecuador.

Rocha e Silva-Albuquerque and Fraga (1975) described two new species (*X. roppai* and *X. vera*) from Brazil.

Grandcolas (1992) noted that species of *Xestoblatta*, found in the litter of neotropical forests, are nocturnal. He also made the observation that the tree hole-dwelling *X. cavicola* Grandcolas, 1992 and *X. immaculata* Hebard, 1920 are atypical in their gregarious, rather than solitary, behavior. Grandcolas (1992) also characterized *Xestoblatta* by its morphological homogeneity, being monophyletic, and supported the idea that the genital characters and the styles of the subgenital plate (very diversified) form a basis to recognize the various groups within *Xestoblatta.*

Lopes and Oliveira (2007), Pellens and Grandcolas (2008), and Lopes et al. (2012) included *Xestoblatta* in the subfamily Blattellinae based on genital characteristics (i.e. phallomere of the male genitalia being hooked and located on the left side in dorsal view).

Bell et al. (2007) stressed that species of *Xestoblatta*, similarly to other members of Blattaria, are important in the recycling of organic matter.

Lopes and Silva-da-Silva (2014) placed *X. iani* Rocha e Silva-Albuquerque, 1964 in *Dendroblatta* Rehn, 1916, in view of the morphology of the pronotum, leg spines, and the configuration of the tergal process of the abdomen and the internal genital plates. These characters supported their placement of the species in Pseudophyllodromiinae based on the position of the hooked structure of the male genitalia.

Evangelista et al. (2015) listed the species of cockroaches known from the Guiana Shield, based on literature records and field collection, which included a new species, *Xestoblatta berenbaumae*.

Xestoblatta includes 43 species, all of which are neotropical (Lopes et al. 2012; Beccaloni 2015; Evangelista et al. 2015). They occur in the United States, south to Bolivia and southern Brazil. In Brazil the genus is represented by 17 species.

In this paper we provide additional characters to define the *buscki* group (Gurney, 1939), provide a key for the species of this group, and describe two new species from the states of Amazonas and Rondônia. Two previously described species are also newly included in the group and are redescribed, including new information on their genital structures (*X. roppai* Rocha e Silva Albuquerque & Fraga, 1975) and paraprocts (*X. mamorensis* Lopes & Oliveira, 2006).

Material and methods

The genital plates were removed after dissection of the posterior part of the abdomen, using traditional dissection techniques, for examination (Lopes and Oliveira 2000) (*X. roppai* and *X. mamorensis* had been previously dissected and the genitalia were mounted on a slide). After study, the genitalia of all species were stored in glycerin in micro-vials and attached to the respective sample, follow Gurney et al. (1964). The terminology for the genitalia and the taxonomic classification follows Roth (2003). The specimens were compared with other specimens of *Xestoblatta* deposited in the Blattaria Collection of the Museu Nacional of the Federal University of Rio de Janeiro (MNRJ). The types of *X. roppai* and *X. mamorensis* deposited in the Blattaria collection of the Museu Nacional/UFRJ, were examined and compared with descriptions in the literature. Digital images of the habitus, pronotum, head and genitalia were taken with a camera mounted on a stereoscopic microscope. The descriptive terminology follows Beier (1970). The holotypes of *Xestoblatta buhrnheimi* sp. n. and *Xestoblatta rondonensis* sp. n. are deposited in the collection of the Department of Entomology at the Museu Nacional of Rio de Janeiro (MNRJ).

Results

Blattodea Brunner, 1865
Ectobiidae Brunner von Wattenwyl, 1865
Blattellinae Karny, 1908

Xestoblatta Hebard, 1916 *buscki* group

Diagnosis. The males of the species in this group have the subgenital plate trapezoidal in shape, regular or irregular, with accessory styles on both sides of the plate; tergal modification in the 7th tergite; left paraprocts on the supra-anal plate developed and hooked, reaching beyond half the length of supra-anal plate, with or without setae.

Species included: *Xestoblatta buhrnheimi* sp. n.; *Xestoblatta rondonensis* sp. n.; *Xestoblatta mamorensis* Lopes & Oliveira, 2006; *Xestoblatta roppai* Rocha e Silva & Fraga, 1975 (transferred from *castanea* group to *buscki* group in this paper).

Remarks. Rocha e Silva Albuquerque and Fraga (1975) placed *Xestoblatta roppai* in the *castanea* group and considered its general aspect similar to *X. para* Hebard, 1926 and *X. nyctiboroides* (Rehn, 1906). Based on analysis of the holotype and its genitalia, which had not been described in the original description, we have concluded that it should be included in the *buscki* group, in view of the morphological similarities such as in the subgenital plate, styles, and left phallomere.

Key for the identification of males of species in the *buscki* group of *Xestoblatta*

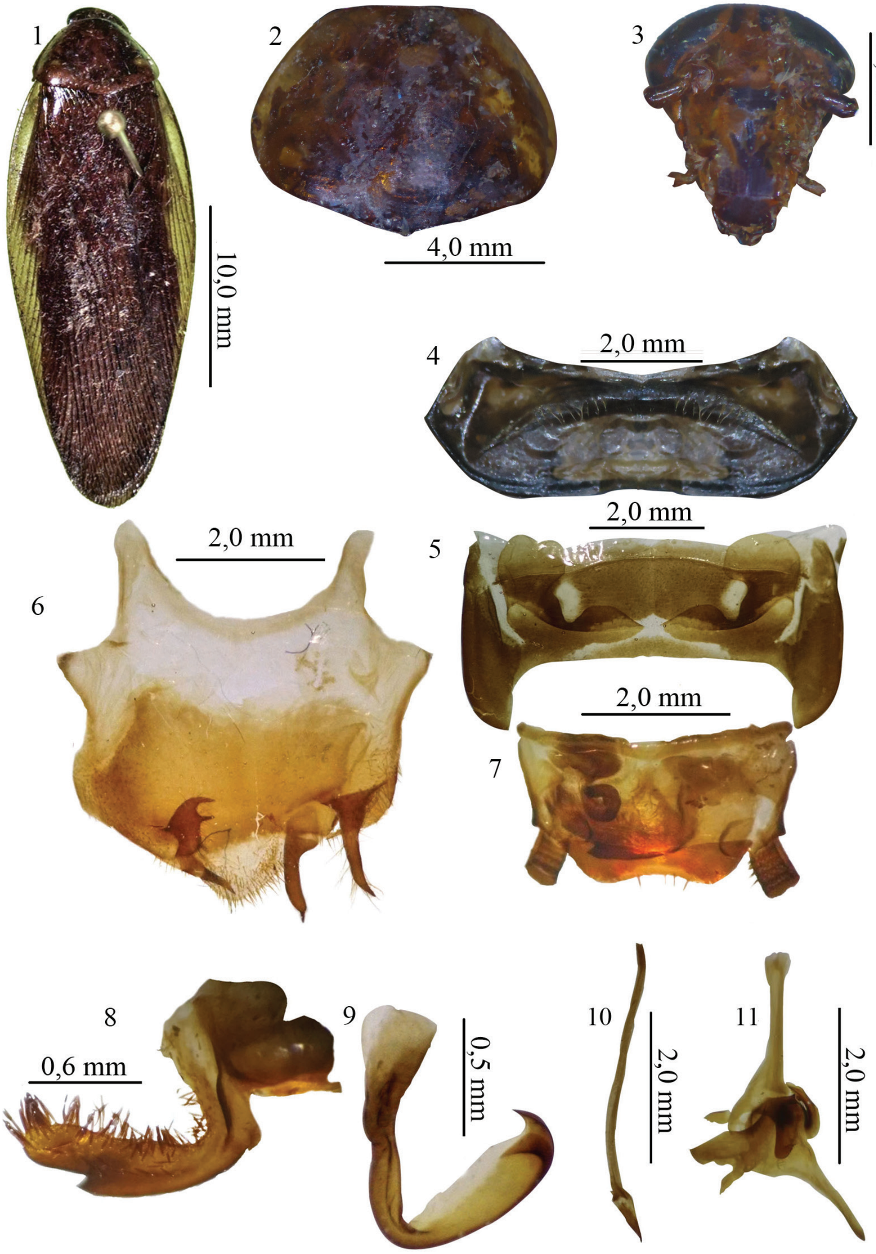
1 Paraproct bifid, without setae or with only a few sclerotized setae; one apex slender, the other convex **2**
– Paraproct bifid or not, with sclerotized setae resembling spines **3**
2 Left style slender, simple, with bifid accessory style; Body mostly brown .... ***X. mamorensis* Lopes & Oliveira, 2006**
– Left style slender, bifid, with accessory style simple; Body mostly dark brown .... ***X. rondonensis* sp. n.**
3 Right style trapezoidal, with below 6 spiniform projections **4**
– Right style trapezoidal, with 6 spiny projections .... ***X. roppai* Rocha e Silva Albuquerque & Fraga, 1975**
4 Right style with two small lateral projections, with spiny apex .... ***X. buscki* Gurney, 1939**
– Right style with three larger projections, two next to one another. All with spiny apex .... ***X. buhrnheimi* sp. n.**

Xestoblatta buhrnheimi sp. n.

http://zoobank.org/C3B1EE44-7AE8-4605-AEE3-7119CD3739DE
Figs 1–11

Type material. Holotype ♂. BRAZIL, Amazonas, Coari, Rio Urucu, ROC 27’ - 4°49'34"S/ 065°15'37"W, 05–18/03/1994. P.F. Bührnheim et. cols. (Shannon trap), in MNRJ.

