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Southern hemisphere deep-water stylasterid corals including a new species, *Errina labrosa* sp. n. (Cnidaria, Hydrozoa, Stylasteridae), with notes on some symbiotic scalpellids (Cirripedia, Thoracica, Scalpellidae)

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Abstract

A number of stylasterid corals are known to act as host species and create refuges for a variety of mobile and sessile organisms, which enhances their habitat complexity. These include annelids, anthozoans, cirripeds, copepods, cyanobacteria, echinoderms, gastropods, hydroids and sponges. Here we report the first evidence of a diverse association between stylasterids and scalpellid pedunculate barnacles and describe a new stylasterid species, *Errina labrosa*, from the Tristan da Cunha Archipelago. Overall, five stylasterid species are found to host eight scalpellid barnacles from several biogeographic regions in the southern hemisphere (Southern Ocean, temperate South America and the southern Indo-Pacific realms). There is an apparent lack of specificity in this kind of association and different grades of reaction to the symbiosis have been observed in the coral. These records suggest that the association between pedunculate barnacles and hard stylasterid corals has a wide distribution among different biogeographic realms and that it is relatively rare and confined largely to deep water.

Keywords

Deep-water symbiosis, Scalpellidae, Stylasteridae, new species

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Introduction

Many stylasterid corals, like their shallow-water largely scleractinian counterparts (see e.g. Patton 1994, Stella et al. 2011, Hoeksema et al. 2012), are considered habitat-forming species because they contribute to the structuring of deep and shallow water coral banks (Roberts et al. 2006, Häussermann and Försterra 2007). In this context the tridimensional structure of their calcareous skeleton should enhance the complexity of the habitat, by creating refuges for a variety of mobile and sessile organisms (Braga-Henriques et al. 2010): basibionts for many other invertebrate such as annelids, anthozoans, cirripeds, copepods, cyanobacteria, echinoderms, gastropods, hydroids and sponges (Zibrowius 1981, Braga-Henriques et al. 2010, Goud and Hoeksema 2001, Pica et al. 2012, Puce et al. 2009). Species of the gastropod *Pedicularia*, considered obligate symbionts of Stylasteridae, usually assume the colour of the host colony and modify the branch coral surface where they reside (Zibrowius 1981, Goud and Hoeksema 2001, Cairns and Zibrowius 2013). Other organisms induce changes in the coral morphology and growth, like copepods that induce the formation of a gall on the coral branches (Zibrowius 1981, Buhl-Mortensen and Mortensen 2004a) and balanomorph or acorn barnacles (Zibrowius 1981) that usually are completely covered by the coral coenosteum. The presence of polychaetes on stylasterid colonies seems to occur in about 30% of the stylasterid species and frequently induces pronounced changes in the growth form and branching pattern in many species. For example, in *Inferiolabiata labiata* (Moseley, 1879) the polynoid *Polyeunoa laevis* McIntosh, 1885 induces modifications in the growing branches prior to the production of a reticulate tube in which the worm travels (Moseley 1879, Cairns 1983a). Those epibionts probably receive protection from predators, and also access to food is increased due to the tridimensional shape of the colonies (Braga-Henriques et al. 2010).

Such associations between cnidarians and other invertebrates are fairly common. Crustaceans, in particular cirripeds, are most prevalent in shallow water, the latter largely with corals having calcareous skeletons. The most notable include the burrowing barnacles or acrothoracicans (Kolbasov 2009) and thoracican coral barnacles generally belonging to the sessile balanomorph family Pyrgomatidae (Ross and Newman 1973). Such obligate, often host specific forms attain a remarkable diversity on scleractinian corals (Newman et al. 1976, Malay and Michonneau 2014), especially regarding shell modifications in species that have become nutritionally parasitic (Ross and Newman 1995).

The general situation in deep water is quite different as it is pedunculate scalpellomorphs rather than sessile balanomorphs that predominate (Newman and Ross 1971, cf. lepadomorph/balanomorph ratio). In their review of deep-water coral symbiosis, Buhl-Mortensen and Mortensen (2004b) reported on 74 host species (33 gorgonians, 29 scleractinians, seven alcyonaceans, and five antipatharians, but no stylasterids) with obligate as well as facultative associates. They conclude that Cirripedia (including their close relatives, the Ascothoracida), are the most common crustacean taxa associates of

deep-water corals. While the ascothoracids range from somewhat vagile ectoparasites to highly modified gall-forming endoparasites, the scalpellomorph pedunculates have made no obvious morphological adaptations to their hosts. However, it has been shown that calices of deep-water scleractinians such as *Lophelia pertusa* (Linnaeus, 1758), can grow up around a substantial portion of the peduncle of the scalpellomorphs (Newman et al. 2002), and herein we demonstrate for the first time that the coenosteum of stylasterid corals can do likewise. Furthermore, this paper reports the first evidence of a diverse association between stylasterids and scalpellid pedunculate barnacles from several southern biogeographic regions and describes a new stylasterid species from the Tristan da Cunha Archipelago involved in this symbiosis.

Methods

The Stylasteridae collections of several European Museums have been studied: MNA – Museo Nazionale dell'Antartide "Felice Ippolito", Italy; Museo di Storia Naturale of Genova, Italy; BNHM – Natural History Museum of London, United Kingdom; MNHN – Muséum National d'Histoire Naturelle of Paris, France; RMNH and ZMA in Naturalis Biodiversity Center of Leiden, Nederland. A number of specimens with pedunculate barnacles on them were examined for further analyses. The coral specimens (dry or preserved in ethanol) were, largely from the South Atlantic Ocean and the Antarctic and Sub-Antarctic region, whereas *Stephanohelia* corals were from off New Caledonia (South Pacific). The morphology of the specimens and details of the associations were first examined using a stereomicroscope. Selected portions were prepared for the scanning electron microscope (SEM) and photographic analyses. Longitudinal sections of coral branches were cut with an electric grinder in order to study the internal structures. Small portions of the coral were treated with sodium hypochlorite for 10 minutes, rinsed with distilled water, and dried, and coated with gold–palladium in a Balzer Union evaporator and examined with a Philips XL20 SEM.

Results

Among a total of about 600 stylasterid colonies observed, only 11 (<2%) belonging to five species revealed the presence of scalpellid barnacles (Table 1). The range of morphological responses of the corals to a notable diversity of barnacles was initially not fully appreciated owing to the scarcity of the material. The identification of the barnacles has been limited to illustrated specimens and while at least two subfamilies of the species-rich Scalpellidae are represented, it was not possible to identify all to species or even genus level. Nonetheless, this paper sheds considerable light on this kind of interspecific relationship and sets the stage for future taxonomic work on the barnacles involved.

Systematic part

Phylum Cnidaria
Class Hydrozoa Owen, 1843
Subclass Hydroidolina Collins & Marques, 2004
Order Anthoathecata Cornelius, 1992
Suborder Filifera Kühn, 1913
Family Stylasteridae Gray, 1847

Genus *Stephanohelia* Cairns, 1991

Diagnosis. Colonies with irregular shape, all with commensal polychaetes. Branches polychotomous with gastropores exclusively in the branch axils. Coenosteal texture linear-imbricate. Gastrostyle massive. Dactylopore spines small and without dactylostyles. Male ampullae superficial.

Discussion. The genus *Stephanohelia* is monospecific (Cairns 1991). The genus is easily diagnosed by its characteristic polychotomous branching and the gastropores exclusively at branch axils.

Type species. *Stephanohelia praecipua* Cairns, 1991.

Depth range. 318–793 m.

Distribution. New Zealand and New Caledonia.

Stephanohelia sp.

Figure 1

Material studied. Three colonies of sample MNHN IK 2010-152: expedition MUSORSTOM 4 N/O Vauban, Sta. CP194, 18°53' S, 163°22' E, New Caledonia, 550 m depth 19 September 1985 (in ethanol).

Description. Coral colonies arborescent, up to 8 cm long and 7 cm wide, with the basal branches up to 1.5 cm in diameter (Figure 1a). They are characterised by few main branches that are uniplanar around which several polychotomously tiny branches originate, formed by two to five branchlets (Figure 1b). The tiny branches are characterised by small abcauline spines (Figures 1b, c), up to 20 μm tall, mainly on the lateral edges. The branches are oval in cross-section. The tiny branches on both faces of the main branches are often anastomose, forming a gallery, which is caused by a commensal polychaete (Figure 1a). The colonies are attached to the substrate by an incrusting base. The colour of the coenosteum is white (Figure 1a). The coenosteal texture is linear-imbricate, composed of platelets irregular in shape and showing an alternating polarity (Figure 1d). The coenosteum is pierced by numerous coenosteal pores, 15-22-30 μm in diameter (Figure 1d). The strips are not well defined. The coenosteum is white.

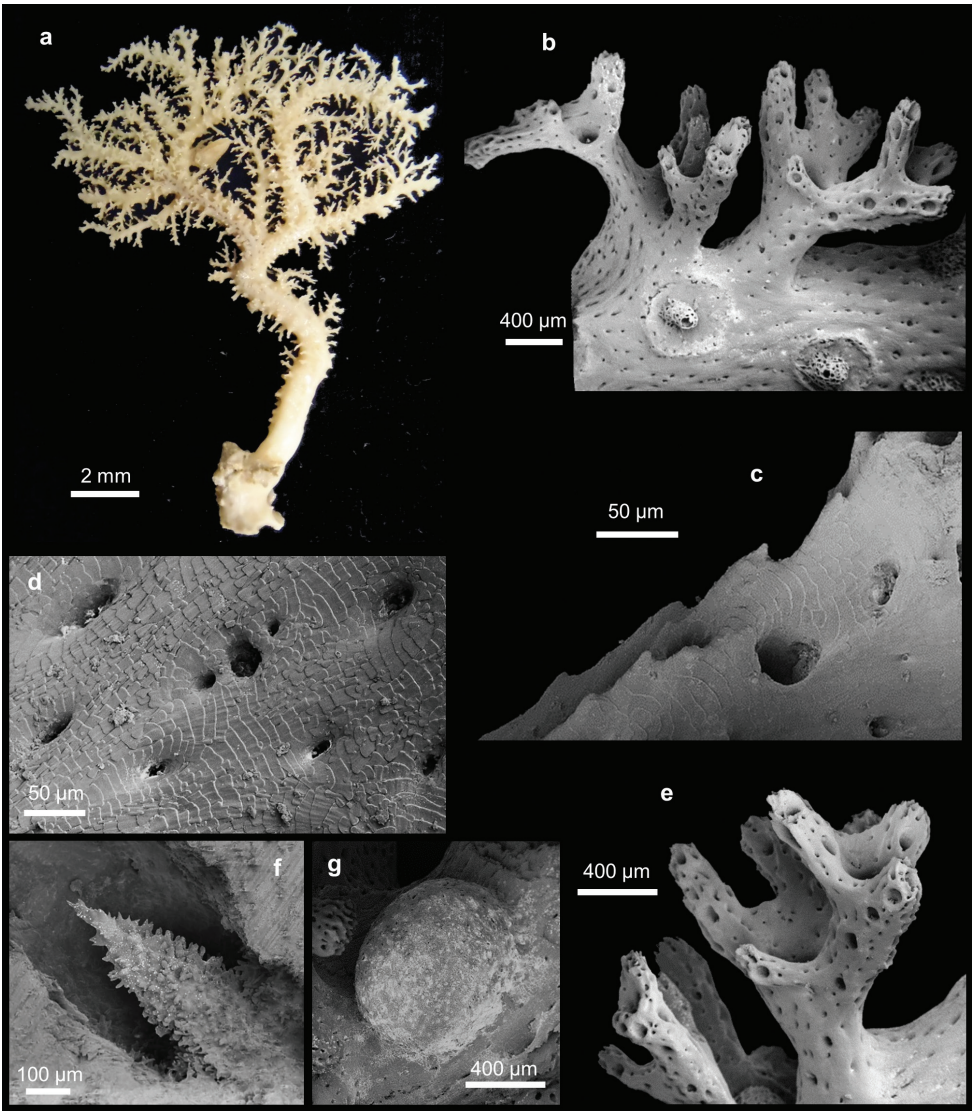

Figure 1. *Stephanohelia* sp. **a** Colony. SEM micrographs of **b** branch with polychotomous tiny branches and male ampullae **c** small abcauline spines **d** texture **e** polychotomous branches with aligned dactylopores **f** gastrostyle **g** female ampulla.

Gastropores are circular, 100-175-230 µm in diameter, occurring exclusively at branching axils (Figure 1e). The gastropore tubes are cylindrical to conical in apical branches where they are less deep. The gastrostyle tips are visible on the coenosteum surface. The gastrostyles are robust and tree-like in shape without ridges and ornamented with multi-tipped spines (Figure 1f). The gastrostyles measure 96-170-205 µm in length and 50-80-100 µm in diameter (L:D=1.8–2.6). A ring palisade is not present.

The dactylopores are flush with coenosteum and aligned on branch edges (Figure 1e). They are circular in shape and 40-60-95 μm in diameter. Dactylostyles are absent.

The female ampullae are round, superficial, 600-820-900 μm in diameter, and have a smooth surface (Figure 1g). They are distributed uniformly around the branches. Male ampullae are 400-510-600 μm in diameter and characterised by a round depression with a small central dome (Figure 1b). The domes vary in shape and have a highly perforate surface, usually with an apical pore (Figure 1b).

Remarks. The characteristic shape of the colonies with polychotomous branching, the presence of the gastropores exclusively at branch axils, the large gastrostyles and the absence of the ring palisade and the dactylostyles are characteristic for *Stephanohelia*. This species differs from the type species, *S. praecipua*, mainly in the gastrostyle shape. In fact, *S. praecipua* has a gastrostyle characterised by a main basal shaft with a very expanded midsection and a slender tip. The scarcity of the analysed material is insufficient to enable the description of a new species.

Genus *Inferiolabiata* Broch, 1951

Diagnosis. Colonies commonly associated with a commensal polychaete. Gastropores and dactylopores randomly distributed. Coenosteal texture linear- or reticulate-imbricate. Gastrostyles are present but a ring palisade is usually absent. Tabulae often present. Dactylopore spines with a primarily abcauline dactylotome. Dactylostyles present. Ampullae superficial.

Discussion. The genus *Inferiolabiata* includes four species (Cairns and Zibrowius 2013). The present material represents part of the first record of identified stylasterid corals from the Tristan da Cunha Archipelago.

Type species. *Errina labiata* Moseley, 1879.

Depth range. 80–2100 m.

Distribution. Tristan da Cunha Archipelago, South Africa, Antarctica and Sub-Antarctic area, New Zealand.

Inferiolabiata spinosa Cairns, 1991

Inferiolabiata spinosa Cairns 1991: 42; Cairns and Zibrowius 2013: 14.

Material studied. BNHM 1977.8.10.2: two broken colonies and seven fragments, *Discovery* Expedition Sta. 6, Tristan da Cunha, 3 miles N 30° E of Settlement, 80–140 m depth, 1 February 1926 (in ethanol).

Remarks. The genus *Inferiolabiata* consists of only four species: *I. labiata* (Moseley, 1879), *I. lowei* (Cairns, 1983a), *I. spinosa* Cairns, 1991 and *I. africana* Cairns & Zibrowius, 2013. Our specimens match *I. spinosa* described from New Zealand and South Africa (Cairns 1991, Cairns and Zibrowius 2013). They only differ in having

longer and thinner gastrostyles (L:D up to 15), in lacking a well-defined ring palisade, and the presence of two unlinear series of dactylostyles instead of three.

This is the first record of *I. spinosa* from the Atlantic and together with *Errina labrosa* sp. n. (see below), it is part of the only known stylasterid fauna reported from Tristan da Cunha Archipelago.

Genus *Errina* Gray, 1835

Diagnosis. Gastropores and dactylopores randomly distributed. Coenosteal texture reticulate-granular and linear-imbricate. Lower gastropore lip present in some specimens. Gastrostyles present but ring palisade usually absent. Dactylopore spines represented by up to two types and varying in shape and dimension. Dactylopore spines with a primarily adcauline dactylotome. Dactylostyles rarely present. Ampullae superficial and deep.

Discussion. The genus *Errina* includes 25 Recent species and one extinct species (Cairns 2014). The presence of dactylostyles in this genus is reported here for the first time.

Type species. *Millepora aspera* Linnaeus, 1767.

Depth range. 6–1772 m.

Distribution. North Atlantic, Mediterranean Sea, Galápagos, South Africa, Antarctica and Sub-Antarctic area, New Zealand, Japan and Tristan da Cunha Archipelago.

Errina antarctica (Gray, 1872)

See Cairns (1983a: 83) for synonymy.

Material studied. BNHM 1977.8.10.20: two colonies, *Discovery* Expedition, Sta. WS 248, Falkland Islands 52°40'00"S 58°30'00"W, 210-242 m depth, 20 July 1928, (preserved in ethanol); BNHM 1977.8.10.17: five broken colonies, *Discovery* Expedition, Sta. WS 841, 54°11'S 60°23"W, 200-370 m depth, 6 February 1932 (preserved in ethanol); BNHM 1977.8.10.34: 3 broken colonies and fragments, *Discovery* Expedition, Sta. WS 85, Falkland Islands, 52°09'00"S 54°14'00"W, 79 m depth, 25 March 1927 (dry).

Remarks. Within the genus *Errina* our specimens match *Errina antarctica* as described by Cairns (1983a) in all aspects of the colony morphology (see remarks of *E. fissurata*).

Errina fissurata (Gray, 1872)

Figure 2

Madrepora fissurata Stokes 1847: 336
Errina fissurata Gray 1872: 745; Moseley 1879: 479; 1881: 84; Boschma 1957: 53; 1964: 284; Boschma and Lowe 1969: 15; Cairns 1983a: 89.
Labiopora fissurata Hickson 1912: 878.

Errina (*Eu-Errina*) *fissurata* Broch 1942: 38.
Errina (*Eu-Errina*) *antarctica* Broch 1951: 35 (part of material from sta. 1948).
Errina (*Errina*) *fissurata* Boschma 1963: 337; Cairns 1983a: 89.
Errina antarctica Boschma 1966: 109 (part of material from sta. 30).

Material studied. MNA 3070, MNA 3071: two colonies, Cruise Carbonant 2002, Sta. 24, 72°30'456"S, 174°05'552"E, 438 m depth, 13 January 2002 (in ethanol); MNA 3079, MNA 3080, MNA 3081, MNA 3082, MNA 3086: a total of five colonies, Cruise Tangaroa 2004, Sta. 77, 72°07'47"S, 172°42'36"E, 499 m depth, 14 February 2004 (dry); BNHM 1977.8.10.26: one colony, *Discovery* Expedition, Sta. 1948, 60°49'24"S, 52°40'00"W,490–610 m depth, 4 January 1937 (in ethanol).

Description. Specimens consist of up to 16.4 cm long broken branches of uniplanar colonies, all lacking the base (Figure 2a). The branching pattern is irregular and dichotomous, most branches oriented nearly parallel (Figure 2a). They are oval in cross-section and up to 6 mm in diameter. The blunt tips are 2–3 mm in diameter (Figure 2b).

The colour of the coenosteum is pale orange (Figure 2a) with the core of the branches white. The texture is reticulate-granular with small and rounded granules 1.4–10 μm in diameter (Figures 2c, d). On the surface there are non-linear slits, up to 140 μm wide and provided with teeth projecting inward (Figure 2d). They connect the coenosteal pores, 20–30 μm in diameter (Figure 2d).

The gastropores and dactylopores are scattered over the coenosteum (Figure 2b). They are decreasing in abundance and density from the tip of each branch towards the base, being mainly present on the lateral branch edges and almost absent on the faces while they are generally lacking in the basal region. The round gastropores, 100–300 μm in diameter, are not lipped and the gastrostyle tips are visible from the coenosteum surface (Figure 2b). The gastrostyles are robust and lanceolate without ridges and have multi-tipped bifurcating spines (Figures 2e, f). They are up to 470 μm long and up to 220 μm in diameter (L:D=1.7–2.9). Ring palisades and tabulae are not recorded (Figure 2e).

The coenosteum surface contains two kinds of dactylopores, with either large or small spines, which protrude perpendicularly from it (Figure 2g). The large spines are U-shaped in cross-section and have an adcauline opening; they are mainly present in the distal portion of the branches (Figures 2h–j). They are 250–400 μm long with a diameter of 250–500 μm and are characterised by a thick porous wall (Figure 2h). Laterally they are composed of smooth overlapping platelets, while the internal wall is characterised by the typical reticulate texture (Figures 2i, j). The dactylotome is 60–110 μm wide (Figure 2j). From the apex to the base, the large dactylopore spines tend to become flush with the coenosteum and to disappear from the colony faces, remaining only on the lateral branch edges. The small spines are scattered between the large ones (Figures 2g, h, k), and, toward the base of the colony they become increasingly difficult to distinguish from the large dactylopores. Their external wall is smooth or reticulate and measures 60–140 × 60–85 μm in diameter and up to 70 μm in length (Figures 2h, k). The dactylotome is randomly

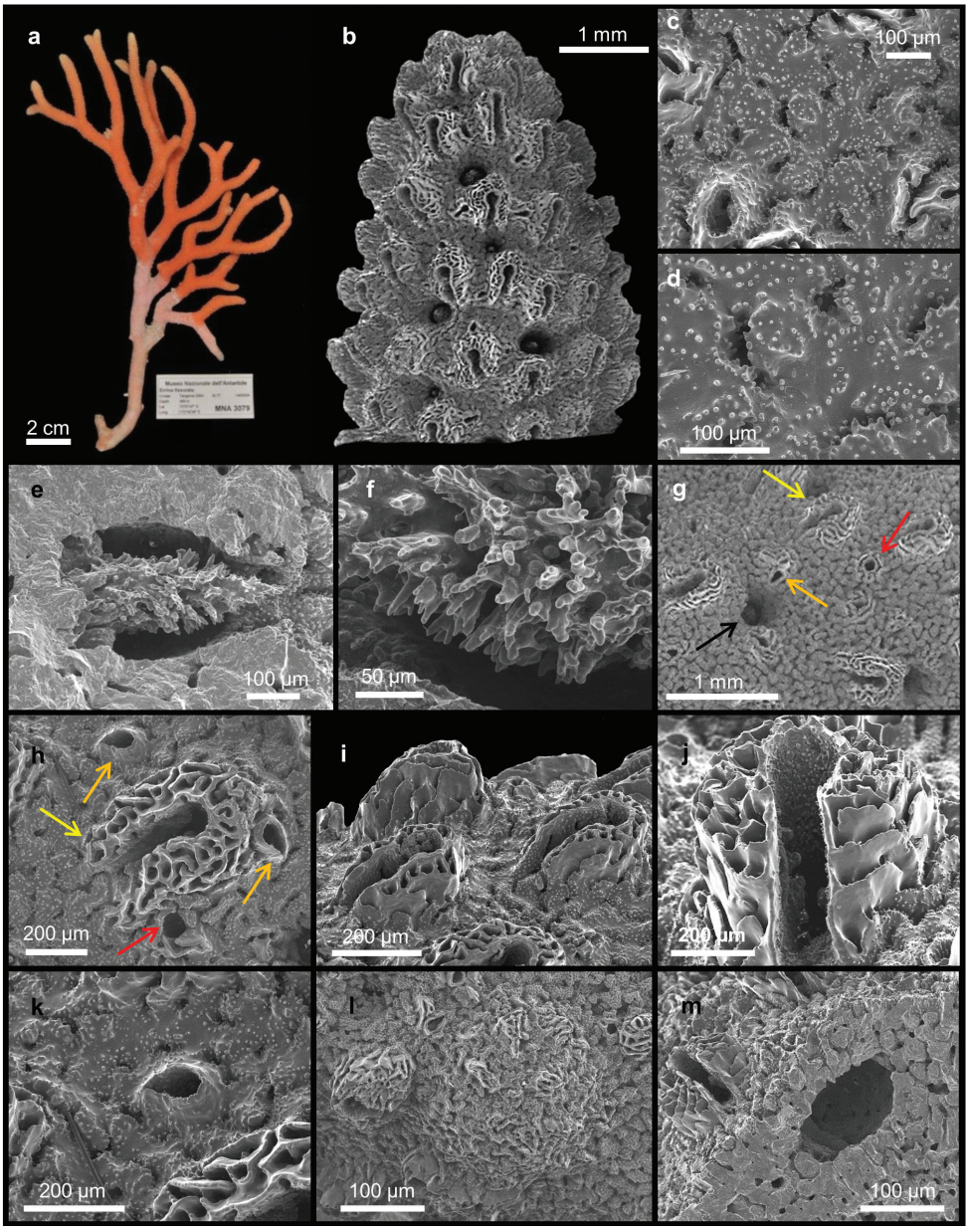

Figure 2. *Errina fissurata* Gray, 1872. **a** Colony. SEM micrographs of **b** apical branch **c–d** reticulate-granular coenosteal texture **e** gastrostyle **f** bifurcating spines of gastrostyle **g** different type of pores: gastropore (black arrow), large dactylopore spine (yellow arrow), small dactylopore spine (orange arrow) and large round pore (red arrow) **h** large dactylopore spine (yellow arrow), small dactylopore spines (orange arrows) and large round pore (red arrow) **i** large adcauline dactylopore spines **j** dactylostyles **k** small dactylopore spine **l** female ampulla **m** male ampulla.

oriented (Figure 2h). Dactylostyles are present only in the large spines (Figure 2j). They are composed by rudimentary elements up to 35 μm long and are arranged in two linear series on the lateral internal wall of the spine.

Large round pores (50–90 μm in diameter) almost flush with the coenosteum. They are scattered over the coral surface between the dactylopore spines (Figures 2g, h).

The colonies present sexual dimorphism in both size and position of the ampullae. The female colonies have round ampullae (up to 1 mm in diameter) that protrude from the coenosteum surface (Figure 2l). Small dactylopores are frequently present over the ampullae. The efferent pores are up to 175 μm in diameter and may be visible laterally. Male colonies have smaller, round to elliptical ampullae (up to 500 μm in diameter), which are partially embedded in the coenosteum and almost no detectable at the surface (Figure 2m).

Remarks. In the Antarctic and Sub-Antarctic region 11 *Errina* species have been recorded (Cairns 1983b, 1991). Among them, *E. fissurata* and *E. antarctica* are very similar to our specimens in various characters such as coenosteum colour and texture, non-lipped gastropore, and in having two kinds of dactylopores. The characteristic shape of the large dactylopore spines, the shape of the gastrostyles and the dimorphism of the ampullae reported in *E. fissurata* clearly match with our Antarctic specimens. Moreover, *E. fissurata* and *E. antarctica* show a distinct geographical and bathymetric distribution: *E. fissurata* is described around continental Antarctic, and almost exclusively at > 300 m depth, whereas *E. antarctica* is only known from South America and usually reported from < 300 m depth.

Our specimens compare favourably with samples described by Cairns (1983a), but differ in having the coenosteal pores distinguishable at the coenosteum surface, the presence of large pores at the surface, and having dactylostyles in the large dactylopores, never described before for this species. To date, the only other *Errina* species described with dactylostyles is *E. capensis* Hickson, 1912 from South Africa (Cairns and Zibrowius 2013).

Errina labrosa Pica, Cairns & Puce, sp. n.

http://zoobank.org/5F5BDBA9-ED95-47AC-8533-71208763C146
Figures 3–5

Holotype. BNHM 1977.8.10.2: four branches of a single colony, *Discovery* Expedition Sta 6, Tristan da Cunha, 3 miles N 30° E of Settlement, 80–140 m depth, 1 February1926 (in ethanol).

Paratypes. MNA 3085: two colonies, Cruise Icefish 2004 (dry); MNA 3087: several fragments (dry).

Diagnosis. The new species has a characteristic abcauline lip, ring palisade and one type of dactylopore with very elongated spines.

Description. The holotype (Figure 3a) is composed of several branches of a single colony. The larger branch is about 10 cm long and 9 cm wide. The other specimens

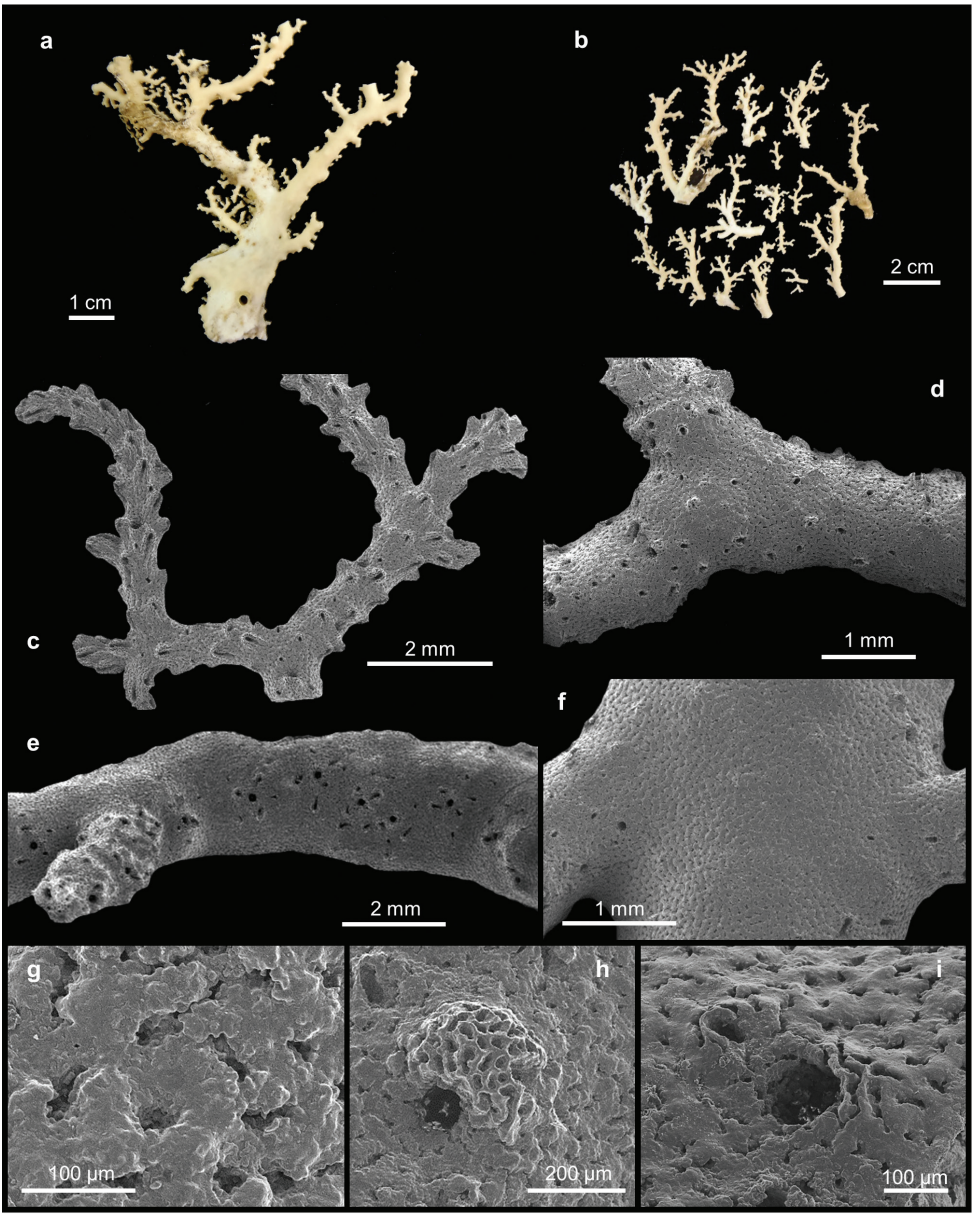

Figure 3. *Errina labrosa* sp. n. **a–b** Holotype. SEM micrographs of **c** spiny branch apex with gastropores and dactylopores uniformly distributed **d** middle portion of the colony **e** lateral view of the colony branch with gastropores are aligned and surrounded by the dactylopores **f** superficial coenosteum without pore **g** texture reticulate-granular **h** gastropore with lip **i** gastropore without lip.

(Figure 3b) consist of two large colonies and one small and broken colony attached to a black coral. All colonies have an wide base from where flabellate and uniplanar branches arise. Their bases are elliptical in cross-section and the axis of the largest colony is 6

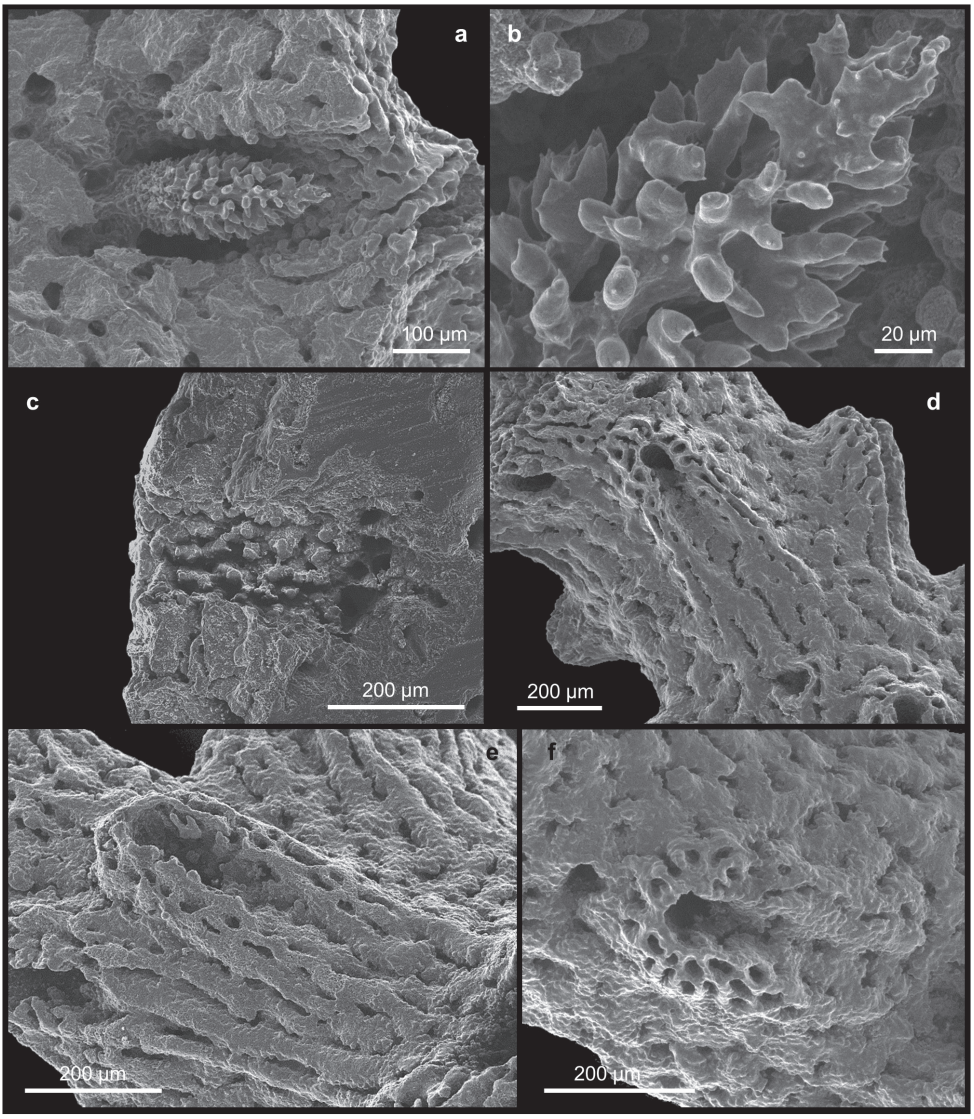

Figure 4. *Errina labrosa* sp. n. SEM micrographs of **a** gastrostyle **b** multitipped bifurcating spines of the gastrostyle **c** diffuse ring palisade **d–f** dactylopores from the apical region to the base.

by 4 mm. The apexes are up to 1 mm in diameter. The branches are irregularly sparse and unequal, without anastomosis.

The gastropores and the dactylopores are predominantly concentrated on the terminal branches (Figure 3c) and decrease in abundance towards the base (Figures 3d–f). In this region the pores remain confined to the lateral branch edges where the gastropores are aligned and surrounded by dactylopores characterised by a small spine.

The coenosteum is white-cream in colour and the texture is reticulate-granular with poorly-defined granules (Figure 3g). The strips are irregular in shape, 21–79 μm wide. The surface appears uniformly lumpy.

The gastropores are circular in shape (Figures 3h–i), 80–150 μm in diameter. Predominantly in the apical region of the colony they are bordered by a well-pronounced abcauline lip (Figure 3h). This lip is porous and rounded to rectangular in shape, up to 273 μm wide, and may bear one or two dactylopore spines. The gastropore tubes are cylindrical and shallow, gastrostyles are visible at the surface. The gastrostyle (Figure 4a) has a spindle shape, ornamented with multi-tipped bifurcating spines (Figure 4b) in the apical portion, while the basal region presents a small smooth constriction. They measure 205–289 × 68–114 μm (L:D=2.3–3.4). The wall of the gastropore tube bears a diffuse ring palisade (Figure 4c) composed of irregularly shaped elements up to 20 μm in diameter. Tabulae are absent.

Dactylopores are of one kind. In the apical branches they are adcauline and bordered by well-defined spines (Figures 4d–f; 5a). These spines are 104–244 μm long and 158–223 μm wide, truncate, with a long groove (the dactylotome) 300–550 μm long, which is oriented with an angle up to 45° with respect to the branch surface. Laterally, the spines show the same texture as the surface, while the internal wall is characterised by rudimentary dactylostyles, uniformly distributed on all surfaces (Figure 5b). The dactylostyle elements are rounded and 2–6 μm in diameter. The dactylotome is 48–73 μm wide. Proximally, the dactylopore spines are shorter with a smaller groove. In this region the spines are oriented in all directions and they are located mainly on the lateral side of the branches around the gastropores.

The ampullae (Figures 5c–d) are distributed homogenously over the colony. In the apical branches they are external while in the basal branches they are predominantly internal. The female ampullae, 550–842 μm in diameter, are round in shape but appear hemispherical from outside, and may have some dactylopores above them (Figure 5c) and an efferent pore on one side (Figure 5c). The male ampullae, 400–500 μm in diameter, are also round in shape (Figure 5d). No efferent pores were observed for them.

Remarks. Among the 25 known species of *Errina*, the only two other species having a gastropore lip, ring palisade and one type of dactylopore, as in our species, are *E. cheilopora* Cairns, 1983 and *E. reticulata* Cairns, 1991. The gastropore lip of these two species projects over the gastropore (Cairns 1991) and therefore differs in shape with respect to the lip observed in our specimens. In addition, both species have large gastropores (180–330 μm and 140–200 μm, respectively) and mainly show a linear-granular texture (Cairns 1991). Our specimens show a characteristic gastropore lip and very elongated dactylopore spines, which distinguish *E. labrosa* easily from the other species. Moreover, from a geographic point of view, *E. labrosa* together with *I. spinosa* (see above) represent the first identified stylasterids from the Tristan da Cunha Archipelago in the central part of the South Atlantic Ocean.

Errina was reported earlier from Tristan da Cunha by Moseley (1881) based on a specimen dredged by the *Challenger* Expedition (Sta. 135), which was identified as *E. labiata* (now *Inferiolabiata labiata*). Boschma (1964) doubted this identifica-

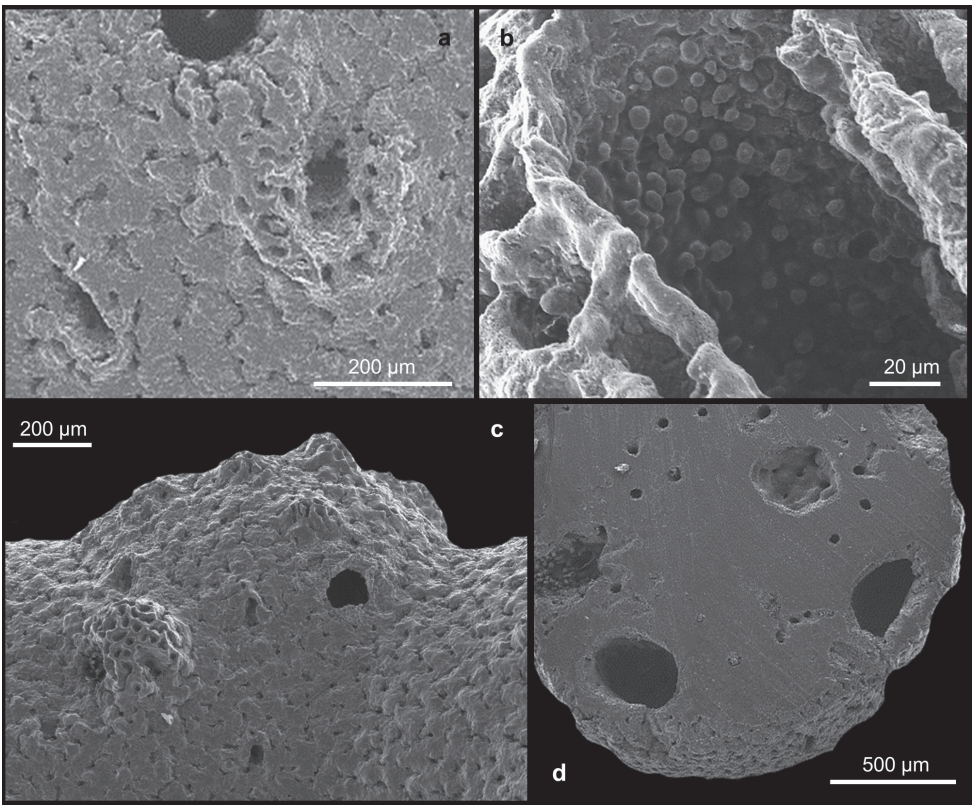

Figure 5. *Errina labrosa* sp. n. SEM micrographs of **a** dactylopore without spine **b** dactylostyle **c–d** ampullae.

tion because he noted that the openings of the groove spines of the dactylopores are turned toward the basal part of the colony instead of the apical part, as in *I. labiata*. He identified the specimen as *Errina gracilis*. Subsequently Cairns (1983a), reviewing the stylasterids from the Antarctic and Subantarctic region, reidentified the same specimen as *Errina* (*Errina*) sp. to because its poor description that did not allow a correct identification and therefore a comparison with our specimen is impossible.

Etymology. From the Latin word *labrum* (meaning lip) for the characteristic abcauline lip of the gastropores.

Scalpellid barnacles associated with stylasterid corals

The stylasterid *Errina fissurata* is reported as host for two different scalpellids (Table 1). One of them is *Trianguloscalpellum* sp. (Arcoscalpellinae, Figures 6a, b) on specimens MNA 3079 and 3082, while the other is *Ornatoscalpellum* cf. *vanhoeffeni* (Scalpellinae, Figure 6c) on specimen BNHM 1977.8.10.26. In all specimens the peduncles are par-

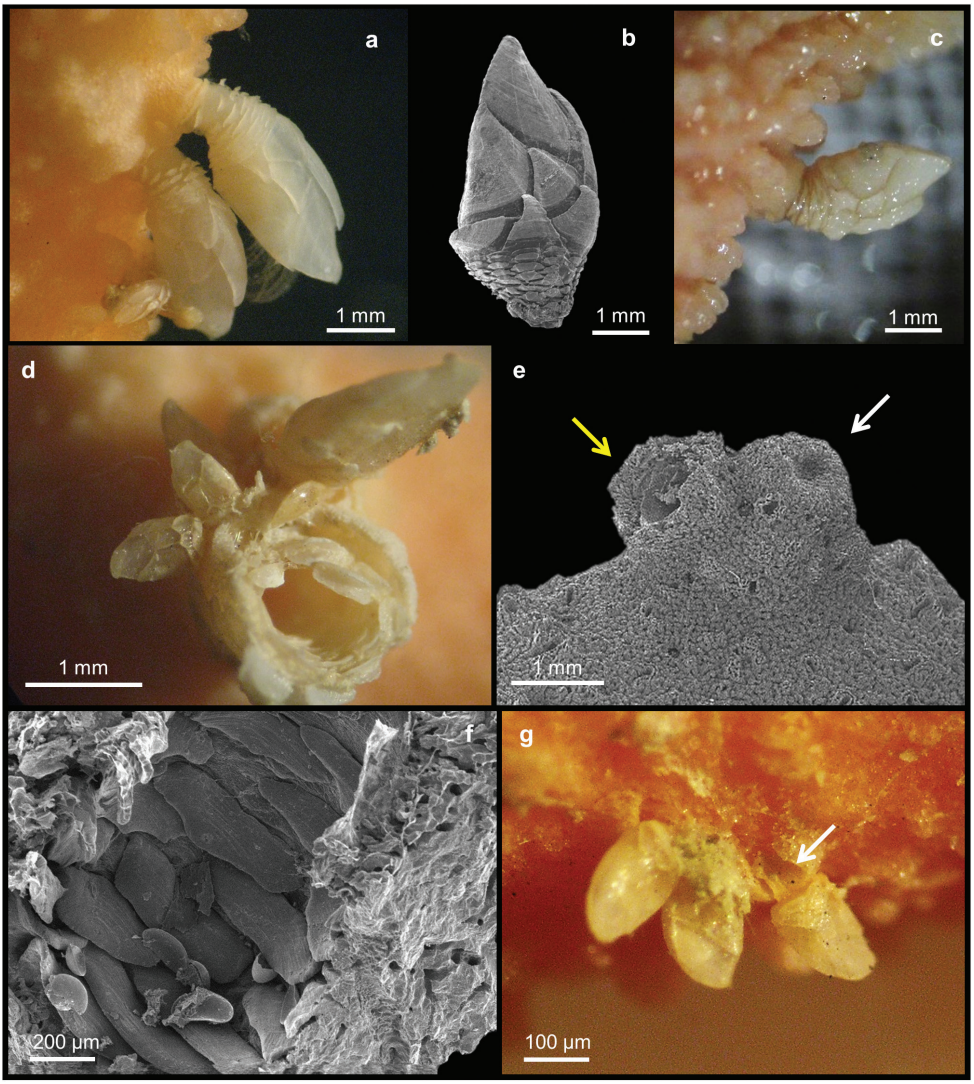

Figure 6. *Errina fissurata.* **a** Specimen with *Trianguloscalpellum* sp. **b** SEM of *Trianguloscalpellum* sp. **c** specimen with *Ornatoscalpellum* cf. *vanhoeffeni* **d** peduncular plates in cavity in coral coenosteum **e** SEM of where a barnacle was detached (yellow arrow) next to a superficial bump (white arrow) **f** peduncular scales in a bump **g** young barnacles one with peduncle in a dactylopore (arrow).

tially covered by a thin layer of coenosteum (Figures 6a, c). By removal of the unburied portion of the peduncle supporting the capitulum, a peduncular cavity within the peduncular plates can be seen penetrating deep into and surrounded by coral coenosteum (Figure 6d). Moreover, on the surface of *E. fissurata* corals several irregular calcareous bumps can be observed (Figure 6e), which are filled with peduncular scales (Figure 6f). At the base of one of these barnacles, several juvenile barnacles are found (Figure 6d). Similar young specimens have been found at some distance from mature ones attached

Table 1. Five stylasterid species and the eight scalpellids associated with them.

Stylasterid corals	Scalpellomorph barnacles
Stephanohelia sp. New Caledonia, 550 m	scalpellid sp. 3
Inferiolabiata spinosa Cairns, 1991 Tristan da Cunha, 80–140m	*Arcoscalpellum* sp. 2
Errina antarctica (Gray, 1872) Off Falkland Islands 79–370 m	scalpellid sp.1, scalpellid sp. 2 and *Ornatoscalpellum* cf. *gibberum*
Errina fissurata (Gray, 1872) off Daniell Peninsula, Antarctica, 438–610 m	*Trianguloscalpellum* sp. and *Ornatoscalpellum* cf. *vanhoeffeni*
Errina labrosa sp. n. Tristan da Chuna, 80–140 m	*Arcoscalpellum* sp. 1

to the surface or inside dactylopores of the host coral (Figure 6e). The barnacles on *E. fissurata* are scattered about mainly on the apical region of the corals.

The new species, *Errina labrosa* is observed in association with *Arcoscalpellum* sp. 1 (Figure 7a, b), while the species *Inferiolabiata spinosa* (Figure 7c) hosted *Arcoscalpellum* sp. 2 (Figure 7d) (Table 1). Specimens of these two cirripedes are attached to the surface of the corals albeit their peduncles are not covered by the coenosteum (Figures 7a–c). Moreover, when such occasional arcoscalpellines are detached nothing more than small depressions are left behind on the coral surface, and no recently settled juveniles were found around them. In *E. labrosa* individuals of *Arcoscalpellum* sp. 1 are scattered along the length of the colonies, while in *I. spinosa*, *Arcoscalpellum* sp. 2 is mainly distributed over the apical portions (Figure 7c).

Three different scalpellids are found in association with three different specimens of *Errina antarctica*: scalpellid sp.1 on specimens BNHM 1977.8.10.17, scalpellid sp.2 on BNHM 1977.8.10.20 (Figure 7e) and the scalpelline *Ornatoscalpellum* cf. *gibberum* on BNHM 1977.8.10.34 (Figure 7f) (Table 1). Individuals of scalpellid sp. 2 (Figure 7e) are concentrated in a mass on the basal portion of the stylasterid. While attached to the coenosteum, their peduncles are not covered by it. On the other hand, individuals of *O.* cf. *gibberum* are scattered individually over the entire length of the coral colony (Figure 7f). In this species too the peduncle remained uncovered by the coral coenosteum. The same can be said for scalpellid sp. 1, but in this case the coral surface several little bumps are present, circular in shape and with a small depression on the top (Figure 7g). No peduncular scales are visible in the depressions.

The stylasterid *Stephanohelia* sp. has been observed to host a single unidentified scalpellid, sp.3 (Figure 7h) (Table 1) which is located in the middle portion of the coral colony and has its peduncle covered by the coral skeleton up to the capitulum (Figure 7h). No other bumps or scars are observed on the coral surface.

In all cases the barnacles are attached through living tissue of the stylasterids, where their cyprid larvae had settled.

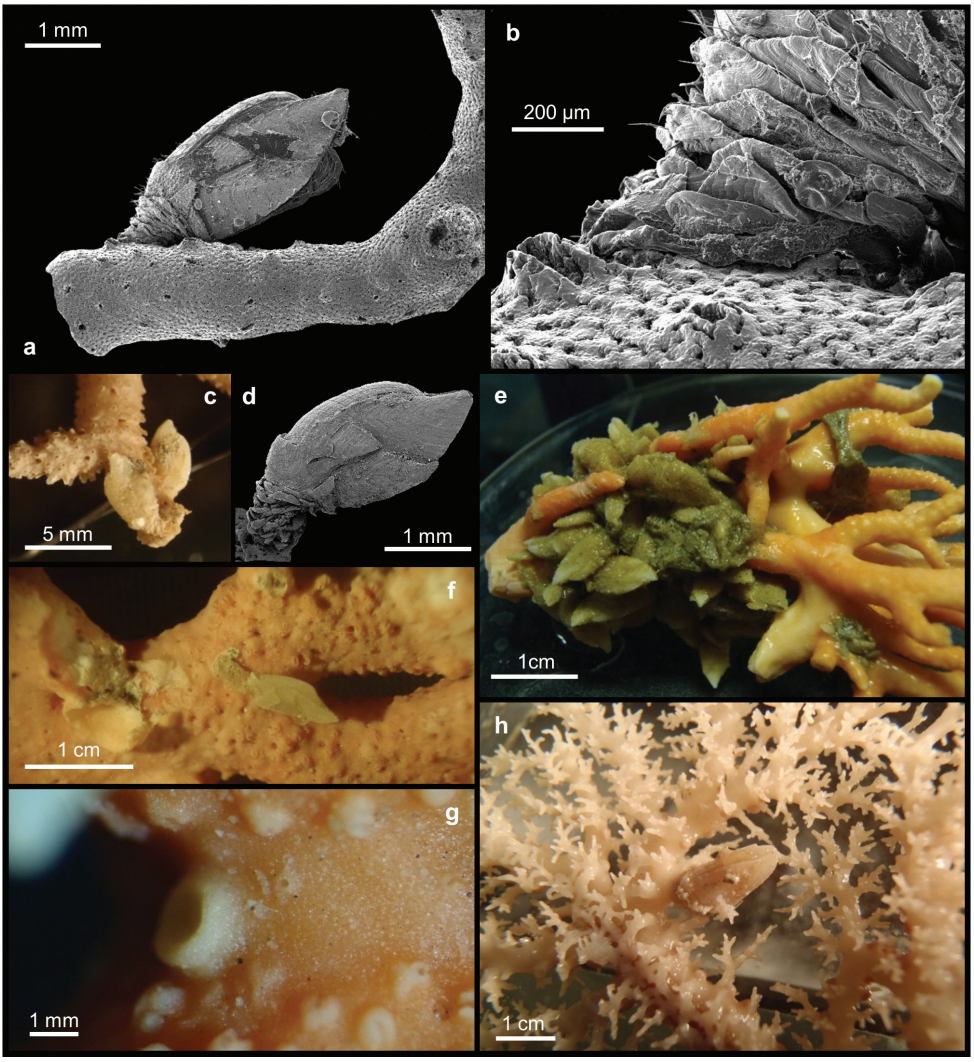

Figure 7. a–b Peduncle of *Arcoscalpellum* sp. 1 not covered by coenosteum of *Errina labrosa* sp. n. **c–d** Peduncle of *Arcoscalpellum* sp. 2 not covered by coenosteum in *Inferiolabiata spinosa* and SEM micrograph of same species **e** scalpelline sp. 2 concentrated in the basal portion in *Errina antarctica* **f** peduncle *Ornatoscalpellum* cf. *gibberum* attached to but free of coral skeleton in *Errina antarctica* **g** circular bumps with little depressions on the top in *Errina antarctica* **h** scalpelline sp. 3 with peduncle fully and lower margin of capitulum partially covered by the calcareous skeleton of *Stephanohelia* sp.

