

**Using four different methods to reach a taxonomic conclusion in
dung beetles (Scarabaeinae)**

THESIS

Submitted in fulfilment of the requirements
for the Degree of

MASTER OF SCIENCE
of
RHODES UNIVERSITY

by

CHRISTIAN MICHEL DESCHODT

Department of Zoology and Entomology
Rhodes University
Grahamstown, South Africa

December 2017

This work is not issued for purposes of zoological nomenclature and is not published within the meaning of the International Code of Zoological Nomenclature (Art. 8.2.).

Abstract

Four different techniques to make taxonomic decisions concerning different species in Scarabaeinae are being investigated.

Firstly, I made measurements of the body dimensions which are plotted on a two dimensional graph. This method is successfully used to erect one new species, *Copris crassus* Deschodt and Davis, 2015, and to establish the synonymy of *Copris bihamatus* Balthasar, 1965 with *Copris fidius* (Olivier, 1789).

Thereafter the classical or traditional comparative method is used to propose seven new species *Scarabaeolus soutpansbergensis* (Deschodt and Davis 2015), *Scarabaeolus megaparvulus* (Davis and Deschodt 2015), *Scarabaeolus niemandi* (Deschodt and Davis 2015), *Scarabaeolus carniphilus* (Davis and Deschodt 2015), *Scarabaeolus ermienae* (Deschodt and Davis 2015), *Scarabaeolus planipennis* (Davis and Deschodt 2015) and *Scarabaeolus afromitidus* (Davis and Deschodt 2015) and formally synonymise *Scarabaeolus vansoni* (Ferreira, 1958) with *Scarabaeolus lucidulus* (Boheman, 1860) and *Scarabaeolus xavieri* (Ferreira, 1968) with *Scarabaeolus andreaei* (zur Strassen, 1963).

Morphometric measurements of external structures of a group of flightless relict beetles in the tribe Canthonini are used to compile a nexus file which is analysed with computer software. The interpretation of these results is used here to support the erection of a new genus *Drogo* Deschodt, Davis & Scholtz 2016,

Lastly I analysed the DNA sequences of specimens from different species belonging to a species complex in the genus *Epirinus* Reiche, 1841 occurring over a wide geographic range. These sequences are used together with external morphological characters to propose the synonymy of *Epirinus hluhluwensis* Medina & Scholtz 2005 and *Epirinus ngomae* Medina & Scholtz 2005 with *Epirinus davisii* Scholtz & Howden 1987.

Table of Contents

Introduction	1
References	3
Chapter 1	6
Abstract	6
Introduction	6
Materials and methods	7
Comparative graphs	8
Synonymy	8
New species description	8
Key to the species in the <i>fidius</i> group	10
Geographical ranges	12
Acknowledgements	12
References	13
Figures and legends	14
Chapter 2	19
Abstract	19
Introduction	19
Material and methods	21
New synonymies and status revision in the subgenus <i>Scarabaeus</i> (<i>Scarabaeolus</i>)	21
Descriptions of new species	22
Key to the known species in the subgenus <i>Scarabaeus</i> (<i>Scarabaeolus</i>) Balthasar adapted from Zur Stassen 1967	32
Notes on some of the currently valid species	36
Acknowledgements	38

References	38
Figures and legends	43
Chapter 3	54
Abstract	54
Introduction	54
Materials and methods	55
List of characters used for the cladistic analysis	55
Institutions mentioned in this paper are	57
Systematic entomology	57
Discussion and support for generic status	59
New synonymy	60
Key to the genera and species in the <i>Byrrhidium</i> group	60
Acknowledgements	61
References	62
Figures and legends	64
Table and appendix	69
Chapter 4	72
Abstract	72
Introduction	72
Materials and Methods	73
Synonymy	74
Molecular analyses	74
Morphological variation	74
Material visually examined	75
Distribution	75
Conclusion	75

Acknowledgements	76
References	76
Figures and tables	78
Chapter 5	82
Final Conclusion	82
References	83

Acknowledgements

Ermiena, thank you for bearing our two lovely children, Kara and Chris, for getting up night after night for them, feeding me, keeping the house clean, allowing live insects in the house (grudgingly) and yet being sane enough to encourage me to finish this project.

Professor Clarke Scholtz, thank you for all the support, funding, and the gallons of the (often very palatable) red stuff. Doctor Adrian Davis, thank you for giving me a fraction of your knowledge. Professor Martin Villet, thanks for your continued support throughout my time as your student.

Riaan Stals is thanked for being an idea improving soundboard and source of knowledge. Marna Ferreira and Kitty Stamhuis helped with chemicals and laboratory equipment whenever I needed anything.

This work was made possible from funding to the various projects run inside the Scarab Research Group under the leadership of Professor Clarke Scholtz.

Introduction

Why different methods to distinguish species?

Species may be defined as a natural grouping of interbreeding individuals that share similar morphology, behaviour and ecological attributes and which is reproductively isolated from other such groups (Biological Species Concept) (Mayr 1942) or “the smallest set of organisms that share an ancestor and can be distinguished from other such sets” as is defined by the Phylogenetic Species Concept (Cracraft 1983). Between these two definitions lies a host of other explanations of what a species actually is or is perceived to be. Noteworthy, but not specifically to dung beetles, is Paterson’s Specific Mate-Recognition System (Paterson 1985), where the concept of a common fertilization system is invoked to justify separating species of dung beetles according to the shape of the male aedeagus. However none is entirely satisfactory as Hey (2006) clearly states that species definitions cannot resolve the problems encountered with species identification. E. O. Wiley has already in 1978 stated that: “In all probability more paper has been consumed on the questions of the nature and definition of the species than any other subject in evolutionary and systematic biology” and, currently, Aldhebiani (in press) could only give a list and discussion of the various species concepts. Thus the purpose of this study is not to concern itself with the species problem of what constitutes a species but rather to investigate and use some methods on how to treat the entities that taxonomists are faced by, I present here a short summary of some of the different species concepts.

Probably the first species concept is the Typological-morphological idea that was formally given by Linnaeus (1751), who stated that “There are as many species as the infinite being created diverse forms in the beginning, which, following the laws of generation, produced many others, but always similar to them: therefore there are as many species as we have different structures before us today.” Later in Darwin’s (1859) view, species and varieties were seen as essentially the loose grouping of individuals resembling each other. Mayr (1942), with some slight changes later, formally tried to define a species with his Biological Species Concept. This was followed by Simpson (1961) with the Evolutionary Species Concept, Ghiselin (1974) with the Individual Species Concept, the Phenetic Species Concept, where classification of organisms is numerically based on their similarities or “the grouping by numerical methods of taxonomic units into taxa on the basis of their character states” by Sneath and Sokal (1973), the Ecological Species Concept by Van Valen (1976), then the revision of the Evolutionary Species Concept by Wiley (1978), the Phylogenetic Species Concept by Cracraft (1983), Paterson’s (1985) Specific Mate-Recognition System Species Concept and finally the Cohesion Species Concept by Templeton (1989).

None of these, including the concepts or views not mentioned above, satisfies all taxonomists across

all Domains of organisms, while sometimes using a wrong concept can result in (subjectively) incorrectly lumping or splitting species.

Whatever concept is used to define a species, it is not a fixed entity and can change over time as new information about it, methods to define it or different taxonomic opinions arise. However, the species taxon that taxonomists are confronted by is current and thus for various ecological and/or conservational reasons needs a “box” or a name of its own. How these “species names” are defined depends largely on the researcher’s knowledge and own interpretation of the group of organisms in question and the set of diagnostic characteristics that specialists who have studied the groups agree on, are diagnostic of the different entities at different hierarchical ranks.

Traditionally, morphological similarity (while keeping in mind sexually dimorphic or polymorphic species) of a specific suite of characters was the main test of the species taxon. In insects generally, these are mainly external morphological characteristics often supplemented by various genitalic structures. This was extended later to comparison of chromosomes, and more recently, the comparison of the arrangement of basal pairs of DNA, in a section of a selected gene region, or even the whole genome. If the species can be studied in the field, other biological attributes may contribute to the delimitation of the species – in some Orthoptera and Hemiptera sound recordings of singing males are important (King 1999, Iorgu et al 2017). In the taxonomy of the Scarabaeinae, the group in question here, the traditional approach is possibly still the most widely used, although preliminary work shows some promise for identifying cryptic species in the tribe Canthonini (unpublished data by the Scarab Research Group at the University of Pretoria). In this thesis I will also discuss the use of some other methods to identify certain species taxa that are morphologically very similar and not easily separated using traditional methods.

Insect taxonomic research is based largely on dead specimens in museum collections and the demarcation of species boundaries is usually subjectively assigned by the researcher on the basis of characteristics considered by specialists who study the group, to be important in defining a particular species. Stace (1989) and repeated by Aldhebiani (in press) states that to identify a species the term “*sufficiently distinct*” with the following criteria (one or more) should be used:

“-The individuals should bear a close resemblance to one another such that they are always readily recognizable as members of that group.

- There are gaps [as is done in DNA barcoding] between the spectra of variation exhibited by related species; if there are no such gaps then there is a case for amalgamating the taxa as a single species.
- Each species occupies a definable geographical area (wide or narrow) and is demonstrably situated to the environmental conditions which it encounters.
- In sexual taxa, the individuals should be capable of interbreeding with little or no loss of fertility

[Note that some host species of the microbe *Wolbachia* cannot reproduce without being infected by the microbe], and there should be some reduction in the level or success (measured in terms of hybrid fertility or competitiveness) of crossing with other species.”

If live or adequately preserved specimens are available for study, various molecular techniques may be used for testing for genetic closeness which provides another measure with which the species can be defined. However, as with morphological similarity, the threshold for percentage of genetic “relatedness” remains a subjective decision by the researcher in question.

Some of the questions that may arise in a taxonomic study are whether a set of specimens under review appear morphologically identical, but quite probably represent different species (sibling species), whether slight morphological differences, particularly between groups of specimens separated geographically, should be considered to be natural variants of the same or different species. The group being studied and the material available will normally determine the best method suitable for distinguishing between the species.

The starting point in any such study is usually morphological, irrespective of the method that will eventually be selected to test for “conspecificity”. The specimens available will be arranged in groups on the basis of perceived morphological similarity. When sexual dimorphic species or species with minor to major male variation are studied, those variable characters are discarded. Depending on the nature of the specimens, the taxonomist must make a decision about whether the specimens will be compared morphologically using confirmed, traditional diagnostic characters, or whether tissue will be extracted and DNA analysed, or various structures on the specimens will be measured using various techniques after which some multivariate statistical analysis are done that may group the specimens in a way that suggests specific differences.

In this study four different methods are used to try to define species taxa amongst various Scarabaeidae: Scarabaeinae (dung beetle) groups.

First, I have noted that *Copris bihamatus* Balthasar, 1965 might be a synonym for *Copris fidius* (Olivier 1789). Moczek & Emlen (1999) have eloquently shown that there is a relationship between two body dimensions in the dung beetle species *Onthophagus taurus*. I have thus decided to use measurements of the body dimensions to address this taxonomic issue. I planned to demonstrate that the relationship between two body dimensions (lateral horn length and mid-line elytron length) plotted on a two-dimensional graph correspond between *Copris fidius* (Olivier 1789) and *Copris bihamatus* Balthasar, 1965. This technique was also used as further support for the erecting of the new species *Copris crassus* Deschodt and Davis, 2015.

Second, I have noted seven new species in the current Scarabaeinae genus *Scarabaeolus* Balthasar,

1965 including several taxonomic issues. My aim with this group was to use classical or traditional taxonomy by comparing the external and internal morphology under the dissecting microscope of different specimens next to each other to delineate the species. I evaluated the possible synonymy of *Scarabaeus (Scarabaeolus) vansoni* Ferreira, 1958 with *Scarabaeus (Scarabaeolus) lucidulus* (Boheman, 1860) and *Scarabaeus (Scarabaeolus) xavieri* Ferreira, 1968 with *Scarabaeus (Scarabaeolus) andreaei* zur Strassen, 1963. I have also assessed whether *Scarabaeus (Scarabaeolus) reichei* Waterhouse, 1890 was in my opinion erroneously synonymized with *Scarabaeus (Scarabaeolus) canaliculatus* Fairmaire, 1888. I recognized several undescribed species and proposed names for them.

Third, I found a single and peculiar specimen belonging in the tribe Canthonini that is housed in the South African National Collection of Insects in Pretoria. I decided to use statistical methods to support my feeling that it belonged to a higher taxonomic rank and warrant the description of a new genus. I also suspected the synonymy of *Byrrhidium namaquense* Scholtz and Howden, 1987 with *Byrrhidium ovale* Harold, 1869. In the resulting paper I describe the new genus and show the synonymy of the two *Byrrhidium* species by using statistical analyses.

