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Scopaeus saotomensis spec. nov., a flightless rove beetle from the Island of São Tomé (Coleoptera: Staphylinidae: Paederinae: Lathrobiini) – Isolation and adaptation in a dark, humid, tropical forest environment

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Abstract

Scopaeus saotomensis Frisch, spec. nov. is described from the island of São Tomé situated in the Gulf of Guinea and assigned to the *S. gracilis* species group. This micropterous species is considered endemic to São Tomé. Its habitat around Lagoa Amélia is described and illustrated. The abdomen of *S. saotomensis* exhibits deep, furrow-like basal impressions of the tergites III-VI and basal constrictions of the sternites IV-VII that were previously unknown in the Scopaeina. Though flightless, the new species has well developed, functional eyes, which suggest it is epigeal. Flightlessness in the Scopaeina, and a possible species group relevance of the recently discovered stridulum of *Scopaeus*, are briefly discussed.

Keywords Afrotropics | Lagoa Amélia | flightlessness | stridulum | basal impression of abdominal tergites

1. Introduction

The biota of volcanic islands such as São Tomé situated in the Gulf of Guinea are well known for a high degree of endemism. In this contribution, the first species of *Scopaeus* Erichson, 1839 is described from this island. Due to its flightlessness, the new rove beetle species is most probably endemic to São Tomé.

Scopaeus, with a worldwide distribution, is the most speciose genus of the lathrobiine subtribe Scopaeina Mulsant & Rey, 1878. Recently, the generic classification of the Scopaeina was thoroughly revised by Herman (2023). A major outcome of this landmark publication is the discovery of a stridulum in *Scopaeus*, the characters of which are unique in Coleoptera (Herman 2023: 20-23, 67). It is made up of a stridular file on the lateral surface of the metaventrite and corresponding plectral ridges on the mesial base of the mesofemur. Herman (2023: 21) established the plausible hypothesis that *Scopaeus* species can stridulate, which remains to be tested. Due to the absence of the stridulum and other features, Herman (2023: 110) raised *Hyperscopaeus* Coiffait, 1984, previously considered a subgenus of *Scopaeus* (e.g. Frisch et al. 2002: 45, 46), to generic rank. As a consequence, the worldwide number of named *Scopaeus* dropped from some 480 to 380 species

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(Herman 2023: 98) plus 22 Oriental and Australasian species subsequently described by Frisch & Mainda (2022) and Frisch & Narakusumo (2023). However, it is likely the number of species of the genus will return to and far surpass 480. This new classification of the Scopaeina had even more drastic consequences for the Afrotropical scopaeine species, by far most of which were described by Fagel (1973). Only 72 of the 136 named species from sub-Saharan Africa including Madagascar and the Mascarene Islands assigned to *Scopaeus* prior to Herman's revision remained in *Scopaeus*, while almost half of which (64 species) are currently in *Hyperscopaeus* (see 'Species Included and Material Examined' for *Scopaeus* and *Hyperscopaeus* in Herman 2023: 98-109, 118-121). Inferring from numerous undescribed species in museum collections, the Afrotropical fauna of *Scopaeus* and *Hyperscopaeus* is still far from being well known, which - apart from the Western Palaearctic fauna - also applies to the rest of the world. The description of *Scopaeus saotomensis* spec. nov. from São Tomé represents a small step towards addressing this substantial gap in biodiversity knowledge.