Discussion

The Stylasteridae of the South Atlantic Ocean, between the Antarctic and the Tropic of Capricorn, with a total of 22 known species, are poorly known (Boschma 1957, Cairns 1983a, Cairns and Zibrowius 2013). They are largely distributed along the

coasts of South America and South Africa, except for *Errina labiata* (see remarcks of *Errina labrosa* sp. n.) sampled from Tristan da Cunha during the *Challenger* Expedition (Moseley 1881). This identification was deemed highly questionable by both Boschma (1964) and Cairns (1983a) and currently it is just known as *Errina* sp. (Cairns 1983a). Thus, *E. labrosa* sp. n. and *Inferiolabiata spinosa* represent the only two identified stylasterid corals known from this locality. This Archipelago is considered part of the Temperate South America Region (Briggs 1974, Briggs and Bowen 2013), where 16 stylasterid species were reported from along the coasts of South America (Cairns 1983a).

Associations between cirripeds and cnidarians are fairly common in both shallow and deep water, involving numerous species of coral-associated barnacles. These include inconspicuous burrowing barnacles or acrothoracicans (Kolbasov 2009), which burrow in limestone and coral skeletons, and the conspicuous shallow-water balanomorph thoracicans of the family Pyrgomatidae (Simon-Blecher et al. 2007, Malay and Michonneau 2014), which settle on and keep pace with the growing coral skeleton (Ross and Newman 1973). Stalked barnacles have been recorded in association with some deep-water cnidarian taxa such as black corals (Molodtsova and Poltarukha 2008, Bo et al. 2012), gorgonians (Buhl-Mortensen and Mortensen 2004a, 2004b, 2005) and scleractinian corals (Newman et al. 2002). There is but one previous record of an association between stylasterid corals and a stalked barnacle (Newman and Ross 1971) even though several taxonomic papers provide information about symbionts of stylasterids (Zibrowius 1981, Goud and Hoeksema 2001, Puce et al. 2009, Pica et al. 2012). General works on stylasterids such, as Cairns (2011) and earlier, only mention barnacles in passing. That leaves Pica et al. (2012) for an overview, upon which the following list is based.

Subclass Cirripedia Burmeister, 1834 (those previously known associated with shallow as well as deep-water stylastrid corals, plus the scalpellids (Table 1))

Superorder Acrothoracica Gruvel, 1905

Order Lithoglyptida Kolbasov, Newman & Høeg, 2009

Family Lithoglyptidae Aurivillius, 1892

Armatoglyptes stirni (Turquier, 1987), off Strait of Gibraltar (Cape Spartel), in *Errina aspera* (L.) and other corals, 90–390 m (Kolbasov 2009).

Lithoglyptes s.l. in *Paraerrina decipiens* Brock, 1942 from Mauritius (Zibrowius 1981).

Order Cryptophialida Kolbasov, Newman & Høeg, 2009

Family Cryptophialidae Gerstaecker, 1866

Australophialus pecorus Turquier, 1985, off Strait of Gibraltar (Cape Spartel), in *Errina aspera* (L.) ~200 m and other corals between 20–390 m (Kolbasov 2009).

Australophialus tomlinsoni (Newman & Ross, 1971), off Ross Sea and Antarctic Peninsula, in skeletons of *Errina* sp. and other invertebrates, ~400 m (Newman and Ross 1971).

Superorder Thoracica Darwin, 1854

Order Scalpelliformes Buckeridge & Newman, 2006

Family Scalpellidae Pilsbry, 1907

Three species unidentified to genus herein, two on *Errina antarctica*, off Falkland Is. 79–370 m and one on *Stephanohelia* sp. New Caledonia 500 m.

Subfamily Scalpellinae Pilsbry, 1907

Ornatoscalpellum gibberum (Aurivillius, 1892), off Tierra del Fuego on *Errina* cf. *antarctica* (Gray, 1872), 250 m (Newman and Ross 1971).

Ornatoscalpellum cf. *gibberum* (Aurivillius, 1892) on *Errina antarctica* off Falkland Is, 79–370 m (Aurivillius 1892).

Ornatoscalpellum cf. *vanhoeffeni* (Gruvel, 1907) on *Errina fissurata* off Daniell Peninsula, Antarctica 438–610 m (Gruvel 1907).

Subfamily Arcoscalpellinae Zevina, 1978

Trianguloscalpellum sp., on *E. fissurata* (Gray, 1872) from off Daniell Peninsula, Antarctica 438–610 m (Gray 1872).

Arcoscalpellum sp. 1 and 2, one on *E. labrosa* sp. n., the other on *Inferiolabiata spinosa* Cairns, 1991, all from Tristan da Chuna, 80–140 m (Cairns 1991).

Order Sessilia Lamarck, 1818

Suborder Verrucomorpha Pilsbry, 1916

Family Verrucidae Darwin, 1854

Verruca s.l. on *Errina dabneyi* (De Pourtalès, 1871) from Açoc Seamount at 400 m (Braga-Henriques et al 2010, Braga-Henriques pers. comm.).

Suborder Balanomorpha Pilsbry, 1916

Family Pachylasmatidae Utinomi, 1968

Pachylasma giganteum (Philippi, 1836), Strait of Messina to off W. Africa, facultative with *Errina aspera* (L.), at shelf break, 150–200 m (Darwin 1854, Zibrowius 1981, Fredj and Giermann 1982, Di Geronimo and Fredj 1987, Zibrowius and Cairns 1992, Foster and Buckeridge 1995, Salvati et al. 2010).

Family Archaeobalanidae Newman & Ross, 1976

Solidobalanus enbergi (Pilsbry, 1921) shallow water, facultative on a stylasterid; possibly a senior synonym or sibling of *Armatobalanus nefrens* (see Young and Shimek 1982).

Armatobalanus nefrens (Zullo, 1963) shallow water, generally in *Stylaster californicus* (Verrill, 1866) and *Errinopora pourtalesi* (Dall, 1884).

Family Pyrgomatidae Gray, 1825

?*Pyrgoma* sp. on *Stylaster ramosus* Broch, 1947 from Tanzania, shallow water, possibly a pyrgomatid, but not likely a *Pyrgoma* species as presently known.

?*Pyrgoma* sp. on *Stylaster scabiosus* Broch, 1935 from Mauritius, shallow water, possibly a pyrgomatid, but not likely a *Pyrgoma* species as presently known.

Family Balanidae Leach, 1806

Balanus nubilus Darwin, 1854, intertidal and shallow water, occasionally all but overgrown by a *Stylaster* sp. in British Columbia.

Only two previously recorded cases of associations between scalpellomorphs and cnidarians provided with a hard calcareous skeleton are known, one illustration of

Ornatoscalpellum gibberum (Aurivillius, 1892) on *Errina* sp., likely *E. antarctica* (Newman and Ross 1971, Plate XIII), and the other of calanticids of the *Scillaelepas* complex on scleractinians from North Atlantic and New Zealand (Newman et al. 2002).

The scapellids reported here have been found in different positions on the stylasterid colonies and also in different stages of development. On the colony of *E. fissurata* and *E. antarctica* a morphological reaction to the presence of the symbiont has been observed. In fact, the cirriped induces or allows the production of a calcareous collaret surrounding the lower portion of its peduncle. A similar arrangement was reported by Newman et al. (2002) in the association between calanticid scalpellomorph and the scleractinian, *Lophelia pertusa*, where it settled in the coral calices. The presence of the barnacle caused coral skeleton or coenosteum to grow up around the base of the barnacle peduncle in much the same manner as seen here in some of the stylasterids. Regarding black corals, Bo et al. (2012) confirmed previous reports that the barnacle's settling induces a skeletal reaction resulting in an outgrowth of skeletal tissue with modified spines, and this can apparently also occur in cases involving some stylasterids-inhabiting barnacles (Figure 7h).

It was observed that when a cirriped accidentally detaches or dies, the hydroid partially plugs the gall with skeleton material which remains clearly visible as a bump-like scar. On the internal face of the bump the peduncular scales of the barnacle are still visible (Figures 6e, f). Similar attachment scars consisting of scleractinian skeleton material are reported by Newman et al. (2002, Figure 3 B and C) but here the cavity was only partially coated, not filled by the coral.

Several scalpellid individuals in different early stages of growth were found on colonies of *E. fissurata*. The cyprid larvae settled on the peduncle of established individuals as well as directly on the coral surface. In the latter case the cyprid larvae may settle inside dactylopore openings.

Conclusions

The study of the Stylasteridae corals from European museum collections did not only reveal various associations between stylasterid corals and pedunculate barnacles, but also allowed the description of *Errina labrosa* sp. n., which also participated in this association.

Overall, eight scalpellid species are recorded in association with five stylasterid coral species belonging to at least three genera. Our study suggests a lack of host specificity in this association. In fact, several barnacle species are found to be associated with *Errina fissurata* and *E. antarctica*, but it appears that in a single host coral colony only a single barnacle species can be represented. Although no specific association has been found, different grades of reaction to the symbiosis have been recorded in the coral. In *E. labrosa* and *I. spinosa* no reaction has been observed, while in *E. fissurata* and *Stephanohelia* sp. the coenosteum covered the peduncles of both observed barnacles species. *Errina antarctica* shows both kinds of interaction. This suggests that the reaction of stylasterid corals depends on the barnacle species, but because a wide range of sizes (ages)

of each species was not available, further investigations are needed to test this hypothesis. The symbiosis between stylasterid corals and scalpellid barnacles, albeit relatively rare, is largely confined to vulnerable marine ecosystems of the Southern Ocean (Jones and Lockhart 2011). Such biodiversity is not spread evenly across the ocean floor but follows complex patterns determined by climate, geology and evolutionary history.

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Review of the millipede genus *Kronopolites* Attems, 1914 (Diplopoda, Polydesmida, Paradoxosomatidae), with the description of a new species from Laos

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Abstract

The millipede genus *Kronopolites* currently comprises 11 species, including a new species from northern Laos: *K. lunatus* **sp. n.** The generic diagnosis is updated, a key given to all known species, and their distributions are mapped.

Keywords

Millipede, *Kronopolites*, new species, key, distribution, Paradoxosomatidae

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Introduction

The flat-back millipede genus *Kronopolites* Attems, 1914 is widespread in tropical Asia ranging from the Himalayas of Kashmir, India in the west to Taiwan in the east (Fig. 4). This genus belongs to the mainly Southeast Asian tribe Sulciferini in the family Paradoxosomatidae which is one of the largest families in the entire class Diplopoda, dominating the millipede fauna of Indo-Australia (Jeekel 1968, Nguyen and Sierwald 2013). The genus *Kronopolites* currently contains 10 described species (Golovatch 2013a, 2013b, 2014): *K. swinhoei* (Pocock, 1895), the type-species which is widespread in central and southeastern China, *K. acuminatus* Attems, 1937, from northern Vietnam, *K. formosanus* (Verhoeff, 1939), from northern Taiwan, *K. biagrilectus* Hoffman, 1963, from Jiangxi Province, China, *K. fuscocingulatus* Jeekel, 1982, from northern Thailand, *K. occidentalis* Golovatch, 1983, from the Kashmir Himalaya, India, *K. montanus* Golovatch, 2009, from northern Vietnam, *K. rugosus* Golovatch, 2013 and *K. davidiani* Golovatch, 2014, both from Yunnan Province, China, as well as *K. semirugosus* Golovatch, 2013 from Sichuan Province, China.

The present study treats some new material collected in Laos during several field trips. Prompted by the discovery of a new species, the authors have revised the entire genus *Kronopolites* adding a new diagnosis and updating both the catalogue and key to species. In addition, its distribution is mapped.

Material and methods

Material was collected in northern Laos in 2014 by SP and members of the Animal Systematics Research Unit, Chulalongkorn University. Specimens were preserved in 75% ethanol, and morphological investigations were carried out in the laboratory using an Olympus stereomicroscope. Scanning electron micrographs (SEM) of gonopods coated with gold were taken using a SEM JEOL JSM–5410 LV microscope. The gonopods were then removed from stubs and returned to alcohol after examination. Digital images of freshly fixed specimens were taken in the laboratory and assembled using the "Cell^{D}" automontage software of the Olympus Soft Imaging Solution package. In addition, line drawings of gonopod characters were also prepared. The types are housed in the Museum of Zoology, Chulalongkorn University (CUMZ), Bangkok, Thailand.

Collecting sites were located by GPS using the WGS84 datum.

In the catalogue sections, D stands for the original description, subsequent descriptive notes or appearance in a key, R for a subsequent record or records, and M for a mere mention.

Taxonomic part

Family Paradoxosomatidae Daday, 1889
Subfamily Paradoxosomatinae Daday, 1889
Tribe Sulciferini Attems, 1898

Genus *Kronopolites* Attems, 1914

Kronopolites Attems 1914: 219 (D).
Kronopolites – Attems 1929: 272 (D); 1931: 113 (D); 1936: 225 (D); 1937: 49 (D); Verhoeff 1939: 274 (D); Takashima 1950: 38 (M); Takakuwa 1954: 30 (D); Hoffman 1963: 579 (D); 1980: 169 (M); Jeekel 1968: 71 (R); 1971: 225 (M); 1982: 243 (M); 1988: 98 (M); Chen et al. 2006: 252 (M); Golovatch 2009: 121 (D); 2013a: 12 (M); Nguyen and Sierwald 2013: 1287 (M).
Kansupus Verhoeff 1934: 17 (D), synonymized by Attems (1936: 233).
Kansupus – Jeekel 1971: 225 (M); Hoffman 1980: 169 (M).
Parakansupus Verhoeff 1939: 273 (D), synonymized by Hoffman (1963: 579).
Parakansupus – Jeekel 1971: 230 (M); Hoffman 1980: 169 (M).

Diagnosis. Body medium-sized to large (ca 23–42 mm long, ca 1.6–6.5 mm wide), with 20 segments. Paraterga from poorly to strongly developed, mostly without lateral incisions. Transverse metatergal sulcus distinct. Sterna usually modified, an acute cone often present near each coxa. Sternal lobe or cone(s) between ♂ coxae 4 present or absent. Pleurosternal carinae usually well-developed.

Gonopods rather simple to relatively complex; coxites elongate, subcylindrical, distoventrally sparsely setose, without tubercles; prefemoral (= setose) part of telopodite moderate to relatively large, 1/3–1/2 as long as acropodite; femorite rather slender to stout, slightly curved, enlarged distad, with an evident groove on mesal face and a distinct distolateral sulcus demarcating a postfemoral part; the latter typically carrying a fork consisting of two lateral/ventral processes: usually a smaller basal process **b** with its tip pointed basad to prefemoral part, and a larger, normally suberect or ventrally curved process **a**; solenophore strongly developed, slender, slightly longer than or nearly as long as femorite, strongly curved mesad, sometimes with a membranous, distally strongly expanded end, almost completely sheathing a flagelliform and longer solenomere; seminal groove running entirely or mostly mesally along an excavate femorite, then directed slightly dorsad in distal part of femorite to follow onto solenomere thereafter.

Type species. *Strongylosoma swinhoei* Pocock, 1895, by original designation.

Other species included. *K. acuminatus* Attems, 1937, *K. formosanus* (Verhoeff, 1939), *K. biagrilectus* Hoffman, 1963, *K. fuscocingulatus* Jeekel, 1982, *K. occidentalis* Golovatch, 1983, *K. montanus* Golovatch, 2009, *K. rugosus* Golovatch, 2013, *K. semirugosus* Golovatch, 2013, *K. davidiani* Golovatch, 2014, *K. lunatus* sp. n.

Remarks. Pocock (1895) described the type species in *Strongylosoma* Brandt, 1833, from a single female from Chee Foo, China. Soon after that Brölemann (1896),

having received a male of this species from Chou-San Island, China, gave a more detailed description, including that of gonopod structure. Attems (1914) proposed a new genus, *Kronopolites*, and designated *Strongylosoma swinhoei* as type species.

Kronopolites acuminatus Attems, 1937

Kronopolites acuminatus Attems 1937: 52 (D).
Kronopolites acuminatus – Attems 1938: 227 (D); Jeekel 1968: 59 (R); Enghoff et al. 2004: 38 (M, R); Golovatch 2009: 121 (D); Nguyen and Sierwald 2013: 1287 (M).
Kronopolites acuminatus acuminatus – Hoffman 1963: 584 (M, R); Golovatch 1983a: 181 (M); Enghoff et al. 2004: 38 (M, R).

Remarks. This species was described from Hagiang, Hagiang Province, Vietnam (Attems 1937), later redescribed from the type locality (referred to as Ha Giang, 22°50'N, 105°E, 20 miles south of the Vietnam-China frontier) (cf. Hoffman 1963).

Kronopolites biagrilectus Hoffman, 1963

Kronopolites acuminatus biagrilectus Hoffman 1963: 584 (D).
Kronopolites acuminatus biagrilectus – Wang and Mauriès 1996: 86 (M); Enghoff et al. 2004: 38 (M); Jeekel 1968: 71 (M); Sierwald 2009: 125 (M).
Kronopolites biagrilectus – Golovatch 2009: 121 (D); Nguyen and Sierwald 2013: 1287 (M).

Remarks. This species was described from Kuling, 29°30'N, 116°E, 10 miles south of Kiukiang, Kiangsi (= Guangxi) Province, China (Hoffman 1963).

Kronopolites davidiani Golovatch, 2014

Kronopolites davidiani Golovatch 2014: 10 (D).

Remarks. This species has been described from near Wenchian, 3365 m a.s.l., 27°20'35"N, 99°52'34"E, 214 National Road, Yunnan (not Sichuan!) Province, China (cf. Golovatch 2014).

Kronopolites formosanus (Verhoeff, 1939)

Kronopolites (*Parakansupus*) *formosanus* Verhoeff 1939: 273 (D).
Kronopolites formosanus – Attems 1940: 540 (D); Takashima 1950: 38 (R); Chamberlin and Wang 1953: 5 (R); Wang 1964: 69 (M); Takakuwa 1954: 31 (D); Hoffman

1963: 585 (D); Jeekel 1968: 71 (M); Golovatch 1983b: 298 (M); 2009: 121 (D); Chen et al. 2006: 259 (D); Nguyen and Sierwald 2013: 1287 (M).
Kronopolites ralphi Wang 1957: 106 (D), synonymized by Hoffman (1963: 585).
Kronopolites ralphi – Wang 1958: 342 (R); 1964: 69 (M).

Remarks. This species had been erroneously listed as a synonym of *Kronopolites swinhoei* by Wang and Mauriès (1996: 86) and by Korsós (2004: 23) until these mistakes were corrected by Chen et al. (2006). In fact, *K. formosanus* is endemic to northern Taiwan (Verhoeff 1939, Chamberlin and Wang 1953, Wang 1957), occurring below 1000 m a.s.l.: FuShan Botanical Garden, 726 m a.s.l., Ulai, Taipei County; Yang Ming Shan National Park, ca. 750 m a.s.l., near YuYouRen Tomb, Taipei City, Taiwan (Chen et al. 2006).

Kronopolites fuscocingulatus Jeekel, 1982

Kronopolites fuscocingulatus Jeekel 1982 (D): 238 (D).
Kronopolites fuscocingulatus – Enghoff 2005: 97 (R); Golovatch 2009: 121 (D); Nguyen and Sierwald 2013: 1288 (M).

Remarks. Jeekel (1982) described this species from several places in northern Thailand: Hakka village, 50 km N of Chiang Rai City, 800–900 m a.s.l.; Mac Chan (= Mae Chan), Mae Chan District, Chiang Rai Province; Doi Suthep National Park, Chiang Mai Province. Later, Enghoff (2005) reported new specimens of this species in his checklist: Doi Pha Hom Pok National Park, Northwest of Fang, 1550–1660 m a.s.l.; limestone area, 1300 m a.s.l., Doi Chiang Dao National Park; Kontathan (= Montha Than) Waterfall area, Doi Suthep National Park, Chiang Mai Province.

Kronopolites montanus Golovatch, 2009

Kronopolites montanus Golovatch 2009: 121 (D).
Kronopolites montanus – Nguyen and Sierwald 2013: 1288 (M).

Remarks. This species was described from Hoang Lien National Park, ca 2000 m a.s.l., west of Sapa, Lao Cai Province, Vietnam (Golovatch 2009).

Kronopolites occidentalis Golovatch, 1983

Kronopolites occidentalis Golovatch 1983b: 297 (D).
Kronopolites occidentalis – Golovatch 1984: 328 (R); 2009: 121 (D); Nguyen and Sierwald 2013: 1288 (M); Shelley 2014: 3 (R).

Remarks. This species was described from Pir Panjal Mountains, 2600 m a.s.l., Tangmarg, Jammu and Kashmir State, India (Golovatch 1983). New specimens were collected near the ruins of Pari Mahal Monastery, 1500 m a.s.l., Srinagar, Jammu and Kashmir State, India (Golovatch 1984).

Kronopolites rugosus Golovatch, 2013

Kronopolites rugosus Golovatch 2013a: 12 (D).
Kronopolites rugosus – Nguyen and Sierwald 2013: 1288 (M); Golovatch 2013b: 311 (M).

Remarks. This species has been described from north of Lijiang, 27°01'N, 100°12'E, 2400 m a.s.l., Yunnan Province, China (Golovatch 2013a).

Kronopolites semirugosus Golovatch, 2013

Kronopolites semirugosus Golovatch 2013b: 311 (D).

Remarks. This species was described from NW of Mianning, 2955 m a.s.l., 28°39'13"N, 101°58'34"E, Sichuan Province, China (Golovatch 2013b).

Kronopolites swinhoei (Pocock, 1895)

Stronglosoma Swinhoei Pocock 1895: 354 (D).
Kronopolites Swinhoei – Brölemann 1896: 354 (D); Attems 1898: 304 (D); 1914: 219 (R).
Kronopolites swinhoei – Attems 1936: 226 (D); 1937: 51 (D); Chamberlin and Wang 1953: 5 (R); Hoffman 1963: 581 (D); Jeekel 1968: 71 (M); Golovatch 1978: 678 (R); 1983b: 298 (M); 2009: 121 (D); 2013a: 2 (R, M); Wang and Mauriès 1996: 86 (M); Geoffroy and Golovatch 2004: 20 (R); Korsós 2004: 23 (R, M); Chen et al. 2006: 252 (M); Nguyen and Sierwald 2013: 1286 (M).
Kronopolites swinhoei swinhoei – Attems 1937: 51 (D).
Kansupus svenhedini Verhoeff 1934: 17 (D), synonymized by Hoffman (1963: 581).
Kronopolites svenhedini – Attems 1936: 233 (R); 1937: 53 (D); Zhang and Li 1978: 12 (R); Wang and Mauriès 1996: 86 (M).
Kansupus svenhedini var. *dentiger* Verhoeff 1934: 19 (D), synonymized by Hoffman (1963: 581).
Kronopolites svenhedini dentiger – Attems 1936: 233 (R); 1937: 54 (D).

Remarks. This species is especially widely distributed in mainland China: Chee Foo (Pocock 1895); Chou San Island (Brölemann 1896); Lan Tschou, Gansu (Attems

1936); Pei-shui-ho, 700 m a.s.l., northeastern Sichuan and southern Gansu (Attems 1937); Wenchow (= Yung-chia), Chekiang Province; Chekiang Province (Chamberlin and Wang 1953), Hangchow, Chekiang Province (Hoffman 1963); Taibai Shan Mountains, 1300–1700 m a.s.l.; southern slopes, above Houshenzi, 33°51'N, 107°50'E, Shaanxi Province; Bei Shan National Park, 36°56'N, 102°39'E, ca 90 km NE of Xining, Gansu (not Qinghai) Province (corrected here versus Golovatch 2013a); Grotte du Cirque (Circus Cave), Zheng Xiong County, Yunnan Province; Cave Yan Bao Dong, Zheng Xiong County, Yunnan Province; Cave Ha Chong Dong, near Xingren Huawu, Guizhou Qianxi Province, China (Geoffroy and Golovatch 2004).

***Kronopolites lunatus* sp. n.**
http://zoobank.org/BCEF7CDD-7BE6-4B47-B02D-5FA3F658A242
Figs 1–3

Holotype ♂, Laos, Xieng Khouang Province, Phookood District, Cave Pra, ca 1180 m a.s.l., 19°30'02"N, 102°52'20"E, 02.07.2014, leg. R. Srisonchai.

Paratype. 1 ♂, Laos, Luang Prabang Province, Chomphet District, Kacham Waterfall, ca 440 m a.s.l., 19°38'57"N, 102°04'52"E, 01.07.2014, leg. C. Sutcharit.

Name. To emphasize the lateral crescent-shaped processes on the gonopod.

Diagnosis. Superficially very similar to *K. acuminatus*, but differs in the smaller size, the width of midbody pro- and metazonae being 2.4–2.5 and 3.1–3.2 mm, respectively (versus 4.5 mm and 6.5 mm, respectively); tarsal brushes are present until ♂ leg 9 (versus absent), and gonopod process **b** is > 2 times as long as process **a** (versus shorter), process **a** being clearly curved (versus nearly straight) while process **b** is enlarged and lies adjacent to the femorite (versus clearly separated from the femorite). Eventually, it keys out closest to *K. formosanus* (see Key below).

Description. Length 28.4–29.5 (♂), width of midbody pro- and metazonae 2.4–2.5 and 3.1–3.2 mm (♂), respectively.

Live coloration mostly dark, blackish brown; antennae and head dark brown to light brown, venter and a few basal podomeres light brown to yellow-brown; coloration of alcohol material after four months of preservation faded to dark brown; antennae and epiproct light brown to light yellow, venter and a few basal podomeres light brown to pallid (Fig. 1A–I).

Clypeolabral region and vertex densely setose, epicranial suture distinct. Antennae moderately long (Fig. 1A), extending behind body segment 3 (♂) when stretched dorsally. In width, segment 4 < 3 < head < 5 < collum < segment 2 < 6–17 (♂); thereafter body gently and gradually tapering. Collum with three transverse rows of setae: 4+4 anterior, 3+3 intermediate and 4+4 posterior; lateral incisions absent; caudal corner of paraterga very broadly rounded, declined ventrad, produced behind rear tergal margin (Fig. 1A, B).

Tegument smooth and shining, prozonae finely shagreened, metaterga finely rugulose (Fig. 1A, C, F); surface below paraterga finely microgranulate (Fig. 1B, D, E). Postcollum metaterga with two transverse rows of setae: 3+3 in anterior (pre-

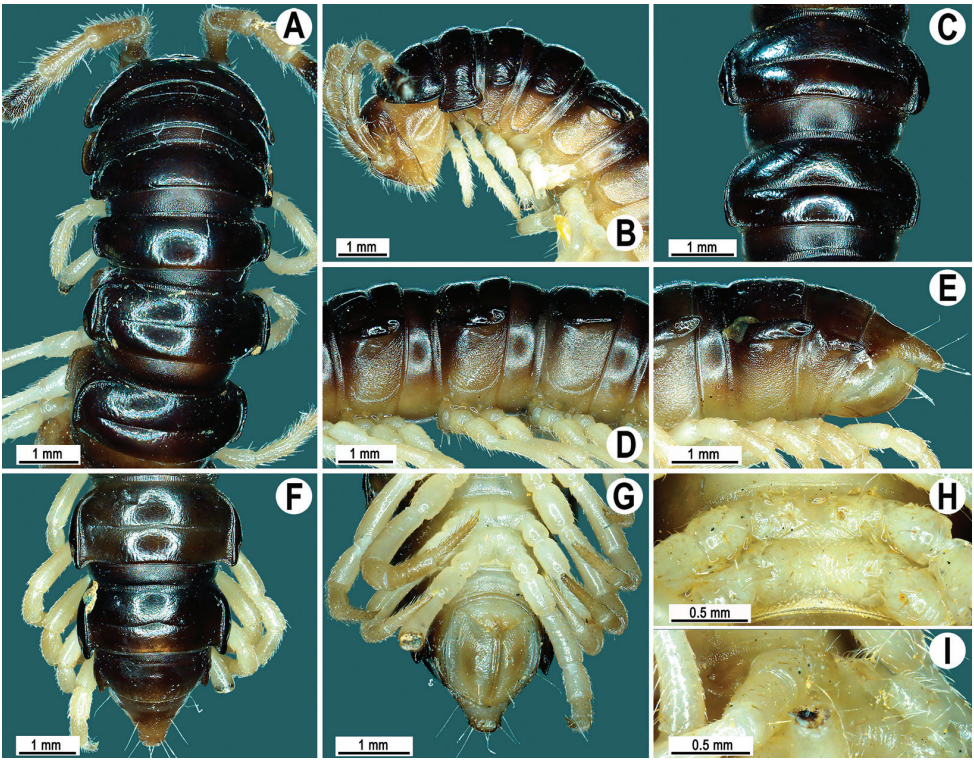

Figure 1. *Kronopolites lunatus* sp. n., ♂ paratype. **A, B** anterior part of body, dorsal and lateral views, respectively **C** segments 10 and 11, dorsal view **D** segments 9–11, lateral view **E–G** posterior part of body, lateral, dorsal and ventral views, respectively **H, I** sternal cones between coxae 4, subcaudal and sublateral views, respectively.

sulcus) and 3+3 in posterior (post-sulcus) row, traceable as insertion points. Tergal setae long and slender, mostly abraded, about 1/3 as long as metaterga. Axial line barely traceable both on pro- and metazonae. Paraterga strongly developed (Fig. 1A–F), lying rather high (at upper 1/3 of body), slightly upturned, but lying below dorsum; anterior edge broadly rounded and narrowly bordered, fused to callus; caudal corner very narrowly rounded, starting from segment 15 extending increasingly well beyond rear tergal margin (Fig. 1E, F); lateral edge without incisions (Fig. 1A, C, F); posterior edge nearly straight. Calluses on paraterga narrow, delimited by a sulcus both dorsally and ventrally. Ozopores evident, lateral, lying in an ovoid groove at about 1/4 in front of posterior edge of metaterga. Transverse sulcus usually distinct (Fig. 1A, C, F), slightly incomplete on segment 19, complete on metaterga 3–18 (♂), narrow, line-shaped, shallow, reaching bases of paraterga, faintly ribbed at bottom. Stricture between pro- and metazonae evident, broad and deep, ribbed at bottom down to base of paraterga (Fig. 1A–F). Pleurosternal carinae complete crests with a sharp caudal tooth on segments 2–7, thereafter increasingly strongly reduced until segment 17 (♂). Epiproct (Fig. 1E–G) conical, flattened dorsoventrally, with two small apical papillae;

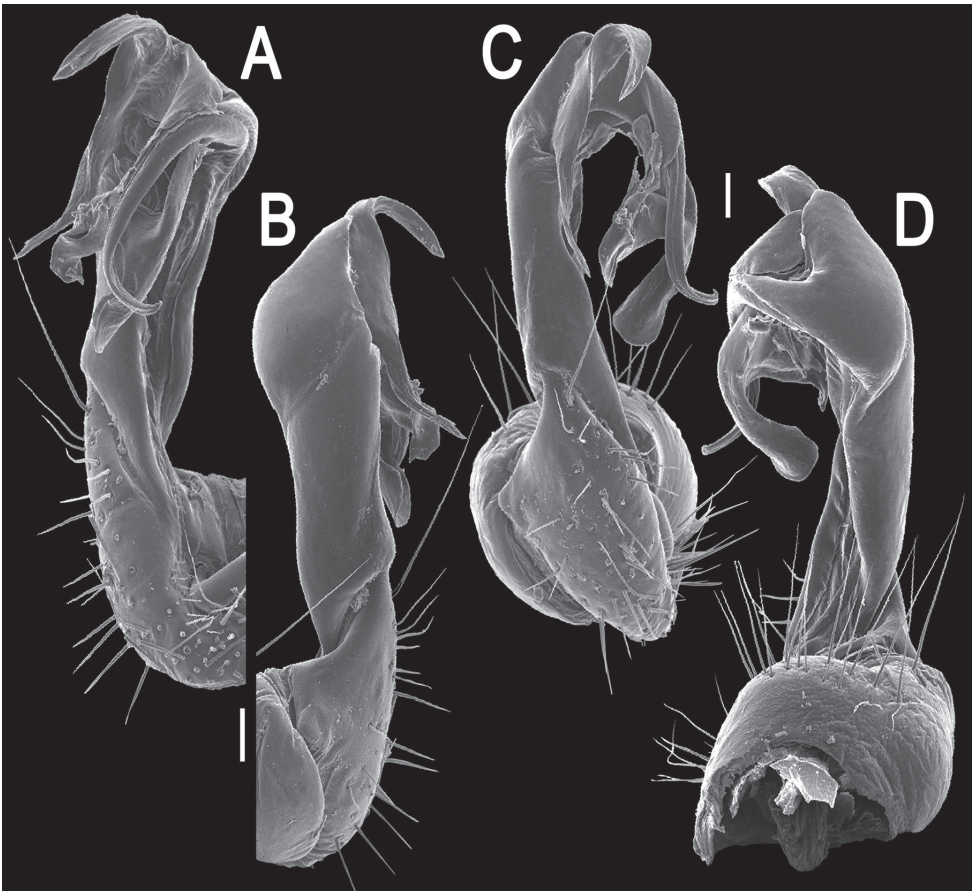

Figure 2. *Kronopolites lunatus* sp. n., ♂ holotype, right gonopod. **A–D** mesal, lateral, subcaudal and suboral views, respectively. Scale bars: 0.1 mm.

tip subtruncate; pre-apical papillae small, lying close to tip. Hypoproct roundly subtriangular, setiferous knobs at caudal edge small and well-separated (Fig. 1G).

Sterna densely setose, without modifications, but with two small, rounded, fully separated, setose cones between ♂ coxae 4 (Fig. 1H, I). Legs rather long and slender, midbody ones ca 1.2–1.3 (♂) as long as body height (Fig. 1A, B, F, G); prefemora without modifications, tarsal brushes present until ♂ leg 9.

Gonopods (Figs 2, 3) rather complex; coxa a little curved caudad, sparsely setose distoventrally. Prefemur densely setose, about 1/3 as long as femorite + postfemoral part. Femorite rather stout, with an evident mesal groove and a strong distolateral sulcus demarcating a postfemoral part; the latter well-developed, with very prominent, bipartite, crescent-shape, lateral processes: process **a** rather short, coiled and pointed; process **b** long and coiled, also pointed; solenophore clearly curved, long, expanded distomesally, trifid, lamina medialis supporting a long flagelliform solenomere.

Remarks. This is the first *Kronopolites* to be found in Laos.

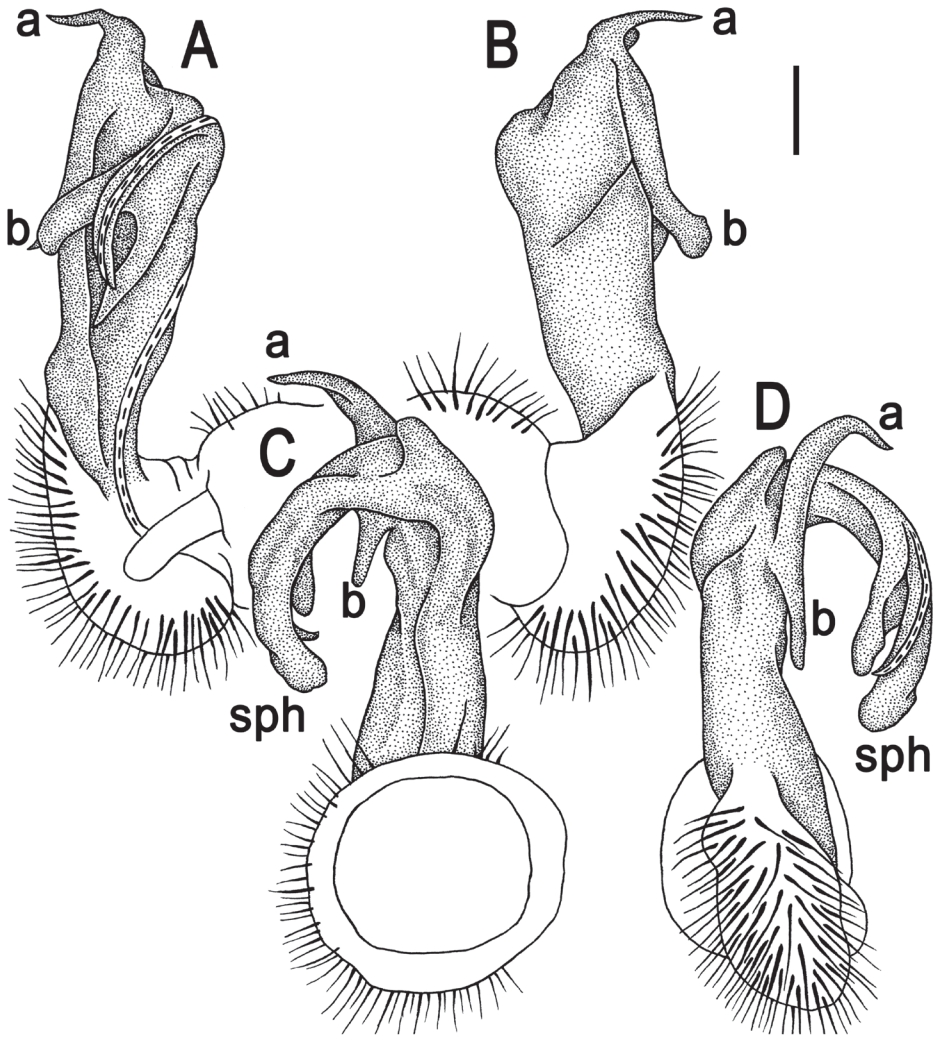

Figure 3. *Kronopolites lunatus* sp. n., ♂ holotype, right gonopod. **A–D** right gonopod, mesal, lateral, oral and caudal views, respectively. Scale bar: 0.2 mm.

Key to the species of *Kronopolites*, chiefly based on ♂ characters (modified after Golovatch 2009)

1 Coloration with a contrasting pattern, some parts of body segments being much paler, some other ones much darker **2**

– Coloration rather uniformly brown to brown-blackish, only venter and legs largely yellowish (Fig. 1A–I) **8**

2 Paraterga relatively poorly developed, set low (mostly at about upper 1/3 of segments), caudal corners of midbody paraterga usually not projecting behind rear tergal margin, at most narrowly rounded (Fig. 1C, D)..... **3**

– Paraterga usually relatively well developed, mostly set higher, caudal corners of midbody paraterga produced behind rear tergal margin, acuminate **6**

3 Sternal cones on ♂ coxae 4 missing; processes **a** and **b** of gonopod nearly independent, slender and long. Northern Thailand..... ***K. fuscocingulatus***

– Sternal cones on ♂ coxae 4 present, processes **a** and **b** of gonopod on a broad common stem, shorter. China **4**

4 Surface of metaterga rather smooth; gonopod femorite slender, process **a** longer, process **b** shorter, beak-shaped ..... ***K. swinhoei***

– Surface of metaterga rugose; gonopod femorite stout, processes **a** and **b** of gonopod different **5**

5 Process **a** of gonopod short and spiniform, process **b** large and axe-shaped ... . ***K. rugosus***

– Processes **a** and **b** of gonopod subequal in length, ribbon-shaped..... ..... ***K. semirugosus***

6 Coloration dark brown with yellow paraterga; sternal cones between ♂ coxae 4 missing; processes **a** and **b** of gonopod short and small, sharing a very distinct common stem; Kashmir Himalayas ..... ***K. occidentalis***

– Colour pattern different, rear halves of prozonae and fore halves of metazonae usually being black-brown, remaining parts yellowish; sternal cones between ♂ coxae 4 present; processes **a** and **b** of gonopod longer and slenderer, their shared base far less conspicuous **7**

7 Process **a** of gonopod somewhat shorter than process **b**. Northern Vietnam ... . ***K. acuminatus***

– Process **a** of gonopod somewhat longer than process **b**. Jiangxi Province, China ..... ***K. biagrilectus***

8 Paraterga relatively well developed (Fig. 1A, C, F); pleurosternal carinae evident in ♂ segments 2–16; process **a** of gonopod clearly shorter than **b** **9**

– Paraterga rather poorly developed; pleurosternal carinae evident until ♂ segment 10 at most; processes **a** and **b** of gonopod subequal in length **10**

9 Sternal cones between ♂ coxae 4 present; ♂ tarsal brushes missing; solenophore with conspicuous bipartite, complex, apical processes .... ***K. montanus***

– Sternal cones on ♂ coxae 4 missing; ♂ tarsal brushes present until legs of segment 17; solenophore simple and slender, with a little branch set off before apex ..... ***K. davidiani***

10 Sternal cone between ♂ coxae 4 single, large. Northern Taiwan... ***K. formosanus***

– Two small sternal cones between ♂ coxae 4 (Fig. 1H, I). Northern Laos..... ..... ***K. lunatus* sp. n.**

Conclusions

To date, 11 species have formally been described in *Kronopolites*, mostly found in China (5 species) and northern Vietnam (2 species). Only a single species each has been

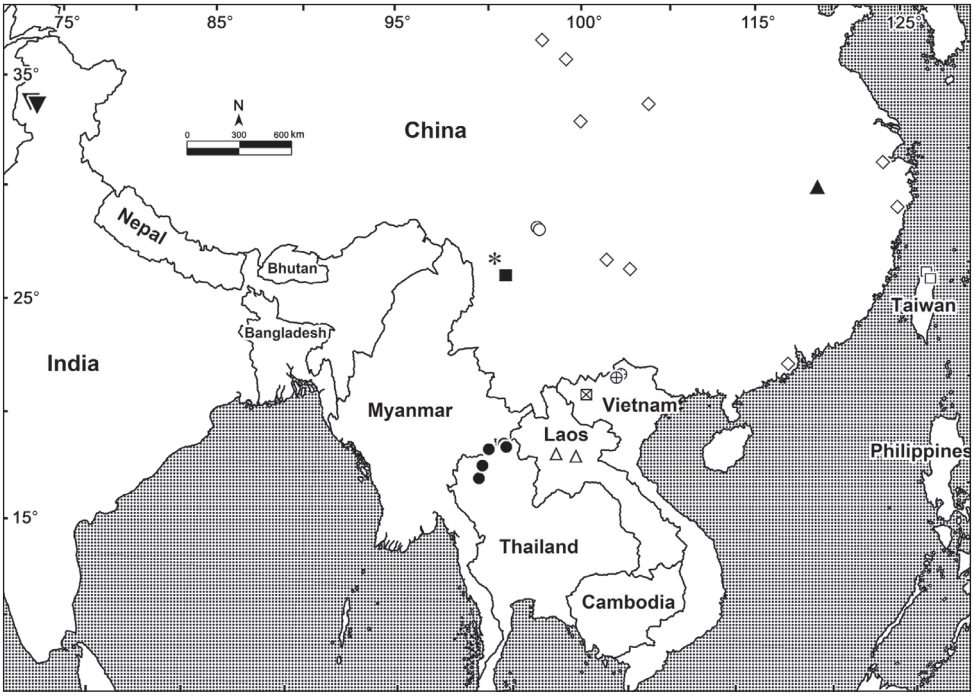

Figure 4. Distribution of *Kronopolites* (11 species). Inverted filled triangle, more or less from west to east: *K. occidentalis* Golovatch, 1983; Filled circle: *K. fuscocingulatus* Jeekel, 1982; Open circle: *K. semirugosus* Golovatch, 2013; Asterisk: *K. davidiani* Golovatch, 2014; Filled square: *K. rugosus* Golovatch, 2013; Open triangle: *K. lunatus* sp. n.; Crossed square: *K. montanus* Golovatch, 2009; Cross circle: *K. acuminatus* Attems, 1937; Open diamond: *K. swinhoei* (Pocock, 1895); Filled triangle: *K. biagrilectus* Hoffman, 1963; Open square: *K. formosanus* (Verhoeff, 1939).

reported from northwestern India, northern Thailand, northern Taiwan and northern Laos (Fig. 4). There is little doubt that many more *Kronopolites* species are to be found in the future.

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RESEARCH ARTICLE

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Ants of Ambon Island – diversity survey and checklist

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Abstract

The present checklist of ants (Hymenoptera: Formicidae) of Ambon is the first comprehensive overview of ant species recorded on the island during the last 150 years. The species list is based on literature and museum collections' records combined with data from our field survey in 2010. In total, there are 74 ant species and subspecies representing 34 genera and six subfamilies known from Ambon. Five of the species found in undisturbed forest were exotic and indicate the overall habitat degradation on the island. The largest proportion of Ambon ant fauna are species with affinities to the Oriental region and species of Oriental-Austro-Melanesian origin. At least 20% of the species are regional endemics. In comparison to other islands in the region, the Ambon fauna seems more diverse and better sampled; however it is clear that a large part of it still remains to be described.

Keywords

Moluccas, Indo-Australia, Melanesia, Indonesia, Wallacea, species distributions, biogeography, taxonomy, habitat preferences, invasive species, biodiversity

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Introduction

The Indonesian region of Moluccas (Maluku) is one of the most biogeographically and biologically complex areas on Earth. Many of its local invertebrate groups remain undescribed, including ant diversity, which is mostly unknown from this region. Despite being a frequent subject of ecological and taxonomic studies in surrounding regions, there are a limited number of ant species records from Moluccas (e.g. Chapman and Capco 1951, Trainor and Andersen 2010, Andersen et al. 2013).

Ambon is a smaller (775 km^2), densely populated island (estimate for 2014 is 369 000 inhabitants; BPS-Statistics, Indonesia 2014) at the north of Banda islands arc, adjacent to the much larger Seram to the north. Ambon consists of two parts, Latimor and Hitu, which are connected by a short isthmus. Both parts are characterized by cordierite-rich dacites, granites, ultramafic rocks, and uplifted Quaternary coral reefs (Pownall et al. 2013). There are also two inactive volcanoes present on Hitu.

Ambon and Seram are located in the eastern Indonesia region, which is a geologically complex zone, influenced by the activity of three major plate regions: the Eurasian, Indian-Australian and Pacific-Philippine Sea plates. Boundaries among them form deformation zones that contain many small plates, crustal fragments or terranes and are characterized by the presence of subduction zones (Hall and Wilson 2000). The Banda Arc consists of an inner volcanic arc and an outer non-volcanic arc of islands formed by sedimentary, metamorphic and igneous rocks of Permian and Quaternary age (Hall 2000). Both Ambon and Seram lay within a belt of subducted Australian crust that is south of a deep subduction trench encircling the Banda Sea. Similar to most of the Banda Sea islands, Ambon and Seram are true oceanic islands, having never been connected to the mainland, although the distances between them and the Asian and Australian continents decreased significantly during periods of glaciation (Voris 2000). It is estimated that Ambon and Seram emerged above the sea about six to five million years ago (Fortuin and De Smet 1991, de Jong 1998).

Due to its position between the Oriental and Australian regions, the Moluccas host an interesting mixture of fauna and flora from both biogeographic origins, in addition to an important proportion of local endemics. Which faunal elements prevail is often taxon and island specific and has been a subject of multiple debates (Gressit 1958, Keast and Miller 1996). The distance between New Guinea and Ambon (and Seram) is shorter (140 km) then between Sulawesi (550 km). However, there are several islands between Ambon and Sulawesi which could serve as stepping stones. We can also expect that the exchange of biotas was mostly unidirectional as Ambon, Seram and other islands are younger than New Guinea and Sulawesi (de Jong 1998).

Based on the distribution of butterfly species, Vane-Wright and Peggie (1994) suggest that fauna of northern Moluccan islands (Halmahera, Ternate, Morotai and others) is biologically related to New Guinea, while the Buru, Ambon, Seram arc is related to North-West Australia and the Sula islands in west Moluccas are part of the 'Sulawesi region'. A similar pattern was confirmed for the butterfly genus, *Hypolycaena*

by Cassidy and Rawlins (2011), although the authors also found links among Ambon, Seram and Sulawesi as well as Mindanao in the Oriental zone. Close relationship between Moluccan and Sulawesi species was also suggested by phylogenetic reconstruction of the grasshopper genus *Chitaura* (Acrididae: Oxyinae) (Butlin et al. 1998).

A distributional analysis of hawk moths (Lepidoptera: Sphingidae) revealed that Ambon species are nested within Seram fauna and both are close to Halmahera and Sulawesi. They all are however less similar to south Philippines fauna than to New Guinean fauna (Beck and Kitching 1998). Finally, a comprehensive comparison based on the distribution of over 200 Lepidopteran species (de Jong 1998) supports greater similarity of Moluccan islands to New Guinea than to Sulawesi, suggesting a much higher diversity of New Guinean fauna and shorter distance as the main contributing factors. This pattern is also repeated at the generic level (de Jong 1998). These studies suggest a complex pattern of relationships among Mollucan Islands and the surrounding regions, with the most prominent links to Melanesia or Oriental regions (often through Sulawesi).

Unfortunately, no comparable data exist for Moluccan ant fauna. Although a number of species were described early on from specimens collected by A. R. Wallace (Smith 1859, 1860, 1871) and the regional list was expanded in the following 150 years, a detailed overview of the regional fauna is missing. In this respect, the most relevant studies are by Karavaiev (1925, 1927, 1929, 1930, 1935) and by Chapman and Capco (1951) which provide summaries of ant species from the Oriental and Austro-Melanesian regions.

In recent years, studies focusing on the ants of Timor Island were conducted, contributing important knowledge of ants of the region (Trainor at al. 2010; Andersen et al. 2013). In Timor, the largest proportion of ant species (76%) had South-East Asian (Oriental) affinities, while Australian taxa accounted for 18% of the fauna and the proportion was even smaller for other neighboring islands. In addition, a distributional analysis of ants of genus *Polyrhachis* confirms that at least some other Moluccan islands have high levels of endemism, even higher than plants and birds (Andersen et al. 2013). However, it is unclear to what extent these patterns are representative of northern Moluccan islands, as they are positioned closer to New Guinea which contributes Austro-Melanesian taxa, as well as to Sulawesi, which could serve as a source of Oriental fauna. Understanding the distribution patterns and origin of the ant fauna of Moluccas is desirable, since ants can provide another line of evidence for reconstructing the biogeographic history of the region. Due to their diverse biological roles, ants are ideal for assessing the effects of life strategy on dispersal and diversification patterns across oceanic islands.

Here, we assemble all available information on ants occurring on Ambon Island and combine it with new data from a recent field survey. The main objectives of our study are 1) to create a checklist which can be used as a reference for follow up studies; 2) to identify new species records collected during our survey of Sirimau forest in Ambon; and 3) to compare habitat preferences of collected ants, analyze biogeographical affinities, and asses the levels of endemism of ant fauna currently known from Ambon.

Methods

Survey of Sirimau area

We surveyed ants in forested areas of Sirimau, one of two protected areas of Ambon Island. Sirimau forest covers an area of approximately 3.5 Ha and is located on the eastern side of Ambon Island between -3.6707°; -3.6918° and 128.2394°; 128.2859°, at elevations between 100 to 200 meters above sea level. Although the study area has been referred to as 'primary' forest, it is more appropriate to call it 'undisturbed', as many parts of Ambon underwent habitat transformation in the last two centuries and a large proportion of the island's surface was altered at some point. Today, urban areas cover more than 40% of the island (Miller 1999). The undisturbed forest at the collecting site was dominated by the following plant taxa: *Eucalyptus* sp., *Acacia mangium* (Willdenow, 1806), *Tectona grandis* (Linnaeus, 1782), *Nephelium lappaceum* (Linnaeus), *Anacardium occidentale* (Linnaeus), and *Shorea* sp.

Ants were collected in 500 m long transects each of which included 25 pitfall traps, 25 bait traps on the ground and 25 bait traps on vegetation. A mixture of sardines and honey was used for bait. The pitfall traps were exposed for two days and bait traps for one hour. Six such transects, located at least 200 m apart, were surveyed in undisturbed forest and six transects in secondary forest. In addition to collections in transects the area was repeatedly surveyed with general hand collecting and species not recorded in transects were added to the checklist. Samples were collected between July and September 2010 and preserved in 95% ethanol.

Species identification and compilation of species list

Collected specimens were initially sorted to morphospecies, mounted and then identified by the authors using several reference collections: Basic Entomology Laboratory, Agriculture Faculty Gajah Mada University Jogyakarta, Indonesia; Ant Collection at Museum of Comparative Zoology, Harvard University, USA (MCZ); Melanesian Ants Collection at Czech Academy of Sciences (CAS); and taxonomic literature for relevant genera. For selected species which were not possible to match with museum, literature or online records, we sequenced ~ 650 bp fragment of mitochondrial gene cytochrome c oxidase (COI), using primers LCO1490 and HCO2198 (Folmer et al. 1994). The COI sequences were used to confirm species identities among samples and to improve the identification of unknown species. The sequences were compared with records available at the online databases, Barcodes of Life – BOLD (http://barcodinglife.org) and GenBank (www.ncbi.org), and used to identify the most closely related described species or species group and to confirm morphology-based identification. When we were not able to reliably match the specimen with a described species we used a morphospecies number and attempted to identify it to at least the closest described species or species group. The specimen duplicates were deposited in CAS, Czech Republic and

the MCZ, USA. The DNA sequences of COI were deposited in the Barcode of Life database (http://barcodinglife.org), as part of the Ants of New Guinea project (ASPNA) and photos of selected specimens are available online at Ants of New Guinea database (www.newguineants.org, search query 'Ambon'). Sequences were deposited in BOLD under accession numbers: ASPNA3025-14 – ASPNA3033-14.