Fourth, I suspected the synonymy of *Epirinus hluluwensis* Medina and Scholtz, 2005 and *Epirinus ngomae* Medina and Scholtz, 2005 with *Epirinus davisii* Scholtz and Howden. My objective was to test this synonymy using molecular methods.

To answer the question from above: a species could be seen as a dynamic and anthropogenic amalgamation of entities that unfortunately needs to be bounded in a box with a nametag. It is the seemingly insurmountable task of the taxonomist to combine all of the modern and classical techniques available to him with his specialist knowledge to complete the task originally ordained on humankind from biblical times.

References

- Aldhebiani, A.Y. (in press) Species concept and speciation. *Saudi Journal of Biological Sciences* ISSN 1319-562X, <https://doi.org/10.1016/j.sjbs.2017.04.013>.
- Cracraft, J. (1983) Species Concepts and Speciation Analysis. In: Johnston, R.F. (eds) *Current Ornithology*. Current Ornithology, vol 1. Springer, Boston, MA DOI https://doi.org/10.1007/978-1-4615-6781-3_6
- Darwin, C. (1859) *On the Origin of Species by Means of Natural Selection or the Preservation of*

- Favoured Races in the Struggle for Life*. London: Murray 502p
- Ghiselin, M.T. (1974) A radical solution to the species problem. *Systematic Zoology* 23, 536–544
- Hey, J. (2006) On the failure of modern species concepts. *Trends in Ecology & Evolution* 8, 447–450
- Iorgu, I.Ş., Iorgu, E.I., Szövényi, G. and Orci, K.M. (2017) A new, morphologically cryptic bush-cricket discovered on the basis of its song in the Carpathian Mountains (Insecta, Orthoptera, Tettigoniidae). *ZooKeys* 680, 57–72. <https://doi.org/10.3897/zookeys.680.12835>
- King, I.M. (1999) Species-specific sounds in water bugs of the genus *Micronecta*. Part 1. Sound analysis. *Bioacoustics* 9, 297–323. DOI: 10.1080/09524622.1999.9753406
- Linnaeus, C. 1751. *Philosophia botanica, in qua explicantur fundamenta botanica cum definitionibus partium, exemplis terminorum, observationibus rariorum, adjectis figuris aeneis*. G. Kiesewetter, Stockholm
- Paterson, H.E.H. (1985) The Recognition Concept of Species. *Species and Speciation* (ed. E.S. Vrba), Pretoria: *Transvaal Museum Monograph* 4, 21–29
- Mayr, E. (1942) *Systematics and the Origin of Species* (Columbia Univ. Press, New York) 334p
- Moczek, A.P. & Emlen, D.J. (1999) Proximate determination of male horn dimorphism in the beetle *Onthophagus taurus* (Coleoptera: Scarabaeidae). *Journal of Evolutionary Biology*, 12 (1), 27–37. <http://dx.doi.org/10.1046/j.1420-9101.1999.00004.x>
- Sneath, P.H.A. and Sokal, R.R. (1973) *Numerical Taxonomy*. 2nd edition. San Francisco: W. H. Freeman 573p
- Stace, C.A. (1989) *Plant Taxonomy and Biosystematics*, second ed., Edward Arnold, a division of Hoddoer and Stoughton, London.
- Templeton, A.R. (1989) The meaning of species and speciation: A genetic perspective. In: Otte, D. and Endler, J.A. *Speciation and its consequences*. Sinauer Associates. pp. 3–27
- Van Valen, L. (1976) Ecological species, multispecies and oaks *Taxon* 25, 233–239
- Wiley, E.O. (1978) The Evolutionary Species Reconsidered. *Systematic Zoology* 27, 17–26

Chapter 1

A new synonymy in the *fidius* group of *Copris* Müller 1764 (Coleoptera: Scarabaeidae: Scarabaeinae) and a new species from the highland grasslands of South Africa

CHRISTIAN M. DESCHODT^{1, 2,3}, ADRIAN L.V. DAVIS² & CLARKE H. SCHOLTZ²

¹*Department of Zoology and Entomology, Rhodes University, Grahamstown, South Africa*

²*Department of Zoology and Entomology, University of Pretoria, Pretoria, South Africa*

³*Corresponding author. E-mail: cdeschodt@zoology.up.ac.za*

Abstract

The *fidius* group constitutes the basal clade in a phylogeny of the Afrotropical members of the genus, *Copris* Müller, 1764. In this paper we describe *Copris crassus* Deschodt and Davis as a new species in this group. We also demonstrate that the distributional function between two body dimensions (lateral horn length and mid-line elytron length) differs between *Copris fidius* (Olivier 1789) and *C. crassus*. *Copris bihamatus* Balthasar, 1965 is also a member of the *fidius* group. Nguyen-Phung (1988) suspected that it was a synonym of *C. fidius* (Olivier) so we compare specimens of similar body size and use the distributional function between body dimensions to demonstrate that *C. bihamatus* is indeed a synonym of *C. fidius*. We provide a key for all known valid species in the *fidius* group, except *C. serius* Nguyen-Phung, 1987.

Key words: Scarabaeidae, Scarabaeinae, New species, *Copris*, *crassus*, *fidius*, *bihamatus*, endemic, New synonym

Introduction

The group of species allied to *Copris fidius* (Olivier, 1789) (Nguyen-Phung 1987; 1988, Marchisio & Zunino 2012) forms the most basally-derived clade in a phylogeny of the Afrotropical members of the genus *Copris* Müller, 1764 (Cambefort & Nguyen-Phung 1996). These Afrotropical species have speciated in the forests, savannas, and highlands on the eastern side of the continent (seven species) with a single species distributed from west to northeast and east-central Africa (Nguyen-Phung 1987; 1988; Marchisio & Zunino 2012). In this paper we describe a new species of the group recorded primarily from high altitude grasslands along the eastern escarpment of South Africa. We also investigate the validity of *Copris bihamatus* Balthasar, 1965, described from a male holotype and two paratypes housed in the NMPC.

Copris crassus Davis and Deschodt n. sp. shows closest affinities to *C. fidius*, a species that is

centred on forest patches, both along the eastern coastline of South Africa as far as the extreme south of Mozambique, and at higher altitude along the edge of the eastern escarpment in the north of its South African range. Other published records for *C. fidius* outside of South Africa (Nguyen-Phung 1988) probably represent old labelling errors.

As prominence of secondary sexual characters varies with body size and body size varies between species, as part of the description, we have used the relationship between lateral horn length and mid-line elytral length to demonstrate two parallel but separate scatters of data points for *C. fidius* and *C. crassus*. This is akin to the relationship between horn length and body size (thorax width) measured for *Onthophagus taurus* Schreber, 1759, which generated a sigmoidal distribution (Moczek & Emlen 1999).

In the case of *C. bihamatus*, Nguyen-Phung, (1988) was unable to see the type specimens for her review of the *fidius* group but she suggested that it would likely be a synonym of *C. fidius*. In the plot of the horn length against elytral length, we demonstrate that *C. bihamatus* is close to *C. fidius* and distant from *C. crassus*. Furthermore, by comparing material of similar body size, we concur with Nguyen-Phung (1988) that *C. bihamatus* Balthasar is, indeed, a junior synonym of *C. fidius* (Olivier) so that, with the addition of *C. crassus*, the number of species in the *fidius* group remains at a total of eight.

Materials and methods

Males and females were separated by examining each specimen for the presence of an aedeagus. Using a jig, each pinned male specimen was then visually aligned to a standardized position and orientation in order to make lateral photographic images (Canon 500D camera body fitted with a Canon 100 mm macro lens set to manual focus) from which measurements were made (Fig. 1). Because the head, pronotum and elytra move in relation to one another, two images were made for each specimen, one for measuring elytral length and one for measuring horn length in side view. For measuring elytron length, the specimen was viewed from the side and tilted slightly until the elytral suture entirely visible. The camera was then triggered and the photograph stored for measurement. Thereafter a measurement was then made from the anterior end of the left elytron along the margin to the posterior end. For measuring horn length, the specimen was tilted until the maximum visible horn area was seen and the second photograph was stored. The measurement was made from where the horn starts rising off the clypeus to the furthest tip of the horn. Each image had a gauge of known length to scale the images. Measurements were made using the program Analyzing Digital Images by John Pickle (Concord Academy; formerly, Museum of Science, Boston). Terminology for the male genitalia follows Medina *et al.* (2013).

Acronyms for depositories from which specimens were viewed and where types were deposited:

NMPC Czech Republic, Prague, National Museum

SANC South Africa, Pretoria, South African National Collection of Insects

TMSA South Africa, Pretoria, Ditsong National Museum of Natural History

UPSA South Africa, Pretoria, University of Pretoria

Locality labels are reported verbatim with authors' comments in square brackets.

Comparative graphs.

The relationship between lateral horn length and mid-line elytral length forms two separate scatters of data points for males, suggesting two different species (Fig 2). Whereas the data points for *C. crassus* are clearly separate from those for *C. fidius*, the single *C. bihamatus* data point is nested within those for *C. fidius*.

Curvilinear regression lines (negative exponential) were fitted to the data points for *C. fidius* and *C. crassus*. The failure to demonstrate sigmoid distributions may be related to sample size (absence of extreme major male *C. fidius* and extreme minor male *C. crassus*).

Synonymy

Copris fidius (Olivier, 1789) Figure 3 A, 4 C, E, 5.

Copris bihamatus Balthasar, 1965 new synonym Figure 3 B.

We have compared the habitus of the holotype male and two female paratypes of *C. bihamatus* with male and female specimens of *C. fidius*. Following the similarity of habitus (Fig 3 A, B), identical aedeagi, and similarity of the relationship between elytral length against horn length for male specimens (Fig 2), it is clear that *C. fidius* and *C. bihamatus* are the same species. Consequently *C. bihamatus* Balthasar, 1965, is, here, synonymized with *C. fidius* (Olivier, 1789).

New species description.

For easy comparison with Nguyen-Phung (1988), we conform to her style.

Copris crassus Deschodt and Davis Figure 4 A, B, D–H, 5.

Diagnosis. This species and *C. fidius* are the only species in the group with almost round eyes

However, this species can be separated from *C. fidius* by its larger size, the pronotal lateral lobes in major specimens ending with a single peak instead of two, and the male and female pronotal and elytral punctures being larger and closer together.

Description. Holotype: Length: 21.0 mm, long 12.4 mm at widest and 9.0 mm high. Body somewhat squat, shiny black, glabrous dorsally.

Major male. Head: apical edge of clypeus slightly indented and with two small denticles, forming very shallow “v”; area behind clypeal horn and genae punctate; genal angle sharp; clypeal horn elongate and narrow, slightly curved backwards, sharp at apex, distal edge with a small hooked tooth at basal fourth. Epipharynx: anterior edge convex, median sensory setae dense and tight, forming a strongly sclerotized cone; sensory setae more or less in straight lines diverging anteriorly. Labium: apical edge with deep notch, median depression deep, almost one third as wide as labium at widest. Prothorax: median lateral indentation present, punctate laterally, with anterior median region smooth; anterior, outside angles obtuse, the lateral edges slightly curved; median excavation wide, somewhat concave, punctate anteriorly and smooth posteriorly, the prothoracic lobes significantly elevated with apices terminating in a single point, turned inward distally. Elytra: interstriae flat, finely punctate, punctation less than one puncture diameter apart, striae clearly visible. Pygidium: with dense punctation less than one puncture diameter apart. Sterna: meso-metasternal suture lines straight, forming obtuse, anteriorly-pointing angle medially; mesosternum somewhat rugose; on metasternum, meso-metasternal suture, posterior edge and area between coxae smooth; area outside of coxae punctate. Legs: protibial spur spatulate, slightly curved ventrally towards apex; profemora covered with dense hair; metatibiae with two thin spurs on distal outside edge; proximal spur is half the length of distally curving distal spur. Male genitalia: apices of parameres dorsally rounded with hooked ventral tip. The apical sclerites of the internal sack consist of the basal sclerite (“lamelle conique” in Nguyen Phung (1988)) that is bulbous at base and hooked at the tip; the elongate sclerite with long filaments that is typical of all *Copris* spp.; and of the plate sclerite with a file-like surface and ends that are twisted 90 degrees (Fig. 4E). Length: 18.0 to 21.0 mm.

Variation. *Minor males*. Size somewhat variable. Lateral lobes on pronotum range between half that of the major male to completely absent with between-lobe concave excavation becoming flat and less distinct. Clypeal horn ranges between one third of that in major males to only a small protrusion with distal basal tooth relatively smaller or absent.

