RESEARCH ARTICLE



# Are Cristaria herculea (Middendorff, 1847) and Cristaria plicata (Leach, 1815) (Bivalvia, Unionidae) separate species?

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### Abstract

The number of species in the freshwater mussel genus *Cristaria* Schumacher, 1817 recognized from Far East Russia has varied over the last several decades. While some authors consider the occurrence of only one species, *Cristaria plicata* (Leach, 1815), widespread in East Asia, others, recognize two separate species *Cristaria herculea* (Middendorff, 1847) and *Cristaria tuberculata* Schumacher, 1817 from Far East Russia, distinct from *C. plicata*. For the present study, freshwater mussels, identified as *C. herculea*, were collected in the Upper Amur basin (Transbaikalia, Russia). The shell morphology and the whole soft body anatomy were analysed in detail and compared with previously published information on other *Cristaria* spp.. Additionally, a cytochrome oxidase subunit 1 (CO1) gene fragment was sequenced from foot tissue samples of selected animals, collected from the same region, and compared with published data. Based upon morphological similarities of glochidia and adult morphology and anatomy as well as the mitochondrial DNA sequence analysis, we consider *C. herculea* as a synonym of *C. plicata*. Further analysis of Far East Russia *C. herculea* and *C. tuberculata* specimens using both molecular and morphological characters should be carried in the future to enhance our knowledge about the taxonomy within the *Cristaria* genus. Moreover, a comprehensive revision of the genus *Cristaria* is needed, restricting the type locality and comparing topotypic specimens for both *C. plicata* and *C. tuberculata*, and including all recognized *Cristaria* species.

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#### **Keywords**

Bivalvia, Unionidae, Anodontini, CO1, Transbaikalia, Russia

#### Introduction

Freshwater bivalves of the Unionidae provide important ecosystem functions and services (Vaughn and Hakenkamp 2001; Aldridge et al. 2007). However, many of their populations are in decline and this faunistic group is presently among the most threatened worldwide (Bogan 1993). In terms of conservation, it is essential to have a classification system that reflects the freshwater bivalve taxonomic diversity as well as their evolutionary relationships. Over the last decade, there have been an increasing number of taxonomy papers reflecting phylogenetic patterns with the aid of molecular tools. However, most included North American and European taxa. On the other hand, other taxa e.g. from the Southern Hemisphere or East Asian countries have been neglected and are still poorly studied. This is the case of *Cristaria* Schumacher, 1817, a relatively widespread genus in South East Asia, where its interspecific and intraspecific phylogenetic relationships are still not well understood.

The taxonomy and status of Cristaria species in Far East Russia has not been consistent among malacologists. While some authors, consider the presence of only one species, Cristaria plicata (Leach, 1815) which is widespread in Eastern Asia, from Russia (Amur River basin and Khanka Lake) to Japan and south to South Korea, China, Vietnam, Lao People's Republic, Thailand and Cambodia (Zhadin 1938, 1965; Haas 1969; Brandt 1974; Đặng et al. 1980; Kondo 2008; He and Zhuang 2013), others, consider Cristaria herculea, Cristaria tuberculata, and Cristaria plicata are separate species (Sayenko et al. 2005). Cristaria herculea, with a laterally compressed shell, is widespread in the whole Amur River basin including the Zeya, the Argun, the Nercha, the Shilka and the Onon rivers as well as Khanka Lake and Buir-Nur Lake (Mongolia) (Zatravkin and Bogatov 1987; Starobogatov et al. 2004; Klishko 2012). The other species recognized in Far East Russia, with an inflated shell, C. tuberculata Schumacher, 1817, is limited to the Far East Russia in Khanka Lake and the Ussury River basin (Moskvicheva 1973; Zatravkin and Bogatov 1987; Starobogatov et al. 2004). Curiously, and although no type locality for this species was given, Cristaria *tuberculata* is the type species of the genus and usually listed as a junior synonym of Cristaria plicata (Leach, 1815) (Simpson 1914; Haas 1969).

*Cristaria herculea* (Middendorff, 1847) known from the Transbaikalia, in Far East Russia, occurs mainly in rivers and reservoirs with slow or no currents, in a variety of substrates, including gravel, sand and mud, being tolerant of silty conditions. The fish-hosts, necessary for glochidia metamorphosis, are still unknown. The conservation status of *C. herculea* from the rivers of Transbaikalia was considered to be relatively stable during the last century. However, our research over the last ten years showed that the species has become very rare due to pollution and other anthropogenic impacts on rivers and habitats. Under this view, *Cristaria herculea* was included in the Red Book of Transbaikalsky territory (Klishko 2012).

To solve taxonomic issues when conchological characters (especially shell convexity) form the basis of species separation, it is relevant to test these uncertainties with molecular DNA sequence analyses. Under these assumptions, the aims of this paper were to study the morphological and anatomical characteristics of *C. herculea* from the Upper Amur basin in Transbaikalia, to compare them with published *Cristaria* spp. data and to test the species level status of *C. herculea* with the use of molecular data.

#### Material and methods

#### Sampling and morphometry

Specimens of *C. herculea* were collected in 2008–2012 from the Shilka, the Nercha and the Onon rivers, from the Kharanorsky reservoir, situated in the upper reaches of the Amur (Transbaikalia, Russia), and also from Buir-Nur Lake (Mongolia) (Table 1). Foot tissue samples were collected from living mussels of the Onon River and Kharanorsky reservoir and were preserved in 96% non-denatured ethanol for molecular

**Table 1.** Shell morphometry characteristics of *Cristaria herculea* from the upper Amur River basin. L – shell length; H – maximal shell height; h – shell height measured from umbo;  $h_1$  – shell height measured from middle lateral tooth to ventral margin;  $l_1$  – the distance from umbo to posterior end of the lateral tooth; B – maximal shell inflation (width);  $R_1 = B/l_1$ ,  $R_2 = B/h_1$ ; n – number of measured shells; \* – living mollusks dissected for the anatomical study and  $(n_1)$  – their number.

Characteristics	Kharanorsky reservoir	Onon River	Nercha River	Shilka River	Buyr-Nur Lake
L, mm	128.7–290.0 258.0*	147.6–238.0 167.2*	120.2–174.0	152.0	148.9–151.0
H, mm	93.8–212.3 187.5*	94.9–124.8 102.0*	73.3–112.9	92.1	99.9–102.0
h, mm	65.3–148 130.6*	66.5–112.0 74.9*	51.6-80.0	66.3	69.2–71.1
h <sub>1</sub> , mm	75.0–161.2 152.5*	82.1–134.0 88.9*	68.7–98.1	82.3	63.1–64.9
l <sub>1</sub> , mm	52.5–113.0 104.9*	58.0–99.4 66.9*	50.0-74.0	58.2	83.0-84.8
B, mm	41.2–88.0 79.4*	44.3–76.1 50.7*	39.0–53.9	47.1	46.0-48.0
B/L	$0.316 \pm 0.0055$ $0.308^{*}$	0.294 ± 0.0169 0.289*	$0.317 \pm 0.007$	0.309	0.312 ± 0.0065
R <sub>1</sub>	0.760 ± 0.0311 0.756*	0.763 ± 0.0039 0.758 <sup>*</sup>	0.768 ± 0.033	0.807	0.736 ± 0.0053
R <sub>2</sub>	$0.540 \pm 0.0119$ $0.521^*$	$0.552 \pm 0.0192$ $0.570^{*}$	0.561 ±0.0087	0.571	0.558 ± 0.0052
n (n <sub>1</sub> )	5 (1)	4 (1)	3	1	3

analyses. The following shell dimensions (mm) were measured in all collected animals: length, width, height at umbo and maximal height. For species identification, the ratio of maximal shell inflation to the distance from the umbo to the posterior end of the posterior tooth was determined, according the identification key by Zatravkin and Bogatov (1987) and Starobogatov et al. (2004).

#### DNA extraction, PCR and sequencing analyses

Whole genomic DNA was extracted from small tissue pieces of two individuals (preserved in 96% ethanol) using a standard high-salt protocol (Sambrook, Fritsch and Maniatis 1989). A fragment of ~700 bp of CO1 gene was amplified by PCR, using the primers LCO\_22me2 and HCO\_700dy2 (Walker et al. 2006, 2007) with PCR conditions described in Froufe et al. (2014). Amplified DNA templates were purified and sequenced by a commercial company, Macrogen, using the same primers. Chromatograms were checked by eye using ChromasPro 1.41 (technelysium.com.au) and the alignment was performed using Bioedit v50.9 (Hall 1999). For a preliminary analysis, all *Cristaria* sp. CO1 sequences available on GenBank were downloaded (n= 65). Afterwards, 52 of these sequences were excluded from the present analysis for clarity (they all represented different haplotypes that fell inside the *C. plicata* clade, see results; data not shown). A final alignment was analysed, where the selected outgroups included one *Anodonta beringiana* individual and one *Sinanodonta woodiana* (Table 2).

The final data set was then analysed using maximum likelihood (ML) and Bayesian inference (BI) methods. The best-fit model of nucleotide substitution evolution under corrected Akaike Information Criterion was estimated using JModelTest 2.1.4 (Darriba et al. 2012). Model GTR+I+G was chosen and used in the phylogenetic analyses. ML trees were built in RAxML 7.2.6 (Stamatakis 2006) running 1,000 bootstrap replicates and searching for the best-scoring ML tree. Phylogenetic BI was performed

Species	Locality	Country	Code/GenBank	Study
Cristaria herculea	Onon River	Russia	Biv246	This study
Cristaria herculea	Charanorsky Reservoir	Russia	Biv247	This study
Cristaria plicata	Lower Yangtze	China	EU698893; EU698897; EU698913; EU698948	Jia and Li*
Cristaria plicata	Unknown	China	JF700152; JF700153	Zhang et al.*
Cristaria plicata	Zhejiang	China	FJ986302	Jiang, Zheng and Wang 2010
Cristaria plicata	Unknown	South Korea	GQ451860	Park et al.*
Cristaria plicata	Unknown	South Korea	GU944476	Lee et al. 2012
<i>Cristaria</i> sp.	Lower Yangtze	China	EU698909; EU698910; EU698940; EU698942	Jia and Li*
Anodonta beringiana	Jo-Jo Lake	Canada	DQ272370	Gustafson and Iwamoto 2005
Sinanodonta woodiana	Unknown	Poland	HQ283347	Soroka and Burzynski*

Table 2. List of specimen samples sequenced (CO1) and GenBank accession numbers. \*Unpublished

using MrBayes version 3.2.2 (Ronquist and Huelsenbeck 2003). Two independent runs 1 million generations long were sampled at intervals of 100 generations producing a total of 10,000 trees. Burnin was determined upon convergence of log likelihood and parameter estimation values using Tracer 1.6 (Rambaut and Drummond 2007). Estimates of sequence divergence (uncorrected *p*-distances) were assessed using MEGA 6 software (Tamura et al. 2013).

#### Results

#### Morphometry and species identification

The morphometric characteristics of *C. herculea* are summarized in Table 1. The shell length of the collected *Cristaria* individuals ranged from 120 to 290 mm, the maximum shell height from 73 to 212 mm and the shell width was 39–88 mm. The ratio of maximal shell inflation to the distance, measured from umbo to posterior end of the lateral tooth ( $R_1$ ) was 0.76–0.81, and to shell height measured from the middle of the lateral tooth to ventral margin ( $R_2$ ) – 0.52–0.57. This ratio enabled the identification of the collected mussels as *Cristaria herculea*, according to the published keys (Zatravkin and Bogatov 1987; Starobogatov et al. 2004)

#### Shell morphology

The shells from the reservoir are elongated diamond-shaped with a green-brown or red-brown coloured periostracum, with developed posterior dorsal wing and hardly expressed anterior wing (Fig. 1A, B). On the other hand, the shells from Buir-Nur Lake are oval-triangular with a dark brown or black coloured periostracum and with less developed or broken dorsal wing (Fig. 1 C). The shells from the different river biotopes are elongated, oval-triangular, which may become oval when a dorsal wing is eroded or broken, alate, and with a periostracum colour that varies from yellow-brown to dark brown or black; the posterior dorsal wing is underdeveloped and the anterior dorsal wing is absent (Fig. 1D-F). Umbos are broad and slightly elevated above the dorsal margin. The umbo sculpture is presented in the form of a few sub-concentric bars. The dorsal margin behind the umbo turns into the high posterior wing, which is sometimes eroded or broken. There are large undulating folds or ridges on the posterior slope extending onto the posterior dorsal wing that are expressed more clearly in smaller specimens. The shell anterior margin is straight and the ventral margin may vary from slightly convex to straight or even slightly concave. The posterior margin in river shells is evenly rounded, slightly curved or concave when meeting the dorsal margin. The lateral teeth are straight or slightly curved, one in each valve (Fig. 2). While the anterior adductor scar is deep, the posterior is shallow and slightly visible. The nacre is blue, pale-pink, or yellow-pink



**Figure 1.** *Cristaria herculea* from Upper Amur River basin. **A, B** from Kharanorsky reservoir **C** from Buir-Nur Lake (Mongolia) **D** from Onon River **E** from Shilka River **F** from Nercha River. Scale bar 1 cm.

with large olive spots. The shell outlines of river shells presented, in general, similar anterior margins with those from reservoirs but differ in having a smaller slope of the dorsal margin as seen in Fig. 3 (1-6).



Figure 2. Lateral tooth of riverine shells (upper two) and from reservoir (lower).



Figure 3. Shell outlines of *Cristaria herculea*. 1–3 (reservoir/lakes) 4–6 (rivers).

## Soft body anatomy

A general view of the whole soft body morphology of *C. herculea* is shown in Fig. 4. Mantle colour is creamy white, with black or brown edges (Fig. 4a). Dorsal mantle



**Figure 4.** Morphology of *C. herculea* soft body:  $\mathbf{a}$  – mantle,  $\mathbf{b}$  – outer gill,  $\mathbf{c}$  – inner gill,  $\mathbf{d}$  – foot,  $\mathbf{e}$  – labial palps,  $\mathbf{f}$  – incurrent aperture,  $\mathbf{g}$  – excurrent aperture,  $\mathbf{h}$  – supra-anal aperture,  $\mathbf{i}$  – dorsal adductor muscle,  $\mathbf{j}$  – mantle bridge,  $\mathbf{k}$  – dorsal wing mantle projections,  $\mathbf{l}$  – muscular anterior margin of dorsal mantle wing.



**Figure 5.** *Cristaria herculea*: **A** excurrent aperture (to the left) and incurrent aperture (to the right) **B** excurrent aperture (magnification) **C** shape of papillae in incurrent aperture (magnification).



Figure 6. Labial palps of *C. herculea* (A, B, C) and of *Sinanodonta* sp. (D).

margin presents a well expressed high angle with a comb-shaped projections on the top (Fig. 4k) and a muscular anterior margin (Fig. 4l). Gills are creamy white or light brown; dorsal margin is straight to sinuous and ventral margin is moderately convex. Inner gills are much longer and higher than outer gills (Fig. 4b, c); gill length is 46–54% of shell length, gill height is 25–40% of gill length and outer gill height is 67–75% of the inner gill height. The foot is massive, creamy white and darker distally (Fig. 4d). Labial palps are triangular, creamy white to blue-grey, straight or slightly convex dorsally; straight or gently concave ventrally and bluntly pointed ventrally (Fig. 4e). Labial palp length is 3.9–4.2% of inner gill length and labial palp height 34–35% of labial palp length. Incurrent aperture (Fig. 4f) is longer than the excurrent aperture (Fig. 4g) and shorter than the supra-anal aperture (Fig. 4h). Supra-anal aperture opening is located from the dorsal margin of the posterior adductor muscle (Fig. 4i) to the posterior dorsal edge of the posterior mantle wing. Supra-anal aperture; it is creamy white to pearly white inside, with a very thin yellow-brown marginal band.



Figure 7. Dorsal mantle wing of *C. herculea* with comb-shaped projections.

Mantle bridge (Fig. 4j) separates the excurrent from the supra-anal aperture and is 8-10% of the supra-anal aperture length. Incurrent aperture length is 11-13% of the shell length, is creamy white to light tan within, with a combination of orange, brown and black basal to the papillae and to the bands margin which may present a reticular pattern. Excurrent aperture length is 46% of incurrent aperture length, colour is creamy white within with black or dark brown edges basally, margin papillate; have irregular mottled pigmentation of some combination of dark brown and orange (Fig. 5A–C). Papillae of the incurrent aperture are located in 3–4 rows, linearfusiform in shape, mostly simple, with thickening of the papilla basement in the first and second medial rows, dark-orange; papillae of outer or lateral rows are shorter and more numerous (Fig. 5C). Labial palps of *Cristaria herculea* and *Sinanodonta* sp. are morphologically distinct (Fig. 6A-D). The anterior acuminate edges of Sinanodonta sp. labial palps are not completely attached to the mantle (Fig. 6D) in contrast with those on *C. herculea* (Fig. 6A–C). The distinctive feature of the genus *Cristaria* within the tribe Anodontini is the posterior dorsal mantle wing and projections (Fig. 7). The comb-shaped projections are dorsal extensions of the mantle that penetrate into the cavities of shell wing, to provide for the wing growth.

#### Phylogenetic analysis

Aligned CO1 sequences had a total length of 620 bp, with 143 polymorphic and 92 parsimony informative sites. No indels and no unexpected stop codons were observed after translating all sequences to amino acids. The tree topologies resulting from the single tree recovered from ML and BI approaches were congruent, and results of both analyses are shown in Figure 8. Two major mtDNA clades were retrieved with strong



**Figure 8.** Phylogenetic tree obtained by Bayesian Inference and Maximum Likelihood analyses, using mtDNA fragments (CO1). Support values are given as Bayesian posterior probability above nodes and as bootstrap support below nodes, except for those within major clades, which have been omitted for clarity. Available sequences downloaded from GenBank and new sequences codes refer to Table 2.

support: one includes all the individuals from *Cristaria plicata*, including the new sequences collected for this work (Biv246 and Biv247; Fig. 8) and the other includes six individuals also originally assigned to *Cristaria plicata* (Jia and Li, Unpublished). However, it is obvious that the phylogeny of the *Cristaria* genus needs further evaluation, since these individuals are 8.9% (uncorrected *p*-distance) from the others, strongly indicating the existence of two different *Cristaria* species in this data set. Thus, this clade is here referred as *Cristaria* sp.

### Discussion

The whole shell morphology of *C. herculea* from the Upper Amur basin described here is very similar and corresponds to that previously described by Zhadin (1938 1965) for *C. plicata*. Relative to *C. tuberculata*, Prozorova and Sayenko (2001) contend

that, although shell shape differences are considerably smoothed with age or in more dynamic habitats, there are enough conchological differences and divergence in ecological preferences to distinguish them easily using both morphological and ecological characters. On the other hand, while many early researchers gave special importance to soft body anatomical characters in freshwater bivalves for taxonomic research (e.g. Ortmann 1923; Reardon 1929; Fuller and Bereza 1975; Kat 1983; Bogan 1992), there is no published information about anatomical differences between these two species. The soft body anatomy described here for the *C. herculea* from Transbaikalia and the previously described *C. herculea* from the Far East (Khanka Lake) (Sayenko and Bogatov 2004) are similar, although the papillae of the incurrent aperture of *C. herculea* from Khanka Lake (Far East) have no thickening and are located more closely in contrast to Transbaikalian ones (Sayenko and Bogatov 2004) (Fig. 5 A–C).

The study of C. herculea and C. tuberculata glochidia has also shown no differences in shell size and proportions or in the disposition of macro spines on the distal end of hooks (Sayenko 2006). Sayenko noted that the morphological indices of C. herculea and C. tuberculata glochidia, when compared with the indices of C. plicata from China and similar species from Japan, are within the same size and shape range limits. Under this view, the selected morphological features of glochidia, on which is based the separation of species Cristaria herculea, Cristaria tuberculata, and Cristaria plicata are varied and probably cannot be considered as systematic. Furthermore, no differences were revealed in the reproductive cycle timing of Cristaria species from Khanka Lake (Far East Russia) and Biwa Lake (Japan). In both lakes, reproduction may last from October to April (Higashi and Hayashi 1964; Chernyshev 1996; Prozorova and Sayenko 2001). In another study, based on the similarity level analyses of the electrophoretic patterns of myogens, Kodolova and Logvinenko (1988) concluded that both C. tuberculata and C. herculea belong to one single species. More recent publications by Graf (2007) and He and Zhuang (2013) based on morphological observations, also state that C. tuberculata and C. herculea represent a single species, C. plicata. The synonymy of C. herculea from the Transbaikalia with C. plicata is confirmed in the present study since they both fall inside the diverse Cristaria plicata clade. An additional clade was retrieved with sequences from the Yangtze basin (China) mussels. Although these animals were originally described as C. plicata, they belong to a distinct Cristaria sp. which may refer to either Cristaria tenuis (Griffith & Pidgeon, 1833) or Cristaria radiata Simpson, 1900, both present in the Yangtze River basin (He and Zhuang 2013). Furthermore, the newly sequenced C. herculea individuals collected from Transbaikalia are five mutations away from the closest Yangtze haplotype (data not shown). Thus, more individuals from the Transbaikalia, including the vast Amur basin, as well as specimens from Far East Asia (e.g. Khanka Lake) are needed to determine if they form a distinct evolutionary unit (e.g. subspecies) within Cristaria plicata.

In summary, the shell morphology, anatomy, and known ecological traits of *C. herculea* from the Upper Amur basin are similar to those described for *C. plicata*. Additionally, the CO1 molecular analysis confirms *C. herculea* as a synonym of *C. plicata*. As for *C. tuberculata*, while some studies reported similar morphological and molecular characters to *C. herculea*, other authors reported differences not only in shell shape

(inflation) but also in ecological requirements and morphological features of the glochidia, suggesting the occurrence of two distinct species in Far East Russia. Therefore, the distinction of *C. tuberculata* from *C. herculea/C. plicata* is still an open question that should be carefully investigated using additional molecular data.

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RESEARCH ARTICLE



# A new species of *Gastrosaccus* Norman, 1868 (Mysida, Mysidae, Gastrosaccinae) from a sandy shore of Indonesia

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#### Abstract

A new species of the mysid crustacean genus *Gastrosaccus* Norman, 1868 (Mysida, Mysidae, Gastrosaccinae) is reported from a sandy shore of Lombok Island, Indonesia. These specimens resemble *G. sorrentoensis* Wooldridge & McLachlan, 1986 and *G. yuyu* Bamber and Morton, 2012 by the possession of an articulated process on the fifth abdominal somite together with a fringe of spine-like filaments on the posterodorsal margin of the carapace. The Lombok population differs from the known congeners by having comparatively fewer numbers of carpopropod segments on the endopod of the third to eighth thoracic limbs and the conformation in the telson and in the male third pleopod. Hence, *G. lombokiensis* **sp. n.** is proposed herein as a third species of "*G. sorrentoensis*" species group.

#### **Keywords**

Mysid shrimp, taxonomy, new species, Lombok Island, Indonesia

#### Introduction

The mysid genus *Gastrosaccus* Norman, 1868 (Crustacea, Mysida) currently comprises 24 species (Mees and Meland 2013) and has been recorded in the coastal waters of the eastern Atlantic to the western Pacific, through the Indian Ocean. Among these members, two species are particularly remarkable by having an articulated broad process on the fifth abdominal somite as well as a fringe of spine-like filaments on the posterodorsal margin of the carapace, i.e., *Gastrosaccus sorrentoensis* Wooldrige & McLachlan, 1986 recorded from Western Australia and *G. yuyu* Bamber & Morton, 2012 from Java Island, Indonesia. They are assigned in this paper to the "*G. sorrentoensis*" species group. Interestingly, *G. yuyu* is reported to be harvested for human consumption on sandy beaches of Java (Bamber and Morton 2012).

During a recent survey of coastal crustaceans in Indonesia, which aimed in part to clarify the nature of planktonic crustacean fisheries in the country (Mantiri et al. 2012), several specimens of gastrosaccini mysids sharing the aforementioned intriguing characters were found from a sandy beach collection in Lombok Island. Morphological analysis revealed that these specimens differ from the known relatives in having the carpopropodus of the thoracic endopods with comparatively fewer numbers of segments, as well as the ornamentation in the telson and the structure of the third male pleopod. Consequently, *Gastrosaccus lombokiensis* sp. n. is described here as the third species of the "*G. sorrentoensis*" species group from Lombok Island, southern Indonesia.

#### Materials and methods

The sampling site, Padak Guar beach is located on the north-east coast of Lombok Island, Indonesia. The beach substratum is predominately fine sand particles.

The material used in this paper was collected by the second author (RM) using a push net (2 m in mouth width, 3 m long, and 1 mm mesh openings), which was towed along the beach on the evening of June  $6^{th}$ , 2010. Mysid specimens were fixed in 70–99% ethanol immediately upon collection and preserved prior to analysis.

Body size of mysids (TL: mm) was measured between the distance from the apex of the rostrum to the posterior end of the telson excluding the apical spine-like setae. Description is based on adult specimens unless stated otherwise. Watling's (1989) setal/spine system was basically adopted for the terminology of cuticle projections.

The type specimens are deposited in the National Museum of Nature and Science at Tsukuba, Japan (NSMT).

#### Taxonomy

## Family Mysidae Haworth, 1825 Subfamily Gastrosaccinae Norman, 1892

#### Genus Gastrosaccus Norman, 1868

*Gastrosaccus* Norman, 1868: 438. *Acanthocaris* Sim, 1872: 185. *Pontomysis* Czerniavsky, 1882: 77.

## Type species. Mysis spinifera Goës, 1864; by monotypy.

**Remarks.** Norman (1868) instituted the genus *Gastrosaccus* to accommodate mysid specimens having a characteristic formation of marsupium, for which the pleura of the female first abdominal somite are greatly expanding as to support the oostegites. When establishing *Gastrosaccus*, Norman actually intended to place *M. spinifera* Goës, 1864, in the genus but he mistakenly referred his specimens to *M. sancta* van Beneden, 1861 because he first thought that *M. spinifera* could be a synonym of *M. sancta*. This was later corrected by replacing it with *G. spinifer* (see Norman 1892, Tattersall and Tattersall 1951). The genus currently contains 24 species (Mees and Meland 2013).

#### Gastrosaccus lombokiensis sp. n.

http://zoobank.org/69425BB7-03E6-4FA1-8AF9-18A878A4CC7B Figs 1–5

Holotype. Male (TL ca. 7.5 mm) (NSMT-Cr 22940), sandy beach, Padak Guar (08°25.665'S, 116°42.561'E), Lombok Island, push net, evening time (17:00), 6 June 2010, coll. R. Mantiri.

**Paratypes.** 11 males (TL 4.0-ca. 7.5 mm), 3 females (TL 4.0-ca.7.5 mm), 3 juvs (TL 2.8–3.5 mm) (NSMT-Cr 22941), data same as for holotype.

**Diagnosis.** Rostrum produced into sub-triangular plate. Posterodorsal edge of carapace bearing 7–12, commonly 9–11, spine-like filaments between dorsolateral slits and normally further 5–10 feeble denticulations/undulations on each side of posterolateral lobe posterior to slit. Fifth somite of abdomen with articulated triangular process at posteromedian end; pleuron of female first somite greatly expanded, fully covering marsupium. Telson typical of Gastrosaccinae form, with apical cleft occupy-ing 1/8–1/6 length of telson, armed laterally with 8 or 9 robust spine-like setae, including posteriormost one. Uropod with exopod shorter than endopod, armed laterally with 13 or 14 spine-like setae; endopod with 6 or 7 spine-like setae on mesial margin. Labrum with single anteromedian tooth and additional smaller spines absent. Third pleopod of male with endopod multi-articulated; exopod greatly elongated, extending well beyond sixth abdominal somite, comprising 4 major segments, and basal segment



**Figure 1.** *Gastrosaccus lombokiensis* sp. n., entire body of paratype male (TL 6.9 mm) in lateral view. Scale = 1 mm.

without distinct sub-articles, distal segment 0.65–0.7 times length of penultimate one, armed with short sub-terminal seta and moderately long 2 terminal setae. First pleopod of female bi-lobed, second to fifth pleopods rudimentary, unsegmented lobe.

Description. Male. Body (Fig. 1) moderately robust.

Carapace (Figs 1, 2a, b) produced into sub-triangular rostrum with sub-acute apex; posterior dorsal margin deeply excavate, leaving exposed last thoracic somite, dorsolateral part of emargination forming slit with posterior lobe overlapping onto anterior one; lateral wing of carapace well developed, extending to anterior 1/3 of first abdominal pleuron; anterolateral part rounded; cervical sulcus marked dorsally anterior to anterior 1/3; posterior dorsal edge between dorsal slits bearing 7–12, most commonly 9–11, spine-like filaments, and further 5–10 feeble denticles/undulations on each margin posterior to slit (often hard to define exact numbers due to its poor development particularly in posterior part).