Diagnosis. This species is characterized by having supra-anal plate with lower margin with two small medio-lateral protuberances; left paraproct slender, weakly sclerotized, folded on itself; right paraproct hooked, strongly sclerotized, round apically, reaching beyond half of plate and covered with spines ventrally; genitalia with left phallomere hooked, concave, sclerotized, slender apically;. median sclerite long, slender, with lanceolate tip (Fig. 10). Right phallomere triangular medially, weakly sclerotized and bearing convex sclerotized structure apically.



Figures 1–11. 1 Habitus, dorsal view, of the species *Xestoblatta buhrnheimi* sp. n. holotype male (MNRJ) **2** Pronotum, dorsal view, holotype male (MNRJ) **3** Head, ventral view, holotype male (MNRJ) **4** Tergal modification of the tergite I, dorsal view, holotype male (MNRJ) **5** Tergal modification of the tergite VII, dorsal view, holotype male (MNRJ) **6** Subgenital plate, ventral view, holotype male (MNRJ) **7** Supra anal plate, dorsal view, holotype male (MNRJ) **8** left paraproct, dorsal view, holotype male (MNRJ) **9** left phallomere, dorsal view, holotype male (MNRJ) **10** median sclerite, dorsal view, holotype male (MNRJ) **11** right phallomere, dorsal view, holotype male (MNRJ).

Description. Holotype. Male dimensions (mm): total length: 28. length of pronotum: 5.3; width of pronotum 7.4; length of tegmen: 24.1; width of tegmen 6.1. General coloration brown (Fig. 1). Pronotum light brown, shiny, with small irregular marks (Fig. 2). Head with vertex yellowish; palp light brown; antenna with apical segments dark brown (Fig. 3). Legs yellowish brown with dark brown spines. Pulvilli milky yellow. Arolia brown. Tegmen with anal field dark brown, lateral flap yellowish brown. Abdomen dark brown with white marks on medial area of first tergites. Supra-anal plate and subgenital plate yellowish brown.

Head. Triangular; interocular space narrow, occupying more than half the space between antennal insertions; vertex completely exposed. Ocelli small and little differentiated. Antennae long, slender, reaching beyond tip of abdomen; last segment of maxillary palp setose, 5th segment subequal to 4th segment.

Thorax. Pronotum convex and subtrapezoidal, apex straight, base slightly angular with lateral flaps slightly deflexed and margins round, widest at mid-caudal region. Disk of pronotum without sulci. Fore femur on anteroventral surface with 12 spines decreasing in size and two apical spines; mid femur on anteroventral surface with five spines decreasing in size and three spines increasing in distally; geniculate spine present; posteroventral surface with four subequal spines. Hind femur on anteroventral surface with seven subequal spines, plus one apical spine and one geniculated spine. Mid and hind coxae with latero-apical projections on inner surface. Arolia present. Claws symmetrical and without specialization. Tegmen developed, reaching beyond apex of abdomen, wider in anterior 1/3; marginal field well marked and slightly concave; scapular field slightly widened and round; discoidal field ample, anal field wide, with 8 axillary veins. Wings developed; ulnar vein with five incomplete rami and seven complete rami; apical triangle not developed; anal field folded as a fan.

Abdomen. Tergite I bearing median concavity with a series of marginal setae (Fig. 4). Tergite VII with two sulci on lateral margins, which are hidden by expansion of tergite VI (Fig. 5). Subgenital plate widened, with lower border setose, apex “V”shaped; left style small, wide, sclerotized with 2-3 apical spines; right accessory style similar to right style, and inserted next to it; left style small, wide, sclerotized, with 2-3 apical spines; left accessory style slender, shorter than other styles (Fig. 6). Supra-anal plate with lower margin with two small medio-lateral protuberances (Fig. 7). Left paraproct slender, weakly sclerotized, folded on itself; right paraproct hooked, strongly sclerotized, round apically, reaching beyond half of plate and covered with spines ventrally (Fig. 8). Genitalia with left phallomere hooked, concave, sclerotized, slender apically (Fig. 9). Median sclerite long, slender, with lanceolate tip (Fig. 10). Right phallomere triangular medially, weakly sclerotized and bearing convex sclerotized structure apically (Fig. 11).

Remarks. This species is close to *X. roppai* in size, in the paraproct covered with spines ventrally, and modifications of tergite VII. It differs in the shape of the subgenital plate and the paraproct is longer and more slender than in *X. roppai* (Figs 39 and 41).

Etymology. The species was named in honor of Frederico Bührnheim, collectors of the specimens.

Known geographical distribution. Brazil (AM)

***Xestoblatta rondonensis* sp. n.**

http://zoobank.org/B724266D-065E-4926-801B-3F073D1BD5CF
Figs 12–22

Type material. Holotype ♂, Brazil, Rondônia, Parque Estadual Guajará-Mirim, 26/01/1998, M.C. Araújo, Robson, Laurivite & João Raimundo leg. Atrás do acampamento. Paratypes: 1 ♂ and 2 ♀, same data as the holotype, and 3 ♀, Reserva Mamoré, trilha atrás do acampamento (trail behind campsite) MNRJ.

Diagnosis This species is characterized by having subgenital plate with margin ciliated, styles inserted laterally and spiny projection below left style. Right style rectangular with seven small sclerotized spines, inserted on lateral surface of style; left style short, not extending to 1/5 of subgenital plate, bifid, claw-shaped; accessory style present, curved, pointed, smaller than right style. Supra-anal plate trapezoidal with margin setose, cerci with 19 segments. Right paraproct long, extended beyond half of supra-anal plate, with two apical lobes, one slender and the other convex. Genitalia with left phallomere hook-shaped and with apical projection sclerotized; median sclerite slender, pointed, with slight apical curvature; right phallomere shaped as an inverted "Y" with sclerotized base.

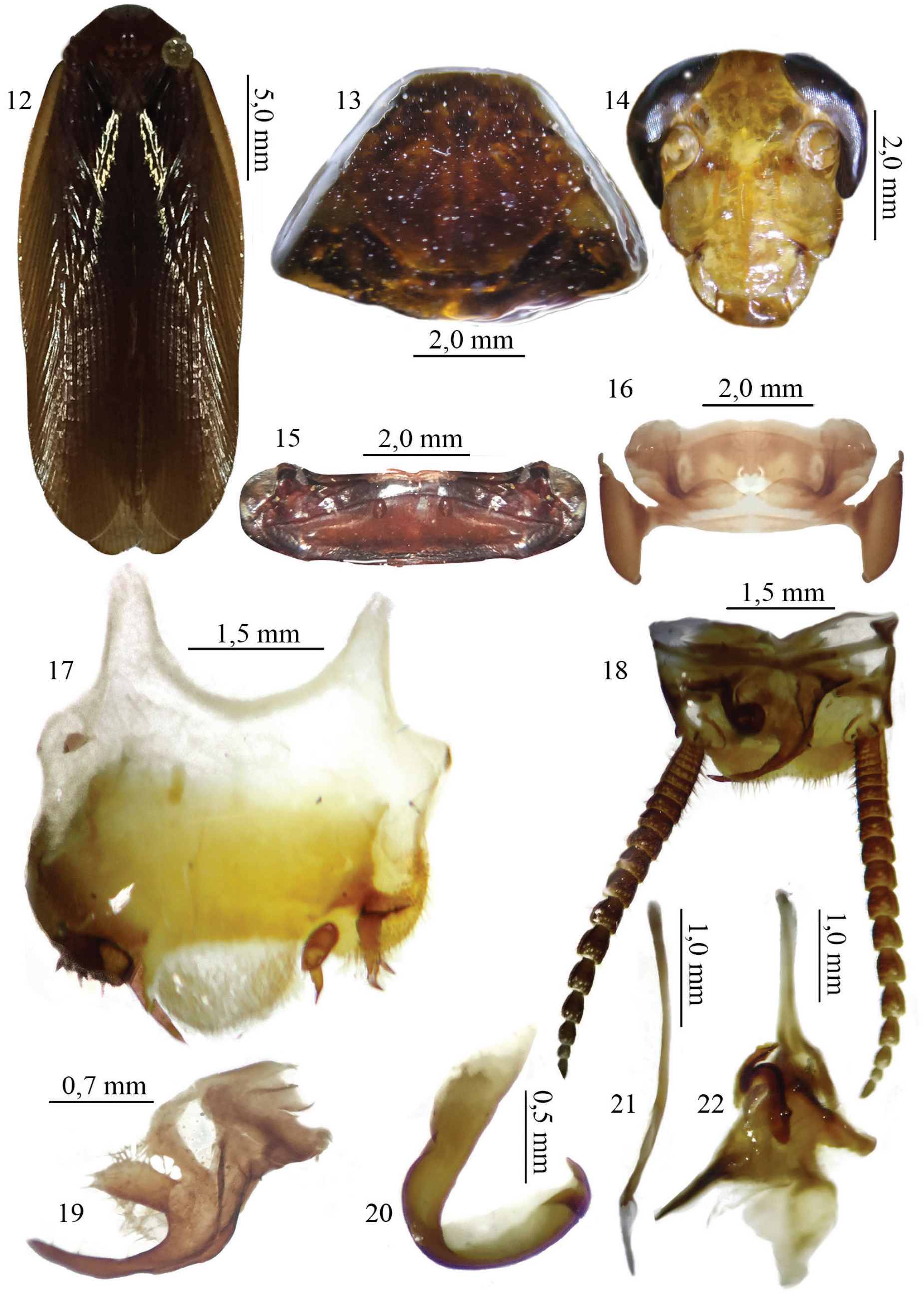
Description. Holotype. Male dimensions (mm) holotype ♂: Total length: 26.0; length of pronotum: 5.4; width of pronotum: 6.8; length of tegmen: 23.5; width of tegmen: 6.5.