The species checklist was compiled from collected specimens, literature records and database records. We reviewed the names of all taxa that were originally described from Ambon and included specimen records found on Antwiki (www.antwiki.org) and Antweb (www.antweb.org). Other resources including Formis 2013 (Porter and Wojcik 2013), Google Scholar (www.scholar.google.com) and Web of Science (www.webofknowledge.com) were also searched for relevant records (Ambon, Amboina etc.). We also searched for ant records associated with Seram Island and checked if species were recorded on Ambon as well. Searching the Indo-Australian collections deposited at the MCZ did not result in additional species records. We used the taxonomic nomenclature based on the online version of An Online Catalogue of the Ants of the World (Bolton 2014), as published at online Ant Catalogue (www.antcat.org). We eliminated names where the records could not be confirmed due to possible misidentification or erroneous and insufficient labeling. We retained trinomial names for all cases where status of the names were not disputed and considered valid.

Data analysis

The specimen records from all traps and transects within the same habitat type were combined and the occurrence frequency of each species was used as input data. Diversity statistics and accumulation curves were calculated in EstimateS (Colwell 2013), using 100 iterations. To compare species diversity, evenness and species occurrence frequency between habitats we used the Shannon diversity index, Shannon diversity t-test and Mann-Whitney test in the program PAST 2.14 (Hammer et al. 2001).

For each described species in the checklist, we assembled data about its distribution range using online resources (Antwiki.org, Antweb.org) and the literature. The distribution categories reflected main areas of occurrence of the given taxa and were based on recognized biogeographic regions (Holt et al. 2013) with Oceania more finely divided into regions of Melanesia, Micronesia and Polynesia to provide more sensitivity for distributional comparisons. A species was considered widespread if it occurred in more than five major biogeographic regions. A species was considered introduced if it was known as non-native in the area or unlikely originating in Moluccas. A species was considered endemic it if was recorded only from Ambon or other Moluccan islands. This latter category was broader as the ant fauna of the whole region is highly undersampled and unknown. It is thus possible that species described from a particular island are in fact distributed across several neighboring islands. For these reasons our endemic species category included regional endemics.

Results

Based on our literature survey, 48 species have been reported to occur on Ambon. In our field survey, we collected 31 ant species, 16 of which could be identified, while 15 did not match any described taxa on the basis of morphological or molecular characters. Of the 16 described species, only 5 species were previously reported. Our results suggest there are at least 74 ant species from 34 genera and six subfamilies on Ambon Island. The combined checklist of described ant species currently known from the island is 59.

Habitat types differed in species richness: 30 ant species were found in undisturbed forest, while 19 ant species were found in secondary forest. All species occurring in secondary forest were also recorded in undisturbed forest; the overlap as expressed by Jaccard Index was 0.63. Shannon index of diversity for undisturbed forest was 2.96, and 2.6 for secondary forest. The habitats differed significantly in species occurrences, calculated as the proportion of visited traps (Shannon diversity t-test $p < 0.01$, $t = 10.9$, d.f. = 1010.5). The accumulation curves suggest that both habitats were sufficiently sampled, as both curves and the statistical indicators (Mao Tau, ICE) reached an asymptote (Figure 1).

The most frequent species in both undisturbed and disturbed forest was *Pheidole* sp. AMB01 (cf. *P. submonticola* (Eguchi, 2001) from Borneo). The other most frequent species in undisturbed forest were *Pheidole* sp. AMB02, *Polyrhachis dives* (Smith, F., 1857), *Oecophylla smaragdina* (Fabricius, 1775), *Dolichoderus thoracicus* (Smith, F., 1860) and *Carebara* sp. AMB01 (cf. *C. diversa* (Jerdon, 1851)). In secondary forest plots, the most frequently encountered were *Anoplolepis gracilipes* (Smith, F., 1857) *Lophomyrmex opaciceps* (Viehmeyer, 1922), *Monomorium pharaonis* (Linnaeus, 1758) and *Odontoponera denticulata* (Smith, F., 1858). Such species composition is typical for secondary and disturbed forest vegetation in the Indo-Australian region.

The comparisons of biogeographic associations of described species suggest that the ant fauna of Ambon is dominated by species with Oriental affinities (13 spp., 22%)

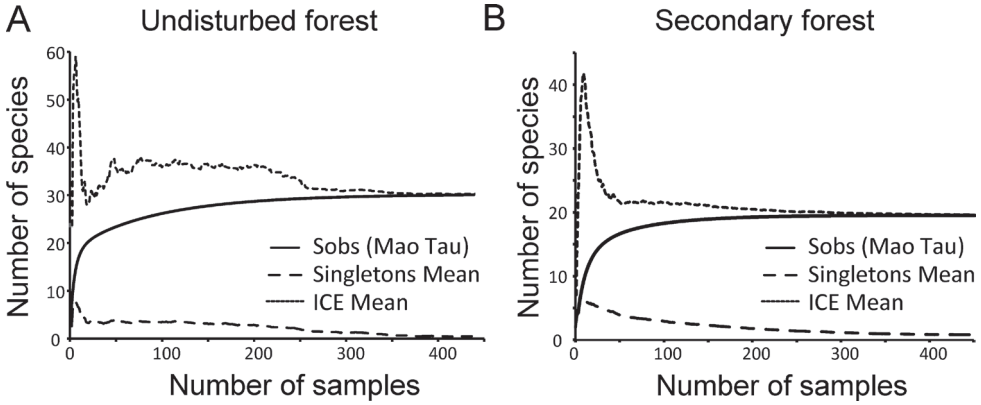

Figure 1. The cumulative number of species (Sobs) for 450 samples collected at both habitat types: **A** undisturbed forest **B** secondary forest. Each curve represents the average of 1000 replicate randomizations of samples order. Richness estimator ICE (mean) and average number of singletons are shown with dashed lines.

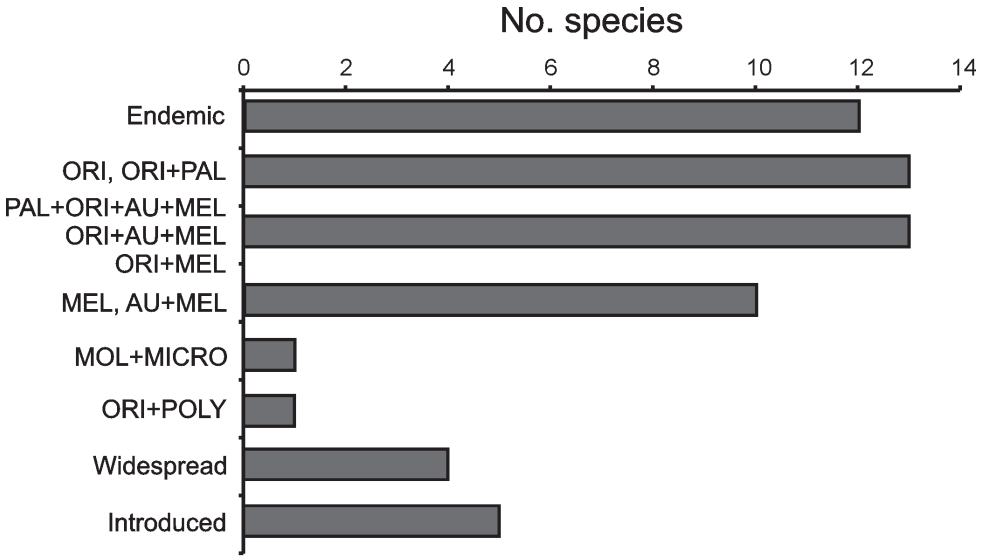

Figure 2. Biogeographic associations of valid ant species occurring on Ambon Island. The distribution categories reflected main areas of occurrence (see text). The abbreviations refer to following biogeographic regions and their combinations: AU – Australia, MEL – Melanesia, MIC – Micronesia, MOL – Moluccas, ORI – Oriental region, PAL – Palearctic region, POLY – Polynesia.

and by species distributed equally across Oriental and Austro-Melanesian regions (13 spp., Figure 2). The proportion of species of solely Melanesian origin is slightly smaller (10 spp.) and there are 12 species (20%) which can be considered as local or regional endemics (restricted to Ambon and/or Moluccas). In addition, we detected five species which are most likely introduced on the island. A smaller proportion of species are either widespread (occurring in five or more biogeographic regions) or have more restricted distribution throughout Moluccas (Figure 2).

Discussion

Our study provides the first formal checklist for ant species occurring at Ambon Island. In addition to nearly 50 species reported previously from the literature and databases, our field survey contributed new distributional records for 11 species (marked in Table 1). The additional 15 species which did not match with any currently described taxa are likely to expand the checklist once incorporated into taxonomic revisions of corresponding groups. Our survey also confirms the presence of several species recorded more than 100 years ago and provides evidence of several introduced species in the area.

Despite the addition of 26 species to the checklist, the total number of ant species recorded from Ambon (74) is most likely underestimated. Our survey focused on forested area of only one of the two Ambon islands and in the current checklist some of

Table 1. List of valid species recorded from the Ambon Island arranged by subfamily, genus and species. Column 'Habitat' refers to habitat type at which species was recorded during this study, U = undisturbed forest; S = secondary forest. Abbreviations in 'Distribution' category refer to following biogeographic regions: AU – Australia, MEL – Melanesia, MIC – Micronesia, ORI – Oriental region, PAL – Palearctic region, POLY – Polynesia, Intro. – introduced species, Wide – widespread species.

Taxon	Author	Distribution	Habitat (U/S)
Amblyoponinae			
Myopopone castanea	(Smith F, 1860)	ORI, AU, MEL	
Dolichoderinae			
Dolichoderus thoracicus	(Smith F, 1860)	ORI	U, S
Iridomyrmex anceps	Roger, 1863	Wide	U, S
Iridomyrmex pallidus	Forel, 1901	AU, MEL	
Tapinoma melanocephalum	Fabricius, 1793	Intro.	U, S
Formicinae			
Acropyga acutiventris	Roger, 1862	ORI,AU,MEL	
Anoplolepis gracilipes	(Smith F, 1857)	Intro.	U, S
Camponotus bellus	Forel, 1908	ORI	
Camponotus quadriceps	(Smith F, 1859)	MEL	
Camponotus indefinitus	Karavaiev, 1929	Ambon	
Camponotus variegatus ambonensis	Karavaiev, 1930	Ambon	
Echinopla striata gibbosa	Karavaiev, 1927	ORI	
Oecophylla smaragdina	(Fabricius, 1775)	ORI, AU, MEL	U, S
Opisthopsis halmaherae	Karavaiev, 1930	Moluccas	
Paratrechina longicornis	(Latreille, 1802)	Intro.	U, S
Polyrhachis arcuata	(Le Guillou, 1842)	ORI, AU	
Polyrhachis dives	Smith F, 1857	ORI, PAL, AU, MEL	U, S
Polyrhachis fervens	Smith F, 1860	ORI, AU, MEL	
Polyrhachis pressa	Mayr, 1862	ORI	U
Polyrhachis batesi	Forel, 1911	Ambon, Seram	
Polyrhachis bicolor weyeri	Karavaiev, 1930	Ambon	
Polyrhachis creusa	Emery, 1897	ORI, AU, MEL	
Polyrhachis denticulata	Karavaiev, 1927	AU,MEL	
Polyrhachis dives rectispina	Karavaiev, 1927	Ambon	
Polyrhachis derecyna	Smith F, 1871	MEL	
Polyrhachis dolomedes	Smith F, 1871	ORI, MEL	
Polyrhachis fervens	Smith F, 1860	ORI, AU, MEL	
Polyrhachis fruhstorferi torta	Santschi, 1928	Ambon	
Polyrhachis goramensis	Emery, 1887	Ambon	
Polyrhachis keratifera	Karavaiev, 1927	Ambon	
Polyrhachis nigrescens	Karavaiev, 1927	Ambon	
Polyrhachis radicicola	Dahl, 1901	MEL	
Polyrhachis rastellata	(Latreille, 1802)	ORI, AU, MEL	
Polyrhachis rufofemorata	Smith F, 1859	AU, MEL	U, S
Polyrhachis tibialis orientalis	Karavaiev, 1927	Ambon	
Polyrhachis tricuspis	André, 1887	Moluccas	
Polyrhachis vindex	Smith F, 1857	ORI	

Taxon	Author	Distribution	Habitat (U/S)
Pseudolasius breviceps	Emery, 1887	MEL	
Pseudolasius familiaris	(Smith F, 1860)	ORI	
Pseudolasius mayri bedoti	Emery, 1911	Ambon	
Myrmicinae			
Calyptomyrmex beccarii	Emery, 1887	ORI, AU, MEL	
Cardiocondyla nigrocerea	Karavaiev, 1935	Moluccas	
Carebara weyeri	Karavaiev, 1930	Ambon	
Lophomyrmex opaciceps	Viehmeyer, 1922	ORI	U, S
Monomorium pharaonis	(Linnaeus, 1758)	Intro.	U, S
Pheidole ambonensis	Karavaiev, 1930	Ambon	
Pheidole plagiaria	Smith F, 1860	ORI	
Podomyrma basalis reyi	Karavaiev, 1935	Ambon	
Solenopsis geminata	(Fabricius, 1804)	Intro.	U, S
Strumigenys doriae	Emery, 1887	ORI	
Tetramorium pacificum	Mayr, 1870	ORI, AU, MEL	
Ponerinae			
Anochetus graeffei	Mayr, 1870	Wide	U
Diacamma rugosum	(Le Guillou, 1842)	ORI, MEL	
Odontomachus saevissimus	Smith F, 1858	MEL, Moluccas	
Odontomachus simillimus	Smith F, 1858	Wide	U
Odontoponera denticulata	(Smith F, 1858)	ORI	U
Brachyponera atrata	Karavaiev, 1925	Moluccas, MIC	
Ectomomyrmex striatulus	Karavaiev, 1935	AU, MEL	
Platythyrea parallela	Smith F, 1859	Wide	U

the genera (e.g. *Pheidole*, *Tetramorium*, *Camponotus*, *Nylanderia*) which are generally diverse in this region are represented by only few species or completely missing. Our study also did not include sampling of more cryptic leaf litter fauna which would probably contribute substantially to the local species list. For example, we anticipate that species diversity of the genera *Pheidole*, *Nylanderia*, *Hypoponera* and *Strumigenys* will be higher than reported here. On the other hand, we report significantly higher species richness than the number of species recorded from the southern Moluccan islands of Wetar (3600 km^2), Pantar (728 km^2) and Lembata (Trainor and Andersen 2010) or the Solomon Islands (e. g. Lembata – 70 ant spp., Sarnat et al. 2013) which are larger than or of similar size to Ambon. We anticipate that the ant species richness of Ambon might be even higher than that of other comparably sized islands, as it is adjacent to the much larger Seram, which could potentially serve as a source area for ant species that would otherwise go extinct on small and disturbed islands.

The accumulation curves indicate that both our sites were sampled exhaustively, within the limits of the methods used. This suggests that our survey provides a representative view of the above ground foraging ant fauna of the area. General collecting in the area outside the transects yielded only one additional species (*Anochetus graeffei* Mayr, 1870). The fact that all the species from secondary forest were also found in

Table 2. List of unidentified and undescribed species collected during our survey of Sirimau forest, Ambon. U = undisturbed forest; S = secondary forest.

Taxon	Ident. note	Habitat	Voucher code
Ectatomminae			
Rhytidoponera sp. AMB01		U, S	FLAM10/0125
Formicinae			
Camponotus sp. AMB01		U, S	FLAM10/0073
Camponotus sp. AMB02		U	FLAM10/0001
Camponotus sp. AMB03		U	FLAM10/0040
Nylanderia sp. AMB01	cf. *N. vividula*	U, S	FLAM10/0013
Polyrhachis sp. AMB04		U, S	FLAM10/0121
Myrmicinae			
Crematogaster sp. AMB01		U	FLAM10/0044
Pheidole sp. AMB01	cf. *P. submonticola*	U, S	FLAM10/0051
Pheidole sp. AMB02	cf. *P. submonticola*	U	FLAM10/0037
Pheidole sp. AMB03	*P. umbonata* group	U	FLAM10/0027
Pheidole sp. AMB04		U	FLAM10/0026
Carebara sp. AMB01	cf. *C. diversa*	U, S	FLAM10/0018
Romblonella sp. AMB01		U	FLAM10/0012
Ponerinae			
Diacamma sp. AMB01		U, S	FLAM10/0141
Leptogenys sp. AMB01		U, S	FLAM10/0125A

undisturbed forest is somewhat surprising and probably indicates a limited regional species pool and relative similarity of both types of habitats. A thorough sampling of other microhabitats (leaf litter, canopy) could contribute additional species.

Both forests were also inhabited by several invasive species not native to the area, including: *Anoplolepis gracilipes*, *Paratrechina longicornis* (Latreille, 1802), *Solenopsis geminata* (Fabricius, 1804) and *Monomorium pharaonis*. Although, these species mostly did not reach high frequencies in either type of forest (only *A. gracilipes* reached a high frequency, being the fourth most frequent species in disturbed forest), their presence is indicative of medium to strong habitat disturbance (Invasive Species Specialist Group, www.issg.org, New Zealand biosecurity system, http://www.biosecurity.govt.nz). The most frequently collected taxa in both habitats were several species of *Pheidole* and *Polyrhachis*, as well as *Oecophylla smaragdina* and *Dolichoderus thoracicus*.

Although the undisturbed forest site was inhabited by 11 more species than the disturbed site, the high abundances of *O. smaragdina*, *D. thoracicus* and moderate abundances of *M. pharaonis* and *Tapinoma melanocephalum* (Fabricius, 1793) indicate that this area has likely been disturbed in the past, as these species are often associated with secondary or disturbed forests (Invasive Species Specialist Group database, http://www.issg.org, Way and Khoo 1991, Klimes et al. 2012).

Biogeographic affinities

Out of the 59 valid species currently known from Ambon, the largest proportion (13 spp.) is of Oriental (South East Asian) and Oriental-Austro-Melanesian origin (13 spp.). The latter category represents species which are equally distributed across Oriental and Austro-Melanesian regions, mostly spread across islands of South East Asia, New Guinea and/or Australia. The third largest group of Ambon myrmecofauna is of local origin (12 spp.). Here, they represent a smaller proportion of fauna compared to data from the ant genus *Polyrhachis* on the much larger Timor (~70% endemics, Andersen et al. 2013). Our data suggest that the Oriental faunal elements are somewhat more prominent in Ambon than Austro-Melanesian elements. The most important part of the fauna are however regional endemics and species distributed equally across parts of the Oriental and Austro-Melanesian regions – an area which corresponds with a largely extended Wallacea. This group includes taxa that either originated within this region and/or lineages which expanded into the region from either Oriental or Australian continental shelves. However, without detailed phylogenetic reconstruction for each of these genera it is not possible to reveal their exact area of origin. A detection of five introduced species in a relatively preserved habitat should be of conservational concern and suggests that these exotic species are well established in Ambon. This is indeed a case in other parts of the island, especially in urban and suburban areas (FL personal observation).

Conclusions

Our field survey and literature search revealed that there are over 70 ant species and subspecies found on Ambon Island, of which at least 59 have been previously described. The total number is likely to increase once data from other parts of the island and from understudied microhabitats such as tree canopy or forest leaf litter become available. The occurrence of several non-native ant species recorded in old preserved forest is of conservational concern and suggests that the introduced species are well established on the island. The overall structure of the ant community recorded in the forested area is indicative of a strong effect of habitat fragmentation and large habitat conversion on the island, where urban habitat is prominent. From a biogeographic perspective, the largest portions of Ambon ant fauna are species with Oriental affinities and species native to the Oriental-Austro-Melanesian region. Interestingly, the portion of Austro-Melanesian species is smaller which contrasts to patterns observed in Moluccan Lepidoptera. Our study provides the first basis for future research on ants of Ambon Island and surrounding areas. As habitat conversion in this region continues, the unique and endemic fauna of Moluccas is particularly endangered and in urgent need of proper conservational efforts. Ants, along with moths and butterflies can serve as useful indicators of habitat quality and uniqueness and for identification of conservational priorities.

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RESEARCH ARTICLE

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The genus *Arctorthezia* Cockerell (Hemiptera, Ortheziidae) with the description of a new species

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Abstract

This paper describes a new species of *Arctorthezia* Cockerell (Hemiptera: Coccoidea: Ortheziidae) from the Palaearctic region. The specimens were extracted from forest litter in the collections of Muséum d'histoire Naturelle de Genève, Switzerland, using Berlese funnels. Three further species, *A. cataphracta* (Olafsen), *A. occidentalis* (Douglas) and *A. pseudoccidentalis* Morrison, are redescribed and re-illustrated. The genus *Arctorthezia* now contains five species. An identification key, diagnostic illustrations, photographs of unmounted females and new locality records of the *Arctorthezia* species currently known are provided.

Keywords

Ensign scale, archaeococcoids, taxonomy, distribution, Palaearctic Region, Switzerland

Introduction

Ensign scale insects (Hemiptera: Coccoidea: Ortheziidae) are considered to be one of the most ancient families of the Coccoidea (Koteja 1996, Vea and Grimaldi 2012) and are thought to be either 'ancestral' to all scale insects or a 'primitive', isolated branch of the grade of families, the archaeococcoids (Vea and Grimaldi 2012). Ensign scales are readily distinguished by (i) possessing distinctive, well-developed legs and antennae,

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(ii) having much of the body cloaked in bunches of white wax secretions (Vea and Grimaldi 2012). There are approximately 212 described species of Ortheziidae to date, classified in 21 genera (including four extinct genera) (Vea and Grimaldi 2012). Only a few species of ortheziids are serious pests; these include *Insignorthezia insignis* (Browne), the greenhouse ensign scale, and an invasive pest in Afro-tropical region, *Praelongorthezia praelonga* (Douglas), the citrus orthezia (Kondo et al. 2013). In Ortheziidae, two main groups of host plant specialization can be observed; the first group is composed of species that occur in leaf litter (feeding on roots and fungal mycelia), and on mosses and lichens; the second group feeds on vascular plants, including grasses, herbaceous and woody plants (Koteja 1996, Kozár 2004, Vea and Grimaldi 2012).

The subfamily Ortheziinae is characterized by having the tibia and tarsus well separated, and 7- or 8-segmented antennae (Kozár 2004). Two tribes can be recognized in the subfamily, namely Arctortheziini Kozár and Ortheziini Amyot & Serville. The Arctortheziini includes species living in moist habitats – in litter, moss and feeding on the roots of different plants; whereas the Ortheziini includes species feeding on different kinds of plants (grasses, herbaceous, woody plants), mostly living in dry habitats. The monotypic tribe Arctortheziini includes only one genus, *Arctorthezia* Cockerell, which contains four living species: *A. cataphracta* (Olafsen), *A. occidentalis* (Douglas), *A. pseudoccidentalis* Morrison and *A. vardziae* Hadzibejli (Richard 1998) and one extinct species (Koteja and Zak-Ogaza 1988). *Arctorthezia* is characterized by (i) 9 pairs of dorsal wax plates in each marginal row, 8 pairs in the submedian band and 3 triangular or shield-shaped plates in the center of the thorax; (ii) 7- or 8-segmented antennae; (iii) 7 or 8 pairs of abdominal spiracles, and (iv) 3 or 4 spine rows within the ovisac band.

In the present paper, one new *Arctorthezia* species is described from the Palaearctic region (Switzerland); three species, namely *A. cataphracta* (Olafsen), *A. occidentalis* (Douglas), *A. pseudoccidentalis* Morrison, are redescribed and re-illustrated; an identification key and new additional locality records for the currently known *Arctorthezia* species are provided; and macromorphological characters are illustrated and discussed.

Material and methods

The specimens examined in this study were mostly from the scale insect collections of the Plant Protection Institute, Centre for Agricultural Research, Hungarian Academy of Sciences (PPI) and the Muséum d'histoire Naturelle de Genève (MHNG). Important material was processed from the Soil Zoology Collection of the Hungarian Natural History Museum, Budapest (HNMH), and part of the material was loaned from the United States National Entomological Collection, Washington (USNM). The material examined from Japan belongs to the collection of Tottori Prefectural Museum, Japan (TRPM).

Specimens were prepared for light microscopy using the slide-mounting method described by Kosztarab and Kozár (1988). The morphological terminology used follows Kozár (2004).

The holotype of the new species is deposited in the Muséum d'histoire Naturelle de Genève collection (MHNG), and the paratypes are shared between MHNG and PPI.

The digital images of unmounted females were made with a Canon Eos400D camera and an MBC-10 stereomicroscope, and focus-stacking was processed by CombineZP software (Hadley 2010).

Measurements and counts were taken from all available material, and the values are given as a range for each character.

Result and discussion

Genus *Arctorthezia* Cockerell, 1902

Orthezia (*Arctorthezia*) Cockerell 1902: 114.

Type species: *Orthezia occidentalis* Douglas, 1891.

Arctorthezia, Morrison 1925: 143 (as subgenus). Change of status.

Arctorthezia, Morrison 1952: 53 (as genus). Change of status.

Type species. *Orthezia occidentalis* Douglas, 1891: 245. Subsequently designated by Cockerell 1902: 259.

Comments. Cockerell (1902) described *Arctorthezia* as a "section" of *Orthezia*. According to the International Code of Zoological Nomenclature, Article 10 (e) a "section" is deemed to be a subgeneric name when proposed for a species-group division of a genus. Thus, Cockerell is considered to be the author of *Arctorthezia* (Kozár 2004).

Description. *Unmounted female.* Live adult female with 9 pairs dorsal wax plates in each marginal row, 8 pairs in each submedian band, and 3 triangular or shield-shaped plates in centre of thorax. Ovisac parallel sided, short, about half length of body (Fig. 5).

Mounted female. Antenna 7 or 8 segmented, covered with strong spines; apical seta a blunted strong spine. Claw without denticle. Abdominal spiracles numbering 7 or 8 pairs, situated on margin of dorsum. Three triangular wax plates present on mid-dorsum. Three or four rows of spines present within ovisac band.

Host plant. Found under mosses and stones on the roots of different plants, also reported from ant nests.

Distribution. The known species are distributed only in the Holarctic Region.

Key to adult females of species of *Arctorthezia*

Unfortunately the type material of *A. vardziae* was not available. For this reason we could not include this species in the key. In the original description, Hadzibejli (1963) only provided generic characters that refer to the genus description, so further studies are needed to clarify the species concept of *A. vardziae*.

1 Triangular wax plate on mid-dorsum longer than wide; triangular wax plate between mid coxae on venter longer than wide, like those on dorsum; ovisac band containing 3 wide wax plate bands ..... ***A. cataphracta***

– Triangular wax plate on mid-dorsum various widths but never the longer than wide; triangular wax plate between mid-coxae on venter at least twice as wide as long; ovisac band containing 4 wide wax plate bands **2**

2 On the dorsum, with 9 circular discoidal pore plates present between marginal and submedian setal plates (Fig. 4) ..... ***A. pseudoccidentalis***

– On the dorsum, circular discoidal pore plates absent from between marginal and submedian setal plates **3**

3 Dorsal triangle-shaped mid-thoracic setal plates more than two times wider than long (Fig. 6e); distal to vulva, proportion of simple pores to quadrilocular pores ca. 1:6 ..... ***A. occidentalis***

– Dorsal triangle-shaped mid-thoracic setal plates hardly wider than long (Fig. 6a); distal to vulva, proportion of simple pores to quadrilocular pores ca. 1:15 ..... ***A. helvetica* sp. n.**

***Arctorthezia helvetica* Kozár & Szita, sp. n.**
http://zoobank.org/AFE6A314-D608-4728-B3CD-BB3E2BFDF8EE
Figs 1, 5a, 6a–b

Material. Type material: Holotype female Switzerland, Valais, s/Venayaz, 700 m a.s.l., 7.x.1980, leg. C. Besuchet [PPI 8864, MHNG without code]. Paratypes female: 6 adult females with the same data as holotype, on separate slides.

Other material examined: 3 adult females on separate slides, Switzerland, Valais, Dorenaz, oak, 28.iii.1964, leg. C. Besuchet [PPI 8862, MHNG without code].

Description. Live adult female: dorsum with 9 pairs dorsal wax plates in each marginal row, 8 pairs in each submedian band, and 3 triangular or shield-shaped plates in middle of thorax. Ovisac short, about half length of body (Fig. 5a).

Slide-mounted adult female (Figs 1, 6a–b). Body elongate oval, 2.124−2.719 mm long, 1.425−1.942 mm wide. Antenna 7 segmented. Measurements of antennal segments: 1st 180−230, 2nd 183−209, 3rd 96−117, 4th 84−107, 5th 76−92, 6th 76−96 and apical 204−220 mm long, apical spine of antenna 22−24 mm long, subapical seta absent; fleshy sensory seta near apical seta 22−24 mm long; all segments of antenna covered with very robust, spine-like setae, the longest 17 mm long; first antennal segment with 4 spines on each side of segment. Eyes sub-conical, well separated from base of first antennal segment.

Venter: Labium 260−285 mm long, apparently one segmented. Stylet loop usually longer than labium. Legs well developed; leg measurements: front coxa 155−189 mm, middle 155−189 mm, hind 188−204 mm; front trochanter+femur 546−577 mm long, middle 548−572 mm, hind 597−650 mm; front tibia+tarsus 700−722 mm long, middle 679−740 mm, hind 804−866 mm; claw 74−89 mm long; hind claw digitules

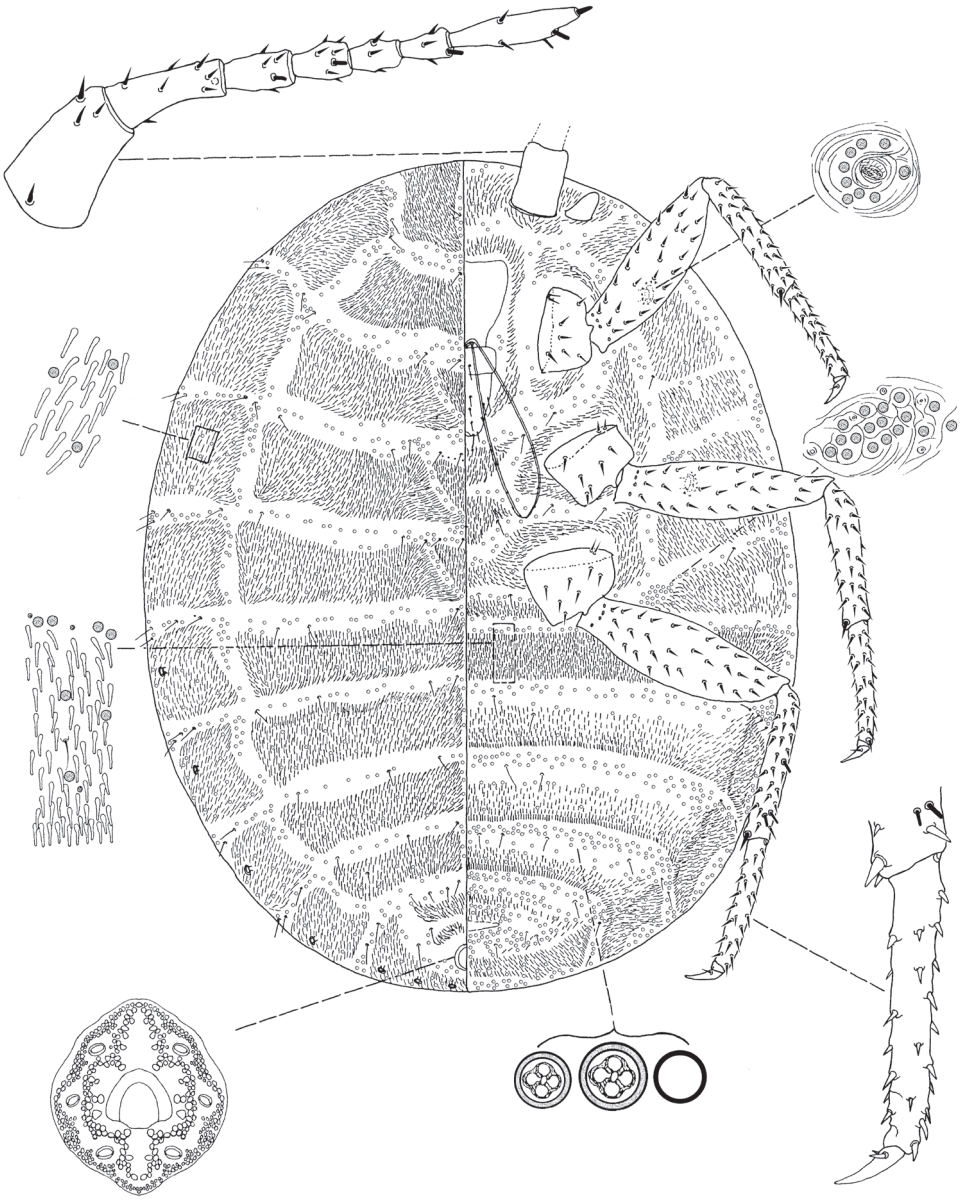

Figure 1. *Arctorthezia helvetica* sp. n., mounted adult female. Illustration by Konczné Benedicty & Kaydan.

each 15–21 mm. Legs with rows of robust spine-like setae, tibia with fleshy sensory seta 24 mm long, trochanter with 4 placoid sensilla on each surface. Wax plates present on ventral areas of head and thorax, with wide marginal plate laterad of each thoracic spiracle; two wax plates present between mid-coxae, both triangular, almost same size (Fig. 6a).

Thoracic spiracle with wide band of disc pores inside atrium. Setae few, scattered in medial areas of thorax; several setae near anterior edge of ovisac band and associated with simple pores. Ovisac band wide, parallel side in the middle, with 4 spine rows within ovisac band. Multilocular pores with 4 loculi around perimeter, each loculus 4–5 mm in diameter and 1 loculus in central hub, 3 mm in diameter; pores present in 3 complete bands near posterior edges of each spine band, and scattered around vulva.

Dorsum: Wax plates covering entire dorsum; three triangular wax plates on mid-dorsum, anteriormost 185–190 mm wide, 135–150 mm long; middle 250–270 mm wide, 150–160 mm long; posteriormost 260–280 mm wide, 170–180 mm long (Fig. 6b). Spines at margin of each wax plate each 22–24 mm long, apically capitate. A few setae present in marginal clusters near posterior edges of marginal wax plates; 3–6 setae present laterad of thoracic spiracle, longest seta 24 mm long; also present in very small numbers on other wax plates and in medial bare area. Multilocular pores generally with 4 loculi around perimeter and one loculus in central hub, sparsely present in wax plates. Abdominal spiracles numbering 8 pairs on the margin, last 3 pairs situated in posterior apical spine clusters. Anal ring 108–120 mm long, 108–120 wide, bearing 6 blunt anal ring setae, each 156–192 mm long.

Etymology. he species was named after the ancient name of its *locus typicus*, Switzerland (Helvetia).

Distribution. Switzerland.

Ecology. *Host plant*: unknown, found in leaf litter and soil samples.

Diagnosis. *Arctorthezia helvetica* sp. n. can be recognized by the following combination of characters: (i) 7-segmented antennae, (ii) dorsal triangle-shaped mid-thoracic setal plates hardly wider than long (iii) the proportion of simple pores and quadrilocular pores distal to vulva ca. 1:15, (iv) diamond-shape setal plate between mid-coxae on venter.

Comments. *Arctorthezia helvetica* sp. n. is closest to *A. occidentalis* in having 4 spine rows within the ovisac band and lacking circular pore clusters on the dorsum, but differs from *A. occidentalis* as follows (characters of *A. occidentalis* in brackets): (i) adult female body length less than 3 mm (adult female body length at least 3.5 mm); (ii) the fourth spine row within ovisac band weak (the fourth spine row within ovisac band strong); (iii) the proportion of simple pores to quadrilocular pores distal to vulva ca. 1:15 (the proportion of simple pores to quadrilocular pores distal to vulva ca. 1:6); (iv) dorsal triangle-shaped mid-thoracic setal plates hardly wider than long (dorsal triangle-shaped mid-thoracic setal plates more than two times wider than long).

Arctorthezia cataphracta (Olafsen, 1772)

Figs 2, 5b–c, 6c–d

Material examined. Austria: 1 female, Kesselspitze Mt., 3.vii.1999, leg. K. Thaler [PPI 6545]. **Greenland:** 2 females on 1 slide, s-o, Nanortalik, dwarf willow, 26.vii.1979, leg. G. Primatesta [PPI 8933, MHNG nr.7]; 1 female at Boston, Sedum sp., 6.vi.1945, leg.

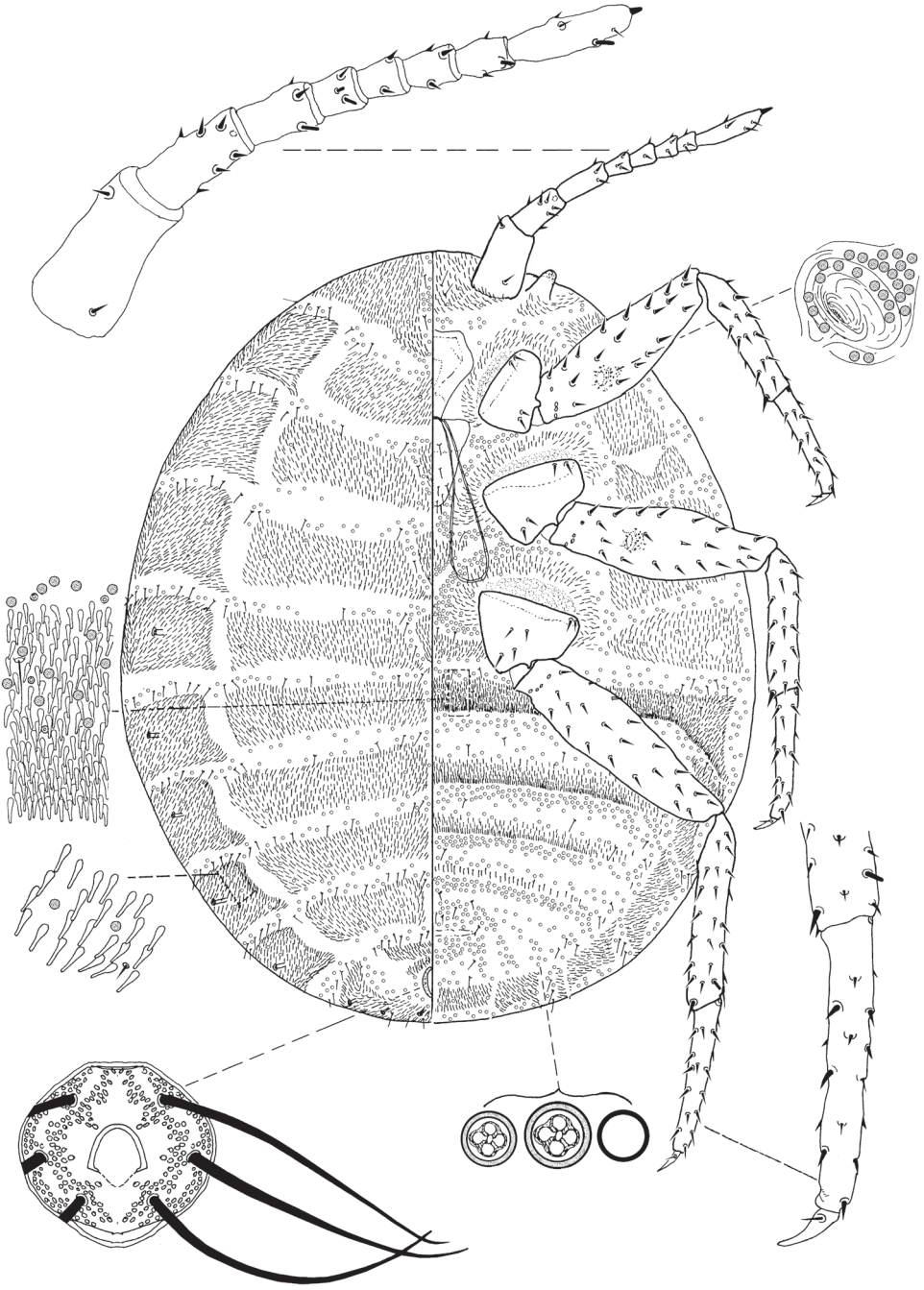

Figure 2. *Arctorthezia cataphracta* (Olafsen, 1772), mounted adult female. Illustration by Konczné Benedicty & Kaydan.

Hodson [PPI 8967, USNM 45 1781]. **Italy:** 2 females on 2 slides, Piedmont, Monte Autoroto, 1700 m a.s.l., 16.vi.1982, leg. A. Focarile [PPI 9854, MHNG 13]. **Japan:** 1 female, Tochigi, Nikkô, Kawamata, Nikkô-zawa-onsen, 1500 m a.s.l., *Dryopteris crassirhizoma*, 5.vi.2013., leg. S. Maehara. (collected by beating) [TRPM]; 1 female, same locality, *Dryopteris crassirhizoma*, 2.vii.2013, leg. S. Maehara. (collected by beating) [TRPM]. **Mongolia:** 1 female, Bogdo, 3.vi.1967, leg. Z. Kaszab [HNHM As 77]. **Switzerland:** 2 females on 2 slides, Valais, Gornergat, 3050 m a.s.l., under stones, 12.ix.1982, leg. C. Besuchet [PPI 8857, MHNG without code]; 3 females on 3 slides, Valais, Fluhalp, near Leuerbad, 2000 m a.s.l., mosses and dead leaves, 14.viii.1980, leg. C. Besuchet [PPI 8858, MHNG without code]; 2 females on 2 slides, Obwald, Melchsee, 1800 m a.s.l., mosses, 2.x.1987, leg. I. Löbl [PPI 8861, MHNG without code]; 4 females on 4 slides, Valais, Tursten, s/Zermatt, 2200 m a.s.l., 14.vii.1966, leg. A. Comellini [PPI 8863]; 5 females on 5 slides, Valais, Saas-Almagell, 1650 m a.s.l., wet mosses, 5.vii.1997, leg. C. Besuchet [PPI 8866, MHNG without code]; 2 females on 2 slides, Valais, Grand St. Bernard, 2150 m a.s.l., mosses at foot of rocks, 10.ix.1996, leg. C. Besuchet [PPI 8873, MHNG without code]; 1 female, at N.Y., on lichens around *Rhododendron*, 12.vii.1938, leg. Harley [PPI 8968, USNM 98-2244, NY77615]; 1 female, Valais, Torrenthorn, near Lukerbad, 2500-2600 m a.s.l., alpine meadows, 12.viii.1980, leg. C. Besuchet [PPI 8870, MHNG without code]; 1 female, Studen, moss, 20.ix.1992, leg. F. Kozár [PPI 4071]; 1 female, Romoos, Weise, 23.viii.1994, leg. Rézbányai [PPI 6144, HNHM]; 2 females on 1 slide, Romoos, Weise, 28.iv.1994, leg. Rézbányai [PPI 6143]. **Turkey:** 1 female, Ilgardagi Gecidi, 2350 m a.s.l., 13.vi.1986, leg. Löbl, Besuchet, Burckhardt [PPI 8881, MHNG without code]; 2 females on 2 slides, Kars, Ilgandas, Gecidi, on herbs and flowers, 13.vi.1986, leg. Löebl & Bernhardt [MHNG 10699/1-2 Ar.tube II]. **UK:** 2 females on 1 slide, Scotland, N. Berwich, E. Lothian, under moss, .ix.1926, leg. E.E. Green [PPI 8965, USNM without code]; 1 female, Scotland, Braemar, at base of grass, 8.viii.1979, leg. J.N. Cox [USNM 5/79].

Synonymy. *Pediculus cataphractus* Olafsen, *Coccus cataphracta* (Shaw), *Dorthezia cataphracta* (Shaw), *Orthezia cataphracta* (Shaw), *Dorthesia chiton* Zetterstedt, *Orthezia signoreti* White, *Coccus uva* (Modeer), *Orthezia uva* (Modeer), *Orthezia* (*Arctorthezia*) *cataphracta*, Cockerell, *Coccus cataphractus* Lindinger (Ben-Dov et al. 2014, Kozar 2004).

Description. Live adult female: dorsum with 9 pairs dorsal wax plates in each marginal row, 8 pairs in each submedian band, and 3 small triangular or shield-shaped ones in middle of thorax. Ovisac parallel sided, short, about half length of body (Fig. 5b–c).

Slide-mounted adult female (Figs 2, 6c–d). Body elongate oval, 2.0−2.9 mm long, 1.5−2.7 mm wide. Antenna 8 - (rarely 6 or 7) segmented. Measurements of antennal segments: 1st 189–273, 2nd 144–210, 3rd 102–145, 4th 64–110, 5th 61–93, 6th 67–90, 7th 70–115, and apical segment 176–220 mm long, apical spine of antenna 11–20 mm long, subapical seta absent; fleshy sensory seta near apical seta 13–21 mm long; all segments of antenna covered with very robust, spine-like setae, the longest spine 21–37 mm long; first antennal segment with 0–2 spines on each side of segment. Eyes conical, well separated from base of first antennal segment.

Venter: Labium 285–350 mm long, apparently one segmented. Stylet loop usually longer than labium. Legs well developed; leg measurements: coxa length: front 186–310 mm long, middle 192–300 mm, hind 224–330 mm; front trochanter+femur 623–800 mm long, middle 647–820 mm, hind 705–883 mm; front tibia+tarsus 423–991 mm long, middle 448–994 mm, hind 548–1165 mm; front claw 82–106 mm long, middle 96–108 mm, hind 97–120 mm; hind claw digitules each 26–39 mm. Legs each with rows of robust spine-like setae, with a fleshy sensory seta on hind tibia, trochanter with 4 placoid sensilla on each surface. Wax plates present on ventral areas of head and thorax, and wide marginal plate laterad of each thoracic spiracle; two wax plates present between mid-coxae, both in triangular shape, anterior one relatively small and longer than wide (Fig. 6c); with 3 spine rows within ovisac band. Thoracic spiracles each with wide band of disc pores inside atrium. Setae few, scattered in medial areas of thorax, with several setae near anterior edge of ovisac band and associated with simple pores. Ovisac band narrow, indented in the middle. Multilocular pores each with 4 loculi around perimeter and 1 loculus in central hub, 4–5 mm in diameter; present in 3 complete bands near posterior edge of each spine band, and scattered around vulva.

Dorsum: Wax plates cover entire dorsum; three triangular wax plates on mid-dorsum, anterior 40–130 mm wide, 60−195 mm long; middle 60−120 mm wide, 90−250 mm long; posterior 80−110 mm wide, 90−240 mm long, (Fig. 6d). Spines at margin of wax plate each 14–20 mm long, apically capitate. A few setae present in marginal clusters near posterior edges of marginal wax plates; with 3−6 setae laterad of thoracic spiracles, longest seta 17–20 mm long; also present in very small numbers on other wax plates and in medial bare area. Multilocular pores generally each with 4 loculi around perimeter, one loculus in central hub, sparsely present in wax plates. Abdominal spiracles numbering 8 pairs on the margin, last 3 situated in posterior apical spine clusters. Anal ring 120–132 mm long and 118–146 wide, bearing 6 blunt anal ring setae, each seta 136 mm long.

Distribution. Austria, Belgium, Canada, Czech Republic, Denmark (Faeroe Islands), Estonia, Finland, France, Georgia, Greece, Greenland, Iceland, Ireland, Italy, Japan, Mongolia, Norway, Poland, Romania, former Soviet Union, Spain, Sweden, Switzerland, U.K., Ukraine, U.S.A. (Alaska).

Ecology. *Host plants*: *Alnus viridis* (Betulaceae), *Caltha* sp. (Ranunculaceae), *Capparis* sp. (Capparaceae), *Calamagrostis langsdorfii*, *Carex* sp., *Deschampsia caespitosa* (Poaceae), *Chrysanthemum alpinum*, *Hieracium* sp., *Hymogyne* sp., *Solidago* sp. (Asteraceae), *Dryas octopetala* (Rosaceae), *Gentiana* sp. (Gentianaceae), *Geranium* sp. (Geraniaceae), *Iris setose* (Iridaceae), *Racomitrium lanuginosum* (Grimmiaceae), *Calluna vulgaris*, *Rhododendron ferrugineum*, *Vaccinium myrtillus* (Ericaceae), *Saxifraga aizoon* (Saxifragaceae), *S. cuneifolia*, *S. oppositifolia*, *Sedum* sp. (Crassulaceae), *Soldanella* sp. (Primulaceae), *Trientalis europaea* (Myrsinaceae), and *Collybia* sp. (Fungi: Tricholomataceae). Under mosses (*Sphagnum* sp.: Sphagnaceae) and stones on roots, also reported from ant nests (Ben-Dov et al. 2014, Kozár 2004). In Primorsky region of Russia (Danzig 1980) and Japan, some individuals were observed on ferns.

***Arctorthezia occidentalis* (Douglas, 1891)**
Figs 3, 5d–e, 6e–f

Material examined. Canada: 2 females on 1 slide, British Columbia, Victoria, Highland Rd., moss, 12.vii.1988, leg. F. Kozár [PPI 3330, USNM 57]; 2 females on 1 slide, British Columbia, Vancouver Island, Ladysmith, entering a dwelling, 9.xi.1945, leg. W.A. Ross [PPI 8986, USNM 45-2340]; 6 females on 4 slides, British Columbia, Kaslo B.C., root of trees and grass, 19.v.1908, leg. J.W. Cockle [PPI 8974, USNM without code]; **USA:** 5 females on 5 slides, Montana, on apple, .ix.1949, leg. W.S. Regan [PPI 8975, USNM 49-2173]; 1 female, Colorado, Boulder, on *Castilleja* sp., 8.vi.1917, leg. H.F. Dietz [PPI 8977, USNM FHB #16096]; 4 females on 2 slides, Colorado, Boulder, on *Castilleja* sp., 12.vi.1919, leg. H.F. Dietz [PPI 8976, USNM without code].

Synonymy. *Orthezia occidentalis* Douglas, *Orthezia californica* (Ehrhorn), *Orthezia* (*Arctorthezia*) *occidentalis* Morrison (Ben-Dov et al. 2014).

Description. Adult female, with secretion, fairly large, 3.5 mm wide and 4.5 mm long. Body completely covered with dense, sharply defined wax plates, these occurring in the usual marginal and dorsal tufts, white or variously discoloured, sometimes appearing yellow-brown or grey (Morrison 1925). Live adult female with 9 paired dorsal wax plates in each marginal row, 8 in each submedian band, and 3 wide, triangular or shield-shaped plates in centre of thorax (Fig. 5d–e).

Slide-mounted adult female (Fig. 3, 6e–f). Body elongate oval, 3.45−4.25 mm long, 3.00−2.68 mm wide. Antenna 8- (rarely 7) segmented. Measurements of antennal segments: 1st 280−330, 2nd 190−230, 3rd 110−140, 4th 100−110, 5th 90, 6th 90−100, 7th 90−120, and apical segment 235−240 mm long; apical spine of antenna 20 mm long, subapical seta absent; fleshy sensory seta near apical seta 25 mm long, all segments of antennae covered with very robust, spine-like setae, longest spine 15 mm long, first antennal segment with 2 spines on each side of segment. Eye with sub-parallel sides, tall, 120−180 mm long, situated very close to first segment of antenna.