Abdomen (Figs 1, 2c) with anterior 4 somites rounded dorsally, sub-equal in length; fifth somite rounded dorsally, 1.3–1.4 times longer than precedents, with remarkable articulated sub-triangular process on posterodorsal margin; sixth somite very slightly longer than fifth, with transverse carinate ridge on anterodorsal part; brown to dark-brown melanophores on lateral surface of first to fifth somites and also in posterolateral part of sixth somite in ethanol preserved specimens.

Antennule (Fig. 2d) with basal segment longest, very slightly shorter than length of 2 anterior segments combined; second segment shortest, about 0.55 times longer than wide, with 2 spine-like setae, one at mid-length and another one at anterior end of lateral margin; third segment about twice the length of second, with short spinelike seta at distal 1/3 of lateral margin; lateral flagellum slightly widened at mesiobasal part, forming somewhat small male lobe bearing moderately long sensory setae; mesial



**Figure 2.** *Gastrosaccus lombokiensis* sp. n., paratype male (TL ca. 7.5 mm) (**a**, **c**-**h**) and paratype female (TL ca. 7.5 mm) (**b**): **a** carapace and cephalic appendages in male, dorsal view **b** same in female **c** fifth and sixth abdominal somites, dorsal view **d** right antennule, dorsal view **e** right antenna, dorsal view **f** labrum, ventral view **g** right mandible, external view **h** same, distal article of mandibular palp enlarged.

flagellum more slender than lateral one. Antenna (Fig. 2e) with scale proportionately short, barely reaching or falling slightly short of anterior end of second antennular segment, slightly more than 3 times as long as wide, lateral margin smooth, distolateral spine not extending beyond anterior margin of lamella; antennal peduncle long, extending slightly beyond scale, penultimate segment elongated, approximately 3 times as long as distal one.

Labrum (Fig. 2f) with single sharp anteromedian tooth, additional teeth absent.

Mandibular palp (Fig. 2g, h) composed of 3 segments, distal segment about 0.8 times length of penultimate, with 2 long terminal setae, of which proximal one curved around its mid-length, often forming sub-chelate structure with terminal segment, and another seta moderately long at distal end, and also about 3 short spine-like setae as well as several short obtuse setae, all confined to distal part, forming comb-like structure. Mouthparts (maxillule, maxilla and second thoracopod) general form of genus (Fig. 3a, b, e). First thoracopod (Fig. 3c, d) with basal plate of exopod about 1.6 times length of its width.

Third to eighth thoracopods (Figs 3f, 4a, b) similar in basic structure; exopods with basal plate smooth on lateral margin, and small process at distolateral corner except for eighth limb, and also with 11–14 segmented flagellar part; third to eighth endopods with carpopropodus composed of 5–9 segments, progressively increasing in numbers posteriorly, in which eighth endopod is divided into 8 or 9 segments.

Penis (Fig. 4b) about 1.7 times as long as wide, with short terminal seta directed posteriorly and 4 or 5 long setae along lateral surface.

All pleopods of male biramous (Figs 1, 5a–e). First pleopod with sympod bearing several long setae along anterior margin; endopod rudimentary, unsegmented lobe possessing several marginal setae distally; exopod articulated to about 8 segments. Second pleopod with endopod articulated to about 7 segments; exopod articulated to about 8 segments, slightly longer than endopod. Third pleopod with endopod articulated to 6 or 7 segments; exopod greatly elongated, extending beyond posterior end of abdomen fully by distal segment, composed of 4 major segments, basal segment markedly compressed and broader than distal series of segments, sub-equal length or very slightly longer than second one, without distinct sub-segments but with slight indication of 2 incipient articulations, second segment tubular and unarmed, penultimate segment bearing short spine-like sub-distal seta, distal segment shortest, 0.65–0.70 times length of penultimate, armed distally with 2 moderately long spine-like setae with subsidiary setules on its distal half. Fourth and fifth pleopods similar in basic form, endopod unsegmented, bearing a few setae on distal margin; exopod articulated to about 8 segments.

Uropod (Fig. 4d) with exopod shorter than endopod, lateral margin armed with 13 or 14 robust spine-like setae, length increasing posteriorly, each spine-like seta with subsidiary setules on posterior margin and also short terminal protrusion; endopod extending beyond telson and reaching as far as end of distal telson setae, commonly bearing 7, occasionally 6, spine-like setae along entire mesial margin, showing general tendency towards increased setae length distally.



**Figure 3.** *Gastrosaccus lombokiensis* sp. n., paratype male (TL ca. 7.5 mm): **a** right maxillule, external view **b** right maxilla, external view **c** right endopod of first thoracic limb, external view **d** right exopod of first thoracic limb, external view **e** right second thoracic limb, internal view **f** right third thoracic limb, posterior view.

Telson (Fig. 4c) 1.1–1.2 times as long as sixth abdominal somite and 2.6–2.8 times as long as wide, apical cleft occupying about 1/7 length of telson, bearing approximately 15 dentations along each mesial margin; lateral margin with 8 or 9 spine-like setae of varying length, including longest apical seta, penultimate seta distinctly shorter than apical and located noticeably posterior to level of anterior edge of apical cleft, proximal lateral seta sub-equal in length to penultimate one, posterior series of lateral setae spaced equidistantly and unarmed gap between apical and penultimate setae subequal in distance with those of others; procurved sharp process (Fig. 4c') present at proximal part of ventral side. Melanophores widely distiributed on dorsal surface of telson but not along mesiodorsal axis and often distal part of apical lobes in both sexes.

Female. Sexual dimorphism as common for genus.

Pleuron of first abdominal somite greatly expanded, fully covering marsupium.

Antennule (Fig. 2b) might differ slightly from that of male but is damaged in the present material and not dissected.

First pleopod (Fig. 5f) biramous, with unsegmented endopod and exopod, subequal in length and markedly shorter than sympod, exopod and endopod each with several long plumose setae on distal part; sympod with a few long setae near anterobasal part and further several long setae along anterior distal margin. Second to fifth pleopods (Fig. 5g) similar in shape and size, all rudimentary, unarticulated rod-shaped lobe, bearing several long setae on lateral surface and also on distal margin.

Etymology. The name "lombokiensis" refers to the type locality, Lombok Island.

**Remarks.** This species is remarkable among the members of *Gastrosaccus* in having an articulated process at the posterodorsal end of the fifth abdominal somite throughout its life stages, coupled with a fringe of spine-like filaments on the posterodorsal margin of the carapace. The combination of these intriguing characters is shared by *G. sorrentoensis* Wooldridge & McLachlan, 1986 from Western Australia (see also Hanamura 1998) and *G. yuyu* Bamber & Morton, 2012 from Java Island, Indonesia.

Specimens from Lombok Island have the carpopropodus of the thoracic endopods comprising fewer numbers of segments, and at most 8 or 9 segments in the eighth limb compared to 13 or more segments in the previously known species (Table 1). There is a slight possibility that the paucity in the segment counts in Lombok specimens is due to comparatively smaller body sizes, thus showing a condition of younger stages. Although ovigerous females were not available in our collection, the largest female has a well-developed first abdominal pleuron, which is fully covering the marsupium lamellae. Also larger males (> ca. 6.5 mm) were considered as adult because there third pleopods are fully developed, extending well beyond the posterior margin of the abdomen at least by length of distal article. Furthermore, the posterior part of the *vas deferens* of several males exhibited whitish colour just above the ejaculatory duct, common in mature males.

The male third pleopodal exopod of this group basically has four major segments. In *G. sorrentoensis* and *G. yuyu*, the basal article is divided further into two or three



**Figure 4.** *Gastrosaccus lombokiensis* sp. n., paratype male (TL ca. 7.5 mm): **a** right sixth thoracic limb, posterior view **b** left eighth thoracic limb and penis, anterior view **c** telson, dorsal view **c'** basal part of telson, lateral view **d** right uropod, dorsal view.



**Figure 5.** *Gastrosaccus lombokiensis* sp. n., paratype male (TL ca. 7.5 mm) ( $\mathbf{a}$ - $\mathbf{e}$ ) and paratype female (TL ca. 7.5 mm) ( $\mathbf{f}$ ,  $\mathbf{g}$ ):  $\mathbf{a}$  right male first pleopod, mesial view  $\mathbf{b}$  right male second pleopod, mesial view  $\mathbf{c}$  right male third pleopod, lateral view  $\mathbf{d}$  right male fourth pleopod, lateral view  $\mathbf{e}$  right male fifth pleopod, mesial view  $\mathbf{f}$  right first female pleopod, mesial view  $\mathbf{g}$  right female third pleopod, mesial view.

short sub-segments instead of an entire basal article, without distinct short sub-segments. In the Lombok population, we do not find distinct short sub-articulations. However, a slight indication of incipient sub-segmentations was observed in the inter-

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Item/species	G. sorrentoensis Wooldridge & McLachlan, 1986	G. yuyu Bamber & Morton, 2012	G. lombokiensis sp. n.
Rostrum	wide triangular protrusion with sub-acute apex	tongue-like protrusion with widely round apex	sub-triangular protrusion with sub-acute apex
Posterior margin of carapace	about 25 spine-like filaments between dorsolat- eral slits and 14–25 filaments or undulations on dorsolateral edge posterior to slits (fewer number of filaments in smaller specimens)	6–12 spine-like filaments between dorsolateral slits and 6–12 filaments on dorsolateral edge posterior to slits	7–12, commonly 9–11, spine-like filaments between dorsolateral slits and 5–10 very feable denticles or undulations on dorsolateral edge posterior to slits
Mandibular palp	distal segment 0.8 times length of penultimate, terminally with long slender seta and long robust undulate seta directed laterally	distal segment 0.9 times length of penultimate, terminally with 2 slender setae not distinctly directed laterally	distal segment 0.8 times length of penultimate, terminally with long slender seta, long undulate seta directed laterally and one moderately long seta
First thoracic limb	basal plate of exopod about twice length of width	basal plate of exopod about 1.5 times length of width	basal plate of exopod about 1.6 times length of width
Third to eighth thoracic limbs	carpopropodus of endopod with 8–16 segments, and 14–16 on eighth	carpopropodus of endopod with 12–14 segments, and probably 13 or 14 on eighth	carpopropodus of endopod with 5–9 segments, and 8 or 9 on eighth
Female first pleopod	endopod slightly longer than exopod; sympod about 4 times length of width	endopod distinctly longer than exopod; sympod about 4 times length of width	endopod slightly longer than exopod; sympod about 3 times length of width
Male third pleopo- dal exopod	basal segment noticeably longer than second, divided into distinct 3 short sub-segments; distal segment 0.75 times length of penultimate	basal segment noticeably longer than second, divided into 2 or 3 sub-segments; distal segment 0.8 times length of penultimate	basal segment not divided into distinct sub-seg- ments but with slight sign of possible 2 indicipent segmentations; distal segment 0.65–0.70 times length of penultimate
Uropodal endopod	5 or 6 irregularly spaced mesial setae along entire margin	7 or 8 irregularly spaced mesial setae confined to basal 2/3	usually 7, occasionally 6, irregularly spaced mesial setae along entire margin
Telson	sharp process present at proximalventral part; about 2.5 times as long as wide; apical deft 1/6 length of telson; 7 or 8 robust lateral setae, penultimate seta arising around level of anterior end of apical deft, apical spine distinctly longer than penultimate	sharp process absent at proximal ventral part; about 2.8 times as long as wide, apical deft 1/8 length of telson; 10 robust lateral setae, penul- timate seta arising anterior to anterior end of apical cleft, apical spine very slightly longer than penultimate	sharp procurved process present at proximal ventral part, 2.6–2.8 times as long as wide, apical cleft 1/8–1/7 length of telson, 8 or 9 robust lateral setae, penultimate seta arising distinctly posterior to ante- rior end of apical cleft, apical spine distinctly longer than penultimate
Body size	male 7.0–9.3 mm, female 8.5–11.3 mm	male holotype 8.4 mm, female 9–13 mm	male ca. 6.5–7.5 mm, female ca. 7.5 mm
Occurrence	surf zone of sandy beach, Perth, Western Australia	surf zone of sandy beach, Java, Indonesia	surf zone of sandy beach, Lombok, Indonesia
Data source	Wooldridge and McLachlan 1986; Bamberand Morton 2012	Bamber and Morton 2012	present study

# New species of Gastrosaccus from Indonesia

nal muscular part; but an associated segmented exoskeleton could not be found. Also the shape of the telson is noticeably different among the three populations and these features are regarded as size independent.

Compared to those of *G. sorrentoensis*, the Lombok population tended to have larger number of spine-like setae in the uropodal endopod and telson despite their smaller body size. The female telson of *G. sorrentoensis* bears a pair of pigmented spots at the inner side of the fifth lateral setae (Wooldridge and McLachlan 1986) whereas in Lombok specimens the telson is tinted by melanophores widely along the margins in both sexes.

According to Bamber and Morton (2012), the Javanese G. *yuyu* is devoid of an anteroventral process on the telson, and this feature is unique among the three populations.

Our observation suggested that *G. lombokensis* starts to develop external secondary sexual characteristics at a size around TL 3.5-4 mm in both sexes.

**Distribution.** This species is known only from the sandy shore of Lombok Island, Indonesia.

#### Further notes on morphological characteristics of Gastrosaccus and related genera

The possession of an articulated process on the fifth abdominal somite together with spine-like filaments on the carapace is a remarkable feature among the 25 species of *Gastrosaccus* known to date, although the latter character is shared by several species of *Gastrosaccus* as well as *Eurobowmaniella* Murano, 1995 (see Bamber and Morton 2012). Interestingly, *Chlamydopleon* Ortmann, 1893 has a similar type of articulated projection on the fifth abdominal somite. Based on this and several other congruent characters, *Bowmaniella* sensu Băcescu, 1968 is now split into the two genera, *Chlamydopleon* Ortmann, 1893 and *Coifmanniella* Heard & Price, 2006 (Wittmann 2009). In the "*G. sorrentoensis*" species group, this articulated process may be present throughout the entire life history (Bamber and Morton 2012, present study).

*Iiella kojimaensis* (Nakazawa, 1910) has been believed to possess a posterodorsal process on the fifth somite (Ii 1964, Băcescu and Udrescu 1982, Bamber and Morton 2012). This morphological recognition in *I. kojimaensis* is probably due to Ii (1964: 240), who noted that the fifth abdominal somite of this species has an obtuse posterodorsal projection. That projection suggested by Ii, however, might have been confused with a transverse ridge (fold/apophysis) situated at the anterior dorsal end of the sixth somite (cf., Jo 1991, personal observations), which is a structure commonly observed across species of *Gastrosaccus* and its closer allies (e.g., Jo 1991, Jo and Murano 1992, Murano 1995, Hanamura 1997, personal observations).

Similarly, *Eurobournaniella simulans* (Tattersall, 1915) has been reported to bear a mid-dorsal apophysis on the fifth abdominal somite in its early life stage. We have re-examined specimens of *E. simulans* (TL 2.3–7.1 mm) collected from the northern Malacca Strait, but have failed to observe an articulated process, even in the smallest specimens. However, an anterodorsal ridge of the sixth abdominal somite is present throughout the

Item/genera	Archaeomysis Czerniavsky, 1882	Chlamydopleon Ortmann, 1893	<i>Coifmanniella</i> Heard & Price, 2006	<i>Eurobowmaniella</i> Murano, 1995	Gastrosaccus Norman, 1892	<i>Haplostylus</i> Kossman, 1888	<i>Iiella</i> Băcescu, 1968
Posterior dorsal margin of carapcace	no median concavity; no fringe of spine-like filaments	median concavity and protruded median lobes; no fringe of spine-like filaments but with minute undulations	median concavity and protruded median- lobes; no fringe of spine-like filaments but minute undulations	no median concavity; fringe of spine-like filaments	median concavity and protruded median lobes present/absent, fringe of spine-like filaments present or absent	median concavity and protruded median lobes present/absent; no fringe of spine-like filaments	no median concavity; no fringe of spine-like filaments
Labrum	single long anterome- dian spine	long anteromedian and several additional smaller spines	long anteromedian and several additional smaller spines	long anteromedian and several additional smaller spines	single long anterome- dian spine	single long anterome- dian spine	long anteromedian and several additional smaller spines
Abdomen (fifth somite)	no movable process at posterodorsal margin	movable process present at posterodorsal margin	no movable process at posterodorsal margin	no movable process at posterodorsal margin	no movable process at posterodorsal margin (except <i>G. sorrentoensis</i> and its closest affinities)	no movable process at posterodorsal margin (except H. brisba- nensis)	no movable process at posterodorsal margin
Male second pleopod	exopod multi-segments; endopod multi- segments	exopod multi-segments; endopod uni-segment	exopod multi-segments; endopod uni-segment	exopod multi-segments; endopod multi- segments	exopod multi-segments; endopod multi- segments	exopod multi-segments; endopod uni-/multi- segments	exopod multi-segments; endopod multi- segments
Male third pleopod	exopod styliform; endopod multi- segment	exopod greatly complicated; endopod uni-segment	exopod greatly complicated; endopod uni-segment	exopod moderately modified; endopod multi-segments	exopod styliform; endopod multi- segments	exopod styliform; endopod uni-segment	exopod styliform; endopod multi- segments
Female pleo- pods	first pleopod biramous; second-fifth pleopods with rudimentary exopod	first pleopod biramous; second-fifth pleopods rudimentary rod-shaped lobe	first pleopod biramous; second-fifth pleopods rudimentary rod- shaped lobe	first pleopod biramous; second-fifth pleopods rudimentary rod- shaped lobe	first pleopod biramous; second-fifth pleopods rudimentary rod- shaped lobe	first pleopod biramous; second-fifth pleopods rudimentary rod- shaped lobe	first pleopod unira- mous; second-fifth pleopods rudimentary rod- shaped lobe
Geographical range	North Pacific, from Hong Kong to Califor- nia, through subarctic Pacific islands	tropical and subtropical coasts of East Pacific as well as West Atlantic	tropical coasts of East Pacific and tropical and subtropical coasts of West Atlantic	Northeastern Indian Ocean, from India to northwestern Malay Peninsula	tenperate to tropical waters of East Atlantic through Indian Ocean to Australia and New Zealand	Mediterranean Sea through Indian Ocean to western Pacific	Northwestern Pacific, from Singapore to Ja- pan and Korea

genera.
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Table

Data sources: Jo and Murano (1992), Murano (1995), Hanamura (1997), Heard and Price (2006), Wittmann (2009), Fukuoka (2011), and Bamber and Morton (2012).

observed size ranges (see also Hanamura et al. 2007). Further our examination demonstrated that smallest juveniles of *E. simulans* (TL 2.5 mm) have a smooth posterodosal carapace edge, where the spine-like filaments subsequently appeared in later stages (TL  $\geq$  3 mm). Bamber and Morton (2012) remarked that the posterodorsal filaments of the carapace observed in *G. sorrentoensis* are also fewer in numbers in smaller individuals than in fully grown adults, indicating its progressive development with growth.

The East Australian species *Haplostylus brisbanensis* (Băcescu & Udrescu, 1982) appears to have the same type of articulated process that is found in *Chlamydopleon* and the "*G. sorrentoensis*" species group. *Haplostylus brisbanensis*, however, has no spine-like filaments on the carapace and the endopod of the third male pleopod is reduced to a non-articulated lobe, a typical form for *Haplostylus* (see Băcescu and Udrescu 1982, Wooldridge and McLachlan 1986).

The character distribution among the genera of *Gastrosaccus* affinities is an admixture of character states (Table 2). The articulated abdominal process is shared by small members of this animal group that are found in the geographically isolated Pacific and Atlantic coasts of American continents and Indonesia-Western Australian coasts. This remarkable morphological structure is most probable to have been acquired independently in different lineages rather than it is regarded as a plesiomorphic character and lost in the majority of gastrosaccini descents, although its phylogenetic significance is still not very clear. The taxonomic position of the Indonesia–Australian species of *Gastrosaccus* (and also *Haplostylus brisbanensis*) that bear the articulated abdominal process would be a subject of future consideration.

The finding of *G. lombokiensis*, as a third species of the "*G. sorrentoensis*" group, implies possible further diversification of this species group in the eastern Indian Ocean. Despite a rather intensive survey of the beach mysids across the South East Asia, other species of gastrosaccini mysids could not be found except for *E. simulans*, which was sampled in sandy beaches of Langkawi Island, off the north-east coast of Peninsular Malaysia (Hanamura et al. 2007). Hence, the "*G. sorrentoensis*" species group is highly probable to be endemic to the south-east Indian Ocean Arc, in a somewhat restricted geographical area from Indonesia through Australia.

### Key to the species of the "Gastrosaccus sorrentoensis" group

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RESEARCH ARTICLE



# The genus Galumna in Nepalese oribatid mite fauna, with notes on systematic placement of some species (Acari, Oribatida, Galumnidae)

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#### Abstract

The oribatid mite genus *Galumna* (Oribatida, Galumnidae) is recorded for the first time in Nepal. A new species, *Galumna tetraporosa* **sp. n.**, is described from soil of secondary mixed broadleaved forest. It is most similar morphologically to *G. tokyoensis* Aoki, 1966 and *G. valida* Aoki, 1994, however, it differs from both by the absence of interlamellar setae and the presence of two pairs of notogastral porose areas *Aa. Galumna granalata* Aoki, 1984 is redescribed on the basis of specimens from Nepal. *Galumna floridae* (Jacot, 1929) and *G. hexagona* Balogh, 1960 are transferred to the genus *Notogalumna*; *G. mauritii* Mahunka, 1978 is transferred to the genus *Dimidiogalumna*.

#### **Keywords**

Oribatida, new species, supplementary description, new combination, Galumnidae, *Galumna*, *Notoga-lumna*, *Dimidiogalumna*, Nepal

### Introduction

*Galumna* is a genus that was proposed by Heyden (1826) with *Notaspis alatus* Hermann, 1804 as type species. Currently, it comprises more than 170 species having a cosmopolitan distribution (for example, Subías 2004, online version 2014). The main generic characters are summarized by Ermilov et al. (2013). An identification key to many species of *Galumna* has been presented by Balogh and Balogh (2002). In the course of taxonomic identification of Nepalese *Galumna*, we discovered two species: *G. granalata* Aoki, 1984 and a new one. This genus is recorded for the first time in Nepal. The primary goal of this paper is to describe and illustrate a new species. The secondary goal is to make a supplementary description of *G. granalata* based on the Nepalese material. This species was described Aoki (1984) and is distributed in Japan and Taiwan (Subías 2004, online version 2014). The original description of *G. granalata* is incomplete (lacking information about the length of morphological structures, leg setation and solenidia, gnathosoma; only figures of the pteromorph and the dorsal side of the body present).

Additionally, the systematic placement of three species of the genus *Galumna*, *G. floridae* (Jacot, 1929), *G. hexagona* Balogh, 1960 and *G. mauritii* Mahunka, 1978, are discussed.

#### Material and methods

Three specimens (holotype: male; two paratypes: one male and one female) of *Galumna tetraporosa* sp. n. are from: Nepal, 2450–2720 m a.s.l., Terhathum District, ridge Tinjura Dara, broadleaved forest, soil, 17.IX.1983, collected by J. Martens and B. Daams.

Eight specimens of *Galumna granalata* are from: Nepal, 1650–1800 m a.s.l., Taplejung District, valley of the Kabeli River, below village Yamputhin, secondary mixed broadleaved forest with bamboo, soil, 03–04.IX.1983, collected by J. Martens and B. Daams.

Specimens were mounted in lactic acid on temporary cavity slides for measurement and illustration. The body length was measured in lateral view, from the tip of the rostrum to the posterior edge of the ventral plate. The notogastral width refers to the maximum width in dorsal aspect. Lengths of body setae were measured in lateral aspect. All body measurements are presented in micrometers. Formulae for leg setation are given in parentheses according to the sequence trochanter–femur–genu–tibia–tarsus (famulus included). Formulae for leg solenidia are given in square brackets according to the sequence genu–tibia–tarsus. General terminology used in this paper follows that of Grandjean (summarized by Norton and Behan-Pelletier 2009).

#### Taxonomy

#### Galumna tetraporosa sp. n.

http://zoobank.org/58AC6AB0-8289-46C9-8BA0-2CADF9DE6029 Figs 1–5

**Diagnosis.** Body size: 913–979 × 730–763. Rostrum pointed. Rostral and lamellar setae of medium size. Interlamellar setae represented by alveolus. Bothridial setae long,



Figure I. Galumna tetraporosa sp. n., adult: dorsal view. Scale bar 200 µm.

clavate, barbed. Lamellar and sublamellar lines divergent in medio-distal part. Anterior notogastral margin not developed. Notogaster with five pairs of small, rounded porose areas, *Aa* divided into two parts. Median pore absent. Aggenital and ano-adanal setae minute. Postanal porose area present, elongated.

**Description.** *Measurements.* Body length: 962 (holotype), 913–979 (two para-types); notogaster width: 730 (holotype), 730–763 (two paratypes).

*Integument*. Body color black to dark brown. Body surface smooth. Pteromorphs with poorly visible radiate wrinkles.



**Figure 2.** *Galumna tetraporosa* sp. n., adult: ventral view (gnathosoma and legs not illustrated). Scale bar 200 µm.

*Prodorsum.* Rostrum with strong tooth (12–20). Rostral setae (*ro*, 53–65) setiform, barbed. Lamellar setae (*le*, 65–77) setiform, little thicker and less barbed than rostral setae. Interlamellar setae absent, represented alveolus. Bothridial setae (*ss*, 114–123) with long stalk and shorter, barbed clavate head. Exobothridial setae absent. Porose areas *Ad* present, elongate oval (24–32 × 12–16), but visible only in dissected specimen. Lamellar lines (*L*) curving backwards; sublamellar lines (*S*) parallel in basal part and divergent in medio-distal part to lamellar lines.


**Figures 3–5.** *Galumna tetraporosa* sp. n., adult: **3** dorso-lateral view of prodorsum and anterior part of notogaster and pteromorph **4** pteromorph **5** posterior view of notogaster. Scale bars 200  $\mu$ m (**3**, **5**), 100  $\mu$ m (**4**).

*Notogaster.* Anterior notogastral margin not developed. Dorsophragmata (*D*) of medium size, elongated. Notogastral setae represented by 10 pairs of alveoli. Five pairs of small, rounded porose areas with distinct borders: Aa divided into two porose areas – smaller lateral (8–16) and larger medial (20–28); A1 (12–16) and A2 (16–28) located close to each other; A3 (24–36) usually largest. Alveoli

Leg	Trochanter	Femur	Genu	Tibia	Tarsus
Ι	v	d, (l), bv"	<i>(l)</i> , ν', σ	<i>(l)</i> , <i>(v)</i> , φ <sub>1</sub> , φ <sub>2</sub>	(ft), (tc), (it), (p), (u), (a), s, (pv), v', (pl), l", $\varepsilon$ , $\omega_1$ , $\omega_2$
II	v	d, (l), bv"	<i>(l)</i> , ν', σ	<i>(l), (v),</i> φ	(ft), (tc), (it), (p), (u), (a), s, (pv), $\omega_1, \omega_2$
III	v	d, ev'	<i>l</i> ', σ	<i>l'</i> , <i>(v)</i> , φ	(ft), (tc), (it), (p), (u), (a), s, (pv)
IV	v	d, ev'	d, l'	<i>l'</i> , <i>(v)</i> , φ	ft", (tc), (p), (u), (a), s, (pv)

Table 1. Leg setation and solenidia of adult Galumna tetraporosa sp. n. (same data for G. granalata Aoki, 1984).

Roman letters refer to normal setae (ε to famulus), Greek letters to solenidia. Single prime (<sup>\*</sup>) marks setae on anterior and double prime (<sup>\*</sup>) setae on posterior side of the given leg segment. Parentheses refer to a pair of setae.

*la* inserted posteriorly to *Aa*. Lyrifissures *im* located anteriorly or antero-laterally to *A1*. Opisthonotal gland openings (*gla*) located antero-laterally to *A2*. Median pore absent.

*Gnathosoma*. Generally, morphology of subcapitulum, palps and chelicerae typical for most Galumnidae (for example, see Ermilov and Anichkin 2010, 2011; Ermilov et al. 2011). Subcapitulum little longer than wide (196 × 192). Subcapitular setae setiform, slightly barbed; *a* (32–36) longer, more barbed and thicker than *m* (24) and *h* (16–20). Two pairs of adoral setae ( $or_1$ ,  $or_2$ , 20) setiform, barbed. Palps (143) with setation 0–2–1–3–9(+ $\omega$ ). Solenidion straight, thickened, bluntended, attached to eupathidium. Chelicerae (246) with two barbed setae; *cha* (94) longer than *chb* (53). Trägårdh's organ distinct.

*Epimeral and lateral podosomal regions*. Apodemes (1, 2, sejugal, 3) well visible. Four pairs of epimeral setae (*1b*, *3b*, *4a*, *4b*) observed ventrally, all setiform, thin, smooth, similar in length (24–32). Discidia (*dis*) triangular, circumpedal carinae (*cp*) distinct.