Females. Similar to males, but with a much reduced clypeal horn or a slightly projecting point on the fronto- clypeal suture; the prothorax is very slightly excavated or flat and densely punctate medially.

Etymology. The name for this largest known species in the *fidius* group is the Latin word for “fat” reflecting the squat body shape.

Type material examined. Holotype: 1 ♂ Suikerbosrand Nat. Res., Gauteng, South Africa, 28°28–32'S 28°10–17'E, 12–13.xii.2001 1631–1930 m, Davis & Deschodt (TMSA).

Paratypes: 4 ♂ same data as holotype (2 UPSA, 1 TMSA, 1 SANC), 1 ♂ RSA: Kwazulu-Natal, Sani Pass, alt. 1747m, S29°37'37.57" E29°25'21.87", 21.ix.2003; Pitfall – Cattle dung, W.P. Stru[m]pher, A. Henning (UPSA), 3 ♂ RSA:NATAL, Giants Castle Res., 32.02S–19.13E [29.43°S 29.52°E] 250m [2500m] 15/17-XI-1985, AVEvans, CHScholtz, (UPSA), 1 ♀ Avontuur, E. CP, (23 kms S) [33.841°S 23.189°E] 2.IX.77, Sandy loam, Rocky hillside pasture with shrubs 570m C, A.L.V. Davis, (SANC), 1 ♀ QUEENSTOWN, CP (35 kms N) [31.669°S 26.708°E] 12.XI.74, I.D. Temby, (SANC), 1 ♂ S.Afr.;KWZ Natal, Lotheni Nat.Res. 29[°].26['] S - 29[°].31['] E, 27–30.3.2011;E-Y:3902, at light; 1497m, leg. Ruth Müller, (TMSA), 1 ♂ RSA, KZN, Lotheni, 29.44558[°]S/ 29.53784[°]E, 1718m, Grassland, 13 j[J]anuary 2007, Site No. 107, Capture: Ground, MDTP No. 97353, [Michelle Hamer, Maluti Drakensberg transect project] and 1 ♂ same as previous but with MDTP No. 96745, (2 UPSA), 1 ♂ SOUTH AFRICA: MPU, Groenvaly, 10km NE of Badplaas, 25°52'S, 30°46'E 04.ii.1995 S.H. Foord, (SANC), 6 ♂ Lotheni Nature Reserve, 29.44558°S 29.53784°E, 07–09.12.2014, 1700m, Grassland, C. Deschodt & A. Davis (4 UPSA, 2 NMPC).

Key to the species in the *fidius* group

(translated and modified from Nguyen-Phung (1988))

The key includes all species assigned to the *fidius* group, except *Copris serius* Nguyen-Phung, 1987 which we were unable to examine.

1. *Copris* species without two parallel lobes on the sides of the pronotum ... Most *Copris* groups
- *Copris* species with two parallel lobes on the sides of the pronotum in major males ... 2
2. Horn with one basal to median posterior denticle, internal margin of the eye rounded and row of piliferous punctures on the dorsal surface of hind femora comprising six points or less ... 3, *Copris fidius* group
- Horn with postero-apical denticles, internal margin of eye angular and single row of piliferous punctures on the dorsal surface of hind femora comprising more than ten points ... *Copris bootes* Klug 1855 group
3. Apical edge of clypeus not emarginate but slightly denticulate; epipharynx: sensory setae very fine. Male: prothoracic excavation narrow; genitalia, apical ends of parameres strongly elongated. Male and female of larger size (14.5 to 21.0 mm) ... 4

- Apical edge of clypeus emarginated, distinctly denticulate; epipharynx: sensory bristles thick. Male: prothoracic excavation broad; genitalia: apical ends of parameres slightly elongated. Male and female of smaller size (14–18 mm) ... 5

4. Apex of prothoracic lobes forming two peaks, apex blunt, proximal peak lower than distal peak, inner tooth on clypeal horn straight. Punctures on elytra small, about one puncture diameter apart, punctures on pronotum small and well separated, specimens tending to be more elongate and relatively smaller ... *fidius* (Olivier)

- Apex of prothoracic lobes forming a single peak, sharp at apex, inner tooth on clypeal horn curving forward. Punctures on elytra larger, less than one puncture diameter apart, punctures on pronotum large and close together, specimens tending to be squat and relatively larger ... *crassus* Deschodt and Davis

5. Male and female: front femora with ventral keels very close together, very dense elytral punctuation; epipharynx strongly convex in lateral anterior margins. Male: Tooth of cephalic horn near the base; prothoracic excavation strongly concave; genitalia, basal sclerite very small/thin and somewhat enlarged at the base. Female: A small tooth-like projection on frons ... *coriarius* Gillet

- Male and female: front femora with ventral carina well separated; elytral punctuation less dense; epipharynx to weakly convex anterior lateral edges. Male: Tooth of the cephalic horn near the middle of the horn; prothoracic excavation slightly concave; genitalia: basal sclerite sinuous strongly enlarged at the base. Female: no protruding tooth on head ... 6

6. Male and female: elytral striae with clear punctures; epipharynx with medium number of sensory bristles that are very elongated; labium: enlarged median depression; fore tibiae expanded, the second apical tooth highly developed. Male: apex of prothoracic lobes slightly serrated. Female: frontal projection (=ridge of frons) reduced and angular ... 7

- Male and female: elytral striae with shallower punctures; epipharynx with many sensory setae that are shorter; labium: narrow elongated central depression, fore tibia slightly expanded, the second apical tooth undifferentiated. Male: apex of prothoracic lobes not notched. Female: frontal projection (=ridge of frons) enlarged, somewhat rounded ... 8

7. Male and female: dense elytral punctuation. Male: broad prothoracic excavation at basal edge slightly concave, posterior punctuation deep; genitalia: dorsal edge angular at the apex of parameres. Female: pronotal punctuation deep ... *mesacanthus mesacanthus* Harold

- Male and female: sparser elytral punctuation. Male: prothoracic excavation close to basal edge clearly concave, posterior punctuation shallow; genitalia: dorsal edge rounded at apex of parameres. Female: pronotal punctuation less deep ... *mesacanthus transvaalensis* Nguyen-Phung

8. Male and female: rounded body; elytral punctuation deep; genae strongly projecting; epipharynx median sensory bristles sparser; labium: apical notch rounded, flared lobes. Male: pronotum with

dense punctuation; genitalia: apex of parameres strongly curved, basal sclerite of the internal sac in the form of a stout hook. Female: front projection reduced pronotal punctuation dense. ... *cambeforti* Nguyen-Phung.

- Male and female: elongate body; elytral punctuation shallow; genae slightly projecting; epipharynx: median sensory bristles are very close; labium: apical notch angular, acute lobes. Male: pronotum very slight or absent punctuation in the anterior region; genitalia: apex of parameres slightly curved, basal sclerite of the internal sac pointed at the proximal extremity. Female: frontal projection wide, less dense pronotal punctuation ... 9

9. Male and female: strong genal punctuation; epipharynx: median sensory setae dense and tight; labium: very acute apical lobes. Male: pronotum with anterior area smooth, prothoracic excavation wide ... *vankhail vankhail* Nguyen-Phung

- Male and female: weak genal punctuation; epipharynx: median sensory setae less tight; labium: less acute apical lobes. Male: pronotum completely punctuated, prothoracic excavation narrow ... *vankhail genopunctatus* Nguyen-Phung

Geographical ranges

Copris crassus Deschodt and Davis is endemic to South Africa (fig 5). Although it is found primarily in high altitude grasslands to the north, its southernmost occurrence lies at lower altitude in the cooler Eastern Cape. In Suikerbosrand Nature Reserve, it was recorded from south-facing, high altitude grassland at >1880 m but not in the surrounding, lower-lying, Highveld grasslands (1630–1690 m). In the Drakensberg at Lotheni Nature Reserve it has been collected in grassland at 1700m on south facing slopes amongst scattered *Protea sp.* trees. In the south, it has been recorded in a mountain valley of the Eastern Cape, south of Avontuur. *Copris fidius* (Olivier 1789) is also virtually endemic to South Africa except for a marginal occurrence on the coastline of southeast Mozambique. It is found primarily in shade and forest patches. It shows a coastal distribution along the entire southern and eastern seaboard of South Africa as well as along the edge of mountain blocks in the Western Cape and the lower edge of the eastern escarpment from the Eastern Cape to Limpopo Provinces.

Acknowledgements

We thank Jiří Hájek (NMPC), Ruth Muller (TMSA) and Riaan Stals (SAMC) for the loan of specimens. Jiří Zidek, Prague, is thanked for obtaining the original images of *C. bihamatus* from NMPC and František Sládeček is thanked for conveying the loaned types to South Africa and back to NMPC. The two reviewers are thanked for invaluable comments on an earlier version of this paper. We wish to gratefully acknowledge the JRS Biodiversity Foundation for funding the project that led to the recognition of the taxonomic issues addressed in this paper. We thank Ezemvelo KZN Wildlife for the

permit (No: OP 5434/2014) to collect at Lotheni Nature Reserve.

References

Analyzing Digital Images (2014) Available from: <http://www.umassk12.net/adi/> (accessed 14 January 2015)

Balthasar, V. (1965) Eine neue Undergattung und neue Arten der Familie Scarabaeidae (Col). (121. Beitrag zur Kenntnis der Scarabaeoidea). *Acta entomologica bohemoslovaca*, 62 (1), 14–23.

Cambefort, Y. & Nguyen-Phung, T. (1996) On the genus *Copris* Müller, 1764: Definition and phylogenetic survey of the Afrotropical species-groups (Coleoptera: Scarabaeidae). *Journal of African Zoology*, 110 (4), 270–289.

Olivier, A.G. (1789) *Entomologie, ou histoire naturelle des insectes, avec leurs caractères génériques et spécifiques, leur description, leur synonymie, et leur figure enluminée. Coléoptères*. T. I, N^o3 Baudouin, Paris, 190 pp. <http://dx.doi.org/10.5962/bhl.title.49479>

Marchisio, R. & Zunino, M. (2012) *Il genere Copris Müller. Tassonomia, filogenesi e note di Zoogeografia*. WBA Monographs, Verona, 174 pp. [ISBN 978-88-906379-1-9]

Medina, C.A., Molano, F. & Scholtz, C.H. (2013) Morphology and terminology of dung beetles (Coleoptera: Scarabaeidae: Scarabaeinae) male genitalia. *Zootaxa*, 3626 (4), 455–476. <http://dx.doi.org/10.11646/zootaxa.3626.4.3>

Moczek, A.P. & Emlen, D.J. (1999) Proximate determination of male horn dimorphism in the beetle *Onthophagus taurus* (Coleoptera: Scarabaeidae). *Journal of Evolutionary Biology*, 12 (1), 27–37. <http://dx.doi.org/10.1046/j.1420-9101.1999.00004.x>

Nguyen-Phung, T. (1987) Révision des *Copris* afro-tropicaux V. Une nouvelle espèce du "groupe *fidius* Olivier". *Bulletin de la Société entomologique de France*, 91 (9–10), 271–273. [1986]

Nguyen-Phung, T. (1988) Révision des espèces Afrotropicales du genre *Copris* Müller, 1764 IV. Le groupe *fidius*, *Revue française d'Entomologie*, 10 (1), 5–15.

Schreber, J.C.D. (1759) *Novae species Insectorum*, Schneider. *Halae*, 1759, 1–16.

Figures and legends



FIGURE 1. Lateral view of *Copris fidius* (red lines indicate the positions where measurements of length for the horn and elytron were acquired).