Venter: Labium 340−450 mm long, apparently one segmented. Stylet loop usually longer than labium. Legs well developed; measurements of front coxa 220−260 mm long, middle 200−250 mm, hind 240−350 mm; front trochanter+femur 660−720 mm long, middle 720−820 mm, hind 760−920 mm; front tibia+tarsus 460−670 mm long, middle 540−580 mm, hind 340−400 mm; front claw 80 mm long, middle 90−110 mm, hind 90−110 mm; hind claw digitules 5−10 mm; legs with rows of robust spine-like setae, with four fleshy sensory setae on tibia, trochanter with 4 placoid sensilla on each surface. Wax plates present on ventral areas of head and thorax, with wide marginal plate laterad of each thoracic spiracle; two wax plates present between mid-coxa upper one in triangular shape (Fig. 6e), below one knickers shape. Thoracic spiracles with wide band of disc pores inside atrium. Setae few, scattered in medial areas of thorax, with several setae near anterior edge of ovisac band and associated with simple pores. Ovisac band wide, straight in the middle; with 4 spine rows within ovisac band. Multilocular pores with 4 loculi around perimeter, 1 loculus in central hub; 5 mm in

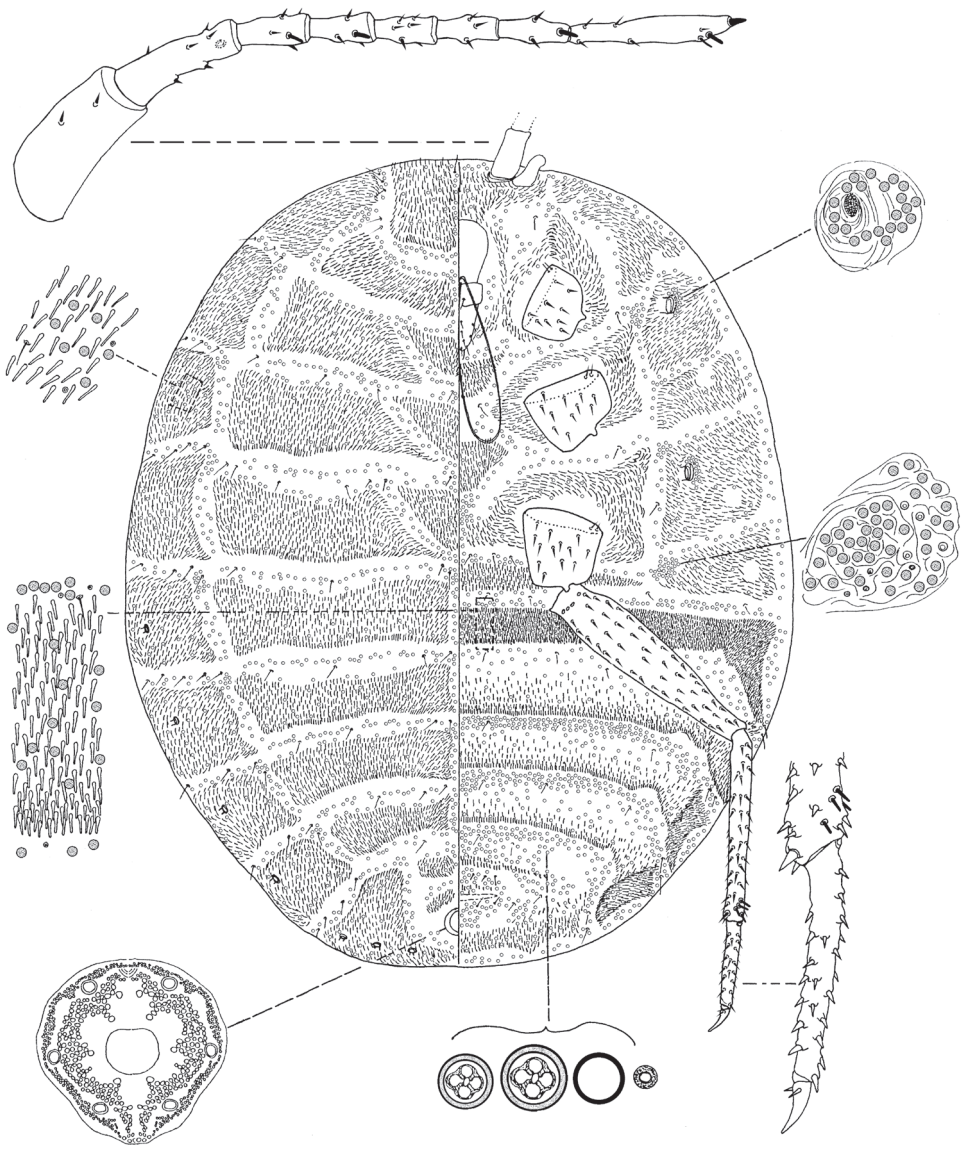

Figure 3. *Arctorthezia occidentalis* (Douglas, 1891), mounted adult female. Illustration by Konczné Benedicty & Kaydan.

diameter; present in 3 complete bands near posterior edges of each spine bands, and scattered around vulva.

Dorsum: Wax plates cover all dorsum; three triangular wax plates on middorsum (first 340–540 mm in width, 140–240 mm in length; middle 440–740 mm in width, 300–370 mm in length; third 640–650 mm in width, 220–330 mm in length, Fig. 6f). Spines at margin of wax plate 20–22 mm long, spines apically capitate. A few setae

present in marginal clusters near posterior edges of marginal wax plates, with 3−6 setae laterad of thoracic spiracles, longest seta 40−50 mm long also present in very small numbers on other wax plates and in medial bare area. Multilocular pores generally with 4 loculi around perimeter, one loculus in central hub, sparsely present in wax plates. Abdominal spiracles 7 pairs on the margin, last 2 in posterior apical spine clusters. Anal ring 130−145 mm long and 100−125 wide with 6 anal ring blunted setae, each 225−250 mm long.

Distribution. Canada (British Columbia), Spain, USA (Alaska, California, Colorado, Hawaiian Islands, Idaho, Montana, New Mexico, Oregon, Washington).

Ecology. *Host plant*: *Bahia* sp., *Eriophyllum*, *Argyroxiphium* sp., *Eriophyllum confertifolium*, *Agrostis sandwicensis*, *Grossularia* sp., *Fragraria* sp. *Rubus* sp., *Castilleja* sp (Ben-Dov et al. 2014, Kozar 2004).

Biology. On the roots, associated with *Formica integra*, and *Myrmica*? ants (Ben-Dov et al. 2014, Kozar 2004).

Comments. Its presence in the Palaearctic Region (Spain) (Gómez-Menor 1937) is under question. Searches for slides in Spanish collections were unsuccessful (personal communication from Carolina Martin (Madrid), and Angeles Vásquez (Madrid)).

Arctorthezia pseudoccidentalis Morrison, 1952

Figs 4, 5f–g, 6g–h

Material examined. USA: 4 females on 4 slides, Nevada, 15 mi S of Ely, beneath boards, 6.vii.1960, leg. T.R. Haig [PPI 8964, USNM 60-0381]

Description. Adult female, with secretion, fairly large, similar to *A. occidentalis*. Body completely covered with dense, sharply defined wax plates, these occurring in the usual marginal and dorsal tufts, white. With 3 wide, shield-shaped plates in centre of thorax (Fig. 5f–g).

Slide-mounted adult female (Fig. 4, 6g–h). Body elongate oval, 4.015 mm long, 3.497 mm wide. Antenna 7 or 8 segmented. Measurements of antennal segments: 1st 320−350, 2nd 227−260, 3rd 144−155, 4th 113–124, 5th 103, 6th 93–103, 7th 103, apical segment 191 mm long; apical spine of antenna 26 mm long, subapical seta absent; fleshy sensory seta near apical seta 18 mm long; all segments of antennae covered with very robust, spine-like setae, longest spine 11 mm long; first antennal segment with 2 spines on each side of segment. Eye with sub-parallel sides, tall, situated very close to first segment of antenna.

Venter: Labium 391−402 mm long, apparently one segmented. Stylet loop usually longer than labium. Legs well developed; measurements of front coxa 247−310 mm long, middle 309−330 mm, hind 330−340 mm; front trochanter+femur 917 mm long, middle 958 mm, hind 1060−1088 mm; front tibia+tarsus not seen, middle 649 mm, hind 824–868 mm; front claw 1 not seen, middle 108 mm, hind 113 mm; hind claw digitules 23–26 mm; legs with rows of robust spine-like setae, without 2 fleshy sensory seta on tibia each 10 mm, trochanter with 4 placoid sensilla on each surface.

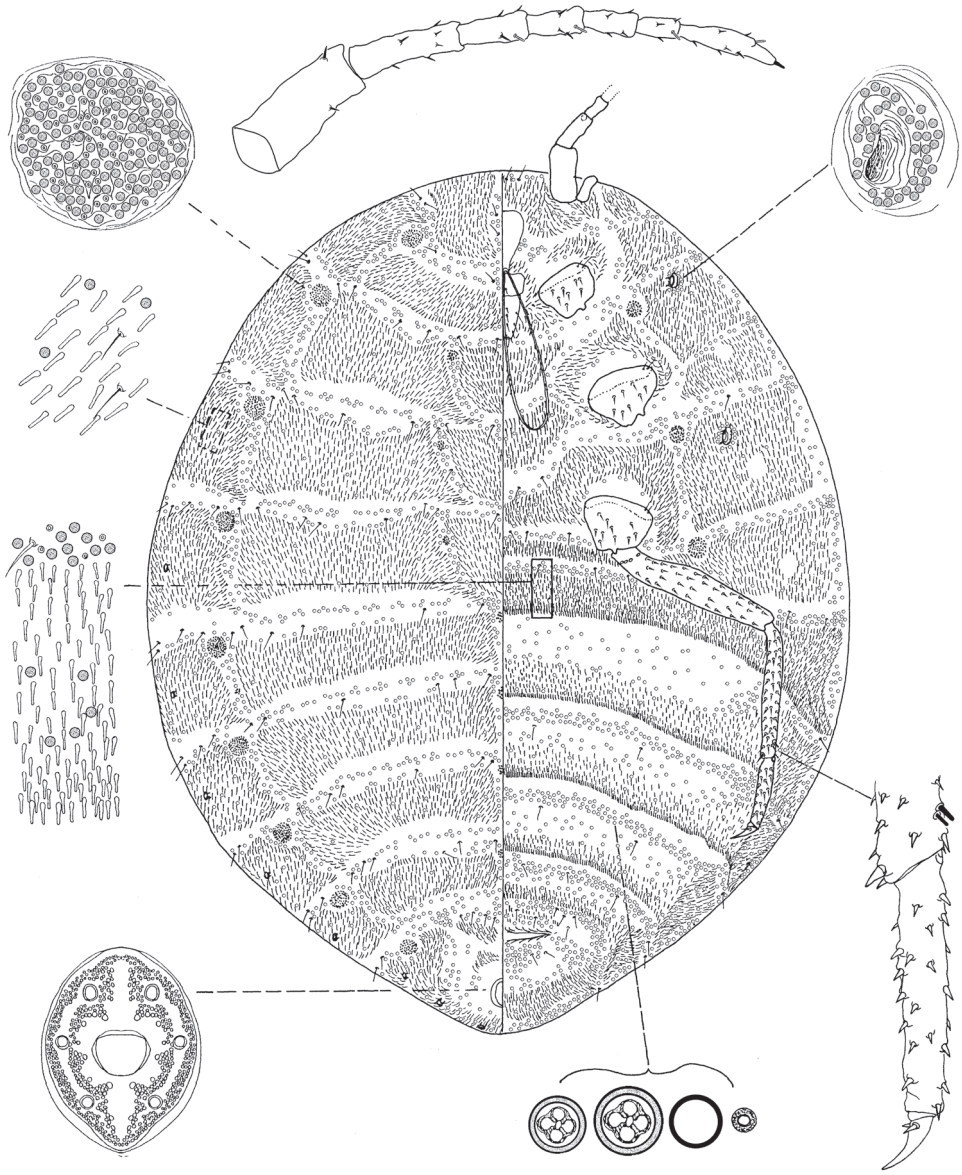

Figure 4. *Arctorthezia pseudoccidentalis* Morrison, 1952, mounted adult female. Illustration by Konczné Benedicty & Kaydan.

Wax plates present on ventral areas of head and thorax, with wide marginal plate laterad of each thoracic spiracle; two wax plates present between mid-coxa in wide triangular shape, below one wide arch shape, with 4 spine rows within ovisac band (Fig. 6g). Thoracic spiracles with wide band of disc pores inside atrium. Setae few, scattered in medial areas of thorax, with several setae near anterior edge of ovisac band and associated with simple pores. Ovisac band wide. With four wide wax plate bands within

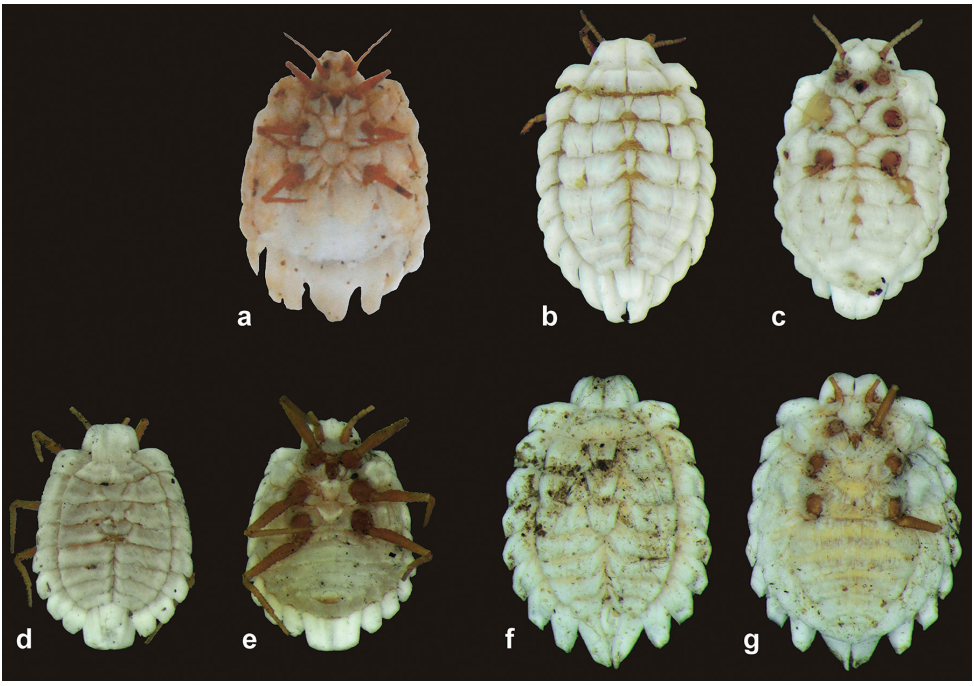

Figure 5. Dorsal and ventral views of unmounted adult female *Arctorthezia* species. *A. helvetica* sp. n., **a** venter. *A. cataphracta* **b** dorsum **c** venter. *A. occidentalis* **d** dorsum **e** venter. *A. pseudoccidentalis* **f** dorsum **g** venter. Photographs by: **a** P. van Helsdingen **b–g** É. Szita.

ovisac band. Multilocular pores with 4loculi around perimeter, 1 loculus in central hub; 5 mm in diameter; present in 4 complete bands near posterior edges of each spine bands, and scattered around vulva.

Dorsum: Wax plates cover all dorsum; three shield-shaped setae plates on middorsum (first 390–540 mm in width, 290–400 mm in length; middle 540–710 mm in width, 330–460 mm in length; third 570–720 mm in width, 370–460 mm in length, Fig. 6h), 9 circular pores clusters, separating the dorsal and marginal wax plate bands. Spines at margin of wax plate 22–27 mm long, spines apically capitate. A few setae present in marginal clusters near posterior edges of marginal wax plates, with 3–6 setae laterad of thoracic spiracles, longest seta 40–50 mm long also present in very small numbers on other wax plates and in medial bare area. Multilocular pores generally with 4 loculi around perimeter, one loculus in central hub, sparsely present in wax plates. Abdominal spiracles 8 pairs on the margin, last 3 in posterior apical spine clusters. Anal ring 161 mm long and 127–138 wide with 6 anal ring blunted setae, each 259–264 mm long.

Distribution. USA (California, Idaho, Nevada, Washington).

Ecology. *Host plant*: *Berberis aquifolium* (Berberidaceae). Grass roots, litter under different trees, often under rocks.

Concluding comment. Macromorphological characters of ortheziid species, such as the shape, number and arrangement of the wax plates of live (or dead) ensign scales

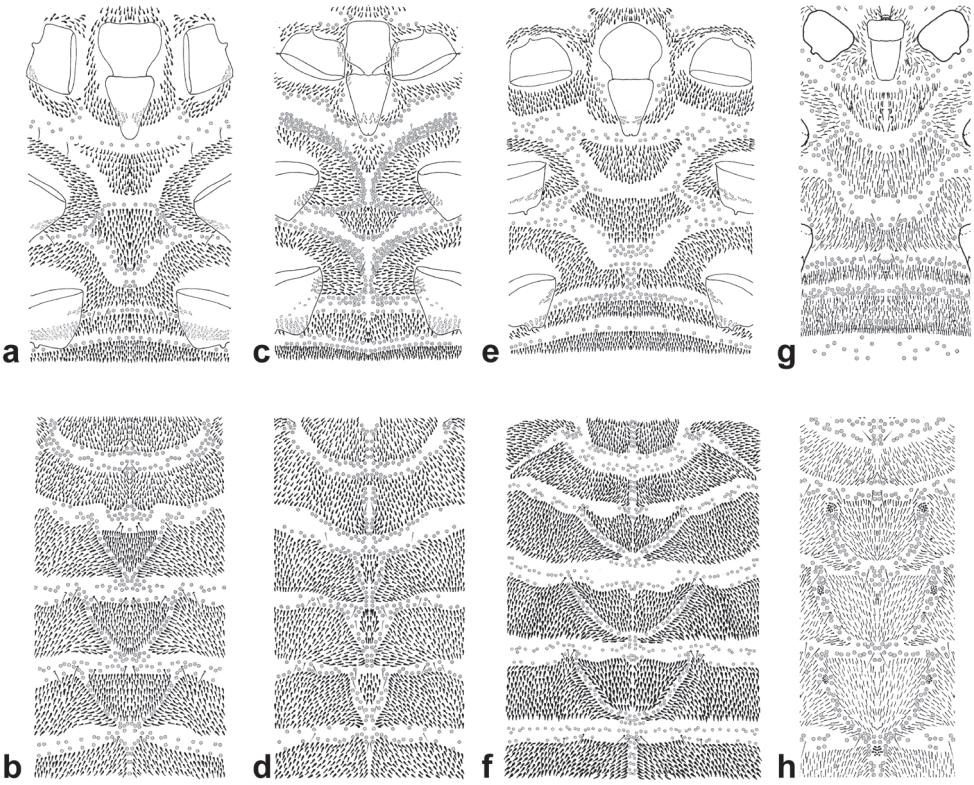

Figure 6. Enlargement of mid-dorsal and mid-ventral thoracic region of *Arctorthezia* species. *A. helvetica* sp. n., **a** ventral **b** dorsal; *A. cataphracta* **c** ventral **d** dorsal; *A. occidentalis* **e** ventral **f** dorsal; *A. pseudoccidentalis* **g** ventral **h** dorsal. Illustrations by Konczné Benedicty & Kaydan.

have been useful for genus and in some cases for species identification (Kondo et al. 2013, Kozár 2004, Szita et al. 2010). These wax plates on the intact body (Fig. 5) do not always have the same appearance as the wax plates of the mounted female (Figs 1–4, 6). For example, the submedial dorsal wax plates of *A. cataphracta* are apparently in two parts on the intact body (Fig 5b), while on the mounted female there is only one undivided wax plate on each tergite in the same position (Fig. 2). In the case of *Arctorthezia* species both the usability and limitations of this method for separating species within the genus are clear; the medial wax plates and midcoxal wax plates can be useful characters for quick separation of species (Figs 5–6). Nevertheless, the correct identification of a species needs always to be confirmed by slide mounting.

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RESEARCH ARTICLE

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New genera, species and records of Phaneropterinae (Orthoptera, Phaneropteridae) from sub-Saharan Africa

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Abstract

The results of the study of many specimens preserved in different European museums are reported. The tribe Terpnistrini Brunner von Wattenwyl, 1878 is resurrected. The distribution of the following species is enhanced: *Pardalota asymmetrica* Karsch, 1896, *Diogena denticulata* Chopard, 1954, *Diogena fausta* (Burmeister, 1838), *Plangiopsis adeps* Karsch, 1896, *Poreuomena sanghensis* Massa, 2013 and *Tylopsis continua* (Walker, 1869). Further, for their peculiar characteristics, two African representatives of the American genus *Symmetropleura* Brunner von Wattenwyl, 1878 are included in two new genera: *Symmetrokarschia africana* (Brunner von Wattenwyl, 1878), **comb. n.** and *Symmetroraggea dirempta* (Karsch, 1889), **comb. n.** A new genus and species from the Democratic Republic of Congo, *Angustithorax spiniger* **gen. n., sp. n.**, and a new genus and species from Tanzania, *Arostratum oblitum* **gen. n., sp. n.** are described. Finally *Melidia claudiae* **sp. n.** and *Atlasacris brevipennis* **sp. n.** are described and compared with related species.

Keywords

Distribution, taxonomy, revision, tropical Africa

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Introduction

Central Africa is one of the richest areas of the world for Orthoptera. Despite the many studies carried out since 1800, this wide geographic region still hides many unknown taxa. One of the groups that shows an amazing diversity of forms and species is that of Phaneropteridae (sensu Heller et al. 2014). There are areas of tropical forests or high mountains where many species belonging to the same genus live together, and localities are known from which dozens of types of species come (e.g., Barombi Station in Cameroon).

The present paper is the result of the study carried out on material collected in sub-Saharan Africa by different collectors and preserved in various museums, and follows two other papers on the same subject (Massa 2013, 2014). It demonstrates that we still lack data on many interesting taxa, and very probably many others are waiting to be discovered.

Material and methods

The study of series of sub-saharan African specimens was possible during visits to the following museums: Museo Nacional de Ciencias Naturales, Madrid; Museum für Naturkunde, Berlin; Museo Civico di Storia Naturale 'G.Doria', Genoa; Museo di Storia Naturale, University of Pavia; in addition some unidentified specimens from Democratic Republic of Congo were obtained on loan from the Museo di Storia Naturale of Terrasini (Palermo).

Abbreviations used in this paper:

BMCP Bruno Massa Collection, University of Palermo;
MfN Museum für Naturkunde, Berlin;
MNCN Museo Nacional de Ciencias Naturales, Madrid;
MRT Museo Regionale di Storia Naturale, Terrasini (Palermo);
MSNG Museo Civico di Storia Naturale 'G.Doria', Genoa;
MSNP Museo Storia Naturale, University of Pavia.

Some specimens were photographed with a Nikon Coolpix 4500 digital camera, mounted on a Wild M5 Stereomicroscope or Leika MZ75, and photos were integrated using the freeware CombineZP (Hadley 2008). Mounted specimens were measured with a digital calliper (precision 0.01 mm); the following measures were taken (all measurements in mm): body length: dorsal length from the head to the apex of the abdomen, ovipositor excluded in females; pronotum length: length of the pronotum along dorsal median line; pronotum height: maximum height of the pronotum; hind femur: length of hind femur; hind tibia: length of hind tibiae; tegmina: length of tegmina; ovipositor: maximum length.

Results

Tribe Pardalotini Brunner von Wattenwyl, 1878

Pardalota asymmetrica Karsch, 1896

Material examined. Democratic Republic of Congo, Nulunau (1800 m) 24.V.1970, T. De Stefani (♀) (MRT).

Distribution. *P. asymmetrica* was described by Karsch (1896) on a series of specimens from Uganda and Tanzania (see also Hollier 2010). It has been recently recorded in the Democratic Republic of Congo by Heller et al. (2014). This new record extends the known distribution of this species westwards.

Tribe Terpnistrini Brunner von Wattenwyl, 1878

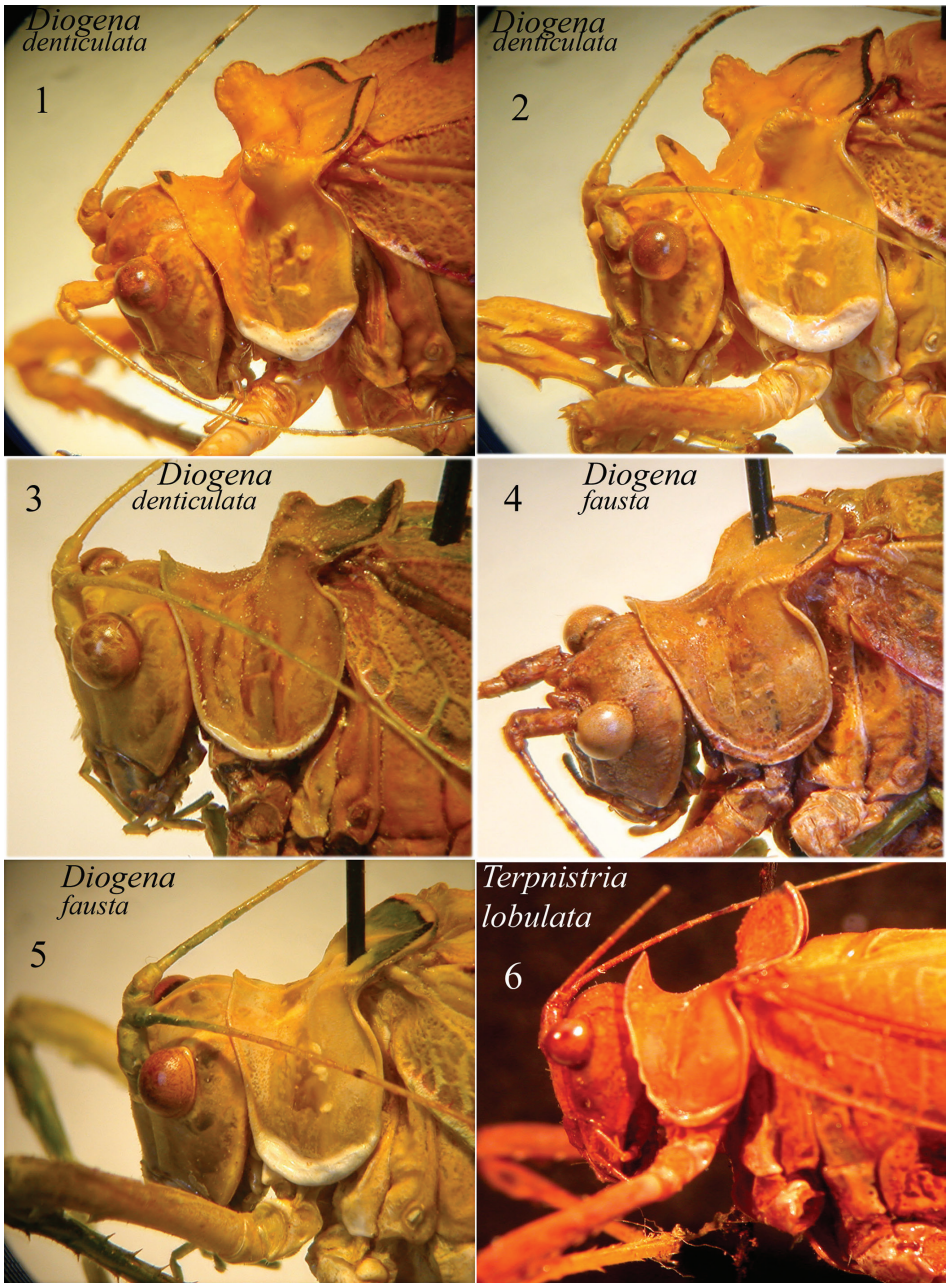
Remarks. Following Ragge (1980) *Terpnistria* Stål, 1873, *Diogena* Brunner von Wattenwyl, 1878 (Figs 1–6) and *Tropidophrys* Karsch, 1896 are most unusual among African Phaneropterinae; the dorsal spurs of the fore and mid tibiae are usually replaced towards the base by broad-based spines; in *Gelotopoia* Brunner von Wattenwyl, 1891 the fore and mid tibiae have no dorsal spurs except at the apex, but the mid tibiae have broad-based, thorn-like dorsal spines on each side. *Terpnistria*, *Diogena* and *Tropidophrys* form a distinct group with thorn-like spines on the legs, frontogenal carinae on the head and characteristic coloration. The fact that they are allopatric suggests a comparatively recent divergence from a more widespread ancestor. *Terpnistrioides* Ragge, 1980 and *Gelotopoia* also seem to stand somewhat apart from the other three genera of the group. Altogether, their general habitus is rather similar, mainly in the shape of the pronotum and the external genitalia. They are generally treated together as a genus group, but the tribe Terpnistrini should be resurrected for these five genera, which is proposed in this study.

Diogena denticulata Chopard, 1954

Figs 1, 2, 3

Material examined. Somalia, Mogadishu 1937, A.Negrotto, I.Cambiasol (♀); Somalia, Bud Bud 28–30.XI-4.XII.1982, S.B.S. (♀); Somalia, El Da 6–7.XII.1982, S.B.S. (♀) (MSNG).

Remarks. According to Chopard (1954), the anterior margin of pronotum is elevated in a triangular point, posterior margin is acute in the middle, lateral tubercles are massive, a little compressed at their upper extremities, irregularly truncated, the female sub-genital plate is triangular, a little rounded at the apex, and foliaceous spines of the



Figures 1–6. Tribe Terpnistrini. **1–3** *Diogena denticulata* from Bud Bud (**1**), El Da (**2**) and Mogadishu (Somalia) (**3**) **4–5** *Diogena fausta* from Burkina Faso **6** *Terpnistria lobulata* from Namibia.

hind femora are much wider than in *D. fausta*, the last two contiguous. The smallest in size of the above specimens has not the triangular point on the fore margin of the pronotum and lateral tubercles are much variable (Figs 1–5).

Distribution. *Diogena denticulata* was described from two females from El Wak (Kenya), not far from the border with Somalia. The male is still unknown. Localities of Somalia listed above are northeast of Mogadishu and next to the border with Kenya; thus, this species has a wider distribution in East Africa and is not confined to Kenya and Tanzania (Hemp 2013).

Diogena fausta (Burmeister, 1838)

Figs 4, 5

Material examined. Burkina Faso, Pama VIII.2004, P.Moretto (♀); Burkina Faso, Yako VIII.2005, P.Moretto (♂); Burkina Faso, Gorom Gorom, Essakane 10–13. IX.2012, 22–24.VIII.2012, 2–4.X.2012, 14.X.2012 (UV trap), P.Moretto (6♂, 9♀); Burkina-Faso, Boromo, Ft. of Sorobouli 4–5.VII.2013 (UV trap), P.Moretto (1♂, 1♀); Burkina-Faso, Dori 23–27.VIII.2013, 30.VIII–5.IX.2013 (UV trap), P.Moretto (6♂, 3♀); Senegal, Niokolo Korba VIII.2008, P.Moretto (♀); Senegal, Niolo du Rip VII.2008, P.Moretto (♂); Guinea, Ziama Forest near Seredou 7.VII.2004, A.Kudrna (♀); Central African Republic, Dzanga-Ndoki National Park, Lac 3, 25–26.II.2012 (UV trap), P.Moretto (♀) (BMCP); Democratic Republic of Congo, Yangambi IV.1964, M.Pavan (2♀) (MSNP).

Distribution. *Diogena fausta* is known from a wide area covering the Middle East, North Africa, from Egypt to Mauritania, the Arabian Peninsula, semi-desert regions of south of the Sahara, East Africa and West Africa (Senegal, the Ivory Coast); the presence in the Central African Republic and Burkina Faso was hitherto unknown (Chopard and Mc Kevan 1954, Ragge 1968a, 1980, Popov 1981).

Tribe Phaneropterini Burmeister, 1838

Genus *Symmetropleura* Brunner von Wattenwyl, 1878

Remarks. When Brunner von Wattenwyl (1878) described the genus *Symmetropleura* (from Latin: *symmetro* = symmetric, equal; *pleura* = side), he placed it in the American group of Scudderiae. According to Brunner von Wattenwyl (1878) characters of the genus are the following: fastigium of vertex triangular and sulcate; pronotum disc flat, with lateral excisions, anterior margin straight, and rounded posterior margin; tegmina wide with rounded hind margin or narrow with straight hind margin; fore and mid femora with ventral inner spines, hind femora with double row of ventral spines. Fore and mid tibiae dorsally unarmed or with some spinules; cerci long, in-curved and pointed; male sub-genital plate short with rounded posterior margin or (in *S. africana*) long with triangular apex; styli absent; ovipositor longer than pronotum, not much curved, sharp, with upper and lower apices serrate (differently shaped in *S. africana*: see below); female sub-genital plate triangular, just concave. In the description Brunner von Wattenwyl (1878) referred mainly to *S. laevicauda*, both within the text and in the

figure 73; thus, by subsequent designation, Kirby (1906) established *S. laevicauda* as the type-species of the genus. The description of the female of *S. laevicauda* by Brunner von Wattenwyl (1878) from Bahia (Brasil) is as follows (translated from Latin): small (28 mm), tegmina width about two times the length of pronotum, anterior margin basally pale with a darker outer area, posterior margin rounded. Radius forked before Media, ovipositor little up-curved, acuminate.

Ragge (1968b, 1980) pointed out that *Symmetropleura* is a New World genus, occurring in South America, Mexico and eastern USA, and that the two African species are not very similar either to each other or to the Neotropical type-species of the genus. He observed also that the name *Cameronia* Karsch, 1888 was available for *S. africana*. However, the genus *Cameronia* should be considered a junior homonym, because was pre-occupied since 1879, when *C. spekii* Bourguignat (Mollusca Bivalvia) was described from Lake Tanganyika (R. Poggi, pers. comm.)[1].

There are three African species so far included in the genus *Symmetropleura*: one of them is *S. africana*, others are *S. dirempta* Karsch, 1889, that occurs in Madagascar, treated below, and *S. plana* (Walker, 1869), that occurs in South Africa. Concerning the latter, some photographs, kindly taken by C. Hemp, show that the pronotum is not keeled and the male sub-genital plate has a very different shape from that of *S. africana* and *S. dirempta*; it is very probable that it belongs to another undescribed genus, but specimens were not available to establish this.

For the reasons reported above and below, two new genera are described for *Symmetropleura africana* and *S. dirempta*.

Genus *Symmetrokarschia* gen. n.
http://zoobank.org/DE10724C-FD67-483D-9611-B663BD047F0D

Type-species. *Symmetropleura africana* Brunner von Wattenwyl, 1878, here designated.

The original description of the male holotype of *Symmetropleura africana* Brunner von Wattenwyl, 1878, from Congo is the following (translated from Latin): large (37 mm), pronotum disc with regular impressed punctures, wide tegmina, with rounded hind border, radius forked before media, male tenth tergite laminate and protruding, with straight hind border, cerci little in-curved, with flat apex and pointed, sub-genital plate long, narrow, with obtuse and short cut apex; the description of the female from Chinchoxo (Cameroon) by Karsch (1889) reports the ovipositor shape, shorter than pronotum, with upper border and apex of lower border finely serrulate. Karsch (1889) observed the differences between *S. africana* and others of the genus and reported it as: *S.* (*Cameronia*) *africana*. Later, only Bolívar (1906) recorded this species with the name used by Karsch, which we hardly may interpret as a subgenus, not still used at that time (cf. Ragge 1968b).

[1] The name *Cameronia* of Bourguignat was overlooked and another genus *Cameronia* was described in 1948 by Basin for a nematode Oxyurida, parasite of *Gryllotalpa*, pre-occupied as well, but currently used (R. Poggi, pers. comm.).

Etymology. After the German entomologist and arachnologist Ferdinand Karsch (1853–1936), whose contribution to the knowledge of tropical African Orthoptera was really remarkable; he also observed the differences between African and American species of the genus *Symmetropleura*.

Remarks. Main differences between *Symmetrokarschia* and *Symmetropleura* are: in *Symmetropleura* lateral margins of metanotum are keeled, male sub-genital plate is short with rounded margin, ovipositor is longer, basally straight and gently arcuate in the posterior part.

***Symmetrokarschia africana* (Brunner von Wattenwyl, 1878), comb. n.**
Figs 7–13

Material examined. Cameroon, Chinchoxo (2♀) (MfN); Angola, Dundo (1♂) (MCNM).

Redescription. Fastigium of vertex compressed, narrower than first antennal segment, sulcate above (Fig. 9). Eyes oval, prominent, without fronto-genal carinae. Pronotum just depressed, fore part with just definite lateral carinae, central and hind parts with vague lateral carinae; fore margin slightly concave, posterior margin rounded; surface dotted, matt (Figs 7–9). Fore coxae with a long spine (Fig. 10). Fore tibiae with open tympanum on each side, furrowed on upper border. Fore and mid femora with 3–5 spines, hind femora with 5–8 inner ventral and 6–7 outer ventral spines. Fore and mid tibiae with 1 dorsal and 1 ventral spur, hind tibiae with 3 apical spurs on each side. Male tenth tergite laminate and protruding, with straight posterior margin, cerci little in-curved, with flat apex and pointed, sub-genital plate long, narrow, with obtuse and short cut apex, styli absent (Fig. 13b). Ovipositor well developed, sharply bent upwards near the base, shorter than pronotum, with upper border and apex of lower border finely serrate (Fig. 12), sub-genital plate triangular and pointed (Fig. 11). Tegmina are oval, more pronounced in the female (Fig. 7) than in male (Fig. 13a).

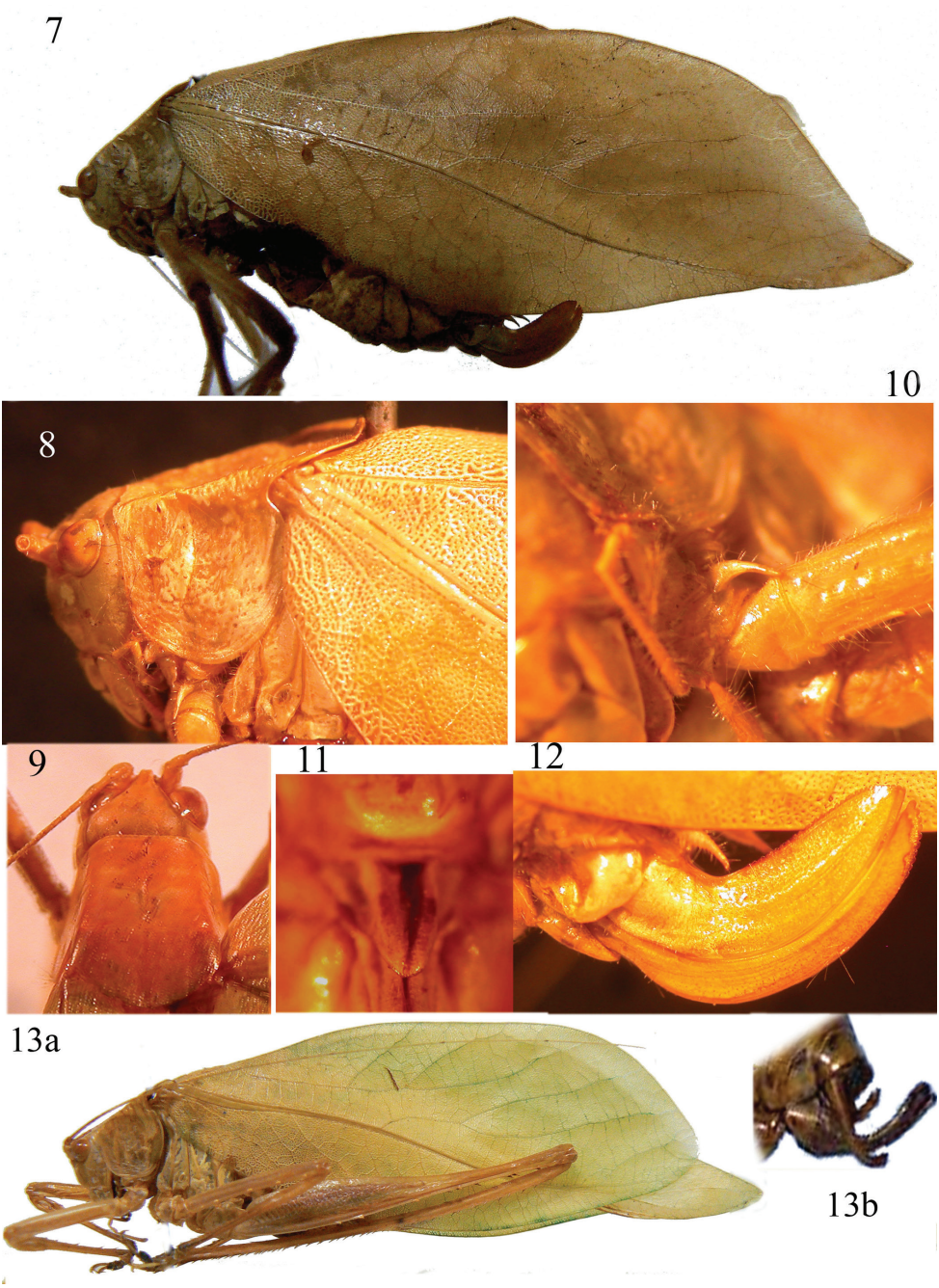
Distribution. Democratic Republic of Congo, Cameroon and Angola.

Genus *Symmetroraggea* gen. n.
http://zoobank.org/DC6C78C5-B2E5-402E-A694-B847E654CFFC

Type-species. *Symmetropleura dirempta* Karsch, 1889, here designated.

Among the species described within the genus *Symmetropleura* Brunner von Wattenwyl, 1878, Karsch (1889) included also *S. dirempta* from Madagascar, that has the characters reported below, not corresponding to those of the genus *Symmetropleura* (see above the translation of the description of the type-species *S. laevicauda*, in particular the round margin of upper tibiae and the fronto-genal carinae present in *Symmetroraggea* gen. n.).

Etymology. The genus is dedicated to David R. Ragge, authority on African Phaneropteridae taxonomy, who also pointed out the differences of African *Symmetropleura* when compared to American species (Ragge 1968b, 1980).



Figures 7–13. *Symmetrokarschia africana* (Brunner von Wattenwyl, 1878) from Cameroon. Lateral view of female (**7**), pronotum in lateral view (**8**) and from above (**9**), spine on fore coxa (**10**), sub-genital plate of female ovipositor (**11**), lateral view of the ovipositor (**12**), lateral view of male (**13a**) and last abdominal segments of male (**13b**).

***Symmetroraggea dirempta* (Karsch, 1889), comb. n.**
Figs 14–19

Material examined. Madagascar, Nossi bé, Hildabrandt (♂ holotype of *S. dirempta*) (MfN); it bears a label with a former identification: *laevicauda* Brunner.

Redescription. Eyes oval, with fronto-genal carinae below them (Figs 15–16); fastigium clearly narrower than first antennal segment, sulcate above. Flat pronotum, without lateral carinae, with the exception of the last part of metanotum, whose margins are sharp (Figs 15–16). Very narrow tegmina, with posterior margin nearly straight (Fig. 14), Radius of wing just forked before media, the fore base is black, as well as a longitudinal line bordering the stridulatory area and extending posteriorly with a wide marking on left tegmen (Fig. 17); coxae armed, 6 spines on ventral margin of fore femora, 6 inner spines plus 1 spur and 6 outer spines plus 1 spur on ventral margins of fore tibiae, fore tibiae dorsally rounded, not sulcate, mid femora with 7 outer spines, mid tibiae with 12 outer spines plus 1 spur and 5 inner spines plus 1 spur, hind femora with 7 outer and 4 inner spines, hind tibiae with 13 outer and 11 inner spines plus 3 spurs in each side; male tenth tergite posteriorly not protruding, with hind margin concave, male supra-genital plate protruding, with very acuminate apex, cerci stout, long, incurved, with pointed apex, male sub-genital plate exceeding cerci, long, triangular, posteriorly narrowed, with deeply cut apex, whose margins are parallel and close between them (Figs 18–19); titillators[2] are present and show a long, downcurved and hooked apex, with 2 spines basally and 3–4 small spines dorsally on each border (Figs 18–19).

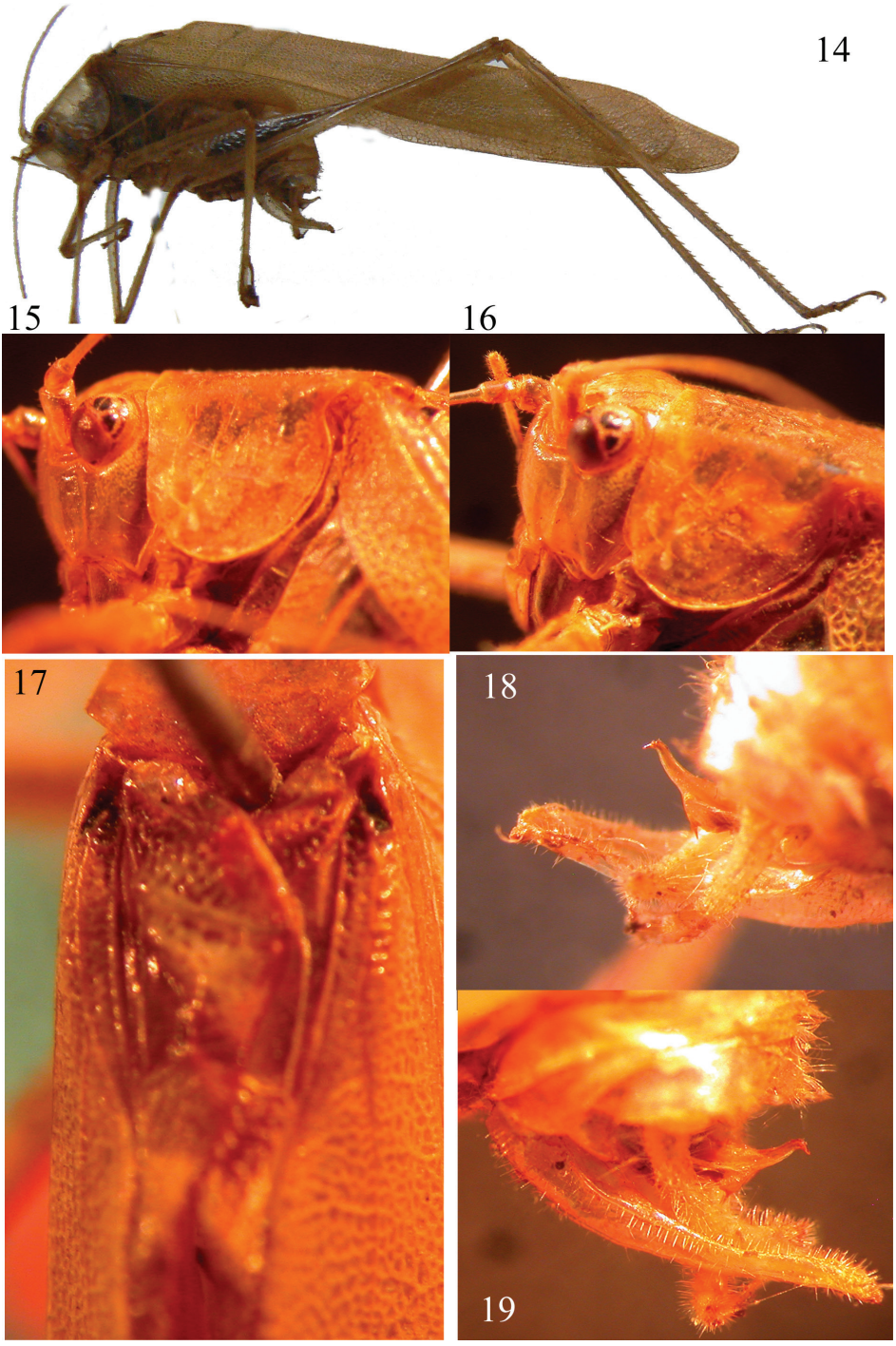
Distribution. *Symmetroraggea* gen. n. is known only from Madagascar, where only one species has been recorded, *S. dirempta* (Krauss, 1889), of which only the type is known.

***Plangiopsis adeps* Karsch, 1896**

Material examined. Cameroon, Lolodorf, L.Conradt (2♀ syntypes) (MfN); Central African Republic, Dzanga-Ndoki National Park, Ndoki, Lake 1 10–11.II.2012 (UV trap), P.Moretto (1♀); same data 28–29.II.2012 (1♂); same data 29.II–1.III.2012 (1♀); Ivory Coast, Bondoukou Zamou VII.2004, P.Moretto (2♂, 4♀); Ivory Coast, Sassandra I.1998, P.Moretto (1♂); Togo, Fazao hotel 3–4.VIII.2013 (UV trap), P.Moretto (2♀); Togo, Kpalimé, Ft of Missahöhe 29–30.VII.2013, P.Moretto (1♂) (BMCP).

Remarks. *Plangiopsis adeps* is the largest species of the genus; only females from Cameroon (Lolodorf) were described by Karsch (1896). New distribution data now suggest that this species is widespread throughout Cameroon and Central African Republic to the Ivory Coast and Togo. Sexual characters of the male, previously undescribed, are the following: cerci slender and long, in-curved and a little up-curved, sub-genital plate narrow and long, ending with a v-shaped concavity, styli long. The stridulatory file is comparatively long.

[2] Titillators have been recently found in other genera of African Phaneropterinae (Massa 2013).



Figures 14–19. *Symmetroraggea dirempta* (Karsch, 1888), male holotype from Madagascar. Lateral view of habitus (**14**), lateral view of head and pronotum (**15**), lateral view of head (**16**), dorsal view of tegmina (**17**), right (**18**) and left (**19**) view of genitalia.

***Poreuomena sanghensis* Massa, 2013**

Material examined. Cameroon, Bare-Dschang 2–6.XII.1908, Riggenbach (2♂); Cameroon, Victoria (3♀) (MfN).

Among specimens of *Poreuomena* of MfN there are 5 unidentified specimens of this species, recently described from Central African Republic (Massa 2013).

Genus *Melidia* Stål, 1876
Figs 20–31

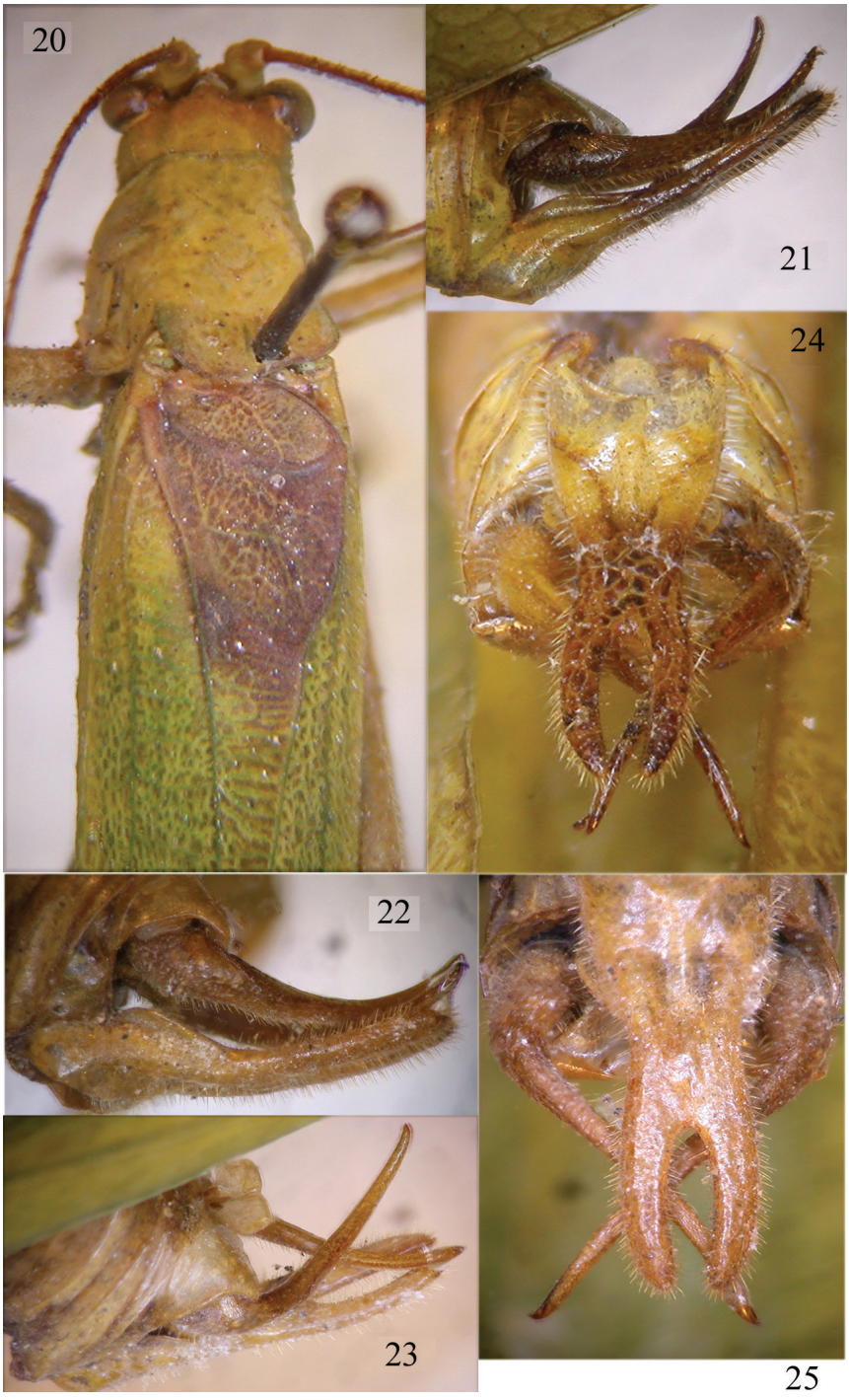
Remarks. The genus *Melidia* Stål, 1876 is characterized by the fastigium of the vertex, which is prominently raised in the region of the lateral ocelli. It looks like the genus *Phaneroptera*, but differs from this mainly in the shape of the head, the male cerci and the sub-genital plate, and broader fore wings. It has a well-developed spine on the fore coxae and males have the stridulatory region of the left tegmina brown or conspicuously marked with brown (Ragge 1980).

***Melidia claudiae* sp. n.**
http://zoobank.org/90BC4041-BD4F-4B19-A729-D66AFD4FE46B
Figs 20–26

Material examined and depository. *Melidia claudiae* sp. n.: Democratic Republic of Congo, Lubumbashi (11°42'1.06"S, 27°31'57.07"E) 1.II.1968 (♂ holotype), 5.II.1968 (♂ paratype), T. De Stefani (MRT). *Melidia laminata* Chopard, 1954: Tanzania, Kilimanjaro (♂) (MCNM). *Melidia brunneri* Stål, 1876: Namibia (♂) (MCNM); Namibia, Okahandja (4♂, 2♀); Namibia, Okahandja, near Waterberg 1936, W.Hoesch (1♂, 2♀); Namibia, Gobabis I.1897 (1♂); Namibia, Keetmanshoop (1♂); Namibia (1♂); SW Africa 11.XI.1903 (1♂); South Africa, Rietfontein II.1897, Borchmann (1♂) (MfN). *Melidia kenyensis* Chopard, 1954: Kenya (♀ holotype in OSF).