Anogenital region. Six pairs of genital setae  $(g_1-g_6, 24-28)$  setiform, thin, smooth. Anterior edge of genital plates with three setae. One pair of aggenital (ag), two pairs of anal  $(an_1, an_2)$  and three pairs of adanal  $(ad_1-ad_3)$  setae minute, similar in length (4). Adanal setae  $ad_3$  inserted laterally to adanal lyrifissures *iad*. Postanal porose area (Ap) elongated (36–49 × 8–12).

*Legs.* Generally, morphology of leg segments, setae and solenidia typical for most Galumnidae (for example, see Ermilov and Anichkin 2010, 2011; Ermilov et al. 2011). Formulae of leg setation and solenidia: I (1-4-3-4-20) [1-2-2], II (1-4-3-4-15) [1-1-2], III (1-2-1-3-15) [1-1-0], IV (1-2-2-3-12) [0-1-0]; homology of setae and solenidia indicated in Table 1.

**Type deposition.** The holotype and one paratype are deposited in the collection of the Senckenberg Institution Frankfurt, Germany; one paratype is deposited in the collection of the Tyumen State University Museum of Zoology, Tyumen, Russia.

**Etymology.** The specific name "*tetraporosa*" refers to the four notogastral porose areas *Aa*.

**Remarks.** In having the pointed rostrum and bothridial setae with well developed head, *Galumna tetraporosa* sp. n. is most similar to *G. tokyoensis* Aoki, 1966 from the

eastern Palaearctic region and *G. valida* Aoki, 1994 from the Pacific Islands. However, it clearly differs from both by the absence of interlamellar setae (versus long in *G. tokyoensis* and *G. valida*) and the presence of two pairs of notogastral porose areas *Aa* (versus one pair in *G. tokyoensis* and *G. valida*).

#### Galumna granalata Aoki, 1984

Figs 6–10

**Description.** *Measurements.* Body length: 431–464 (eight specimens); notogaster width: 332–356 (eight specimens).

*Integument*. Body color light brown. Body surface smooth. Pteromorphs with radiate wrinkles and small (length up to 12), elongate, grain-shaped tubercles. Wrinkles and tubercles very poorly visible in some specimens.

*Prodorsum.* Rostrum rounded. Rostral (28–32) and lamellar (16–20) setae setiform, thin, smooth, often not visible in dorsal view. Interlamellar setae minute (4). Bothridial setae (57–65) with long stalk and shorter, barbed, clavate head. Exobothridial setae absent. Porose areas *Ad* present, elongate oval (10–16 × 4–6). Lamellar and sublamellar lines parallel, curving backwards.

*Notogaster*. Anterior notogastral margin well developed, convex. Dorsophragmata of medium size, triangular. Notogastral setae represented by 10 pairs of alveoli. Four pairs of rounded porose areas with distinct borders: Aa (16–20) larger than A1 (12–16), A2 (8–10) and A3 (10–16). Alveoli *la* inserted posteriorly to Aa. Lyrifissures *im* located between *lm* and *lp*. Opisthonotal gland openings located laterally to A1. Median pore present, located little posterior to the virtual line connecting porose areas A1.

*Gnathosoma*. Generally, morphology of subcapitulum, palps and chelicerae typical for most Galumnidae (for example, see Ermilov and Anichkin 2010, 2011; Ermilov et al. 2011). Subcapitulum little longer than wide ( $106 \times 98$ ). Subcapitular setae setiform, smooth; *a* (24) longer and little thicker than *m* (12) and *h* (16). Two pairs of adoral setae (10) setiform, slightly barbed. Palps (86) with setation  $0-2-1-3-9(+\omega)$ . Solenidion straight, thickened, blunt-ended, attached to eupathidium. Chelicerae (131) with two barbed setae; *cha* (49) longer than *chb* (28). Trägårdh's organ distinct.

*Epimeral and lateral podosomal regions.* Apodemes (1, 2, sejugal, 3) well visible. Three pairs of epimeral setae (1a, 3b, 4a) observed ventrally, all setiform, thin, smooth; 1a and 3b (12-16) longer than 4a (8). Discidia triangular, circumpedal carinae distinct.

Anogenital region. Six pairs of genital setae (12–16) setiform, thin, smooth. Anterior edge of genital plates with three setae. One pair of aggenital (8), two pairs of anal (4) and three pairs of adanal (4) setae minute. Adanal setae  $ad_3$  inserted laterally to adanal lyrifissures *iad*. Postanal porose area (*Ap*) very small, rounded (6–12). Ovipositor of typical morphology for Galumnidae (Ermilov 2010): elongate, narrow (183 × 41). Length of lobes 77, length of cylindrical distal part 106. Setae setiform, smooth,  $\psi_1 \approx \tau_1$  (36–41) longer than  $\psi_2 \approx \tau_a \approx \tau_b \approx \tau_c$  (16–20). Six setae *k* short (6).



Figure 6. Galumna granalata Aoki, 1984, adult: dorsal view. Scale bar 100 µm.

*Legs.* Generally, morphology of leg segments, setae and solenidia typical for most Galumnidae (for example, see Ermilov and Anichkin 2010, 2011; Ermilov et al. 2011). Formulae of leg setation and solenidia: I (1-4-3-4-20) [1-2-2], II (1-4-3-4-15) [1-1-2], III (1-2-1-3-15) [1-1-0], IV (1-2-2-3-12) [0-1-0]; homology of setae and solenidia indicated in Table 1.



**Figure 7.** *Galumna granalata* Aoki, 1984, adult: ventral view (gnathosoma and legs not illustrated). Scale bar 100 μm.

**Remarks.** Galumna granalata distinctly differs from other species of the genus Galumna by the presence of grain-shaped tubercles (granules in opinion of Aoki) on pteromorphs. The present Nepalese specimens of this species are morphologically and in general appearance similar to the Japanese specimens (Aoki 1984). Only one difference is that the body body size larger (431–464 × 332–356 versus 310–330 × 250–260 in Japanese specimens). We believe these differences represent intraspecific (e.g. geographical) variability.



**Figures 8–10.** *Galumna granalata* Aoki, 1984, adult: **8** dorso-lateral view of prodorsum and anterior part of notogaster and pteromorph **9** pteromorph **10** posterior view of notogaster. Scale bar 100 µm.

#### Notes on systematic placement of some Galumna

The analysis of literature on the *Galumna*-species has revealed an incorrect systematic placement of three species: *Galumna floridae* (Jacot, 1929), *G. hexagona* Balogh, 1960 and *G. mauritii* Mahunka, 1978.

*Galumna floridae* and *G. hexagona* were described by Jacot (1929, see also 1935; from U.S.A.) and Balogh (1960; from Angola), respectively. However, both species have a specific morphology of the notogaster (almost hexagonal, truncated posteriorly unlike other species of *Galumna* with well rounded notogaster posteriorly). Hexagonal

and truncated posteriorly notogaster is a generic character of the genus *Notogalumna*. It was proposed by Sellnick (1959) with *Notogalumna praetiosa* Sellnick, 1959 as type species, and includes five species, which are distributed in the Oriental region, Tanzania, Polynesia and Seychelles (Subías 2004, online version 2014). Representatives of *Notogalumna* differ from *Galumna floridae* and *G. hexagona* also by the setiform bothridial setae (clavate in *G. floridae* and *G. hexagona*), fused porose areas *A1* and *A2* (versus not fused in *G. floridae* and *G. hexagona*) and localization of porose areas *Aa* dorsally (versus lateral localization close to hinge in *G. floridae* and *G. hexagona*). However, all listed characters are known in the other species in Galumnidae. For example, the large genera *Galumna* and *Pergalumna* Grandjean, 1936 include species with numerous variations of morphology of bothridial setae and localization of notogastral porose areas. Hence, in our opinion, inclusion of *Galumna floridae* and *G. hexagona* in the genus *Galumna* is incorrect. We suggest these species should be transferred to *Notogalumna*: *N. floridae* (Jacot, 1929) comb. n. and *N. hexagona* (Balogh, 1960), comb. n.

*Galumna mauritii* was described by Mahunka (1978) from Mauritius. However, this species has very short sublamellar lines; they are almost absent – see Fig. 59 in the original description (versus all species of *Galumna* with long, well developed sublamellar lines). Absence of sublamellar lines and localization of lamellar setae laterally to lamellar setae are the generic characters of the genus *Dimidiogalumna*. This genus was proposed by Engelbrecht (1972) with *Dimidiogalumna villiersensis* Engelbrecht, 1972 as type species, and includes four species, which are distributed in the Ethiopian region, Comoro Islands, Vietnam, central China and Japan (Subías 2004, online version 2014; Ermilov and Anichkin 2014). Hence, in our opinion, inclusion of *Galumna mauritii* in the genus *Galumna* is incorrect. We suggest this species should be transferred to *Dimidiogalumna*: *D. mauritii* (Mahunka, 1978), comb. n.

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RESEARCH ARTICLE



# Two new species of *Neoperla* (Plecoptera, Perlidae) from Dabie Mountains of China

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#### Abstract

Two new species of the stonefly genus *Neoperla*, *N. nigromarginata* **sp. n.** and *N. similiflavescens* **sp. n.**, are described from Dabie Mountains of Central China in the Liankangshan National Nature Reserve. The new species are compared with related congeners.

#### Keywords

Plecoptera, Perlidae, Neoperla nigromarginata, Neoperla similiflavescens, new species, China

## Introduction

*Neoperla* is the most species-rich stonefly genus in the family Perlidae in China (Du et al. 1999, Sivec et al. 1988, DeWalt et al. 2014). To date, seventy-seven *Neoperla* species from China have been reported and the systematic study of this genus in China includes contributions from Chu (1929), Du (1999, 2000a, 2000b), Du (1998), Du and Sivec (2004, 2005), Du and Wang (2005, 2007), Du et al. (1999, 2001), Kong Li et al. (2014), Li et al. (2011a), Li et al. (2011b), Li and Wang (2011), Li et al. (2012a), Li et al. (2012b), Li and Li (2013a, b), Li et al. (2013a), Li et al. (2013b), Li et al. (2014a), Li et al. (2013b), Wang et al. (2013b), Wu (1935, 1938, 1948, 1962, 1973), Wu and Claassen (1934), Yang and Yang (1990, 1991), and Yang and Yang (1992, 1993, 1995a, 1995b, 1996, 1998).

In the present paper, two new species of *Neoperla*, *N. nigromarginata* sp. n. and *N. si-miliflavescens* sp. n., are described from Liankangshan National Nature Reserve of China, based on the specimens collected in the recent two years. The Reserve is located in the northern escarpment of Dabie Mountains, the border of Henan and Hubei provinces of Central China. The Reserve also includes the watershed of Yangtze River-Huaihe River basins and the northernmost boundary of subtropical zone (Ye et al. 2002).

#### Material and methods

The specimens used in this study were collected by light trap. Types and other examined material are deposited in the Insect Collection of Henan Institute of Science and Technology (HIST), Xinxiang, and the Entomological Museum of China Agricultural University (CAU), Beijing. They were examined with the aid of a Motic SMZ 168 microscope and the color illustrations were captured using digitalized Motic Images Advanced 3.2 software. All specimens were kept in 80% ethanol. Aedeagi were everted using the cold maceration technique of Zwick (1983). Terminology follows that of Sivec et al. (1988). All the scale lines in the figures represent 1.0 mm.

#### Results

*Neoperla nigromarginata* Li & Zhang, sp. n. http://zoobank.org/14EAFB99-1450-4DF2-8ACF-E7FDB99620A3 Figs 1–2

**Type material.** Holotype. male (HIST), China: Henan Province, Xinyang City, Xin County, Liankangshan National Nature Reserve, Laomiao Protection station, 31°64,39'N, 114°87,95'E, light trap, 17 June 2014, W.H. Li. Paratypes: 4 females (2 in CAU), the same locality and data as holotype.

**Adult habitus.** Distance between ocelli slightly wider than diameter of the ocellus. Head pale yellow to brownish with black areas, slightly wider than pronotum, with a black rectangular area covering ocelli, a large black anterior spot and two small lateral spots present on frons (Fig. 1a); compound eyes black, antennae dark brown except several basal segments which are brown; maxillary palpi dark brown. Pronotum with black median areas of rugosities and lateral margins around the kidney shaped pale disc area (Fig. 1a); wings subhyaline, veins dark brown; legs dark brown with femora and inner part of tibia brownish to brown (Fig. 1e). Cerci dark brown, basal segments brown.

Male. Forewing length 11.8 mm. Tergum 7 with an anteromedian pair of sclerotized, upraised, nipple-shaped processes and a distal subquadrate process on posterior margin, covered with small sensilla basiconica (Fig. 1b). Tergum 8 with a recurved tongue shaped process, fringed with small spines at its distal margin (Figs 1b). Ter-



Figure 1. Neoperla nigromarginata Li & Zhang, sp. n. Male (a–e) a Head and pronotum, dorsal view
b Terminalia, dorsal view c Terminalia, lateral view d Aedeagus before eversion, lateral view e Hindleg
f Female subgenital plate, ventral view.



**Figure 2.** *Neoperla nigromarginata* Li & Zhang, sp. n. Male. **a** Dorsal aspect of aedeagal sac, top view **b** Aedeagus, lateral view. Note that the spines in **b** appear lightly pigmented and unclear, actually they are located on the lower surface of the sac, and are seen from beneath through the cuticle.

gum 9 without patches of sensilla basiconica. Hemitergal processes of tergum 10 with a swollen wide base medially curved with sharp tip (Fig. 1b). Aedeagal tube nearly straight, with basoventral and dorsal sclerites. Aedeagal sac membranous but basal half heavily sclerotized ventrally (Figs 1d, 2b). Sac about as long as tube and curved ventrally forming a right angle to tube, dorsal surface with 2-3 irregular rows of numerous small spines (Fig. 2a); lateral surface of sac with a large patch of numerous small spines at subapcial region (Fig. 2b); a pair of flagella present more evident in uneverted sac apex in dorsal view (Fig. 2a). **Female.** Forewing length 13.4–14.0 mm. General color pattern similar to male. Sternum 7 slightly sclerotized except the posterior margin slightly produced forming sclerotized subgenital plate. Subgenital plate a small dark brown tab with slightly emarginate tip (Fig. 1f). Sternum 8 moderately sclerotized medially, posterior margin slightly produced in a narrow wide lobe.

**Etymology.** The specific epithet refers to the dark lateral margins of pronotum. **Distribution.** China (Henan Province).

**Diagnosis and remarks.** The new species is a typical member of the *Neoperla montivaga* species group as defined by Zwick (1983). The new species has similar head pattern, terminalia and paired apical flagella of the aedeagal sac with *N. flagellata* Li & Murányi, 2012 and *N. tuberculata* Wu, 1937 (Figs 1–4, 7 in Li et al. 2012, Figs 5 and 10 in Li et al. 2013). However, *N. nigromarginata* is easily distinguishable from the latter two species by the distinctively pigmented pronotal lateral margins, short aedeagal sac (nearly as long as tube) with only dorsal spine patch at base and absence of a sac loop (Figs 1a, 2). In *N. flagellata* and *N. tuberculata*, both have long aedeagal sac (at least 1.5× as long as tube) forming a loop with lateral spine patches at base of aedeagal sac (Figs 5-9 in Li et al. 2012b, Figs 5 & 11 in Li et al. 2013a).

#### Neoperla similiflavescens Li & Zhang, sp. n.

http://zoobank.org/5071BF60-1E10-4ABF-A529-7D88DC4A71D3 Figs 3–4

**Type material.** Holotype. male (HIST), China: Henan Province, Xinyang City, Xin County, Liankangshan National Nature Reserve, Laomiao Protection station, 31°64,39'N, 114°87,95'E, light trap, 15 June 2014, W.H. Li.

**Male.** Forewing length 13.9 mm. Distance between ocelli barely as wide as diameter of the ocellus. Head slightly wider than pronotum, mostly yellow brown, lateral margins and occiput behind compound eyes pale, a triangular dark area covering ocelli, a dark spot in front of M-line and U-shaped brownish spot between M-line and ocellus, M-line pale; antennae brown to dark brown, scape darker; compound eyes black; mouthparts brown (Fig. 3a). Pronotum brownish with wide darker median stripe and scattered markings of rugosities, legs brown; wings pale brown with dark vein. Abdomen brownish.

*Terminalia.* Tergum 7 with trapezoidal median process at posterior margin, covered by numerous tiny sensilla basiconica, anterior and lateral margins forming elevated plateau but with posteromedian concativity in which process of tergum 8 lies. Sclerotized process of tergum 8 recurved backward and triangular in shape. Tergum 9 with two submedial patches of long hairs. Hemitergal processes of tergum 10 strongly sclerotized and straight (Figs 3b and c). Aedeagus heavily sclerotized, subapical ventral projection triangular in lateral view and gradually tapering to a triangular tip (Figs 3d, 4a and b).

Female. Unknown.

**Etymology.** The specific epithet refers to the similarity to *Neoperla flavescens* Chu, 1929. **Distribution.** China (Henan Province).



**Figure 3.** *Neoperla similiflavescens* Li & Zhang, sp. n. Male. **a** Head and pronotum, dorsal view **b** Terminalia, dorsal view **c** Terminalia, lateral view **d** Aedeagus, lateral view.



**Figure 4. a–b** *Neoperla similiflavescens* Li & Zhang, sp. n. Male. **c–d** *Neoperla flavescens* Chu. Male. **a** Aedeagus, oblique ventral view **b** Aedeagus, ventral view **c** Head and pronotum, dorsal view **d** Aedeagus, lateral view. *Neoperla flavescens* Chu for comparison. 1 male from Henan Province, Luoyang City, Song County, Cecun town, Muzhaling, 2012.VIII.19, Weihai Li.

**Diagnosis and remarks.** The new species may be assigned to the *Neoperla montivaga* species group as defined by Zwick (1983), because of the incomplete sclerotization of the aedeagal tube in ventral aspect (Fig. 4a). The new species seems closely related to *Neoperla flavescens* Chu originally known from Zhejiang Province, and recently also found from several provinces (Henan, Fujian and Shanxi) of China (Li et al. 2011a, Li et al. 2014). They are similar in general features of male terminalia and the aedeagal tube. However, the new species can be easily separated from *N. flavescens* Chu by the shape of ventral projection of aedeagal tube. The projection in *N. similiflavescens* is generally triangular in lateral view and tapers to a triangular tip (Fig. 3d) whereas it is generally finger-like and abruptly constricted subapically in a nipple-like tip in *N. flavescens* (Figs 4d & 5 in Li et al. 2011a). Their general body color and head pattern also differ to some degree: *N. similiflavescens* is generally brownish in color and spots on frons are well defined and small (Fig. 3a) while in *N. flavescens*, the general body color is brown and darker, the spots on frons are larger and obscure (Fig. 4c, Fig. 1 in Li et al. 2011a, Fig. 1a in Li et al. 2014a).

#### **Concluding remarks**

The present study is based on the insect collection of two years surveys to the Liankangshan National Nature Reserve organized by administrative bureau of the Reserve. In the year 2013 only several stonefly nymphs were collected before the present *Neoperla* finding. Previous study on the stoneflies from the Dabie Mountains only includes the description of *Neoperla jigongshana* Li & Li, 2014 (Li et al. 2014b) from Mountain Jigongshan, about 100 km far from the Reserve. However, there was no record of any group of stoneflies in previous studies on the insect fauna of the Liankangshan Nature Reserve. In this study, two additional new species are described and up to 3 *Neoperla* species are known from the Dabie Mountains presently.

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RESEARCH ARTICLE



# The ant genus Carebara Westwood (Hymenoptera, Formicidae): synonymisation of Pheidologeton Mayr under Carebara, establishment and revision of the C. polita species group

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#### Abstract

In this paper the genus *Pheidologeton* Mayr, 1862 is synonymized under *Carebara* Westwood, 1840 and the *Carebara polita* group is established and revised. This species group currently includes six species from the Afrotropical region (*C. madibai*, *C. nicotianae*, *C. perpusilla*, *C. polita*, *C. silvestrii*, and *C. villiersi*) and two species from the Neotropical region (*C. brevipilosa* and *C. urichi*). The *polita* group clearly links *Carebara* and *Pheidologeton*, and, due to a lack of autapomorphic characters for the latter, a separation of the two genera is no longer justified. As a result *Carebara* is presented as a monophyletic and better defined genus that can be separated from other genera with more confidence. We present an overview of the distribution and biology of *Carebara* as well as images from the various genera currently in synonymy under *Carebara*, and discuss the characters they share. The polymorphism present in Afrotropical and Malagasy *Carebara* is discussed and one new species from Africa, *C. madibai* **sp. n.**, is described. The subspecies *Carebara perpusilla arnoldiana* **syn. n.**, *Carebara perpusilla concedens* **syn. n.**, and *Carebara perpusilla spinosa* **syn. n.** are new synonyms of *Carebara* perpusilla. *Oligomyrmex politus nicotianae* is re-elevated to species level and transferred into *Carebara*, *C. nicotianae* **comb. n.**, **stat. rev.**; *C. punctata* is a new synonym

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of *C. silvestrii* **comb. n.** and *C. pygmaea albipes* **comb. n., syn n.**, *C. pygmaea bugnioni* **comb. n., syn. n.**, and *C. simularensis* **syn. n.** are new synonyms of *C. pygmaea* **comb. n.**. The following names are transferred from *Pheidologeton* to *Carebara* as new combinations (with the species epithets adjusted to female endings where necessary): aberrans, affinis, affinis javana, affinis minor, affinis spinosior, affinis sumatrensis, ceylonensis, dentiviris, diversa, diversa draco, diversa ficta, diversa laotina, diversa macgregori, diversa philippina, diversa standfussi, diversa taprobanae, diversa tenuirugosa, diversa williamsi, hammoniae, hostilis, kunensis, latinoda, maccus, mayri, melanocephala, melasolena, nana, nanningensis, obscura, petulens, pullata, pungens, pygmaea, rubra, rugiceps, rugosa, schossnicensis, silena, silvestrii, solitaria, transversalis, trechideros, varia, vespilla, volsellata, yanoi, and zengchengensis. Three new combinations are creating secondary junior homonyms and are here replaced with new names: *C. mayri* (Santschi, 1928) = *C. gustavmayri* **nom. n.**, *C. rugosa* (Karavaiev, 1935) = *C. rugoflabella* **nom. n.**, and *C. silvestrii* (Wheeler, 1929b) = *C. luzonensis* **nom. n.** Two new combinations are creating secondary junior homonyms among species already in Carebara: *C. taprobanae* (Forel, 1911a) = *C. sinhala* **nom. n.**, and *C. nana* Santschi, 1919 = *C. pumilia* **nom. n.** 

#### **Keywords**

Carebara, Pheidologeton, new genus synonymy, Oligomyrmex, Paedalgus, taxonomic revision

#### Introduction

The ant genus *Carebara* currently contains approximately 250 described taxa (including the newly described species and all taxonomic changes in this work), and is distributed worldwide, being present mainly in tropical and subtropical regions (Azorsa and Fisher, in review, Bharti and Kumar 2013, Bolton 2014, Sharaf and Aldawood 2013). Many undetermined specimens and morphospecies are present in museum collections around the world and with ongoing taxonomic research the species number within the genus is expected to grow considerably (FA and GF, unpublished data). *Carebara* contains some of the smallest (e.g. *C. minuta*) and largest (e.g. *C. aberrans* comb. n.) ants in the world. Relatively little is known about the biology of this genus, except for the generalized foraging and mass raiding habits of several marauder ant species (*Pheidologeton*: Moffett 1988, Berghoff et al. 2003). The majority of species are very small and seem to have cryptic lifestyles. Stable isotope analyses of six *Carebara* species from Kenya revealed predatory to specialized predatory diets (Fischer 2012).

In recent years, the boundaries of the ant genus *Carebara* have changed significantly, mainly because of a lack of a clear genus definition. The latter is a result of not only the incomplete species record, but also from taxonomic difficulties inherent in a group that contains many cryptic and morphologically reduced species and that is also highly diverse, both morphologially and ecologically. These boundaries have changed constantly, especially with the extensive treatments by Ettershank (1966) and Fernández (2004, 2010). Ettershank (1966) split the tribes Solenopsidini and Pheidologetini into four genus groups, *Monomorium, Megalomyrmex, Pheidologeton* and *Solenopsis* group, and expanded the boundaries of the genus *Oligomyrmex*, (included in the *Pheidologeton* genus group), by synonymizing *Aeromyrma, Pheidologeton* subgenera *Aneleus & Lecan*- omyrma, Erebomyrma, Oligomyrmex subgenera Octella & Hendecatella, Spelaeomyrmex, Solenopsis subgenera Solenops & Crateropsis, and Nimbamyrma under Oligomyrmex. Bolton (2003) included Pheidologetini in Solenopsidini and split all the genera into the Carebara and Solenopsis groups. The Carebara group was represented by the genera Adlerzia, Afroxyidris, Carebara, Machomyrma, Mayriella, Oligomyrmex, Paedalgus, Pheidologeton and Tranopelta. Bolton and Belshaw (1993), and Belshaw and Bolton (1994) pointed out that Afroxyidris and Paedalgus are closely related to Carebara and Oligomyrmex. Fernández (2004), in the revision of the American fauna expanded the boundaries of Carebara, by including Afroxyidris, Oligomyrmex and Paedalgus.

Fernández (2010) included *Parvimyrma* in *Carebara* and also suggested the inclusion of *Pheidologeton* as a junior synonym of *Carebara*, mainly because of the morphological similarity between *C. villiersi* and *Pheidologeton* workers, and the similarity of the sting apparatus of *Carebara*, *Oligomyrmex* and *Pheidologeton* (Kugler 1986). Despite Fernández's suggestion *Pheidologeton* continued to be recognized as a separate genus mainly because its worker caste is polymorphic, often with continuous series of intermediates between minor and large major workers, versus a monomorphic and dimorphic worker caste in *Carebara*. However, in a recent study of *Carebara* from the Malagasy Region, Azorsa and Fisher (in review) found that most *Carebara* species were polymorphic, with one to four intermediate subcastes being present between the small and large major workers. These findings (and unpublished data on polymorphic *Carebara* species from Africa with a specialized phragmotic major worker subcaste) suggest that a pronounced worker polymorphism could also be present in other species of *Carebara*. Given this morphological evidence we consider *Pheidologeton* likely nested within *Carebara* and thus not deserving generic status.

The differences between intermediate worker subcastes in *Carebara* are mainly as follows: head and mesosoma size, size of posterolateral head corners, eye size, number of ocelli from one to three (ocelli are reduced compared to the queen caste), and full-sized versus reduced flight sclerites. Intermediates or additional major worker subcastes are also present in other groups of ants (e.g. *Acanthomyrmex, Camponotus, Cephalotes, Crematogaster, Pheidole*), and it is possible that the intermediates in *Carebara* are trophic specialists as in some of those genera (see Molet et al. 2012, and Peeters et al. 2013). Studies of some *Carebara* species (*C. overbecki, C. urichi*) found that the colonies contain up to 1000 individuals (minor and major workers) and that the proportion of the major workers in one nest can approach ten percent (Moffett 1986, Wilson 1962). Smaller workers nurse the brood, and larger workers defend the nest. The diets of these ants include mites, entomobryid collembolans and arthropod eggs (Wilson 1962, 1986).

In addition to the inclusion of *Pheidologeton* within *Carebara*, we establish and revise the *C. polita* species group, which is morphologically very close to *Pheidologeton*, with eight species from the Afrotropical and Neotropical regions. We also provide high-quality montage images from a few typical morphologies of genera synonymised under *Carebara* and discuss the similarities between them.

#### Abbreviations of depositories

BMNH	The Natural History Museum (British Museum, Natural History), London, U.K.
CASC	California Academy of Sciences, San Francisco, CA, U.S.A.
IAvH	Insect Collection, Instituto Humboldt, Claustro de San Agustín, Villa de
	Leyva, Colombia
LACM	Los Angeles County Museum of Natural History, Los Angeles, CA, U.S.A.
MCZ	Museum of Comparative Zoology, Cambridge, Massachusetts, U.S.A.
MHNG	Muséum d'Histoire Naturelle de la Ville de Genève, Geneva, Switzerland
MNHN	Muséum National d'Histoire Naturelle, Paris, France
MSNG	Museo Civico di Storia Naturale "Giacomo Doria", Genova, Italy
NHMB	Naturhistorisches Museum, Basel, Switzerland
PSWC	Philip S. Ward Collection, University of California, Davis, CA, U.S.A.

#### Material and methods

The majority of specimens examined in this work are deposited in the ant collection at CASC, and PSWC. We also examined type material of *Carebara* and *Pheidologeton* deposited at MHNG. Specimens were examined using a Leica M165 (maximum magnification 160×).