General coloration. Dark brown and shiny (Fig. 12). Pronotum with lateral flaps light brown, contrasting with disk (Fig. 13). Head light brown (Fig. 14); antennae and maxillary palp golden tomentose. Tegmen with marginal field light brown. Legs reddish-brown and shiny; pulvilli whitish.

Head. Triangular and small; vertex covered by pronotum in dorsal view, interocular space ample, about 2/3 distance that separates antennal insertions; ocelli large and conspicuous; antennae long and ciliated, extending past apex of abdomen; maxillary palp ciliated, 3rd segment longer than the others, 4th segment slightly smaller than 5th, both dilated, 4th segment expanded apically and 5th basally.

Thorax. Pronotum convex and subtrapezoidal, with apex straight, base slightly angular and lateral flaps deflected, with round borders. Disk of pronotum without sulci. Tegmen long, extending beyond apex of abdomen; marginal field narrow and elongated, scapular field long with veins obliquely arranged; discoidal field ample, with veins arranged longitudinally and anal field elongate, with 8–9 axillary veins. Wings developed; apex of radial vein rami and costal field not dilated; anal field fan-folded and with small apical triangle. Legs long and spiny; fore femur on anteroventral surface with four spines up to median region, followed by series of strong spines that gradually decrease in size toward apex, and three large apical spines; posteroventral surface with five developed spines, one apical. Mid and hind femora with ventral surfaces similar, with seven developed spines, spaced, one apical; genicular spine present; pulvilli present on all tarsal segments; arolia developed; claws symmetrical and not specialized.

Abdomen. Tergite I modified, bearing row of setae (Fig. 15) and segment VII with medio-lateral concavity (Fig. 16). Subgenital plate with margin ciliated, styles inserted later-



Figures 12–22. 12 Habitus, dorsal view, of the species *Xestoblatta rondonensis* sp. n. holotype male (MNRJ) **13** Pronotum, dorsal view, holotype male (MNRJ) **14** Head, ventral view, holotype male (MNRJ) **15** Tergal modification of the tergite I, dorsal view, holotype male (MNRJ) **16** Tergal modification of the tergite VII, dorsal view, holotype male (MNRJ) **17** Subgenital plate, ventral view, holotype male (MNRJ) **18** Supra anal plate, dorsal view, holotype male (MNRJ) **19** right paraproct, dorsal view, holotype male (MNRJ) **20** left phallomere, dorsal view, holotype male (MNRJ) **21** median sclerite, dorsal view, holotype male (MNRJ) **22** right phallomere, dorsal view, holotype male (MNRJ).

ally and spiny projection below left style. Right style rectangular with seven small sclerotized spines, inserted on lateral surface of style; left style short, not extending to 1/5 of subgenital plate, bifid, claw-shaped; accessory style present, curved, pointed, smaller than right style (Fig. 17). Supra-anal plate trapezoidal with margin setose, cerci with 19 segments (Fig. 18). Right paraproct long, extended beyond half of supra-anal plate, with two apical lobes, one slender and the other convex (Fig. 19). Genitalia with left phallomere hook-shaped and with apical projection sclerotized (Fig. 20); median sclerite slender, pointed, with slight apical curvature (Fig. 21); right phallomere shaped as an inverted "Y" with sclerotized base (Fig. 22).

Remarks. This species is similar to *X. mamorensis* in the bilobed right paraproct with one slender lobe, and the distribution of styles on the subgenital plate. It differs in the shape of the right style (Fig. 17), coloration and habitus (Fig. 12), and right phallomere (Fig. 22)

Etymology. The species name honors the state of Brazil where the species was collected.

Known geographical distribution. Brazil (RO)

Xestoblatta mamorensis Lopes & Oliveira, 2006

Figs 23–33

Type material. Holotype ♂ (examined) Brasil: Rondônia, Reserva Mamoré, 25/01/1998, without collector. Museu Nacional, UFRJ, Rio de Janeiro, Brazil.

Dimensions (mm). Holotype ♂ Total length: 30; length of pronotum: 5.0; width of pronotum: 8.0; length of tegmen: 25; width of tegmen: 7.0.

Description. This species was found in the Reserva Mamoré, Rondônia. It can be separated from other *Xestoblatta* species by the habitus (Fig. 23), coloration of the pronotum (Fig. 24) and head (Fig. 25), shape of the tergal modifications (Figs 26 and 27), and morphological differences in the subgenital plate (Fig. 28). In the original description, tergite VII and the right paraproct were not described. These characters are deemed very important to separate the species and therefore are described below.

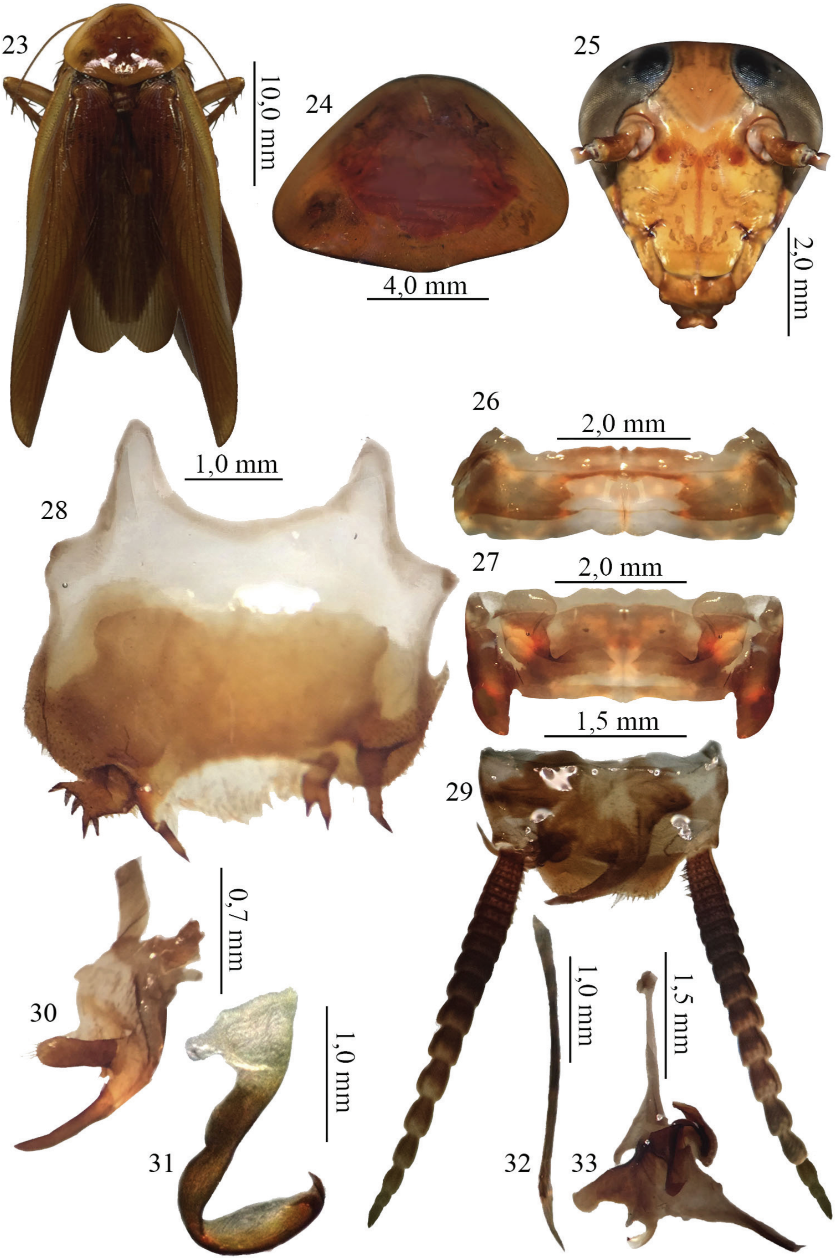
Abdomen. Tergite VII with two lateral grooves (Figs 26 and 27). Supra-anal plate with right paraproct reaching beyond half of plate (Fig. 29). Also with two lobes, one convex at apex and covered with weakly sclerotized setae, and the other slender, curved and larger than the first (Fig. 30). Genital plate with left phallomere hooked (Fig. 31); median sclerite slender, lanceolate (Fig. 32); right phallomere shaped as inverted "Y" and with sclerotized base (Fig. 33).