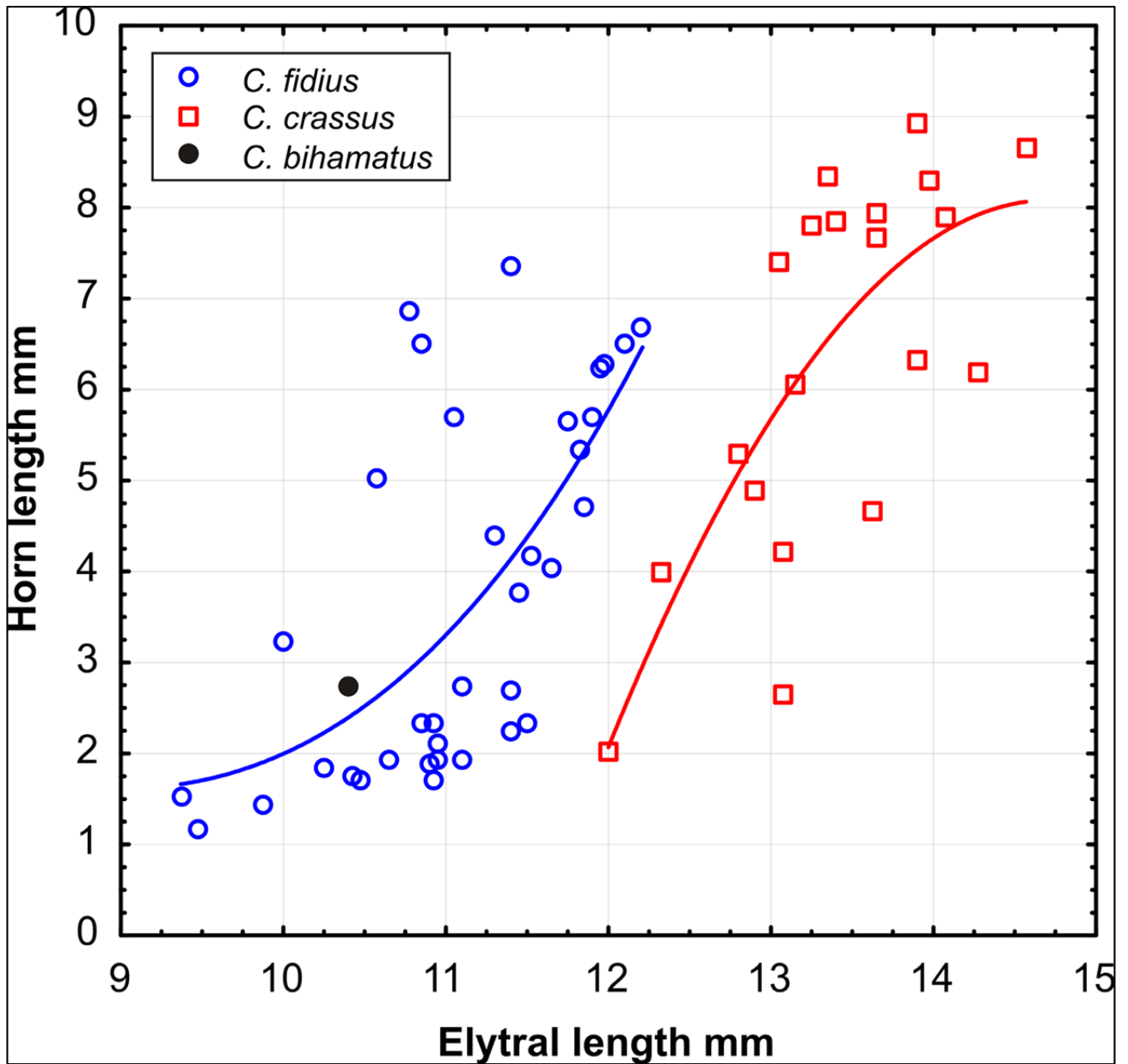


FIGURE 2. Graph showing horn length plotted against the length of elytral curvature for ■ *Copris crassus*, ● *Copris fidius* and ● *Copris bihamatus* Holotype (regression lines = negative exponential).

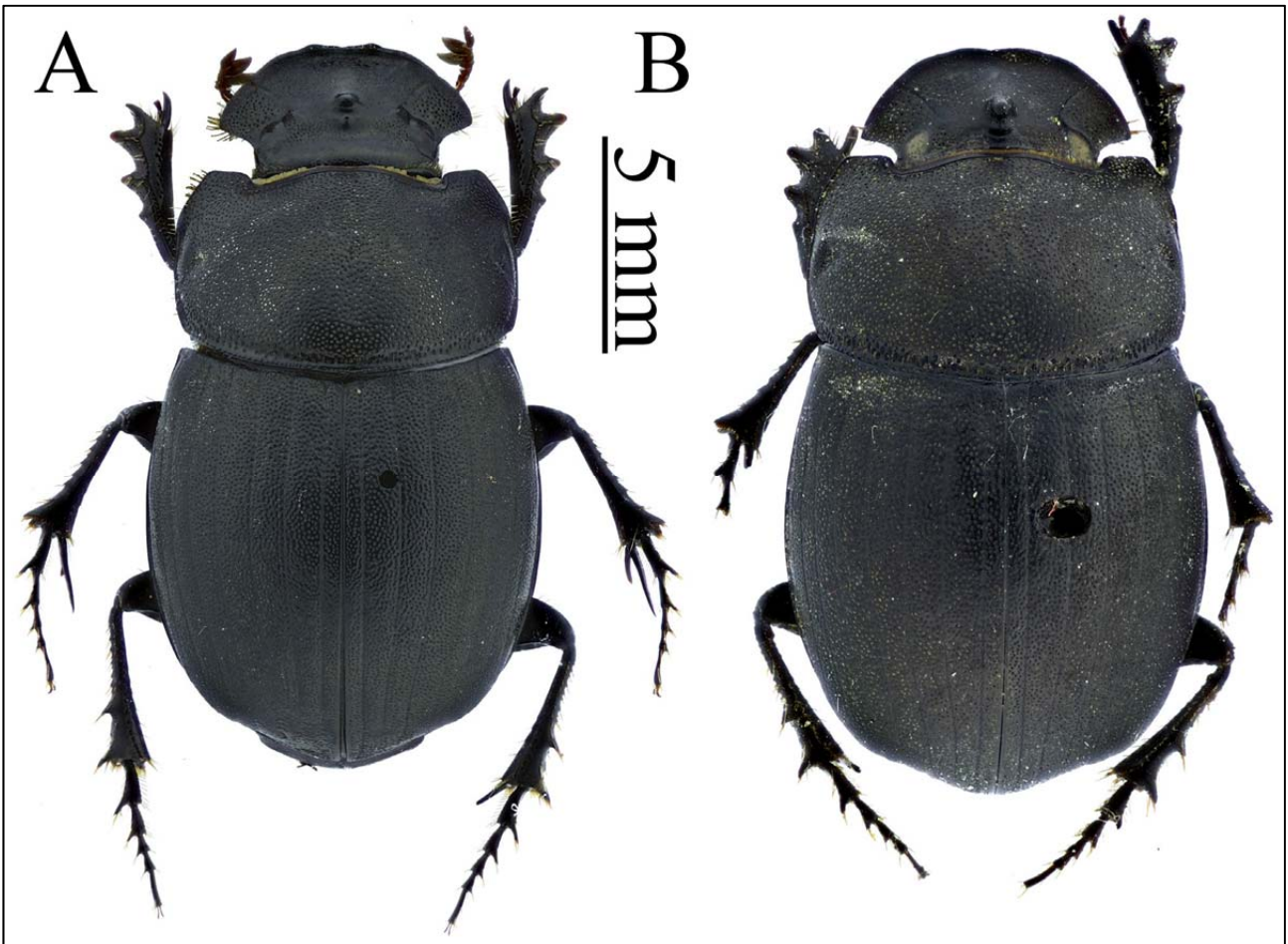


FIGURE 3. Habitus of a male *C. fidius* (A) and the male *Copris bihamatus* holotype (B) of similar body size.

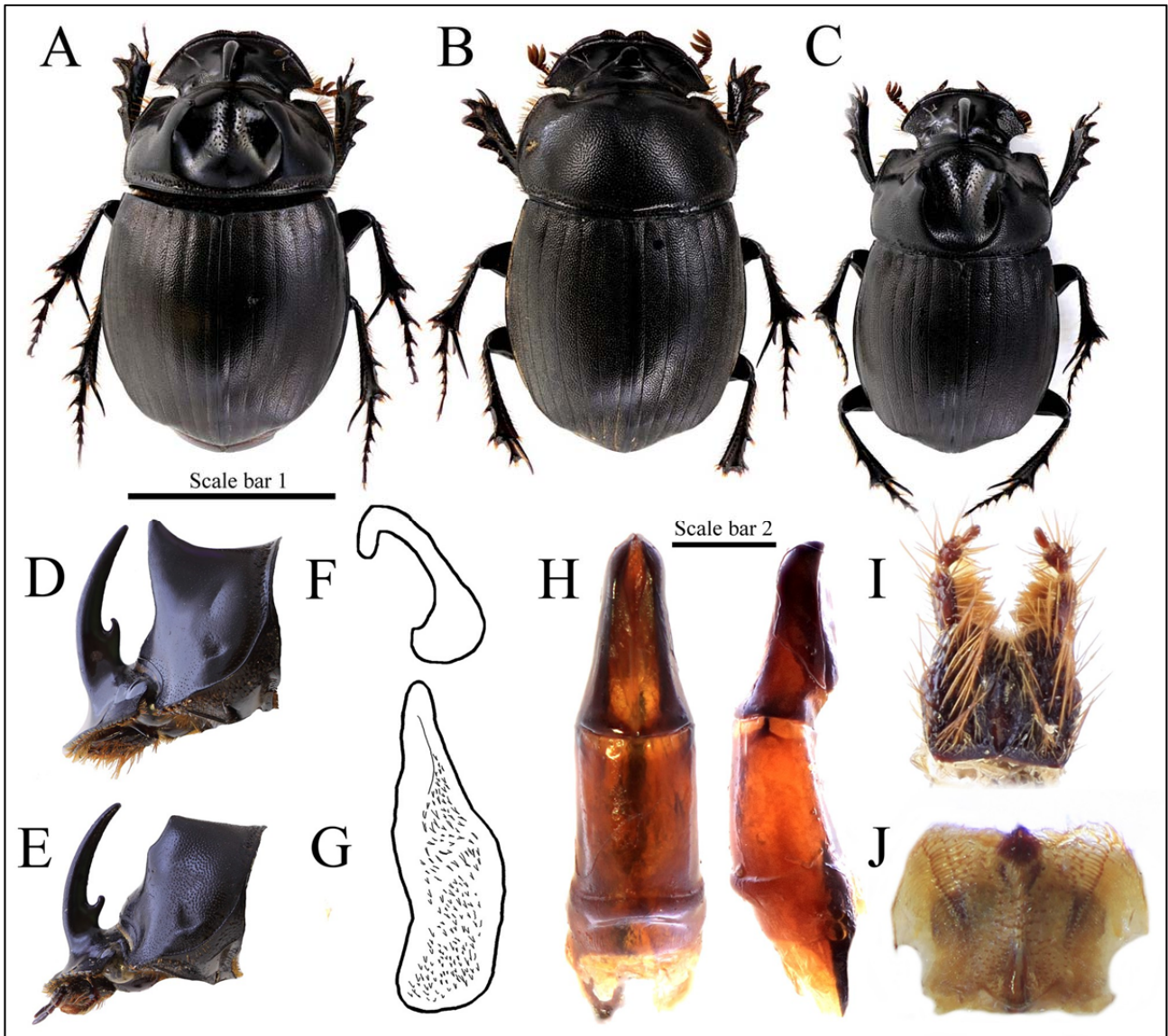


FIGURE 4. Habitus of *C. crassus* (A) major male, (B) female and (C) *C. fidius* major male. Head and pronotum side profile of major males of (D) *C. crassus* and (E) *C. fidius*. Outlines of apical sclerites of the internal sack of aedeagus for *C. crassus*: (F) basal sclerite and (G) plate sclerite. (H) Aedeagus of *C. crassus*. *C. crassus*, (I) labium and (J) epipharynx. *C. fidius*. Scale bar 1 (10mm) for A–E and scale bar 2 (1mm) for F–J.