For morphological characters we followed Bolton (1994), Bolton and Belshaw (1993), Belshaw and Bolton (1994), Ettershank (1966), Bolton (2003) and Fernández (2004, 2006, 2010). For sculpture characters we followed Harris (1979). The terminology we used to describe the inclination of pilosity follows the five types of hair inclination described by Wilson (1955). **Erect:** hairs that are vertical or nearly vertical to the cuticular surface (inclination 90°); **suberect:** hairs with an inclination of 70° from the cuticular surface; **subdecumbent:** hairs with an inclination of 50° from the cuticular surface; and **appressed:** hairs with an inclination of 10° or nearly parallel to the cuticular surface. The hairs described may be of different sizes. In most cases the larger hairs are usually two to three times the size of the shorter pilosity and have a different inclination than their smaller counterparts.

We present high-resolution images of all *polita* group species, as well as a comparison of some representatives of the genera previously synonimized under *Carebara* (Fig. 2). 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). All images were edited using Photoshop and Adobe Ilustrator software. Images can be viewed and downloaded at www.AntWeb.org. Updatable distribution maps are also available via www.Ant-Web.org. Distribution maps (Fig. 18) were generated with the freeware R (R Core Team 2014).

## Measurements and indices

All measurements were taken with a Leica M165 equipped with an orthogonal pair of micrometers up to a magnification of 160×.

The following terminology and abbreviations are used (see Fig. 1):

- **HL** head length: maximum distance from the midpoint of the anterior clypeal margin to the midpoint of the posterior margin of the head, measured in full-face view; in majors, measured from the midpoint between anteriormost positions of clypeus to midpoint between posteriormost projections of the posterolateral lobes.
- HW head width: measured at widest point of the head in full-face view.
- SL scape length: maximum scape length, excluding basal condyle and neck.
- EL eye length: maximum diameter of compound eye measured in oblique lateral view.
- **MFL** metafemur length: measured from the junction with the trochanter to the junction with the tibia.
- MTL metatibia length: measured from the junction with femur to the junction with first tarsal segment.
- MDL mandible length: maximum length, measured in oblique frontolateral view, from apex to lateral base.
- **PNW** pronotal width: maximum width of pronotum measured in dorsal view.
- **WL** Weber's length: diagonal length of mesosoma in lateral view from the anterior point of the pronotal slope and excluding the neck, to the posteroventral margin of the propodeum.
- **PNH** pronotum height: maximum height of pronotum, measured in profile from the posterior base of the lateral sides of pronotum, where procoxa is attached, to the highest point of the pronotum.
- **MNH** promesonotum height: maximum height of promesonotum, measured in profile from the anterior base of the katepisternum, where mesocoxa is attached, to the highest point of the dorsal pronotum.
- **PDH** propodeum height: maximum height of propodeum, measured in profile from the highest point of the dorsopropodeum perpendicular to a line that marks the lateroventral borders of the katepisternum and the propodeum.
- **PSL** propodeal spine length: in dorsocaudal view, with the apex of the measured spine, its base, and the center of the propodeal concavity between the spines in focus: measurement is taken from apex to base along one axis of a dual–axis micrometer, which is aligned along the length of the spine, while the second axis crosses the base of the measured spine, and connects the base with the center of the propodeal concavity.
- **PTL** petiole length: maximum diagonal length of petiole, measured in lateral view, from most anteroventral point of the peduncle, at or below the propodeal lobe, to most posterodorsal point at the junction withhelcial tergite.



**Figure 1.** Illustration of standard measurements used for this revision: *Carebara* sp.: **A** profile **B** full-face view **C** dorsal view of major worker.

- **PTH** petiole height: maximum height of petiole, measured in lateral view from the highest (median) point of the node, orthogonally to the ventral outline of the node.
- **PTW** petiole width: maximum width of the petiole node, measured in dorsal view.
- **PPL** postpetiole length: maximum length of postpetiole, measured in lateral view, from anterior beginning of the dorsal slope to the posterior end of postpetiole tergite.
- **PPH** postpetiole height: maximum height of postpetiole, measured in lateral view, from the highest (median) point of the node to the lowest point of the ventral process, often in an oblique line.
- PPW postpetiole width: maximum width of postpetiole, measured in dorsal view.

#### Indices

CI	cephalic index: HW / HL × 100
SI	scape index: SL / HW × 100
MDI	mandible index: MDL / HW × 100
EI	eye index: EL / HW × 100
FI	metafemur index: MFL / HW × 100.
PSLI	propodeal spine index: PSL / HW × 100
LPpI	lateral postpetiole index: PPL / PPH × 100
DPpI	dorsal postpetiole index: PPW / PPL × 100
PpŴI	postpetiole width index: PPW / PTW × 100
PpLI	postpetiole length index: PPL / PTL ×100
PpHI	postpetiole height index: PPH / PTH × 100
PPI	postpetiole index: PPW / PNW × 100

## Results

#### Synonymic list of the genus Carebara

- *Pheidologeton* Mayr, 1862: 750. Type species: *Oecodoma diversa* Jerdon, 1851: 109, by subsequent designation of Bingham 1903: 160. syn. n.
- *Oligomyrmex* Mayr, 1867: 110. Type species: *Oligomyrmex concinnus* Mayr, 1867: 111, by monotypy. [Junior synonym of *Carebara*: Fernández 2004: 194].
- Aeromyrma Forel, 1891: 198. Type species: Aeromyrma nosindambo Forel, 1891: 199, by monotypy. [Subgenus of Oligomyrmex: Emery 1915: 59; revived as genus: Arnold 1916: 256; maintained as genus: Wheeler 1922a: 663, 882; junior synonym of Oligomyrmex: Ettershank 1966: 119; junior synonym of Carebara: Fernández 2004: 194.]
- Aneleus Emery, 1900: 327 (as subgenus of *Pheidologeton*). Type species: *Solenopsis similis* Mayr, 1862: 751, by designation of Wheeler 1911: 158. [Raised to ge-

nus: Emery 1914: 41; maintained as genus: Arnold 1916: 254; Forel 1917: 243; Wheeler 1922a: 663; Emery 1924: 213. Senior synonym of *Sporocleptes*: Consani 1951: 169; Arnold 1952: 460. Junior synonym of *Oligomyrmex*: Ettershank 1966: 119; junior synonym of *Carebara*: Fernández 2004: 194.]

- *Erebomyrma* Wheeler, 1903: 138. Type species: *Erebomyrma longii* Wheeler, 1903: 140, by monotypy. [Senior synonym of *Spelaeomyrmex*: Wilson 1962: 63; junior synonym of *Oligomyrmex*: Ettershank 1966: 119; revived as valid genus: Wilson 1986: 61; returned to synonymy of *Oligomyrmex*: Bolton 1994: 106; junior synonym of *Carebara*: Fernández 2004: 194.]
- Phidologeton Bingham, 1903: 160. Phidologeton as junior synonym of Pheidologeton: Wheeler 1922a: 880. syn. n.
- *Paedalgus* Forel, 1911a: 217. Type species: *Paedalgus escherichi* Forel, 1911a: 218. [Junior synonym of *Carebara*: Fernández 2004: 235.]
- Lecanomyrma Forel, 1913c: 56 (as subgenus of Pheidologeton). Type species: Pheidologeton (Lecanomyrma) butteli Forel, 1913c: 56, by monotypy. [Subgenus of Aneleus: Emery 1924: 215; junior synonym of Oligomyrmex: Ettershank 1966: 123; junior synonym of Carebara: Fernández 2004: 235.]
- *Spelaeomyrmex* Wheeler, 1922b: 9. Type species: *Spelaeomyrmex urichi* Wheeler, 1922b: 45, (Fig. 1), by original designation. [Junior synonym of *Erebomyrma*: Wilson 1962: 63; junior synonym of *Carebara*: Fernández 2004: 194.]
- *Hendecatella* Wheeler, 1927: 93 (as subgenus of *Oligomyrmex*). Type species: *Oligomyrmex* (*Hendecatella*) *capreolus* Wheeler, 1927: 93, by monotypy. [Junior synonym of *Oligomyrmex*: Ettershank 1966: 119; junior synonym of *Carebara*: Fernández 2004: 194.]
- Amauromyrmex Wheeler, 1929a: 1. Type species: Amauromyrmex speculifrons Wheeler, 1929a: 1 (junior synonym of Pheidole silenus Smith: Ettershank 1966: 119). [Amauromyrmex as junior synonym of Pheidologeton: Ettershank 1966: 115.] syn. n.
- Solenops Karavaiev, 1930: 207 (as subgenus of Solenopsis). Type species: Solenopsis (Solenops) weyeri Karavaiev, 1930: 207, by monotypy. [Junior synonym of Oligomyrmex: Ettershank 1966: 119; junior synonym of Carebara: Fernández 2004: 194.]

Figure 2. Genera synonymised under *Carebara*, illustrating some of the morphologial diversity expressed across the genus, with each specimen shown in full-face view and in profile. *Carebara: Carebara lignata* minor worker: CASENT0902404 (A1, A2). *Parvymyrma: Carebara sangi* minor worker: CASENT0905888 (B1, B2). *Paedalgus: Carebara pisinna* minor worker: CASENT0902374 (C1, C2). *Carebara: Carebara spinata* major worker: CASENT0906099 (D1, D2); minor worker: CASENT0906101 (D3, D4). *Carebara: Carebara intermedia* major worker: CASENT0603534 (E1, E2); minor worker: CASENT0603535 (E3, E4). *Oligomyrmex* (*Aneleus*): *Carebara diabola* major worker: CASENT0904663 (F1, F2); minor worker: CASENT0904664 (F3, F4). *Pheidologeton* (*Aneleus*): *Carebara perpusilla* major worker: CASENT0904661 (G1, G2); minor worker: CASENT0904662 (G3, G4). *Pheidologeton: Carebara pygmaea* major worker: CASENT0906203 (H1, H2); minor worker: CASENT0906214 (H3, H4). *Pheidologeton: Carebara diversa* major worker: CASENT0906200 (I1, I2); minor worker: CASENT0906201 (I3, I4).



- *Idrisella* Santschi, 1937c: 372. Type species: *Pheidologeton dentiviris* Forel, 1913b: 192, by original designation. [*Idrisella* as junior synonym of *Pheidologeton*: Ettershank 1966: 115.] **syn. n.**
- Sporocleptes Arnold, 1948: 219. Type species: Sporocleptes nicotianae Arnold, 1948: 219, by original designation [Junior synonym of Aneleus: Consani 1951: 169; Arnold 1952: 460; junior synonym of Oligomyrmex: Ettershank 1966: 119; junior synonym of Carebara: Fernández 2004: 194.]
- *Crateropsis* Patrizi, 1948: 174 (as subgenus of *Solenopsis*). Type species: *Solenopsis* (*Crateropsis*) elmenteitae Patrizi, 1948: 174, by monotypy. [Junior synonym of Oligomyrmex: Ettershank 1966: 120; junior synonym of Carebara: Fernández 2004: 194.]
- Nimbamyrma Bernard, 1953: 241. Type species: Nimbamyrma villiersi Bernard, 1953: 241. [Junior synonym of Oligomyrmex: Ettershank 1966: 120; junior synonym of Carebara: Fernández 2004: 235.]
- *Afroxyidris* Belshaw & Bolton, 1994: 631. Type species: *Afroxyidris crigensis* Belshaw & Bolton, 1994: 632, by original designation. [Junior synonym of *Carebara*: Fernández 2004: 235.]
- Neoblepharidatta Sheela & Narendran, 1997: 89. Type species: Neoblepharidatta nayana Sheela & Narendran, 1997: 89, by original designation. [Junior synonym of Oligomyrmex: Bolton 2003: 273; junior synonym of Carebara: Fernández 2004: 196.]
- *Parvimyrma* Eguchi & Bui, 2007: 44. Type species: *Parvimyrma sangi* Eguchi & Bui, 2007: 44, by original designation. [Junior synonym of Carebara: Fernández 2010: 235.]

#### Pheidologeton Mayr – a junior synonym of Carebara Forel

Kugler (1986), by studying their sting apparatus, suggested that *Pheidologeton pyg*maeus (Carebara pygmaea comb. n.) and Carebara overbecki, and C. silena comb. n. and C. urichi respectively, must be closely related. Fernández (2010) pointed out the similarity between Carebara (Nimbamyrma) villiersi and Pheidologeton workers. There are also strong similarities between Carebara alperti and Carebara pygmaea comb. n., C. rubra comb. n., and C. transversalis comb. n. workers. Since all former Pheidologeton species are dimorphic or polymorphic it seems very likely that C. alperti is dimorphic or polymorphic as well. The C. polita species group here established possesses several morphological features that closely link the former *Pheidologeton* with *Carebara*, the only morphological difference being the prescence of an elongated postpetiole in the C. polita group versus a rounded or globular postpetiole in Pheidologeton workers. We found that the species of the C. polita group are most similar to the following former Pheidologeton species: C. aberrans comb. n., C. affinis comb. n., C. diversa comb. n., C. kunensis comb. n., C. melanocephala comb. n., C. nana comb. n., and C. silena comb. n.. Our morphological analyses are strongly supported by a recent molecular phylogeny of the subfamily Myrmicinae as part of the Ant Tree of Live project (AToL), which found that Pheidologeton affinis (old combination) is nested within Carebara

(*C. alperti*, *C. urichi*, and *C. vidua*), coupled with the conclusion that *Carebara* is sister to the genus *Diplomorium* (Ward et al. 2014).

These independently generated results finally led us to the current synonymization of *Pheidologeton* under *Carebara*, as proposed in the present publication. As a result of the synonymization, *Carebara* becomes a morphologically and ecologically highly diverse genus, with a variety of monomorphic, dimorphic and polymorphic species. However, it is possible that the majority of *Carebara* species have at least dimorphic or even potentially polymorphic workers, since recent collections show that worker dimorphism is common in species that were previously known as monomorphic, and polymorphism is common in species that were previously known as dimorphic (Azorsa and Fisher, in review; GF and FA, unpublished). We speculate that species in the *polita* group and in other *Carebara* groups that are currently only known from minor workers may produce major workers infrequently or only on specific environmental or genetic cues that are yet unstudied. Despite a large number of collections from a large distribution range across sub-Saharan Africa, the major workers of C. polita remained undescribed for 100 years and the earliest collection with major workers is from 2001 (by R.R. Snelling) and only from Kakamega Forest in Western Kenya. Alternatively, the need to maintain major workers may have subsided during the evolution of some species or even whole species groups, resulting in a complete loss or reduction of worker polymorphism.

There are other examples of species within *Carebara* that are morphological links between other previously separated genera (Fernández 2004; 2010), such as between *C. spinata* and *C. intermedia* and the former *Paedalgus*, the only difference between them being armed versus an unarmed propodeum. An unarmed propodeum, however, is not synapomorphic for *Paedalgus*, because it is present in several other species of *Carebara* and in the former *Oligomyrmex*. Similarly, the only known species of the former genus *Parvimyrma* (*C. sangi*), described by Eguchi and Bui (2007), and included in *Carebara* by Fernández (2010), is closely related to workers of the dimorphic *C. diabola*, as well as to *C. carinata*. The elongated head and the shapes of the propodeum and petiole are almost the same in workers of all three species. It is difficult to see whether the type specimens of *C. diabola* have a central clypeal hair, but regardless, the state of this character (one hair in *C. sangi* versus two central clypeal hairs in other *Carebara*) is not sufficient to treat *Parvimyrma* as a separate genus. A single central clypeal hair is also present in *Carebara carinata*.

Due to the considerable amount of morphological diversity across the genus *Carebara*, its workers can be distinguished from those of other myrmicine genera with a two-segmented antennal club only by a combination of the following characters.

# Diagnostic characters for *Carebara* workers (revised to include former *Pheidologeton* species)

1. Antenna with eight to eleven segments and a two-segmented club.

- 2. Clypeus of minor workers usually with four distinct setae (some species with a central isolated seta).
- 3. Mandibles of workers triangular or subtriangular and usually with four to seven teeth or denticles present (3 teeth in *Carebara crigensis* (Belshaw and Bolton 1994)), the apical and preapical tooth often larger than the following ones.
- 4. Palp formula 2,2 or 1,2.
- 5. Frontal lobes separated by median part of clypeus.
- 6. Eyes either absent or reduced to one or few ommatidia and situated anterior of cephalic midlength, or larger, not reduced, and situated at or posterior of cephalic midlength.
- 7. Antennal scrobes absent, weakly developed only in species with workers with phragmotic head.
- 8. Frontal carinae varying from absent to weakly developed and short to very rarely reaching beyond cephalic midlength, but never extending towards posterior head margin.
- 9. Promesonotal dorsum in profile convex to weakly convex, very rarely near-linear.
- 10. Propodeum often with a pair of spines, short teeth or angulate posterior corners, in which cases often with a lamella reaching down towards propodeal lobes, but sometimes propodeum posteriorly completely unarmed and rounded.
- 11. Petiole with a distinct peduncle and well-differentiated node.
- 12. Different worker subcastes in dimorphic and polymorphic species, sometimes with enormous size variation (e.g. in *C. polita* group and in many former *Pheidologeton*).
- 13. Major workers, where present and especially when large, often with at least a few small remnants of queen flight sclerites present, and some *polita* group and former *Pheidologeton* major workers with all flight scerites recognizable.

# Comments on diagnosis of Carebara worker caste

*Carebara* workers may be monomorphic, dimorphic, or continuously polymorphic. When the latter is the case, there are often several subcastes intermediate between minor and large major workers. Intermediate workers of some marauder ant species in the former genus *Pheidologeton* differ gradually in size and general morphology. In other species with polymorphic workers (e.g. in several former *Oligomyrmex*) the morphological differences are less gradual, with little variation in the minor workers, but with one to several different major worker phenotypes that differ in size and morphology.

Some species, like *C. elmenteitae* from Kenya, *C. nayana* from India and *C. butteli* from Sri Lanka, however, have an additional major worker subcaste with phragmotic heads, which represent a special defense line against predators and are often described as living plugs for nest entrances. Interestingly *C. butteli* (Forel 1913c) was originally described as *Pheidologeton butteli*.

### Species groups in Carebara

The establishment of the *Carebara polita* species group highlights the need to revise all *Carebara* species to better delimit species group boundaries in the genus and to rearrange the groups suggested by Fernández (2004, 2010) and later adapted to include the Indian *Carebara* fauna treated by Bharti and Kumar (2013). The establishment of new species groups will likely be necessary with ongoing taxonomic research and will help unravel the evolutionary history of this genus. Especially the Afrotopical region holds a large number of unrevised and new species, many of which are located in the BMNH collection in London.

The former *Pheidologeton* species could in future revisions be split into two species groups, one that shares characters with *C. aberrans* comb. n. and *C. affinis* comb. n., where the minor and large major workers are connected through a continuous series of intermediate subcastes, and another group that shares characters with *C. pygmaea* comb. n. and *C. alperti*, that are dimorphic and morphologically similar to some species of the former genus *Oligomyrmex*. In this publication we are establishing and focusing on the *polita* species group, which is mostly characterized by their minor workers' morphology, i.e. head and mesosoma shape, medially smooth and shiny frons, present propodeal spines, and, most importantly, an elongate postpetiole in minor workers. The diagnosis for minor and major workers (where known) of the *polita* group is summarized below.

### Diagnostic characters of the polita species group

- 1. Antennae with usually eleven, but one species with nine segments; scapes, when laid back, never reaching or surpassing posterior head margin.
- 2. Eyes of minor workers small, in most specimens consisting of only one ommatidium, in major workers absent to multi-facetted, in all subcastes situated anterior to cephalic midlength and relatively close to anterior head margin.
- Madibles with four to six teeth, number in minor workers often one less than in major workers.
- 4. Posterior margin of head concave to weakly concave medially, or nearly straight.
- 5. Frons in minor workers medially smooth and shiny.
- 6. Minor workers with short to comparatively long propodeal spines present, in major workers sometimes reduced to a blunted angle (*C. urichi*).
- 7. Minor and/or major workers often with petiolar ventral process present as anteriorly directed small tooth, which is sometimes reduced or inconspicuous.
- 8. Petiole node in minor workers usually subangulate to rounded in profile, dorsally smooth and shiny, in major workers very well-developed and high, the dorsum rounded to angulate-subangulate and anterodorsally compressed.
- 9. Minor worker postpetiole relatively elongate, distincly longer than high (LPpI 131–173) and lower than petiole, major worker postpetiole compact, dorsally rounded, and in profile about as high as long (LPpI 83–107).

#### Comments on diagnosis of polita group worker caste

Range in head shape and sculpture, the number of distinctly expressed mesosomal sclerites in major workers, and the propodeum varying from having spines or not in this group is relatively large and comparable to the range found in former *Phei-dologeton* species. Interestingly the major worker caste has shown itself completely elusive in two of the *polita* group species. Despite a multitude of collections from several localities *C. brevipilosa* and *C. villiersi* are known only from the minor workers so far. But *C. polita* has been collected without any major workers for almost a century, and *C. nicotianae* for more than 50 years. The minor workers of *C. polita* were described by F. Santschi in 1914 and majors have not been collected until 2001 by the late R. R. Snelling, but remained unidentified at first. If not for another collection of major workers together with queens and minor workers in 2008 by the first author, the fact that these two different worker subcastes belong to the same species, and one important link between *Carebara* and the former *Pheidologeton*, might have remained unnoticed.

#### Biogeographic notes on the *polita* species group

Six species occur in the Afrotropical region, two of them are widely distributed throughout sub-Saharan Africa: *C. perpusilla* in Kenya, Rwanda, South Africa, Tanzania, Uganda, Zambia, and Zimbabwe and *C. silvestrii* in Cameroon, Central African Republic, Equatorial Guinea, Gabon, Ghana, Ivory Coast, Kenya, Uganda, and Zimbabwe. Two species are widely distributed from Western to Eastern Africa: *C. polita* in Cameroon, Central African Republic, Gabon, Kenya, Tanzania, and Uganda and *Carebara madibai* sp. n. is known from the Central African Republic, Dem. Rep. Congo, Gabon, and Uganda. *Carebara villiersi* occurs throughout Western Africa and was found in Cameroon, Central African Republic, Gabon, Ghana, Guinea, and Ivory Coast. *Carebara nicotianae* seems restricted to Zambia and Zimbabwe in Southern Africa. Two of the species included in this group are present and widespread in the Neotropical Region: *C. brevipilosa* is reported from Brazil, Colombia, Costa Rica, and Panama, while *C. urichi* was found only in Belize, Brazil, Colombia, Costa Rica, Mexico, Panama, Peru, Suriname, and Trinidad.

#### Synopsis of the *polita* species group

Carebara brevipilosa Fernández, 2004 Carebara madibai Fischer & Azorsa, sp. n. Carebara perpusilla (Emery, 1895)

= Oligomyrmex perpusillus arnoldianus Ettershank, 1966 syn. n. [Replacement name for *Pheidologeton perpusillum* subsp. arnoldi Forel: Ettershank 1966: 123. Junior secondary homonym of Oligomyrmex arnoldi Forel 1913a: 123.]

Pheidologeton (Aneleus) perpusillus spinosus Forel, 1907, syn. n.
Aneleus perpusillus concedens Santschi, 1914a, syn. n.
Carebara polita (Santschi, 1914a)
Carebara nicotianae Arnold, 1948, comb. n. et stat. rev.
Carebara silvestrii (Santschi, 1914b), comb. n.
Aneleus (Aneleus) punctatus Karavaiev, 1931, syn. n.
Carebara urichi (Wheeler, 1922b)
Erebomyrma nevermanni Mann, 1926
Erebomyrma morai Menozzi, 1931

= Erebomyrma eidmanni Eidmann, 1936 Carebara villiersi (Bernard, 1953)

# New combinations for all former species of *Pheidologeton* synonymised under *Carebara*

Where necessary, the endings of specific epithets were changed in order to agree with the gender of the genus *Carebara*, e.g. as in *Carebara diversa* (Jerdon, 1851) comb. n. – previously *Pheidologeton diversus*. To avoid the creation of secondary junior homonyms, original species names of three former *Pheidologeton* and two species already in *Carebara* are here replaced with new names.

Carebara aberrans (Santschi, 1937b), comb. n. Carebara affinis (Jerdon, 1851), comb. n. Carebara affinis javana (Emery, 1893a), comb. n. Carebara affinis minor (Emery, 1900), comb. n. Carebara affinis spinosior (Forel, 1911b), comb. n. Carebara affinis sumatrensis (Forel, 1913c), comb. n. Carebara ceylonensis (Forel, 1911a), comb. n. Carebara dentiviris (Forel, 1913b), comb. n. Carebara diversa (Jerdon, 1851), comb. n. Carebara diversa draco (Santschi, 1920), comb. n. Carebara diversa ficta (Forel, 1911b), comb. n. Carebara diversa laotina (Santschi, 1920), comb. n. Carebara diversa macgregori (Wheeler, 1929b), comb. n. Carebara diversa philippina (Wheeler, 1929b), comb. n. Carebara diversa taprobanae comb. n. (Smith, 1858). [Senior secondary homonym of Carebara taprobanae Forel, 1911a, replacement name Carebara sinhala nom. n.] Carebara diversa standfussi (Forel, 1911b), comb. n. Carebara diversa tenuirugosa (Wheeler, 1929b), comb. n. Carebara diversa williamsi (Wheeler, 1929b), comb. n. Carebara gustavmayri nom. n. (Replacement name for Pheidologeton mayri Santschi, 1928). [Junior] secondary homonym of Carebara mayri (Forel, 1901).]

- Carebara hammoniae (Stitz, 1923), comb. n.
- Carebara hostilis (Smith, 1858), comb. n.
- Carebara kunensis (Ettershank, 1966), comb. n.
- Carebara latinoda (Zhou & Zheng, 1997), comb. n.
- Carebara luzonensis nom. n. (Replacement name for Pheidologeton silvestrii Wheeler,
  - 1929b). [Junior secondary homonym of Carebara silvestrii (Santschi, 1914b).]
- Carebara maccus (Wheeler, 1929b), comb. n.
- Carebara melanocephala (Donisthorpe, 1948), comb. n.
- Carebara melasolena (Zhou & Zheng, 1997), comb. n.
- *Carebara nana* (Roger, 1863), comb. n. [Senior secondary homonym of *Carebara nana* (Santschi, 1919), replacement name *Carebara pumilia* nom. n.]
- Carebara nanningensis (Li & Tang, 1986), comb. n.
- Carebara obscura (Viehmeyer, 1914), comb. n.
- Carebara petulens (Santschi, 1920), comb. n.
- Carebara pullata (Santschi, 1920), comb. n.
- Carebara pungens (Smith, 1861), comb. n.
- Carebara pygmaea (Emery, 1887), comb. n. (Syntypes: 1 major & 4 minor workers. Emery 1887: 465. INDONESIA: Ternate Acqui Conora xi. 1874 (*Beccari*) [MHNG] [examined]).
  - *= Pheidologeton pygmaeus albipes* Emery, 1893b, comb. n., syn. n. (Holotype worker. Emery 1893b: 266. PHILIPPINES: Antipolo [MSNG] [examined]).
  - *= Carebara simularensis* Forel, 1915, syn. n. (Syntypes: 3 major & 3 minor workers, 1 queen. Forel 1915: 27. INDONESIA: Sinabang, Sumatra 47, No. 13. i.1913 (*E. Jacobson*) [MHNG] [examined]).
  - = *Pheidologeton (Aneleus) pygmaeus bugnioni* Forel, 1915, comb. n., syn. n. (Syntypes: 5 major & 5 minor workers. Forel 1915: 28. SRI LANKA: Peradeniya (*Bugneon*) [MHNG] [examined]).
- Carebara rubra (Smith, 1860b), comb. n.
- † Carebara rugiceps (Heer, 1849), comb. n.
- † Carebara schossnicensis (Assmann, 1870), comb. n.
- *Carebara rugoflabella* nom. n. (Replacement name for *Pheidologeton rugosus* Karavaiev, 1935). [Junior secondary homonym of *Carebara ampla rugosa* (Santschi, 1928).]
- Carebara silena (Smith, 1858), comb. n.
- Carebara solitaria (Stitz, 1910), comb. n.
- Carebara transversalis (Smith, 1860a), comb. n.
- Carebara trechideros (Zhou & Zheng, 1997), comb. n.
- Carebara varia (Santschi, 1920), comb. n.
- Carebara vespilla (Wheeler, 1921), comb. n.
- Carebara volsellata (Santschi, 1937a), comb. n.
- Carebara yanoi (Forel, 1912), comb. n.
- Carebara zengchengensis (Zhou, Zhao & Jia, 2006), comb. n.
## Identification key for the species of the *polita* species group

[Combined key for major and minor workers, but note that majors of *C. brevipilosa* and *C. villiersi* are unknown.]

- 1b Antennae with 9 segments. **Major workers:** Head anterior significantly wider than posterior (Fig. 3C). **Minor workers:** Frontal carinae extending to about <sup>3</sup>/<sub>4</sub> of the length of the head (Fig. 3D) and dorsum of promesonotum smooth and shiny. (Central African Republic, Dem. Rep. Congo, Gabon, Uganda)...... *C. madibai*



**Figure 3.** Full-face view of *C. polita* major worker (**A**) and minor worker (**B**); full-facev view of *C. madibai* major worker (**C**) and minor worker (**D**).