Known geographical distribution. Brazil (RO)

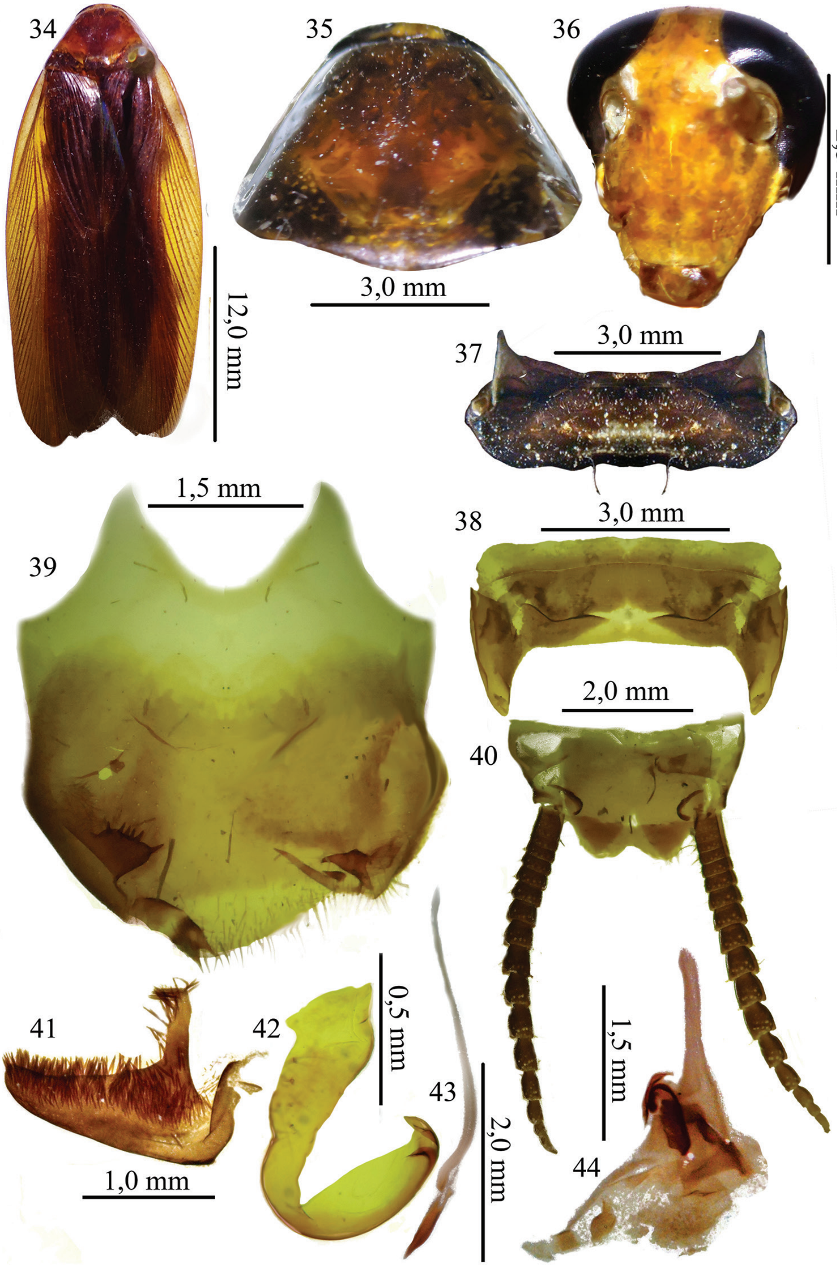
Xestoblatta roppai Rocha e Silva & Fraga, 1975

Figs 34–44

Type material. Holotype ♂ – Brazil: Mato Grosso, Vila Vera, X-1973, Roppa & Alvarenga col. Museu Nacional, UFRJ, Rio de Janeiro, Brazil.



Figures 23–33. 23 Habitus, dorsal view, of the species *Xestoblatta mamorensis* Lopes & Oliveira, 2006. holotype male (MNRJ) **24** Pronotum, dorsal view, holotype male (MNRJ) **25** Head, ventral view, holotype male (MNRJ) **26** Tergal modification of the tergite VII, dorsal view, holotype male (MNRJ) **27** Tergal modification of the tergite VII, dorsal view, holotype male (MNRJ) **28** Subgenital plate, ventral view, holotype male (MNRJ) **29** Supra anal plate, dorsal view, holotype male (MNRJ) **30** right paraproct, dorsal view (MNRJ) **31** left phallomere, dorsal view (MNRJ) **32** median sclerite, dorsal view MNRJ **33** right phallomere, dorsal view, of the holotype (MNRJ).



Figures 34–44. 34 Habitus, dorsal view, of the species *Xestoblatta roppai* Rocha e Silva & Fraga, 1975. holotype male (MNRJ) **35** Pronotum, dorsal view, holotype male (MNRJ) **36** Head, ventral view, holotype male (MNRJ) **37** Tergal modification of the tergite I, dorsal view, holotype male (MNRJ) **38** Tergal modification of the tergite VII, holotype male (MNRJ) **39** Subgenital plate, ventral view, holotype male (MNRJ) **40** Supra anal plate, dorsal view, holotype male (MNRJ) **41** right paraproct, dorsal view (MNRJ) **42** left phallomere, dorsal view (MNRJ) **43** median sclerite, dorsal view (MNRJ) **44** right phallomere, dorsal view (MNRJ).

Dimensions (mm). Holotype ♂ Total length: 26 to 30; length of pronotum: 4.0; width of pronotum: 5.9; length of tegmen: 22.3; width of tegmen: 11.4.

Description. General coloration dark brown, shiny (Fig. 34). Pronotum yellowish brown; central disk with scattered brown marks (Fig. 35). Head rusty yellow; frons and clypeus with occasional marks and labrum brown (Fig. 36). Antennae with basal segments pale and apical segments pigmented. Ocelli whitish. Legs with brown mark at base of coxae and margins. Abdomen dark brown with white marks from tergite I to tergite IV; tergite VII with white lateral marks; sternite orange brown.

Head. Triangular, interocular space half width of antennal insertions. Ocelli well developed. Vertex slightly exposed. Maxillary palp setose on segments 4 and 5, 3rd and 5th segments subequal in length; 4th segment slightly smaller than both.

Thorax. Pronotum slightly convex, angulate on posterior surface, widest in mediocaudal region. Lateral flaps developed and deflexed. Legs robust with coxae wide; fore femur on anteroventral surface with row of 9 long spines, decreasing in size toward apex and ending in 3 elongate apical spines. Posteroventral surface with sparse spines, irregular, last spine apical. Fore and hind femora with spines on both margins and genicular spines. Pulvilli, arolia, and claws well developed. Tegmen well developed, reaching beyond tip of cerci. Marginal field well demarcated. Discoidal field convex and with venular arrangement. Anal field ample, convex, with 6 axillary veins. Wings developed; anal field fan-folded; apical triangle small.

Abdomen. Tergites I and VII modified (Figs 37 and 38). Subgenital plate asymmetrical, setose at apex and styles unequal in shape and size, inserted laterally on plate. Right style bifid and pointed, with accessory style; left style rectangular, with approximately six spines on ventral margin (Fig. 39). Supra-anal plate projected between cerci, bilobed apically, setose on margins. Cerci long (Fig. 40). Right paraproct long, L-shaped, reaching beyond half the length of the supra-anal plate, covered ventrally with sclerotized setae resembling spines (Fig. 41). Genitalia with left phallomere hook-shaped, recurved internally (Fig. 42). Median sclerite elongate, with apex slightly curved and pointed (Fig. 43); right phallomere weakly sclerotized, median portion triangular (Fig. 44).

Known geographical distribution. Brazil (MT)

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RESEARCH ARTICLE

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Three new species of *Fonsecaiulus* (Hemiptera, Cicadellidae, Cicadellini) from Brazil and key to species of the genus

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Abstract

Three new sharpshooter species of the genus *Fonsecaiulus* Young, 1977 are described and illustrated from specimens collected in the Brazilian Atlantic Forest, *F. rectangularis* **sp. n.** and *F. guttiformis* **sp. n.**, and in the Brazilian Cerrado, *F. filiformis* **sp. n.** The descriptions are based on features from the external morphology, color pattern, and male and female genital structures. Comparisons of the three new taxa with the remaining six *Fonsecaiulus* species are provided. An identification key to males of all known species of the genus is given.

Keywords

Atlantic Forest, Auchenorrhyncha, Cerrado, leafhopper, morphology, sharpshooter, taxonomy

Introduction

The genus *Fonsecaiulus* Young, 1977 occurs in Venezuela, NE, CW, SE and S Brazil, Bolivia, and Argentina, being composed of six species (Young 1977): *F. cognatus* (Schmidt, 1928); *F. dorsifascia* (Osborn, 1926); *F. flavovittata* (Stål, 1859), the type species; *F. gaudialis* Young, 1977; *F. sanguineovittata* (Signoret, 1855); and *F. sciotus* Young, 1977. Specimens of *Fonsecaiulus* have a conspicuous median yellow stripe covering at least the anterior dorsum, limited by a pair of black to brown stripes or areas.

In this paper three new species of *Fonsecaiulus* are described and illustrated from specimens collected in Atlantic Forest areas from Espírito Santo State, SE. Brazil, and in the Cerrado (tropical savanna) from Goiás State, CW. Brazil. An identification key to males of all known species of the genus is given. Notes comparing the three new taxa with the remaining *Fonsecaiulus* species are provided.

Material and methods

The genital structures were prepared according to the techniques of Oman (1949) and Mejdalani (1998) for males and females, respectively. The dissected parts were stored in small vials with glycerin and attached below the specimens. Morphological terminology follows mainly Young (1977), except for the head (Hamilton 1981, Mejdalani 1993, 1998) and the female genitalia (Hill 1970, Davis 1975).

The specimens studied herein were deposited in the Coleção Entomológica do Instituto Oswaldo Cruz, Fundação Oswaldo Cruz (CEIOC, Rio de Janeiro), Coleção Entomológica Prof. José Alfredo P. Dutra, Departamento de Zoologia, Instituto de Biologia, Universidade Federal do Rio de Janeiro (DZRJ, Rio de Janeiro), and Departamento de Entomologia, Museu Nacional, Universidade Federal do Rio de Janeiro (MNRJ, Rio de Janeiro). Label data of type specimens are given inside quotations with a reversed virgule [\] separating lines on a label and a semicolon separating different labels.