General habitus and colour. Yellow with green tegmina, antennae brownish. The stridulatory region of left tegmen is brown. Abdomen yellowish with brown vertical stripes on posterior margins of tergites.

Description. Male. Medium sized (Fig. 26). Head and antennae: fastigium of vertex very narrow, scarcely furrowed above, separated from the fastigium of frons, which is tuberculated. Eyes rounded, well projecting (Fig. 20). Legs comparatively long, green. Fore coxae armed with a well-developed spine. Fore tibiae furrowed on upper margin, distinctly widening above tympanum, which is open on inner and outer sides. Fore femora armed on inner ventral margin with 3–4 spines, fore tibiae with 1 spine plus 1 spur on inner and outer ventral margins, 1 spur on outer dorsal margin, mid femora armed with 2 spines on outer ventral margin, mid tibiae with 8 on outer



Figures 20–25. *Melidia claudiae* sp. n. Head, pronotum and tegmina of holotype from above (**20**), lateral view of cerci and sub-genital plate of holotype (**21–22**) and paratype (**23**), ventral view of the sub-genital plate of the holotype (**24**) and paratype (**25**).

and 5 spines on inner ventral margins, plus 1 spur on each side, hind femora armed with 3–4 small spines on outer and 2 on inner ventral margins, hind tibiae with many spines on ventral and dorsal margins and 3 spurs on each side. Thorax: pronotum little narrowing anteriorly, flat above, anterior margin straight, posterior margin rounded, humeral sinus evident, lobes of pronotum rounded (Fig. 20). Tegmina comparatively narrow with convex fore margins and rounded apices. Wings longer than tegmina (Fig. 26). The stridulatory region of left tegmen is long (Fig. 20). Abdomen: tenth tergite with a straight hind margin; sub-genital plate long and deeply divided into two robust in-curved lobes; styli absent (Figs 24–25). Cerci long, fine and decussate, longer than the sub-genital plate (Figs 21–23).

Female. Unknown.

Etymology. *Melidia claudiae* is dedicated to the German orthopterist Claudia Hemp, who is working with competence and great interest on the Orthoptera of tropical Africa, Phaneropteridae in particular.

Distribution. Democratic Republic of Congo. Considering that other species are currently known from Kenya, Tanzania, Nigeria, Botswana, South Africa and Namibia (Chopard 1954, Ragge 1980, Hemp 2013), it is likely that the genus covers a wider distribution and further species will be found.

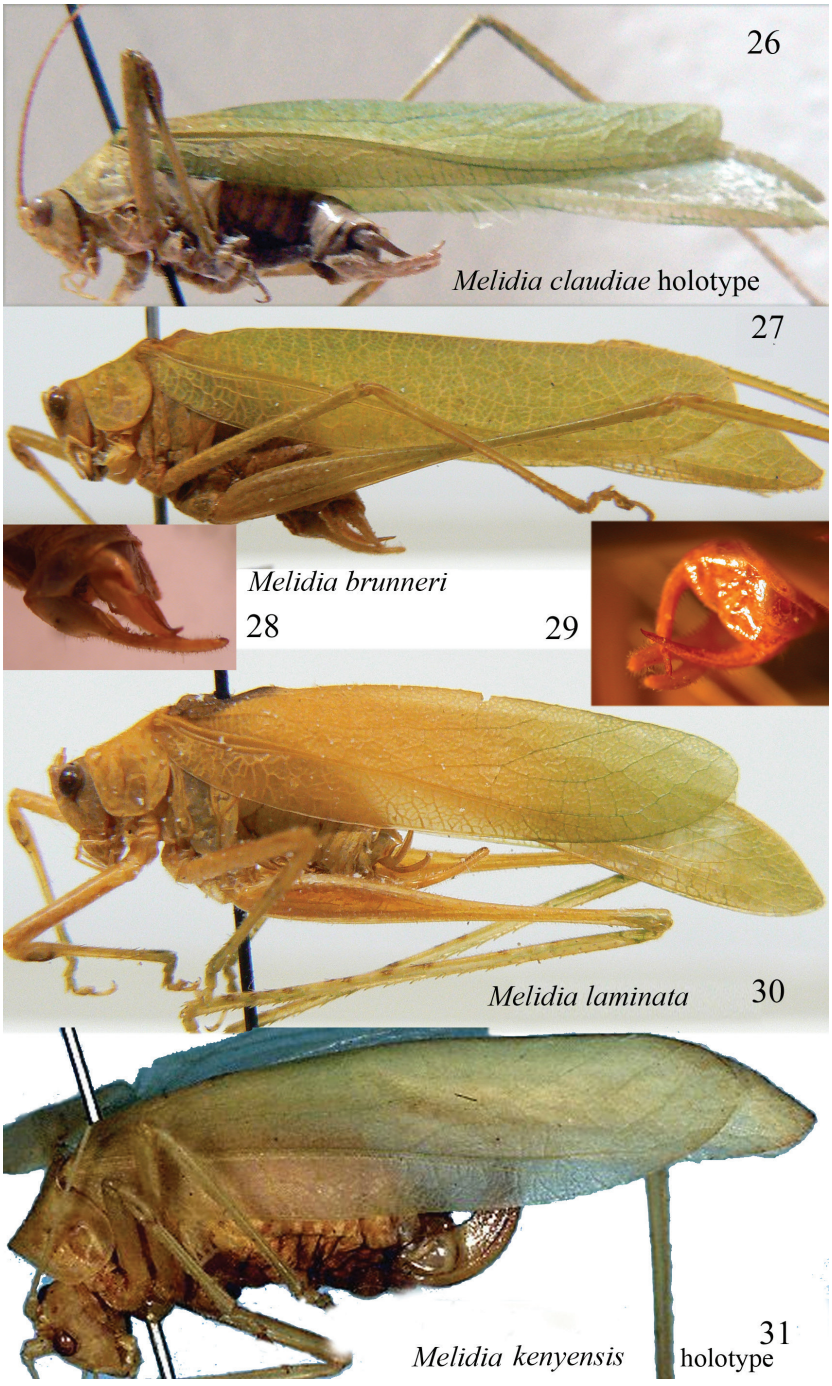
Measurements. Body length: 15.1–15.2; pronotum length: 3.6–3.9; pronotum height: 3.0–3.2; hind femur: 17.0–17.5; tegmina: 25.9–26.5.

Diagnosis. *Melidia kenyensis* Chopard, 1954 was described from Kenya (Chopard 1954). Although only the female is known, it has a different shape of tegmina than *M. claudiae* sp. n. (Fig. 31). *Melidia laminata* Chopard, 1954 (Fig. 30), described from Kenya (Wajir, El Katulo) and recorded from Kilimanjaro (Tanzania) by Hemp (2013) is more similar in tegmina shape to the new species, but the male sub-genital plate is longer, surpassing the cerci (Fig 29). *Melidia brunneri* Stål, 1876 (Fig. 27) from southern and central Africa (Ragge 1980) is more similar to *M. claudiae* sp. n., but differs from it in the shape of the male sub-genital plate, which is longer than cerci (Fig. 28). Further, the cerci of *M. brunneri* are more robust and shorter than those of *M. claudiae* sp. n. (compare Figs 23 and 28), and the tegmina are broader than those of *M. claudiae* sp. n. (compare Figs 26 and 27).

Tylopsis continua (Walker, 1869)

Material examined. Democratic Republic of Congo, Goma 14.I.1968, T. De Stefani (♂, morph with unicolor pronotum) (MRT).

Distribution. According to Ragge (1964), *T. continua* is widespread in southern Africa, with records also in Zimbabwe, Mozambique, Tanzania and Angola. The record from Goma, on the border between the Democratic Republic of Congo and Rwanda, expands the distribution of this species further.



Figures 26–31. Species of the genus *Melidia*. Lateral view of *Melidia claudiae* sp. n. (**26**), lateral view of *M. brunneri* holotype (**27**), cerci and sub-genital plate of *M. brunneri* from Namibia (**28**), cerci and sub-genital plate of *M. laminata* (**29**), lateral view of *M. laminata* (**30**) and *M. kenyensis* (**31**). Photo **27**, **29**, **30** and **31** by S. Ingrisch for OSF.

Genus *Angustithorax* gen. n.
http://zoobank.org/24EA627C-9066-466F-9B2C-08426273483E

Type species. *Angustithorax spiniger* sp. n., here designated.

Description. Head and antennae: fastigium of vertex narrow and pointed, not contiguous with the fastigium of frons, much narrower than the first antennal segment (Figs 34–35). Eyes round, moderately prominent (Figs 33–35), placed behind antennae. The scapus is placed within an area with raised margins and is a bit narrower than the eye. Face with fronto-genal carinae below antennae (Fig. 35). Thorax: pronotum as long as high, narrow and compressed, mainly anteriorly, well-developed humeral excision. Legs: upper and lower margins of legs densely covered by hairs. Fore coxae armed with a long and flattened spine (Fig. 36), fore and mid femora laterally compressed (Fig. 34); fore femora with ventral spines, fore tibiae with ventral spines, closed tympanum on inner side and open on outer side. Mid femora and tibiae with ventral spines. Hind femora with ventral spines, hind tibiae with ventral spines. Tegmina well developed, slightly shiny and shorter than hind wings (Fig. 32). Abdomen: male tenth abdominal tergite unmodified, sub-genital plate without styli, very long, upward curved and pointed; cerci are also very long and in-curved, decussate below the sub-genital plate[3] (Figs 37–38).

Diagnosis. This genus is vaguely similar to *Miltinobates* Sjöstedt, 1902, mainly in the shape of fastigium of vertex and in the sub-genital plate; however, *Miltinobates* has longer and rounded legs, the medial field of fore wings has clear parallel veins, its sub-genital plate is wider and its size is much bigger.

Etymology. From Latin: *angustus* = narrow, *thorax* = cuirass; because of its very slender pronotum and the entire slender habitus.

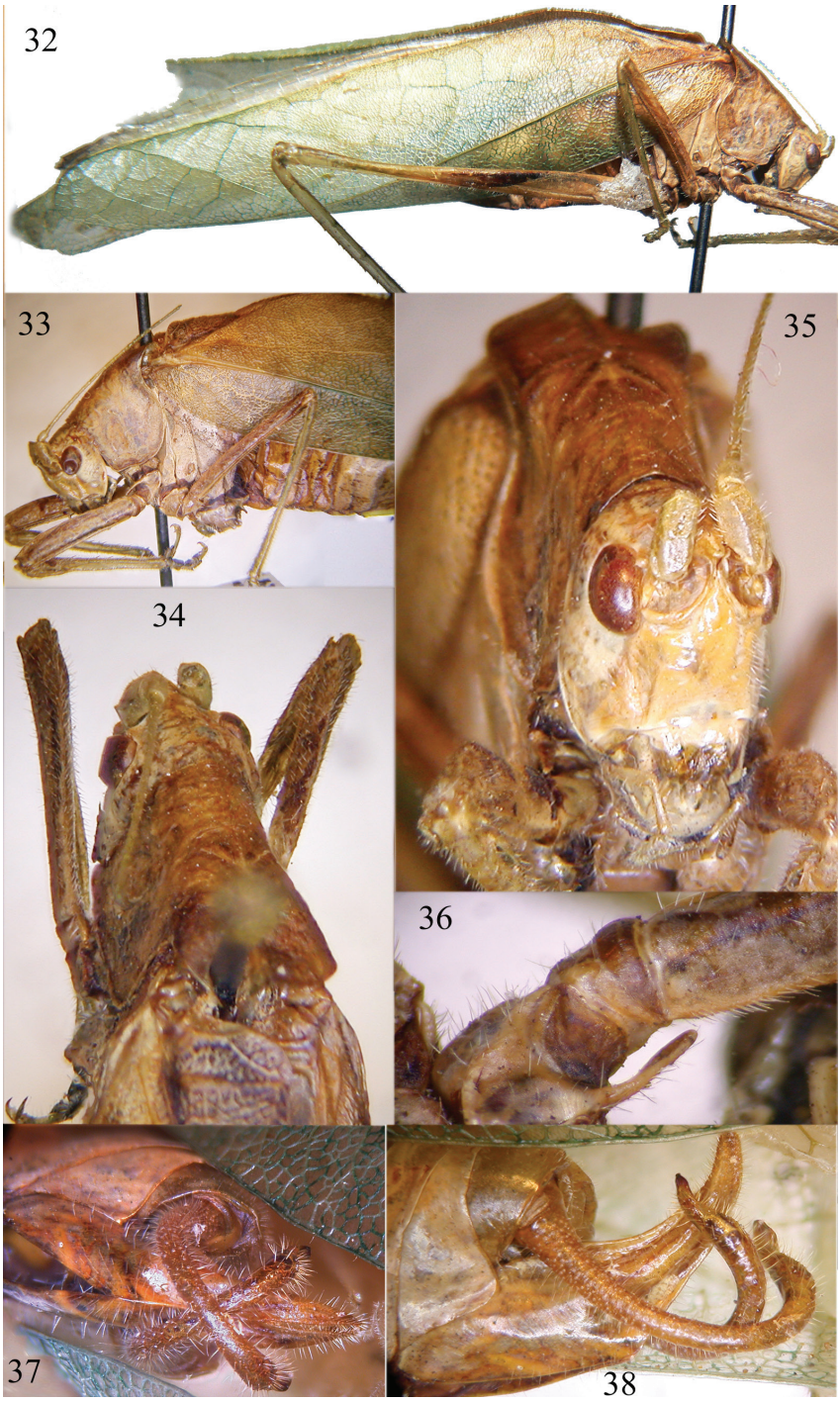
***Angustithorax spiniger* sp. n.**
http://zoobank.org/73B54715-EB4A-4AF6-9069-AA85F82DCBB3
Figs 32–38

Material examined and depository. Democratic Republic of Congo, Lubumbashi (11°42'1.06"S, 27°31'57.07"E) 3.II.1968 (♂ holotype), T. De Stefani (MRT).

General habitus and colour. Yellow-green. The stridulatory area of left tegmen is brownish.

Description. Male. Head and antennae: fastigium of vertex narrow and pointed, not contiguous with the fastigium of frons, much narrower than the scapus, not furrowed above (Figs 34–35). Eyes round, moderately prominent (Figs 33–35), placed behind antennae. The scapus is placed within an area with raised margins and is just narrower than the eye. Face with sparse hairs, narrow with fronto-genal carinae below antennae, forming a small triangular area (Fig. 35). Thorax: pronotum longer than

3 This may be artificial in the mounted specimen and the living insect might hold the cerci otherwise.



Figures 32–38. *Angustithorax spiniger* gen. n., sp. n. Lateral view of holotype (**32**), lateral view (**33**) and dorsal view of pronotum (**34**), frontal view of head (**35**), spine on fore coxa (**36**), ventral (**37**) and lateral view (**38**) of cerci and sub-genital plate.

high, without lateral carinae, much narrow and compressed, mainly anteriorly, surface shiny, well developed humeral excision on the lateral lobes (Fig. 33). Anterior margin of pronotum straight, posterior margin rounded, pronotum lobes rounded on posterior margins, sinuous on lower margins. Legs: upper and ventral borders of legs densely covered by hairs (Fig. 35). Fore coxae are armed with a long and flattened spine (Fig. 36), fore and mid femora are laterally compressed (Fig. 34); fore tibiae have conchate tympanum on inner side and open on outer side; fore femora have 6 inner ventral spines and 2 spines on outer margin, fore tibiae have 6 inner and 4 outer spines on ventral margins, plus 1 spur on each side, upper margin is furrowed and apically unarmed; mid femora have 8 spines on outer ventral margin, mid tibiae have 9 outer and 6 inner spines on ventral margins, plus 1 spur on each side, upper margin is apically unarmed; hind femora have 7 outer and 2 inner ventral spines, hind tibiae have many ventral and dorsal spines plus 2 spurs on inner margin and 3 spurs on outer margin. Tegmina are well developed, slightly shiny and shorter than hind wings, medial field has only crossed veinlets, in the rest of tegmina veinlets delimit small hexagons (Fig. 32). The stridulatory area of left tegmen is comparatively long (Fig. 34). Abdomen: male tenth abdominal tergite is unmodified, styli are absent, sub-genital plate is very long, upward curved and pointed. The cerci are also very long and in-curved, decussate and apically pointed with a black tip (Figs 37–38). The sub-genital plate and cerci are covered by hairs.

Female. Unknown.

Measurements. Body length: 23.3; pronotum length: 5.9; pronotum height: 4.9; hind femur: 20.2; tegmina: 37.2.

Diagnosis. Very slender body, fore coxae are armed with a long and flattened spine, cerci long and decussate.

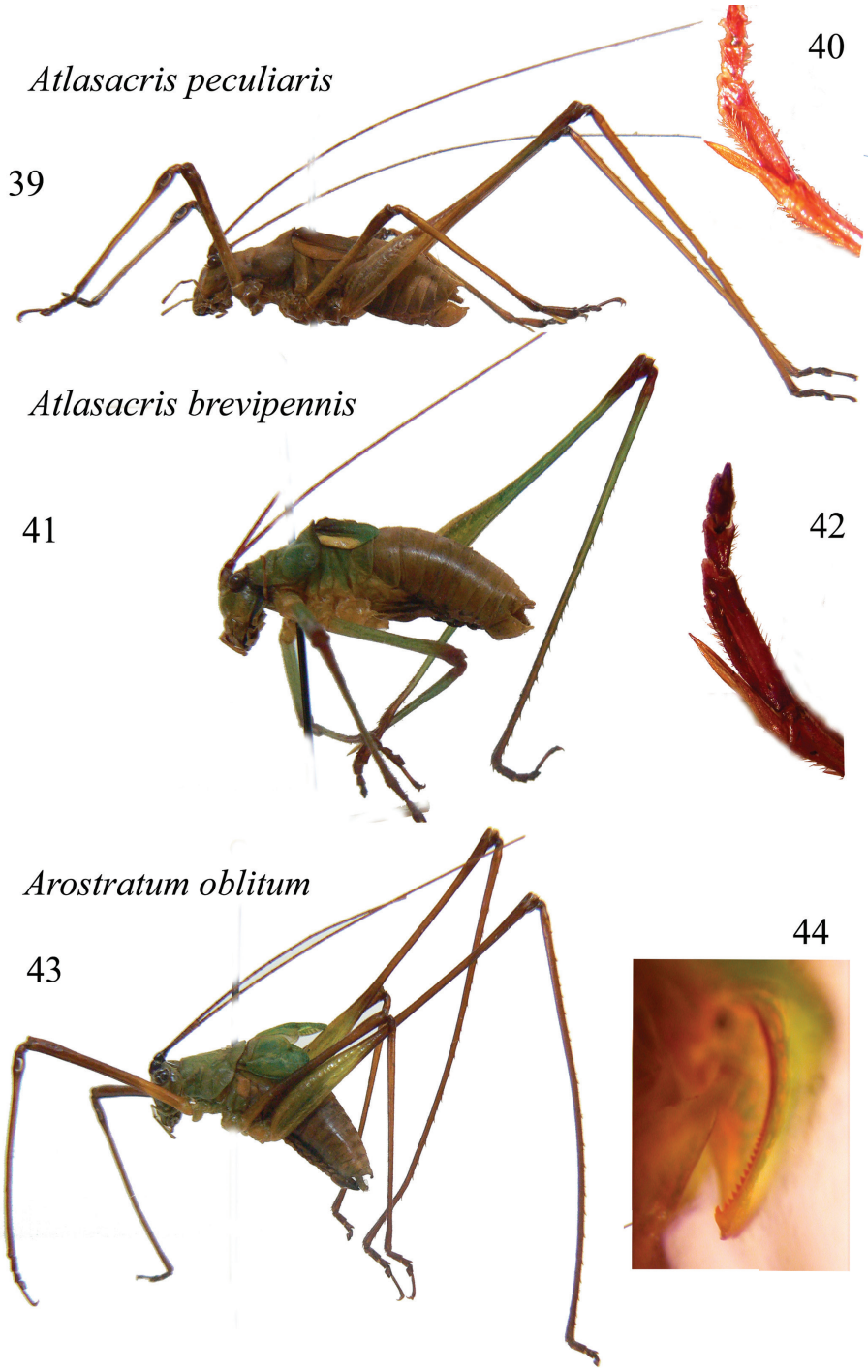
Etymology. From Latin: *spiniger* = thorny, after the long and stout spine on the fore coxae.

Distribution. Only known from the type locality: Lubumbashi (Democratic Republic of Congo).

Tribe Odonturini Brunner von Wattenwyl, 1878

Genus *Atlasacris* Rehn, 1914

Remarks. The genus is characterized by fastigium of vertex compressed, narrower than first antennal segment, eyes circular, prominent, pronotum markedly selliform with posterior part of lateral lobes strongly inflated, surface smooth and matt, fore coxae may be armed with a small spine or not, femora unarmed, fore tibiae with open tympana on each side, fore wings reduced to short lobes, hind wings vestigial. The male mid tibiae have a much enlarged and up-curved ventral spur, its first tarsal segment is greatly enlarged, more than twice as that of fore legs, the female has not the inflated pronotum and is lacking spurs on mid tarsi (Rehn 1914, Ragge 1980).



Figures 39–44. *Atlasacris* and *Arostratum* gen. n. Lateral view of males of *Atlasacris peculiaris* (**39**), *Atlasacris brevipennis* sp. n. (**41**) and *Arostratum oblitum* gen. n., sp. n. (**43**); mid tibia spur of male of *Atlasacris peculiaris* (**40**) and *Atlasacris brevipennis* (**42**); stridulatory file of *Arostratum oblitum* gen. n., sp. n. (**44**).

***Atlasacris peculiaris* Rehn, 1914**
Figs 39, 40, 51, 53

Material examined. Uganda, Ruwenzori, 2500 m II.1908 (Deutsche Zentr.-Afr.-Exp.), R.Grauer (♂ holotype, originally in alcohol, now mounted); Democratic Republic of Congo, Kwidschwi-Inseln, Kiwu-See, IX.1907 (Deutsche Zentr.-Afr.-Exp) (♂ paratype, originally in alcohol, now mounted) (MfN).

Remarks. The male of *Atlasacris peculiaris* has tegmina just exceeding the 2nd abdominal segment, overlapped for the half of their length, brown with a longitudinal clearer stripe on the fore border (Fig. 39). The most peculiar character is found on the mid tibiae, which end with a long spur, which is little shorter than the first tarsal segment, and is as long as the following ones together (Fig. 40). The female does not show these characters and the tegmina are very short, less than half the pronotum length.

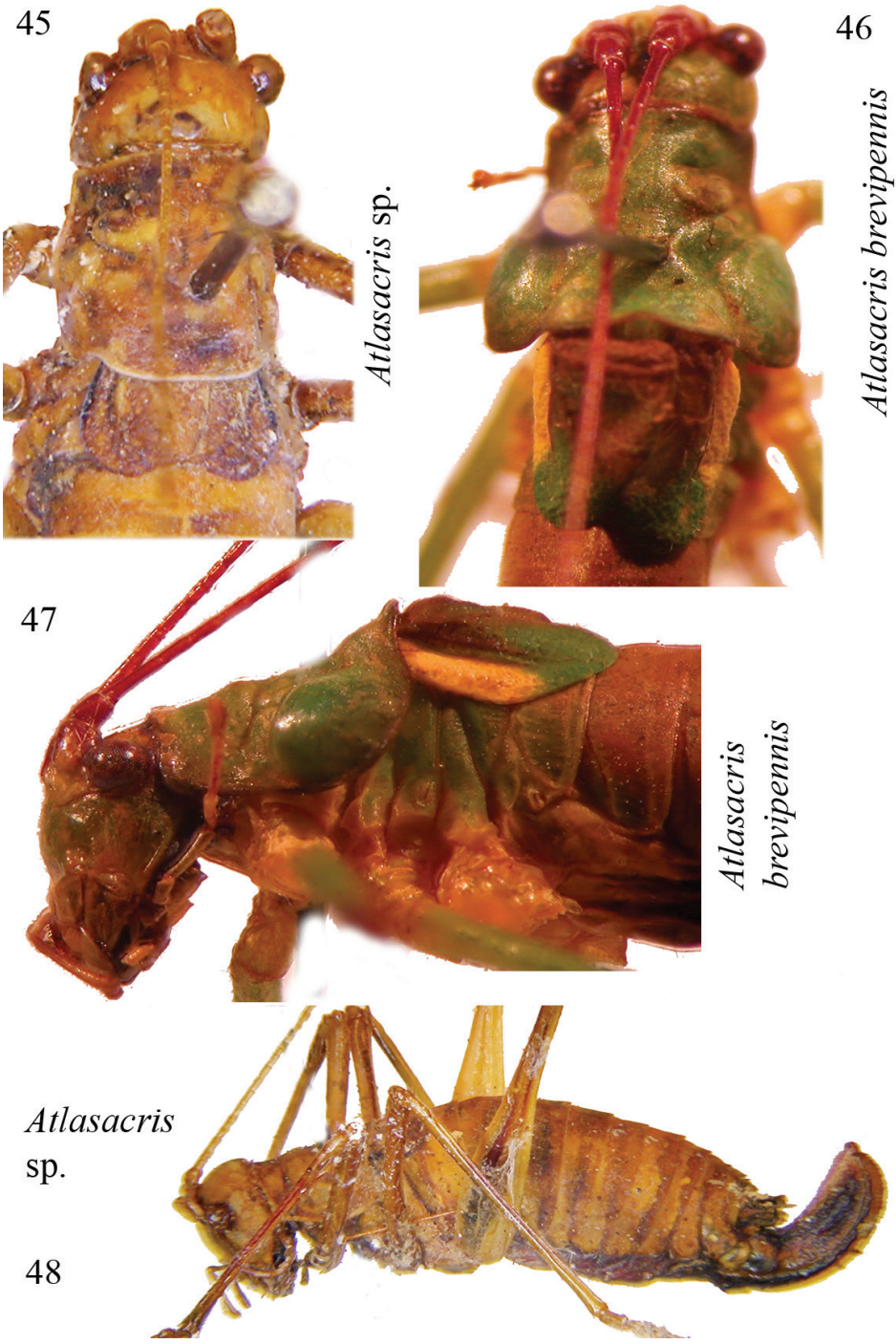
Distribution. According to Ragge (1980) known distribution of *A. peculiaris* covers the region of Albert-Edward-Kiwa Valley, from Ruwenzori to Burundi.

***Atlasacris brevipennis* sp. n.**
http://zoobank.org/A8212038-F75F-4E48-9A20-CC1B95F27926
Figs 41, 42, 46, 47, 52

Material examined and depository. NW Tanganyika (now Tanzania) 1910 (♂ holotype), Grauer (MfN).

General habitus and colour. Antennae reddish, green on the face, pronotum and apical parts of tegmina; also femora are green, but their apex is reddish; tibiae are green with apex and base reddish, tarsi are reddish; fore area of tegmina brown, their fore borders cream; abdomen yellow.

Description. Male. Head and antennae: head long, eyes round, prominent. Fastigium of vertex compressed, narrower than the first antennal segment, sulcate above, a small concave in lateral view. Thorax: pronotum without carinae, undulated and selliform, with inflated posterior lateral and hind parts, anterior margin rounded, posterior margin undulate and inflated (Figs 41, 46-47). Legs: the spine on fore coxae is not present, fore tibiae have 3 spines on the outer ventral margin plus apical spur, 2 spines on outer upper margin plus apical spur, and only apical spur on upper inner margin; femora are unarmed. Tympana of fore tibiae are open. Mid tibiae end with a long inner spur and the first tarsal segment is longer than the other ones and shows a long concavity, where the long spur may be hidden (Fig. 42). Tegmina are reduced, just surpassing the 1st abdominal segment, overlapping for most of their median length (Fig. 46). Alae present, but concealed below tegmina. The stridulatory file corresponds to that described by Hemp et al. (2009) for *Monticolaria* Sjöstedt, 1909; it consists of about 50 teeth. The proximal part contains more teeth (about 35) than the much longer distal part which bears around 20 large, asymmetrical and widely spaced teeth. The right tegmen has a wide triangular speculum that covers ca. ¾ of the tegmen



Figures 45–48. Genus *Atlasacris*. Dorsal view of the female of *Atlasacris* sp. from the Democratic Republic of Congo (**45**), and of the male of *Atlasacris brevipennis* sp. n. (**46**); lateral view of head, pronotum and tegmina of the male of *Atlasacris brevipennis* sp. n. (**47**); lateral view of the female of *Atlasacris* sp. (**48**).

length. Abdomen: tenth tergite enlarged, with a wide concavity and two postero-lateral pointed and up-curved tips (Figs 49–50); the sub-genital plate is long and has apically a v-shaped concavity. Styli are absent, but two small protrusions are present on the lateral tips of the sub-genital plate (Fig. 52). Cerci are stout, in-curved and with an apical in-curved pointed tip.

Female. Unknown.

Measurements. Body length: 16.2; pronotum length: 4.0; fore femur: 7.2; mid femur: 7.4; hind femur: 18.7; tegmina: 3.4.

Etymology. From Latin: *brevis* = short, *pennis* = feather, because of its reduced tegminal lobes.

Diagnosis. *A. brevipennis* is smaller than *A. peculiaris* (body length 16.2 vs 17–19.5; pronotum length 4.0 vs 4.6–5.2; tegmina: 4.0 vs 5.2–5.5; hind femora: 18.7 vs 19.5–21.5) and the shape of tegmina is clearly different (Figs 39, 41, 46, 47); speculum of *A. peculiaris* covers ca. half the length of right tegmen. Tenth tergite, cerci and sub-genital plate of *A. peculiaris* (Figs 51, 53) are very similar to those of *A. brevipennis* sp. n.

Distribution. *Atlasacris brevipennis* sp. n. is known only from the type locality: NW Tanzania.

***Atlasacris* sp.**
Figs 45, 48

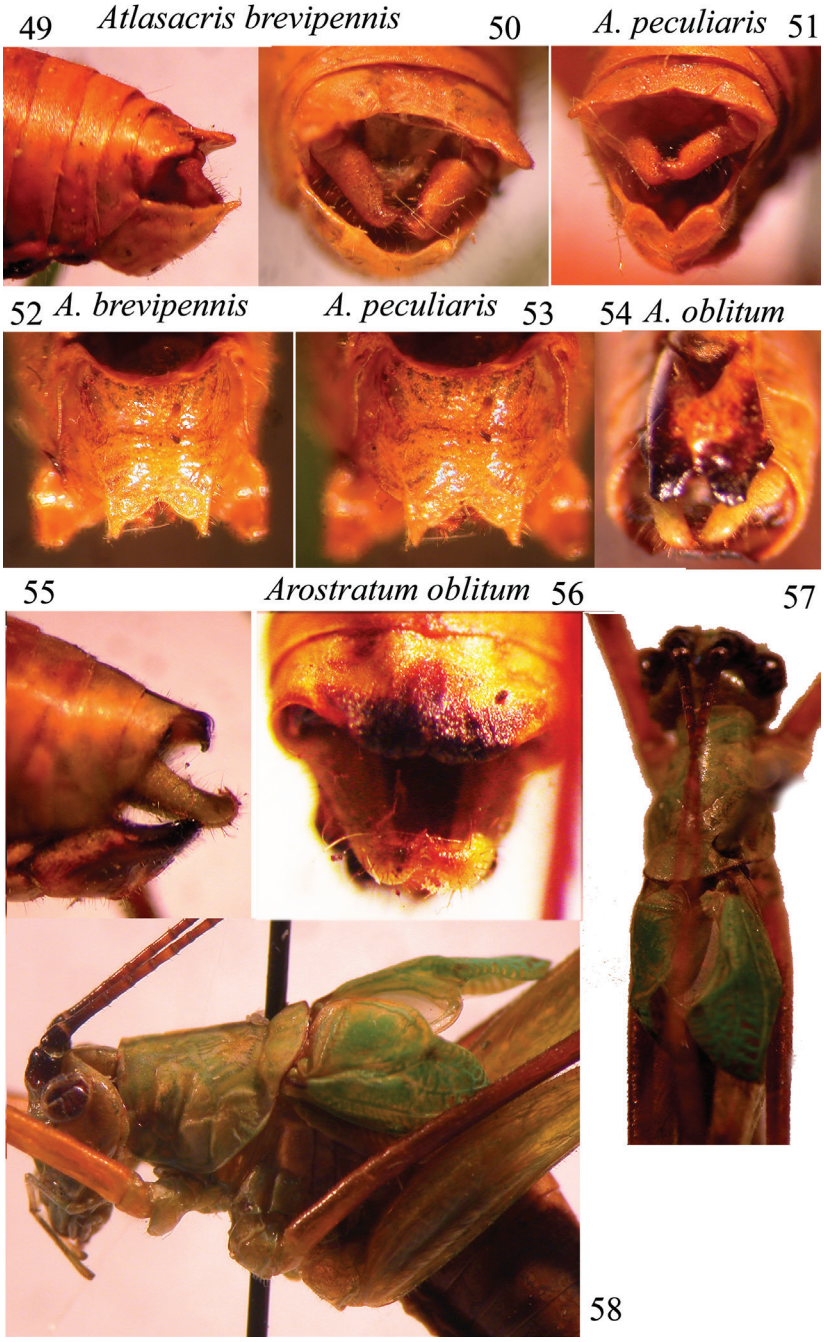
Material examined. Democratic Republic of Congo, Kahuzi National Park (1°55'44.37"S, 28°0'50.52"E) (2200–2700 m) 15.IX.1971, T. De Stefani (1♀) (MRT).

Remarks. In the female of *Atlasacris peculiaris* pronotum is not selliform and inflated, mid tibiae do not have the *Atlasacris* characteristic ventral spur and a first long tarsal segment, and the tegmina are very short (♂ 4.6–5.2, ♀ 2.2), less than half the pronotum length (cf. Rehn 1914). The ♀ listed above, characterized by its very short tegmina (1.4 mm) (Figs 45, 48), has a very small spine on the fore coxae, that consents to exclude that it belongs to the gen. *Monticolaria* Sjöstedt, 1910 (Hemp et al. 2009). Due to the existence of another species of *Atlasacris*, described above, the finding of one female without the male does not allow a reliable identification. Here the measurements of the specimen are reported and in parenthesis those of the female paratype of *A. peculiaris* recorded by Rehn (1914) are given. However, this paratype is no more present in the MfN.

Measurements. Body length: 17.1; pronotum length: 3.6 (4.2); pronotum height: 2.6 (3.5); fore femur: 6.7 (8.0); mid femur: 6.8 (8.0); hind femur: 15.7 (19.0); tegmina: 1.4 (2.2); ovipositor: 6.1 (7.2).

Genus *Arostratum* gen. n.
http://zoobank.org/66430012-FB2B-4683-B5F1-4D68CA51FDA0

Type species. *Arostratum oblitum* sp. n., here designated.



Figures 49–58. *Atlasacris* and *Arostratum* gen. n. Lateral (**49**) and dorsal (**50**) view of last abdominal segments and cerci of *A. brevipennis* sp. n.; dorsal view (**51**) of last abdominal segments of *A. peculiaris*; sub-genital plate of *A. brevipennis* sp. n. (**52**), *A. peculiaris* (**53**) and *A. oblitum* gen. n., sp. n. (**54**); lateral (**55**) and dorsal view (**56**) of last abdominal segments of *A. oblitum* gen. n., sp. n.; dorsal (**57**) and lateral (**58**) view of head, pronotum and tegmina of *A. oblitum* gen., n. sp. n.

Description. Head and antennae: 1st antennal segment larger than fastigium, eyes round. Legs: open tympana on both sides of fore tibiae. Coxae unarmed. 4 spines are present on ventral outer margin of fore tibiae, spines on femora are lacking. Mid tibiae without apical spur and first tarsal segment is of normal size. Thorax: pronotum with a small inflated area on metanotum. Tegmina very short, 2nd pairs of wings very reduced. Abdomen: tenth tergite almost straight, cerci in-curved, ending with a pointed tip at right angle. Sub-genital plate with a v-shaped concavity and thickened margins. Styli absent.

Diagnosis. Peculiar characters of this genus are the very long legs, hind femurs being 1.4 longer than the body length. *Arostratum* gen. n. is clearly related to *Atlasacris*, *Monticolaria*, *Odonturoides* and *Meruterrana* Sjöstedt, 1912. *Arostratum* gen. n. shows very unique characters, as the absence of the enlarged spur on the mid tibiae of the male (that are present in males of *Atlasacris*, *Monticolaria*, *Odonturoides* and *Meruterrana*: Ragge 1980) and the very long legs. In *Atlasacris* male hind femurs are 1.1–1.2 longer than the body length (in the female of *A. specularis* they are as long as the body, Rehn 1914), in *Monticolaria* the male hind femurs are 0.8–1.0 times as the body length. Also the external genitalia are very characteristic, as given in the description of the new species *Arostratum oblitum*.

Etymology. From Latin: *Arostratum* = without rostrum or spur.

***Arostratum oblitum* sp. n.**
http://zoobank.org/D331F578-2CFC-44BD-8187-91CB8A10FF18
Figs 43, 44, 54–58

Material examined and depository. NW Tanganyika (now Tanzania) 1910 (♂ holotype), Grauer (MfN).

General habitus and colour. First antennal segments are black, other reddish, pronotum and tegmina green, abdomen brownish, femora green and yellowish, tibiae reddish. The apex of tenth tergite and of sub-genital plate are black.

Description. Male. Head and antennae: fastigium of vertex compressed, much narrower than the first antennal segment, eyes round, prominent (Figs 57, 58). Antennae longer than the body. Legs: open tympana are present on both sides of fore tibiae. Coxae unarmed. 4 spines plus 1 apical spur are present on ventral external margin of fore tibiae, 1 spine is present on outer upper margin and no spurs are present on apical upper margins; mid tibiae with 3 spines on outer ventral margin plus 2 small apical spines; 2 apical spines are also present on inner ventral and on inner dorsal margins; hind tibiae have some spines on ventral margins plus 4 apical spines; many spines are present on upper margins of hind tibiae plus 2 apical ones; spines are absent on femora. Thorax: pronotum without lateral carinae, anteriorly narrower than on the posterior part, similar to that of *Atlasacris*, with a small inflated area on lower and posterior areas (Figs 43, 58). Tegmina are very short, not exceeding the 2nd abdominal segment (Figs 57–58). Wings are reduced to very small scales. As in *Atlasacris*, the stridulatory file matches the model described by Hemp et al. (2009) for *Monticolaria*; it consists of

about 50–60 teeth. The proximal part contains more teeth (about 40) than the distal part, which bears around 17–18 large, asymmetrical and widely spaced teeth, in the same space of former 40 teeth. The last tooth on the posterior border of left tegmen is similar to a hook, longer and bigger than previous ones (Fig. 44); it probably produces a sound similar to a click. The right tegmen has a wide triangular speculum that covers ca. ¾ of the tegmen length. Abdomen: tenth tergite almost straight with undulate and down-curved posterior margin (Figs 54, 55, 56), cerci are stout, in-curved, ending with a pointed black tip, placed at right angle (Fig. 56). The sub-genital plate is long with an apical v-shaped concavity and thickened lateral margins. Styli are absent (Fig. 54).

Female. Unknown.

Diagnosis. Small species with very short wings and very long legs, pronotum anteriorly narrower than on the posterior part, with a small inflated area on lower and posterior areas.

Measurements. Body length: 14.2; pronotum length: 3.4; fore femur: 11.2; mid femur: 10.4; hind femur: 20.0; hind tibiae: 24.0; tegmina: 4.8.

Etymology. From Latin: *oblitum* = forgotten. The specimen here treated of *Arostratum oblitum* sp. n. was collected in 1910 and was forgotten for 73 years, when in 1983 D. Ragge studied it and established that it was belonging to one unidentified genus; finally, 104 years after its collection it is described.

Diagnosis of *Atlasacris*, *Arostratum* gen. n. and related genera

Hemp et al. (2009) have pointed out some characteristics of *Monticolaria*, shared with *Meruterrana*, *Odonturoides* and *Atlasacris*, in particular the presence of a long apical spur on the mid tibiae of males. They share also reduced wings (but *Meruterrana elegans* Sjöstedt, 1912 has less reduced wings). In addition, Hemp et al. (2009) have found in *Monticolaria* a peculiar stridulatory file, consisting of two parts, the distal one composed of large, asymmetrical and widely spaced teeth. The study of the male specimens of *Odonturoides jagoi* Ragge, 1980 (MfN) showed that also in the genus *Odonturoides* Ragge, 1980 the stridulatory file is similar to that found in *Monticolaria*. Moreover, Naskrecki and Bazelet (2011) found a similar stridulatory file in the genus *Austrodontura* Fontana et Buzzetti, 2004. Additionally, the study of stridulatory files in different species of the Palaearctic genus *Odontura* Rambur, 1838 (BMCP) confirmed the same type discovered by Hemp et al. (2009). Thus, the same model was found in African genera *Monticolaria*, *Atlasacris*, *Austrodontura*, *Odonturoides*, *Arostratum* gen. n., and in the Palaearctic genus *Odontura*; however, *Odontura*, *Austrodontura* and *Arostratum* gen. n. do not have the enlarged apical spurs on the mid tibiae in males and the stridulatory file of *Arostratum* gen. n. has a final hook, not present in related genera. *Arostratum* gen. n. probably presents the ancestral state of Phaneropterinae with normal spurs on the mid tibiae and long legs and probably the distal "hook" on the stridulatory file is an apomorphism. Altogether, the similar type of the stridulatory file (that is responsible for the song type and therefore sexual relationships) suggests that also *Arostratum* gen. n. is closely related to *Monticolaria*, *Meruterrana*, *Odonturoides*, *Atlasacris* and *Odontura*.

The genera treated above (except *Odontura*) are located in a region covering Uganda, Kenya, Tanzania, the Democratic Republic of Congo and Burundi, corresponding to the Eastern Arcs. According to Hemp et al. (2009) this area is a well-known hotspot of biodiversity: many of Saltatoria species are endemic to these mountain ranges. The fact that they are sympatric suggests a comparatively old divergence from isolated ancestors on single mountains or single mountainous habitats in respective areas.

Acknowledgements

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RESEARCH ARTICLE

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A new species of the genus *Orthotemnus* Wollaston, 1873 (Coleoptera, Curculionidae, Cossoninae) from China

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Abstract

A new species, *Orthotemnus longitarsus* **sp. n.**, is described from China, representing the first record of the genus *Orthotemnus* Wollaston, 1873 from China. Illustrations of diagnostic features of the new species and a key to all six species of the genus *Orthotemnus* (including *O. reflexus* Wollaston, *O. disparilis* Pascoe, *O. filiformis* Champion, *O. expansus* Hustache and *O. ulmi* Zherichin) are provided. All type specimens of the new species are deposited in the National Zoological Museum in the Institute of Zoology, Chinese Academy of Sciences, Beijing, China.

Keywords

Weevil, Proecini, morphology, systematics, plectra, key, China, new record

Introduction

Based on the classification of Alonso-Zarazaga and Lyal (1999), *Orthotemnus* belongs to the tribe Proecini in the subfamily Cossoninae. The genus was erected by Wollaston (1873) for *O. reflexus*, described from specimens collected by Wallace in Dorey, New Guinea, as well as in Batchian, Makian and Ceram. Pascoe (1885) described a second

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species, *O. disparilis*, from Cape York, Northern Australia, and Champion (1914) a third, *O. filiformis*, from a single specimen (♀ ?) collected by Scott at Silhouette in the Seychelles. The fourth species, *O. expansus*, was described by Hustache (1955) based on one specimen collected from Watsa, Kibali-Ituri, D.R. Congo. Zherikhin (in Zherikhin and Egorov 1990) added the fifth species, *O. ulmi*, collected from rotten timbers of elm (*Ulmus*) at the Ussuriysk reserve in the Far East of the USSR. Morimoto (1973) and Zhang (1992) presented diagnostic features for the genus *Orthotemnus* in their respective keys to the Oriental and Chinese genera of Cossoninae (also see Folwaczny 1973).

The aim of this paper is to establish the first record of the genus *Orthotemnus* for China by describing a new species from Jiangsu province in eastern China and to provide a key to all the known species currently recognised in *Orthotemnus*.

Materials and methods

The type specimens of the new species are deposited at the Institute of Zoology (IOZ), Chinese Academy of Sciences (CAS), in Beijing, China. Morphological observations were made using a Zeiss Semi stereomicroscope Discovery V12, and photos were taken using a Micropublisher 5.0 RTV digital camera, model MP5.0-RTV-CLR-10A-color 10 BIT, attached to the same stereomicroscope. The recognition of the new species and the key to the species are based on comparison of the Chinese specimens with the original descriptions and illustrations of the previously described species.

All measurements were taken using an ocular micrometer. Abbreviations of characters given in the text are as follows: **ACL** – antennal club length; **ACW** – antennal club width; **AFL** – antennal funicle length; **AL** – antennal length; **ASL** – antennal scape length; **BL** – body length (excluding rostrum); **EL** – elytral length; **EWB** – elytral width at base; **EWW** – elytral width at widest part; **PL** – pronotal length; **PW** – pronotal width (widest part); **RL** – rostral length; **RWA** – rostral width at apex; **RWB** – rostral width at base.

Hind wing terminology follows Zherikhin and Gratshev (1995).

Taxonomic treatment

Orthotemnus Wollaston, 1873

Type species. *Orthotemnus reflexus* Wollaston, 1873: 489, by monotypy.

Diagnosis. *Body* (5.50–6.60 mm) not or slightly compressed longitudinally, elongate; derm glossy, glabrous, at most with sparse setae on elytra. *Rostrum* rather long and robust, much shorter than pronotum; longer than head; often wider before antennal insertion (equal width throughout: Wollaston (1873)). *Antennae* inserted above middle of rostrum in lateral view so that anterior part of scrobes visible from above;

scapes reaching or passing hind margin of eyes, longer than funicles; funicles with seven segments. *Head* with forehead between eyes as broad as or broader than base of rostrum; postocular constriction not touching eyes. *Eyes* large, distance between eyes and postocular constriction shorter than diameter of eye. *Pronotum* not bisinuate at base (if weakly bisinuate, tarsal segment 5 broadest near base and tapering distally, or derm matt); triangular, truncate at base, as wide as elytral base. *Elytra* evenly parallel-sided, linearly truncated at base, not setose, recurved at their apex. *Legs*. with pro- and mesocoxae very widely and subequally separated, metacoxae less remote than pro- and mesocoxae; procoxae not very close to hind margin of prosternum; tibiae normal; tarsal groove of front tibiae not or bluntly pointed laterally; tarsi with segment 3 small, simple, entire or slightly notched, segment 5 normal, clavate, not compressed (Wollaston 1873, Hustache 1924, Morimoto 1973, Zhang 1992).

***Orthotemnus longitarsus* Omar & Zhang, sp. n.**
http://zoobank.org/F8FA4CA4-ECE4-4998-8137-FA8A1EE5AB5C
Figs 1–40

Diagnosis. Rostrum widening after antennal insertion; scapes passing posterior margin of eye and reaching postocular constriction; temples swollen; forehead with short median furrow; sutural striae deep and depressed near scutellum; intervals smooth, equal, convex, with a single row of fine punctures, wider than striae; humeri truncate, quadrate; tarsi longer than tibiae.

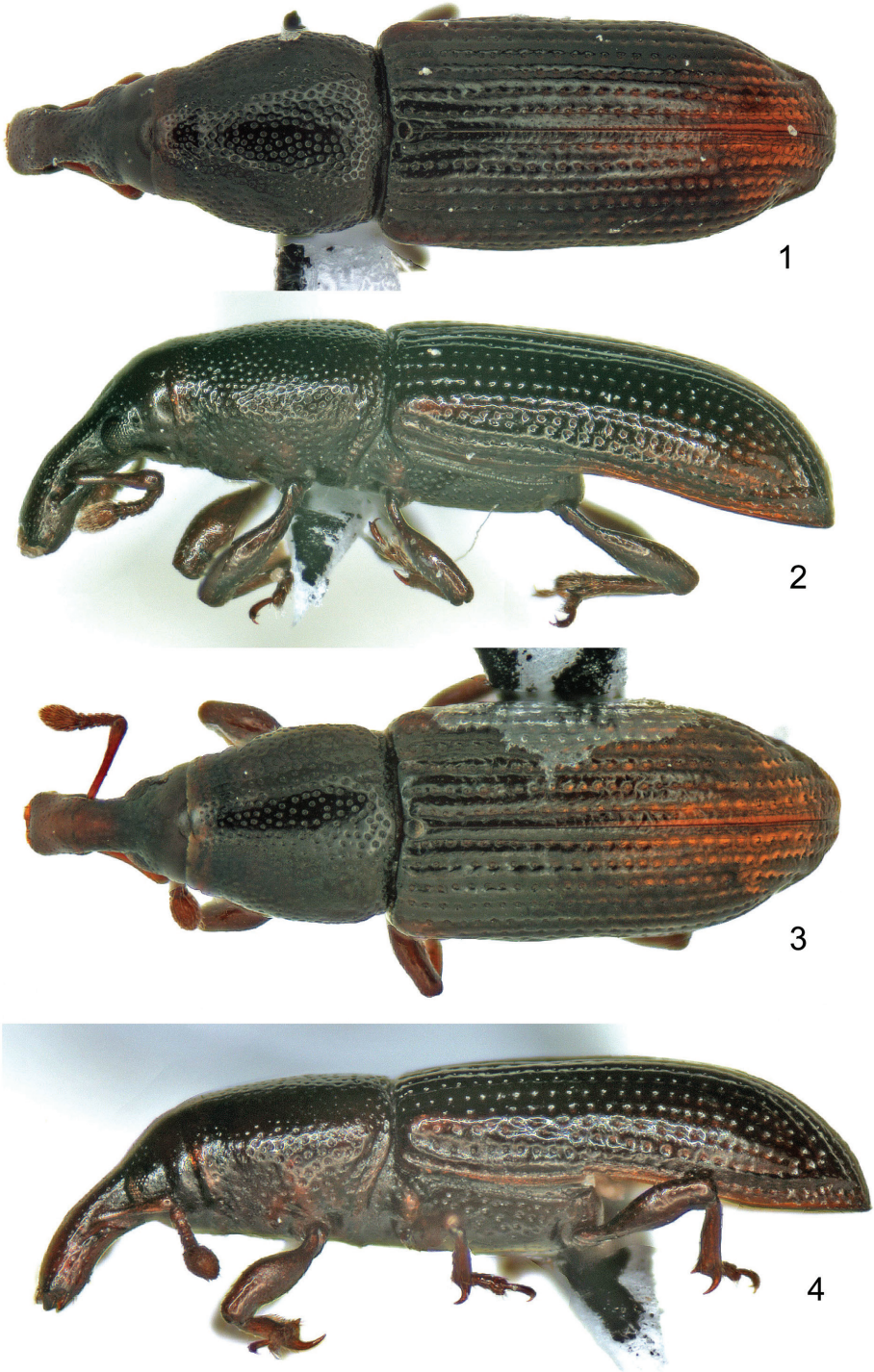
Description. *Measurements* (male): **BL**: 3.29–3.40 mm; **EL**: 2.33–2.38 mm; **EWB**: 1.02–1.08 mm; **EWW**: 1.02–1.08 mm; **PL**: 0.96–1.02 mm; **PW**: 0.90–0.94 mm; **RL**: 0.52–0.55 mm; **RWA**: 0.31–0.34 mm; **RWB**: 0.25–0.30 mm; **AL**: 0.90–0.94 mm; **ASL**: 0.40–0.42 mm; **AFL**: 0.30–0.31 **ACL**: 0.20–0.22; **ACW**: 0.12–0.14 mm. *Measurements* (female): **BL**: 2.58–2.80 mm; **EL**: 1.70–1.90 mm; **EWB**: 0.84–0.96 mm; **EWW**: 0.84–0.96 mm; **PL**: 0.88–0.90 mm; **PW**: 0.77–0.78 mm; **RL**: 0.48–0.50 mm; **RWA**: 0.26–0.28 mm; **RWB**: 0.19–0.20 mm; **AL**: 0.70–0.90 mm; **ASL**: 0.32–0.40; **AFL**: 0.20–0.30; **ACL**: 0.13–0.20; **ACW**: 0.10–0.11 mm.

Body (Figs 1–5) oblong, curved, glossy.