**Figure 4.** Full-face view of *C. nicotianae* major worker (**A**) and *C. villiersi* minor worker (**B**); full-face view of *C. urichi* major worker (**C**) and *C. perpusilla* minor worker (**D**).



Central African Republic, Gabon, Ghana, Guinea, Ivory Coast)... C. villiersi

**Figure 5.** Full-face view of *C. nicotianae* major worker (**A**), *C. polita* major worker (**B**), and *C. polita* minor worker (**C**); full-face view of *C. villiersi* minor worker (**D**).



**Figure 6.** Profile of *C. polita* major worker mesosoma and petiole (**A**), profile of *C. polita* minor worker mesosoma (**B**); profile of *C. nicotianae* major worker mesosoma and petiole (**C**), profile of *C. nicotianae* minor worker mesosoma (**D**).

5a Major workers: Head distinctly longer than wide in full-face view (CI 71-87) (Fig. 7A). Posterior head margin with transverse carina. Minor workers: Anteroventral face of petiole straight or weakly concave and subpetiolar process absent (Fig. 7B). (Afrotropics)......6 5b Major workers (C. urichi only): Head about as long as wide to slightly longer (CI 92-99) (Fig. 7C). Posterior head margin lacking transverse carina. Minor workers: Subpetiolar process present (Fig. 7D). (Neotropics)......7



Figure 7. Full-face view of C. silvestrii largest major worker (A), profile of C. perpusilla minor worker petiole (**B**); full-face view of *C. urichi* major worker (**C**), profile of *C. urichi* minor worker petiole (**D**).

6a Smaller species (HW major worker: 0.52–0.70). Major workers: Lateropronotum and anepisternum smooth and shiny, katepisternum and lateropropodeum weakly to superficially areolate (Fig. 8A). Postpetiole relatively wide, compared to pronotal width (PPI 60-66) and postpetiole length (DPpI 100-128). Minor workers: Cephalic dorsum and pronotum smooth and shiny, head shape subrectangular with weakly convex sides (Fig. 8B). (Kenya, Rwanda, South Africa, Tanzania, Uganda, Zambia, Zimbabwe)...... C. perpusilla Slightly larger species (HW major worker: 0.64–0.99). Major workers: Lateropronotum, anepisternum, katepisternum, and lateropropodeum usually densely areolate (Fig. 8C). Postpetiole relatively narrower, compared to pronotal width (PPI 45-52) and postpetiole length (DPpI 132-167). Minor workers: Frons often smooth and shiny, remainder of cephalic dorsum usually coarsely rugoreticulate, pronotum never completely smooth, usually with some areolate or rugose sculpture present, head shape suboval with strongly convex sides (Fig. 8D). (Cameroon, Central African Republic, Equatorial Guinea, Gabon, Ghana, Ivory Coast, Kenya, Uganda, Zimbabwe)...... C. silvestrii



Figure 8. Profile of *C. perpusilla* major worker mesosoma (A), full-face view of *C. perpusilla* minor worker (B); profile of *C. silvestrii* major worker mesosoma (**C**), full-face view of *C. silvestrii* minor worker (**D**).

6b



**Figure 9.** Dorsal view of *C. brevipilosa* minor worker mesosoma (**A**), profile of minor worker metatibia (**B**); full-face view of *C. urichi* major worker (**C**), dorsal view of *C. urichi* minor worker mesosoma (**D**), profile of minor worker metatibia (**E**).

## Species accounts

# Carebara brevipilosa Fernández

Figure 10

*Carebara brevipilosa* Fernández, 2004: 210. Holotype worker: COLOMBIA: Caquetá, San José de la Fragua, La Esmeralda, Yuruyaco River, 1500m, 7-10.ix.2002 (*E.L. González*) (IAvH), [examined].

**Diagnosis.** Antennae with 11 segments. **Major workers:** unknown. **Minor worker:** Head almost as wide as long, with longitudinal rugulae and reticulations, except for smooth and shiny frons, petiole anteroventrally with small anteriorly directed tooth, dorsal promesonotum weakly to superficially rugoreticulate, and sometimes with a few weak to superficial rugulae present and metatibiae with short appressed to decumbent pilosity.

**Description of minor workers.** Measurements (n=5): HW 0.31–0.32 (0.31), HL 0.32–0.33 (0.32), SL 0.20–0.21 (0.21), MDL 0.20-0.21 (0.20), EL 0.01–0.02 (0.01), WL 0.35–0.37 (0.35), PNH 0.14–0.16 (0.15), PNW 0.19–0.20 (0.19), MNH 0.20, PDH 0.14, PTL 0.13–0.14 (0.14), PPL 0.07–0.08 (0.08), PTH 0.09–0.11 (0.10), PPH 0.05–0.06 (0.05), PTW 0.05, PPW 0.08–0.09 (0.08), PSL 0.04–0.05 (0.04),

MFL 0.23–0.25 (0.24), MTL 0.17–0.19 (0.18), CI 95–98 (97), SI 65–68 (67), MDI 65–67 (66), EI 4–5 (5), FI 74–80 (77), PSLI 12–15 (14), LPpI 136–143 (139), DPpI 100–116 (108), PpWI 157–190 (170), PpLI 53–58 (55), PpHI 50–67 (56).

Head in full-face view almost as wide as long (CI 95–98), narrowed anteriorly and posteriorly, posterior margin straight or feebly concave medially, posterolateral corners bluntly angulate, sides convex. Mandibles with four teeth, apical and preapical tooth larger than following teeth. Clypeus anteriorly concave, bicarinate, subangulate toward sides. Antennae with eleven segments, scapes failing to reach posterior margin of head by about the length of the preapical funicular segment. Eyes reduced to a single ommatidium. Frontal carinae present, usually feebly developed but long, in some specimens almost reaching posterior head margin.

In profile, promesonotum convex or weakly convex, metanotal groove broadly concave and deeply impressed. Dorsum of propodeum almost straight in profile and sloping posteriorly, anterodorsal corner convex, propodeal spines relatively short, triangular and upwardly directed, declivity of propodeum concave. Propodeal spiracle near posterior border of propodeum.

Petiole moderately long, peduncle in profile about as long as petiole node, ventral face convex, anteroventral corner with a small triangular tooth which, in some specimens, can be reduced and inconspicuous, petiole node broadly wedge-shaped and rounded dorsally. Postpetiole in profile weakly convex dorsally, almost straight ventrally, about 1.4 times longer than high (LPpI 136–143) and much lower than petiole (PpHI 50–67). In dorsal view, petiole node almost as wide as long, and roundly convex, postpetiole on average 1.7 times wider than petiole (PpWI 157–190), with convex sides and posteriorly wider than anteriorly.

Head with some irregular, longitudinal striations and rugosities, except for smooth and shiny frons. Mandibles and median portion of clypeus smooth and shiny with scattered punctures, face with scattered punctuations. Mesosoma, petiole and postpetiole areolate-rugose, except for smooth spot on anteroventral pronotum, and smooth and shiny petiole and postpetiole dorsum. Gaster smooth and shiny.

Head and body with relatively few long, suberect standing hairs and with decumbent to subdecumbent short pilosity. Scapes with abundant decumbent pilosity. Four longer hairs on clypeal margin extending close to the anterior border of mandibles. Color dark orange, legs and antennae lighter colored orange.

**Distribution and biology.** *Carebara brevipilosa* is relatively widespread in the Neotropical Region, found in Brazil, Colombia, Costa Rica, and Panama. This species was collected mainly in the rainforest and at elevations ranging from 50–1050 m. Individuals and nest series were collected from the leaf-litter and soil, using Winkler extractors and pitfall traps.

**Comments.** Carebara brevipilosa can be confused with C. urichi, but is easily distinguished by the lack of long suberect hairs at the outer edge of the metatibiae and the sculpture on the dorsal promesonotum, which is typically irregularly longitudinally rugose to rugoreticulate with few irregular longitudinal rugae in C. urichi and weakly to superficially reticulate without or with very few short rugulae in C. brevipilosa. Also,



**Figure 10.** *Carebara brevipilosa*. Minor worker, CASENT0609948: **A** head in full-face view **B** body in profile **C** body in dorsal view.

*C. brevipilosa* (HW minor workers 0.41–44, WL 0.48–0.57) seems to be distinctly smaller than *C. urichi* (HW minor workers 0.31–0.32, WL 0.35–3.37). These are the only two species in the *polita* group recorded from the Neotropical Region. Major workers of *C. brevipilosa* have not been collected or identified yet.

Material examined. COLOMBIA: Caquetá, San José de la Fragua, La Esmeralda, Yuruyaco River, 1500 m, 7–10.ix2002 (*E.L. González*); Magdalena, 4km N San Pedro, 10.95, -74.05, 550m, 14.viii.1985 (*P.S. Ward*); PANAMA: Darieni Cana, 7.716667, -77.2, 800m, 23.viii.1987 (*D.M. Olson*).

#### Carebara madibai Fischer & Azorsa, sp. n.

http://zoobank.org/83A0FC28-0D89-4FC8-8918-A5B7CD64A02E Figure 11

**Holotype.** (major worker) CENTRAL AFRICAN REPUBLIC: Parc National Dzanga-Ndoki, Mabéa Bai, 21.4 km 53° NE Bayanga, 3.03333, 16.41, 510m, rainforest, 10–17.v.2001 (*B.L. Fisher*), Collection code BLF4032 (CASC: CASENT0415384).

**Paratypes.** (8 major workers and 32 minor workers) 8 major workers, same data as holotype: CASC: CASENT0415383, CASENT0415382, CASENT0709000, CASENT0709001, CASENT0709002, CASENT0709003, CASENT0709004,

CASENT0709005.9 minor workers, same data as holotype: CASC: CASENT0415374, CASENT0415375, CASENT0415381. 23 minor workers with same data as holotype but with different collection number, BLF4000.2 workers: BMNH: CASENT0405752, CASENT0413423. 2 workers: MCZ: CASENT0413424, CASENT0405761. 19 workers: CASC: CASENT0405759, CASENT0402669, CASENT0405760, CASENT0405750, CASENT0405763, CASENT0405751, CASENT0402678, CASENT0405754, CASENT0402671, CASENT0402672, CASENT0402673, CASENT0405765, CASENT0413325, CASENT0405762, CASENT0405764, CASENT0402674, CASENT0405753, CASENT040681, CASENT0413329.

**Diagnosis.** Antennae with nine segments. **Major worker:** Head almost subrectangular, longer than wide and anteriorly wider than posteriorly, face smooth and shiny and with comparatively large and scattered foveae in frontal view. Head and body with very short, mostly appressed pilosity, lacking long, standing hairs. **Minor worker:** Posterior margin of head nearly straight, frontal carinae reaching towards posterior quarter of head, dorsum of promesonotum smooth and shiny, propodeal dorsum areolate rugose.

**Description of major workers.** Measurements (n=4): HW 1.09–1.13 (1.12), HL 1.19–1.28 (1.23), SL 0.52–0.54 (0.53), MDL 0.60–0.65 (0.63), EL 0.0, WL 1.02–1.07 (1.04), PNH 0.53–0.56 (0.54), PNW 0.55–0.56 (0.56), MNH 0.72–0.75 (0.74), PDH 0.49–0.51 (0.50), PTL 0.51–0.56 (0.54), PPL 0.32–0.33 (0.32), PTH 0.36–0.44 (0.41), PPH 0.31–0.33 (0.32), PTW 0.33–0.36 (0.34), PPW 0.44–0.50 (0.46), PSL 0.15–0.17 (0.16), MFL 0.69–0.74 (0.72), MTL 0.60–0.63 (0.62), CI 88–92 (91), SI 47–48 (47), MDI 55–58 (56), EI 0, FI 63–65 (64), PSLI 13–15 (15), LPpI 100–102 (101), DPpI 138–150 (143), PpWI 130–141 (135), PpLI 58–62 (60), PpHI 73–88 (78).

Head longer than wide (CI 88–92), in full-face view nearly subrectangular, slightly narrowed posteriorly, posterior margin shallowly concave medially, corners rounded, sides of head straight to weakly convex. Mandibles with five teeth. Frontal carinae absent or inconspicuous. Anterior margin of clypeus weakly concave, sides subangulate. Antennae nine-segmented, scapes short, not surpassing cephalic midlength (SI 47–48). Eyes absent.

In profile, promesonotum nearly straight or weakly convex, slightly higher than propodeum. Scutum well-developed, scutellum present, but smaller than scutum. Promesonotal suture present or absent on dorsum, metanotum present as small and reduced sclerite. Dorsal face of propodeum in profile straight, or slightly concave, declining posteriorly, propodeum with anterodorsal corner weakly rounded, posterior corners with a pair of stout and subtriangular teeth, declivity of propodeum vertical, slightly concave in the middle, lamella well–developed and extending from the propodeal teeth to the propodeal lobe, forming a subangulate triangular shape. Propodeal spiracle rounded, situated close to center of lateral propodeum.

Petiole with moderately long peduncle, ventral face concave and posterior margin convex, subpetiolar process relatively large, forward-directed. In profile, petiole node with anterior margin deeply concave in middle, posterior margin vertical, nearly straight to slightly concave, and dorsal face roundly convex. Petiole node high, and well developed, antero-posteriorly compressed. Postpetiole roundly convex, and lower than petiole. In dorsal view, postpetiole almost as wide as petiole (PPW 0.44–0.50, PTW 0.33–0.36), petiole node wider than long, and flattened anteroposteriorly, anterior face of petiole nearly straight, posterior face roundly convex, sides rounded, postpetiole wider than long, anterior face nearly straight and posterior face roundly convex, posterolateral corners convex.

Face, clypeus, mandibles, pronotum and mesonotum smooth and shiny with scattered punctures and widely spaced foveae, each punctum and fovea with small hair. Gena with longitudinal striations and weakly marked reticulations on frontal lobes, mandibles with weak rugulae laterally near the bases. Sculpture on mesosoma consisting of transverse striations at metapleuron, rugosities at the junctions of pronotum, anepisternum, katepisternum and metapleuron, and weak rugae on dorsopropodeum. Petiole node and postpetiole dorsally smooth and shiny, lateroventrally finely areolate. Gaster smooth and shiny, foveolate near the anterodorsal corner, and with weak longitudinal carinae at articulation to postpetiole. Head and body with very short and appressed to subdecumbent pilosity. Scape and tibiae with abundant and appressed pilosity. Color light to reddish brown, gaster, legs and antennae orange to very light brown.

**Description of minor workers.** Measurements (n=5): HW 0.33–0.41 (0.38), HL 0.37–0.45 (0.42), SL 0.26–0.29 (0.27), MDL 0.26–0.27 (0.26), EL 0.02–0.02 (0.02), WL 0.38–0.56 (0.45), PNH 0.16–0.20 (0.18), PNW 0.20–0.24 (0.22), MNH 0.22–0.27 (0.25), PDH 0.17–0.20 (0.19), PTL 0.17–0.20 (0.19), PPL 0.12–0.15 (0.14), PTH 0.12–0.14 (0.13), PPH 0.08–0.09 (0.09), PTW 0.05–0.07 (0.07), PPW 0.08–0.11 (0.10), PSL 0.05–0.06 (0.05), MFL 0.26–0.32 (0.30), MTL 0.20–0.26 (0.24), CI 88–92 (90), SI 69–84 (72), MDI 65–82 (70), EI 5–6 (5), FI 76–81 (79), PSLI 11–16 (13), LPpI 165–167 (165), DPpI 67–75 (71), PpWI 142–161 (156), PpLI 72–77 (75), PpHI 63–67 (66).

Head longer than wide (CI 88–92), in full-face view weakly subrectangular, with convex sides, nearly straight posterior head margin and rounded posterolateral corners. Mandibles with five teeth, apical and preapical teeth larger than others. Anterior margin of clypeus medially concave, bicarinate, with a small triangular tooth laterally. Frontal carinae extending beyond midlength of head. Antennae with nine segments, scapes ending before posterior quarter of head (SI 69–84). Eyes present, consisting of one ommatidium (EI 5–6).

In profile, promesonotum weakly convex, slightly more convex posterodorsally, metanotal groove narrow, but deeply impressed. Dorsum of propodeum straight to slightly convex and much shorter than posterior declivity, rounded anteriorly, declining posteriorly towards posterodorsal corners, spines small, acute-triangular, and upwardly directed, declivity of propodeum nearly straight and lamella of propodeal declivity concave medially between the spines and propodeal lobes. Propodeal spiracle situated close to posterolateral border of propodeum.

Petiole in profile with moderately short peduncle, ventral face almost straight or weakly concave at center, anteriorly directed subpetiolar process present, posteroventrally with a pronounced convex corner, petiole dorsum anteriorly concave, petiole node roundly convex. Postpetiole longer than high (LPpI 165-167), lower than petiole (PpHI 63–67), in profile dorsally convex and rounded, ventrally weakly convex. In



**Figure 11.** *Carebara madibai.* Paratype minor worker, CASENT0405752: **A** head in full-face view **C** body in profile **E** body in dorsal view. Holotype major worker, CASENT0415384: **B** head in full-face view **D** body in profile **F** body in dorsal view.

dorsal view petiole node almost as wide as long, postpetiole almost 1.6 times wider than petiole (PpWI 142–161) with sides tapering anteriorly.

Head smooth and shiny at frons, rugulose at the sides and with scattered punctations except medially on frons, posterior margin of head with carina. Promesonotum, posterior declivity of propodeum, dorsum of petiole and postpetiole, and gaster smooth and shiny, remainder of mesosoma, petiole and postpetiole areolate rugulose. Head, scapes and tibiae with short, decumbent pilosity, mesosoma and metasoma with moderately long subdecumbent to suberect hairs and scattered shorter, decumbent pilosity. Color orange with lighter legs. **Distribution and biology.** *Carebara madibai* is found in the Central African Republic, Dem. Rep. Congo, Gabon and Uganda, where it was collected from leaf-litter at elevations ranging from 375–680 m. Individuals and nest series were collected from sifted litter, leaf mold and rotten wood.

**Comments.** *Carebara madibai* is the only species of this group with nine-segmented antennae.

Material examined. CENTRAL AFRICAN REPUBLIC: Parc National Dzanga-Ndoki, Mabéa Bai, 21.4 km 53° NE Bayanga, 3.03333, 16.41, 510m, rainforest, 10–17.v.2001 (*B.L. Fisher*); Réserve Spéciale de Forêt Dense de Dzanga Sangha, 12.7 km 326°, 3.005, 16.19333, 420m, rainforest, 10–17.v.2001, (*B.L. Fisher*); GA-BON: Woleu Ntem: 31.3 km 108° ESE Minvoul, 2.08, 12.40667, 600m, rainforest 11.ii.1998 (*B.L. Fisher*); Ogooue-Maritime, Aire d'Exploit. Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, –2.22639, 10.40972, 375m, rainforest, 6.iii.2000 (*B.L. Fisher*); UGANDA: Semuliki NP, 0.84483, 30.15052, 680m, rainforest, 02.viii.2012 (*B.L. Fisher* et al.).

**Etymology.** Named in memory Nelson Rolihlahla Mandela (18 July 1918–5 December 2013), who was nicknamed Madiba by his people, former South African president and anti-apartheid revolutionary, often also described as "father of the nation".

## Carebara nicotianae (Arnold), comb. n., stat. rev.

Figure 12

Sporocleptes nicotianae Arnold, 1948: 220. Three syntype(?) minor workers: ZIMBA-BWE: Macheke, 3.x.1948? [not examined].

Aneleus politus nicotianae (Arnold): as subspecies of Aneleus politus (Santschi): Arnold 1952: 460 (combination; change of status).

Oligomyrmex politus nicotianae (Arnold): Ettershank 1966: 124 (combination).

**Diagnosis.** Antennae with 11 segments. **Major worker:** Head in full-face view wider than long, wider posteriorly than anteriorly, posterior margin of head widely and shallowly concave to V-shaped medially, face with coarse, irregular, longitudinal rugose-reticulate sculpture and weakly punctate interspaces, dorsum of scutum in profile strongly convex, propodeal spines acute, triangular and directed upward, petiole with short, anteriorly directed tooth anteroventrally, gaster with abundant, short, appressed pilosity plus longer suberect standing hairs. **Minor worker:** Head in full-face view oval with strongly convex sides, face smooth and shiny with frontal carinae ending at about cephalic midlength, posterior margin of head deeply concave, in profile propodeal dorsum straight, mesonotum and propodeum with areolate sculpture and spines well developed, moderately long and triangular. Gaster with several relatively long suberect hairs.

**Description of major worker.** Measurements (n=1): HW 2.09, HL 1.78, SL 0.82, MDL 0.94, EL 0.15, WL 2.27, PNH 1.48, PNW 1.71, MNH 2.27, PDH 0.94, PTL 0.91, PPL 0.59, PTH 0.73, PPH 0.70, PTW 0.70, PPW 1.01, PSL 0.45, MFL

1.45, MTL 1.22, CI 117, SI 39, MDI 45, EI 7, FI 70, PSLI 21, LPpI 83, DPpI 172, PpWI 143, PpLI 64, PpHI 97.

Head distinctly wider than long (CI 117), in full-face view massive and weakly heart shaped, posteriorly wider than anteriorly. Posterior margin of head widely and shallowly emarginate, sides convex. Mandibles triangular and masticatory margin with six teeth including the basal tooth. Anterior margin of clypeus medially straight, laterally concave. Antennae eleven-segmented, scapes reaching slightly beyond midlength of head (SI 39). Eyes relatively small, multi-faceted (EI 7).

In profile, mesosoma queenlike and large, pronotum high, with large and convex scutum, scutellum inconspicuous, most likely fused with scutum. Promesonotal suture present, metanotal sclerite strongly reduced, present as narrow band below overhanging scutum-scutellum. Anepisternum and katepisternum large and well-separated from each other and segmental plates surrounded by relatively wide grooves with several short, parallel, coarse and transverse carinae. Dorsal face of propodeum nearly straight, propodeal spines relatively long, acute and with blunt tips, posterior declivity of propodeum slightly concave with a shallow lamella starting from below the base of the spines towards propodeal lobes. Propodeal spiracle situated nearly in the center of lateropropodeum.

Petiole with short peduncle, in profile ventrally straight, with rounded posteroventral corner, subpetiolar process short and digitiform, pointing anteroventrally, anterodorsal face slightly concave, posterodorsal face vertical and concave, petiole node massive and tapering apically, widely transverse on dorsal edge and posteriorly marginate. Postpetiole roundly convex in profile, about as high as petiole (PpHI 97) and distinctly higher than long (PpLI 64), convex anterodorsally, the posterior margin towards gaster oblique and linear, and with a very short ventral face. In dorsal view, petiole node anteriorly and posteriorly compressed, wider than long, anterior and posterior faces nearly straight, postpetiole about 1.4 times wider than petiole (PpWI 143), anterior and posterior faces convex.

Mandibles smooth and shiny, with weak rugulae laterally near the bases. Clypeus smooth and shiny medially, with lateral carinae. Frons and remainder of face with coarse, irregular, longitudinal rugose-reticulate sculpture, the interspaces superficially reticulate-punctate. Frontal carinae absent or inconspicuous. Dorsal pronotum anteriorly rugose-reticulate, grading to posteriorly weakly punctate, scutum grading from medially superficially punctate to laterally irregularly and posteriorly coarsely rugose-reticulate. Lateral pronotum, anepisternum and katepisternum mostly smooth and shiny, the latter weakly rugulose at margins. In profile propodeum longitudinally rugulose near the lateral base, dorsolaterally with coarse rugae and punctures in between. Posterior propodeal declivity weakly punctate. Petiole node punctate and with strong vertical rugae near the posterodorsal base. Postpetiole dorsum with irregular, longitudinal rugoreticulate sculpture. Gaster, near articulation to postpetiole, with many short, but strongly developed, longitudinal carinae, covered with a dense coat of short pubescence, and anterior quarter of first gastral tergite with faint longitudinal rugulae present.

Head and body with abundant long, erect to subdecumbent hairs, and with short, appressed to decumbent, very fine pilosity, the latter very abundant on postpetiole and

gaster. Scapes and tibiae with short, very fine, and decumbent pilosity. Color reddish brown, antennae, legs and gaster yellowish light brown.

**Description of minor workers.** Measurements (n=5): HW 0.46–0.47 (0.46), HL 0.52–0.54 (0.53), SL 0.35–0.37 (0.36), MDL 0.27–0.29 (0.28), EL 0.02–0.03 (0.02), WL 0.52–0.65 (0.56), PNH 0.23–0.24 (0.23), PNW 0.26–0.28 (0.27), MNH 0.31–0.33 (0.32), PDH 0.23, PTL 0.23–0.26 (0.24), PPL 0.14–0.15 (0.15), PTH 0.14–0.15 (0.15), PPH 0.09–0.10 (0.10), PTW 0.07–0.09 (0.08), PPW 0.11–0.12 (0.11), PSL 0.09–0.10 (0.09), MFL 0.38–0.43 (0.41), MTL 0.30–0.34 (0.31), CI 86–89 (88), SI 76–80 (77), MDI 58–61 (60), EI 5–6 (5), FI 84–90 (88), PSLI 19–21 (20), LPpI 141–167 (153), DPpI 70–81 (76), PpWI 127–161 (140), PpLI 56–67 (62), PpHI 63–68 (65).

Head longer than wide (CI 86–89), narrowed anteriorly and posteriorly, posterior margin of head sharply concave, occipital corners convex, sides strongly convex. Mandibles with five well-defined teeth. Anteromedian margin of clypeus concave, with triangular denticle laterally. Antennae with eleven segments, scapes reaching about 6/7 towards posterior margin of head (SI 76–80). Eyes consisting of one ommatidium (EI 5–6).

In profile, promesonotum weakly convex to almost straight, roundly convex at posterodorsal corner, metanotal groove weakly impressed to inconspicuous. Pronotum in profile about as high as propodeum. Dorsum of propodeum slightly convex and much shorter than posterior declivity, propodeal spines long, very acute and lamellate, lamella reaching from spines down toward propodeal lobes. Propodeal spiracle in profile close to posterior border of propodeum, somewhat below base of spine.

In profile, petiole with relatively long peduncle, ventrally weakly concave near the anterior corner and convex near the posterior corner, with a very short and angular tooth anteriorly, anterodorsally deeply concave at center, peduncle about as long as petiole node, dorsal face of node subangulate, anterodorsally rounded. Postpetiole in profile on average about 1.5 times longer than high (LpPI 141–167) and lower than petiole (PpHI 63–68), dorsally convex, bluntly angulate anteriorly and slightly rounded posteriorly, with a small, convex ventral process anteriorly. In dorsal view, petiole node about 1.5 times longer than wide, postpetiole on average 1.4 times wider than petiole (PpWI 127–161), with anteriorly converging sides. Gaster very slender in dorsal view, with acute anterior corners lateral of postpetiole attachment.

Mandibles, clypeus and face smooth and shiny, malar area up to eye level weakly longitudinally striate, with one or a few faint striae reaching posteriorly towards posterolateral lobes. Frontal carinae moderately long, continuing behind eye level to about midlength of head. Promesonotum and posterior declivity of propodeum mostly smooth and shiny, but mesopleuron and lateral and dorsal propodeum entirely areolate. Petiole areolate. Postpetiole mostly smooth and shiny and covered with weak punctures. Gaster smooth and shiny.

Head and body with several, relativel uniformly spaced, moderately long suberect to subdecumbent hairs, short decumbent pilosity very scattered and almost entirely absent from head and body surface. Posterolateral head corners with two to three short



**Figure 12.** *Carebara nicotianae.* Minor worker, CASENT0066894: **A** head in full-face view **C** body in profile **E** body in dorsal view. Major worker, CASENT0066710: **B** head in full-face view **D** body in profile **F** body in dorsal view.

stiff hairs. Scapes and tibiae with short, decumbent pilosity. Color dark orange with slightly lighter legs and gaster.

**Distribution and biology.** *Carebara nicotianae* is found in Zambia and Zimbabwe (type locality), collected in miombo woodland (Zambia) and at elevations ranging from 1300 to 1650 m.

**Comments.** *C. nicotianae* may be confused with *C. polita* but major workers of *C. nicotianae* are without horns at posterolateral lobes while those of *C. polita* have small protuberances or horns, and mesonotum and propodeum of *C. nicotianae* minor workers are areolate while those of *C. polita* are smooth and shiny.

As the type material for this species could not be obtained during our studies, we used the original description and drawing of the type specimen by Arnold for the identification of our material. The facts that the material collected in Zambia is fairly close to the locality of the old types and that it does not fit the character distribution found within material of *Carebara polita* led us to the conclusion that the new material is conspecific with *C. nicotianae*. Therefore it is here reinstated to the status of full species.

Material examined. ZAMBIA: Central: Lusaka, Leopard Hill, Kapuka Farm, –12.55483, 30.29567, 1300m, miombo woodland, 29.xi–3.xii.2005 (*B.L. Fisher* et al.); Central, Lusaka, Leopard Hill, Kapuka Farm, 1330m, miombo woodland, 3.xii.2005 (*B.L. Fisher* et al.); Northern, 5.3 km 247° Senga Hill, –9.386, 31.19683, 1650m, miombo woodland, 27.xi.2005 (*B.L. Fisher* et al.).