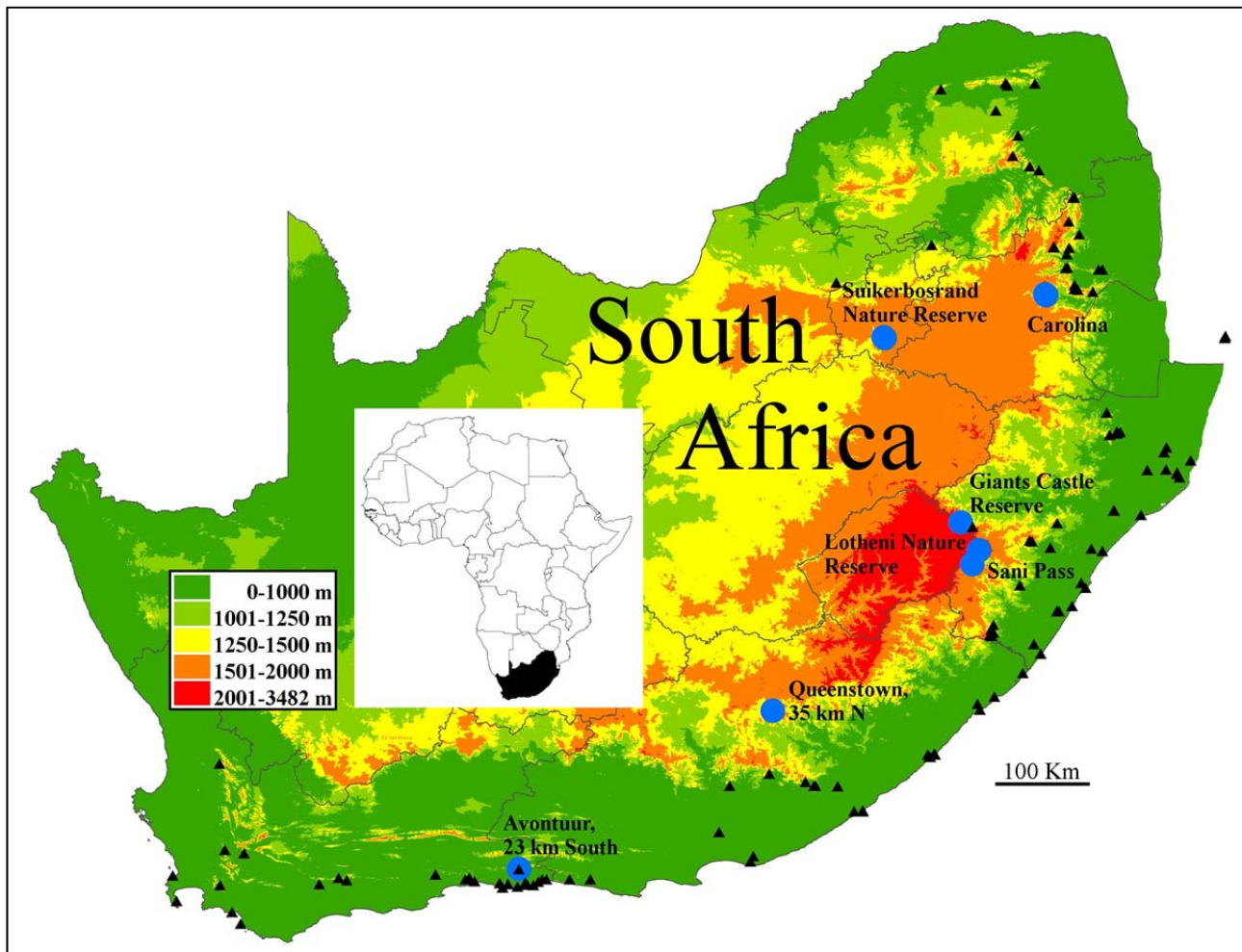


FIGURE 5. Map indicating the location of the collecting sites of (●) *Copris crassus* and (▲) *C. fidius* specimens in Southern Africa.

Chapter 2

Status changes, new synonymies, key and descriptions of seven new species in the subgenus *Scarabaeus* (*Scarabaeolus*) Balthasar 1965 (Coleoptera: Scarabaeidae: Scarabaeinae)

CHRISTIAN M. DESCHODT^{1, 2, 3}, ADRIAN L.V. DAVIS² & CLARKE H. SCHOLTZ²

¹*Department of Zoology and Entomology, Rhodes University, Grahamstown, South Africa*

²*Department of Zoology and Entomology, University of Pretoria, Pretoria, South Africa.*

³*Corresponding author: E-mail: cdeschodt@zoology.up.ac.za*

Abstract

Distribution of the subgenus *Scarabaeus* (*Scarabaeolus*) Balthasar, 1965 (tribe Scarabaeini) is centred on southern and south central Africa with only three out of 27 species recorded from West and northeast Africa. After taxonomic corrections and descriptions of seven new southern African species this somewhat controversial subgenus now comprises 33 valid species of which one is flightless. In this paper, *Scarabaeus* (*Scarabaeolus*) *vansonii* Ferreira, 1958 syn. nov. is synonymized with *Scarabaeus* (*Scarabaeolus*) *lucidulus* (Boheman, 1860) and *Scarabaeus* (*Scarabaeolus*) *xavieri* Ferreira, 1968 syn. nov. is synonymized with *Scarabaeus* (*Scarabaeolus*) *andreaei* zur Strassen, 1963. *Scarabaeus* (*Scarabaeolus*) *reichei* Waterhouse 1890 stat. rev. is removed from synonymy with *Scarabaeus* (*Scarabaeolus*) *canaliculatus* Fairmaire, 1888 and reinstated as a valid species. Distribution maps for *S. (S.) reichei*, *S. (S.) canaliculatus* and a third close relative, *Scarabaeus* (*Scarabaeolus*) *fritschii* Harold, 1868 are provided. The seven new species comprise: *Scarabaeus* (*Scarabaeolus*) *soutpansbergensis* Deschodt and Davis spec. nov., *Scarabaeus* (*Scarabaeolus*) *megaparvulus* Davis and Deschodt spec. nov., *Scarabaeus* (*Scarabaeolus*) *niemandi* Deschodt and Davis spec. nov., *Scarabaeus* (*Scarabaeolus*) *carniphilus* Davis and Deschodt spec. nov., *Scarabaeus* (*Scarabaeolus*) *ermienae* Deschodt and Davis spec. nov., *Scarabaeus* (*Scarabaeolus*) *planipennis* Davis and Deschodt spec. nov. and *Scarabaeus* (*Scarabaeolus*) *nitidus* Davis and Deschodt spec. nov. A key is provided for all the known winged species together with notes on some of the previously described species.

Key words: Botswana, South Africa, Mozambique, Zambia, Scarabaeidae, new species, synonymies, status revised, key

Introduction

The status of genera and subgenera within the tribe, Scarabaeini, has a long and confused history that

continues to the present day (Zidek & Pokorny 2004, Forgie *et al.* 2006). At the current time, the composition of the tribe depends on which authority one follows. Here, our classification follows that of Forgie *et al.* (2006) who divided the Afrotropical members of the tribe into three genera (*Pachylomera* Griffith & Pidgeon, 1831, *Pachysoma* Macleay, 1821 and *Scarabaeus* L., 1758) and four subgenera of *Scarabaeus* (*Scarabaeus* (*Kheper*) Janssens, 1940, *Scarabaeus* (*Sceliages*) Westwood, 1837, *Scarabaeus* (*Scarabaeus*) L., 1758 and *Scarabaeus* (*Scarabaeolus*) Balthasar, 1965).

Even with this structure, we accept that classification of the tribe remains controversial and may require further revision. Recently *Pachysoma* was reduced to subgeneric status within *Scarabaeus* by Harrison *et al.* (2003), listed under *Scarabaeus* by Zidek & Pokorny (2004), but subsequently revalidated (Forgie *et al.* 2006). Other recent reductions of long-established Afrotropical genera (*Kheper*, *Sceliages*) to subgeneric status within *Scarabaeus*, (Forgie *et al.* 2005) may, like *Pachysoma*, also deserve review and revalidation as full genera on morphological, molecular and behavioural grounds. This applies particularly to *Sceliages*, which shows modification of the clypeal margin associated with the specialized use of millipede gut contents for breeding (Forgie *et al.* 2002).

In the case of the earlier division of *Scarabaeus s. str.* into two subgenera Balthasar (1965) the separation was based, primarily, on the presence of a vestigial second mesotibial spur in *Scarabaeus* (*Scarabaeolus*) and its absence in *Scarabaeus* (*Scarabaeus*). Other cited characters for *Scarabaeus* (*Scarabaeolus*) included: the absence of an overhanging elytral edge; widely separated, parallel, lateral carinae; small size (length: 10–14 mm); and elytra tapering posteriorly. However, as Balthasar (1965) noted that the principal character was apparently not universal (i.e. *Scarabaeus* (*Scarabaeolus*) *palemo* Olivier 1789 has a single mesotibial spur), subsequent workers differed in opinion with zur Strassen (1967) and Zidek & Pokorny (2004) failing to recognize the subgenus whereas Mostert & Scholtz (1986) noted that most species have the second spur.

Although recognition of the subgenus is not universal, of the 27 *Scarabaeolus* species, currently known, 24 show a regionally restricted distribution pattern (Davis *et al.* 2008) centred on southern and southern central Africa. Furthermore, one observation of a *Scarabaeus* (*Scarabaeolus*) *bohemani* (Harold 1868) female following a male rolling a ball (Tribe 1976) suggests that members of the subgenus may also show behavioural differences to *Scarabaeus* (*Scarabaeus*) species in which the female clings to the side of a ball being rolled by the male (Sato 1998). In addition, the preferred morphological phylogenetic analysis of Afrotropical Scarabaeini (Forgie *et al.* 2005) divides the tribal members into a number of clades, one of which includes *Scarabaeolus* species. However, in view of the controversy, comprehensive molecular analysis would be desirable to support the higher classification of the tribe.

On the understanding that stronger support for *Scarabaeolus* as a valid entity is pending, here, we

revise the alpha taxonomy by synonymizing two species, revalidating one previously synonymized species, and describing seven others as new. This raises the total number of species to 33 for the subgenus. These comprise 30 southern or Southern Central African species and three that are west or pan-African centred, or are found in northeast Africa, including one flightless taxon (*Scarabaeus* (*Scarabaeolus*) *scholtzi* Mostert and Holm, 1982), possibly misplaced, in the subgenus.

Material and methods

In this study we examined specimens and photographs of specimens housed in the following depositories:

BMNH	United Kingdom, London, Natural History Museum
MNHN	France, Paris, Muséum National d'Histoire Naturelle
NHRS	Sweden, Stockholm, Naturhistoriska Riksmuseet
SANC	South Africa, Pretoria, South African National Collection of Insects
SAMC	South Africa, Cape Town, Iziko South African Museum
TMSA	South Africa, Gauteng, Pretoria, Ditsong National Museum of Natural History
UPSA	South Africa, Pretoria, University of Pretoria

The order which the descriptions follow is the same as the species key out in the key below. Locality labels are reported verbatim with author comments in square brackets.

Colour photographs were obtained using a Canon 500D body with either a Canon 100mm macro lens or Canon 65mm MPE 1–5x zoom lens. Image stacking was done using Helicon remote and Helicon focus software.

New synonymies and status revision in the subgenus *Scarabaeus* (*Scarabaeolus*)

Scarabaeus (*Scarabaeolus*) *lucidulus* (Boheman, 1860)

Scarabaeus (*Scarabaeolus*) *vansoni* Ferreira, 1958 new synonym

We have compared photographs of both the type specimens of *Scarabaeus* (*Scarabaeolus*) *lucidulus* (Boheman, 1860), housed in the NHRS (type locality: Lake Ngami, N. Botswana), with the holotype of *Scarabaeus* (*Scarabaeolus*) *vansoni* Ferreira, 1958, housed in the TMSA (type locality: Mangetti, Ovamboland, N. Namibia) (Fig. 1), and are of the opinion that they are synonymous. The type of *S.* (*S.*) *lucidulus* is female thus aedeagi could not be compared. However punctuation of the prothoracic disc is similar in both type specimens and the interstriae are similarly lacking in punctuation.

Scarabaeus (*Scarabaeolus*) *andreaei* Zur Strassen, 1963

Scarabaeus (Scarabaeolus) xavieri Ferreira, 1968 new synonym

We have compared photographs of the holotype and paratype specimens of *Scarabaeus (Scarabaeolus) andreaei* Zur Strassen, 1963, housed in the SAMC (type locality: Inhambane, coastal Mozambique), with the holotype of *Scarabaeus (Scarabaeolus) xavieri* Ferreira, 1968, housed in the TMSA (type locality: Inharrime, coastal Mozambique) (Fig. 1), and are of the opinion that they are synonymous. The type of *S. (S.) andreaei* is female thus aedeagi could not be compared. However the fine dense punctation of the prothoracic disc and slightly convex interstriae is similar in both type specimens.

Scarabaeus (Scarabaeolus) reichei Waterhouse, 1890 stat. rev.

Gillet (1911) synonymized *Scarabaeus (Scarabaeolus) reichei* Waterhouse, 1890 with *Scarabaeus (Scarabaeolus) canaliculatus* Fairmaire, 1888. Subsequently, this decision was followed by Janssens (1940), Zur Strassen (1967), Ferreira (1972) and Zidek & Pokorný (2004). However, photographs of the type specimen of *S. (S.) canaliculatus* (Fig. 2) show strongly convex interstriae, tan pilosity and yellow antennae that are comparable to specimens recently collected in southern Namibia whose distribution (Fig. 7) coincides with the “Namaqua” type locality of *S. (S.) canaliculatus* (Fairmaire 1888) [interpreted as Great Namaqualand or the Karas Region in Namibia]. The photographs of *S. (S.) canaliculatus* differ to those of the type specimen of *S. (S.) reichei* (Fig. 2) that show flat interstriae, dark pilosity and dark antennae comparable to many specimens recorded from the west coast of South Africa whose distribution (Fig. 7) coincides with the “Cape of Good Hope” type locality of *S. (S.) reichei* (Waterhouse 1890). The photographs also differ from many specimens recorded from the interior of southern Africa that show strongly convex interstriae, dark pilosity and dark antennae, whose distribution (Fig. 7) coincides with the “Afric. austral. inter.” [Interior of Southern Africa] type locality of *Scarabaeus (Scarabaeolus) fritschi* (Harold, 1868) (type not located). Thus, *Scarabaeus (Scarabaeolus) reichei* Waterhouse, 1890 is removed from synonymy with *Scarabaeus (Scarabaeolus) canaliculatus* Fairmaire, 1888 and is reinstated as a valid species.