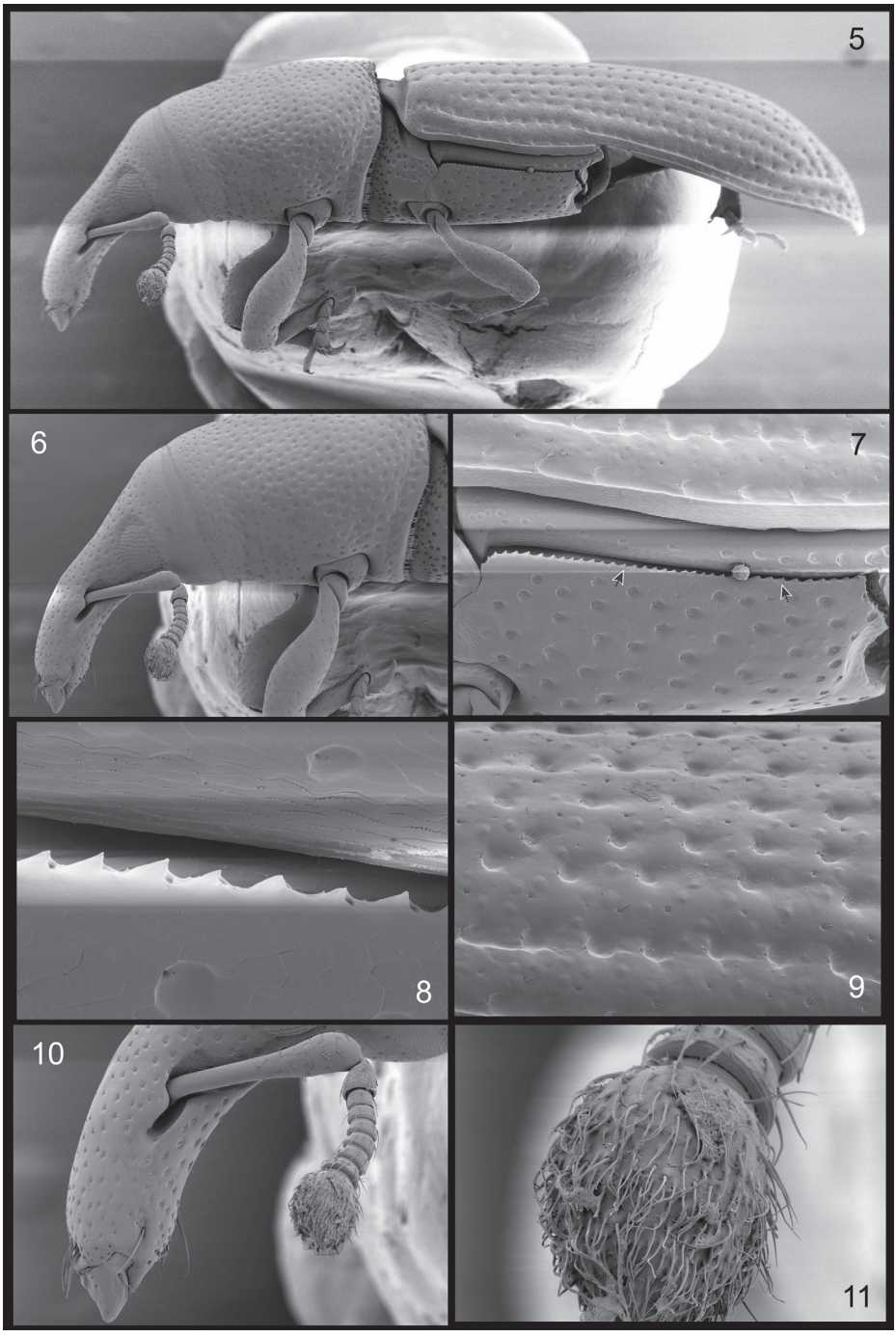
Colour dark reddish-brown; rostrum, antennae and legs paler brown than body.

Rostrum (Figs 6, 10) long, more than 2 × longer than width at base, more or less 0.5 × as long as pronotum; narrow before antennal insertions (basal half), sides parallel, curved dorsally, widening after antennal insertion (in apical half), curved ventrally at antennal insertions; antennae inserted after middle of rostrum; with fine, subcircular, shallow punctures along dorsum, becoming oblong, denser towards apex; narrower at base than at apex; scrobes (Fig. 10). well-defined, deep, short, located in middle of rostrum, dorsal margin slightly lower than upper margin of eye, ventral margin black, visible in dorsal view.

Mouthparts. Maxillae (Fig. 25) with palpiger with large, slender seta near basolateral margin; galeo-lacinial complex with several large, tooth-like setae along margin, a few



Figures 1–4. *Orthotemnus longitarsus* habitus. **1** ♂ dorsal aspect **2** ♂ lateral aspect **3** ♀ dorsal aspect **4** ♀ lateral aspect.



Figures 5–11. *Orthotemnus longitarsus* SEM photographs. **5** ♂ habitus, lateral aspect **6** enlargement of head and prothorax, lateral aspect **7** enlargement of lateral part of metathorax **8** enlargement of serrate dorsal margin of metaventrite **9** enlargement of left elytron **10** enlargement of apical half of rostrum, lateral aspect **11** enlargement of antennal club.

smaller, slender setae near base. Labium (Fig. 26) with prementum elongate, lacking setae; 1st segment of palpus with 2 setae, 2nd segment with 1 seta, 3rd (apical) segment lacking setae. Right mandible (Fig. 24) with 3 teeth and a small molar region, primary tooth largest, second and third teeth smaller; left mandible (Fig. 23) mainly with large primary tooth and molar region, other teeth reduced to small ridges.

Antennae (Figs 10–12) pale, long, glossy brown, clubs pilose; scapes slightly bent at middle, thick and widening in distal third, widened part with sparse, shallow, oblong punctures with fine suberect setae, smooth, passing posterior margin of eye, approaching postocular constriction, approximately as long as or slightly shorter than funicle; clubs compact; funicles with all segments with few fine, erect setae, loose, segment 1 stout, longer than wide, segments 2–5 subequal, 6 and 7 wider than long, 7 wider than 6; clubs (Fig. 11). longer than wide, oval, slightly laterally flattened, 3-segmented, setigerous, setae suberect towards apex, acuminate.

Head oval, laterally constricted behind eyes, constriction weak dorsally, temples swollen, with subcircular punctures, fine sparse punctures behind postocular constriction, wrinkled, glossy; forehead slightly convex, broader than rostral base, with clear circular punctures, interspaces 2–3 × puncture diameter, with short median longitudinal furrow; vertex bulbous, convex, wrinkled. Eyes oval, widely separated, convex, with coarse, convex facets.

Pronotum conical, anteriorly constricted, deep laterally but weak dorsally, forming collar with large, circular punctures throughout, punctures separated by approximately 1–2 × their diameter, with abbreviated smooth median line not reaching anterior and posterior margins, dorsally and laterally convex, truncate along posterior margin.

Mesonotum (Fig. 29) typical of Cossoninae; axillary cord enlarged, lateral margins rounded.

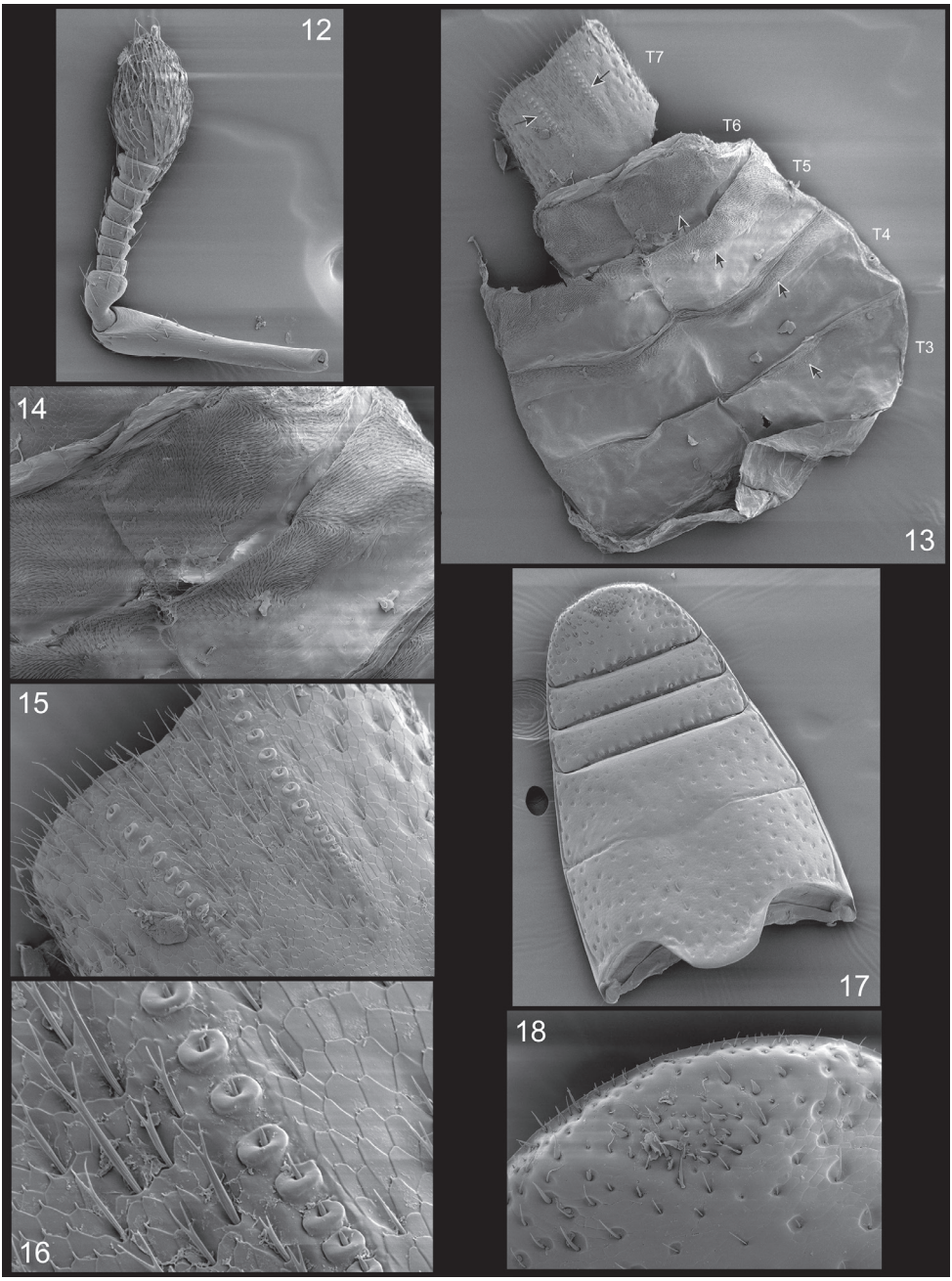
Scutellum visible, transverse-oblong, smooth, dull.

Metanotum (Fig. 30) with metascutum reaching posterior margin of notum; scutellar groove nearly reaching posterior margin of notum; allocrista angular at anteromesal angle.

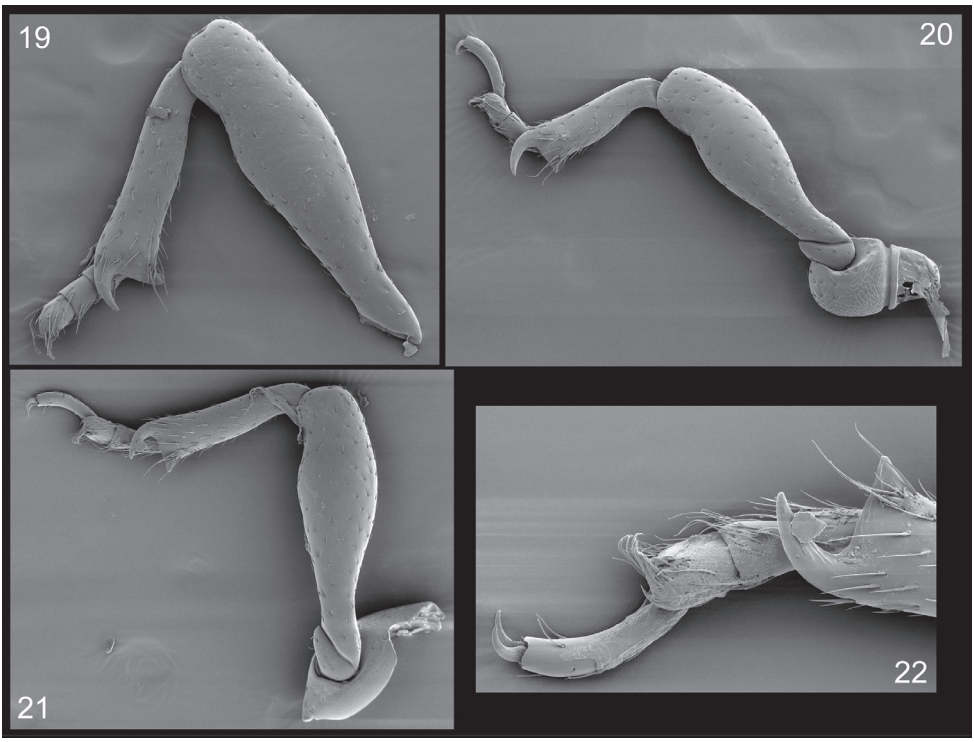
Metendosternite (Fig. 28) stalk slightly taller than wide; longitudinal flange short; furcal arm slender, bifid at apex; hemiductus slender.

Proventriculus as in Fig. 27.

Elytra (Figs 5, 9) glossy, long, disk convex, lateral margins parallel until declivity, base truncate, slightly broader than pronotal base; striae with large, deep circular punctures, punctures separated by approximately 1–1.5 × puncture diameter, first stria (sutural stria) deeper and depressed near scutellum; intervals smooth, equal, convex, with a single row of fine punctures, wider than striae; sutural interval deeper and depressed near scutellum, dilated at declivity to apex, interval 3 elevated caudally of declivity, with more than one row of fine punctures; intervals 4, 5 and 6 connected slightly caudally of declivity but not reaching apex; interval 9 forming oblique, ridged elevation caudally of declivity and connected to interval 3, not reaching apex; humeri truncate, quadrate.



Figures 12–18. *Orthotemnus longitarsus* SEM photographs. **12** antenna **13** ♂ abdominal tergites **14** enlargement of portions of tergites 5 and 6 showing spiculate patches **15** enlargement of tergite 7 showing rows of plectra **16** enlargement of plectra on tergite 7 **17** ♂ abdominal venter **18** enlargement of apical portion of ventrite 5.

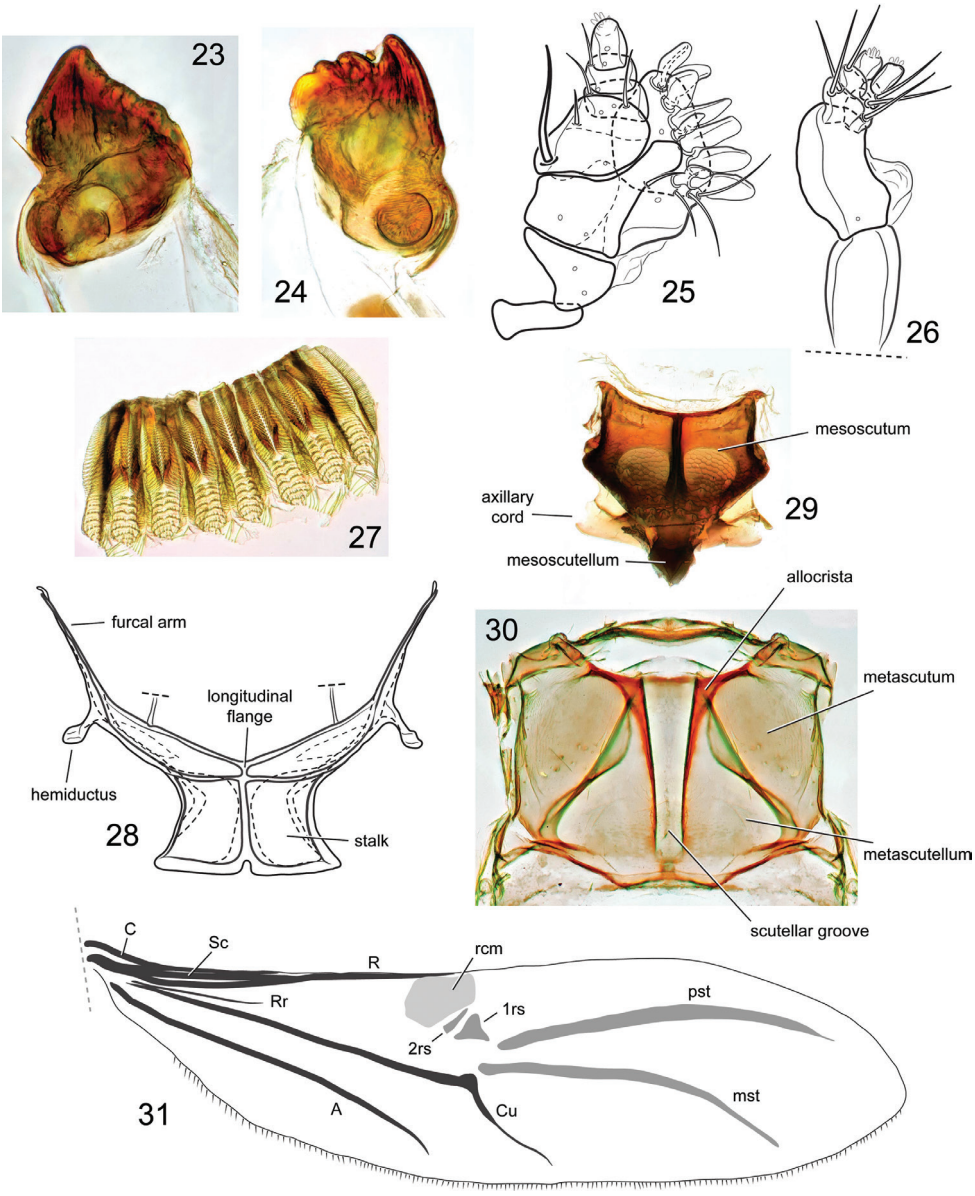


Figures 19–22. *Orthotemnus longitarsus* SEM photographs of legs. **19** foreleg **20** middle leg **21** hindleg **22** enlargement of hind tarsus.

Hindwings (Fig. 31) slender, lacking jugal area (anal lobe); *Rr* slender, abbreviated, not reaching *rcm*; *rc* absent; *1rs* triangular and larger than *2rs*; *R3* absent; *Cu1* not reaching posterior margin; *r-m* absent; *A* simple, other anal veins absent.

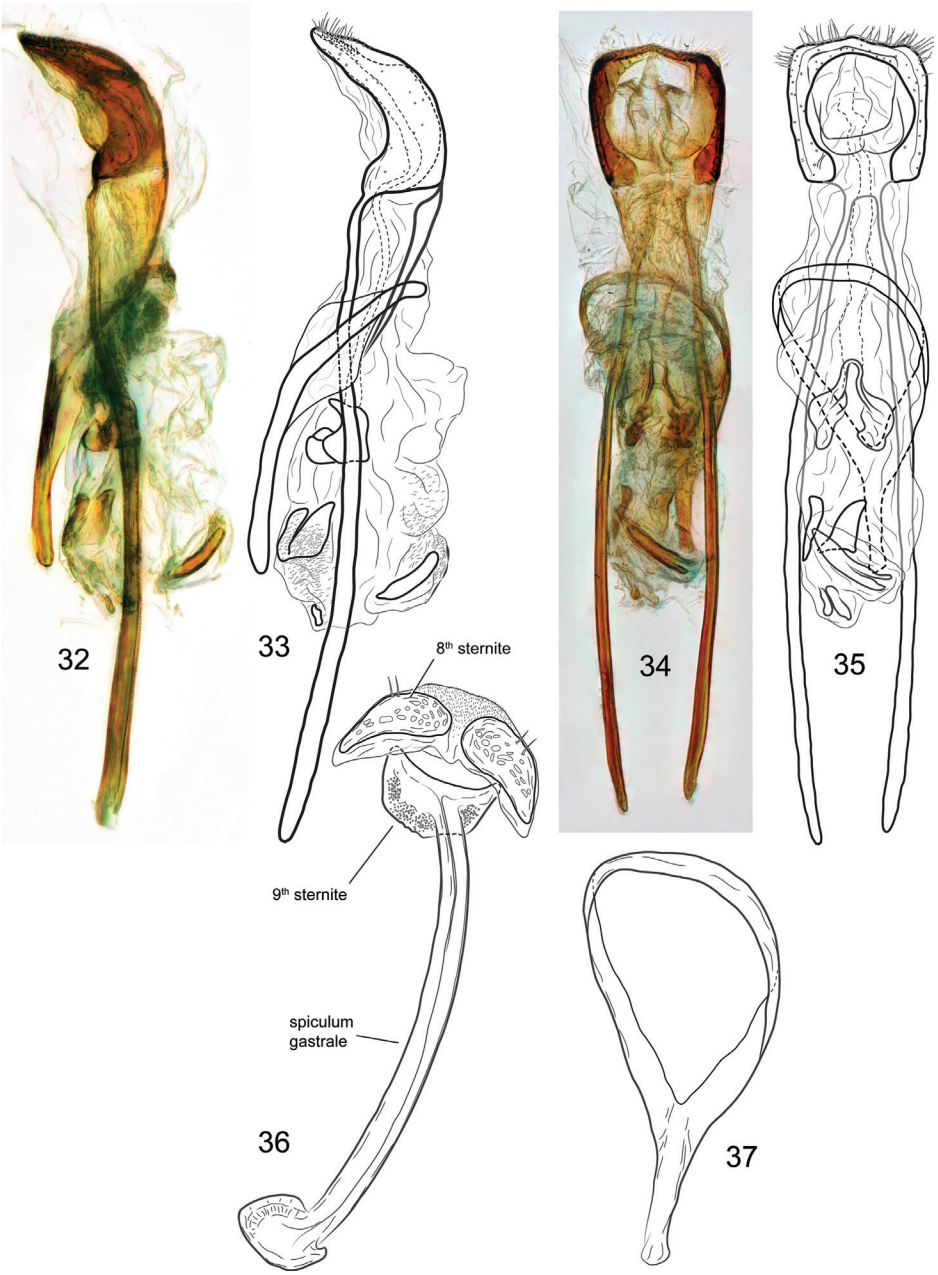
Thoracic sterna flat; prosternum wrinkled, with deep circular punctures; procoxae separated by 0.5 × diameter of coxa; mesoventrite flush with prosterum, base bisinuate, mesocoxae separated by approximately coxal diameter; metaventrite transverse, longitudinal sulcus from base to beyond middle, with circular punctures spaced by 2–3 × diameter of puncture, meta coxae separated by slightly less than 2 × diameter of coxa; dorsal margins of metaventrite serrate (sclerolepidial setae absent, though setal sockets present; Figs 7–8).

Legs (Figs 19–22). Femora glossy, robust along distal two-thirds, with small, circular, sparse punctures, separated by approximately 2–4 × puncture diameter, slightly less than 2 × length of tibia; tibiae with smaller, similarly spaced punctures, straight, nearly uniform in width; uncus small, at outer apical margin, approximately 0.5 × as long as tarsomere 5, praemucro at inner apical margin covered by a small tuft of setae; tarsi longer than tibiae, 5-segmented; segments 1–3 with long, pale yellowish setae, 1 2 × longer than wide; 2 subequal in length and width; 3 wider than long, notched; 4 small, 5 longer than others combined, curved, dorsally convex, glossy, with appressed pale yellowish setae; claws simple, free.



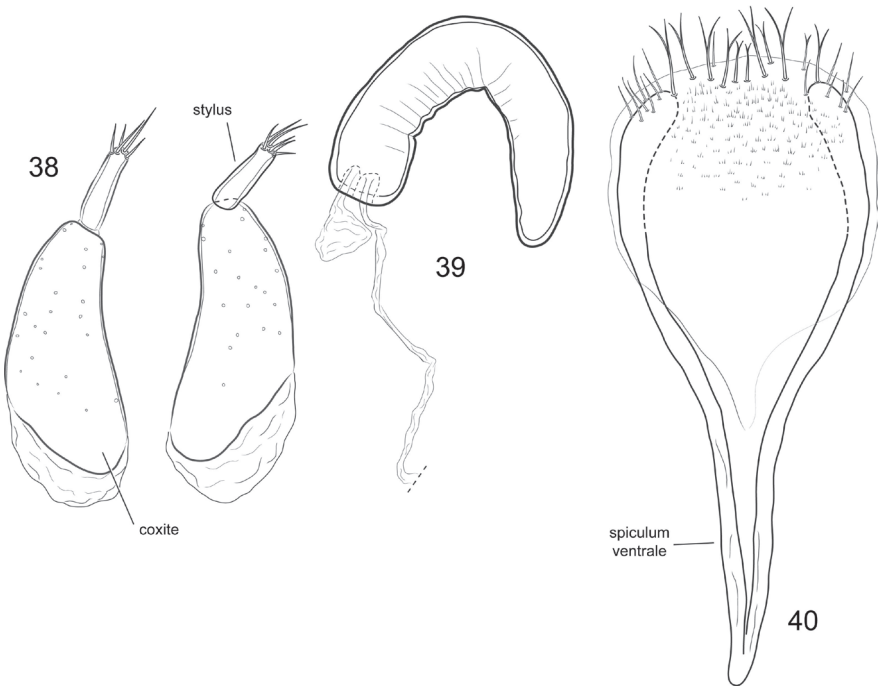
Figures 23–31. *Orthotemnus longitarsus* mouthparts, internal structures and hindwing. **23** left mandible **24** right mandible **25** maxilla **26** labium **27** proventriculus **28** metendosternite **29** mesonotum **30** metanotum **31** hindwing: **C** = Costa **Sc** = Subcosta **Rr** = radial recurrent vein **R** = Radius **rcm** = margin of radial cell **2rs, 1rs** = radial sclerites **pst** = postradial stripe **mst** = medial stripe **Cu** = Cubital **A** = Anal.

Abdomen. **Tergites** (Figs 13–16) with microtrichial wing-locking patches restricted to posterior half of tergites 2–5 and present on most of tergite 6; two linear rows of plectra present on tergite 7 (Lyal and King 1996). **Ventrites** (Fig. 17, 18). glossy, 1 and



Figures 32–37. *Orthotemnus longitarsus* ♂ terminalia. **32–33** Penis, lateral aspect **34–35** aedeagus, dorsal aspect **36** sternites VIII and IX **37** tegmen.

2 with large, circular punctures, punctures separated by 2–3 × their diameter; 1 broader than 2, projecting between metacoxae, 1 and 2 clearly separated; 3 and 4 narrow, equal, each with two rows of punctures, basal row with large, deep, oblong punctures,



Figures 38–40. *Orthotemnus longitarsus* ♀ terminalia. **38** ovipositor (coxites and styli) **39** spermatheca **40** sternite VIII.

apical row with fine small punctures, with fine suberect setae apically; 5 transverse, posterior margin rounded, with large, oblong, deep punctures at base, punctures becoming sparse and subcircular apically with some appressed setae.

Male terminalia and genitalia (Figs 32–37). Spiculum gastrale of sternite IX with flattened, expanded apex; apex approaching size of sternite at base. Sternite VIII divided, with 2 setae on each hemisternite. Tegmen complete; manubrium nearly 0.5 × length of tegmen. Penis with temones ca. 4.5 × body of penis; apical margin setose; endophallus (internal sac) extensive, greater than 0.5 × length of temones, bearing several internal sclerites from approximate middle of endophallus to its apex.

Female terminalia and genitalia (Figs 38–40). Gonocoxites of typical form; oblong; styli elongate, narrow. Spermatheca approximately crescent-shaped. Sternite VIII with spiculum ventrale gradually narrowing towards apex; base with many setae, setae mostly bifid at middle of base and mostly simple laterally; many microtrichia along basal region of sternite anteriorly of setae.

Material examined. Holotype: male: China: Jiangsu: Jiangsu Province, Nanjing, Zijingshan, 32.30°N, 118.49°E, 05 III 2008, collected by Liang Ding (IOZ). **Paratypes:** 4 ♀ and 4 ♂: same data as holotype; found under trees in park.

Etymology. The specific epithet is a combination of the Latin word *longus* and the Latinized Greek word *tarsus*, referring to the longer tarsus in relation to the tibia; it is a noun in apposition.

Distribution. China: Jiangsu Province: Nanjing, Zijingshan.

Sexual dimorphism. The female (Figs 3–4) is smaller than the male (Figs 1–2), and its rostrum is slightly shorter and slenderer than that of the male. Males also have concave first and second ventrites, the first slightly more projected between the metacoxae than in the female.

Discussion

The new species here differs from other species of the genus as detailed in the key below as well as in the following features: its large size; the rostrum narrow and strongly convex, narrow basally after the antennal insertions but widening distally; the forehead with a short, median longitudinal furrow starting in the basal half and extending posteriad; the long scapes reaching the postocular constriction; the swollen temples; the transverse-oblong scutellum; the quadrate humeri; the parallel-sided tibiae; the tarsi being longer than the tibiae. This species marks the first record of the genus for China.

The genus is currently known to comprise six species, including the one newly described here, distributed as follows: *O. reflexus* and *O. disparilis* in the Australian, *O. filiformis* and *O. expansus* in the Afrotropical and *O. ulmi* and the new species in the Palaearctic region (Csiki 1936, Alonso-Zarazaga and Lyal 1999, Setliff 2007). The genus has seemingly not been recorded from the Nearctic, Neotropical, nor Oriental regions. This distribution suggests that the genus may occur more widely in the Old World including the Oriental region.

Key to the species of *Orthotemnus*

1 Apical margin of elytra reflexed or recurved **2**

– Apical margin of elytra normal, subacute **4**

2 Elytral intervals flat, obsoletely punctate; prothorax conical, strongly constricted before apex; closely, rather coarsely punctate, except along abbreviated narrow median space; interspaces finely alutaceous..... ***O. filiformis***

– Elytral intervals depressed or weakly convex, finely shagreened or sparsely and finely punctate; prothorax slightly constricted or with flat constriction not reaching disc at apex **3**

3 Rostrum longer than pronotum, equal breadth throughout, with fine, dense, shallow punctures; prothorax elongate, triangular, with evenly sparse, moderately deep punctures; base truncate and as broad as elytra, weakly constricted at apex ..... ***O. reflexus***

– Rostrum shorter than pronotum (4:5), conical, gradually narrowing from base to apex, with fine sparse punctures; short elongate fovea between antennal insertions; prothorax less elongate than in *O. reflexus*; punctures round,

shallow, rather dense, unevenly distributed; base weakly bisinuate, slightly narrower than elytra..... ***O. ulmi***

4 Antennae inserted before middle of rostrum; rostrum strongly curved at middle or at point of antennal insertions.....**5**

– Antennae inserted behind middle of rostrum; rostrum slightly curved ....***O. expansus***

5 Prothorax small, oblong, with large coarse punctures; elytra short, gradually narrowing to apex; striae with large, dense, quadrate punctures ... ***O. disparilis***

– Prothorax conical, constricted anteriorly; constriction deep laterally and weak dorsally, with large, circular punctures throughout; elytra long, parallel-sided until declivity; striae with large, deep, circular punctures... ***O. longitarsus* sp. n**.

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REVIEW ARTICLE

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Discovery of an unknown diversity of *Leucinodes* species damaging Solanaceae fruits in sub-Saharan Africa and moving in trade (Insecta, Lepidoptera, Pyraloidea)

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Abstract

The larvae of the Old World genera *Leucinodes* Guenée, 1854 and *Sceliodes* Guenée, 1854 are internal feeders in the fruits of Solanaceae, causing economic damage to cultivated plants like *Solanum melongena* and *S. aethiopicum*. In sub-Saharan Africa five nominal species of *Leucinodes* and one of *Sceliodes* occur. One of these species, the eggplant fruit and shoot borer *L. orbonalis* Guenée, 1854, is regarded as regularly intercepted from Africa and Asia in Europe, North and South America and is therefore a quarantine pest on these continents. We investigate the taxonomy of African *Leucinodes* and *Sceliodes* based on morphological characters in wing pattern, genitalia and larvae, as well as mitochondrial DNA, providing these data for identification of all life stages. The results suggest that both genera are congeneric, with *Sceliodes* **syn. n.** established as junior subjective synonym of *Leucinodes*. *L. orbonalis* is described from Asia and none of the samples investigated from Africa belong to this species. Instead, sub-Saharan Africa harbours a complex of eight endemic *Leucinodes* species. Among the former nominal species of *Leucinodes* (and *Sceliodes*) from Africa, only *L. laisalis* (Walker, 1859), **comb. n.** (*Sceliodes*) is confirmed, with *Leucinodes translucidalis* Gaede, 1917, **syn. n.** as a junior subjective synonym. The other African *Leucinodes* species were unknown to science and are described as new: *L. africensis* **sp. n.**, *L. ethiopica* **sp. n.**, *L. kenyensis* **sp. n.**, *L. malawiensis* **sp. n.**, *L. pseudorbonalis* **sp. n.**, *L. rimavallis* **sp. n.** and *L. ugandensis* **sp. n.** An identification key based on male genitalia is provided for the African *Leucinodes* species. Most imports

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of *Leucinodes* specimens from Africa into Europe refer to *Leucinodes africensis*, which has been frequently imported with fruits during the last 50 years. In contrast, *L. laisalis* has been much less frequently recorded, and *L. pseudorbonalis* as well as *L. rimavallis* only very recently in fruit imports from Uganda. Accordingly, interceptions of *Leucinodes* from Africa into other continents will need to be re-investigated for their species identity and will likely require, at least in parts, revisions of the quarantine regulations. The following African taxa are excluded from *Leucinodes*: *Hyperanalyta* Strand, 1918, **syn. rev.** as revised synonym of *Analyta* Lederer, 1863; *Analyta apicalis* (Hampson, 1896), **comb. n.** (*Leucinodes*); *Lygropia aureomarginalis* (Gaede, 1916), **comb. n.** (*Leucinodes*); *Syllepte hemichionalis* Mabille, 1900, **comb. rev.**, *S. hemichionalis idalis* Viette, 1958, **comb. rev.** and *S. vagans* (Tutt, 1890), **comb. n.** (*Aphytoceros*). *Deanolis iriocapna* (Meyrick, 1938), **comb. n.** from Indonesia is originally described and misplaced in *Sceliodes*, and *L. cordalis* (Doubleday, 1843), **comb. n.** (*Margaritia*) from New Zealand, *L. raondry* (Viette, 1981) **comb. n.** (*Daraba*) from Madagascar as well as *L. grisealis* (Kenrick, 1912), **comb. n.** (*Sceliodes*) from New Guinea are transferred from *Sceliodes* to *Leucinodes*. While *Leucinodes* is now revised from Africa, it still needs further revision in Asia.

Keywords

Leucinodes, *Leucinodes orbonalis* complex, *Sceliodes*, Solanaceae, eggplant, pest species, DNA Barcoding, revision, identification key, Africa

Introduction

Leucinodes orbonalis Guenée, 1854, the eggplant fruit and shoot borer, is a species of moth that was first described from specimens from India and Java (Guenée 1854). According to current knowledge, it is widely distributed in tropical and subtropical Asia (CABI 2012a) and sub-Saharan Africa (Walker 1859, Frempong 1979, CABI 2012a). The larvae are pests of Solanaceae, especially *Solanum melongena* L. (aubergine, eggplant or brinjal) fruits and stems where they feed internally. Their infestation can substantially reduce yields from aubergine cultivation, and yield losses of more than 65% have been recorded from Asia (EPPO 2008).

The larvae are commonly moved in international trade with plants and fruits, as their internal feeding and the resulting damage may not be visible during pre-export inspections. Thus, *Leucinodes orbonalis* is a quarantine pest of concern to a number of countries outside its native range. This includes the member countries of the European and Mediterranean Plant Protection Organisation (EPPO), where it was recommended as an addition to the alert list of pests in 2008 (EPPO 2008), and in 2012 transferred to the A1 list of pests recommended for statutory regulation (EPPO 2012, 2013). It is an A1 pest for several South American countries including Uruguay and Argentina (COSAVE 2006) and has repeatedly been intercepted in the USA (Whittle and Ferguson 1987, Solis 1999, 2006). In England and Wales, the Plant Health and Seeds Inspectorate (PHSI) regularly intercept *Leucinodes* Guenée, 1854 larvae inside aubergines from South Asia and West Africa (The Food and Environment Research Agency (Fera), unpublished data).

Due to the economic impact of *Leucinodes orbonalis*, the development of a genetically modified eggplant was initiated in 2005 in India by introducing a crystal protein

gene (Cry1Ac) from the bacterium *Bacillus thuringiensis* Berliner, 1915 (*Bt*) into the plant (Sood 2012). The insecticidal effect of the crystal proteins makes eggplant less susceptible to infestations by larvae of *Leucinodes orbonalis*. After field trials and approval for commercial cultivation from government scientists in 2009, a moratorium on the commercialisation of *Bt* brinjal was imposed due to public concerns on food safety (Pandey 2010).

Until recently, all pyraloid larvae damaging Solanaceae fruits in Asia and Africa and intercepted from imports to Europe have been regarded as two species, *Leucinodes orbonalis* and *Sceliodes laisalis* (Walker, 1859). Hayden et al. (2013) and Gilligan and Passoa (2014) pointed out that *Leucinodes orbonalis* is restricted to Asia and that there are "three species in the *L. orbonalis* complex in Africa that are not conspecific with the Asian species. Our investigations reveal that an even largernumber of *Leucinodes* species are intercepted from Africa. This points to the question of the identity of the intercepted species as well as on further four species of *Leucinodes* known from Africa, *L. aureomarginalis* Gaede, 1916, *L. hemichionalis* (Mabille, 1900), *L. translucidalis* Gaede, 1917 and *L. vagans* (Tutt, 1890) (Nuss et al. 2003–2014). Besides *Leucinodes*, there is the similar genus *Sceliodes* Guenée, 1854, of which *Sceliodes cordalis* (Doubleday, 1843) and *S. laisalis* (Walker, 1859) are also pests on solanaceous crops in Australia (Davis 1964), New Zealand (Martin 2010) and Africa (CABI 2012b).

Here we taxonomically revise *Leucinodes* and *Sceliodes* and their species from continental sub-Saharan Africa, in order to delimit species and to allow their proper identification.

Methods

Specimens were examined from the following institutions: private collection David J. L. Agassiz, Weston-super-Mare, Great Britain (coll. DJLA), Natural History Museum, London, Great Britain (BMNH), Invertebrate Reference Collection, Food and Environment Research Agency, Sand Hutton, England (Fera), International Centre of Insect Physiology and Ecology, Nairobi, Kenya (ICIPE), private collection Timm Karisch, Dessau, Germany (coll. Karisch), University of Oslo, Natural History Museum, Norway (NHMO), National Museum of Kenya, Nairobi, Kenya (NMK), National Plant Protection Organization, Wageningen, the Netherlands (NPPO), Muséum national d'Histoire naturelle, Paris, France (MNHN), Musée royal de l'Afrique centrale, Tervuren, Belgium (RMCA), Senckenberg Deutsches Entomologisches Institut, Müncheberg, Germany (SDEI), Senckenberg Museum für Tierkunde, Dresden, Germany (SMTD), National Museum of Natural History, Washington, D.C., U.S.A. (USNM), Museum für Naturkunde, Berlin, Germany (ZMHB), University of Copenhagen, Museum of Zoology, Denmark (ZMUC).

Larvae were sourced through quarantine interceptions of eggplant fruit from Africa and Asia at several ports of entry in England. Most larvae were studied alive and subsequently reared to adults in order to confirm the species identity. In large containments a few larvae were preserved by boiling them in water for 30–90 seconds, then transferred to 70% ethanol. After 3–5 days, the ethanol was replaced to limit dilution from body contents. Reared adults were killed soon after emergence, with cyanide, ammonia or by

freezing at -20 °C for a minimum of 2 hours. Field-collected adults were attracted by artificial light and killed with cyanide. All adult specimens were subsequently pinned. Genital dissections of thoroughly dried specimens were performed according to Robinson (1976). Setal nomenclature follows Hinton (1946). The chaetotaxic descriptions and the setal map focus on those microscopic setae visible at 60 × magnification.

DNA was extracted using either the NucleoSpin tissue kit (Macherey-Nagel) according to the manufacturer's instructions or using the Chelex-100 resin based method (Boonham et al. 2002). DNA extraction with the NucleoSpin tissue kit was performed following the procedure of Knölke et al. (2005), extracting DNA from the abdomen of adult specimens and subsequent dissection of the genitalia from the macerated abdomen. Extracted abdomina were stored in 70% ethanol until genitalia were dissected. For the Chelex-100 resin based method single legs or wings were removed from dried, pinned specimens using fine forceps and placed in individual 0.6 ml Eppendorf tubes. Briefly, 100 µl molecular-grade water was added to the tissue sample and ground using a micropestle. 100 µl of a 50% w/v chelex resin:water slurry was added, the sample heated to 95 °C for 5 minutes, centrifuged for 5 minutes and the supernatant transferred and stored at -20 °C prior to use.

PCR of the 5' half of the cytochrome C oxidase subunit I (COI) gene, the so-called DNA Barcode (for Metazoa), was performed using primers HybLCO (Folmer et al. 1994, Wahlberg and Wheat 2008) and HybNancy (Wahlberg and Wheat 2008). For degraded material primer pairs HybLCO/K699 and Ron/HybNancy (Wahlberg and Wheat 2008) were used to amplify the COI Barcode in two fragments. PCR was performed in 25 µl reactions comprising 0.4u BIO-X-ACT Short DNA Polymerase (Bioline), 2.5 µl 10×OptiBuffer, 1.5 mM $MgCl_2$, 200 nM each primer, 200 nM dNTP mix and 1–2 µl DNA (concentration as extracted). Cycling conditions were as follows: initial denaturation for 5min at 95 °C, 40 cycles with 1) 30 sec at 95 °C, 2) 30 sec at 48 °C, 3) 90 sec (HybLCO/HybNancy) or 60 sec (primers for degraded material) at 70 °C, final extension of 10 min at 70 °C. Alternatively primers LepF and LepR (Hajibabaei et al. 2006) were used in 25 µl PCR reactions using BIO-X-ACT Short 2× mix (Bioline), 400 nM each primer and 1–2 µl DNA (concentration as extracted). Cycling conditions were as follows: initial denaturation for 5 min at 94 °C, 35 cycles with 1) 30 sec at 94 °C, 2) 45 sec at 50 °C, 3) 1min at 72 °C, final extension of 10 min at 72 °C.

PCR products were visualised by separation in 1–1.5% agarose gels in 1 × TBE buffer (89 mM Tris-borate 2 mM EDTA) containing GelRed or ethidium bromide and visualised under UV light. PCR amplicons were cleaned up using ExoSAP-IT (Affymetrix) or QIAquick PCR purification kit (QIAGEN). Sequencing of both strands was performed by Eurofins MWG Operon (Germany) or in-house as follows. Sequencing PCRs were performed with BigDye Terminator v3.1 cycle sequencing kit (Applied Biosystems) using 5pm of the sequencing primer tails T7/T3 (Wahlberg and Wheat 2008) and 0.5–4 µl PCR product. Final clean-up was done via sodium acetate-ethanol precipitation. Sequencing was performed on a 3130 Genetic Analyzer (Applied Biosystems). PCRs, PCR clean-up and sequencing PCRs were performed on a Mastercycler ep gradient S (Eppendorf) or GeneAmp9700 (Applied Biosystems).

Obtained DNA sequences were proofread by eye and aligned using PhyDE 0.9971 (Müller et al. 2008) or MEGA version 4.1 (Tamura et al. 2007). Ambiguous

Barcode nucleotides were coded according to the IUPAC Ambiguity Code (Cornish-Bowden 1985). Sequences were then checked for plausibility using BLAST with the *blastn* algorithm (Altschul et al. 1990; URL: http://blast.ncbi.nlm.nih.gov/Blast.cgi) as well as the BOLD Identification System (IDS, URL: http://www.boldsystems.org/index.php/IDS_OpenIdEngine). A 615 basepair fragment was analyzed with MEGA version 6 (Tamura et al. 2013), using the distance criterion and the Neighbor Joining (NJ) algorithm (Saitou and Nei 1987) with uncorrected p-distances (Srivathsan and Meier 2011). Statistical support was evaluated through 1,000 Bootstrap replicates. *Udea ferrugalis* (Hübner, 1796) was used to root the NJ tree.

We apply the morphospecies concept to our study. The DNA Barcode is used as additional source of information and as an identification tool for all developmental stages of African *Leucinodes* species. The Solanaceae species names mentioned in this study refer to their former context and do not necessarily correspond to the revised *Solanum* taxonomy by Knapp et al. (2013).

Label data of studied specimens were compiled in order to generate a distribution map. Geographical coordinates, if not given on the label, were obtained via Google Earth, Version 5.2.1.1588 and subsequently plotted on a map using DIVA-GIS, Version 7.2.3 (Hijmans et al. 2004).

Data resources

The data underpinning the analyses reported in this paper are deposited in the Dryad Data Repository at doi: 10.5061/dryad.kk0n9.

Results

Leucinodes Guenée, 1854

Leucinodes Guenée, 1854. Type species: *Leucinodes orbonalis* Guenée, 1854
= ***Sceliodes*** Guenée, 1854, **syn. n.** Type species: *Sceliodes mucidalis* Guenée, 1854
= *Daraba* Walker, 1859 (synonymised by Hampson, 1899). Type species: *Daraba idmonealis* Walker, 1859
= *Eretria* Snellen, 1880 (synonymised by Hampson, 1899; Shaffer et al. 1996: junior homonym of *Eretria* Robineau-Desvoidy, 1863). Type species: *Eretria obsistalis* Snellen, 1880
= *Leuctinodes* South, 1897 (misspell.)

Diagnosis. *Leucinodes* is characterized by a forewing pattern which includes a brown base, a white antemedian line which is distally brown edged; a median area that is ochreous or brown from the costa to the middle of wing, and red-brown from the middle of wing towards the dorsum; below the apex is a black-brown half moon-shaped patch (missing in *L. malawiensis* sp. n.), edged by a thin white postmedian line and a

white line at the margin of wing. The hindwings are white with inconspicuous pattern elements. *Leucinodes* females with only one frenular bristle in the hindwing, female labial palps with elongated 3rd meron, male genitalia with identical location of the fibula-sacculus process-complex (process lacking in *L. cordalis* (Doubleday, 1843), *L. laisalis* and *L. malawiensis*), female genitalia with fine granular sclerotization of ductus bursae (in most species), antrum with thickened mesocuticula, presence of lateral antrum pockets. Larvae are internal feeders in Solanaceae.

Redescription of adults. Head. Frons conically bulged (Figs 11–12) to flat; labial palps porrect, brownish, 1st meron on ventral side with forward-directed tuft, 3rd meron in males half as long as 2nd meron, longer in females (Figs 11–12); maxillary palps minute or missing; haustellum well developed; eyes large, hemispherical; ocelli present; antennae ciliate, pedicel white to brown, flagellum light brown, cilia in males longer than basal antennal radius (except in *L. malawiensis*), in females shorter than antennal radius; vertex with whitish to brown scales at the collar and brown scales directed forward; chaetosemata absent.

Thorax. Dorsal side whitish to brown with whitish and dark brown scales mixed in; ventral side whitish; legs predominantly whitish, foreleg femur, tibia and epiphysis light to dark brown; tibial spurs 0, 2, 4 (fore-, mid-, hindleg) with outer spur 1/2 to 2/3 the length of inner spur.

Wings. Forewing white translucent, light brown or orange- to grey-brown, basal area light to dark brown, delimited by white and dark brown double line or in species with brown forewing ground colour by dark brown antemedian line; median area with pale to dark brown, sometimes very faint proximal discoidal stigma (absent in *L. malawiensis*); distal discoidal stigma pale to dark brown, reaching from costa to forewing centre; central dorsum with prominent orange to dark brown, broadly L-shaped or triangular spot connected or disconnected with distal discoidal stigma; postmedian line sinuate, faint and grey to grey-brown, white edged, with prominent subcostal bulge; apex brown to grey-brown coloured (absent in *L. malawiensis*), with slim strip of white at outer margin; margin dotted at veins, with large dots at apex and M_3; fringe white to pale brown with dark interruption at apex and at M_3 (absent in *L. malawiensis*). Hindwing in both sexes with one frenular bristle, ground colour whitish, middle of wing with one or two spots, often faint; postmedian line inconspicuous, bent towards spot at middle of wing; area below apex suffused by pale brown to grey; margin dotted at end of veins, with large dot at end of M_3.

Abdomen. First segment whitish, remainder light-, orange- or dark brown to grey.

Male genitalia. Uncus neck constricted, head circular, with dorsal agglomeration of thick setae; narrow transtilla arms with central notch, in *L. ethiopica* with dorsad spike on each arm; vinculum saccus round to V-shaped, short to more or less elongated, with or without keeled tip; juxta oval, subulate, short rhombical or tongue-shaped, with semicircular base; valvae elongate triangular, tapering posteriorly, costa and posterioventral margin loosely covered with long setae; fibula (*fi* in Fig. 13) arising at central part of mesal wall of valva or near costa; sacculus (*sa* in Fig. 13) large, elongate oval, with distal sclerotized process (*sp* in Fig. 13), often in close association with fibula, process absent in *L. laisalis*, *L. malawiensis*; ventral margin of distal valvae

with or without granulated area (*ga* in Fig. 13); phallus simple, with variously shaped sclerites at posterior apodeme, vesica with or without cornuti.

Female genitalia. Corpus bursae ovoid, membranous, without signa; ductus bursae membranous with delicate granulation, partly reaching into posterior corpus bursae; antrum short to long, slim to broader than ductus bursae, anterior part sometimes coiled, mesocuticula thickened (strongly stained with Chlorazol Black) and exocuticula (inner layer) partly sclerotized; ostium bursae with lateral membranous pockets, with or without oval sclerites; both apophyses pairs simple, apophyses anteriores normally stronger developed than posterior apophyses, with or without broadened central portion.

Immature stages. Larva. Last instar larvae with pink dorsal integument, intersegmental areas cream or light pink, the ventral integument cream; strength of the colouration very variable, pink colour on majority of abdominal segments often interrupted laterally by a transverse cream line; head, prothoracic and anal shields mid brown with variable black markings; early instar larvae white or cream with brown pinacula and black head, prothoracic and anal shields. In older larvae the dorsal integument turns beige, then increasingly deeper pink as the moults progress, head and prothoracic shield brown; pinacula pale brown and prominent against the integument in all instars. The chaetotaxy of the thorax and first nine abdominal segments of the last instar is illustrated in Fig. 35. The relative size of pinacula and positions of setae are very variable intraspecifically. The head is mid to light brown, with variable black markings around ocelli and at genal angle; relative positions of cranial setae very unstable in the specimens examined. The prothoracic shield is light to dark brown with pale median sulcus and two variable dark markings: one along part of the posterior margin, strongest medially, and the other mediolaterally; usually additional darker spots bordering the median sulcus and extending laterally, spots very variable in extent and position; prothoracic L pinaculum crescent shaped with variable posterior extension, L setae anterior to the spiracle, usually vertically aligned; microscopic seta MV3 clearly visible in most specimens, can be almost as prominent as the V seta; MV3 setae share a mid-ventral pinaculum or are on separate pinacula; meso- and metathorax with clearly visible dorsal and subdorsal microscopic pinacula at 60 × magnification; three ventral microscopic setae less prominent, with MV3 usually being the least evident, these with or without small pinacula. Many larvae are asymmetrical in this feature, with a pinaculum on one side, and seta only on the other. On the abdomen, there is one SV seta on segment 1, three SV setae on a single pinaculum on segment 2; microscopic seta MV3 visible on both segments 1 and 2, not prominent; microscopic setae on segments 3–8 mostly not visible at 60 × magnification; prolegs with crochets in a mesopenellipse; anal shield often lighter brown than pinacula, usually darker pigmented in anterior half.

Pupa. (Figs 42–46) Yellow to pale brown, lightly sclerotized, developing adult clearly visible as development proceeds; two distinct, raised hood-like structures dorsal to spiracles on abdominal segments 2 and 3 (Figs 42, 44); four pairs of long hooked setae ventral to cremaster; cocoon stout leathery, made of silk, firmly attached to the substrate.

Remarks. *Sceliodes* and *Leucinodes* have traditionally been distinguished by their forewing ground colour, which is predominantly orange-brown to greyish-brown in *Sceliodes* and white translucent in *Leucinodes*. The newly discovered *Leucinodes ethi-*

opica sp. n. is intermediate in this character whereas all other wing pattern elements are homologous among *Leucinodes* and *Sceliodes* species. Study of the genitalia showed that cornuti are present in *Sceliodes* species, but are absent in *Leucinodes*, including *L. ethiopica*. The female genitalia contain oval to semicircular sclerites in the lateral antrum pockets of *L. ethiopica*, African *Sceliodes* and *S. cordalis*, the type-species of *Sceliodes*, which is distributed in Australia and New Zealand. Thus, there is a continuous variation between *Leucinodes* and *Sceliodes* and we here synonymise *Sceliodes* syn. n. with *Leucinodes*. As *Leucinodes* and *Sceliodes* have been published on the same date and in the same work, we here give precedence to *Leucinodes* as it is the better known of the two names, acting as first reviser according to ICZN 24.2.2.