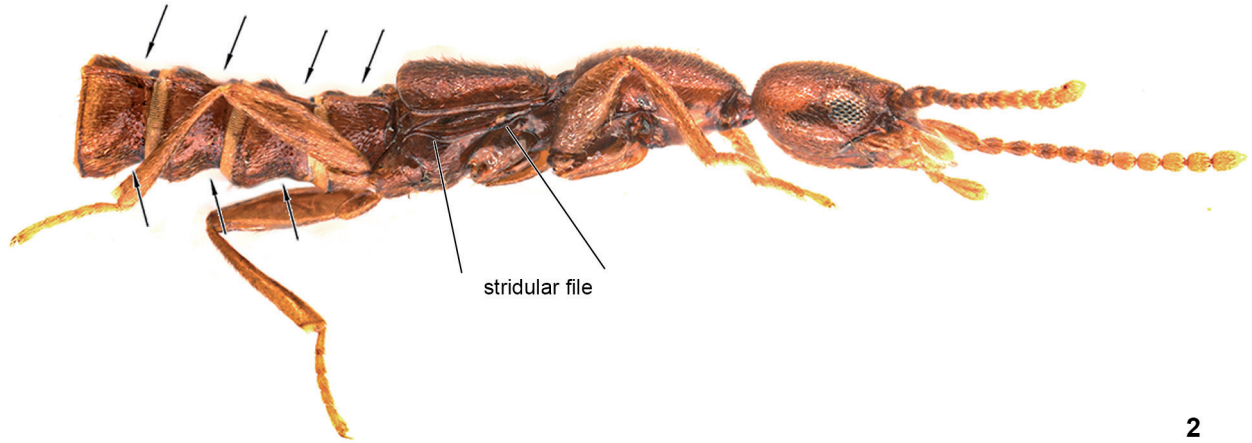
São Tomé island sits at the centre of the oceanic island formation known as the Gulf of Guinea Islands, forming the southern part of the Cameroon Volcanic Line, a 1000 km line of volcanoes active since the Cenozoic. On São Tomé, volcanic activity persisted until recently with the youngest rocks dated between 0.4 Mya and 1.5 Mya and the oldest at about 15.7 Mya (Barfod & Fitton 2014, Caldeira et al. 2003). The island is situated on the equator 150 km south-south-west of the island of Príncipe and 255 km west of Gabon and occupies a total area of 857 km^2, which is roughly the size of Berlin. São Tomé's highest point is Pico de São Tomé at 2024 m asl, from which the well vegetated ridges and ravines form extensive highlands that variably descend to the ocean on all sides. The ecological zones of the island are complicated but can be viewed coarsely as a product of elevation, aspect, rainfall and geological history. These are discussed in detail by Dauby et al. (2022) and Ceríaco et al. (2022). The phytogeography can assist in explaining the ecological context of Lagoa Amélia, the area where *Scopaeus saotomensis* spec. nov. was encountered. Monod (1960) expressed the higher elevational variation of vegetation on São Tomé referring to Mountain Rainforest - a definition that has been further refined by Stévart (1998) and Stévart et al. (2022) who included Lagoa Amélia within the classification of Submontane Rainforest, but suggest that the submontane area around Lagoa Amélia could be a distinct vegetation type.

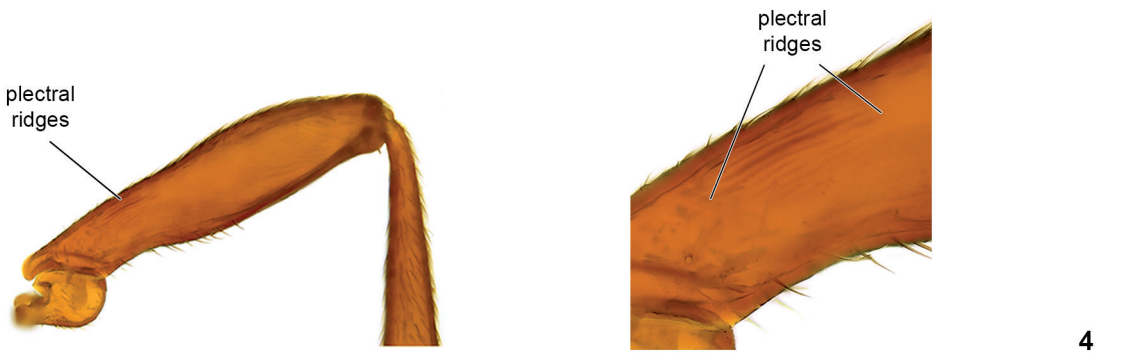
2. Material and methods

Material: The holotype of *Scopaeus saotomensis* spec. nov. is deposited in the Coleoptera collection of the Natural History Museum, London.

Equipment: All photographs were created with the montage software Helicon Focus based on digital image stacks. The habitus photographs (Figs 1, 2) were made with the camera Sony 7R and the Canon Macro Lens MP-E 65mm f/2.8 1-5x. The image of the stridular file of the metaventrite (Fig. 3) was taken with the camera Sony 60 MPX and the Mitutoyo 7.5x lens. Transmitted-light microscopic images of primary and secondary sexual

Figure 1. Habitus of *Scopaeus saotomensis*, holotype, República Democrática de São Tomé e Príncipe, São Tomé, Lagoa Amelia.