Descriptions of new species

Scarabaeus (Scarabaeolus) soutpansbergensis Deschodt and Davis

Figure 3, 8

Diagnosis. This new species is probably most closely related to *Scarabaeus (Scarabaeolus) clanceyi*

Ferreira, 1954 but does not have the characteristic hook on the posterior margin of the hind femur, which characterizes that species. It may be separated from *Scarabaeus (Scarabaeolus) palemo* Olivier, 1789 and *Scarabaeus (Scarabaeolus) bohemani* Harold, 1868 by the medial swelling of the hind femora and by the orange brown antennae compared to black antennae in *S. (S.) bohemani* and *S. (S.) palemo*. It is also much smaller than all the other *Scarabaeolus* species except *Scarabaeus (Scarabaeolus) parvulus* (Boheman, 1860). The male of this new species is unknown.

Description. Holotype: Body length 10.1mm, black. Pubescence black, except on frons where it is dark brown and pronotum where it is orange. Antennae orange brown.

Head: Frons punctate with iso-diametric punctures and dark brown associated setae. Low puncture-free carina present longitudinally between eyes. Clypeus punctate with punctures extended longitudinally.

Pronotum: Black, punctate, space between punctures smooth, punctures forming deep pits, separated by less than one pit diameter, punctures with short orange associated setae. No longitudinal smooth area. Lateral margins curved, crenulate.

Elytra: Black, lateral sides more or less parallel. Striae deep with regular small punctures, punctures separated by less than two puncture diameters. Interstriae matte bearing deep irregular shaped pits that are mostly matte inside; pits are wider than interstriae creating rugose appearance.

Pygidium: Emarginate and somewhat punctate; inside matte with area outside of punctures smooth. Punctures spaced irregularly, sometimes touching or separated by up to two and a half times the puncture width.

Metasternum: Long fovea between the mesocoxae, medially widest, with a second shorter fovea more distally. Metasternal elevation ending in almost a right angle and steeply sloping toward mesosternum. Area behind mesocoxae punctate, punctures small and widely separated.

Abdominal sternites: Glabrous with shallow indentations laterally.

Legs: Anterior femora shallowly punctate ventrally with dark setae dorsally. Inside margin of anterior tibiae crenulate, outside margin crenulate proximally with four outward pointing teeth distally, each separated by two to four saw-like denticles; denticles between last two teeth fused. Meso- and metafemora with irregular median row of punctures and dark setae. Metafemora swollen medially to give appearance of emargination on either end, inside edge of swollen area flattened. Mesotibiae slender, inside margin smooth and with row of black setae, outside margin with two brushes of black setae in distal third. Vestigial second mesotibial spur absent. Metatibiae with black setae, three bulges distally on outside. All tarsomeres of metatarsi with black setae, last tarsomere longest with claws half its length.

Etymology. The species is named for the Soutpansberg Mountains that dominate the area where it was collected.

Material examined. Holotype: ♀, S.Afr.; Limpopo Prov., Messina Nat. Res., 22[°].21['] S–30[°].03['] E, 11.12.2000; E-Y:3396, general collecting, leg. M. Burger, R. Müller, TMSA. Paratype: 1 specimen ♀, Soutpansberg, Limpopo, S22.91579°E29.68756°, 3–4.ii.2009, L. J. Niemand, UPSA.

Scarabaeus (Scarabaeolus) megaparvulus Davis and Deschodt

Figure 3, 6, 9

Diagnosis. This new species can be separated from *S. (S.) parvulus* by not having the anterior pronotal corners drawn forward into a hooked tip. In general, it is also much larger.

Description. Holotype: Body length 14.5 mm, black, convex. Pubescence black except for pronotum and elytra which are glabrous. Antennae black.

Head: Frons matte with very few punctures, each puncture with associated black setae. Clypeus granular with black setae.

Pronotum: Convex, matte with irregularly spaced punctures. No longitudinal smooth area. Distance between punctures is half to two times their width. Lateral margins curved, crenulate anteriorly becoming toothed posteriorly.

Elytra: Slightly wider medially than at base and apex. Striae deep with a few indistinct punctures. Interstriae matte with some punctures medially all along the length, punctures deep and separated by between one and three puncture widths, never touching striae.

Pygidium: Emarginate and somewhat punctate. Punctures spaced irregularly, sometimes touching or separated by up to three times the puncture width.

Metasternum: Fovea between the mesocoxae with a shorter one distally. Metasternal elevation ending in sharp angle and gradually sloping toward mesosternum. Area behind mesocoxae punctate.

Abdominal sternites: Smooth with indentations laterally.

Legs: Anterior femora punctate ventrally with black setae. Outside margin of anterior tibiae bearing small saw-like teeth proximally and four outward pointing teeth distally, each separated by five to eight saw-like denticles. Inside margin slightly curved inward with small tooth like projections and black setae along entire margin. Meso- and metafemora with median row of punctures and associated black setae. Mesotibiae with smooth inside margin and row of black setae; outer margin with two brushes of black setae in distal third. Vestigial second mesotibial spur absent. Metatibiae with black setae. All tarsomeres of metatarsi with setae, last tarsomere longest with claws half its length. This species is restricted to the Nama Karoo Biome.

Aedeagus: see Figure 6.

Etymology. The species name is derived from both its similarity to *S. (S.) parvulus* and its larger size.

Material examined. Holotype: ♂, Farm: Rooiput (30), S29.30289° E21.61613°, 990 m 16–18.iii.2006,

Davis & Deschodt, TMSA. Paratypes: 7 specimens, unsexed, S.W.Afr., Namib, Ganab NE range, 23[°].08[']S–15[°].36[']E, 1.3.1975, E-Y:711, groundtrap: 90day, legEndrödy-Younga, TMSA, 2 specimens, unsexed, S.W.Afr., Namib, Ganab NE range, 23[°].08[']S–15[°].36[']E, 1.3.1975, E-Y:712, groundtrap: 90 days, legEndrödy-Younga, TMSA, 6 specimens, unsexed, S.W.Afr., Namib, Ganab NE range, 23[°].08[']S–15[°].36[']E, 1.3.1975, E-Y:837, groundtrap. 94day, legEndrödy-Younga, ground traps with ferm.banana bait, TMSA, 5 specimens, unsexed, S.W.Afr., c. Namib, Ganab N.E, Hillgap, 23[°].08[']S–15[°].35[']E, 7.7.1978, E-Y:711, groundtraps, 3years, leg. Endrödy-Younga, TMSA, 4 specimens, unsexed, S.W.Afr., Namib, Park SE corner, 23[°].34[']S–15[°].45[']E, 26.11.1974, E-Y:946, groundtraps. 105d, leg. Endrödy-Younga, TMSA, 1 specimen, unsexed, S.W.Afr., Namib, Thomasbg, 340m, 23[°].10[']S–15[°].31[']E, 1.3.1975, E-Y:706, groundtrap. 97 days, leg. Endrödy-Younga, TMSA, 1 specimen, unsexed, S.Afr., Namaqualand, Pofadder 100kmW, 29[°].22[']S–18[°].37[']E, groundtraps. 62 days, leg. Endrödy-Younga, ground traps with meat bait, TMSA, 5 specimens, unsexed, S.Afr.; W Cape, Katdoornkuil Farm, 32.70[°] S–22.75[°] E, 3–6.XII.2007, leg.D.H.Jacobs, TMSA, 2 specimens, unsexed, FARM, WEISENBRON, SWA, (107 kms NW Aus via Farm Neisip) 5.II.1974, Davis & Kirsten, SANC, 2 specimens, unsexed, AUS, SWA, (5 kms NE) 4.II.74, Davis & Kirsten, SANC, 2 specimens, unsexed, AUS, SWA, (6/12 kms W) 4.II.74, SANC, 2 specimens, unsexed, GRUNAU, S.W.A., 6km N 24.II.85, H.H. Aschenborn, SANC, 1 specimen, unsexed, AUS, SWA, (South East) 13.II.74, Davis & Kirsten, (1436) SANC, 10 specimens, unsexed, S.Afr., Cape-Karoo, Farm Zwartskraal, 33[°].10[']S–22[°].32[']E, 8.11.1978,E-Y:1539a, groundtraps, 69 days, leg.R.Oosthuizen, ground traps with meat bait, TMSA, 1 specimen, unsexed, S.Afr., Cape-Karoo, Zwartskraal farm, 33[°].10[']S–22[°].32[']E, 8.11.1980,E-Y:1736a, groundtraps, 42 days, leg.R.Oosthuizen, ground traps with meat bait, TMSA, 3 specimens, unsexed, S.Afr., Cape-Karoo, Zwartskraal farm, 33[°].10[']S–22[°].32[']E, 8.11.1978,E-Y:1540a, groundtraps, 38 days, leg. Endrödy-Younga, ground traps with faeces bait, TMSA, 5 specimens, unsexed, S.Afr., Cape-Karoo, Zwartskraal farm, 33[°].10[']S–22[°].32[']E, 31.3.1979,E-Y:1567a, groundtraps, 30 days, leg. R.Oosthuizen, ground traps with faeces bait, TMSA, 24 specimens, unsexed, Farm Eufeesia (42), S30.933202° E 22.49185°, 2006.03.08–10, Deschodt & Strumpher, UPSA, 1 specimen, unsexed, Vreemdelingspoort., SE, 2415Dd., 22-I-1980, Univ. v. Pretoria, UPSA, 1 specimen, Farm:Deelpan,N-Cape, S29.56306°E22.34164°, A.Davis & C.Deschodt, 19–21.iii.2003, UPSA, 1 specimen, unsexed, Farm: Springputs (17), S29.41316° E22.24810°, 15–17.iii.2005 970m, Davis & Deschodt, UPSA, 4 specimens, unsexed, Farm: Mariba (18), S29.67961° E22.06762°, 18–20.iii.2005, Davis & Deschodt, UPSA, 29 specimens, unsexed, Farm: Sonderpan (29), S29.22260° E21.77542°, 1040m 16–18.iii.2006, Davis & Deschodt, UPSA, 82 specimens, unsexed, same as holotype, 10 UPSA, 18 BMNH 18 MNHN 18 NHRS 18 SAMC.

Scarabaeus (Scarabaeolus) niemandi Deschodt and Davis

Figure 3, 6, 8

Diagnosis. *Scarabaeus (Scarabaeolus) niemandi* is characterized by short black setae on the head and often punctate interstriae compared to brown setae on the head with interstriae that are smooth along their entire length in *S. (S.) lucidulus*. *S. (S.) niemandi* can be separated from *Scarabaeus (Scarabaeolus) anderseni* Waterhouse, 1890 by its larger size and black setae on the head compared to yellow setae on the head of *S. (S.) anderseni*. Punctuation on the elytra of *S. (S.) niemandi* does not often open into the striae as in *S. (S.) anderseni*.

Description. Holotype: Body length 11.7 mm, metallic green. Pubescence dark brown to black.

Antennae yellow.

Head: Frons punctate, each puncture with associated short, stocky black setae. Smooth, puncture free mid- longitudinal area. Clypeus punctate with short stocky black setae.

Pronotum: Metallic green, punctate, space between punctures smooth, punctures separated by less than one puncture diameter, punctures with short stocky black associated setae. Longitudinal smooth area not extending to anterior edge of pronotum. Lateral margins curved, crenulate.

Elytra: Metallic green, lateral sides more or less parallel. Striae shallow with regular small punctures separated by less than two puncture diameters; punctures extending into margins of interstriae.

Interstriae shiny with irregular punctures.

Pygidium: Emarginate and densely punctate, punctures small.

Metasternum: Long thin fovea between the mesocoxae, distally wider, with a shorter fovea more distally. Metasternal elevation ending with rounded angle and gradually sloping toward mesosternum. Area behind mesocoxae densely punctate, punctures small.

Abdominal sternites: Each sternite with row of punctures and associated dark setae anteriorly.

Legs: Anterior femora shallowly punctate ventrally with black setae. Outside margin of anterior tibiae bearing small saw-like teeth proximally and four outward pointing teeth distally, each separated by six to eight saw-like denticles. Inside margin crenulate. Meso- and metafemora with median row of punctures and long fine dark brown setae. Inside margin of mesotibiae smooth with row of black setae, outside margin with two brushes of dark brown setae in distal third. Vestigial second mesotibial spur present. Metatibiae with black setae. All tarsomeres of metatarsi with black setae, last tarsomere longest with claws half its length.