Taxonomy

Fonsecaiulus rectangularis sp. n.

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Fig. 1

Diagnosis. *Fonsecaiulus rectangularis* sp. n. is characterized by the combination of the following features: (1) male pygofer with two acute processes (Fig. 1d), one posterodorsal, short and spiniform, and another posteroventral, long; (2) aedeagus with shaft long and moderately broad in lateral view (Fig. 1g), without processes, apex truncate to slightly concave; (3) paraphyses (Fig. 1h) with pair of simple long rami.

Etymology. The specific epithet, *rectangularis*, refers to the shape of the aedeagal shaft in lateral view.

Description. Length. Male holotype, 5.5 mm; male paratypes, 5.3–5.5 mm.

Male holotype. Head and thorax. Head (Fig. 1a, b) with median length of crown 7/10 interocular width and 4/10 transocular width; frons not flattened medially, muscle impressions distinct; epistomal suture obsolete medially; clypeus with contour continuing profile of frons. Pronotum (Fig. 1a, b) with width equal to transocular width; lateral margins slightly convergent anteriorly. Remaining morphological

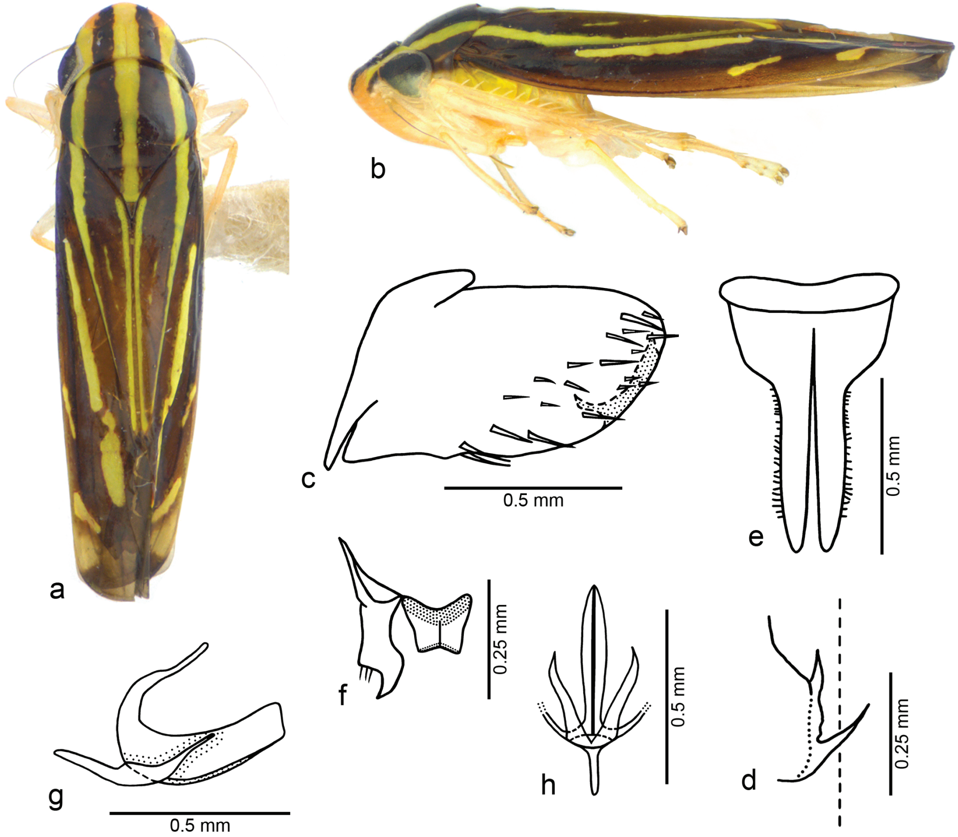

Figure 1. *Fonsecaiulus rectangularis* sp. n., male holotype. **a** body, dorsal view **b** body, lateral view **c** pygofer, lateral view **d** apical left portion of pygofer, posterior view **e** valve and subgenital plates, ventral view **f** left style and connective, dorsal view **g** aedeagus and paraphyses, lateral view **h** aedeagus and paraphyses, ventral view. Body length: 5.5 mm.

characteristics of head and thorax as in the generic description of Young (1977: 760–763).

Male genitalia. Pygofer (Fig. 1c, d) with dorsoapical short spine, directed dorsally; ventro-apical margin with inner long process, anteromedially turned. Valve (Fig. 1e) short and broad, anterior margin concave medially and posterior margin convex. Subgenital plates (Fig. 1e) narrow on apical two-thirds; dorsal surface with two minute, sclerotized dentiform processes on median portion, near which apical portion of styles rests; short microsetae along outer margin. Styles (Fig. 1f) with outer preapical portion with long sparse setae; apex narrowly truncate. Connective (Fig. 1f) short and broad in dorsal view, with median keel. Aedeagus (Fig. 1g, h), in lateral view, with shaft broad and elongate, curved dorsally, subrectangular; apex truncate; ventral margin laterally expanded in caudal view; dorsal apodemes long and curved posteriorly. Paraphyses

(Fig. 1g, h) symmetrical, with pair of long rami extending as far posteriorly as half of aedeagal shaft, posteriorly divergent in ventral view; rami curved dorsally, with apical half dorsoventrally flattened, apex acute.

Color. Dorsum brown with three longitudinal yellow stripes (Fig. 1a, b); median stripe extending from apex of crown to apex of clavus, posteriorly narrowed from median portion of pronotum; pair of lateral stripes extending posteriorly from frontogenal suture along claval sulcus, almost attaining its apex, strongly narrowed on posterior two-thirds of sulcus. Crown (Fig. 1a, b) with lateral areas anteriorly to frontogenal sutures pale orange. Clavus (Fig. 1a, b) with narrow, median, elongate oblique yellow macula. Corium (Fig. 1a, b) with yellow stripe parallel and adjacent to median portion of brachial cell; yellow elongate macula on inner anteapical cell; two smaller oblique yellow maculae near costal margin, anterior one opposite claval apex, posterior one on outer anteapical cell. Face pale orange. Frons with pair of dorsolateral brown maculae continuous with color pattern of crown. Antennal ledges brown (Fig. 1b). Thoracic sclerites mostly yellow (Fig. 1b); lateral lobe of pronotum dorsally brown. Legs mostly pale orange (Fig. 1b). Thoracic sternum mostly pale orange.

Female unknown.

Intraspecific variation (based on eight male paratypes). The direction of the pygofer processes is variable; the aedeagal shaft can be more dorsally curved than in the holotype; its apical portion, in lateral view, can be broader and the apical margin, slightly concave.

Type specimens. Brazil, Espírito Santo State. Holotype: male, "BR, ES, Sta. Teresa, Est. \ Biol. Santa Lúcia, 16.V.2012, \ Buys, Leibão & Antunes \ leg." (CEIOC). Paratypes: two males, same data as holotype (CEIOC); four males, "BR, ES, Sta. Teresa, Est. \ Biol. Santa Lúcia, 18.X.2012, \ Buys, Cordeiro & Tinoco, \ leg. Prato amarelo" (CEIOC); two males, "BR, ES, Santa Maria de \ Jetibá, Fazenda Azaléia, \ 18.V.2012, Buys, Leibão & \ Antunes leg." (MNRJ).

Remarks. *Fonsecaiulus rectangularis* sp. n. (Fig. 1a, b) is similar in color and distributional pattern of stripes to *F. flavovittata* and *F. gaudialis*. The pair of yellow stripes extending posteriorly from the frontogenal sutures is narrower than in *F. flavovittata* on anterior portion of claval sulcus (Wilson et al. 2009: http://naturalhistory.museumwales.ac.uk/sharpshooters/browserecord.php?-recid=1012).

The male genital structures are similar to those of *F. gaudialis*. The posterior margin of the pygofer presents acute processes in both species, being a single ventral process in *F. gaudialis*, not attaining the median line (Young 1977: figs 627c, p). In the new species, there are two processes: one dorsal, short and spiniform, and another ventral, long (Fig. 1c, d). The aedeagal shaft in both species is long and moderately broad in lateral view, without processes. The shaft apex is truncate to slightly concave in *F. rectangularis* (Fig. 1g), while it is convex in *F. gaudialis* (Young 1977: fig. 627f). The paraphyses have a pair of simple long rami in the new species (Fig. 1h). In *F. gaudialis* each ramus is clearly bifid (Young 1977: fig. 627h).

Fonsecaiulus guttiformis **sp. n.**

http://zoobank.org/D23721F8-37E9-4E6E-B444-60300CD6804C

Figs 2, 3

Diagnosis. *Fonsecaiulus guttiformis* sp. n. is characterized by the combination of the following features: (1) single yellow stripe on median portion of clavus (Fig. 2a), directed to commissural margin; (2) valve (Fig. 2d) broad and subtriangular; (3) styles and connective stalk (Fig. 2e) very elongate; (4) aedeagus (Fig. 2f) strongly curved ventrally with apex broad; (5) paraphyses (Fig. 2f, g) very complex, with short basal plate and pair of broad and long rami with processes; (6) female sternite VII (Fig. 3a) subtriangularly produced posterolaterally, with well-produced median lobe.

Etymology. The specific epithet, *guttiformis*, refers to the shape of the aedeagal shaft in lateral view.