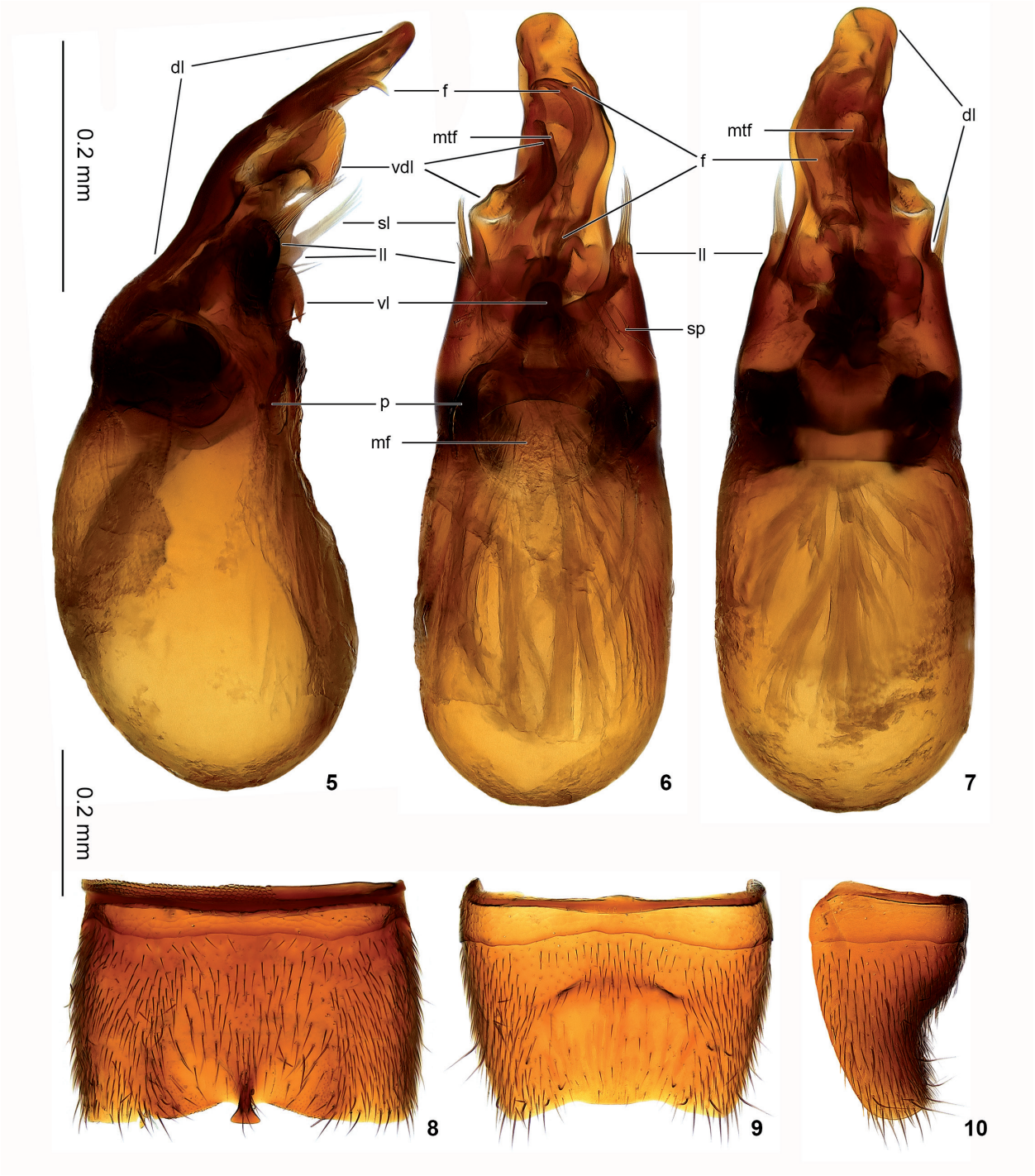




Figures 2–4. *Scopaeus saotomensis*, lateral aspect exhibiting basal depressions of abdominal tergites (upper arrows), basal constrictions of abdominal sternites (lower arrows), and stridular file on dorsolateral surface of metaventrite (2); enlarged view of stridular file (3); plectral ridges on posterior surface of base of mesothoracic leg (4).

characters were made using the Leica imaging system (transmitted light microscope DM6 B, camera K3C, software LasX). The microscopic images were made with the following magnifications: Aedeagus: 200 x (Figs 5–7); abdominal sternites VII and VIII: 100 x (Figs 8–10).