#### Carebara perpusilla (Emery)

Figure 13

- Pheidologeton perpusillum Emery, 1895: 26. Lectotype (major worker, MSNG: ANTC24569/ CASENT0904661) [designated here]: SOUTH AFRICA: Gauteng, Pretoria (Simon) [examined].
- Carebara (Aneleus) pupusilla (Emery): Emery 1900: 327 (combination).
- Aneleus perpusillus (Emery): Santschi 1914a: 77 (combination).
- Oligomyrmex pupusillum (Emery): Ettershank 1966: 124 (combination).
- Carebara pupusilla (Emery): Fernández 2004: 235 (combination).
- = Pheidologeton (Aneleus) perpusillus spinosus Forel, 1907: 17. Syntype (1 major worker, MHNG: CASENT0908885) TANZANIA: Kibosho (Katona) [examined]. syn. n.
- Aneleus perpusillus concedens Santschi, 1914a: 77. Syntypes (1 major & 1 minor worker, NHMB: CASENT0913515, CASENT0913516) TANZANIA: Moshi, 800 m, St. 72, April 1912 (*Alluaud & Jeannel*) [examined]. syn. n.
- Oligomyrmex perpusillus arnoldianus Ettershank, 1966: 123 (replacement name for *Pheidologeton perpusillum* subsp. arnoldi Forel, 1914: 242. Junior secondary homonym of Oligomyrmex arnoldi Forel, 1913a: 123). Syntype (1 major worker, BMNH: ANTC21808/ CASENT0902378): ZIMBABWE: Bulawayo, 1.iv.1913 (G. Arnold) [examined]. syn. n.

**Diagnosis.** Antennae with eleven segments. **Major worker:** Head in full-face view distincly longer than wide, almost rectangular with subparallel sides and rounded posterolateral corners, a transverse carina present near posterior head margin, sculpture on mesosoma reduced, mostly consisting of weak to superficial areolae on katepisternum and lateropropodeum. **Minor worker:** Head in full-face view subrectangular, with weakly convex sides, face and pronotum smooth and shiny, posterior head margin weakly concave medially, posterolateral corners rounded.

**Description of major workers.** Measurements (n=5): HW 0.52–0.70 (0.62), HL 0.68–0.95 (0.80), SL 0.28–0.38 (0.32), MDL 0.32–0.49 (0.38), EL 0.0–0.05 (0.03),

WL 0.53–0.69 (0.62), PNH 0.24–0.35 (0.31), PNW 0.29–0.39 (0.36), MNH 0.37–0.51 (0.44), PDH 0.23–0.29 (0.26), PTL 0.22–0.30 (0.26), PPL 0.14–0.17 (0.15), PTH 0.16–0.22 (0.19), PPH 0.14–0.18 (0.16), PTW 0.13–0.18 (0.16), PPW 0.18–0.24 (0.22), PSL 0.07–0.11 (0.09), MFL 0.32–0.44 (0.38), MTL 0.27–0.40 (0.32), CI 74–80 (77), SI 48–54 (52), MDI 56–69 (62), EI 0–7 (5), FI 57–63 (61), PSLI 14–16 (15), LPpI 88–95 (92), DPpI 132–167 (151), PpWI 128–163 (142), PpLI 50–65 (58), PpHI 81–90 (85).

Head longer than wide (CI 74–80), in full-face view nearly rectangular. Posterior margin of head roundly concave in middle, posterolateral corners slightly rounded or truncate, sides of the head weakly convex, nearly straight. Mandibles with six teeth. Anterior margin of clypeus concave in middle, sides angulate. Antennae eleven-segmented, scapes short, not surpassing cephalic midlength (SI 48–54). Eyes present, usually consisting of six to eight ommantidia (EI 0–7).

In profile, promesonotum roundly convex and higher than propodeum. Scutum and scutellum fused, promesonotal suture absent dorsally, metanotum small but separated from promesonotum. Dorsal face of propodeum straight, or slightly concave, declining posteriorly, propodeal spines subtriangular, directed slightly forward, posterior declivity of propodeum concave in profile. Propodeal spiracle roundly convex, situated closer to dorsum of propodeum than middle, lamella present but not well-developed.

Petiole with long peduncle, in profile ventrally nearly straight or weakly convex, anterior subpetiolar process present as small tooth, petiole node relatively high, dorsally weakly rounded and anteriorly and posteriorly relatively straight to slightly convex. Postpetiole in profile dorsally roundly convex, lower than petiole. In dorsal view petiole node wider than long, anteroposteriorly flattened and slightly convex, sides somewhat rounded, postpetiole about 1.5 times wider than long (DPpI 132–167), on average 1.4 times wider than petiole (PpWI 128–163), shaped almost as a half-circle, with weakly concave anterior, and convex lateral and posterior faces.

Mandibles, clypeus and face mostly smooth and shiny with scattered punctures, head laterally and posteriorly with fine or well-defined, irregular striations or reticulations, gena with well developed and longitudinal reticulations extending to eye level, weakly marked reticulations present on frontal lobes, frontal carinae absent or inconspicuous. Dorsom of promesonotum smooth and shiny, remainder of mesosoma areolate-rugose to weakly areolate, but sculpture on antero- and lateropronotum and on anepisternum often effaced to partly smooth. Petiole node and postpetiole dorsally smooth and shiny, lateroventrally finely areolate. Gaster smooth and shiny with scattered punctures on dorsum.

Head and body with moderately long, suberect standing hairs and fine, decumbent to subdecumbent pilosity, both hair types abundant on gaster. Scapes and tibiae with abundant, decumbent pilosity. Color reddish brown, legs and antennae yellowish.

**Description of minor workers.** Measurements (n=7): HW 0.31–0.39 (0.35), HL 0.37–0.46 (0.42), SL 0.24–0.30 (0.28), MDL 0.20–0.27 (0.23), EL 0.01–0.02 (0.02), WL 0.38–0.56 (0.44), PNH 0.14–0.20 (0.17), PNW 0.20–0.25 (0.23), MNH 0.21–

0.28 (0.25), PDH 0.15–0.20 (0.17), PTL 0.14–0.18 (0.15), PPL 0.09–0.11 (0.10), PTH 0.09–0.10 (0.11), PPH 0.06–0.08 (0.07), PTW 0.05–0.09 (0.07), PPW 0.08–0.11 (0.09), PSL 0.05–0.07 (0.06), MFL 0.25–0.32 (0.28), MTL 0.20–0.27 (0.24), CI 83–87 (85), SI 77–79 (78), MDI 63–69 (65), EI 4–6 (5), FI 77–81 (80), PSLI 14–19 (17), LPpI 133–173 (153), DPpI 81–93 (87), PpWI 122–143 (132), PpLI 59–71 (66), PpHI 60–67 (64).

Head longer than wide (CI 83–87), in full-face view weakly subrectangular, with convex sides, posterior margin slightly concave in middle, posterolateral corners rounded. Mandibles with five teeth, apical and preapical teeth larger than the rest. Anterior margin of clypeus nearly straight, or weakly concave, bicarinate. Frontal carinae not reaching midlength of head, ending posterior of eye level. Antennae with eleven segments, scapes ending before posterior margin of head (SI 77–79). Eyes consisting of one ommatidium (EI 4–6).

In profile, promesonotum weakly convex, anterodorsally marginate, metanotal groove rounded and deeply impressed. Dorsum of propodeum straight, declining towards posterodorsal corners, and about as long as weakly concave posterior declivity, spines acute-triangular and upwardly directed. Propodeal spiracle rounded and situated closely beneath the base of spines.

Peduncle of petiole about as long as petiole node, in profile ventral face anteriorly weakly concave, with very short to almost inconspicuous angulate tooth, and posteriorly convex, petiole node low and dorsally rounded to subtriangular. Postpetiole in profile on average 1.5 times longer than high (LPpI 133-173), lower than petiole (PpHI 60-67), weakly convex dorsally and ventrally weakly concave. In dorsal view, petiole node slightly wider than long, weakly convex laterally, anteriorly and posteriorly slightly convex, postpetiole on average 1.3 times wider than petiole (PpWI 122-143), posterior face roundly convex, with sides oblique and tapering anteriorly.

Mandibles, clypeus and face smooth and shiny with relatively abundant punctures. Promesonotum smooth and shiny, remainder of mesosoma areolate. Petiole and postpetiole areolate–rugose, except for smooth and shiny dorsum of petiole node and lateral and dorsal face of postpetiole. Gaster smooth and shiny.

Head and body with relatively few erect to suberect standing hairs and relativley abundant, decumbent pilosity. Scapes and tibiae with decumbent pilosity. Color yellowish orange.

**Distribution and biology.** *Carebara perpusilla* is a widespread species found in Kenya, Rwanda, South Africa, Tanzania, Uganda, Zambia, and Zimbabwe, mainly in primary rainforest (Kenya) and miombo woodland (Zambia). *Carebara perpusilla* has been collected at elevations ranging from 42–2100 m. Individuals and nest series were collected in leaf-litter and from soil, using Winkler, pitfall and pan traps.

**Comments.** Carebara perpusilla is similar to, but smaller than *C. silvestrii*. Also, major workers of *C. perpusilla* have a smooth and shiny lateropronotum and anepisternum, while these parts are densely areolate in *C. silvestrii*. The minor workers of *C. perpusilla* have a smooth and shiny face and pronotum, while in *C. silvestrii* these parts are never completely smooth, and usually have some areolate or rugose sculpture.



**Figure 13.** *Carebara perpusilla*. Minor worker, CASENT0914219: **A** head in full-face view **C** body in profile **E** body in dorsal view. Major worker, CASENT0914217: **B** head in full-face view **D** body in profile **F** body in dorsal view.

Material examined. KENYA: Western, Kakamega Forest, Salazar, 0.32667, 34.87083, 1650m, primary forest habitat, 9.iii.2009 (*Marcell Peters*); Central Province, Mt. Kenya, Chogoria, point D, 24 km from gate, 3171m, 9–12.iii.2009 (*J. Mugambi*); Coastal Province, Arabuko Sokoke Forest, 3.27257, 39.91735, 42m, Cynometra forest, vi.2009 (*G. Fischer & F. Hita Garcia*); Kakamega district, Isechen Nature Reserve, nr Kalunya Glade, 0.24, 34.86, 1800m, 4.v.2001, rainforest (*R. R. Snelling*). Kenya: Lamu, nr Witu, 26.x.1977 (*V. Mahnert & J.L. Perret*); Tana Riv. Galole, 60m, 21.x.1977 (*V. Mahnert & J. L. Perret*); Tana Riv, Wema, 24.x.1977 (*V. Mahnert & J.L. Perret*); RWANDA: Rangiro, ix.1976 (*P. Werner*); SOUTH AFRICA: KwaZulu-Na-

tal, Umtamvuna Nature Reserve, -31.04507, 30.168, 220m, Pondoland coastal plateau, sour grassland, 18.xi.2000 (*S. Van Noort*); KwaZulu-Natal, Umtamvuna Nature Reserve, -31.04507, 30.168, 220m, Pondoland coastal plateau, sour grassland, 10–17. xi.2000 (*S. Van Noort*); **UGANDA**: Ruwenzori, above ibanda, 2100m, 9.v.1993 (*Cuccodoro & Erne*); Mt Elgon, Sipi, 1750m, 31.v.1993 (*Cuccodoro & Erne*); **ZAMBIA**: Central, Lusaka, Leopard Hill, Kapuka Farm, -12.55483, 30.29567, 1300m, miombo woodland, 2.xii.2005 (*B.L. Fisher* et al.).

#### Carebara polita (Santschi)

Figure 14

 Aneleus politus Santschi, 1914a: 79. Syntypes (3 minor workers, CASENT0913517) KENYA: Blue Post Hotel (Thika, ca. 40 km NE of Nairobi), 1520m, i.1912 (Alluaud & Jeannel) [3 syntypes examined].
Oligomyrmex politus (Santschi): Ettershank 1966: 124 (combination).

Carebara polita (Santschi): Fernández 2004: 235 (combination).

**Diagnosis.** Antennae with 11 segments. **Major worker:** Head in full-face view about as long as wide, posterior wider than anterior, posterior head margin with widely V-shaped emargination and small, tooth-like horns at posterolateral corners, propodeum with short, triangular, bluntly rounded spines, dorsum of propodeum nearly straight or very weakly convex, petiole with small, shallowly triangular ventral process, gaster with little, very short and appressed pilosity. **Minor worker:** Head in full-face view oval with strongly convex sides and deeply concave posterior emargination, face and most of mesosoma smooth and shiny, frontal carinae not extending beyond cephalic midlength, spines elongate-triangular, in dorsal view about as long as distance between them, gaster smooth and shiny and with or without very few standing hairs.

**Description of major workers.** Measurements (n=6): HW 1.20–1.74 (1.62), HL 1.17–1.77 (1.59), SL 0.65–0.74 (0.70), MDL 0.68–0.86 (0.80), EL 0.09–0.15 (0.13), WL 1.58–1.80 (1.71), PNH 0.83–1.05 (0.97), PNW 0.93–1.17 (1.07), MNH 1.13–1.35 (1.28), PDH 0.72–0.77 (0.75), PTL 0.65–0.72 (0.68), PPL 0.42–0.48 (0.45), PTH 0.54–0.57 (0.55), PPH 0.47–0.51 (0.48), PTW 0.47–0.58 (0.55), PPW 0.63–0.69 (0.67), PSL 0.29–0.33 (0.31), MFL 1.07–1.16 (1.12), MTL 0.84–0.95 (0.89), CI 97–108 (102), SI 40–54 (44), MDI 45–56 (50), EI 5–9 (8), FI 62–94 (71), PSLI 17–28 (19), LPpI 88–100 (94), DPpI 140–153 (148), PpWI 109–135 (122), PpLI 63–70 (60), PpHI 84–89 (87).

Head about as long as wide (CI 97–108), in full-face view weakly subquadrate, with posteriorly slightly diverging, convex sides, posterior margin usually triangularly emarginate and with small protuberances or horns at posterolateral lobes. Mandibles with five well-developed teeth. Clypeus slightly concave at anteromedian margin, laterally with two carinae. Antennae eleven-segmented, scapes short, reaching slightly

beyond midlength of head (SI 40–54). Eyes present, with between ten and sixteen ommatidia (EI 5–9).

In profile, promesonotum roundly convex, much higher than propodeum. Scutum well-developed, scutellum either fused with scutum or vestigial in most specimens, but well-developed in a few major workers. Promesonotal suture present on dorsum, metanotum developed and usually well-separated. Anepisternum and katepisternum large and well separated by a wide groove with some cross-ribs. Dorsal face of propodeum straight and declining posteriorly, propodeal spines comparatively short and stout with rounded tips, declivity of propodeum slightly concave, with lamella reaching from basal edge of spines towards propodeal lobes. Propodeal spiracle close to center of propodeum.

Petiole with moderately short peduncle, in profile ventrally weakly concave with rounded posterior corner, subpetiolar process short and subtriangular to reduced, petiole node in profile high and subrectangular, anteriorly concave, posterior margin vertical and nearly straight, dorsal face nearly straight or weakly convex. Postpetiole in profile lower than petiole (PpHI 84–89), subglobular, almost as long as high (LpPI 88–100), dorsally roundly convex, ventral face much shorter than dorsal face. In dorsal view, petiole wider than long, strongly flattened anteroposteriorly, anterior and posterior faces straight to almost straight, postpetiole weakly hexagonally shaped, on average 1.2 times as wide as petiole (PpWI 109–135), and sides weakly subangulate anteriorly and towards posterior face.

Mandible and head with scattered punctures, except medially on frons. Mandibles smooth and shiny, and laterally weakly striate, clypeus smooth and shiny, with lateral carinae, frons finely longitudinally rugulose, rugulae diverging posteriorly towards posterolateral lobes, at sides of head weaker and more irregular, interspaces weakly to faintly punctate-rugose. Frontal carinae weakly developed, length varying from reaching towards anterior eye level to about midlength of head.

Dorsum of pronotum and scutum variably circularly striate, sometimes only on margins, with center being smooth and shiny, lateral portions of pronotum, anepisternum and katepisternum mostly smooth and shiny to faintly striate. Propodeum longitudinally striate lateroventrally, dorsally and dorsolaterally coarsely sculptured with irregular rugulae, posterior propodeal declivity shagreened or micropunctate. Petiole and postpetiole densely punctate lateroventrally, grading to smooth and shiny on dorsal faces. Gaster smooth and shiny, anteriorly, at articulation with postpetiole, weakly punctate.

In profile, head and body with several short, suberect hairs and scattered short, appressed pilosity. Head in full-face view with two or three relatively coarse suberect hairs present on posterolateral lobes. Scapes and tibiae with abundant appressed and yellow pilosity. Color reddish brown, legs and antennae yellowish or light brown.

**Description of minor workers.** Measurements (n=11): HW 0.43–0.54 (0.51), HL 0.50–0.62 (0.57), SL 0.36–0.44 (0.41), MDL 0.25–0.32 (0.30), EL 0.00–0.03 (0.02), WL 0.48–0.76 (0.58), PNH 0.23–0.29 (0.26), PNW 0.26–0.32 (0.29), MNH 0.33–0.42 (0.38), PDH 0.23–0.29 (0.26), PTL 0.23–0.29 (0.25), PPL 0.14–0.18 (0.16), PTH 0.15–0.17 (0.16), PPH 0.10–0.12 (0.11), PTW 0.08–0.12 (0.10), PPW

0.11–0.15 (0.13), PSL 0.08–0.11 (0.09), MFL 0.38–0.49 (0.45), MTL 0.29–0.38 (0.35), CI 86–91 (88), SI 78–84 (81), MDI 53–62 (59), EI 0–7 (5), FI 78–92 (88), PSLI 16–21 (18), LPpI 136–171 (147), DPpI 75–91 (83), PpWI 119–136 (126), PpLI 58–75 (63), PpHI 61–73 (66).

Head in full-face view longer than wide (CI 86–91), with strongly convex sides, posterior margin of head sharply concave, posterolateral corners angulate to subangulate. Mandibles with four well-defined teeth. Anterior margin of clypeus deeply concave medially, bicarinate and anteriorly divergent, laterally with two small, triangular teeth. Frontal carinae extending towards the cephalic midlength. Antennae with eleven segments, scapes reaching about 6/7 towards posterior margin of head (SI 78–84). Eyes usually present and consisting of one or two ommatidia, rarely no ommatidia visible (EI 0–7).

In profile, promesonotal dorsum smoothly rounded and convex, metanotal groove shallowly impressed. Dorsum of propodeum slightly convex and much shorter than posterior declivity, spines long and lamellate, lamella reaching from spines down toward large propodeal lobes. Propodeal spiracle closer to posterodorsal corner than center of propodeum.

Petiole in profile with moderately long peduncle, ventrally nearly straight, anteroventral corner with a very short to inconspicuous angulate tooth present, petiole node anteriorly slightly concave, posteriorly weakly convex, and dorsal face weakly convex to subangulate anteriorly and posteriorly. Postpetiole in profile convex, on average 1.5 times longer than high (LPpI 136–171), lower than petiole (PpHI 61–73). In dorsal view petiole anteriorly and laterally convex, postpetiole slightly wider than petiole (PpWI 119–136), postpetiole convex and tapering anteriorly, sides subparallel, posteriorly almost straight to faintly convex.

Mandibles, clypeus and face smooth and shiny, with scattered punctures, malar area up to eye level longitudinally striate. Mesosoma mostly smooth and shiny without microsculpture, propodeal lamella, dorsal and posterior propodeal margins weakly alveolate. Petiole weakly alveolate, dorsal face of node, postpetiole and gaster mostly smooth and shiny. Head and body usually without standing hairs and with very little appressed pilosity, in some specimens a few erect, relatively short and stiff hairs with blunt apices present on mesosoma and gaster. Scapes and tibiae with short, appressed pilosity. Color orange to dark brown (in Kibale and Semuliki National Parks, Uganda).

**Distribution and biology.** *Carebara polita* is a widespread species found in Cameroon, Central African Republic, Gabon, Kenya, Tanzania, and Uganda, mainly in rainforest, montane wet forest, and evergreen forest. *Carebara polita* has been collected at elevations ranging from 110–2045 m. Individuals and nest series were collected in leaf-litter and from soil, using Winkler and pitfall traps.

**Comments.** *Carebara polita* can be easily separated from the other species, because major workers have small protuberances or horns at the posterolateral lobes of head. Minor workers with sides of head strongly convex and head and body mostly smooth and shiny. This species can be confused with *C. nicotianae*, but major workers of *C. nicotianae* do not have horns at the posterolateral lobes, and the mesonotum and propodeum are areolate in *C. niconianae* minor workers, but mostly smooth and shiny in *C. polita*.



**Figure 14.** *Carebara polita.* Minor worker, CASENT0235574: **A** head in full-face view **C** body in profile **E** body in dorsal view. Major worker, CASENT0914213: **B** head in full-face view **D** body in profile **F** body in dorsal view.

Material examined. CAMEROON: Sud-Ouest, Korup N. P., 6.9 km 317° NW Mundemba, 5.016, 8.864, 110m, rainforest, 19.iv.2000 (*B.L. Fisher*); CENTRAL AFRICAN REPUBLIC: Prefecture Sangha-Mbaéré, Parc National Dzanga Ndoki, 38.6 km 173° S Lidjombo, 2.36, 16.14397, 350m, rainforest, 21–27.v.2001 (*S. Van Noort*); GABON: Ogooue-Maritime, Reserve de Faune de la Moukalaba Dougoua, 12.2 km 305° NW Doussala, –2.31667, 10.53333, 110m, rainforest, 24.ii.2000 (*B.L. Fisher*); Ogooue Maritime, Aire d'Exploit. Rationnelle de Faune des Monts Doudou,

24.5 km 303° WNW Doussala, -2.23283, 10.398, 630m, rainforest, 18.iii.2000 (B.L. Fisher); Woleu Ntem, 31.3 km 108° ESE Minvoul, 2.08, 12.40667, 600m, rainforest, 7.ii.1998, (B.L. Fisher); KENYA: Western, Kakamega Forest, Salazar, 0.32667, 34.87083, 1650m, primary forest habitat, 9.iii.2009 (Marcell Peters); Western, Kakamega Forest, Ivalakale farmland, 0.34556, 34.865, 1650m, farmland, 09.vii.2008 (G. Fischer); Western, Kakamega District, Isecheno, Isecheno Forest Reserve, 0.24, 34.86, 1600m, 31.viii.2001 (W. Okeka); Kikiyu. Esc. Gatamayu, 233 m, montane forest, ii.1999 (Th. Wagner); Mt. Kenya, 0.7km NE Kangaita Forest Sta, 2045m, montane wet forest, 23.i.2000 (R.R. Snelling); TANZANIA: Morogora, Udzungwa Mts. 4.5km W. Chita, 600m, 28.viii.1995 (W.T. Stanley); Morogora, Udzungwa Mts. 3.5km W. 1.7km N Chita, 910m, 7.viii.1995 (W.T. Stanley); UGANDA: Mt. Elgon, Sipi, 1750m, 01.vi.1993 (Cuccodoro & Erne); Kabarole, Kanyawara, Kibale NP, 0.56427485, 30.358759, 1520m, mature wet forest, 4-26.viii.2008 (S. Van Noort); Kabarole, Kanyawara, Kibale NP, 0.56427485, 30.358759, 1510m, evergreen forest, 6-16.viii.2012 (Ant Course 2012); Semuliki NP, 0.83556, 30.15542, 676m, rainforest, 30.vii.-1.viii.2012 (B.L. Fisher et al.).

#### Carebara silvestrii (Santschi), comb. n.

Figure 15

Aneleus silvestrii Santschi, 1914b: 357. Lectotype (1 major worker, NHMB: ANTC27952/ CASENT0913522) [designated here]: GHANA: Cöte d' Or, Aburi [Abury], (Silvestri) [1 minor and 1 major syntype examined].

Oligomyrmex silvestrii (Arnold): Ettershank 1966: 124 (combination).

 Aneleus (Aneleus) punctatus Karavaiev, 1931: 43. Holotype minor worker: KENYA: Mabira (no. 5323) [not examined] syn. n.

**Diagnosis.** Antennae with eleven segments. **Major worker:** Head nearly rectangular or subquadrate but distincly longer than wide, with parallel to weakly convex sides, rounded posterolateral corners and transverse carina present near posterior head margin, lateral portions of mesosoma usually extensively areolate, dorsal face of head smooth and shiny in larger major workers and with sculpture in medium major workers except for medially smooth and shiny frontal area, propodeum with a pair of short, acute, subtriangular spines, gaster covered with abundant decumbent hairs. **Minor worker:** Head suboval in full-face view, sides strongly convex, posterolateral corners subangulate, and posterior margin with convex emargination, frons smooth and shiny, remainder of face with longitudinal rugulae and reticulations, propodeal spines slightly elongate triangular to short spinose, gaster with several decumbent and moderately long hairs.

**Description of major workers.** Measurements (n=6): HW 0.64–0.99 (0.85), HL 0.79–1.15 (1.02), SL 0.34–0.45 (0.41), MDL 0.38–0.57 (0.49), EL 0.04–0.07 (0.05), WL 0.58–0.87 (0.75), PNH 0.24–0.46 (0.37), PNW 0.32–0.48 (0.42), MNH 0.39–0.62 (0.53), PDH 0.24–0.38 (0.31), PTL 0.20–0.36 (0.28), PPL 0.15–0.21 (0.18),

PTH 0.17–0.27 (0.22), PPH 0.14–0.23 (0.18), PTW 0.13–0.18 (0.15), PPW 0.15–0.23 (0.20), PSL 0.09–0.15 (0.12), MFL 0.37–0.60 (0.50), MTL 0.31–0.52 (0.43), CI 76–87 (83), SI 45–53 (49), MDI 56–61 (58), EI 6–7 (6), FI 57–65 (59), PSLI 13–16 (14), LPpI 92–107 (99), DPpI 100–128 (112), PpWI 122–144 (133), PpLI 56–81 (66), PpHI 76–88 (83).

Head longer than wide (CI 76–87), in full-face view nearly rectangular to subquadrate. Posterior margin of head weakly concave to V-shaped medially, posterolateral corners roundly convex, sides of the head nearly straight to slightly convex. Mandibles triangular and masticatory margin with five teeth including the basal tooth. Frontal carinae short or inconspicuous. Anterior margin of clypeus concave medially, sides angulate. Antennae with eleven segments, scapes short and not surpassing cephalic midlength (SI 45–53). Eyes small and consisting of one ommatidium (EI 6-7).

In profile, promesonotum roundly convex and higher than propodeum. Promesonotal suture present or absent on dorsum, metanotal groove present and impressed. Dorsal face of propodeum straight in profile, or slightly concave and declining posteriorly, anterodorsal corner weakly angulate, propodeal spines stout and subtriangular, posterior declivity concave. Propodeal spiracle rounded, situated slightly above center of lateral propodeum.

Petiole with relatively long peduncle, ventrally weakly concave anteriorly and slightly convex posteriorly, sometimes nearly straight over the whole length, subpetiolar process present as a small, angulate, forward-directed tooth, petiole node relatively high, anteroposteriorly somewhat compressed, dorsally subangulate anteriorly and posteriorly in smaller major workers, rounded in larger majors. Postpetiole in profile roundly convex dorsally, about as high as long (LPpI 92–107), and lower than petiole (PpHI 76–88). In dorsal view petiole node small, wider than long, anteriorly and posteriorly flattened and nearly straight to weakly convex, sides subangulate, postpetiole slightly wider than long (DpPI 100–128), about 1.3 times wider than petiole (PpWI 122–144), anteriorly and posteriorly weakly convex, laterally roundly convex.

Mandibles, clypeus and frons medially, and in large majors most of face, smooth and shiny with scattered punctures. In small majors sides of face with irregular longitudinal reticulations, grading to transverse reticulations towards posterior head margin, and with a transverse carina near posterior margin. In large majors, posterior head margin with transverse carina and with short transverse reticulations anterior and posterior of transverse carina. In all majors gena and frontal lobes with well-defined longitudinal striations. Dorsum of promesonotum centrally smooth and shiny, weakly reticulate near its margins, remainder of mesosoma areolate to weakly areolate, sometimes locally effaced on lateropronotum and katepisternum. Petiole node and postpetiole dorsally smooth and shiny, lateroventrally finely areolate. Gaster smooth and shiny with scattered punctures.