Description. Length. Male holotype, 5.4 mm; male paratypes, 5.0–5.5 mm; female paratype, 5.5 mm.

Male holotype. Head and thorax. Head (Fig. 2a, b) with median length of crown slightly less than 7/10 interocular width and slightly less than 4/10 transocular width; frons slightly flattened medially, muscle impressions distinct; epistomal suture obsolete medially; clypeus with contour continuing profile of frons. Pronotum (Fig. 2a, b) with width equal to transocular width; lateral margins slightly convergent anteriorly. Remaining morphological characteristics of head and thorax as in the generic description of Young (1977: 760–763).

Male genitalia. Pygofer (Fig. 2c) slightly concave posteriorly; ventro-apical margin with small rounded lobe, directed medially. Valve (Fig. 2d) broad and subtriangular. Subgenital plates (Fig. 2d) narrow on apical half; dorsal surface with two minute, sclerotized dentiform processes on median portion, near which apical portion of styles rests; short microsetae along outer margin. Styles (Fig. 2e) elongate, extending as far posteriorly as connective apex; outer preapical portion with long sparse setae; apex directed outwards. Connective (Fig. 2e) Y-shaped in dorsal view; stalk elongate, with well-produced median keel. Aedeagus (Fig. 2f, g), in lateral view, with shaft long and gutiform, strongly curved ventrally; apex broadly convex; gonopore apical; dorsal apodemes long and curved posteriorly. Paraphyses (Fig. 2f, g) symmetrical, with short basal plate and pair of complex broad and long rami; each ramus with inner basal process, slender and very short; ventral margin with short process between basal and median thirds, slightly curved posteriorly; apex bifurcated into two long and narrow acute processes, inner one posteromedially curved and crossing median line of pygofer, the other one directed posteriorly, with short triangular basiventral projection.

Color. Dorsum brown with longitudinal yellow stripes (Fig. 2a, b). Head and thorax (Fig. 2a, b) with three stripes, median one extending from apex of crown to apex of clavus, posteriorly narrowed from median portion of pronotum, and pair of lateral stripes extending from frontogenal suture to median portion of clavus, almost attaining median portion of commissural margin. Clavus (Fig. 2a, b) with narrow yel-

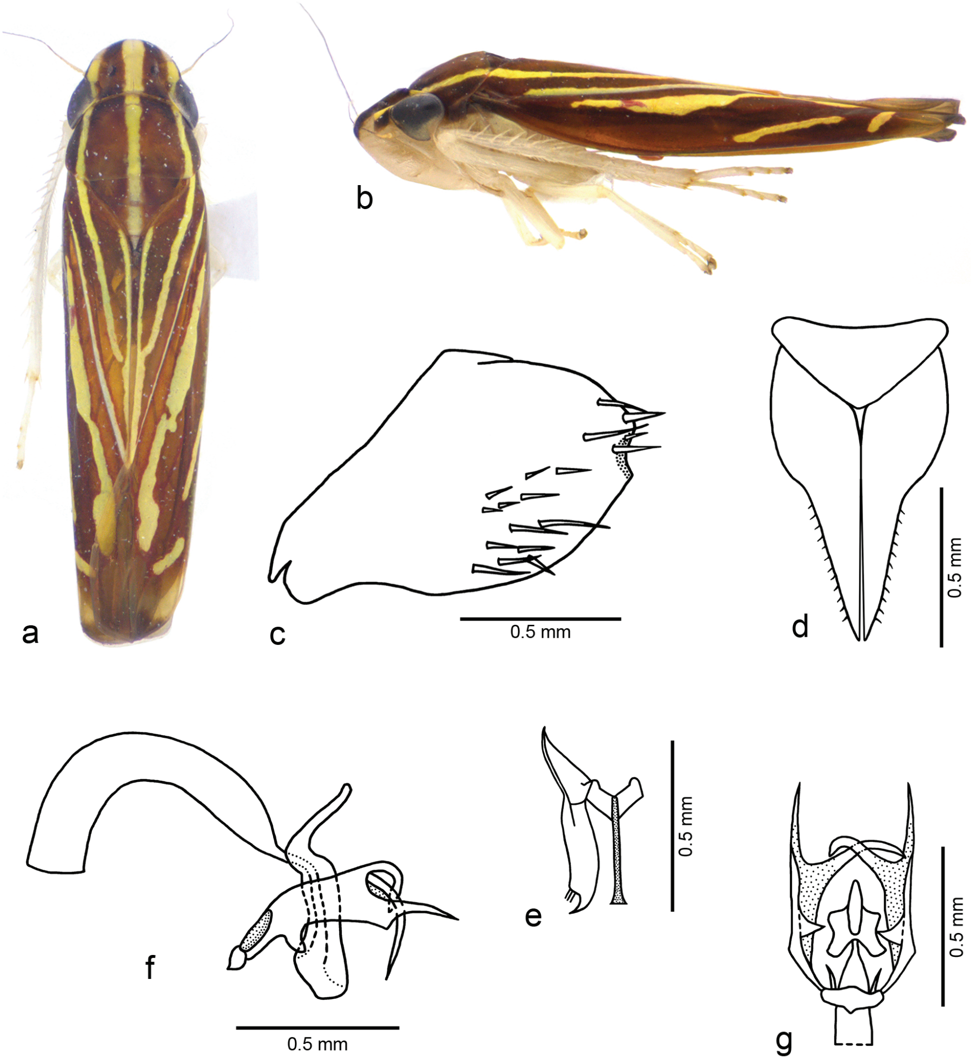

Figure 2. *Fonsecaiulus guttiformis* sp. n., male holotype. **a** body, dorsal view **b** body, lateral view **c** pygofer, lateral view **d** valve and subgenital plates, ventral view **e** left style and connective, dorsal view **f** ejaculatory reservoir, aedeagus, and paraphyses, lateral view **g** part of ejaculatory reservoir, aedeagus, and paraphyses, ventral view. Body length: 5.4 mm.

low stripe adjacent to claval sulcus, absent on basal portion. Corium (Fig. 2a, b) with broad yellow irregular stripe adjacent to brachial cell, extending posteriorly to inner anteapical cell, narrowed on portion opposite claval apex; two elongate oblique yellow maculae near costal margin, anterior one opposite claval apex (interrupted in the right forewing) and posterior one on outer anteapical cell. Face pale yellow. Frons with pair of dorsolateral brown maculae continuous with color pattern of crown. Anten-

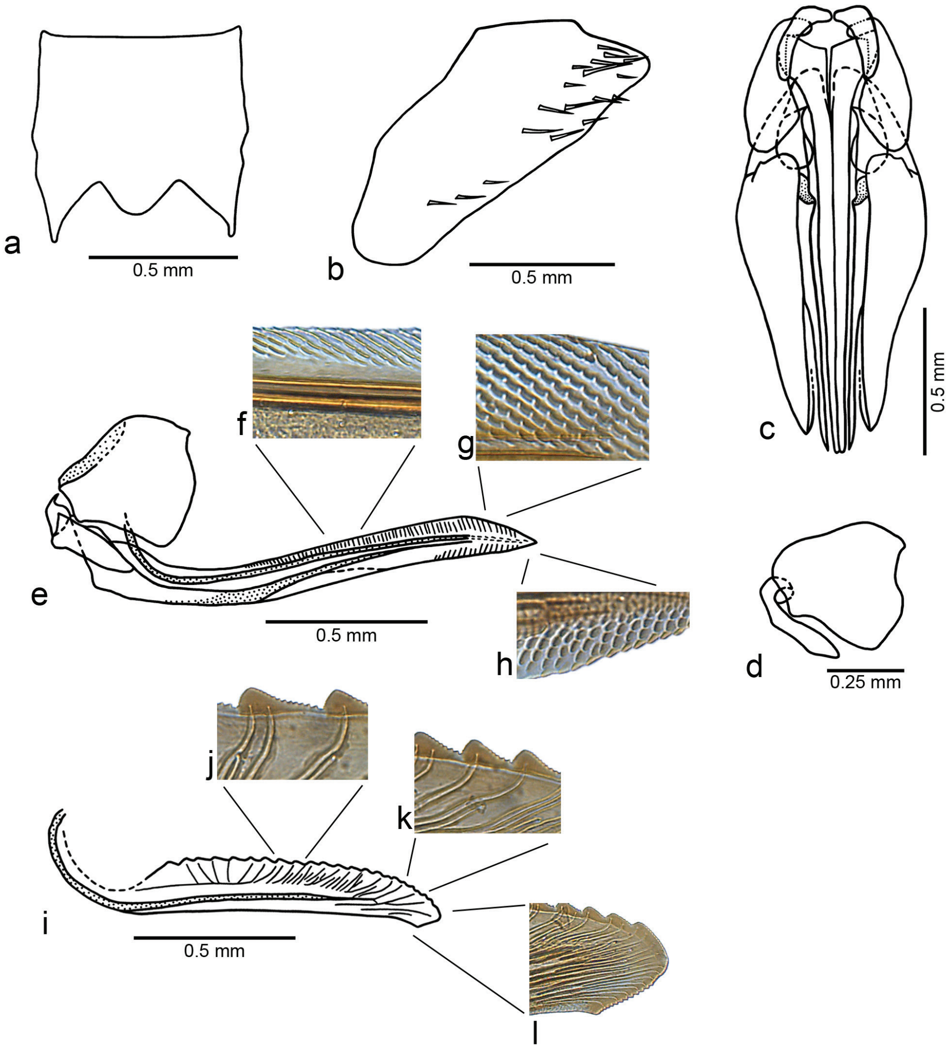

Figure 3. *Fonsecaiulus guttiformis* sp. n., female paratype. **a** abdominal sternite VII, ventral view **b** pygofer, lateral view **c** apical portion of abdomen with sternite VII removed (macrosetae of pygofer omitted), ventral view **d** first valvifer, lateral view **e** first valvifer and valvula of ovipositor, lateral view **f** basal and **g** apical dorsal sculpturing in detail **h** apical ventral sculpturing in detail **i** second valvula of ovipositor, lateral view **j** median **k** preapical, and **l** apical teeth and denticles in detail.

nal ledges brown (Fig. 2b). Thoracic sclerites (Fig. 2b) mostly yellow; lateral lobe of pronotum dorsally brown. Legs (Fig. 2b) mostly pale yellow. Thoracic sternum mostly pale yellow.