Measurements: The body length of the holotype was measured magnified at 70 x using a stereoscopic microscope with an eye-piece linear micrometer. Total length of specimen = interval from apical denticles of labrum to posterior end of abdomen, depending on degree



Figures 5–10. *Scopaeus saotomensis*, holotype, República Democrática de São Tomé e Príncipe, São Tomé, Lagoa Amelia; aedeagus in lateral (**5**), ventral (**6**), dorsal (**7**) view; abdominal sternite VII (**8**); abdominal sternite VIII in ventral (**9**) and lateral (**10**) view. Abbreviations: dl – distal lobes (apical lobes and dorsal lobe not distinguishable), **f** – flagellum, **ll** – lateral lobes, **mf** – median foramen, **mtf** – median tooth of flagellum, **p** – parameres, **sl** – groups of setae of lateral lobes, **sp** – setae of phallobase, **vdl** – ventrodextral, lobiform enlargement of distal lobes, **vl** – ventral lobe.

of contraction of abdomen; forebody length = interval from apical denticles of labrum to posterior margin of elytra at suture; elytral length = interval from posterior end of scutellum to posterior margin of elytra at suture.

Terminology: The morphology of the primary and secondary sexual characters follows the terminology of Frisch (2010: 160, 161; 2014: 200, 201), Frisch et al. (2002: 31-34) and Frisch & Narakusumo (2023: 25, 26).

3. Taxonomy

***Scopaeus saotomensis* Frisch**, spec. nov.
(Figs 1–10)

Type specimen: Holotype ♂, República Democrática de São Tomé e Príncipe, São Tomé, Lagoa Amelia (0°16'30.7"N, 6°35'31.2"E), 1475 m, 18.-26.1.2018, leg. Aristophanous, Lima, Miles & Turner.

Description: Habitus and coloring as in Fig. 1. Body colour unicolorous medium brown with maxillary palpi and legs slightly lighter brown; antennae with scapus and pedicellus medium brown; antennae from blackish median segments gradually lighter towards light brown segment 11. Body surface with short, decumbent pubescence, coarsely and densely punctate with punctures of elytra about twice the diameter of punctures of head and pronotum; microreticulation absent. Head subcircular with posterior angles broadly rounded towards slightly concave posterior margin. Macrophthalmous with eyes about 0.7 times as long as tempora. Antennal segments elongate; penultimate segment 1.2 times as long as wide. Micropterous, with elytra short and narrow, about 0.7 times as long as pronotum and 0.9 times as wide as head, fused at suture, with broadly rounded humeral angles and shallow, transverse depression in anterior half; metathoracic wings vestigial. Mesotibia strongly thickened. Stridular file contiguous with submarginal ridge of metaventrite, occupying about anterior two thirds of submarginal ridge, and curved dorsad at posterior end (Figs 2, 3); cluster of six, subparallel plectral ridges situated in dorsal half of posterior surface of mesofemur and touching dorsal femoral margin; plectral ridges almost straight and parallel to dorsal femoral margin, becoming less prominent and shorter from dorsal femoral margin towards middle of mesofemoral width (Fig. 4). Metakatepisternal processes longer than wide, apically acute. Abdominal tergites III-VI with deep, transverse, basal depression in about proximal half of sternite length with scabrous surface sculpture clearly separated from regularly punctate distal half of tergites (Figs 1, 2); abdominal sternites IV-VI with deep, transverse, basal constriction (Figs 1, 2); palisade fringe absent from abdominal tergite VII. Total body length 3.6 mm; forebody length 1.9 mm.

Male: Abdominal sternite VII posterior of transverse basal ridge with shallow depression in median third of width, triangular emargination in median third of posterior tenth and short, narrow, ventroposteriad pointing, distally widened, median process with truncate end projecting from posterior emargination (Fig. 8). Abdominal sternite VIII in about posterior half with strong, transverse depression convexly curved towards transverse basal ridge, in posterior ninth with short, wide, bisinuate emargination (Fig. 9, 10).