Head and body with moderately long suberect to subdecumbent hairs and short decumbent pilosity, scapes and tibiae with mostly decumbent pilosity. Color reddish brown, legs and antennae yellowish. **Description of minor workers.** Measurements (n=4): HW 0.36–0.44 (0.40), HL 0.41–0.51 (0.46), SL 0.29–0.34 (0.32), MDL 0.23–0.29 (0.26), EL 0.02, WL 0.45–0.59 (0.53), PNH 0.17–0.22 (0.19), PNW 0.23–0.27 (0.25), MNH 0.25–0.31 (0.28), PDH 0.17–0.22 (0.19), PTL 0.15–0.18 (0.16), PPL 0.11–0.12 (0.11), PTH 0.09–0.11 (0.10), PPH 0.08–0.09 (0.08), PTW 0.07–0.08 (0.08), PPW 0.08–0.10 (0.09), PSL 0.07–0.08 (0.07), MFL 0.30–0.39 (0.34), MTL 0.26–0.32 (0.29), CI 86–88 (87), SI 76–91 (81), MDI 62–66 (65), EI 4–6 (5), FI 80–91 (84), PSLI 17–19 (18), LPpI 139–160 (147), DPpI 69–81 (75), PpWI 109–122 (115), PpLI 67–80 (71), PpHI 71–83 (77).

Head longer than wide (CI 86–88), in full-face view anteriorly and posteriorly narrowed, sides strongly convex, posterior margin of head sharply concave, posterolateral corners angulate. Mandibles triangular with five teeth. Anterior margin of clypeus concave, bicarinate and divergent forward, sides angulate. Frontal carinae not surpassing midlength of head. Antennae eleven-segmented, scapes not reaching posterior head margin (SI 76–91). Eyes consisting of one ommatidium (EI 4-6).

In profile, promesonotum weakly convex, posterodorsal corner roundly convex, metanotal groove rounded and deeply impressed, pronotum anterodorsally transversely carinate. Dorsum of propodeum in profile straight, declining posteriorly, anterodorsal corner rounded, propodeal spines subtriangular and upwardly directed, posterior declivity of propodeum concave, lamella extending from the spines to the lobes. Propodeal spiracle rounded and situated below the base of spines and close to posterior border of lateral propodeum.

Petiole with relatively long peduncle, ventrally weakly concave anteriorly and slightly convex posteriorly, sometimes nearly straight over whole length, subpetiolar process present as small, angulate, forward-directed tooth, petiole node relatively low, small, subtriangular, or subangulate anteriorly and posteriorly. Postpetiole roundly convex in profile, on average about 1.5 times longer than high (LPpI 139–160), and lower than petiole (PpHI 71–83). In dorsal view petiole node small, almost wider than long, anteriorly weakly convex, posteriorly almost straight, sides subangulate, postpetiole longer than wide (DpPI 69–81), slightly wider than petiole (PpWI 109–122), anteriorly tapering, almost pedunculate, sides and posterior face roundly convex.

Mandibles, clypeus and frons smooth and shiny with scattered punctures, remainder of face irregularly rugreticulate. Dorsum of promesonotum weakly reticulate except for smooth and shiny center, and central area of lateral pronotum with effaced sculpture. Remainder of lateropronotum, mesopleuron and propodeum areolate, except smooth and shiny posterior declivity. Gaster and dorsum of petiole node and postpetiole smooth and shiny, remainder weakly areolate to areolate-rugose.

Head and body with moderalely long subcrect to subdecumbent hairs and short decumbent pilosity. Scapes and tibiae with decumbent pilosity. Color reddish brown, legs and antennae yellowish.

**Distribution and biology.** *Carebara silvestrii* is a widespread species found in Cameroon, Central African Republic, Equatorial Guinea, Gabon, Ghana (type-locality),

Ivory Coast, Kenya, Uganda and Zimbabwe, mainly in rainforest. *Carebara silvestrii* has been collected at elevations ranging from 10–2250 m. Individuals and nest series were collected from the leaf-litter and the soil with Winkler sifting, pitfall traps, and hand collections.

**Comments.** Carebara silvestrii may be confused with *C. perpusilla*, but lateropronotum and anepisternum are smooth and shiny in major workers of *C. perpusilla* while in *C. silvestrii* they are areolate. The frons is often smooth and shiny in minor workers of *C. silvestrii* and the remainder of the face usually coarsely rugoreticulate, while the entire head is smooth and shiny in *C. perpusilla*. Although type specimens could not be obtained, *Carebara punctata* (Karavaiev) is synonymised with *C. sylvestrii* based on the details provided in the original description.

Material examined. CAMEROON: Sud, P. N. Campo, 43.3 km 108° ESE Campo, 2.2825, 10.20617, 290m, rainforest, 7.iv.2000 (B.L. Fisher); Sud Ouest, Mt. Cameroon, Etinde Forest Res., 3.8 km 330° NNW Mapanja, 4.10767, 9.152, 1440m, 16.iv.2000 (B. L. Fisher); Sud, Res. de Faune de Campo, Massif des Mamelles, 15.1 km 84° E Ébodjé, 2.59417, 9.9595, 180m, 4.iv.2000, (B.L. Fisher); Sud: Bondé Forest, N'kolo village, 27.5 km 155° SSE Elogbatindi, 3.22167, 10.24667, 40m, rainforest, 12.iv.2000 (B.L. Fisher); CENTRAL AFRICAN REPUBLIC: Prefecture Sangha Mbaéré, Parc National Dzanga Ndoki, 37.9 km 169° S Lidjombo, 2.37067, 16.1725, 360m, rainforest, 21.v.2001 (B.L. Fisher); Prefecture SanghaMbaéré, Réserve Spéciale de Forêt Dense de Dzanga Sangha, 12.7 km 326° NW Bayanga, 3.005, 16.19333, 370m, rainforest, 10-17.v.2001 (B.L. Fisher); Prefecture Sangha-Mbaéré, Réserve Spéciale de Forêt Dense de Dzanga Sangha, 12.7 km 326° NW Bayanga, 3.005, 16.19333, 470m, rainforest, 10-17.v.2001 (B. L. Fisher); GA-BON: Ogooue-Maritime, Aire d'Exploit. Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, 2.22639, 10.40972, 375m, rainforest, 6.iii.2000 (B.L. Fisher); Woleu-Ntem, 31.3 km 108° ESE Minvoul, 2.08, 12.40667, 600m, rainforest, 7.ii.1998 (B.L. Fisher); Estuaire, F.C. Mondah, 21 km 331° NNW Libreville, 0.57667, 9.335, 10m, litoral rainforest, 24.ii.1998 (B.L. Fisher); Woleu-Ntem, 31.3 km 108° ESE Minvoul, 2.08, 12.40667, 600m, rainforest, 11.ii.1998 (B.L. Fisher); Ogooue-Maritime: Reserve de Faune de la Moukalaba-Dougoua, 12.2 km 305° NW Doussala, -2.31667, 10.53333, 110m, rainforest, 24.ii.2000 (B.L.Fisher); Ogooue Maritime: Aire d'Exploit. Rationnelle de Faune des Monts Doudou, 24.5 km 303° WNW Doussala, -2.23283, 10.398, 630m, rainforest, 18.iii.2000 (B.L. Fisher); Ogooue Maritime, Aire d'Exploit. Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, -2.22639, 10.40972, 375m, rainforest, 9.iii.2000, (B. L. Fisher); Ogooue-Maritime, Reserve de Faune de la Moukalaba-Dougoua, 10.8 km 214° SW Doussala, -2.42267, 10.54533, 110m, rainforest, 29.ii.2000 (B.L. Fisher); Ogooue-Maritime, Aire d'Exploit. Rationnelle de Faune des Monts Doudou, 25.2 km 304° NW Doussala, -2.2275, 10.3945, 640m, rainforest, 19.iii.2000 (B.L. Fisher); Ogooue-Maritime, Aire d'Exploit. Rationnelle de Faune des Monts Doudou, 24.3 km 307° NW Doussala, -2.22639, 10.40972, 375m, rainforest, 9.iii.2000 (B.L. Fisher); Ogooue-Maritime, Aire d'Exploit. Rationnelle de Faune des Monts Doudou,



**Figure 15.** *Carebara silvestrii.* Minor worker, CASENT0914215: **A** head in full-face view **D** body in profile **E** body in dorsal view. Major worker, CASENT0914214: **B** head in full-face view **F** body in profile **H** body in dorsal view. Large major worker, CASENT0914216: **C** head in full-face view **G** body in profile **I** body in dorsal view.

25.2 km 304° NW Doussala, -2.2275, 10.3945, 640m, rainforest, 14.iii.2000 (*B.L. Fisher*); **IVORY COAST:** Mar, 900m, Mt. Tonkoni, 13.x.1980 (*V. Mahnert & Perret*); **KENYA:** Western, Kakamega Forest, Kaimosi Forest Fragment, 0.12806, 34.84, 1650m, primary rain forest, 27.viii.2005 (*G. Fischer*); Western, Kakamega Forest, Ikuywa, 0.21167, 34.93139, 1650 m, primary forest, 16.viii.2007 (*F. Hita Garcia*); Western, Kakamega Forest, Yala, 0.20144, 34.88073, 1650m, primary forest, v.2008 (*Marcell Peters*); Western, Kakamega Forest, Isecheno B, 0.24778, 34.86806, 1650m, primary forest, 9.ix.2008 (*Florian Herchen*); Western, Kakamega Forest, Isecheno A, 0.24944, 34.86806, 1650m, primary forest, 17.vii.2007 (*Susanne Maurer*); **UGAN-DA:** Mt Elgon, Kapkwata, 2250m, 30.v.1993 (*Cuccodoro & Erne*); Kibale Forest, 1250m, 23.v.1993 (*Cuccodoro & Erne*); Ruwenzori, Ibanda, 1650m, 10.v.1993 (*Cuccodoro & Erne*); Kibale NP, Kanyawara Biol. Stn, 0.55878025, 30.359982, 1510m, evergreen forest, 6–16.viii.2012 (*Ant Course 2012*); Bunyoro District, Budongo Forest FS, 1.72638, 31.55237, 1081m, 8.vii.2009 (*W. Freund & T. Klug*); **ZIMBABWE:** Umtali, Melsetter, 1700m, ii.1969 (*R. Mussard*).

### Carebara urichi (W.M. Wheeler)

Figure 16

- *Spelaeomyrmex urichi* W.M. Wheeler, 1922b: 9. Syntypes (11 minor workers) TRINIDAD: "Guacharo Cave" (*F.M. Urich*) [not examined].
- Erebomyrma urichi (W.M. Wheeler): Wilson 1962: 63 (combination).
- Oligomyrmex urichi (W.M. Wheeler): Ettershank 1966: 124 (combination).
- Carebara urichi (W.M. Wheeler): Fernández 2004: 205 (combination).
- = Erebomyrma nevermanni (Mann): junior synonym of Carebara urichi: Fernández 2004: 205. Type (1 minor worker): COSTA RICA: Hamburg Farm, Reventazon, Santa Clara (F. Nevermann) [not examined].
- Oligomyrmex nevermanni (Mann): Ettershank 1966: 124 (combination).
- Erebomyrma nevermanni (Mann): Wilson 1986: 61 (combination).
- Oligomyrmex nevermanni (Mann): Bolton 1995: 299 (combination).
- = Erebomyrma morai (Menozzi): junior synonym of Carebara urichi: Fernández 2004: 205. Syntype (1 minor worker) COSTA RICA: S. Josè (*F.I. Tristan*) [BMNH] [examined].
- Oligomyrmex morai (Menozzi): Ettershank 1966: 124 (combination).
- Erebomyrma morai (Menozzi): Brandão, 1991: 343 (combination).
- Oligomyrmex morai (Menozzi): Bolton 1995: 299 (combination).
- = Erebomyrma eidmanni (Eidmann): attributed to Menozzi; junior synonym of Carebara urichi: Fernández 2004: 205. BRAZIL: Mendes, 3.x.1933 (Eidmann) [types not examined].
- Oligomyrmex eidmanni (Menozzi): Ettershank 1966: 123 (combination).
- Erebomyrma eidmanni (Menozzi): Wilson 1986: 61 (combination).
- Oligomyrmex eidmanni (Menozzi): Bolton 1995: 299 (combination).

**Diagnosis.** Antennae with eleven segments. **Major worker:** Head almost as long as wide to slightly longer, nearly subquadrate in full-face view, posterolateral corners rounded. Head with longitudinal striations, rugulae on the posterior side, propodeal spines absent or inconspicuous, petiolar ventral process large, digitiform and anteriorly directed, gaster covered by very abundant erect hairs. **Minor worker:** Head subrectangular, sides convex, posterior margin almost straight, posterolateral corners angulate, frons medially smooth and shiny, face with longitudinal rugulae and reticulations, propodeal spines short, acute-triangular and upwardly directed, metatibia with long, suberect hairs along outer edge, petiole anteroventrally with small, anteriorly-pointing tooth, gaster with relatively abundant, long, suberect or subdecumbent hairs.

**Description of major workers.** Measurements (n=4): HW 0.97–0.99 (0.98), HL 1.01–1.06 (1.04), SL 0.41–0.44 (0.43), MDL 0.53–0.54 (0.53), EL 0.08, WL 0.97–1.02 (0.99), PNH 0.53–0.57 (0.54), PNW 0.56–0.61 (0.58), MNH 0.64–0.68 (0.66), PDH 0.42–0.46 (0.45), PTL 0.42–0.46 (0.44), PPL 0.25–0.26 (0.26), PTH 0.35–0.38 (0.37), PPH 0.26–0.30 (0.28), PTW 0.31–0.35 (0.33), PPW 0.38–0.43 (0.41), PSL 0.11–0.14 (0.13), MFL 0.58–0.61 (0.60), MTL 0.44–0.46 (0.45), CI 93–95 (94), SI 43–44 (44), MDI 54–55 (55), EI 8–9 (8), FI 60–62 (61), PSLI 12–14 (13), LPpI 88–96 (91), DPpI 152–167 (161), PpWI 124–132 (127), PpLI 57–60 (58), PpHI 74–80 (77).

Head slightly longer than wide (CI 93–95), in full-face view nearly subquadrate. Posterior margin of head with deep, V-shaped emargination, posterolateral corners rounded, sides subparallel and almost straight. Mandibles with five teeth. Anterior margin of clypeus nearly straight, sides convex. Frontal carinae absent to inconspicuous. Antenna with eleven segments, scapes short and reaching to about midlength of head (SI 43–44). Eyes present, multi-faceted, and comparatively large (EI 8–9).

In profile, promesonotum queen-like with moderately high pronotum, comparatively long scutum, and short scutellum, the latter slightly to strongly raised above convex to weakly convex dorsal outline of mesosoma. Promesonotal suture on dorsum present as broad impression, metanotum small and obliquely raised posteriorly. Propodeum higher than long in profile, with dorsal face oblique, declining posteriorly, propodeal spines and posterolateral lamella absent to reduced to slightly raised, posterior corners bluntly angulate, posterior declivity subvertical with well-developed lobe. Propodeal spiracle roundly convex and situated closer to dorsum of propodeum than to its center, not close to posterior declivity.

Petiole with relatively short peduncle, anteroventrally concave, with very conspicuous, short to relatively long, finger-like anterior process, posteroventrally convex, petiole node high, anteriorly oblique to weakly concave, posteriorly vertical and weakly concave, dorsum straight with a rounded angle anteriorly and a sharp right angle posteriorly. Postpetiole in profile squarish with rounded corners and lower than petiole (PpHI 74-80), with shallow, anteriorly angulate ventral process, anterior face almost vertical, dorsum almost straight and posterior face short and oblique. In dorsal view, petiole node much wider than long and anteroposteriorly flattened, anteriorly slightly convex, posterioly transverse and sharply marginate, postpetiole with wide, lamellate processes extending lateroventrally (PpWI 124-132), the node itself narrower than petiole and slightly wider than long, with convex sides, and anterior and posterior margins almost transverse.

Mandibles smooth and shiny, laterally weakly striate and with scattered punctures. Clypeus smooth and shiny, with several weak lateral carinae. Sculpture on frons and anterior sides of head with strong, irregular rugae, posterior parts of face coarsely rugoreticulate, interspaces weakly to superficially punctate, ventral side of head with long, parallel, longitudinal rugae. Mesosoma mostly coarsely and very irregularly rugoreticulate with punctate ground sculpture, rugoreticulate sculpture can be reduced on lateral surfaces, anepisternum sometimes with smooth and shiny area posteriorly. Petiole node and postpetiole dorsally smooth and shiny to faintly punctate, gaster shagreened or superficially punctate. Head and body usually with abundant, erect to suberect hairs of varying length and shorter decumbent to suberect pilosity, scapes and tibiae with appressed to decumbent pilosity and long suberect to erect hairs along outer edge. Color reddish brown, appendages and gaster light brown.

**Description of minor workers.** Measurements (n=5): HW 0.36–0.44 (0.40), HL 0.41–0.51 (0.46), SL 0.29–0.34 (0.32), MDL 0.23–0.29 (0.26), EL 0.02, WL 0.45–0.59 (0.53), PNH 0.17–0.22 (0.19), PNW 0.23–0.27 (0.25), MNH 0.25–0.31 (0.28), PDH 0.17–0.22 (0.19), PTL 0.15–0.18 (0.16), PPL 0.11–0.12 (0.11), PTH 0.09–0.11 (0.10), PPH 0.08–0.09 (0.08), PTW 0.07–0.08 (0.08), PPW 0.08–0.10 (0.09), PSL 0.07–0.08 (0.07), MFL 0.30–0.39 (0.34), MTL 0.26–0.32 (0.29), CI 86–88 (87), SI 76–91 (81), MDI 62–66 (65), EI 4–6 (5), FI 80–91 (84), PSLI 17–19 (18), LPpI 139–160 (147), DPpI 69–81 (75), PpWI 109–122 (115), PpLI 67–80 (71), PpHI 71–83 (77).

Head almost as wide as long (CI 93–95), posterior margin nearly straight to weakly concave, sides convex. Mandible with four well-defined teeth, apical and preapical tooth larger than others. Anterior margin of clypeus very weakly concave, at each side with a triangular tooth. Frontal carinae moderately long, sometimes reaching posterior third of head. Antenna with eleven segments, scape short and reaching about 6/7 towards posterior margin of head (SI 76–91). Eyes consisting of one ommatidium (EI 4–6).

In profile, dorsum of promesonotum weakly convex, anteriorly sharply marginate and right-angled, posteriorly curving slightly downwards toward widely, but shallowly impressed metanotal groove. Dorsum of propodeum convex, softly declining posteriorly and slightly shorter than posterior declivity, anterodorsal corner convex, propodeal spines relatively short, acute (PSLI 14–15) and lamellate, lamella proceeding ventrally, ending in large propodeal lobes. Propodeal spiracle rounded and situated close to base of spines.

Petiole in profile with peduncle about as long as petiole node, anteroventrally concave, with small, acute, anteriorly pointing ventral process, posteroventrally weakly convex, petiole node low and dorsally rounded. Postpetiole in profile dorsally convex, ventrally almost straight, on average 1.5 times longer than high (LPpI 139–160), lower than petiole (PpHI 71–83). In dorsal view, petiole node almost as wide as long, anteriorly roundly convex,



**Figure 16.** *Carebara urichi*. Minor worker, CASENT0624080: **A** head in full-face view **C** body in profile **E** body in dorsal view. Major worker, CASENT0624077: **B** head in full-face view **D** body in profile **F** body in dorsal view.

posteriorly nearly straight or weakly convex, postpetiole longer than wide (DPpI 69–81), slightly wider than petiole (PpWI 109–122), anteriorly tapering and posteriorly weakly concave. Gaster slender in dorsal view, its anterior margin straight to faintly convex.

Mandibles, clypeus and center of frons smooth and shiny, remainder of face coarsely rugoreticulate, with scattered punctures. Promesonotum dorsally with several irregular longitudinal rugae, interspaces superficially punctate to smooth, remainder of mesosoma alveolate, alveolae on basal lateropronotum sometimes strongly effaced. Gaster and dorsum of petiole and postpetiole smooth and shiny, remainder of waist segments weakly alveolate.

Head and body with long, suberect to erect hairs and shorter subdecumbent to decumbent pilosity. Scapes and tibiae with decumbent to subdecumbent pilosity, the latter with longer suberect hairs along outer edge. Color orange to dark orange with lighter colored antennae, legs and gaster.

**Distribution and biology.** *Carebara urichi* is widespread in the Neotropical Region and was found in Belize, Brazil, Colombia, Costa Rica, Mexico, Panama, Peru, Suriname and Trinidad, mainly in rainforest and cloudforest and at elevations ranging from 20–1470 m. Individuals and nest series were collected from the leaf-litter using Winkler sifting.

**Comments.** *Carebara urichi* can be confused with *C. brevipilosa*, but is easily separated by the sculpture on the dorsal promesonotum, which is irregularly longitudinally rugose to rugoreticulate with few irregular longitudinal rugae in *C. urichi* minor workers and weakly to superficially reticulate or with few very short rugulae in *C. brevipilosa*. *Carebara urichi* and *C. brevipilosa* are the only two species in the *C. polita* group recorded for the Neotropical Region.

Material examined. COSTA RICA: Heredia, La Selva Biol. Sta., 50m, 23.xi.1999 (Project ALAS); Limon, 3 km SSE Cahuita, 70m, 24.xii.1983 (P.S. Ward); PANAMA: Barro Colorado, ix.1941 (J.A.S. Zetek).

## Carebara villiersi (Bernard)

Figure 17

Nimbamyrma villiersi Bernard, 1953: 241. Syntypes (2 minor workers): GUIN-EA: Mt Nimba, forest, moss, ix.1946 (Villiers). [1 syntype examined, MNHN: EY0000000330/CASENT0913610].

Oligomyrmex villiersi (Bernard): Ettershank 1966: 124 (combination).

Carebara villiersi (Bernard): Fernández 2004: 235 (combination).

**Diagnosis.** Antenna with eleven segments. **Major workers:** unknown. **Minor worker:** Head shape rounded, sides strongly convex and posterior margin straight to faintly convex medially, face smooth and shiny, frontal carinae short to inconspicuous, dorsal face of propodeum nearly straight or weakly convex, anepisternum and katepisternum areolate, propodeal spines long and spinose, in dorsal view longer than distance between them, gaster with sparse hairs, some hairs moderately long and suberect.

**Description of minor workers.** Measurements (n=5): HW 0.44–0.49 (0.47), HL 0.50–0.54 (0.52), SL 0.37–0.38 (0.38), MDL 0.27–0.29 (0.28), EL 0.02–0.03 (0.03), WL 0.52–0.54 (0.53), PNH 0.20–0.21 (0.21), PNW 0.26–0.28 (0.27), MNH 0.29–0.31 (0.30), PDH 0.20–0.22 (0.21), PTL 0.21–0.23 (0.22), PPL 0.13–0.14 (0.14), PTH 0.14–0.15 (0.14), PPH 0.10–0.11 (0.10), PTW 0.08–0.09 (0.08), PPW



**Figure 17.** *Carebara villiersi*. Minor worker, CASENT0914220: **A** head in full-face view **B** body in profile **C** body in dorsal view.

0.10–0.11 (0.10), PSL 0.10–0.11 (0.10), MFL 0.40–0.42 (0.41), MTL 0.30–0.34 (0.31), CI 87–90 (89), SI 78–86 (81), MDI 58–62 (60), EI 5–7 (6), FI 85–93 (88), PSLI 21–23 (22), LPpI 131–146 (138), DPpI 68–81 (75), PpWI 113–130 (123), PpLI 59–68 (63), PpHI 68–72 (70).

Head longer than wide (CI 87–90), in full-face view rounded oval to subcircular, narrowed anteriorly and posteriorly, posterior margin weakly concave. Sides strongly convex, smoothly rounding into posterolateral corners. Mandible triangular with five teeth apical and preapical tooth larger than the others. Anterior margin of clypeus concave, bicarinate and divergent forward, sides with short triangular teeth. Antennae with eleven segments, scape almost reaching posterior margin of head (SI 78–86). Eyes consisting of one ommatidium, situated comparatively close to anterolateral margin of head (EI 5–7).

In profile, promesonotum convex, metanotal groove moderately impressed. Dorsum of propodeum short in profile and slightly convex, posteriorly with long, acute, blade-like, and posteriorly pointing spines, in dorsal view distinctly longer than distance between their bases, declivity of propodeum faintly concave to straight and oblique, with straight lamella. Propodeal spiracle rounded and situated near the base of the spines. Petiole in profile with peduncle slightly longer than petiole node, ventrally almost straight with straight and shallowly lamellate anterior process and rounded posterior corner, petiole node low, anterodorsally and posterodorsally with short, weakly concave faces, dorsal face almost straight and subangulate anteriorly and posteriorly. Postpetiole in profile on average 1.4 times longer than high (LPpI 131– 146), lower than petiole (PpHI 68–72), anteroventrally weakly convex. In dorsal view, petiole node narrow, distinctly longer than wide, anteriorly tapering, posteriorly almost straight, postpetiole distinctly longer than wide (DPpI 68–81), slightly wider than petiole (PpWI 113–130), anteriorly tapering, almost pedunculate, and posterior face convex. Gaster anterolaterally with acute shoulders around posterior base of postpetiole.

Mandibles and head smooth and shiny with some punctures, except on frons, malar region anterior of eye level with short rugulae. Mesosoma and metasoma mostly smooth and shiny, except for weak areolae on mesopleuron and metapleuron, comparatively long cross-ribs at dorsal metanotal groove, superficial areolae on anterolateral border of propodeum and on posterolateral lamella. Anterodorsal and ventral surface of petiole weakly to superficially areolate, ventral face of postpetiole weakly punctate.

Standing hairs relatively short and stout, not abundant, evenly distributed, and mostly arrayed in pairs from head to gaster. Scapes and metatibiae with appressed to weakly decumbent pilosity. Color yellowish orange.

**Distribution and biology.** *Carebara villiersi* was described from the Nimba Mountains in Guinea and can also be found in Cameroon, Central African Republic, Gabon, Ghana, and Ivory Coast, where it was collected in rainforest at elevations ranging from 20–1470 m. Individuals and nest series were collected from leaf-litter using Winkler sifting.

**Comments.** Minor workers of *Carebara villiersi* can be confused with *C. nicotia-nae* and *C. polita*, but can be easily separated from them, because the mesopleuron and metapleuron are areolate in *C. nicotianae* and smooth and shiny in *C. polita*, but the mesopleuron is areolate and the metapleuron smooth and shiny in *C. villiersi*. Major workers either not existing or not yet collected or identified as such.

Material examined. CAMEROON: Sud-Ouest, Korup N. P., 6.9 km 317° NW Mundemba, 5.016, 8.864, 110m, rainforest, 19.iv.2000 (*B.L. Fisher*); CENTRAL AFRICAN REPUBLIC: Prefecture Sangha-Mbaéré, Parc National Dzanga-Ndoki, 38.6 km 173° S Lidjombo, 2.36, 16.14397, 350m, rainforest, 21–27.v.2001 (*S. Van Noort*); GABON: Ogooue-Maritime, Reserve de Faune de la Moukalaba Dougoua, 12.2 km 305° NW Doussala, –2.31667, 10.53333, 110m, rainforest, 24.ii.2000 (*B.L. Fisher*); Ogooue-Maritime, Aire d'Exploit. Rationnelle de Faune des Monts Doudou, 24.5 km 303° WNW Doussala, –2.23283, 10.398, 630m, rainforest, 18.iii.2000 (*B.L. Fisher*); Woleu-Ntem, 31.3 km 108° ESE Minvoul, 2.08, 12.40667, 600m, rainforest, 7.ii.1998 (*B.L. Fisher*).



Figure 18. Distribution maps for the *Carebara polita* group: A African species B American species.

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RESEARCH ARTICLE



# A new genus of Grapholitini from Africa related to Thaumatotibia (Lepidoptera, Tortricidae)

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#### Abstract

*Thaumatovalva* gen. n. is described and illustrated from the Afrotropical region. As currently defined the genus includes four species: *T. deprinsorum* sp. n. from the Democratic Republic of Congo; *T. albolineana* sp. n. (type species) from the Democratic Republic of Congo; *T. spinai* (Razowski & Trematerra), comb. n., from Ethiopia and Nigeria; and *T. limbata* (Diakonoff), comb. n., from the Seychelles and Kenya. *Thaumatovalva limbata* has been reared from the fruit of *Cordia somaliensis* Baker and *C. monoica* Roxb. (Boraginaceae) in Kenya. Although structures of the male and female genitalia are extremely similar among three of the four species, male secondary scales on the under surface of the hindwing easily distinguish them.

#### Keywords

Democratic Republic of Congo, Ethiopia, Kenya, male secondary scales, morphology, new species, Seychelles, taxonomy

## Introduction

Male secondary sexual structures are abundant and diverse in the tortricid tribe Grapholitini (e.g., Komai 1999, Horak 2006). Examples include the modified antenna of *Gymnandrosoma aurantianum* Lima (e.g., Adamski and Brown 2001); the unusual scale brush on the metathorax of *Gymnandrosoma punctidiscanum* Dyar (e.g., Adamski and Brown 2001); the tibial hair pencils of *Cryptophlebia* and *Thaumatotibia* species (e.g., Diakonoff 1957, Komai 1999); the costal fold on the forewing of some species of *Dichrorampha* (Brown and Zacharides 2007); pockets in the hindwing bearing hairpencils and/or modified scales in some *Cydia* and *Thaumatotibia* species; and scale brushes ("coremata" *sensu* Komai 1999) surrounding the male genitalia in many species in the *Grapholita* group of genera (Komai 1999). Although the function of these structures is poorly studied, they are assumed to play a role in short-range courtship behavior (Baker and Carde 1979). As such, these features may function as pre-mating isolating mechanisms, and hence, may be of considerable taxonomic significance.