Female genitalia (based on one paratype). Sternite VII (Fig. 3a) subtriangularly produced posterolaterally; posterior margin with well-produced median lobe. "Internal" sternite VIII without sclerites. Pygofer (Fig. 3b, c) moderately produced posteriorly in lateral view; surface with sparse row of macrosetae along ventro-apical margin and a few grouped near apex. First valvifers (Fig. 3c–e) large, subrectangular in lateral view, each with long, basally articulated anterior process directed posteroventrally; basal portion of processes, in ventral view, medially produced and connected to each other by membrane (Fig. 3c). First ovipositor valvulae (Fig. 3e–h) with basal portion enlarged and subrectangular; basal margin truncate and oblique in ventral view (Fig. 3c); sculptured areas mostly scalelike, with linear tegumentary processes on basidorsal portion (Fig. 3f) and separated scales on ventro-apical portion (Fig. 3h); ventral margin broadly concave; apex acute. Second valvulae (Fig. 3i–l) broadened beyond basal curvature, narrowing slightly towards narrowly rounded apex; ventral margin approximately rectilinear; preapical prominence (Fig. 3l) conspicuous, narrowly rounded; dorsal margin with approximately 22 mostly triangular continuous teeth, extending from expanded basal portion to apical portion of blade; most teeth with steep, small ascending portion, and gradually declivous, large descending portion (Fig. 3j, k); denticles distributed on teeth (Fig. 3j, k) and on apical portion of blade, except on apex (Fig. 3l); blade with ducts attaining teeth or terminating below them, also extending to apex (Fig. 3i–l). Gonoplacs with basal half distinctly narrow, abruptly expanded on median portion; ventral margin slightly concave on median third; apex rounded.

Intraspecific variation (based on nine male and one female paratypes). Short curved process between basal and median third of paraphyses rami with variable length; ventral margin of each ramus sometimes irregular, with slight projections and emarginations.

Type specimens. Brazil, Espírito Santo State. Holotype: male, "Coleção Santa \ Teresa"; "BR, ES, Sta. Teresa, Est. \ Biol. Santa Lúcia 17- \ 21.IV.2012, Buys & Leibão \ leg." (CEIOC). Paratypes: one male and one female, same data as holotype (CEIOC); three males, "BR, ES, Sta. Teresa, Est. \ Biol. Santa Lúcia, Trilha do \ Ruschi, 22.VII.2012, Buys, \ leg. Prato Amarelo" (CEIOC); one male, "BR, ES, Sta. Teresa, Est. \ Biol. Santa Lúcia, 18.X.2012, \ Buys, Cordeiro & Tinoco, \ leg. Prato amarelo" (MNRJ); four males, "BR, ES, Sta. Teresa, Est. \ Biol. Santa Lúcia, Trilha do \ Rio, 17.X.2012, Buys, \ Cordeiro & Tinoco leg." (CEIOC).

Remarks. *Fonsecaiulus guttiformis* sp. n. (Fig. 2a, b) is similar in color pattern and male and female structures to *F. cognatus*. In the new species the lateral yellow stripes on anterior dorsum converge posteriorly to the commissural claval margins (Fig. 2a). In *F. cognatus* these stripes have similar position on clavus but they are paired (Wilson et al. 2009: http://naturalhistory.museumwales.ac.uk/sharpshooters/browserecord.php?-recid=1008).

The male genitalia of *F. guttiformis* are the most distinct in the genus. The valve is broad and subtriangular (Fig. 2d), whereas this structure is short and broadly convex posteriorly in the remaining species of the genus. The styles and connective stalk are uncommonly elongate (Fig. 2e). The aedeagus is strongly curved ventrally with the apex broad (Fig. 2f). *Fonsecaiulus cognatus* is the only other known species in which the aedeagal shaft has a ventral curvature (Young 1977: fig. 625q), but it is slighter than in *F. guttiformis*. The paraphyses are very complex in the latter species, with short basal plate and pair of broad and long rami presenting processes (Fig. 2f, g). Until now, the paraphyses of *F. flavovittata* were the most complex in the genus (Young 1977: fig. 622r).

Regarding the female genitalia, the sternite VII of *F. guttiformis* (Fig. 3a) is similar to that of *F. cognatus* (Young 1977: fig. 625i), both being posterolaterally produced and with a well-produced median lobe. The lateral lobes in the new species are subtriangular, whereas in *F. cognatus* they are narrowly rounded.

The first valvifers of *F. guttiformis* bear a conspicuous anterior process that is basally articulated (Fig. 3d, e). Young (1977) described a pair of elongate processes projecting from the dorsal membrane into the genital chamber in *F. sciotus* (see fig. 626p from that author). The position and shape of these processes are similar to the ones observed in *F. guttiformis*. Carvalho and Mejdalani (2014) described processes originating from the same portion of the valvifers, but not basally articulated to them, in two species of *Erythrogonia* Melichar, 1926: *E. phoenicea* (Signoret, 1853) (see fig. 8 from those authors) and *E. calva* (Taschenberg, 1884) (see fig. 22 from those authors). This genus, as well as *Fonsecaiulus*, is included in the *Erythrogonia* generic group (Young 1977).

***Fonsecaiulus filiformis* sp. n.**

http://zoobank.org/D600EBDB-6855-4C5A-9B9A-7D3AE05C14F4
Fig. 4

Diagnosis. *Fonsecaiulus filiformis* sp. n. is characterized by the combination of the following features: (1) dorsum (Fig. 4a) with broad pale yellow median stripe extending from apex of crown to apex of clavus; (2) connective (Fig. 4e, f) with median keel strongly produced dorsally; (3) aedeagus (Fig. 4f) with shaft long and slender, dorsally curved, with long and acute apical process continuing its shape; (4) paraphyses (Fig. 4g) with Y-shaped basal plate with arms widely divergent and pair of long and slender rami.

Etymology. The specific epithet, *filiformis*, refers to the shape of the aedeagus in lateral view.

Description. Length. Male holotype, 5.6 mm.

Male holotype. Head and thorax. Head (Fig. 4a, b) with median length of crown slightly less than 7/10 interocular width and slightly less than 4/10 transocular width; ocelli located slightly behind a line between anterior eye angles; frons slightly flattened medially, muscle impressions distinct; epistomal suture complete; clypeus with contour continuing profile of frons. Pronotum (Fig. 4a, b) with width less than transocular width; lateral margins parallel. Forewings with inner and median anteapical cells opened basally. First tarsomere (Fig. 4b) with length approximately equal to combined length of two more distal tarsomeres. Remaining morphological characteristics of head and thorax as in the generic description of Young (1977: 760–763).

Male genitalia. Pygofer (Fig. 4c) broadly convex posteriorly, posterodorsal portion slightly produced, without processes. Valve (Fig. 4d) broad and very short, subrectangular. Subgenital plates (Fig. 4d) narrow on apical three-fourths; dorsal surface with two minute, sclerotized dentiform processes on median portion, near which apical portion of styles rests; basal portion with few short macrosetae along outer margin; few very short microsetae on apical half. Styles (Fig. 4e, f) with outer preapical portion with