Leucinodes orbonalis Guenée, 1854

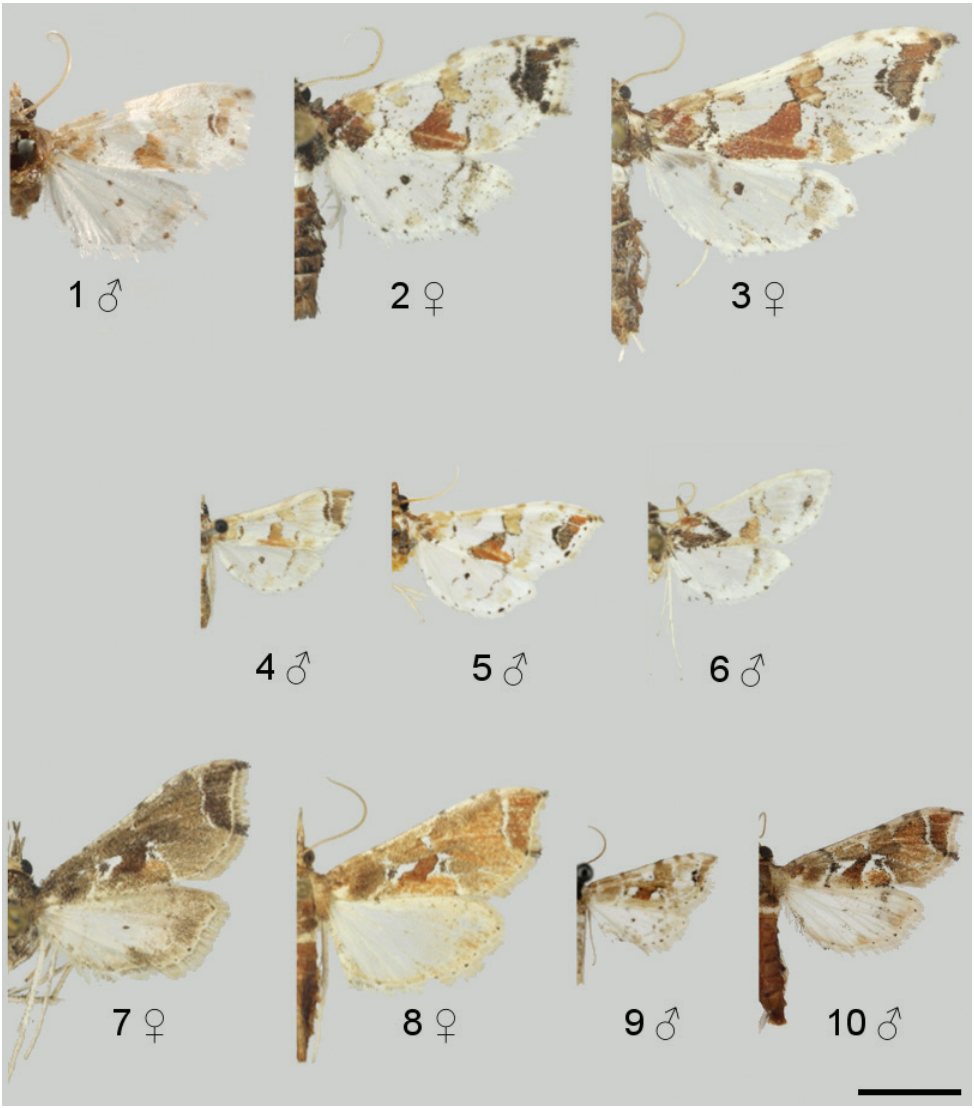
Figs 1, 11–13, 23, 31, 35–37

Leucinodes orbonalis Guenée, 1854: 223.

Type-localities. Bangladesh, Sylhet (male syntype); Java (female syntype).

Material examined. Type-specimens. Syntype ♂ [rectangular whitish label with red border, red letters] "Typicum | Specimen", [rectangular whitish label with black border] "Ex. Musaeo | Ach.Guénée", [rectangular beige label] "Paravicini Coll. | B.M. 1937-383.", [rectangular brownish label] "Orbonalis | Gn. Silhet", [rectangular pale yellow label] "Leucinodes Gn. | orbonalis Gn. | Type ♂ 756.3.", [square white label in red letters, slide number and gender in black] "Pyralidae | Brit.Mus. | Slide No. | 4496♂" (BMNH); syntype ♀ [rectangular whitish label with red border, red letters] "Typicum | Specimen", [rectangular whitish label with black border] "Ex. Musaeo | Ach.Guénée", [rectangular white label] "Paravicini Coll. | B.M. 1937-383.", [rectangular pale yellow label] "Leucinodes Gn. | orbonalis Gn. | Type ♀ 756.3.", transparent capsule with abdomen and left hindwing (BMNH). – **Additional material. VIETNAM.** 1♂ Lao Cai Province, surrounding of Mt. Fan Si Pan, Nui Se, 1927m, 22°21.168'N 103°46.477'E, 20./21.x.2001, leg. S. Löffler, prep. RM503, DNA Barcode BC MTD 01185 (SMTD); **SINGAPORE.** 1♂ 1♀ leg. H.N. Ridley, BMNH Pyralidae slides No. 23092 & No. 23100 (BMNH); **THE NETHERLANDS (IMPORT).** 1♂ Amsterdam (Schiphol), import Thailand, 22.xi.2006, ex larva 26.xi.2006, ex pupa 6.xii.2006, leg. S. Roes, det. M v. d. Straten, prep. RM641; 1♀ Amsterdam (Schiphol), import Thailand, 8.ii.2005, ex larva, leg. R. Hulzinga, det. M v. d. Straten, prep. RM642 (NPPO); **GREAT BRITAIN (IMPORT).** see Suppl. material 2 (Fera material).

Diagnosis. Wing pattern indistinguishable from those of *L. africensis* sp. n., *L. rimavallis* sp. n., *L. pseudorbonalis* sp. n., *L. kenyensis* sp. n. and "*Leucinodes* spp.", but distinguished from *L. malawiensis* by the absence of the forewing basal transversal streak and the presence of the apical half moon-shaped patch, and from *L. laisalis*, *L. ethiopica* and *L. ugandensis* sp. n. by the predominantly white forewing ground colour. Frons usually more strongly bulged than in other *Leucinodes* species, but



Figures 1–10. Adult specimens of *Leucinodes*. **1** *Leucinodes orbonalis*, syntype ♂ (Bangladesh) **2** *L. africensis* ♀ (Angola) **3** *L. rimavallis* ♀ (DR Congo: Kivu) **4** *L. pseudorbonalis* ♂ (Uganda) **5** *L. kenyensis*, holotype ♂ (Kenya) **6** *L. malawiensis*, holotype ♂ (Malawi) **7** *L. laisalis* ♀, greyish form (Tanzania) **8** *L. laisalis* ♀, brownish form (Tanzania) **9** *L. ethiopica*, holotype ♂ (Ethiopia) **10** *L. ugandensis*, holotype ♂ (Uganda). Scale bar represents 5 mm.

L. pseudorbonalis can be very similar in this feature. In male genitalia distinguishable by: dorsal margin of valval sacculus concave; apical sclerotized sacculus process elongated cone-shaped and crossing with the similar-sized fibula (as in *L. pseudorbonalis*); juxta slender, tapering (similar in *L. africensis* and *L. rimavallis*); saccus of vinculum short, less prominent. Female genitalia: antrum only slightly bulged, exocuticula without sclerotized strip.

Redescription of adults. Head. As for the genus, with frons strongly bulged (Figs 11–12).

Thorax. As for the genus, with dorsal side brown.

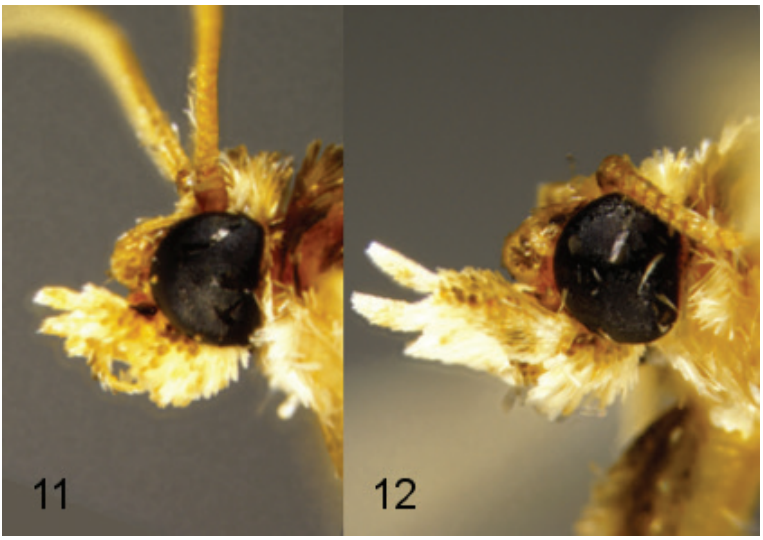
Wings. Forewing length ♂ 8.5–10.5 m, ♀ 9.5–12.0 m; forewing ground colour white, basal area light- to dark brown, delimited by dark brown to grey antemedial line; median area with pale brown, faint proximal discoidal stigma; distal discoidal stigma pale brown, reaching from costa to forewing centre; central dorsum with prominent orange to dark brown L-shaped or triangular spot leading to forewing centre and often meeting with distal discoidal stigma; antemedial line sinuate, more or less distinct, but with prominent subcostal bulge; subapical half of termen with half moon-shaped brown to grey-grown spot; marginal line dotted; fringe and marginal line darkened at the tips of the half moon-shaped spot; hindwing ground colour white, internal area white, with discoidal spot, basicostally often with auxiliary spot; medial line sinuate, distal half approaching the discoidal spot, then turning towards dorsum; external area pale brown to gray; marginal line dotted.

Abdomen. First segment whitish, remainder brownish.

Male genitalia. As for the genus, apart from: juxta subulate, with short, broadly convex base, at 2/3 length slightly broadened; valvae broad, relatively short, nearly triangular; costa simple, slightly convex, subapically with a short concave portion; fibula hooked, its widened base emerging ventrad of costa base; sacculus ventrally convex, dorsally concave, at distal end with spike-shaped, strongly sclerotized process, oriented dorsad and crossing with fibula; distal ventral valva margin granulated (*ga* in Fig. 13), valva apex rounded, strongly granulated; distal 2/3 of ventral valva margin loosely covered with long thin setae; phallus simple, tapering posteriad, posterior apodeme dorsally elongate, ventrally with subapical, weakly serrated sclerite; ventral and dorsal portion of posterior apodeme separated by a slim, less strongly sclerotized region.

Female genitalia. As for the genus, apart from: anterior antrum with spoon-shaped posteriad indentation, flanked on either side by a sclerotized portion (*as* in Fig. 31); sternite 8 anterior edge arched (*ae* in Fig. 31), with a sclerite process leading in each of the lateral pockets; both apophysis pairs simple, slightly curved.

Immature stages. Larva. MSD1 and MSD2 of meso- and metathorax usually on a shared pinaculum, earlier instars frequently have the MSD setae on separate pinacula on one or both segments; dorsal abdominal pinacula show apparent differentiation between West- and East-Asian populations: in live western specimens (e.g., from Pakistan), the abdominal D1 pinacula usually have an unpigmented cream coloured area near to their anteriomedian margin. This unpigmented area may be contiguous with the unmelanized cuticle surrounding the pinaculum or be surrounded by the melanized cuticle of the pinaculum (illustrated on A3–6 in Fig. 35); this cream white, unpigmented area may darken in preserved specimens, and in pre-pupae may be ringed in black. Eastern specimens (e.g., from Thailand) often have dark spots on at least some of the D1 pinacula (illustrated on A2 in Fig. 35); geographically intermediate populations (e.g., Sri Lanka) often show an intermediate form with black spots on occasional pinacula, and any unpigmented area is



Figures 11–12. Head profiles of adult *Leucinodes orbonalis.* **11** male **12** female. Figures at same scale.

usually ringed with black pigmentation (illustrated on A7 in Fig. 35). East-Asian populations usually have mesally triordinal crochets, whereas the crochets of West-Asian populations are mesally biordinal. **Pupa.** Cremaster forms a variable shelf-like, sub-rectangular structure, much wider than long, usually with distinct distal corners and median notch; dorsal surface spinulose, with additional small but distinct spines which are variable in extent, form and number; cocoon of dark brown silk, may be white or beige when newly spun.

Distribution. India, Indonesia: Java (Guenée 1854), Sri Lanka (Walker 1859, Moore 1885), Myanmar (Burma), Andaman Islands (Pagenstecher 1900), Bangladesh, Brunei, Cambodia, China, Japan, Laos, Malaysia, Nepal, Pakistan, Philippines, Singapore, Taiwan, Thailand, Vietnam (CABI 2012a), Australia (Shaffer et al. 1996); imported to Great Britain, the Netherlands (pers. comm. M. van der Straten), Denmark (pers. comm. O. Karsholt) and the U.S.A. (Boateng et al. 2005, Solis 2006).

Food plants. Solanaceae: *Solanum melongena* L., *S. aculeatissimum* Jacq., *S. aethiopicum* L., *S. erianthum* D. Don., *S. anguivi* Lam. (as *S. indicum* L.), *S. integrifolium* Poir., *S. lycopersicum* L., *S. macrocarpon* L., *S. mammosum* L., *S. nigrum* L., *S. torvum* Sw., *S. tuberosum* L., *S. viarum* Dunal, *S. xanthocarpum* Schrad., *Physalis minima* L., *P. peruviana* L., *Capsicum annuum* L. (van der Straten 2005; Hayden et al. 2013).

Remarks. *Leucinodes orbonalis* has previously been reported in Europe from the Netherlands (van der Gaag et al. 2005) and Great Britain (Agassiz 1983; Higgott 2009) as well as from the following African countries due to misidentification: South Africa (Walker 1859; Pagenstecher 1900; Kemal and Koçak 2007); Kenya (Poulton 1916); Ghana (for example, Frempong and Buahin 1977, Frempong 1979, Duodu 1986, Horna et al. 2007); Lesotho, Zambia and Zimbabwe (Kopij 2005); Burundi, Cameroon, Congo, Democratic Republic of the Congo, Ethiopia, Malawi, Mozam-

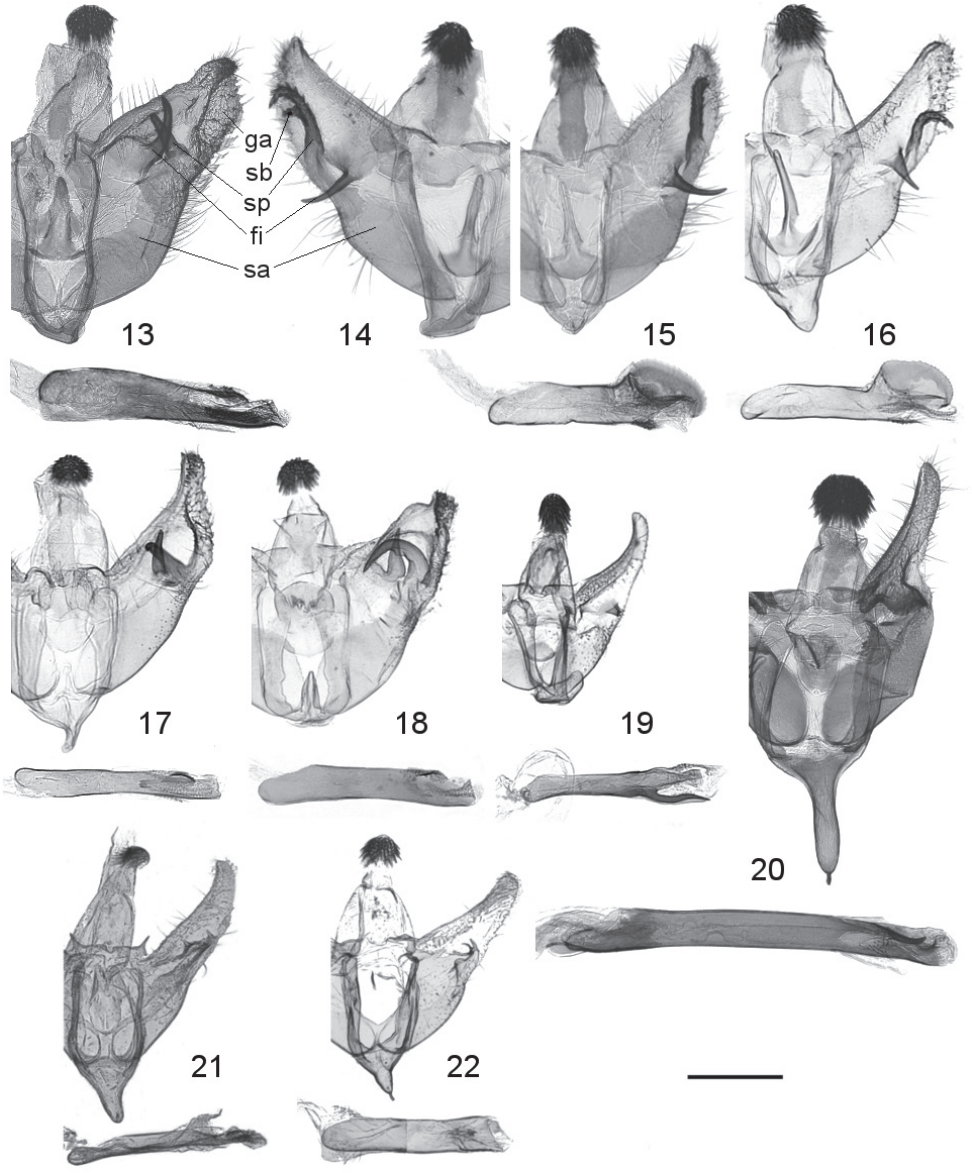
bique, Nigeria, Rwanda, Sao Tome and Principe, Sierra Leone, Somalia, Tanzania and Uganda (CABI 2012a). We have not found a single specimen from Africa belonging to this species and therefore postulate that *L. orbonalis* does not occur in Africa.

***Leucinodes africensis* sp. n.**
http://zoobank.org/F8291E38-9C43-478D-8ED6-9C39EE507065
Figs 2, 14–15, 24, 32, 35, 38–39, 42–43

Type-locality. West Africa, 11 June 1848, H. S. Le Marquand leg.

Material examined. Type-specimen. Holotype ♂ [red-circled label] "Holo- | type", "WEST AFRICA: | H.S. Le Marquand. | 11. xi. 48", BM Pyralidae slide 23118 (BMNH). – **Additional material. GHANA.** 1♀ Kumasi, leg. J. D. G. Sanders, BMNH Pyralidae slide No. 23130 (BMNH); **LIBERIA.** 1♂ Kpaine, 7°10'N 9°07'W, 12.viii.1953, leg. Dr W. Peters, BMNH Pyralidae slide No. 23148 (BMNH); **CÔTE D'IVOIRE.** 1♂ Abidjan, 19.xi.1952, leg. L. Sheljuzhko, prep. RM330 (ZSM); 1♂ Bouaké, Inepa, 14.–15.vi.1983, col. Stam, prep. RM693 (RMCA); 1♀ Bingerville, 11.vi.1961, leg. J. Decelle, prep. RM704 (RMCA]; 1♀ Mont Nimba, Xealé, 6.ii.1959, leg. M. Condamin & R. Roy, prep. RM743 (MNHN); **NIGERIA.** 1♀ Lagos, 31.viii.1987, leg. Boorman, BMNH Pyralidae slide No. 23127 (BMNH); 1 ex. Oyo, Ibadan, International Institute of Tropical Agriculture, 7.501N 3.906E, 240m, 15.iii.2006, leg. S.E. Miller & T.M. Kuklenski, DNA Barcode USNM ENT 196725 (USNM); **GABON.** 1♂ Ntoum, xii.1986, leg. A. Pauly, prep. RM685 (RMCA); **DR CONGO.** 1♂ Sankuru, Dimbelenge, i.–ii. 1957, leg. M. Fontaine, prep. RM697 (RMCA); 1♀ Elisabethville, 20.ii.1934, leg. Ch. Seydel, prep. RM696 (RMCA); **ANGOLA.** 1♂ 3♀ prov. Uíge, Negage, market, 7°45'39.4"S 15°16'00.6"E, 1213 m, 21.iii.2013, fruits of *Solanum aethiopicum*, e.l. 19., 20., 21.iv.2013, leg. M. Nuss, 1♂ prep. RM643, DNA vouchers SMTD Lep1562 & Lep1563 (SMTD); 2♀ same data, but 30.i.2014, fruits of *Solanum aethiopicum*, e.l. 16.ii.2014, leg. M. Nuss (SMTD); **WEST AFRICA.** 1♂ ii.–xi.43, leg. H. S. Le Marquand, BMNH Pyralidae slide No. 23118 (phallus lost) (BMNH); **TANZANIA.** 2♀ Oldeani, 22.x.1961 & 9.xii.1961, leg. J. Killand, preps RM334 & RM634 (ZSM); **THE NETHERLANDS (IMPORT).** 1♂ Schiphol (Amsterdam), import Ghana, 18.ix.2009, ex larva 22.ix.2009, ex pupa 1.x.2009, leg. P. Dekker, det. M v. d. Straten, prep. RM501, DNA voucher SMTD Lep946, DNA Barcode BC MTD 01816 (NPPO); 1♀ Schiphol (Amsterdam), import Ghana, 18.ix.2009, ex larva 23.ix.2009, ex pupa 1.x.2009, leg. P. Dekker, det. M. v. d. Straten, prep. RM640 (NPPO); **GREAT BRITAIN (IMPORT).** 1 ♂ London Airport, import Zimbabwe (Rhodesia), 1965; 1♂ 1♀ import Nigeria, ex tomatoes, London Airport xi.1965 (FERA); for additional FERA material see Suppl. material 2.

Diagnosis. The frons is less strongly bulged than in *L. orbonalis*. In wing pattern this species is indistinguishable from those of *L. orbonalis*, *L. rimavallis*, *L. pseudorbonalis*, *L. kenyensis* and "*Leucinodes* spp.", but distinguished from *L. malawiensis* by



Figures 13–22. Male genitalia. **13** *Leucinodes orbonalis*, Vietnam (prep. RM503) **14** *L. africensis*, two-branched sacculus process, Côte d'Ivoire (prep. RM330, phallus omitted) **15** *L. africensis*, single-branched sacculus process, Ghana (import) (prep. RM501) **16** *L. rimavallis*, Kenya (prep. RM667) **17** *L. pseudorbonalis*, Uganda (prep. RM705) **18** *L. kenyensis*, Zimbabwe (prep. RM694) **19** *L. malawiensis*, Malawi (prep. RM683) **20** *L. laisalis*, South Africa (prep. RM504) **21** *L. ethiopica*, Ethiopia (BMNH Pyralidae slide 23138) **22** *L. ugandensis*, Somalia (BMNH Pyralidae slide 23140); phallus mirrored. Abbreviations: fi fibula, ga granulated area, sa sacculus, sb side branch of sacculus process, sp sacculus process. Scale bar represents 500 μm.

the absence of the forewing basal transversal streak and the presence of the apical half moon-shaped patch, and from *L. laisalis*, *L. ethiopica* and *L. ugandensis* by the predominantly white forewing ground colour. In male genitalia it is distinguished by: the long ventrad fibula (as in *L. rimavallis*, short and triangular in *L. malawiensis*, broad and stout in *L. laisalis*); the elongate, straight or hook-shaped, sometimes branching distal sacculus process projecting towards the valva apex (similar in *L. rimavallis*); the apically thin, subulate juxta (similar in *L. rimavallis*); the prominent oval saw blade-shaped sclerotization of the posterior phallus apodeme (as in *L. rimavallis*); it is distinguished from *L. rimavallis* by the longer, more curved fibula with a slender base, the elongate distal sacculus process, which spans more than half the distance fibula base–valva apex, is straight or hook-shaped and sometimes exhibits a side branch, and the pointed valva apex (rounded in *L. rimavallis*). Female genitalia resemble those of *L. pseudorbonalis* in having a swollen antrum, but they lack the posterior constriction of the ostium bursae.

Description of adults. Head. As for the genus, with frons moderately bulged, base of each meron of labial palps with white scales.

Thorax. As for the genus, with dorsal side brown.

Wings. Forewing length ♂ 7.5–10.5 m, ♀ 7.0–11.5 m; wing pattern as in *L. orbonalis*.

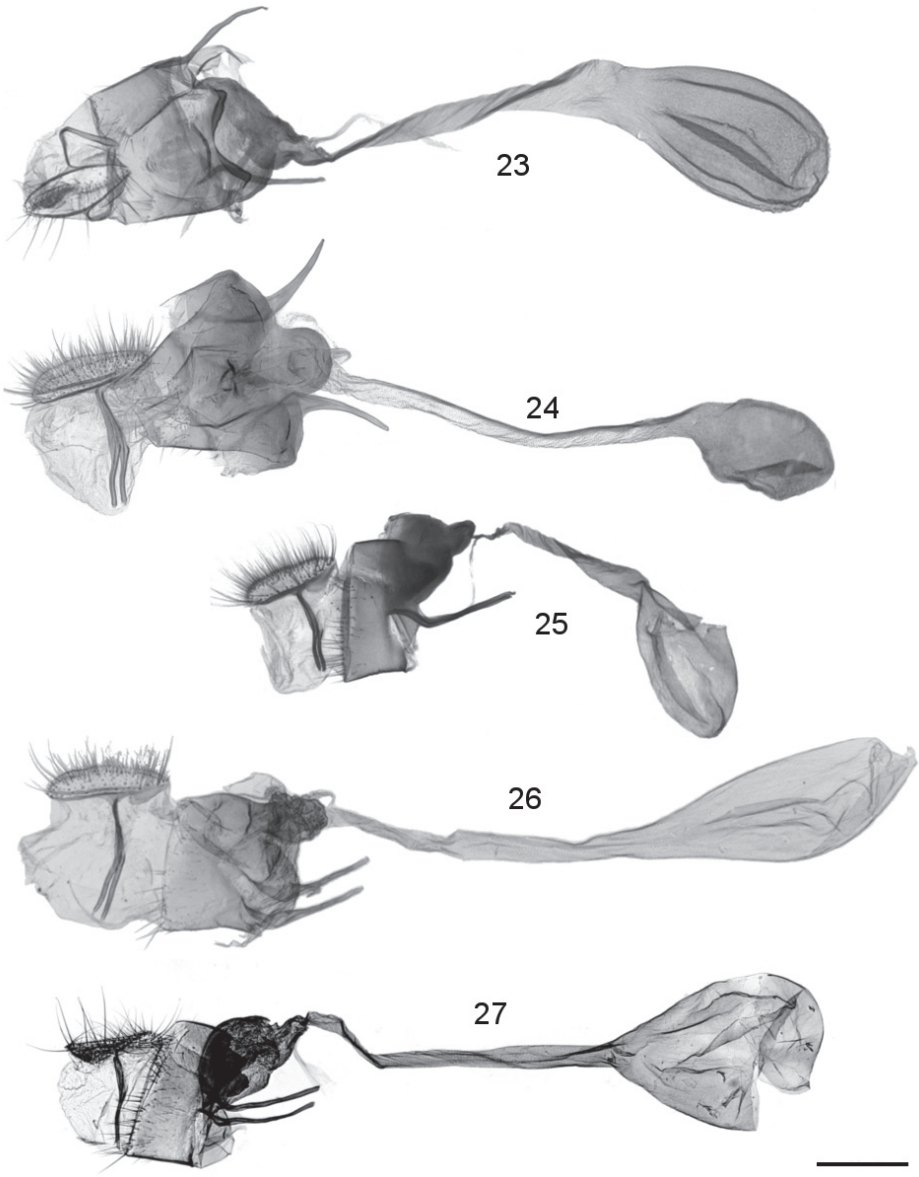
Abdomen. First segment whitish, remainder brown to grey.

Male genitalia. As for the genus, apart from: juxta base broad, semicircular, apical 2/3 of juxta thin, subulate; valvae broad, forming an oblong triangle; sacculus process porrect towards valva apex or apically bent, apex acanthaceous, sometimes with a similarly acanthaceous subapical side branch (*sb* in Fig. 14); ventrad fibula thin, spine-like, curved, crossing distal sacculus anterior to the sacculus process; valva apex pointed; posteriodorsal phallus apodeme with prominent oval saw blade-like sclerite, posterioventral apodeme with posteriodorsad oriented tapering process.

Female genitalia. As for the genus, apart from: colliculum-antrum complex in sagittal plane of sigmoid shape; dorsal surface of antrum exocuticle with longitudinal sclerotized strip running from sternite 8, bearing transverse ridges (Fig. 32); sternite 8 with anteriomedian recess, anteriolateral edges slightly dentate; apophyses anteriores with broadened central portion.

Immature stages. Larva. Final-instar larvae of *L. africensis* and *L. orbonalis* cannot be definitively separated. In final instars of live specimens of *L. africensis*, the majority of the abdominal D1 pinacula have a dark pigmented spot on the anteriomedian margin (illustrated on A2 in Fig. 35), although in the occasional pinaculum this is replaced by an unpigmented area, which can be contiguous with the unmelanized integument surrounding the pinaculum or separated from it by the melanized cuticle of the pinaculum; crochets are mesally triordinal, as in the East-Asian populations of *L. orbonalis*. **Pupa.** length ca. 8.5 m; no consistent features separate the pupae of *L. orbonalis* and *L. africensis*.

Etymology. Latinized *africensis*, derived from the continent of Africa from where the type material originates and referring to the widespread distribution of this species on the African continent.



Figures 23–27. Female genitalia. **23** *L. orbonalis*, Thailand (import) (prep. RM642), ventral view **24** *L. africensis*, Ghana (prep. RM640), ventral view **25** *L. rimavallis*, Kenya (prep. RM666, SMTD Lep1592), lateral view **26** *L. pseudorbonalis*, Uganda (prep. RM706), lateral view **27** *L. kenyensis*, Kenya (prep. MN1134), lateral view. Scale bar represents 500 μm.

Distribution. Known from West Africa (Côte d'Ivoire, Ghana, Liberia, Nigeria), Angola, DR Congo, Gabon, and Tanzania; intercepted with plant imports from Ghana and Zimbabwe to Great Britain and the Netherlands. At least in the southern DR Congo (Lubumbashi) *L. rimavallis* occurs sympatrically with *L. africensis*.

Foodplants. Solanaceae: *Solanum aethiopicum* L. (Angola, leg. Nuss 2013), *S. lycopersicon* L., *S. melongena* L.

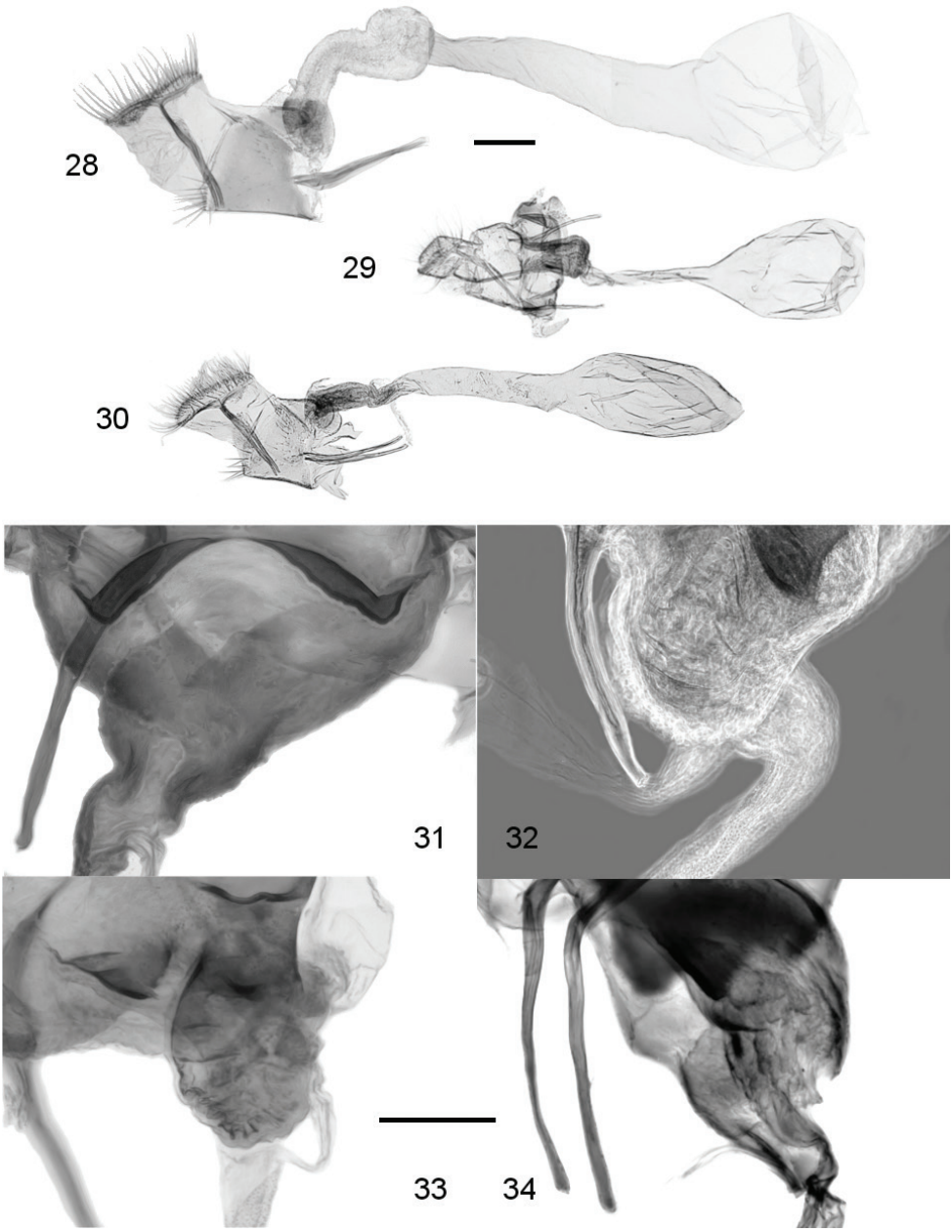
Remarks. This species is very similar to *L. rimavallis*, but both COI Barcoding data and constant morphological differences in genitalia separate the two species.

***Leucinodes rimavallis* sp. n.**
http://zoobank.org/F7EFC84B-D824-420F-8D0D-F5D0FF026CE2
Figs 3, 16, 25

Type-lacality. Kenya, Mt Elgon, 01°07'06"N, 34°41'30"E, February 1952, T. H. E. Jackson leg.

Material examined. Type-specimen. Holotype ♂ [red-circled label] "Holo- | type", "Mt Elgon | Kenya | Feb. 1952 | T.H.E. Jackson", "Pres. by | Coryndon Mus. | B.M. 1961-696.", B.M. Pyralidae Genitalia slide No. 23119 (BMNH). – **Additional material. RWANDA.** 1♂ Gisenyi (Kisenyi), 30.iv.1957, leg. M. Fontaine, prep. RM698 (RMCA); **BURUNDI.** 2♂ Kitega, 30.iv.1968 & 31.v.1969, leg. M. Fontaine, preps RM702 & RM703 (RMCA); **KENYA.** 1♂ Central Province, Castle Forest Lodge (S slope of Mt Kenya), 2050m, 0°21'15"S 35°18'12"E, 20.xi.2009, prep. DJLA1337 (coll. DJLA); 1♂ Central Province, Gatamayu Forest, 0°58.45'S 36°41.83'E, 21.vii.2001, leg. R.S. Copeland, DNA voucher SMTD Lep1593, prep. RM667 (RMCA); 1♂ Central Province, Gatamayu Forest, 0°58.45'S 36°41.83'E, 2284m, 17.viii.2002, leg. R. Copeland, prep. RM684 (RMCA); 1♀ Coast Province, Buda Forest, 4°27.79'S 39°24.20'E, 25.iv.2002, ex fruits *Withania somnifera*, leg. R.S. Copeland, DNA voucher MTD Lep1592, prep. RM666 (RMCA); 1♀ Fort-Hall [Murang'a], 1330 m, i.1912, leg. Alluaud & Jeannel, prep. RM742 (MNHN); 1♀ Taveta, 750 m, iii.1912, leg. Alluaud & Jeannel, prep. RM744 (MNHN); 1♀ Rurunga, 1550 m, i.1912, leg. Alluaud & Jeannel, prep. RM745 (MNHN); 1♂ Western Province, Kericho, 2050m, 0°21'15"S 35°18'12"E, 31.viii.1999, prep. DJLA1317 (coll. DJLA); 1♂ Mt. Elgon, ii.1952, leg. T.H.E. Jackson, BMNH Pyralidae slide No. 23119 (BMNH); 1♀ Mt. Elgon, i.1959, leg. T.H.E. Jackson, BMNH Pyralidae slide No. 23129 (BMNH); **DR CONGO.** 1♂ Ituri, Nioka, 5.ix.1953, leg. J. Hecq, prep. RM692 (RMCA); 1♂ Lubumbashi (Elisabethville), 13.x.1938, leg. Ch. Seydel, prep. RM695 (RMCA); 1♂ N. Kivu Lake, Rwankwi, iv.1948, leg. J. V. Leroy, prep. RM700 (RMCA); **SOUTH AFRICA.** 1♀ Natal, prep. RM735 (MNHN); **THE NETHERLANDS (IMPORT).** 1♂ Barendrecht, import Uganda, 26.ii.2014, leg. Sluijs, on *Solanum melongena*, prep. RM756 (NPPO); 1♂ Rijnsburg, import Uganda, 12.ii.2014, leg. J. de Zeeuw, on *S. melongena*, prep. RM757 (NPPO).

Diagnosis. Frons is moderately bulged; in wing pattern this species is indistinguishable from *L. orbonalis*, *L. africensis*, *L. pseudorbonalis*, *L. kenyensis* and "*Leucinodes* spp.", but distinguished from *L. malawiensis* by the absence of the forewing basal transversal streak and the presence of the apical half moon-shaped patch, and from *L. laisalis*, *L. ethiopica* and *L. ugandensis* by the predominantly white forewing



Figures 28–34. Female genitalia. **28** *L. laisalis*, Kenya (prep. RM308), lateral view **29** *L. ethiopica*, Ethiopia (BMNH Pyralidae slide 23139), ventral view **30** *L. ugandensis*, Somalia (BMNH Pyralidae slide No. 23137), lateral view **31** *L. orbonalis*, Thailand (import) (prep. RM642), ventral close-up of antrum region **32** *L. africensis*, Côte d'Ivoire (prep. RM743), dorsolateral close-up of antrum region (phase contrast filter) **33** *L. pseudorbonalis*, Uganda (prep. RM706), lateral close-up of antrum region **34** *L. kenyensis*, Kenya (prep. MN1134), lateral close-up of antrum region. Abbreviations: as antrum sclerotizations; Scale bar in **28–30** represents 500 μm and in **31–34** represents 200 μm.

ground colour. In male genitalia it is distinguished by: the long ventrad fibula (as in *L. africensis*, short and triangular in *L. malawiensis*, broad and stout in *L. laisalis*); the granulate, hook-shaped distal sacculus process (similar in *L. africensis*, process smooth in *L. kenyensis*); the apically thin, subulate juxta (as in *L. africensis*, broad subulate in *L. orbonalis*); the prominent oval saw blade-shaped sclerotization of the posterior phallus apodeme (as in *L. africensis*); distinguished from *L. africensis* by the shorter, straight to slightly curved fibula with a broader base, the shorter, always hook-shaped distal sacculus process, and the rounded valva apex (pointed in *L. africensis*). Female genitalia have slender apophyses anteriores (as in *L. orbonalis*), the central antrum tube with a short, strongly sclerotized section (long strip in *L. africensis* and *L. pseudorbonalis*), and the anteriolateral edges of sternite 8 with triangular processes extending into the lateral antrum pockets (as in *L. kenyensis*).

Description of adults. Head. As for the genus, with frons moderately bulged.

Thorax. As for the genus, with dorsal side brown, tegula scales whitish-brown.

Wings. Forewing length ♂ 8.5–12.0 mm, ♀ 7.0–14.0 mm; wing pattern as in *L. orbonalis*.

Abdomen. First segment whitish, remainder light to dark brown.

Male genitalia. As in *L. africensis*, but with the fibula short, more triangular and robust, straight or slightly curved; distal sacculus process short and always bent apically; valva apex rounded or stout.

Female genitalia. As for the genus, apart from: anterior antrum with short sclerotized section, central posterior antrum with diffuse weak sclerotization; sternite 8 on each side with anteriad triangular process extending into the lateral antrum pockets.

Etymology. From latin *rima* for 'rift' and *vallis* for 'valley', referring to the African Rift Valley, the main distributional area of this species (as far as known).

Distribution. Burundi, Eastern and Southern Democratic Republic of the Congo, Kenya, Rwanda, South Africa, Uganda (import).

Foodplants. Solanaceae: *Solanum melongena* L., *Withania somnifera* (L.) Dunal.

***Leucinodes pseudorbonalis* sp. n.**
http://zoobank.org/5B6C0A50-209B-407D-A689-4C8716D9EA18
Figs 4, 17, 26, 33

Type-locality. Angola, Huambo Province, Luimbale, Mt Moco, 1800-1900 m, 12°28'S, 15°10'S, 18 March 1934, K. Jordan leg.

Material examined. Type-specimen. Holotype ♂ [red-circled label] "Holo- | type", "Mt. Moco, | Luimbale, | 1800 - 1900m., | 18 March 1934.", "Angola | (Dr K. Jordan)", "Rothschild | Bequest | 1939-1.", BM Pyralidae slide 23135 (BMNH). – **Additional material. SENEGAL.** 1♂ Dakar, 01.viii.1952, leg. A. Villiers (BMNH); **UGANDA.** 1♂ Masindi, 29.xii.1897, leg. Ansorge, BMNH Pyralidae slide No. 23125 (BMNH); 1♂ Labonga, Unyoro, 13.xii.1897, leg. Ansorge, BMBH Pyralidae slide

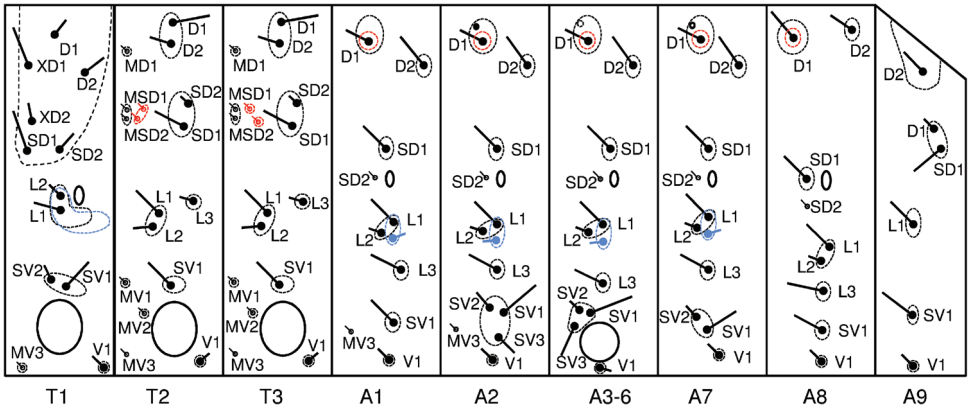


Figure 35. Chaetotaxy map of investigated *Leucinodes* larvae; blue elements illustrate variation found in *L. orbonalis* and *L. africensis*; red elements illustrate the differences found in *L. laisalis* compared to *L. orbonalis* and *L. africensis*.

No. 23126 (BMNH); 1♂ Nabagulo Forest, 15 m from Kampala, 25.x.–06.xi.1921, leg. W. Feather, BMNH Pyralidae slide No. 23145 (BMNH); 1♂, Ruwenzori Range, Ibanda, 4,700ft, 4.–12.ix.1952, leg. D.S. Fletcher, BMNH Pyralidae slide No. 23146 (BMNH); 1♂ Masindi, 30.x.1897, leg. Ansorge, prep. RM707 (BMNH); 2♂ Kampala, 1897, leg. Dr. Ansorge, BMNH Pyralidae slide No. 23149, prep. RM705 (BMNH); 1♀ same data, prep. RM706 (BMNH); **THE NETHERLANDS (IMPORT)**: 1♀ Barendrecht, import Uganda, 26.ii.2014, leg. Sluijs, on *Solanum melongena*, prep. RM758 (NPPO); **GREAT BRITAIN (IMPORT).** see Suppl. material 2.

Diagnosis. Frons is moderately to strongly bulged; Wing pattern indistinguishable from those of *L. orbonalis*, *L. africensis*, *L. rimavallis*, *L. kenyensis* and "*Leucinodes* spp.", but distinguished from *L. malawiensis* by the absence of the forewing basal transversal streak and the presence of the apical half moon-shaped patch, and from *L. laisalis*, *L. ethiopica* and *L. ugandensis* by the predominantly white forewing ground colour. In male genitalia the prominent dorsad fibula and the fibula-like sacculus process are roughly of same size and run parallel or cross each other (as in *L. orbonalis*, fibula and fibula-like sacculus process very small in *L. ugandensis*). Very similar to male genitalia of *L. orbonalis*, but valva tips slimmer and more acute, juxta with larger hemicircular base, elongated saccus tip and more prominent oval sclerite at posterior phallus apodeme. In female genitalia discriminated by the globular, posteriorly somewhat constricted antrum with a longitudinal, sclerotized exocuticular strip bearing transversal ridges (as in *L. africensis*).

Description of adults. Head. As for the genus, with frons moderately to strongly bulged.

Thorax. As for the genus, with dorsal side whitish.

Wings. Forewing length ♂ 7.0–8.5 mm, ♀9.0–11.0 mm; wing pattern as in *L. orbonalis*.

Abdomen. First segment whitish, remainder orange-brown.

Male genitalia. As for the genus, apart from: juxta oval to rectangular; valvae roughly rhombic; sacculus process claw-shaped, extending dorsad, parallel to or crossing with fibula; fibula slightly curved, spine-like, extending dorsad; posteriodorsal phallus apodeme with a small oval or semicircular sclerite, posterioventral apodeme with simple rodlike process.

Female genitalia. As for the genus, apart from: anterior antrum shortly coiled in coronal plane, with the exoculticle exhibiting a longitudinal sclerotized strip bearing transverse ridges (Fig. 33); sternite 8 intruding into the posteriorly somewhat constricted antrum, giving it a globular appearence.

Immature stages. Larva. Only one specimen available, examined live. Black spots present on dorsal pinacula; in the final instar, MSD1 and MSD2 on a shared pinaculum on both meso- and metathorax; crochets mesally triordinal.

Etymology. Composition of greek *pseud(o)* 'false' and *orbonalis*, meaning 'false *orbonalis*', referring to the similarities in external and male genital characters with *L. orbonalis*.

Distribution. Angola, Senegal, Uganda.

Foodplants. Solanaceae: *Solanum aethiopicum* L., *S. melongena* L.

Remarks. We found this species among material from Senegal, Uganda and Angola, leaving a considerable distribution gap in Central Africa.

Recently, several interceptions of larvae in solanaceous fruits imported from Uganda have been recorded in England (own observation) and the Netherlands (Marja van der Straten, pers. comm.). *L. pseudorbonalis* is one of the three African *Leucinodes* species intercepted at European ports of entry.

***Leucinodes kenyensis* sp. n.**
http://zoobank.org/C96D9272-2CEB-4916-948E-72C2999F35C3
Figs 5, 18, 26, 34

Type-locality. Kenya, Eastern Province, Marsabit District, Marsabit National Park Forest, 1158 m, 2°13.996'N, 37°55.676'E, 29 December 2003, R. S. Copeland leg.

Material examined. Type-specimens. Holotype 1♂ "Kenya: Marsabit National | Park Forest. 1158 m. | 2°13.996'N 37°55.676'E. | 29 Dec 2003, A&M Coll. #2636 | R.S. Copeland; ICIPE/USDA", "Reared from fruit: | Withania somnifera", DNA Barcode "USNM ENT 007/19337", "1133 | Nuss prep. no.", coll. NMK. Paratypes 1♂, 1♀, same data, DNA Barcodes USNM ENT 719338, 719339, Nuss prep. no. 1135 (1♀ NMK, 1♂ SMTD); 1♀ Kenya, Laikipia Plateau, Mpala Research Centre, 0.293°N 36.899°E, 1650 m, 21.–24.vi.2005, leg. S.E. Miller, DNA Barcode USNM ENT 719976, Nuss prep. no. 1134 (USNM). – **Additional material. ZIMBABWE.** 1♂ Mashonaland, leg. H. B. Dobbie, prep. RM694 (BMNH).

Diagnosis. Frons less strongly bulged than in *L. orbonalis*. Wing pattern indistinguishable from those of *L. orbonalis*, *L. africensis*, *L. rimavallis*, *L. pseudorbonalis* and *Leucinodes* spp., but distinguished from *L. malawiensis* by the absence of the forewing basal transversal streak and the presence of the apical half moon-shaped patch, and

Figures 36–41. Larvae of *Leucinodes*. **36–37** *L. orbonalis* **36** mid instar **37** late instar **38–39** *L. africensis* **38** mid instar **39** late instar **40–41** *L. laisalis* **40** early instar **41** late instar.

from *L. laisalis*, *L. ethiopica* and *L. ugandensis* by the predominantly white forewing ground colour. Distinguished in male genitalia from all other *Leucinodes* species except "*Leucinodes* spp." (see below) by the prominent distal sacculus process arching anteriodorsally above the shorter, conical fibula. Distinguished from *Leucinodes* spp. by the more or less bulged subapical portion of costa (straight in *Leucinodes* spp.) and the weakly sclerotized basal section of the sacculus process (between sacculus and distal hook-shaped process) which is as wide as base of hook-shaped process (strongly sclerotized and narrower than base of hook-shaped process in *Leucinodes* spp.). Female genitalia resemble those of *L. rimavallis* in having an anteriad triangular process on each side of sternite 8 extending into the lateral antrum pockets, but the exocuticle of the anterior antrum forms a sclerotized tube (short sclerotized section in *L. rimavallis*).

Description of adults. Head. As for the genus, with frons slightly bulged.

Thorax. As for the genus, with dorsal side brown.

Wings. Forewing length ♂ 9.0 mm, ♀ 9.0 mm; wing pattern as in *L. orbonalis*.

Abdomen. First segment whitish, remainder light to dark brown.

Male genitalia. As for the genus, apart from: saccus bent posteriodorsad (not an artifact of embedding); juxta oval to rectangular; valvae roughly triangular; costa subapically more or less bulged; ventral valva apex flipped over, covered with small tubercles; ventral valva edge smoothly rounded at sacculus; base of sacculus process broad, weakly sclerotized, leading over to a large, strongly sclerotized hook which encompasses the fibula dorsally; fibula conical, slightly curved, its base somewhat constricted, projecting dorsad; phallus similar to *L. orbonalis*, posteriodorsal apodeme with short dentate sclerite (sometimes indistinct), vesica with area of minute teeth.

Female genitalia. As for the genus, apart from: anterior antrum with tubular sclerotized exocuticle; sclerotized wall at antero-ventral edge of the ostium bursae which at rest closes the ostium bursae against abdominal segment 8. This wall is not melanized and can be stained with chlorazol black. It is delimited dorso-laterally by sclerotized and melanized lobes arising from the anterior edge of segment 8 just ventral of the apophyses anteriores. Anterior to the sclerotized wall there is a small, melanized colliculum.

Etymology. The species is named after Kenya, the only country from where it is confidently recorded so far.

Distribution. So far only known from Kenya. The record from Zimbabwe needs confirmation by investigation of female specimens and molecular analysis.

Foodplants. Solanaceae: *Withania somnifera* (L.) Dunal.

Remarks. There are further male specimens with indistinctive wing pattern and very similar genitalia, but DNA Barcode data suggest that among them are at least two further species. For more information, see under *Leucinodes* spp.

***Leucinodes malawiensis* sp. n.**
http://zoobank.org/FECB8543-F50F-4CB3-A3D7-5C9ABAA3D9CC
Figs 6, 19

Type-locality. Malawi, Central Region, Lilongwe District, Ntchisi Forest Reserve, 1560 m, 13°18.99972'S, 34°02.99934'E, 18 February 2004, L. Aarvik leg.

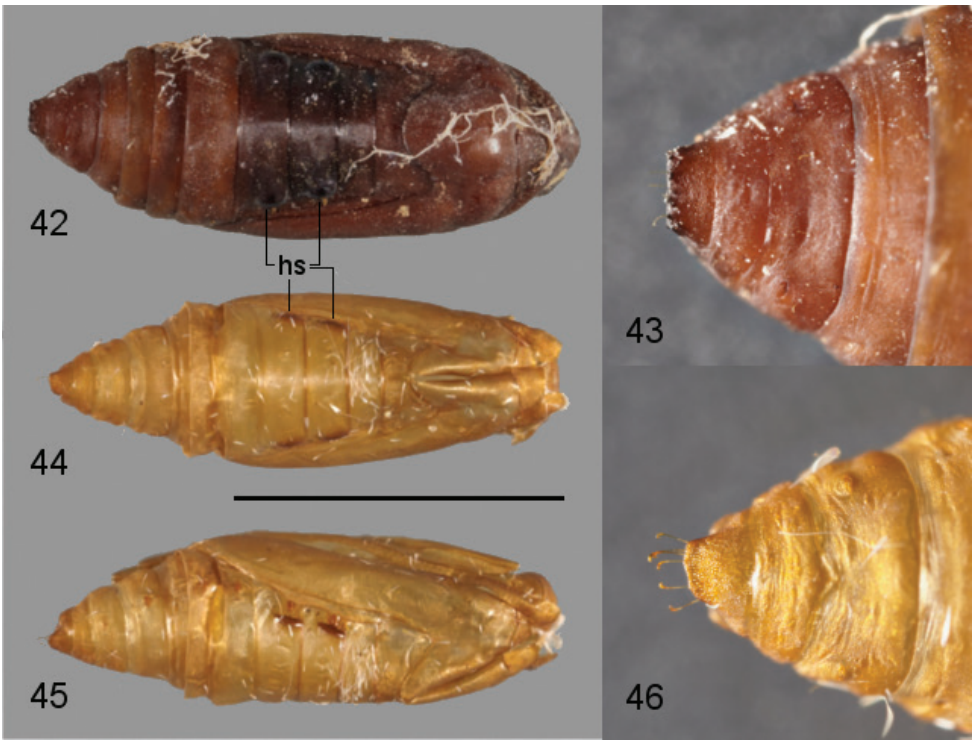
Material examined. Type-specimen. Holotype ♂ "MALAWI Central | Region, Lilongwe District: | Ntchisi Forest Reserve | 1560 m 18. ii. 2004 | leg. L. Aarvik", DNA voucher SMTD Lep1617, prep. RM683 (NHMO).