Aedeagus: see Figure 6.

Etymology. This species is named in honour of Lukas Niemand who collected most of the type series of this species.

Material examined. Holotype: ♂, Soutpansberg, Limpopo, S22.87561°E29.73128°, 3–4.ii.2009, L. J. Niemand, TMSA. Paratypes: 5 specimens, unsexed, same data as holotype. 2 UPSA, 1 TMSA, 2 SANC. 1 specimen, unsexed, S.Afr.; Limpopo Prov., Mabote farm, 24[°].07['] S 28[°]. 39['] E, 14.11.2009, leg. Ruth Müller, TMSA.

Scarabaeus (Scarabaeolus) carniphilus Davis and Deschodt

Figure 3, 6, 8

Diagnosis. *Scarabaeus (Scarabaeolus) carniphilus* can be separated from *Scarabaeus (Scarabaeolus) andreaei* Zur Strassen, 1963 by lacking the fine, but very dense and light brown setae on the elytra that characterize *S. (S.) andreaei*. The punctures on the elytra of *S. (S.) carniphilus* are more random than those in *Scarabaeus (Scarabaeolus) anderseni* Waterhouse, 1890, which are often opposite each other on adjacent interstriae to give the appearance of being two halves of the same puncture.

Description. Holotype: Body length 14.4 mm, metallic green. Pubescence on legs brown, that on body light brown. Antennae orange.

Head: Frons matte with few punctures, each puncture with a central black seta. Median longitudinal carina present. Clypeus punctate with light brown setae.

Pronotum: Convex, matte and punctate. Very narrow longitudinal smooth line present. Punctures sometimes almost touching and sometimes half a puncture diameter apart. Lateral margins strongly curved, crenulate anteriorly, becoming smooth posteriorly.

Elytra: Slightly wider at base than at apex. Striae shallow, indistinct. Interstriae with punctures often overlapping creating rugose effect, punctures often open into striae.

Pygidium: Emarginate and punctate. Punctures dense and irregular, separated by less than one puncture width. Metasternum: Shallow fovea between the mesocoxae with a shorter one distally. End of metasternal elevation rounded, almost right angled, steeply sloping toward mesosternum. Area behind mesocoxae with small densely spaced punctures. Abdominal sternites smooth with indentations laterally.

Legs: Anterior femora: thick at base, ventrally punctate with black setae. Outside margin of anterior tibiae bearing small saw-like teeth proximally and four sharp outward pointing teeth distally, each separated by seven to eight saw-like denticles. Inside margin slightly curved inward, slightly crenulate and with black setae along entire margin. Meso- and metafemora with median row of punctures and associated dark brown setae. Inside margin of mesotibiae smooth with row of black setae, outside margin with two brushes of black setae in distal third. Vestigial second mesotibial spur present.

Metatibiae slightly curved inward with black setae. All tarsomeres of metatarsi with setae, last tarsomere longest with claws half its length.

Aedeagus: see Figure 6.

Etymology. *S. (S.) carniphilus* was only sampled by carrion-baited pitfall traps and not by traps baited with various dung types. It is, thus, named for this association.

Material examined. Holotype: ♂, Mabuasehube Game Reserve, SW Botswana, ii.2006, 25°03'56,3"S 22°01'56.8"E Tshikae & Deschodt, TMSA. Paratypes: 8 specimens, unsexed, same data as holotype, 3 UPSA, 3 TMSA, 2 SANC; 1 specimen, 1012, VRYBURG, N.CP, (50 kms SW) 28.II.73, Bornemissza & Temby, SANC.

Scarabaeus (Scarabaeolus) planipennis Davis and Deschodt

Figure 4, 6, 8

Diagnosis. *Scarabaeus (Scarabaeolus) planipennis* is quite distinct from other species within its geographical range. It can be separated from *Scarabaeus (Scarabaeolus) flavicornis* (Boheman, 1860) (also with flat elytra) by its muted greenish appearance and smaller size.

Description. Holotype: Body length 12.8 mm, green. Pubescence is dark brown to black. Antennae yellow.

Head: Frons punctate, each puncture with associated short black setae. Wide puncture-free mid-longitudinal area. Clypeus punctate with short black setae.

Pronotum: Dark green and punctate with sparse short black setae. Spaces between punctures smooth comprising one to two puncture diameters. No longitudinal smooth area. Lateral margins curved, jagged anteriorly, with one side of jagged edge almost 10 times longer than the other gradually becoming toothed posteriorly.

Elytra: Dark green, lateral sides slightly curved slightly wider medially than at base and apex. Striae shallow with clear regular small punctures separated by about one puncture diameter. Interstriae very flat, matte, with very sparse small punctures.

Pygidium: Shallowly emarginate, matte.

Metasternum: No fovea between the mesocoxae. End of metasternal elevation rounded almost right angled and steeply sloping toward mesosternum. Area behind mesocoxae matte with small widely spaced punctures.

Abdominal sternites: Matte with short, fine black setae laterally.

Legs: Anterior femora swollen basally and shallowly punctate ventrally with black setae. Outside margin of anterior tibiae proximally crenulate merging into small saw-like teeth with four outward pointing teeth distally, each separated by nine to ten saw-like denticles. Inside margin finely crenulate, almost straight. Meso- and metafemora slender with irregular median row of punctures

and fine black setae. Inside margin of mesotibiae smooth with row of black setae, outside margin with two brushes of black setae in distal third. Vestigial second mesotibial spur absent. Metatibiae curving slightly inward with black setae. All tarsomeres of metatarsi with setae, last tarsomere longest with claws almost half its length.

Aedeagus: see Figure 6.

Etymology. The species name is derived from the flat elytra.

Material examined. Holotype: ♂, Maputo Elephant Reserve, Mozambique, [15–18] xi.2006, 26°35'06.8"S 32°46'45.1"E, sand, grassland, Escobar and Deschodt, TMSA. Paratypes: 15 specimens, unsexed, MOZAMBIQUE: Maputo Elephant Reserve, 10–16.xi.2007, 26°30'S 32°51'E Pitfall Trap, W. Strumpher & C. Deschodt, 2 UPSA, 5 TMSA, 5 BMNH, 3 SAMC, 1 specimen SOUTH AFRICA, KZN Pr. Tembe, 26°57'S 32°24'E, 7.iv.2004, J. v.d. Merwe, UPSA, 9 specimens Thembe Elephant Park, KZN, South Africa, 27°01'S 32°24'E, 24–29.i.1996, B.J. Van Rensburg, 2 UPSA, 7 SANC, 3 specimens South Africa: Kwazulu, Thembe Elephant Park, SE 2632 CD Ndumu, 7.x.1990, T. Beyers, UPSA, 1 specimen SOUTH AFRICA: KZN, Tembe Elephant Park, Sihangwane Area, 27[°].02[']S 32[°].25[']E 100m, 01.–04.ii.1996 R.Stals, SANC, 1 specimen, 2705 [Muzi, N. Natal, (26°52' 32°23'E), x–xi.80, G. Vale.], SANC, 1 specimen, MUZI, TONGALAND, Natal (14 km W), (26°52' 32°29'E), 4.xi.80, H.H. Aschenborn, SANC, 1 specimen, S. Afr : KrugerNat . PK, Punda Milia, sand, 22[°].38['] S–31[°].02['] E, 3.2.1994; E-Y: 2974, groundtraps, 8 days, leg. Endrödy-Younga, groundtraps with faeces bait, TMSA, 8 specimens, S. Afr : KrugerNat . PK, Nyandu sands, 22[°].41['] S–31[°].22['] E, 9.2.1994; E-Y: 2989, groundtraps, 4 days, leg. Endrödy-Younga, groundtraps with faeces bait, 6 TMSA, 2 UPSA.

Scarabaeus (Scarabaeolus) ermienae Deschodt and Davis

Figure 4, 6, 8

Diagnosis. *Scarabaeus (Scarabaeolus) ermienae* can be separated from *S. (S.) inoportunus* by its metallic green colour and dense yellow setae on the pronotum. The metasternal elevation is more rounded and flattened whereas in *S. (S.) inoportunus* it is more angular. It can also be readily separated from *S. (S.) damarensis* by its metallic green colour and pronotal punctures that are much larger and closer together than in *S. (S.) damarensis*. The metasternal elevation is more rounded and setose in *S. (S.) ermienae* while in *S. (S.) damarensis* it makes a 90 degree angle toward the prosternum and is not setose on the metasternal elevation. *S. (S.) ermienae* is also easily separated from *Scarabaeus (Scarabaeolus) gilleti* Janssens, 1940 which, similarly to *S. (S.) damarensis*, is black-bodied and shows a 90 degree angle at the metasternal elevation.

Description. Holotype: Body length 15.9 mm, metallic green. Pubescence dark brown to black except on frons where it is yellow. Antennae yellow.

Head: Frons punctate, each puncture with associated yellow setae. Mid-longitudinal area smooth, puncture free. Clypeus granular with yellow setae.

Pronotum: Metallic green and punctate, space between punctures smooth; punctures separated by less than one puncture diameter, each puncture with short yellow associated setae. No longitudinal smooth area. Lateral margins curved, crenulate anteriorly becoming more toothed posteriorly.

Elytra: Metallic green, lateral sides more or less parallel. Striae shallow with regular small punctures separated by less than two puncture diameters. Raised longitudinal median area of interstriae with irregularly shaped punctures, otherwise clear and smooth, longitudinal margins of interstriae mostly matte.

Pygidium: Emarginate and somewhat punctate, whole area matte. Punctures spaced irregularly, sometimes touching or separated by up to three times the puncture width.

Metasternum: Long thin fovea between the mesocoxae, distally wider, with a shorter fovea more distally. Metasternal elevation ending with rounded angle, gradually sloping toward mesosternum. Area behind mesocoxae punctate, punctures small.

Abdominal sternites: Covered with very fine setae, shallow punctures and shallow indentations laterally.

Legs: Anterior femora shallowly punctate ventrally with yellow to dark brown setae. Outside margin of anterior tibiae with small saw-like teeth proximally and four outward pointing teeth distally, each separated by five to six saw-like denticles. Inside margin crenulate, slightly curved inward at third outer tooth. Meso- and metafemora with irregular median row of punctures and long fine yellow setae. Inside margin of mesotibiae smooth with row of black setae, outside margin with two brushes of dark brown setae in distal third. Vestigial second mesotibial spur absent. Metatibiae with dark brown setae. All tarsomeres of metatarsi with setae, last tarsomere longest with claws half its length.

Aedeagus: see Figure 6.

Etymology. The species name is named in homage for Ermiena Deschodt, the wife of CMD.

Material examined. Holotype: ♂, Liuwa Plains Zambia, S14.645339° E022.624761°, 20–23.viii.2004 965m, Deschodt & Groenewald, TMSA. Paratypes: 46 specimens, unsexed, 10 UPSA, 10 SANC, 10 TMSA, 4 BMNH, 4 MNHN, 4 NHRS, 4 SAMC, 3 specimens, unsexed Liuwa Plains Zambia, S14.643259° E022.626423°, 29–30.xi.2003 1050m, Deschodt & Groenewald, UPSA.

Scarabaeus (Scarabaeolus) nitidus Davis and Deschodt

Figure 4, 6, 8

Diagnosis. *Scarabaeus (Scarabaeolus) nitidus* can be separated from *S. (S.) damarensis* by its much shinier appearance and clearly punctate interstriae. The setae on the head are yellow in *S. (S.) nitidus* and dark brown in *S. (S.) damarensis*. Ventrally, *S. (S.) nitidus* has dense yellow pilosity whereas *S. (S.) damarensis* has less dense short dark brown setae.

Description. Holotype: Body length 13.5 mm, metallic black. Pubescence yellow to dark brown. Antennae light brown.

Head: Frons somewhat punctate, each puncture with associated yellow setae. Mid-longitudinal area smooth and puncture free. Clypeus punctate with sparse, short yellow setae.

Pronotum: Shiny black and punctate. Most punctures with short fine yellow setae, punctures sometimes overlapping but mostly separated by less than one puncture diameter, space between punctures smooth. Clear longitudinal smooth area, not extending to anterior edge of pronotum.

Lateral margins curved, crenulate anteriorly becoming more toothed posteriorly.

Elytra: Shiny black, lateral sides slightly curved, slightly wider medially than at base and apex. Striae shallow with regular small punctures separated by less than two puncture diameters, punctures extending into interstriae. Interstriae shiny with some irregular punctures and short associated setae.

Pygidium: Shiny, emarginate with some small punctations.