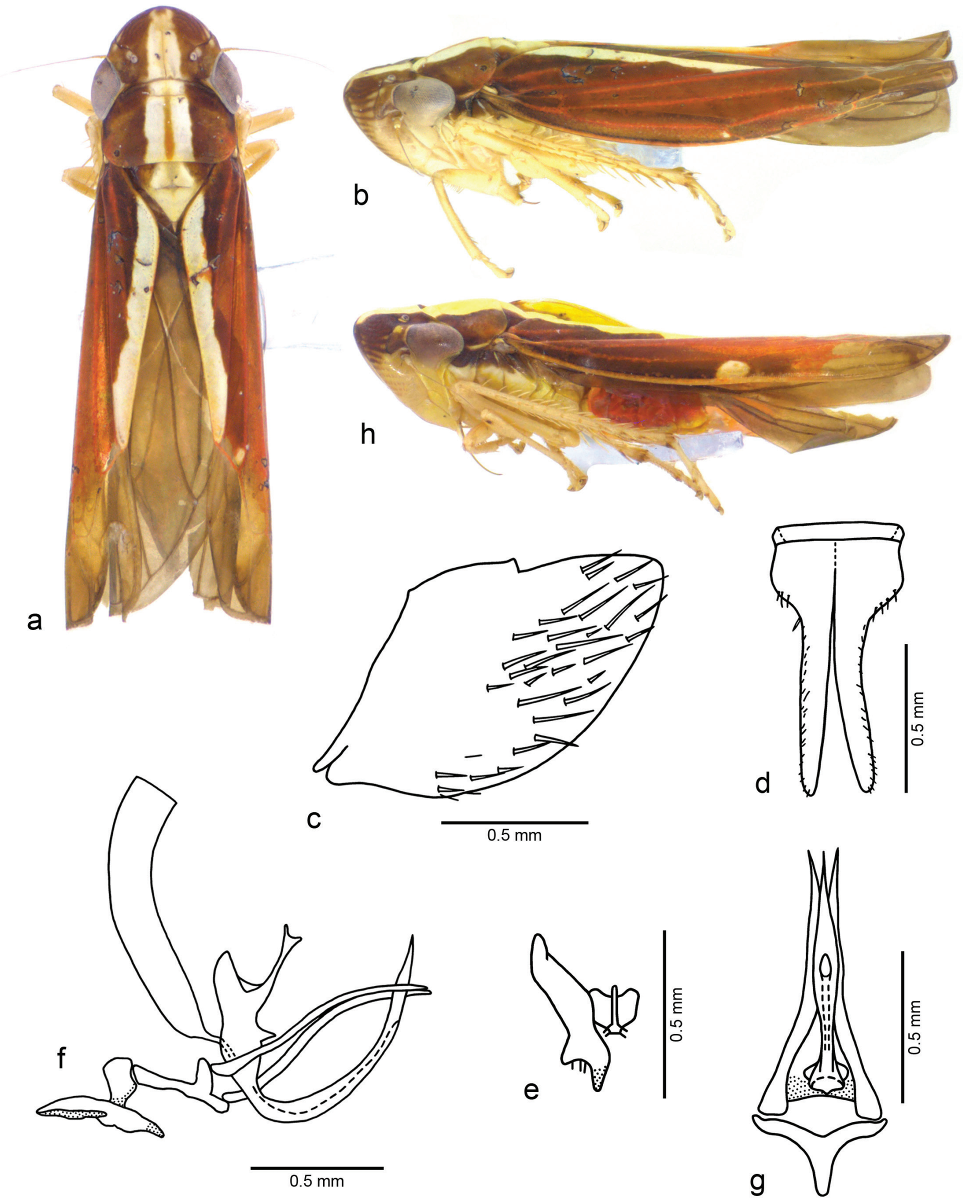

Figure 4. *Fonsecaiulus filiformis* sp. n., male holotype. **a** body, dorsal view **b** body, lateral view **c** pygofer, lateral view **d** valve and subgenital plates, ventral view **e** left style and connective, dorsal view **f** left style, connective, ejaculatory reservoir, aedeagus, and paraphyses, lateral view **g** aedeagus and paraphyses, ventral view. *Fonsecaiulus dorsifascia* (Osborn, 1926) **h** body, lateral view. Body lengths of *F. filiformis* 5.6 mm and of *F. dorsifascia* 5.7 mm.

long sparse setae; apex directed outwards. Connective (Fig. 4e, f) with arms short in dorsal view; stalk moderately elongate, with strongly produced median keel. Aedeagus (Fig. 4f, g), in lateral view, with shaft long and slender, dorsally curved; apex with long and acute process continuing shape of shaft, extending dorsally beyond pygofer border; gonopore ventral; dorsal apodemes long and slightly curved posteriorly. Paraphyses (Fig. 4f, g) symmetrical, basal plate Y-shaped and arms widely divergent; rami articulated to basal plate, long and slender, with apex acute, extending posteriorly beyond pygofer border; each ramus, in lateral view, sinuous, slightly curved dorsally and then slightly curved ventrally.

Color. Dorsum anteriorly brown to yellowish-brown with broad pale yellow median stripe extending from apex of crown to apex of clavus (Fig. 4a, b); stripe occupying approximately one-third of posterior margin of crown, with lateral margins sinuous on clavus. Crown (Fig. 4a) with pair of small pale yellow spots on antennal ledges and another pair adjacent to outer margin of ocelli; subtriangular pale yellow marks adjacent to inner eye angles. Pronotum (Fig. 4a, b) with narrow, median yellowish-brown stripe on pale yellow broad stripe; humeral areas reddish-brown. Forewings (Fig. 4a, b) with basal portion dark brown, median portion and most of corium veins reddish-brown, apical portion pale brown; minute pale yellow spot beyond middle of costal margin and another on apex of brachial cell. Face pale yellow. Frons with median portion bordered by pair of longitudinal narrow brown stripes, connected to each other on dorsal median portion of clypeus, then extending ventrally as a median stripe; narrow transverse brown stripes along muscle impressions. Antennal ledges (Fig. 4b), in lateral view, almost entirely brown. Thoracic sclerites (Fig. 4b) mostly pale yellow; lateral lobe of pronotum, mesepimeron, and mesepisternum dorsally dark brown. Legs (Fig. 4b) mostly pale yellow. Thoracic sternum mostly pale yellow.

Female unknown.

Type specimen. Brazil, Goiás State. Holotype: male, "Brasil, GO, Alto Paraíso \ de Goiás, Parque \ Nacional da Chapada dos \ Veadeiros, trilha para \ canion"; "S14°10'5", W47°49'16" \ 941m 25.X.2013 sweep \ DM Takiya, BM Camisão \ e CC Gonçalves leg." (DZRJ).

Remarks. *Fonsecaiulus filiformis* sp. n. (Fig. 4a, b) is very similar to *F. dorsifascia* (Fig. 4h) in color pattern and male structures. Only these two species have a broad, median pale yellow stripe on dorsum. In the new species the lateral margins of the stripe are sinuous on forewings, whereas in *F. dorsifascia* they are triangularly emarginated.

In the male genitalia, the pygofer and subgenital plates are very similar in both species. The apical portion of the styles in *F. filiformis* differs from that of *F. dorsifascia*. In the former species, the preapical lobe is more produced (Fig. 4e) than in the latter (Young 1977: fig. 624e). The paraphyses of the new species are similar to those of *F. dorsifascia*. The aedeagi are strongly curved dorsally in both species. However, *F. filiformis* has a regularly very narrow aedeagus in lateral view (Fig. 4f), while *F. dorsifascia* has the aedeagal shaft broader (Young 1977: fig. 624f).

Additional material of *Fonsecaiulus* examined

F. dorsifascia – Brazil – Goiás State: one male, Alto Paraíso de Goiás (DZRJ).

F. flavovittata – Brazil – Espírito Santo State: seven males, Santa Teresa (CEIOC); one male, Santa Maria de Jetibá (CEIOC).

Key to males of *Fonsecaiulus*

1 Mesonotum dark brown, rarely with small faint pale yellow marks anteriorly; paraphyses with pair of long and narrow rami, each with short process on median portion and a shorter one on apical portion (Young 1977: fig. 626h)... ***F. sciotus***

– Mesonotum with distinct longitudinal yellow stripes; paraphyses with rami not as above **2**

2 Dorsum with a single broad yellow stripe extending from anterior margin of crown to claval apex (Fig. 4a) **3**

– Dorsum with some yellow stripes, generally narrow (Figs 1a, 2a) **4**

3 Dorsal yellow stripe broad and occupying most of claval region (Fig. 4h) and with outer boarder markedly serrated on clavus; costal yellow mark large and rounded (Fig. 4h); aedeagus, in lateral view, with shaft moderately broad with long dorsoapical acute process (Young 1977: fig. 624f)... ***F. dorsifascia***

– Dorsal yellow stripe narrower and not occupying most of claval region (Fig. 4a, b) and with outer boarder slightly sinuous on clavus; costal yellow mark a very small dot (Fig. 4b); aedeagus, in lateral view, with shaft slender with long dorsoapical acute process continuing its shape (Fig. 4f)...... ***F. filiformis* sp. n.**

4 Crown with median yellow stripe much broader than the adjacent brown stripes **5**

– Crown with median yellow stripe approximately as broad as (Fig. 1a) or narrower than (Fig. 2a) the adjacent brown stripes **6**

5 Clavus with two oblique yellow stripes on central portion, posteriorly directed to commissural margin; aedeagus ventrally curved (Young 1977: fig. 625q); paraphyses with rami crossing each other (Young 1977: fig. 625q, r) ..... ***F. cognatus***

– Clavus with one oblique yellow stripe on central portion, posteriorly directed to commissural margin; aedeagus dorsally curved (Young 1977: fig. 623f); paraphyses with rami posteriorly divergent (Young 1977: fig. 623p) .... ***F. sanguineovittata***

6 Aedeagus, in lateral view, with shaft strongly narrowed towards apex (Young 1977: fig. 622f) .... ***F. flavovittata***

– Aedeagus, in lateral view, with shaft broad 7

7 Pygofer without acute processes (Fig. 2c); subgenital plates narrowed on apical half (Fig. 2d); aedeagus strongly curved ventrally (Fig. 2f) .... ***F. guttiformis* sp. n.**

– Pygofer with at least one acute process; subgenital plates narrowed on apical two-thirds; aedeagus dorsally curved **8**

8 Pygofer with single apical process (Young 1977: fig. 627c, p); aedeagus with apex convex in lateral view (Young 1977: fig. 627f); paraphyses with pair of long bifid rami (Young 1977: fig. 627h) .... ***F. gaudialis***

– Pygofer with two apical processes (Fig. 1c, d); aedeagus with apex truncate to slightly concave in lateral view (Fig. 1g); paraphyses with pair of long simple rami (Fig. 1g, h)... ***F. rectangularis* sp. n.**

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