Diagnosis. Distinguished from the other *Leucinodes* species by the dark, straight-framed forewing base and the absence of the subapical mark of the forewing termen. The male genitalia are similar to those of *Leucinodes ethiopica* and *L. ugandensis*, but are distinct in the long spinoid process of the posterior phallus apodeme.

Description of adults. Head. As for the genus, with frons flat.

Thorax. As for the genus, with dorsal side brown.

Wings. Forewing length ♂ 8.5 mm; forewing base dark brown, its outer margin a straight diagonal line from the costa to the maculation of the central hind margin, a triangular patch leading lateroposteriad from the costa with the costal half reddish-brown and the central tip white; outer median area with a faint brownish transverse



Figures 42–46. Pupae of *Leucinodes*. **42–43** *L. africensis* **42** dorsal view **43** close-up of cremaster **44–46** *L. laisalis* **44** dorsal view **45** lateral view **46** close-up of cremaster. Abbreviations: hs hood-like structures dorsal to spiracles on abdominal segments 2 and 3. Scale bar refers to **42, 44** and **45** and represents 5 mm.

streak; subterminal line indistinct except subapical thickening; apex white; hindwing antemedial line indistinct; dark discal spot; postmedial line clear at costal margin, fading out posteriad; anterior distal area with a faint brownish transverse streak; terminal wing veins dark-spotted.

Abdomen. Pale ochreous, first abdominal segment white, terminal segments brown.

Male genitalia. As for the genus, apart from: saccus elongated, U-shaped; juxta short, oval, twice as broad as long; valvae slender, tapering towards the dorsad bent apex; fibula small, triangular, oriented ventrad; sacculus process absent; phallus with a spinoid posteriad sclerotization emerging from the ventroposterior apodeme.

Female genitalia. Unknown.

Etymology. Latinized *malawiensis* from the country Malawi where the holotype originates.

Distribution. Malawi.

Foodplants. Unknown.

Remarks. *Leucinodes malawiensis* resembles species of the Neotropical genus *Neoleucinodes* Capps, 1948: It shares the prominent diagonal line in the forewing base with *Neoleucinodes dissolvens* (Dyar, 1914), but lacks the long, sabre-like cornutus in

the phallus. The absence of the half moon-shaped pattern at the anterior half of the forewing's outer margin is also found in *Proleucinodes* Capps, 1948. In the COI Barcode Neighbor Joining tree *L. malawiensis* clusters with *Neoleucinodes*, but is weakly supported with 50% Bootstrap support.

Leucinodes laisalis (Walker, 1859), comb. n.

Figs 7–8, 20, 28, 35, 40–41, 44–46

Megaphysa laisalis Walker, 1859: 382–383. (Hampson 1899: 275 to *Sceliodes*)
= *Daraba idmonealis* Walker, 1859: 385–386.
= *Hyamia subterminalis* Walker, 1866: 1145.
= *Daraba plenisignata* Walker, 1866: 1977–1978.
= *Leucinodes translucidalis* Gaede, 1917: 398, **syn. n.**

Type-locality. South Africa, Cape of Good Hope

Material examined. Type-specimen. Holotype, sex unknown, [round white label with green border] "Type"; [round pale white label] [front] "C. G. | Hope", [back] "44 | 6"; [rectangular blue label] "Megaphysa | laisalis Wlk | Type" (BMNH). – **Additional material. MOROCCO.** 1♂ Oued Cherrat, 17.ix.1952, leg. Ch. Rungs, prep. RM 734 (MNHN); **SENEGAL.** 1♂ Dakar, viii.1952, leg. A. Villiers, prep. RM736 (MNHN); **CÔTE D'IVOIRE.** 1♂ Bouaké, Inepa, 29.–30.xii.1983, leg. Stam, prep. RM688 (RMCA); **NIGERIA.** 1 ex. Oyo, Ibadan, International Institute of Tropical Agriculture, 7.501N 3.906E, 240m, 19.vi.2006, leg. G.M. Miller & T.M. Kuklenski, DNA Barcode USNM ENT 676643 (USNM); **KENYA.** 1♂ Nairobi, Kiambu (Kyambu), 6000 ft, x.1916, leg. H. L. Andrewes, BMNH Pyralidae slide No. 23136 (BMNH); 1♂ 1♀ Kitui (Katoteni), 30.viii.2005, ex larva on *Solanum incanum*, adult 30.ix.2005, leg. Muli & Okuku, preps RM301 & RM308 (SMTD); 10ex. Laikipia County, Laikipia Plateau, Mpala Research Centre, 0.293N 36.899E, 1650m, 13.ii.1999 (1ex.), 20.iv.1999 (4ex.), 17.vii.1999 (3ex.), 23.xii.1999 (1ex.), 06.xii.2002 (1ex.), leg. S.E. Miller & T.M. Kuklenski (5ex.), S.E. Miller & R. O'Meara (4ex.), S.E. Miller (1ex.), DNA Barcodes USNM ENT 196697–196706 (USNM); 1ex. Matthews Range, 1.24N 37.29E, 1506m, 17.i.2004, leg. R.S. Copeland, DNA Barcode USNM ENT 719748 (USNM); **TANZANIA.** 1♀ Morogoro, Sokoine University Garden, 06°50'S 037°38'E, 05.vii.2009, leg. J. & W. De Prins, prep. RM668 (RMCA); 1♂ Morogoro Distr. & Town, 550–600 m, 14.xi.1992, leg. L. Aarvik, prep. RM686 (coll. Aarvik); **SOUTH AFRICA.** 1♂ Mpumalanga, Barberton, northern edge of town, suburban garden- and bushland, 610 m, 15./16.i.2007, leg. T. Karisch, DNA Barcode BC MTD 01819, prep. RM504 (coll. Karisch); **SPAIN.** 1♂ Cadiz, 3 km NW Tarifa, 5 m, 25.ix.1987, leg. P. Skou, prep. RM380 (ZMUC); **GREAT BRITAIN (IMPORT).** see Suppl. material 2 (Fera material).

Diagnosis. Distinguished from most other members of *Leucinodes* by the orange-brown to greyish forewing colour. Distinguished from *L. ethiopica* by the generally

darker forewing colour with less amount of white. Differs from both *L. ethiopica* and *L. ugandensis* in: male genitalia with large, oval sacculus; broad, strongly sclerotized ventrad fibula; saccus well elongated; phallus coecum keeled, posteriodorsal apodeme with slim, fingerlike, well sclerotized process; female genitalia with antrum broad, its anterior end coiled, with exocuticle diffusely sclerotized.

Redescription of adults. Head. Frons slightly bulged; labial palps upturned, greyish to brown, first meron on ventral side with forward-directed tuft, third meron in males half as long as second meron, considerably longer in females; maxillary palps minute; haustellum well developed; eyes large, hemispherical; ocelli present; antennae ciliate, cilia considerably longer in males; vertex with creamy white scales; chaetosemata absent.

Thorax. Dorsal side brown with greyish and dark brown scales mixed in; ventral side grey to whitish; legs predominantly whitish or grey, epiphysis present; tibial spurs 0, 2, 4 with outer spur 2/3 the length of inner spur.

Wings. Forewing length 7.0–11.5 mm, the females being somewhat larger; both sexes with one frenular bristle; forewing ground colour orange- to grey-brown, with the general *Sceliodes* wing pattern.

Abdomen. First segment whitish, remainder light-brown; older specimens often with darkened abdomen due to degeneration of abdominal fat body.

Male genitalia. As for the genus, apart from: vinculum saccus conspicuously elongated anteriad; juxta usually with small notch at median base; valvae emerging in narrow angle from vinculum; phallus with keeled coecum, posteriodorsal apodeme with slim, fingerlike, slightly curved and well sclerotized process, vesica with a short line of tiny cornuti.

Female genitalia. As for the genus, apart from: antrum long, tubular, anterior end coiled; apophysis pairs straight, apophyses anteriores with somewhat broader muscle attachment area at posterior quarter.

Distribution. In Africa known from Côte d'Ivoire, Ghana, Kenya, Morocco, Nigeria, Senegal, South Africa, Tanzania (own observations). Externally, *L. laisalis* is similar to *L. ugandensis* (see below), therefore literature records from other African countries than those listed here need verification. In Europe recorded from Spain, Portugal (Speidel 1996, Huertas Dionisio 2000; own observations) and Great Britain (own observations). The records from Great Britain certainly refer to interceptions and it is assumed that those from the Iberian Penninsula also do not refer to a native occurrence. Huertas Dionisio (2000) recorded the species from *Solanum linnaeanum*, a species native to southern Africa.

Food plants. Solanaceae: *Solanum incanum* L. (Kenya, leg. Muli & Okuku 2005), *S. anguivi* Lam. ("*S. sodomaeum* L.,"), *S. macrocarpon* L., *S. melongena* L., *S. linnaeanum* Hepper & P.-M. Jaeger, *S. lycopersicon* L. and *Capsicum annuum* L. (Hayden et al. 2013).

Immature stages. Larva. Generally very similar to *L. orbonalis* and *L. africensis*. On the metathorax the MSD setae are usually on separate pinacula, while the mesothoracic MSD setae are usually on the same pinaculum. The abdominal D1 pinacula

are often smaller than those of *L. orbonalis* and *L. africensis*, and lack dark spots or unpigmented areas (see Ogunwolu (1978) for a detailed larval description and chaetotaxy). **Pupa.** length ca. 8.5 mm; distal margins of cremaster usually evenly rounded, without distinct corners; spinulation of cremaster's dorsal surface a little coarser than dorsal spinulation on abdominal segment 9 dorsal surface, no distinct small spines as in *L. orbonalis* or *L. africensis*; cocoon of beige coloured silk that does not darken significantly over time.

Remarks. We found a significant DNA Barcode difference of 2.4–2.8% uncorrected p-distance between the single South African specimen and the Kenyan and Ghanan/Nigerian Barcode clusters (Fig. 47; see also section 'DNA Barcoding' below). These differences in the DNA Barcode are not reflected in a divergent morphology of the clusters.

The record of *L. laisalis* from Belgium by Nyst (2004) is most probably a misidentification, since the illustrated imago resembles much more the whitish *Leucinodes* species. Apart from that, there is a European record of *L. laisalis* from Spain. Additionally, it is frequently intercepted with the import of solanaceous fruits in Great Britain.

Despite repeated search in the collection of the ZMHB, original material of *Leucinodes translucidalis* Gaede, 1917 from Tanzania, Tendaguru, could not be traced. According to the original description, this taxon can be regarded as conspecific with *L. laisalis* due to all details given in the original description. Especially the white triangle at the anterior line, another white triangle, though often somewhat inconspicuous, at the middle of costa, and the dark brown area below apex support the conspecifity with *L. laisalis*.

***Leucinodes ethiopica* sp. n.**
http://zoobank.org/CC7E081A-7D4A-4C07-887F-4698DD8650EC
Figs 9, 21, 29

Type-locality. Ethiopia, Dire Dawa Region, Dire Dawa District, Dire Dawa, December 1934, H. Ulenhuth leg.

Material examined. Type-specimens. Holotype ♂ [red-circled label] "Holo- | type", "Dire Daoua, | Abyssinia, | December 1934. | (H. Uhlenhuth)."; 19 paratypes: 11♂ 8♀ same data as holotype, including one with BM Pyralidae | slide 23138♂ (BMNH). – **Additional material. ERITREA.** Asmara, 20.x.1905. leg. N. Beccari (without abdomen), 1♀ same data except 28.i.1905 (BMNH); **ETHIOPIA.** 34 ex. same data as holotype except ii.1935, 4 ex. ditto except iv.1935, 7 ex. ditto except v.1935 including BM Pyralidae| slide 23139♀, 1 ditto except ix.1935, 2 ex. labelled Durleti [= Daleti] (BMNH); **SAUDI ARABIA.** 2♀ Taif (BMNH).

Diagnosis. This species' forewing colour has more ochreous than the whitish species of *Leucinodes* but less orange-brown to greyish than in *L. laisalis* and *L. ugandensis*. From *L. ugandensis* and *L. laisalis* it can be distinguished by the genitalia: in the male genitalia the transtilla arms each bear a dorsad spine; in the female genitalia the ductus

bursae lacks the fine granular sclerotization, the antrum is strongly sclerotized, tubular and widest at its anterior end, and the oval ostial sclerites in the lateral antrum pockets are larger.

Description of adults. Head. Head and appendages pale ochreous.

Thorax. Pale ochreous.

Wings. Forewing length 6.0–8.0 mm. Forewing mixed ochreous and white, an oblique dark ochreous fascia from above dorsum reaching halfway across wing, a blackish crescent before ochreous subterminal line, black dots along termen. Hindwing white, a small black discal spot, a faint irregular dark subterminal line, ochreous suffusion in outer part of wing in middle and towards apex.

Abdomen. Pale ochreous, first abdominal segment white.

Male genitalia. As for the genus, apart from: transtilla with short central notch, each transtilla arm with a dorsad spine; vinculum saccus with rounded tip; juxta oval to rectangular, apex with a short central notch; apex of valvae dorsally curved; small, spine-like dorsad fibula emerging from the central inner side of valva; sacculus with a fibula-like spiny dorsad process emerging ventrodistally of the fibula; posteriodorsal phallus apodeme with semicircular dentate sclerite.

Female genitalia. As for the genus, apart from: ductus bursae with fine longitudinal ripples; antrum tubular, with broader anterior end; apophyses anteriores at posterior half laterally broadened for muscle attachment.

Etymology. Latinized *ethiopica* from the country Ethiopia where the holotype originates.

Distribution. Eritrea, Ethiopia, Saudi Arabia.

Foodplants. Unknown.

Remarks. No COI Barcode sequences were obtained for this species.

***Leucinodes ugandensis* sp. n.**
http://zoobank.org/533D9189-05DB-451D-ADB9-71AB3FD3DDD7
Figs 10, 22, 30

Type-locality. Uganda, Eastern Uganda Region, Serere District, Okulongo, 8 December 1958, W. R. Ingram leg.

Material examined. Type-specimens. Holotype ♂ [red-circled label] "Holo- | type", "[transversally written] 1608 | "SERERE | Okulongo | 8 Dec. 1958 | W.R.Ingram | ex *Solanum* sp.", "Pres. by | Com Inst Ent | BM1959 – 499", "C.I.E. No. 16499", with cocoon under specimen. 2 paratypes: 1♂ same data as holotype and "Pyralidae | Brit Mus | Slide No. | 14696". 1♀ same data as holotype except 9 Dec. 1958 (BMNH). – **Additional material. ETHIOPIA.** 2♂ Diredaua, n.w. of Harar, 1914, leg. G. Kristensen, 1♀ Dire Dawa, Abyssinia, i.1935, leg. H. Uhlenkuth (BMNH); **SOUTH SUDAN.** 1♀ Tambura, Southern Bahr-al-Ghasal (BMNH); **SOMALIA.** 4♂ 1♀ Mogadishu, 17.–26.xi.1985, 7.vii.1986, 19–20.viii.1986 and 23.vii.1986, leg. A.G. Parker, BMNH Pyralidae slides No. 23140 & 23137 (BMNH); 1♂ Hargeison,

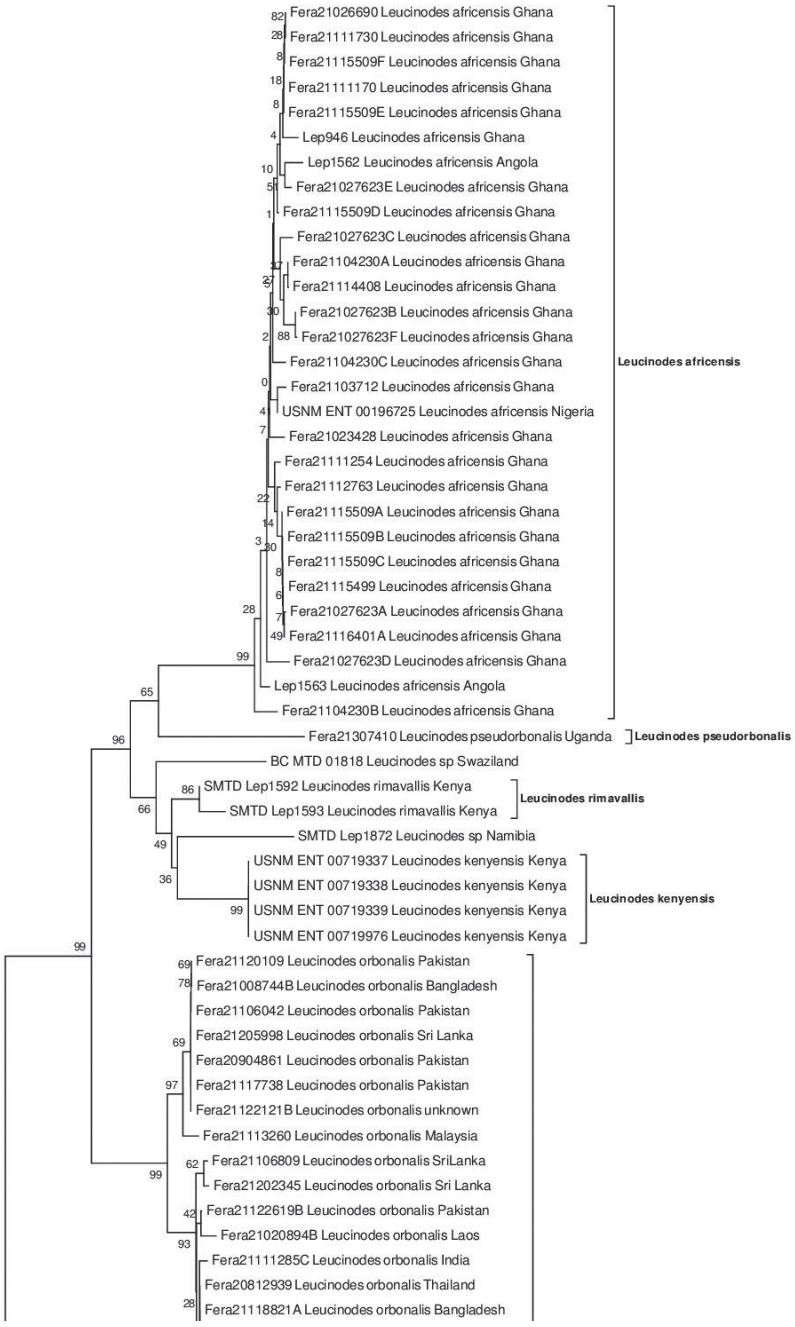


Figure 47. Neighbor Joining tree of COI Barcodes based on uncorr-p distances and rooted with *Udea ferrugalis*. Bootstrap support values derived from 1,000 Bootstrap replicates; scale bar represents 1% uncorr-p Barcode divergence.

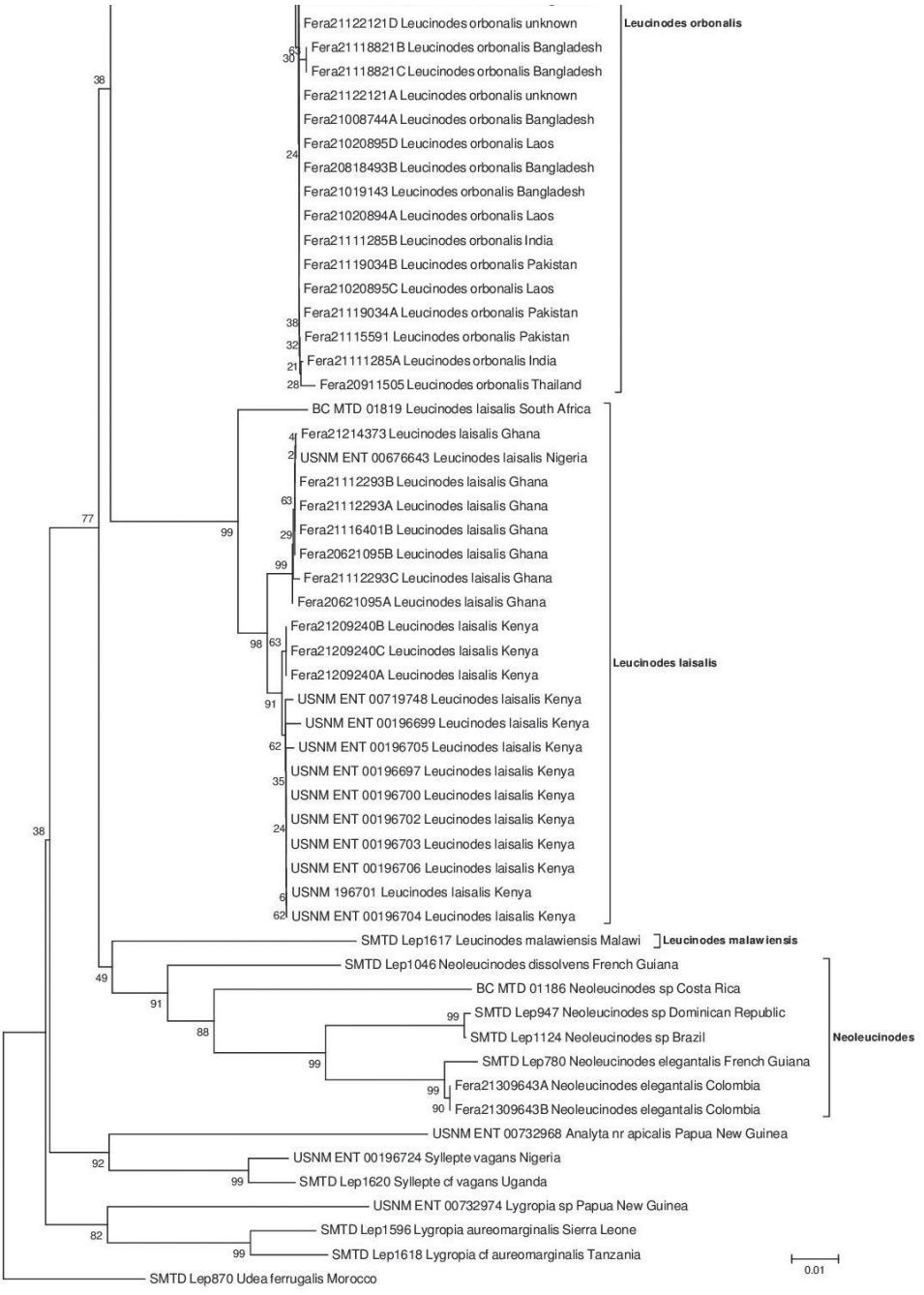


Figure 47. Continue.

4300ft, v.1939, leg. M. Portal Hyatt (BMNH); **KENYA.** 1♀ Somaliland, Mandera, 47km SW of Hubera, 3000ft, 13.xi.1908, leg. W. Feather (BMNH).

Diagnosis. Distinguished from the whitish species of *Leucinodes* and *L. ethiopica* by the predominantly brown forewing ground colour with minor white patches. Distinguished from *L. laisalis* in the male genitalia: less strongly sclerotized, valvae triangular, fibula small, tooth-like, a similarly shaped distal sacculus process present, saccus process shorter, phallus much shorter, dorsoposterior apodeme without slim, finger-like process.

Description of adults. Head. Head and appendages pale fuscous, labial palpus short, erect.

Thorax. Pale fuscous, metathorax blackish fuscous.

Wings. Forewing length 6.5–11.5 mm. Forewing pale fuscous, an oblique brown partial fascia at halfway with white markings on either side, an orange triangle on dorsum beyond halfway, apex deep brown, separated by a whitish line. Hindwing whitish, fuscous suffused near margin in middle and towards apex, a faint subterminal line in costal part of wing.

Abdomen. Abdomen first segment whitish, remainder orange-brown.

Male genitalia. As for the genus, apart from: small, hooked dorsad fibula emerging from the ventrocentral inner side of valva; distal sacculus with dorsad ridge forming a bulge, followed by a spiny, curved terminal process overlapping with the fibula; phallus vesica with several small spiny cornuti.

Female genitalia. As for the genus, apart from: diffusely sclerotized exocuticula reaching into posterior ductus bursae; lateral antrum pockets rather small.

Etymology. Latinized *ugandensis* from the country Uganda where the type specimens originate.

Distribution. Ethiopia, Kenya, Somalia, South Sudan, Uganda.

Foodplants. Solanaceae: *Solanum* sp.

Remarks. No COI Barcode sequences were obtained for this species.

Leucinodes spp.

Note. The following material contains male specimens from southern Africa with indistinctive wing pattern and very similar male genitalia to *Leucinodes kenyensis*. According to morphology, we could not separate these specimens from *L. kenyensis*. In contrast to the morphological data, two of these specimens, the single records from Namibia and Swaziland, have distinctive DNA Barcodes from *L. kenyensis* as well as from each other (Fig. 47). For the remaining specimens listed below, we did not obtain DNA Barcodes. In spite of the absence of further specimens for comparison, especially females, and the lack of convincing morphological differences, we are not going to describe these possibly distinct species here. This complex needs further study.

Material examined. KENYA. 1♂ Rift Valley, Naivasha, 1900m, 0°46'56"S 36°25'23"E, 5.xii.2011, leg. D.J.L. Agassiz, prep. DJLA 1318 (coll. DJLA); **ZAMBIA.**

1♂ Chiwefwe, ii.1950, leg. N. Mitton, BMNH Pyralidae slide No. 23133 (BMNH); **NAMIBIA.** 1♂ Namibia, Waterberg, 20°30'S 17°14'E, 13.iii.2010, leg. F. Koch, DNA voucher MTD Lep1872, prep. RM708 (ZMHB); **SOUTH AFRICA.** 1♂ Cape Province, Knysna, Wilderness, iv.1950, leg. H.B.D. Kettlewell, BM Pyralidae slide 23128 (BMNH); 1♂ Johannesburg, 21.iv.1906, leg. A.T. Cooke, BMNH Pyralidae slide No. 23144 (BMNH); 1♂ E. Cape Prov., Katberg, 4,000ft, 1.–15.i.1933, BMNH Pyralidae slide No. 23150 (BMNH); 1♂ KwaZulu-Natal, Estcourt, leg. J.M. Hutchinson, prep. RM779 (BMNH); 1♂ Eastern Cape [Pondoland], Port St. John, ix.1923, leg. R.E. Turner, prep. RM780 (BMNH); **SWAZILAND.** 1♂ Lebombo-Mountains, Ndzevane Area near Nsoko, Acacia-rich bushland at the foot of the Lebombo Mountains, 23.–24.i.2007, leg. T. Karisch, DNA Barcode BC MTD 01818, prep. RM502 (coll. MTD).

Taxa transferred to *Leucinodes*

***Leucinodes cordalis* (Doubleday, 1843), comb. n. (*Margaritia*)**

Leucinodes cordalis (Doubleday, 1843). Type locality: New Zealand.
= *Daraba extensalis* Walker, 1866 (synonymised by Hampson, 1899). Type locality: New Zealand, Auckland.
= *Eretria obsistalis* Snellen, 1880 (synonymised by Hampson, 1899). Type locality: Indonesia, Sulawesi [Celebes], Boelekomba; Bonthain.
= *Sceliodes mucidalis* Guenée, 1854 (synonymised by Hampson, 1899). Type locality: Australia.

Material examined. Syntype *cordalis* ♂ [circular white label with light blue border] "SYN- | TYPE", [circular white label] [front] "New | Zealand", [back] "42 | 55", [rectangular white label] "Margarita [sic!] | cordalis Doubld. | SYNTYPE | det. D.J. Carter, 1966", transparent capsule containing the head (BMNH).

Remarks. *L. cordalis* is known to occur in New Zealand, Australia, and Indonesia: Sulawesi (Snellen 1880, Dugdale 1988, Shaffer et al. 1996).

***Leucinodes raondry* (Viette, 1981), comb. n. (*Daraba*)**

Type locality. Madagascar, Sambirano, Tsaratanana, Haut Sambirano, Besanetrikely Valley.

Remarks. This species was described in *Daraba* Walker, 1859, a genus that has previously been synonymised with *Sceliodes* Guenée, 1854 by Hampson (1899). The type specimen of *Leucinodes raondry* (Viette, 1981), **comb. n.** from Madagascar could not be traced at MNHN. According to the original description and the illustration of the species given therein (Viette 1981), this species agrees with the

diagnostic wing pattern elements of *Leucinodes*, and we therefore consider it as correctly placed in this genus. It differs from *L. laisalis* in the larger size, the more ochreous grey tone and the reduced half moon-shaped subapical patch of the forewings (Viette 1981). None of the species described here as new have the prominent dark subapical patch in the hindwings of *L. raondry*, so that conspecifity with any of them can be ruled out.

Leucinodes grisealis (Kenrick, 1912) , comb. n. (misplaced) (*Sceliodes*)

Type locality. Indonesia, Dutch New Guinea [West Papua], Arfak Mountains, 4000 ft

Material examined. Holotype ♂ [circular label with red border] "Type", [rectangular whitish label, handwritten, first two words underlined] "Sceliodes | grisealis | Kenrick. | TYPE.", [rectangular white label, handwritten] "SCELIODES | grisealis", [rectangular greyish label] "Arfak Mountains, | North New Guinea. | 4,000ft. Feb.-Mar., 1909. | C.B.Pratt.", [rectangular white label] "Kenrick Coll. | Brit.Mus. | 1928–34." (BMNH). Female unknown.

Remarks. Due to the synonymisation of *Sceliodes*, this species is provisionally transferred to *Leucinodes*, as no proper generic placement has been found. Compared to *Leucinodes*, several differences can be found in wing pattern of *grisealis* Kenrick, 1912: In the fore wing, the postmedian line is originating in the apex, and its median protrusion is closely approaching the termen; the half moon-shaped patch below apex is protruding beyond M_3; in the hind wing, the postmedian line is originating closer to the apex and is running closer to the termen.

Taxa excluded from *Leucinodes*

Analyta Lederer, 1863

Analyta Lederer, 1863. Type species: *Analyta albicillalis* Lederer, 1863.

= ***Hyperanalyta*** Strand, 1918, **syn. rev.** Type species: *Analyta pseudoapicalis* Strand, 1918.

Analyta apicalis (Hampson, 1896), **comb. n.** (*Leucinodes*). Type locality: India, Dharamsala. Sri Lanka.

= *Analyta* (*Hyperanalyta*) *pseudoapicalis* Strand, 1918 (synonymised by Shibuya, 1928). Type locality: China, Taiwan, Anping.

Material examined. Types: Holotype *albicillalis* [circular white label with red border] "Type", [beige label with brown border and triangular edges] "Amboina | Doll.", [rectangular white label] "Felder | Collection.", [rectangular white label] "Rothschild | Bequest | B.M.1939-1.", [rectangular beige handwritten label] "Amboina | Dol.", [rec-

tangular beige handwritten label] "Analyta | albicillalis m", [rectangular brown label with central white area, roundly bordered by dark brown and yellow] "albicillalis Led." (BMNH); Holotype *apicalis* ♂ [circular label with red border] "Type", [rectangular white label] "4-94", [rectangular white label] "Ceylon | 95-119", [rectangular white handwritten label] "Leucinodes | apicalis | type ♂ Hmpsn.", transparent capsule with abdomen (BMNH); Holotype *pseudoapicalis* ♂ [red rectangular label] "Holotypus", [white rectangular label] "Anping | Formosa | H. Sauter VI.1911.", [rectangular white label] "Analyta | pseudoapi | calis m.| Strand det. ♂" (SDEI).

Remarks. *Hyperanalyta* Strand, 1918, with type species *Analyta pseudoapicalis* Strand, 1918 was established as a subgenus of *Analyta* Lederer, 1863. Later, *Analyta pseudoapicalis* was synonymised with *Leucinodes apicalis* Hampson, 1896 by Shibuya 1928. Thus, *Hyperanalyta* had to be regarded as a synonym of *Leucinodes*. Our investigation of *Leucinodes apicalis*, *Analyta pseudoapicalis* and *Analyta albicillalis* Lederer, 1863, the type species of *Analyta* Lederer, 1863, showed for all three species group taxa the presence of two frenular bristles in females (one in *Leucinodes*), the lack of distal discoidal stigma and L-shaped or triangular spot at central dorsum as characteristic for *Leucinodes*, but a homologous wing pattern common for the three taxa: forewing antemedian area brown; distal discoidal stigma a pale brown thin line; postmedian line sinuate; apical dark spot reaching outer forewing margin (white border in *Leucinodes*). We therefore rule out the congenerity of *Leucinodes apicalis* and *Analyta pseudoapicalis* with *Leucinodes* and transfer both to *Analyta*.

Lygropia Lederer, 1863

Type species: *Asopia unicoloralis* Guenée, 1854.

Lygropia aureomarginalis (Gaede, 1916), comb. n. (*Leucinodes*)

Type locality. Cameroon, Buea.

Material examined. Holotype ♂ [small blue label] "Gr. Kamerunberg | Buea 1.–10. XI. 10 | 1000–1200 m | E. Hintz S. G.", [large blue handwritten label with black border] "Leucinodes | aureomarginalis | 83:8a Type Gaede" (ZMHB).

Remarks. *Lygropia* is a polyphyletic genus containing 62 species (Nuss et al. 2003–2014). We provisionally transfer *Lygropia aureomarginalis* (Gaede, 1916), **comb. n.** (*Leucinodes*) from Cameroon to this genus, as this species, according to wing pattern elements, is congeneric, if not conspecific, to *Lygropia vinanyalis* Viette, 1958 from Madagascar. *Lygropia aureomarginalis* can be distinguished externally from species of *Leucinodes* by the shiny golden wing maculation and the presence of two frenulum bristles in the female.

Syllepte Hübner, 1823

Syllepte Hübner, 1823. Type species: *Syllepte incomptalis* Hübner, 1823.

Syllepte hemichionalis (Mabille, 1900), **comb. rev.** (*Sylepta* [sic]). Type locality: Madagascar, baie d'Antongil

= ***Syllepte hemichionalis idalis*** Viette, 1958, **comb. rev.** (*Syllepta* [sic]). Type locality: Comoros, Mohéli.

Syllepte vagans (Tutt, 1890), **comb. n.** (*Aphytoceros*). Type locality: Great Britain, Chepstow.

= ***Aphytoceros longipalpis*** Warren, 1892 (synonymised by South, 1897). Type locality. South Africa, Transvaal.

Material examined. Types: Holotype *hemichionalis* ♂ [red label] "TYPE", [pale green label] "MUSEUM PARIS | MADAGASCAR | BAIE D'ANTONGIL | A. MOCQUERYS 1898", [whitish handwritten label] "Sylepta | hemichionalis Mab. | Ann. Soc.Ent.Fr. | 1899 p. 745.", [whitish handwritten label] "Sylepta | hemichionalis | Mab." (MNHN); Holotype subsp. *idalis* ♂ [red label] "TYPE", [white label] "COMORES | MOHÉLI XI–1955 | A. ROBINSON", [white handwritten label] "[underlined] Sylepta ♂ | [underlined] hemichionalis | [underlined] idalis n. subsp. | Holotype [underlined] P.Viette" (MNHN); Holotype syn. *longipalpis* ♀ [circular label with red border] "Type", [white label] "Transvaal | 91–21" (BMNH). The whereabouts of the type specimen of *vagans* Tutt, 1890 are not known.

Remarks. *Syllepte hemichionalis* and *S. vagans* are similar to each other in wing pattern elements, the presence of two frenular bristles in the female hindwings and features of male genitalia (see Suppl. material 2I), but not so to *Leucinodes*. Their wing pattern differs from *Leucinodes* in the following: forewing without the L-shaped or triangular spot at central dorsum of *Leucinodes* and without the half moon-shaped subapical patch; postmedian line broad, straight, but with long loop before dorsum, reaching to central part of forewing; dorsum with broad brown line leading from brown antemedian area to distal end of postmedian line; in the hindwing they have a comma- or V-shaped distal discoidal sigma, light brown with dark brown border. This homologous wing pattern is also found in *Syllepte chalybifascia* Hampson, 1896 from India and *S. dottoalis* Schaus, 1927 from the Philippines, and we consider them congeneric with each other as well as with *S. hemichionalis* and *S. vagans*. The genus *Syllepte* comprises 193 species (Nuss et al. 2003–2014), is probably polyphyletic and in need for taxonomic revision.

Deanolis Snellen, 1899

Type species: *Deanolis sublimbalis* Snellen, 1899

***Deanolis iriocapna* (Meyrick, 1938), comb. n. (*Sceliodes*)**

Type locality. Indonesia, Yogyakarta

Material examined. Holotype ♂ [circular label with red circle] "Holo- | type", [white label] "südl. M.-Java | Djokjakarta | H.Overbeck", [white label] "M600", [white label] "Sceliodes | iriocapna Meyr. | det. E. Meyrick.", [white label] "Sceliodes | iriocapna | 1/1 | Meyrick | E.Meyrick det. | in Meyrick Coll.", [white label] "Meyrick Coll. | B.M. 1938-290." (BMNH).

Remarks. The wing pattern of *iriocapna* Meyrick, 1938 exhibits none of the features found in *Leucinodes*. Instead, the fore wings are pale yellow, with a yellowish costa, a dark spot in both outer edges of the cell, and a reddish undulating margin along the termen. The hind wings are of the same pale yellow ground colour, and the anterior half of the termen exhibits a similar margin as found in the fore wings. This wing pattern is common to the genus *Deanolis* Snellen, 1899, where this species is correctly placed (pers. comm. James E. Hayden).

Identification key for African *Leucinodes* species based on male genitalia:

1 Transtilla arms each with a dorsad spine..... ***Leucinodes ethiopica* sp. n.**

1* Genitalia without these structures.....**2**

2 Sacculus without distal process; posterior phallus apodeme with finger-like process.....**3**

2* Distal process of sacculus present; posterior phallus apodeme without finger-like process **4**

3 Fibula broad, strongly sclerotized, emerging just ventral of costa; sacculus more than half the length of valva; saccus very elongated, tip pointed; dorsal posterior phallus apodeme with slim, finger-like, well sclerotized process..... .....***L. laisalis* (Walker, 1859), comb. n.**

3* Fibula small, strongly sclerotized, emerging near ventral valva edge; sacculus less than half the length of valva; saccus elongated, tip not pointed; ventral posterior phallus apodeme with slim, posterioventrally protruding, well sclerotized process .....***L. malawiensis* sp. n.**

4 Distal sacculus process projecting towards valva apex, straight or apically hooked, sometimes branching, apex dentate; juxta subulate; posterior phallus apodeme with oval saw blade-shaped sclerotization.....**5**

4* Distal sacculus process tooth- or hook-like; juxta much broader; posterior phallus apodeme without oval saw blade-shaped sclerotization **6**

5 Valva apex rounded; ventrad fibula stout, with broad base, straight or slightly curved; distal sacculus process hook-shaped, not branching, spanning ≤ half the distance fibula base–valva apex..... ***L. rimavallis* sp. n.**

5* Valva apex pointed; ventrad fibula slender, with narrower base, curved; distal sacculus process straight or hook-shaped, sometimes branching, spanning > half the distance fibula base–valva apex.....***L. africensis* sp. n.**

6 Dorsad fibula conical and smaller than distal sacculus process, which is large, hook-like and arching above fibula ..... ***L. kenyensis* sp. n.**

6* Dorsad fibula and fibula-like sacculus process being roughly of same shape and size and running parallel or crossing each other 7

7 Fibula and fibula-like sacculus process large, spanning almost the entire valva transversally; ventral valva edge not straight but with arch dorsal of fibula and fibula-like process; posterior phallus apodeme ventrally with oval sclerite ..... ***L. pseudorbonalis* sp. n.**

7* Fibula and fibula-like sacculus process small, barely reaching the valva centre; ventral valva edge more or less straight; posterior phallus apodeme without oval sclerite ..... ***L. ugandensis* sp. n.**

DNA Barcoding

The Neighbor Joining (NJ) analysis based on uncorrected p-distances (Fig. 47) groups taxa which are excluded from *Leucinodes* in this study outside of the *Leucinodes* + *Neoleucinodes* group. *Deanolis iriocapna*, *Leucinodes ethiopica* and *L. ugandensis* have not been barcoded and are therefore not included in the NJ tree. The *Leucinodes* + *Neoleucinodes* group forms a polytomy comprising *Neoleucinodes*, *L. malawiensis*, *L. laisalis* and a group containing the remaining *Leucinodes* species. Within this last group, 11 barcode clusters are revealed.

Leucinodes laisalis clusters in two Barcode groups: One group containing all specimens imported with fruits from Kenya, Ghana and Nigeria, and a second group comprising a single South African specimen. This single specimen shows high uncorr-p distances of 2.4–2.8% to the other *L. laisalis* specimens.

L. orbonalis clusters in two groups, separated by 1.1–1.8% uncorr-p distance. Within-subcluster distances are 0–0.5% for the smaller and 0–0.9% for the larger of the two subclusters.

A polytomous cluster comprising *L. rimavallis*, *L. kenyensis* and two undescribed 'Barcode species' (*Leucinodes* spp.) are sister to (*L. africensis* + *L. pseudorbonalis*).

Barcode sharing among different *Leucinodes* morphospecies is not observed.

Table 1. Uncorrected p-distances for the DNA-barcoded species of *Leucinodes*. Values in bold denote intraspecific distances, plain values represent interspecific distances.

	orbonalis	***africensis***	***rimavallis***	***pseudorbonalis***	***kenyensis***	***malawiensis***	***laisalis***
***orbonalis* (n=31)**	**0–1.8%**						
***africensis* (n=29)**	5.5–7.2%	**0–1.5%**					
***rimavallis* (n=2)**	4.2–5.7%	3.8–5.7%	**0.4%**				
***pseudorbonalis* (n=1)**	6.4–7.0%	5.4–6.2%	3.3–5.2%	**n.a.**			
***kenyensis* (n=4)**	5.3–6.0%	5.4–6.2%	2.2–2.4%	5.2%	**0%**		
***malawiensis* (n=1)**	9.6–10.7%	11.4–12.1%	10.0–10.8%	11.7%	11.2%	**n.a.**	
***laisalis* (n=22)**	7.3–8.7%	9.4–10.8%	7.8–8.9%	9.9–10.4%	9.4–9.8%	9.3–9.9%	**0–2.8%**

Discussion

The investigation of the *Leucinodes* species from sub-Saharan Africa reveals a new picture on the taxonomy of the Solanaceae fruit feeders. Instead of one widely distributed species in Asia and Africa, there is an endemic species complex in Africa and *L. orbonalis* is restricted to Asia, corroborating the statement by Hayden et al. (2013). Among the African species, *L. africensis* and *L. laisalis* are widely distributed on the continent, whereas *L. ethiopica*, *L. ugandensis*, *L. rimavallis* and *L. kenyensis* seem to have a rather restricted range. *L. malawiensis* is only known from one specimen from Malawi. These data may indicate different, though partly overlapping patterns of distribution as seen in Fig. 48, but this is still an incomplete dataset, resulting in fragmentary distribution patterns for *L. pseudorbonalis* and *L. rimavallis*. The possibility of transport by man also has to be taken into consideration.

Food plant data are only available for *L. africensis*, *L. laisalis*, *L. pseudorbonalis*, *L. rimavallis* and *L. kenyensis* (Table 2). While *L. laisalis* is known to feed on a variety of cultivated and non-cultivated Solanaceae, the other four species are known from cultivated Solanaceae only. This may rather refer to a bias of investigation, which so far has concentrated on fruits of economic importance. In nature, the *Leucinodes* species may have different host plants to which they were originally adapted. Those wild hosts may also have certain areas of origin. Such a scenario has to be expected, considering the fact that several species of *Leucinodes* have evolved in Africa. Some of these species might be restricted to their wild host plants and unable to switch to other, cultivated Solanaceae species. In contrast, species able to adapt to cultivated Solanaceae might be transported with fruits in trade, resulting in a larger range within Africa.

After movement of larvae with fruits in African trade, they may be more frequently intercepted by trade with those fruits into other continents. Most imports of *Leucinodes* specimens from Africa into Europe refer to *Leucinodes africensis*, which has been frequently imported with fruits during the last 50 years. In contrast, *L. laisalis* has been much less frequently recorded, and *L. pseudorbonalis* as well as *L. rimavallis* only very recently in fruit imports from Uganda. Since our investigations show that *L. orbonalis* does not occur in Africa, interceptions of *Leucinodes* from Africa into other continents

Table 2. Food plant records of African *Leucinodes* species. Cultivated plants are given in bold.

	L. africensis	***L. kenyensis***	***L. laisalis***	***L. pseudorbonalis***	***L. rimavallis***
Capsicum annuum			x		
Solanum anguivi			x		
Solanum aethiopicum	x			x	
Solanum incanum			x		
Solanum linnaeanum			x		
Solanum lycopersicon	x		x		
Solanum macrocarpon			x		
Solanum melongena	x		x	x	x
Withania somnifera		x			x

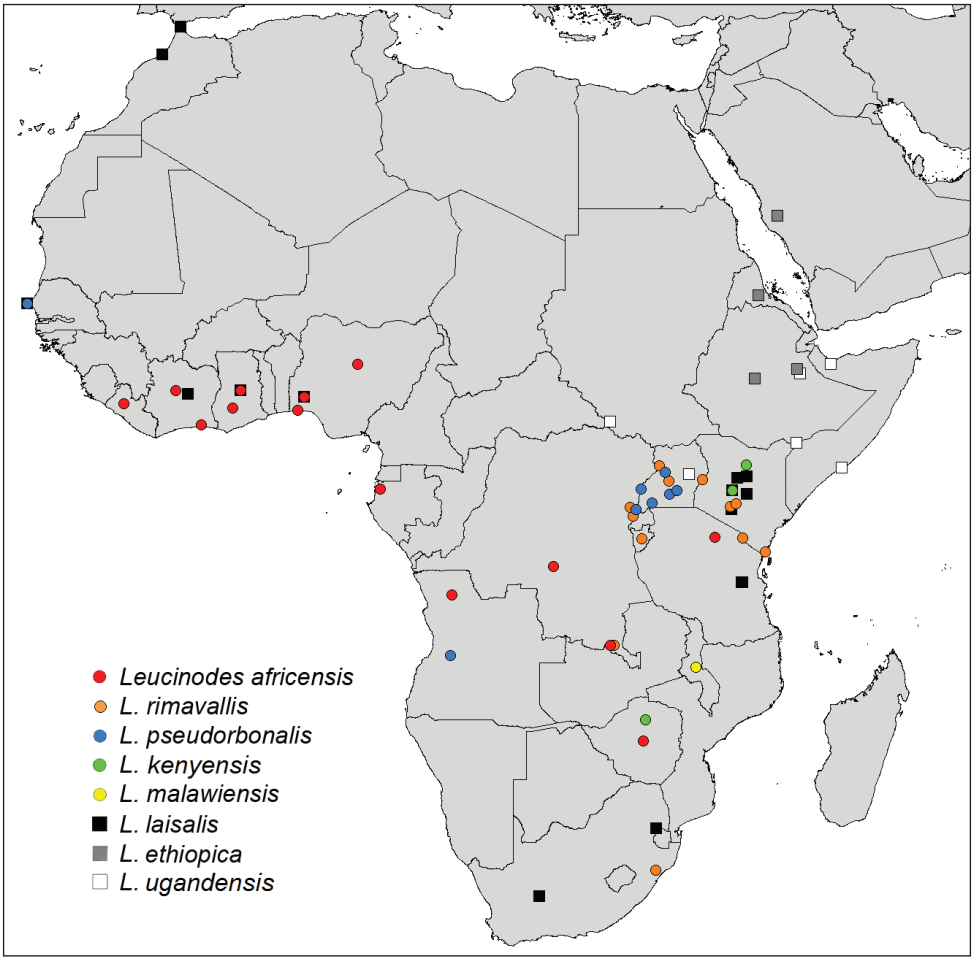


Figure 48. Distribution map of African *Leucinodes* species.

will need to be re-investigated for their species identity and will likely require, at least in parts, revisions of the quarantine regulations. Furthermore, if *Leucinodes* species are transported in trade, it has to be considered that species of *Leucinodes* and related South American genera, e.g. *Euleucinodes* Capps, 1948, *Neoleucinodes* and *Proleucinodes*, might also become introduced from one to another of the southern continents.

Analysis of the COI gene of the *Leucinodes* species demonstrated that interspecific differences allow the use of the marker as a DNA barcode for species identification. However, for *L. kenyensis* and "*Leucinodes* spp.", we found little morphological differences but two distinct barcode species within *Leucinodes* spp. Moreover, we observed high intraspecific divergence in *Leucinodes laisalis* with one specimen from South Africa exhibiting a COI distance of 2.8%.

Outside Africa, the taxonomy and phylogeny of *Leucinodes* requires further research. The characteristic forewing pattern elements of the Old World *Leucinodes* is

also found in the New World genera *Euleucinodes*, *Neoleucinodes* and *Proleucinodes*, all described by Capps (1948). In male genitalia, *Leucinodes* is distinguished from these three genera by the absence of cornuti in the phallus, from *Euleucinodes* and *Proleucinodes* also by the presence of a fibula, and further from *Euleucinodes* by the dorsal location of the uncus spines. In female genitalia, *Leucinodes* is distinguished from *Proleucinodes* by the presence of lateral antrum pockets (condition unknown in *Euleucinodes*), but cannot be clearly distinguished from *Neoleucinodes*, in which antrum pockets can be absent (e.g., *N. elegantalis* (Guenée, 1854)) or present (*Neoleucinodes prophetica* (Dyar, 1914), *N. torvis* Capps, 1948), and pocket sclerites can be absent (e.g., *N. elegantalis*) or present (*N. imperialis* (Guenée, 1854), *N. torvis*). Whether these differences refer to a typological classification or justify the maintenance of the current generic classification needs to be investigated by phylogenetic analysis.

For Austral-Asia, there remain twelve nominal *Leucinodes* species (Nuss et al. 2003–2014). Other than *L. orbonalis*, at least some of these species are certainly misplaced in *Leucinodes*, e.g. *Leucinodes labefactalis* Swinhoe, 1904 from Borneo and *Leucinodes perlucidalis* Caradja, 1933 from China. Therefore, the Asian *Leucinodes* are in need of taxonomic revision. This also points to the question whether all *Leucinodes* samples intercepted from Asian exports refer to *L. orbonalis*, or whether there are several *Leucinodes* species of economic importance in Asia as well (Hayden et al. 2013, Chang et al. 2014, Gilligan and Passoa 2014).

Our work contributes to the identification of African *Leucinodes* species, based on adult characters and on DNA Barcodes, by which also the immature stages can be efficiently distinguished. This may help to systematically survey the continent for distribution of species, in order to discover their wild host plants and their movements in trade. At this stage of knowledge it wouldn't be a surprise to discover additional, still unknown species. The results of our completely revised taxonomy of African *Leucinodes* suggests that a revision of the EPPO A1 List of pests recommended for regulation as quarantine pests (EPPO 2013) will be necessary. During the period from 2004 to 2007, 121 interceptions of *Solanum* fruits infested by *Leucinodes* were recorded by several EPPO member countries. The majority (94 consignments) originated from Thailand, Ghana accounted for 18 infested consignments (EPPO 2008). *L. orbonalis* is also ranked as quarantine species important for the USA, but specimens intercepted from Africa cannot be *L. orbonalis*, as stated by Hayden et al. (2013) and Gilligan and Passoa (2014) and as shown by our results. The USA has recorded 1745 interceptions from Ghana to the USA between 1985 and 2004 (Boateng et al. 2005).

Conclusion

A careful revision of *Leucinodes* in sub-Saharan Africa resulted in the new synonymy of the genus *Sceliodes* syn. n., the revised synonymy of *Hyperanalyta* with *Analyta*, the transfer of four species to *Leucinodes*, the description of seven new *Leucinodes* species, the new synonymy of one species, the omission of the type species *L. orbonalis* from the

African list and the generic transfer of five species found to be misplaced in *Leucinodes*. Of the eight species recognized from Africa now, at least four are frequently intercepted among imports of solanaceous fruits at European ports of entry. We provide the DNA Barcode for these four and two additional African *Leucinodes* species, allowing the identification of all life stages of these species.

Our work shows that typological concepts of taxonomy based on superficial similarity were still the state of the art in the genus *Leucinodes*. The discovery of a complex of highly similar species demonstrates that traditional morphological methods and DNA Barcoding are helpful tools to detect species diversity and to improve their classification based on sound arguments.

Similar revisionary work remains to be done for Austral-Asian *Leucinodes*. A phylogenetic study including *Leucinodes* and the New World *Euleucinodes*, *Neoleucinodes* and *Proleucinodes* is needed in order to test the monophyly of these genera (Hayden and Mally, in prep.).

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Supplementary material 1

Overview of specimens intercepted in Great Britain by the Food and Environment Research Agency (Fera).

Authors: Richard Mally, Anastasia Korycinska, David J. L. Agassiz, Jayne Hall, Jennifer Hodgetts, Matthias Nuss

Data type: sample list.

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Supplementary material 2

Overview of barcoded specimens.

Authors: Richard Mally, Anastasia Korycinska, David J. L. Agassiz, Jayne Hall, Jennifer Hodgetts, Matthias Nuss

Data type: sample list.

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