Aedeagus (Figs 5–7) about 0.6 mm long. Apical lobes and dorsal lobe not distinguishable in the microscopic image, seemingly fused to asymmetrical, narrow, somewhat dextrad curved distal lobe with round apex and large, irregularly convex, ventrodextral, lobiform enlargement at base. Flagellum long, reaching distal fourth of length of distal lobe, slightly running left in proximal half but in distal half strongly curved dextrad with bidentate end owing to sinistral widening over entire length of flagellum ending in long, thin, second apical tooth; additional, apicad pointing tooth seemingly projecting in middle of length of flagellum. Ventral lobe short, with thin, acutely ended, hook-shaped spine pointing proximad. Lateral lobes asymmetrical, each bearing group of long, ventrally pointing setae; dextral lateral lobe reduced; sinistral lateral lobe lobiform, projecting from phallobase. Apical portion of phallobase with additional, isolated, ventral bristles. Median foramen somewhat transverse, limited laterally by strongly sclerotised, vestigial parameres.

Female unknown.

Phylogeny: The asymmetical apical portion of the aedeagus with dextrad curved distal lobes and flagellum, lateral lobes of unequal length and the long flagellum identify *Scopaeus saotomensis* as belonging to the *S. crassipes* lineage of the *S. gracilis* species group (Frisch et al. 2002: 37, 39), which is very speciose in the tropical and subtropical Old World.

Distribution: Due to its flightlessness, *Scopaeus saotomensis* is probably endemic to the island of São Tomé in the Gulf of Guinea.

Habitat and collecting method: The holotype of *Scopaeus saotomensis* was captured in a pitfall trap set near the top of the southern ridge of Lagoa Amélia in an area of rainforest above the crater lake at an elevation of 1475 m asl (Fig. 11). The unlidded and unbaited pitfall trap comprised of a plastic 0.5 L yoghurt pot set in the ground with the edge below the soil surface and partially filled with 100 ml of 50% propan-1,2-diol and finished

Figure 11. The pitfall trap (arrow) in situ at Lagoa Amélia illustrating the exact collecting spot for *Scopaeus saotomensis*.

off with a generous shake of extra hot chilli powder to deter mammals. The trap was set for a period of six days. The rainforest was very wet and extremely humid, characteristic of the montane forests of São Tomé and locally enhanced by the super-humid environment of the Lagoa Amélia area.

Etymology: With the epithet *saotomensis* (adjective, Latin, composed of the geographic name São Tomé and the suffix –ensis, which indicates the geographical origin) reference is made to the island of São Tomé, the area of discovery for the new species.

4. Discussion

4.1 Morphology

Among the many species of the Scopaeina seen by the first author so far, *Scopaeus saotomensis* is unique by the deep, transverse, furrow-like, basal impression of abdominal tergites III-VI and the deep, transverse, basal constriction of abdominal sternites IV-VII (Figs 1, 2). Such modifications of the abdominal segments are widely distributed in staphylinids, for example in the Steninae and many Aleocharinae, but seemingly not in the Scopaeina. Herman (2023) also does not mention any dorsobasal impressions or ventrobasal constrictions of the abdominal tergites for this lathrobiine subtribe. Their biological function remains unknown.