While working on the systematics and taxonomy of Afrotropical Grapholitini, we discovered specimens from the Belgian Congo that are superficially similar to *Thaumatotibia* and/or *Cryptophlebia* and have two conspicuously different patterns in the male secondary scaling on the underside of the hindwing. Upon dissection, it was revealed that males of both have genitalia nearly identical to those of *Thaumatotibia spinai* Razowski & Trematerra from Ethiopia, but also differ from that species in the male secondary scaling. A fourth presumed congener was discovered in material from Kenya, and it possesses genitalia identical to those of *Grapholita limbata* Diakonoff from the Seychelles. These four species differ from other species of *Thaumatotibia* in several diagnostic features, including the possession of a conspicuous dorsal subapical lobe on the phallus, large spindle-shaped secondary sex scales concealed in the last abdominal segment in the male, and a region of long slender scales along the anal region of the hindwing with the scales extending into a scale patch on the fifth abdominal segment in the male. The purpose of this contribution is to describe and illustrate the two new species and to propose a new genus to accommodate the four.

## Methods

The specimens examined are from five sources: the collection of the Royal Museum for Central Africa, Tervuren, Belgium (RMCA) (n = 24); the collection of Pasquale Trematerra, Campobasso, Italy (PTC) (n = 1); the collection of the Natural History Museum, University of Oslo, Norway (NHMO) (n = 5); the collection of Todd Gilligan, Loveland, Colorado, USDA (TGC) (n = 1); and the collection of the National Museum of Natural History, Washington, DC, USA (USNM) (n = 14). Specimens not examined (*T. limbata*) are deposited in the Muséum National d'Historie Naturelle, Paris, France (MNHN) (n = 8); for these we relied on illustrations of the genitalia provided by Diakonoff (1969). Dissection methods followed those summarized by

Brown and Powell (1991). Terminology for morphological structures follows Horak (1984, 2006). Forewing measurements include the fringe. Slide mounted genitalia were examined using dissecting and compound microscopes. Because adults of all species are superficially nearly indistinguishable except for male secondary scaling on the under surface of the hindwing, a description of the upper surface of the fore- and hindwing are given in the generic description to minimize redundancy in the species' descriptions. Geographic distribution of the four species is shown in Map 1.

Nine specimens were sequenced for the 658-bp "barcode" region of the mitochondrial gene cytochrome oxidase I (COI) at the Biodiversity Institute of Ontario, University of Guelph using standard methods (Craft et al. 2010, Wilson 2012) and tissue from the leg of a dried adult moth. The nine specimens were selected based on their age (i.e., less than 10 years old). Unfortunately, most of the material available for examination was considerably older and resulted in no usable sequence data. A single sequence was obtained for *T. spinai* collected from the Ommo Valley in Ethiopia. Eight sequences were obtained for *T. limbata* collected from Kenya. Images captured of the pinned moths are stored on the BOLD (Barcode of Life Database) website.

# Results

### Thaumatovalva Timm & Brown, gen. n.

http://zoobank.org/988181FE-30A9-43B0-8248-71FB16A3EB5C

Type species. T. albolineana Timm & Brown, new species.

**Diagnosis.** Superficially, species of *Thaumatovalva* are highly uniform in forewing pattern and very similar to pale specimens of *Thaumatotibia batrachopa* (Meyrick) or *Cryptophlebia rhynchias* (Meyrick). They are easily distinguished from those and all other species of *Thaumatotibia* and *Cryptophlebia* by the modified scaling of the under surface of the hindwing in the male, the patterns of which are species-specific. In addition, males of all species of *Thaumatovalva* possess a row of long slender scales along the anal region of the hindwing that extends into a modified patch of scales on abdominal segment V; highly unusual, elongate, spindle-shaped scale clusters concealed within the last abdominal segment; and variously developed, parallel, longitudinal rows of black scales subdorsally on abdominal segments 4–6 (occasionally weakly developed on 3). The tegumen of the male genitalia of *Thaumatovalva* is completely confluent with a membranous region behind it, forming what appears to be an extremely broadly, ovoid dorso-anterior portion of the tegumen. The phallus of all species of *Thaumatovalva* have a variably developed, somewhat digitate lobe from the dorsum in the distal 0.3. The latter two features appear to be unique within Grapholitini.

Komai (1999) identified five adult characters that support the monophyly of the clade *Thaumatotibia*+*Cryptophlebia*: (1) forewing with a blackish triangular pretornal patch; (2) forewing with accessory cell small or absent; (3) hindwing with short discal cell, especially in male; (4) T8 and sometimes preceding tergites in male with patch of

long, easily removable mane-like scales; and (5) valva with a patch of very long, curled scales on the outer surface of the cucullus. Among these characters, *Thaumatovalva* lacks the pretornal patch and the mane-like scales.

The male genitalia of *Thaumatovalva*, with their many autapomorphies (e.g., the complex tegumen, the triangular process from the sacculus of the valva, the lobe-like process of the phallus), all serve to obscure the relationship of *Thaumatovalva* to its nearest relative. The simple, unmodified female genitalia, likewise, provide little compelling evidence of the position of the genus. An abundance of different types of male secondary scales is common to many Grapholitini, including Cryptophlebia, Thaumatotibia, Talponia, and others, however, these structures rarely provide compelling evidence of relationships. For example, males of Multiquaestia Karisch have a fascicle of slender scales extending from the base of the hindwing to the abdomen (Aarvik and Karisch 2009: figs 3-4). Although males of Thaumatovalva have a similar complex of scaling, the dense fascicle of scales present in Multiquaestia is quite different from that of Thaumatovalva. In Thaumatovalva the narrow, linear patch of sparse scales originates all along a membranous line in the anal region of the hindwing and inserts into a poorly defined pouch laterally on the abdomen. Barcode data place Thaumatovalva nearest two undescribed species of Grapholitini that lack compelling generic assignments. Hence, this gene is of little value in helping define the position of Thaumatovalva within Grapholitini.

Description. Head: Vertex and upper frons rough scaled, scales mostly directly anterad, lower frons smooth scaled, with small appressed scales (Fig. 1); antenna ca. 0.5 length of forewing, weakly serrulate, scales in two rows per segment, sensory setae extremely short, inconspicuous in both sexes; ocellus moderately large, diameter ca. 0.5 that of base of scape; labial palpus upturned, third segment somewhat porrect, exposed, all segments combined ca. 1.2 times horizontal height of compound eye; proboscis present, presumably functional. **Thorax:** Tegula simple, unmodified; metathorax with upraised scale tuft [inconspicuous in worn specimens]; hindleg with slightly expanded scale tuft on tibia in male only. Forewing length 5.0-8.2 mm; forewing broad, length about 2.4 times width, slightly broaden distally, apex somewhat rounded; no costal fold or upraised scales; all veins separate, CuP well developed at margin, chorda weak, accessory cell weak; forewing dark brown, irregularly and faintly mixed with specks of charcoal, rust, and cream; inconspicuous pair of tiny cream dots ringed with orange near distal end of discal cell; narrow cream (faintly mixed with brown) irregular band extending along termen from apex to ca. 0.66 distance to tornus. Fringe pale brown. Forewing under surface nearly uniform brown, paler than uppersurface. Hindwing with all veins present, M, and M, widely separated, M3 and M4 short-stalked, cubital pecten weak in male, better developed in female; frenulum with one acanthus in male, three in female; male with long slender scales (ca. 30-40) along middle 0.7 of anal margin (Fig. 2) extending to narrow groove on abdominal segment V (groove not evident on dissected integumen), dissection revealing that hairs insert beneath anterior edge of dense, linear patch of



**Figures 1–5.** Morphological features of *Thaumatovalva*. **I** Head (lateral view) of *T. albolineana* **2** Male secondary scales extending from anal vein of hindwing into abdomen in *T. albolineana* **3** Paired patches of subdorsal secondary scales on denuded abdomen of male (USNM slide 144,506) **4** Sclerotized edge of segment VIII on denuded abdomen of male (USNM slide 144,506) **5** Forked scales along outer margin of hindwing.

black sex scales subdorsally on abdominal segment V (Fig. 3); underside of hindwing between anal angle and CuP with variously modified secondary scales in male (Figs 10–13); distally forked scales along outer edge of hindwing, most conspicuous in distal portion of anal margin (Fig. 5). Abdomen: Male with paired, parallel, thick, linear patches of black sex scales subdorsally on segments 4, 5, and 6 (easily lost during dissection) (Fig. 3); scales from anal margin of hindwing inserted into anterior edge of scale patch on segment V; dorsum of segment VIII of male with a narrow line of sclerotization and a weak stem from its middle; invaginated portion of segment VII of male with broad U-shaped sclerotized posterior edge bearing membranous lateral flaps to which a dense cluster (ca. 40-50) of highly modified, long, spindle-shaped male secondary scales are attached, and with rounded membranous mesal lobe (Fig. 4). Male genitalia (Figs 14-18) with uncus, socius, and gnathos absent. Tegumen broad, elongate-ovoid, confluent with membranous region behind it (anellus?), pedunculi not curved, vinculum small, U-shaped; valva narrow basally, broadening to middle, with (in spinai, albolineana, and deprinsorum) or without (in *limbata*) large, triangular expansion of valva along ventral edge just before cucullus, outer edge of cucullus evenly rounded, valva attenuate to acute, rounded apically; cucullus covered with fine hairline setae on outer surface; phallus narrow, relatively straight in basal portion, curved in distal portion, with bulbous subbasal lobe at point of articulation with phallus, with digitate subapical lobe of variable size; cornuti absent. Female genitalia (Figs 18–19) with papillae anales unmodified; apophyses long and slender, posteriores about same length anteriores; ventral portion of segment VII with a broad subrectangular sclerotized patch with V-shaped posterior edge and tiny ostium at apex of V, a short narrow trough from ostium to posterior edge of segment VIII; ductus bursae long, slender, frail, with ring-like sclerite near middle; corpus bursae pear-shaped, finely punctate (at high magnification), with two nearly equal size signa, each a long curved spine from a rounded sclerotized base.

**Sexual dimorphism.** No apparent dimorphism in color or pattern, but females average slightly greater in forewing length and lack secondary scales on the under surface of hindwing, hind tibia, and abdomen.

**Barcode data.** Eight (six reared from Kenya and two field-collected in Kenya) of the nine specimens have identical barcode data, and we assign them to *T. limbata*. All specimens resulted in standard 658-bp sequences. The reared specimens are considerably larger than the field-collected specimens, i.e., about the same size as *T. limbata* from the Seychelles, the type locality of the species. The ninth specimen, the holotype of *T. spinai*, shows about 1.0% divergence from the cluster of *T. limbata*.

**Distribution and biology.** The genus is recorded from Ethiopia, Nigeria, the Democratic Republic of Congo, Kenya and the Seychelles (Map 1). Most species appear to occur in montane regions above ca. 1275 m, but *T. limbata* has been recorded from 35–1272 m; and a single specimen of *T. spinai* from Nigeria was collected at 54 m (Razowski and Wojtusiak 2012). Although the early stages are unknown, the larvae are assumed to be fruit feeders, as are most Grapholitini. *Thaumatovalva limbata* (cited as *Grapholita limbata* by Brown et al. 2014) has been reared from the fruit of *Cordia somaliensis* and *C. monoica* in Kenya.

**Etymology.** The generic name is from the Latin *thaumato*, meaning "miracle" or "wonder," and the morphological term "valva."



Map I. Geographic distribution of species of *Thaumatovalva*.

# Key to the males of Thaumatovalva

1	Upper surface of hindwing pale gray-brown; under surface of hindwing with- out white sex scales along anal margin or inner angle of wing
1'	Upper surface of hindwing nearly uniform brown; under surface of hindwing with white sex scales along anal margin or inner angle of wing
2	Undersurface of hindwing with broad area of white scales along anal region. <i>deprinsorum</i>
2'	Undersurface of hindwing with narrow line of white scales along margin from lower edge of anal margin to about CuP
3	White marginal scales short and compact (i.e., about 3–5 times as long as wide)albolineana
3'	White marginal scales longer (i.e., about 7-10 times as long as wide) spinai

# Thaumatovalva deprinsorum Timm & Brown, sp. n.

http://zoobank.org/1B943CE5-BA8C-4407-A8AĒ-32AF21EF252A Figs 6, 10, 14, 18

**Type material.** Holotype  $\Diamond$ , Democratic Republic of Congo, P. N. A., Secteur Nord, Mutsora, 1200 m, 4 Dec 1957, A. Vanschuytbroeck (RMCA). Paratypes  $(12\Diamond, 1\diamondsuit)$ .

Democratic Republic of Congo: P. N. A.: Secteur Nord, Bumali village pres Mutwanga, 1300 m, piege lumineux, 28 Nov 1957 (33), A. Vanschuytbroeck (RMCA). Secteur Nord, Mutsora, 1200 m, 4 Dec 1957 (13), A. Vanschuytbroeck (RMCA). Secteur Nord, riv. Talya, affl. dr. Lume, 1260 m, 26 Sep 1956 (13), A. Vanschuytbroeck (RMCA). Massif Ruwenzori, riv. Kakalari, 1800 m, affl. Bombi, 28 Nov 1957 (53, 12), A. Vanschuytbroeck (RMCA). Massif Ruwenzori, Kyandolire (lieu-dit), 1810 m (sous bananiers savages), 24 Dec 1957 (13), A. Vanschuytbroeck (RMCA). Massif Ruwenzori, Gotte Ibatama, 1610 m (lumiere), 4 Ma00y 1958 (13), A. Vanschuytbroeck (RMCA).

**Diagnosis.** Thaumatovalva deprinsorum is nearly indistinguishable from *T. albolineana* and *T. spinai* in forewing pattern and size, but it is easily separated by the modified scaling on the underside of the hindwing. In *T. deprinsorum* the patch of white scales occupies the entire inner portion of the anal region with a short dash extending beyond the patch along the wing margin (Fig. 10).

**Description.** *Male.* **Head:** Vertex dark brown mixed with lighter brown, upper frons concolorous with vertex, lower frons cream; labial palpus slightly lighter than vertex, inner surface slightly lighter yet; antennal scaling brown. **Thorax:** Dorsum dark brown, mixed with lighter brown, tegula concolorous with dorsum; hind tibia with dark brown patch of expanded scales. Forewing length 6.5–8.2 mm (mean = 7.0; n = 10), as described for genus; hindwing upper surface nearly uniformly brown, under surface concolorous with forewing undersurface with white scaling from anal margin to about CuP, extending through anal region from wing margin to approximately CuP (Fig. 10). **Abdomen:** Brown; black scale patches not visible on undissected specimens. Genitalia (Fig. 14) with valva narrow basally, broadening to middle, with large, triangular expansion of valva ventrally just before cucullus, outer edge of cucullus rounded, valva attenuate through cucullus, apex rounded; phallus narrow, with bulbous subbasal lobe and conspicuous elongate dorsal lobe ca. 0.66 distance from base to tip.

*Female.* Head and thorax: Essentially as described for male, except forewing length 8.0 mm (n = 1). Abdomen: Brown. Genitalia (Fig. 18) essentially as described for genus; ventral portion of segment VIII with a broad subrectangular semi-scle-rotized patch with V-shaped posterior edge, ostium situated at end of short narrow trough extending from vertex of V-shaped sclerotized region; ductus bursae long, ca. twice length of corpus bursae, slender, frail, with ring-like sclerite near middle; ductus seminalis originating ca. 0.5 distance between sclerotized ring and corpus bursae; ductus gradually broadening into corpus in distal 0.1; corpus bursae pear-shaped, finely punctate (at high magnification), with two nearly equal signa, each a long curved spine from a rounded sclerotized base.

**Distribution and biology.** This species is known only from the middle elevations (1200–1810 m) of the Democratic Republic of Congo. It has been collected primarily in November and December, with a single record from May.

Etymology. The specific epithet is a patronym for Willy and Jurate De Prins.



Figures 6–9. Upper suface of wings of *Thaumatovalva*. 6 *T. deprinsorum* 7 *T. albolineana* 8 *T. spinai* [image enhanced using best parts of both forewings] 9 *T. limbata*.

## Thaumatovalva albolineana Timm & Brown, sp. n.

http://zoobank.org/290DE30B-553D-4DC4-B014-4F6DC9F1AE6F Figs 1, 2, 7, 11, 15, 19

**Type material.** Holotype  $\Diamond$ , Democratic Republic of Congo, North Kivu, Rutshuru, [1.18°S, 29.45°E] [1275 m], Jun 1937, J. Ghesquiere (RMCA). Paratypes  $(5\Diamond, 5\heartsuit)$ . Democratic Republic of Congo: North Kivu: Rutshuru, Feb 1937  $(1\Diamond, 1\heartsuit)$ , Mar 1937  $(2\heartsuit)$ , Apr 1937  $(2\heartsuit)$ , May 1937  $(1\heartsuit)$ , Jun 1937  $(2\heartsuit, 1\heartsuit)$ , J. Ghesquiere (RMCA). Kenya: Kakamega District: Kakamega Forest reserve, Rondo Retreat Centre, 1598 m, 00°13'37.9"N, 34°53'04.6"E, 23–26 Nov 2010  $(1\heartsuit)$ , T. Gilligan & A. Mukiri (TGC).

**Diagnosis.** Thaumatovalva albolineana is similar to T. deprinsorum and T. spinai both superficially and in genital morphology. However, males of T. albolineana are easily distinguished by the modified scaling on the under surface of the hindwing, which consists of a narrow line of short, compact white scales along the rounded portion of the wing from the end of the anal region to about vein CuP.

**Description.** *Male.* **Head:** Vertex dark brown mixed with lighter brown, upper frons concolorous with vertex, lower frons cream; labial palpus slightly lighter than vertex, inner surface slightly lighter yet; antennal scaling brown. **Thorax:** Dorsum dark brown, mixed with lighter brown, tegula concolorous with dorsum; hind tibia with dark brown patch of expanded scales. Forewing length 5.8-7.5 mm (mean = 6.5; n = 5); forewing as described for genus; hindwing upper surface nearly uniformly brown, under surface concolorous with forewing under surface, but slightly darker in anal region; a conspicuous narrow band of shiny, pearly-white scales along wing margin, extending from lower edge of anal margin to approximately CuP (Fig. 11). **Abdomen:** Brown (black scale patches not visible on undissected specimens). Genitalia (Fig. 15) with valva narrow basally, broadening to middle, with large, triangular expansion of valva ventrally just before cucullus, outer edge of cucullus rounded, valva attenuate through cucullus, apex rounded; phallus narrow, with bulbous subbasal lobe and conspicuous elongate dorsal lobe ca. 0.66 distance from base to tip.

*Female.* Head and thorax: Essentially as described for male, except forewing length 6.0–8.0 mm (mean = 7.4; n = 5). Abdomen: Brown. Genitalia (Fig. 19) essentially as described for genus; ventral portion of segment VIII with a broad subrectangular semi-sclerotized patch with V-shaped posterior edge, ostium situated at end of short narrow trough extending from vertex of V-shaped sclerotized region; ductus bursae long, ca. twice length of corpus bursae, slender, frail, with ring-like sclerite near middle; ductus seminalis originating ca. 0.5 distance between sclerotized ring and corpus bursae; ductus gradually broadening into corpus in distal 0.1; corpus bursae pear-shaped, finely punctate (at high magnification), with two nearly equal sized signa, each a long curved spine from a rounded sclerotized base.

**Distribution and biology.** *Thaumatovalva albolineana* is known nearly exclusively from the type locality of Rutshuru in the Democratic Republic of Congo, but there is a single specimen from Kenya. Specimens have been collected between about 1500 and 1600 m elevation. Adults have been collected primary from February through June, with a single record from November (Kenya). Nothing is known of the early stages.

Etymology. The specific epithet refers to the narrow band of white scales on the underside of the hindwing.

#### Thaumatovalva spinai (Razowski & Trematerra), comb. n.

Figs 8, 12, 16

Thaumatotibia spinai Razowski & Trematerra, 2010: 65.

**Type material.** Holotype ♂, Ethiopia, Omo Valley, Dowro Zone, Tarcha, 1400 m, 16 Apr 2004, A. Sciarretta & G. Spina (PTC). Paratypes (1♂). Ethiopia: Omo Valley, Dowro Zone, Tarcha, 1400 m, 16 Apr 2004, A. Sciarretta & G. Spina (PTC).

**Diagnosis.** *Thaumatovalva spinai* is nearly indistinguishable from *T. albolineana* and *T. deprinsorum* in forewing pattern and size, but it can be separated by the modi-



Figures 10–13. Under surface of the hindwing of male *Thaumatovalva*. 10 *T. deprinsorum* 11 *T. albolineana* 12 *T. spinai* 13 *T. limbata*.

fied scaling on the underside of the hindwing. In *T. spinai* the white scales along the inner margin of the hindwing are long and slender and dark-tipped compared to the short, stout, completely white scales of *T. albolineana*.

**Description.** *Male.* **Head:** Vertex dark brown mixed with lighter brown, upper frons concolorous with vertex, lower frons cream; labial palpus slightly lighter than vertex, inner surface slightly lighter; antennal scaling brown. **Thorax:** Dorsum dark brown, mixed with lighter brown, tegula concolorous with dorsum; hind tibia with dark brown patch of expanded scales. Forewing (Fig. 8) length 6.0 mm (n = 2); forewing as described for genus; hindwing upper surface nearly uniformly brown, undersurface slightly darker in anal region; a conspicuous band of shiny white scales along margin of wing extend from lower edge of anal margin to approximately CuP (Fig. 12). **Abdomen:** Brown; black scale patches not visible on undissected specimens. Genitalia (Fig. 16) with valva narrow basally, broadening to middle, with large, trian-

gular expansion of valva ventrally just before cucullus, outer edge of cucullus rounded, valva attenuate through cucullus, apex rounded; phallus narrow, with bulbous subbasal lobe and conspicuous elongate dorsal lobe ca. 0.66 distance from base to tip.

Female. Unknown.

**Distribution and biology.** *Thaumatovalva spinai* is known only from the type locality in Ethiopia at 1400 m elevation. Razowski and Wojtusiak (2012) report a single male from Nigeria (Bendel State, Okomu Forest, 20 Oct 1985), but we are uncertain whether it is conspecific with the holotype. The early stages are unknown.

**Etymology.** The species was named for one of the collectors of the holotype, Giuesppe Spina.

**Remarks.** The holotype male and paratype of this species are both in poor condition, so comparison of forewing pattern is limited. The image of the adult (Fig. 11) is based a photo reconstruction of the holotype, using the best parts of both forewings. An unmodified image of the holotype can be found in Razowski and Trematerra (2010).

# Thaumatovalva limbata (Dakonoff, 1969), comb. n.

Figs 9, 13, 17

Grapholita limbata Dakonoff, 1969: 85; Brown 2005: 361; Brown et al. 2014: in press.

**Type material.** Holotype  $\Diamond$ , Seychelles, Praslin Island, 27 May 1960, M. Gerber (MNHN). Paratypes  $(4\Diamond, 3\heartsuit)$ . Seychelles: Mahé Island, Beau Vallon, 27 Apr 1959  $(1\heartsuit)$ , 29 Mar 1960  $(1\Diamond)$ , 19 Mar 1959  $(1\Diamond, 1\heartsuit)$ , 27 May 1959  $(1\Diamond)$ , H. Legrand (MNHN). Cosmoledo Island 16 Sep 1959  $(1\heartsuit)$ , H. Legrand, 19 Oct 1959  $(1\Diamond)$ , M. Gerber (MNHN).

Additional specimens examined. KENYA: 18 km SW Malindi, Watamu, 35 m, 3°22'S, 39°59'E, 15 Mar 2004 (3 $^{\circ}$ ), J. & W. De Prins (RMAC). Coast Province, Sabaki, 10 m, 3°09.28'S, 40°08.05'E, 10 Jul 2001 (2 $^{\circ}$ , 3 $^{\circ}$ ), reared from fruit of *Cordia somaliensis* Baker (Boraginaceae), R. Copeland (USNM). Rift Valley Province, Mathews Range, 1272 m, 1°10.827'N, 37°17.876'E, 18 Jan 2004 (4 $^{\circ}$ , 4 $^{\circ}$ ), reared from fruit of *Cordia monoica* Roxb. (Boraginaceae), R. Copeland (USNM). Rift Valley Province, Masai Lodge, 1670 m, 37MBU 5679 4682, 25 Nov 2010 (2 $^{\circ}$ , 2 $^{\circ}$ ), L. Aarvik & D. Agassiz (NHMO). Rift Valley Province, Mount Elgon National Park, Chorlin Gate, Rongai Camp, 2206 m, 17-21 Nov 2006 (1 $^{\circ}$ ), L. Hansen & K. Sund (NHMO). SEYCHELLES: Aldabra Atoll, Ile Picard Settlement, 12–22 Mar 1986 (1 $^{\circ}$ ), D. Adamski (USNM).

**Diagnosis.** *Thaumatovalva limbata* shares a similar forewing pattern with its congeners, but males average slightly smaller in forewing length (5.5 mm vs. 7.0 mm), it also has a paler gray brown rather than dark brown under surface of the hindwing, and its male genitalia lack the characteristic triangular process from the venter of the valva. The patch of modified sex scales concealed in the distal end of the abdomen



**Figures 14–19.** Male and female genitalia of *Thaumatovalva*. **14** Male of *T. deprinsorum* (USNM slide 144,491) **15** Male of *T. albolineana* (USNM slide 144,488) **16** Male of *T. spinai* (slide 2656) **17** Male of *T. limbata* (USNM slide 144,490) **18** Female of *T. deprinsorum* (USNM slide 144,492) **19** Female of *T. albolineana* (USNM slide 144,489).

consists of only four large sausage-shaped structures, two on each side, rather than 40–50 scales present in congeners, and the hindwing has no conspicuous white scaling on the under surface.

*Thaumatovalva limbata* is superficially similar to "*Eucosma*" chloroterma Meyrick, 1913, described from Pretoria, South Africa, but the male genitalia of the latter (see Clarke 1958: 355) have little in common with those of *T. limbata*.

Description. Male. Head: Vertex dark brown mixed with lighter brown, upper frons concolorous with vertex, lower frons cream; labial light brown than vertex, inner surface cream; antennal scaling brown. Thorax: Dorsum dark brown, mixed with lighter brown, tegula dark brown mixed with lighter brown, most scale brown with cream tip; hind tibia with dark brown with expanded scales poorly developed. Forewing length 5.0-6.0 mm (mean = 5.5; n = 5); forewing as described for genus; hindwing nearly uniform gravish brown, conspicuously paler than forewing; patch of ca. 30 slender scales from anal margin of hindwing not inserted into scales of abdomen. Fringe conolorous with hindwing. Hindwing under surface concolorous with forewing undersurface, paler than in congeners; an inconspicuous narrow row of slightly enlarged brown scales along margin of wing from lower edge of anal margin to approximately CuP (Fig. 13). Abdomen: Brown; black scale patches subdorsally on abdominal segments 3-5 weakly developed (not visible in undissected specimens); sclerotized posterior edge of segment VIII bearing four (two on each side), long, slender sausage-shaped scales. Genitalia (Fig. 17) with valva narrow basally, broadening to middle, without triangular expansion before cucullus, outer edge of cucullus rounded, valva attenuate through cucullus, apex conspicuously more rounded than in congeners; phallus narrow, with bulbous subbasal lobe and small rounded dorsal lobe ca. 0.5 distance from base to tip, distal 0.2 beyond lobe slight curved.

*Female.* Head and thorax: As described for male, except forewing length 6.0-8.0 mm (mean = 6.8; n = 6). Abdomen. Genitalia as described for the genus and figured for congeners.

**Distribution and biology.** *Thaumatovalva limbata* is known from Praslin, Cosmoledo, and Mahé islands in the Seychelles, and from Kenya on the mainland. Adults have been reared from larvae collected in the fruit of *Cordia somaliensis* and *C. monoica* in Kenya, where the species occupies a broad elevational range from 10 to 2206 m.

**Remarks.** Based on forewing size, small specimens from Kenya (n = 7, from Watamu and Masai Lodge) appear to represent an undescribed species. However, the genitalia of these small specimens are identical to those of larger specimens of *T. limbata* from the Seychelles (see Diakonoff 1969: fig. 11, holotype) and reared specimens from Kenya. Furthermore, DNA barcodes do not separate the small specimens from the larger Kenyan specimens, the latter of which are identical to *T. limbata* from the Seychelles. All eight of our *T. limbata* sequences are identical throughout their sequenced length. Nonetheless, the broad elevational range and size differences suggest that more than one species may be concealed under this name.

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