Scopaeus saotomensis is micropterous with short, narrow, fused elytra, atrophied metathoracic wings and without the usual palisade fringe of abdominal tergite VII of macropterous rove beetles, a device for cleaning and unfolding the functional metathoracic wings (Hammond 1979: 134-137). Micropterous, flightless species are the minority within the Scopaeina but known in all scopaeine genera except for *Hyperscopaeus*. Herman (2023: 145) reports on three unnamed flightless species of the New World genus *Orus* Casey, 1885. Three species of *Trisunius* Assing, 2011 are obligatorily flightless, and other species of that Oriental scopaeine genus are wing dimorphous (Assing 2011-2014, see also Herman 2023: 153). Another *Scopaeus* with fused elytra and without the palisade fringe is *S. apterus* Cameron, 1950 from Three Kings Island, New Zealand, which was redescribed by Frisch (2016: 58-61). In *Micranops*, flightlessness is, however, more widespread (see Herman 2023: 125). The eyes of the micropterous type species of the genus, *M. brunneus* Cameron, 1913 from Jamaica, are reduced to a single corneal lense (Herman 2023: 125), but it was not examined if the elytra are fused. Frisch & Oromí (2006) and Outerelo & Oromí (1987) described four anophthalmous, flightless *Micranops* with fused elytra and without palisade fringes from subterranean habitats and caves of the Canary Islands. Unlike the obligatorily flightless species, micropterous specimens of the wing-dimorphic West Palaearctic *S. minutus* Erichson, 1840, *S. pusillus* Kiesenwetter, 1843, *S. chalcodactylus* Kolenati, 1846 and *M. pilicornis* Baudi di Selve, 1870 exhibit unfused elytra and have the palisade fringe, although it probably no longer has a function in view of the reduced metathoracic wings. It seems to be a general pattern that obligatorily flightless scopaeine species exhibit fused elytra and lack the palisade fringe of abdominal tergite VII in contrast to micropterous specimens of pterodimorphous species. This hypothesis is consistent with Hammond (1985: 20), who studied the expression of palisade fringes in more than 300 wing-dimorphic beetles, presumably mostly staphylinids, and found that micropterous specimens of the vast majority of these species had not lost the fringes. Herman (2023: 152, 153) analysed the publications of Assing (2011–2014) on the scopaeine genus *Trisunius* and found the same pattern of the presence of palisade fringes in flying specimens of wing-dimorphous species and their absence in obligatorily flightless species. Conversely, the unfused elytra and the predominant presence of the palisade fringe in *S. alaschiacus* Frisch, 1998 from Cyprus, of which only brachypterous specimens are known to date, suggest the occasional occurrence of specimens capable of flight.

Flightless endogeal species usually are microphthalmous or anophthalmous. Examples in the Scopaeina are the above mentioned microphthalmous *M. brunneus* and *S. apterus* and the four blind Canarian *Micranops*. Interestingly, even though *S. saotomensis* is flightless, its eyes are not atrophied or lost or any smaller than the eyes of a large number of 'normal', epigeal *Scopaeus*. Due to the presence of functional eyes, *S. saotomensis* is not regarded as subterranean, but part of the epigeal fauna. Thus, like in many Coleoptera, flightlessness in the Scopaeina is not necessarily associated with subterranean habitats and the subsequent loss of eyes. Furthermore, flightlessness in insects has been associated with more stable and isolated habitats such as refugia (Roff 1990, Wagner & Liebher 1992: 216, Yeates et al. 2002). Lagoa Amélia is located on an isolated mountain that retained rainforest habitat during the Pleistocene climatic fluctuations (Castilla-Beltran et al. 2023). It is characterised by cooler temperatures and wetter conditions typical of high elevation refugial habitats in the Afrotropics (Maley 1989, 1991; Maley & Brenac 1998) and other tropical regions (VanDerWal et al. 2009, Bennett et al. 2012, Tang et al. 2018, Meng et al. 2019). Such refugia are known to harbour flightless

insects, including beetles (Darlington 1943, Roff 1990, Scholtz 2000, Yeates et al. 2002, Aristophanous 2014), and hence, the presence of flightless beetles with functional eyes is not surprising.

Herman (2023: 20-23, 67) discovered a metathoracic/mesofemoral stridulum as a unique, apomorphic character of *Scopaeus* and described and illustrated its characters according to one or two species of the species groups of *Scopaeus* established by e.g. Fagel (1973) and Frisch et al. (2002). The question remains if the characters of the stridulum, mainly length and position of the metaventral stridular file and the number, curvature and position of the mesofemoral plectral ridges, are actually species group specific, or if they vary within a group, or are even species specific. For the *S. gracilis* species group, to which *S. saotomensis* belongs, Herman [2023: 40 (Figs 110–112), 80] examined the stridulum of the West Palaearctic *S. gracilis* Sperk, 1835 and found the stridular file contiguous with the submarginal ridge of the metaventrite and about nine mesofemoral ridges situated near the dorsal mesofemoral margin. In *S. saotomensis*, the stridular file is also contiguous with the submarginal ridge (Figs 2, 3). Likewise, the straight, parallel plectral ridges of *S. gracilis* situated in the dorsal half of the mesofemoral width [Herman 2023: 40 (Fig. 112)] roughly correspond to the plectral ridges of *S. saotomensis* in number, shape and position.

Whether the stridulum is diagnostic for species groups of *Scopaeus* or species specific remains an open question. Herman (2023: 22) questioned the biological significance of the stridulum: 'Because among species of *Scopaeus* the files vary in length, shape, and position on the metaventrite, and the teeth vary in number, size, separation, surface, and form, and because the plectral ridges also vary in number, length, curvature, prominence, and position on the mesofemur, there is little doubt the sounds ... will vary. If they vary among species, might the differences suggest conspecific signaling, notifications, between the males and females of location and availability for mating? If the variations of chirps are associated with mating, might that be a barrier between species?'. If this is true, one wouldn't expect the stridulum to be the same in all species of a monophyletic group, i.e. that the species would produce species-specific sounds. However, since the species of many species groups are allopatrically distributed due to vicariance (multiple radiation) and usually do not occur syntopically (Frisch et al. 2002: 40-42), but rather species from different species groups often live syntopically, the sounds of the species living together would differ even if the stridulum was the same in all species of the species groups. Alternatively, stridulation may be a form of defensive behaviour (Wessel 2006: 402). Resolving these questions requires the examination of the stridulum of numerous *Scopaeus* species and its consistent consideration in future species descriptions as well as attempts to detect sound production and possibly existing species-specific sounds.

4.2 Bionomics

The collecting site of *Scopaeus saotomensis* is situated in a rainforest area near the top of the southern ridge of Lagoa Amélia above the crater lake at an elevation of 1475 m asl (Fig. 10). On São Tomé the Submontane Rainforests typically include areas between 800 m and 1400 m with further subclassification on ridges, steep slopes and in valleys. The montane forest occupies elevations between 1400 m asl to 1800 m asl and is further subdivided into forests on ridges, forests on slopes/plateau and montane grasslands. Although Lagoa Amélia has been classified as Submontane Rainforest it occupies an elevation of 1480 m asl and comprises of a crater lake with surrounding ridges, valleys and slopes. This complexity makes the type locality of *S. saotomensis* hard to define within the phytogeographic definitions because the diversity of the site itself means it qualifies for a number of the current habitat definitions. Additionally, Lagoa Amélia is the only significant example of a montane swamp on São Tomé, thus making it unique as a super humid, high-elevation swamp area encircled by ridges and valleys. Whilst there is no evidence that its floral assemblage is distinct, it does represent a unique combination of environmental conditions in the Gulf of Guinea Islands (Dauby et al. 2022). The ecological classification of Lagoa Amélia is best described as undefined and unusual for the region and as such probably is deserving of its own unique classification.

The presence of a *Scopaeus* species away from water and in dense, dark forest seems unusual in view of the habitat description by Frisch et al. (2002: 28), who characterised the genus as mainly ripicolous and hygro-thermophilous and typical for more or less open, sunny banks. However, in the context of montane São Tomé the presence of hygrophilous and even hygrobiontic Coleoptera in terrestrial habitats is not an unusual theme. A number of normally aquatic associated taxa have been observed in the wet leaf litter of the rainforest floor, many utilizing the permanent meniscus and biofilm on fallen leaves (Turner, pers. obs.). This includes the recently described *Hydraena saotometerrestris* Bilton, 2023 from leaf litter. While *Hydraena* is normally found in water, this species occupies leaf litter above an elevation of 1000 m asl. The morphological parallels drawn with endogean and subterranean species is worth noting in the ecological context of the São

Toméan rainforest habitats – a place where darkness prevails day and night. Some vertebrates considered normally nocturnal don't differentiate between day and night. It is not unusual to see day active insectivorous bats (i.e. *Hipposideros ruber*) and owls (i.e. *Tyto alba thomensis*) actively flying in the closed canopy forest. Similar ecological, behavioural and morphological adaptation to extreme humidity and constant darkness would therefore be expected for invertebrates as well, especially those inhabiting the leaf-litter layer. *Scopaeus saotomensis* might be an example for adaptation to dark forest with closed canopy cover, while its congeners usually dwell less shady, open banks (Frisch et al. 2002: 28). According to Herman (2023: 71), label data indicate that in moist [tropical?] areas *Scopaeus* species were repeatedly collected in deep forests. However, as there is only one specimen from the rainforest habitat described, the question remains whether *S. saotomensis* reaches its highest abundance of individuals in a more open habitat.

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