Metasternum: Short wide fovea between the mesocoxae, with a shorter wide fovea more distally.

Metasternal elevation ending with rounded angle and gradually sloping toward mesosternum. Area behind mesocoxae densely punctate, punctures small with dense long fine yellow setae.

Abdominal sternites: Raised, mostly smooth.

Legs: Anterior femora swollen at base, shallowly punctate ventrally with yellow setae. Outside margin of anterior tibiae with small saw-like teeth proximally and four outward pointing teeth distally, each separated by four to five saw-like denticles. Inside margin smooth, curving slightly inward.

Meso- and metafemora with irregular median row of punctures and long fine yellow setae. Inside margin of mesotibiae smooth with row of dark brown setae, outside margin with two brushes of dark brown setae in distal third. Vestigial second mesotibial spur absent. Metatibiae: with dark brown setae. All tarsomeres of metatarsi with dark setae, last tarsomere longest with claws more than half its length.

Aedeagus: see Figure 6.

Etymology. The species is named for its shiny appearance.

Material examined. Holotype: ♂, Kutse Game Reserve BOT [Botswana], S23.44726° E24.39645°, 25.i.2006, Tshikae & Deschodt, TMSA. Paratypes: TMSA, 5 specimens, unsexed, 1 UPSA, 2 TMSA, 2 SANC, 1 specimen, Mabuasehube Game Reserve, SW Botswana, ii.2006, 25°03'56,3"S 22°01'56.8"E, Tshikae & Deschodt, UPSA.

The species name *Scarabaeus (Scarabaeolus) nitidus* was after publication found to be a homonym. A new replacement name, *Scarabaeus (Scarabaeolus) afronitidus* Davis & Deschodt was published by Davis et al. 2015 in: Davis, A.L.V., Stals, R., Deschodt, C.M. (2015) New replacement name for the species *Scarabaeus (Scarabaeolus) nitidus* Davis & Deschodt, 2015 (Coleoptera: Scarabaeidae: Scarabaeinae) — not an American pest. *Zootaxa*. 4057 (4): 582–582 (14 Dec. 2015).

Key to the known* species in the subgenus *Scarabaeus (Scarabaeolus)* Balthasar adapted from Zur Stassen 1967

*The flightless *Scarabaeus (Scarabaeolus) scholtzi* Mostert and Holm, 1982 is not included.

1. Interstriae of the elytra completely covered with large punctures that often open into stria forming ribbon-like patterns on inter- striae, or smooth rectangular areas on elevated disk-like patches on interstriae, habitus always black ... 2
 - Interstriae of the elytra smooth or with small punctures seldom opening into the striae, small dense pitting sometimes present close to the striae but never crossing the interstriae, habitus sometimes metallic green ... 12
2. Hind femora simple, without deep emargination proximally on posterior edge ... 3
 - Hind femora deeply emarginated proximally on posterior edge ... 8
3. Dorsal surface of anterior tibiae without pointed humps at the base of the outer teeth ... 4
 - Dorsal surface of anterior tibiae with a small pointed hump at the base of at least two of the outer teeth ... 6
4. Striae of the elytra narrow, shallow, very finely granulated; interstriae only slightly convex, bearing large, flat, smooth, shiny, and square to rectangular raised sections interrupted by pits; raised sections not interconnected nor reaching the striae. Length 9–14mm. Deep sands, SW and S coasts; South Africa ... *Scarabaeus (Scarabaeolus) intricatus* (Fabricius, 1801)
 - Elytral striae wide, somewhat incised; interstriae somewhat arched with moderately large and deep round excavations regularly opening into striae, distribution mainly in Nama Karoo ... 5
5. Antennae brown. Metasternal elevation with no large punctures proximally. Hind tibiae distally without angular bulges on outside. Raised interstriae smooth. Ventral edges of aedeagus straight, without angular bulging and without small teeth. Length 13–15mm. Nama Karoo; South Africa, S ... *Scarabaeus (Scarabaeolus) pabulator* Péringuey, 1908
 - Antennae black. Metasternal elevation with a few large punctures proximally. Hind tibia distally with three angular bulges on outside, the two proximal ones continue as ridges. Raised interstriae shagreened. Ventral edges of aedeagus widened anteriorly, left paramere widening, forming a small

tooth. Length 11–14mm. Nama Karoo; South Africa, S Namibia ... *Scarabaeus (Scarabaeolus) karrooensis* Zur Strassen, 1961

6. Prothorax at base without a row of punctures. Interstriae with very shallow punctations, space between them only slightly elevated. The three proximal outer teeth of the front tibiae each with a pointed tooth-like protrusion at its base. Length 13 mm. Arid SW Angola, NW ... *Scarabaeus (Scarabaeolus) obsoletepunctatus* Balthasar, 1940

- Prothorax at base with a row of irregular dense punctures. Interstriae with deep punctations, space between them convex. Only the two proximal outer teeth of the front tibiae each with a pointed tooth-like protrusion at its base ... 7

7. Microgranulation in base of elytral pits not covering more than a quarter of the width of the interstriae. Sahel and dry savanna regions; W, N central and NE Africa; Senegal to Sudan ... *Scarabaeus (Scarabaeolus) palemo* Olivier, 1789

- Microgranulation in base of elytral pits often covering more than a quarter of the width of the interstriae. Summer rainfall regions; Namibia, South Africa, Zimbabwe; Botswana (uncommon) ... *Scarabaeus (Scarabaeolus) bohemani* (Harold, 1868)

8. Emargination proximally on posterior edge of hind femora smooth without hooks, sharp angles or denticles ... 9

- Emargination proximally on posterior edge of hind femora with hooks, sharp angles or denticles ... 11

9. Antennae black, no second emargination distally on posterior edge of hind femora. Deep sands of Mozambique Coastal Plain, S Mozambique, NE South ... *Scarabaeus (Scarabaeolus) gracai* Ferreira, 1952

- Antennae orange-brown, second emargination distally on posterior edge of hind femora ... 10

10. Distal emargination on posterior edge of hind femora with clear angular hook at inside.

Mozambique Coastal Plain; S Mozambique, NE South Africa ... *Scarabaeus (Scarabaeolus) clanceyi* Ferreira, 1954

- Distal emargination on posterior edge of hind femora rounded, no angular hook at inside. Sand outlier at base of Soutpansberg, South Africa ... *Scarabaeus (Scarabaeolus) soutpansbergensis* Deschodt and Davis spec. nov.

11. Proximal emargination on posterior edge of hind femora not denticulate, terminating with sharp angles at both sides. Length 9–11mm. SE Kalahari deep sands and outliers (South Africa); Central Botswana ... *Scarabaeus (Scarabaeolus) inquisitus* Péringuey, 1908

- Proximal emargination on posterior edge of hind femora denticulate, not terminating with sharp angles at both sides. Length 10–12mm. SW Kalahari deep sands; South Africa, Botswana, Namibia ... *Scarabaeus (Scarabaeolus) kochi* Ferreira, 1952

12. Striae of the elytra deeply incised and conspicuously coarsely punctate, punctures wider than the

striae ... 13

- Striae of the elytra only slightly incised, either not punctate or with only a few punctures, punctures not wider than the striae ... 18

13. Front corners of the prothorax conspicuously drawn forward to a point. Very small body size. Length 6–10mm. SW Kalahari, N Nama Karoo, edge of Namib Desert; South Africa, Namibia ... *Scarabaeus (Scarabaeolus) parvulus* (Boheman, 1860)

- Front corners of the prothorax hardly drawn forward, obtuse angled ... 14

14. Body and antennae black. Upper Karoo, South Africa; S Namibia uplands ... *Scarabaeus (Scarabaeolus) megaparvulus* Davis and Deschodt spec. nov.

- Upper side of body with green or blue metallic lustre. Antennae yellow to orange brown ... 15

15. Only the 7th interstriae of the elytra in basal half have a few large punctures; the other interstriae smooth, without punctures. Length: 9–12mm. North of S Kalahari deep sands, outliers to east; South Africa, Botswana, Namibia ... *Scarabaeus (Scarabaeolus) lucidulus* (Boheman, 1860)

- All interstriae of the elytra in basal half with several punctures, which partially coalesce with punctures of the same size on the striae ... 16

16. Setae on head black, short. Sand outliers near Soutpansberg and Waterberg, South Africa ... *Scarabaeus (Scarabaeolus) niemandi* Deschodt and Davis spec. nov.

- Setae on head orange to brown, long ... 17

17. Punctures on elytra fine, punctures on interstriae not much wider than interstriae. Interstriae of elytra with dense setae. Length: 11–14mm. SW Kalahari deep sands; South Africa, Botswana ... *Scarabaeus (Scarabaeolus) carniphilus* Davis and Deschodt spec. nov.

- Punctures on elytra coarse, punctures on interstriae not much wider than interstriae. Interstriae of elytra only with sparse setae. Length: 8–10mm. S Kalahari, sand outliers to east, central Namib Desert; South Africa, Botswana, Namibia ... *Scarabaeus (Scarabaeolus) anderseni* Waterhouse, 1890 ... 20

18. Elytra black, sometimes with a greenish, bluish or bronze metallic lustre ... 19

- Elytra reddish yellow or reddish-brown ... 31

19. Sternite V of male with a small granule in the middle just in front of the rear edge. SE coast, Somalia ... *Scarabaeus (Scarabaeolus) laevifrons* Fairmare, 1884

- Sternite V of male simple, without granules in front of posterior edge ... 20

20. Habitus green or muted green ... 21

- Habitus black ... 23

21. Elytral interstriae flat, not raised, elytra not prominently striated. Deep sands of Mozambique Coastal Plain, S Mozambique, NE South Africa ... *Scarabaeus (Scarabaeolus) planipennis* Davis and Deschodt spec. nov.

- Elytral interstriae ribbed or raised, elytra clearly striated ... 22
- 22. Punctuation of prothorax fine. Deep sands of Mozambique Coastal Plain, S Mozambique, NE South Africa ... *Scarabaeus (Scarabaeolus) andreaei* Zur Strassen 1963
- Punctuation of prothorax coarse. Deep Kalahari sands; SW Zambia ... *Scarabaeus (Scarabaeolus) ermiensae* Deschodt and Davis spec. nov.
- 23. Elytral interstriae smooth and flat, elytra not prominently striated. Kalahari deep sands, outliers to east, Central Namib Desert, SW coast; South Africa, Namibia, Botswana, Zambia ... *Scarabaeus (Scarabaeolus) flavicornis* (Boheman, 1860)
- Elytral interstriae raised, elytra conspicuously striated ... 24
- 24. Up to 16mm in length ... 25
- Longer than 17mm ... 29
- 25. Interstriae of elytra with conspicuous punctures ... 26
- Interstriae of elytra without punctures ... 27
- 26. Interstriae of elytra appearing dull. SW Kalahari deep sands; South Africa, Botswana, Namibia ... *Scarabaeus (Scarabaeolus) inoportunus* Ferreira, 1953
- Interstriae of elytra brightly shining. SW Kalahari deep sands, Botswana ... *Scarabaeus (Scarabaeolus) nitidus* Davis and Deschodt spec. nov.
- 27. Hair on the head and pronotum black. Antennal colour-orange brown. Inside of front tibiae somewhat serrated. Central Mega- Kalahari; Angola ... *Scarabaeus (Scarabaeolus) gilleti* Janssens, 1940
- Hair on the head and pronotum yellowish. Antennal colour yellow. Inside of front tibiae finely serrated ... 28
- 28. Punctuation on pronotum fairly dense, punctures close together. S Kalahari deep sands; Namibia, Botswana, South Africa ... *Scarabaeus (Scarabaeolus) damarensis* Janssens, 1940
- Punctuation on pronotum more dispersed. NE Mega-Kalahari; Congo (DRC) ... *Scarabaeus (Scarabaeolus) kwiluensis* Janssens, 1940
- 29. Puncture-free centreline of the prothorax hardly raised; elytra simply striated, not ribbed, interstriae uniformly curved with wide matte area, centreline silky mat. Deep West coastal sands, South Africa (Northern and Western Cape Province) ... *Scarabaeus (Scarabaeolus) reichei* Waterhouse, 1890
- Puncture-free centreline of the prothorax narrow and clearly raised; elytra ribbed, interstices slightly curved, interstriae narrowly matte along lateral edges, central ribs clear. Inland of Western South Africa and Southern Namibia ... 30
- 30. Antennae and dorsal setae black. Sand pans and dunes, South Africa (Free State, Western and Northern Cape Province), Southern Namibia ... *Scarabaeus (Scarabaeolus) fritschi* Harold, 1868

- Antennae and setae entirely orange. Namibia (inland edge of Namib Desert) ... *Scarabaeus* (*Scarabaeolus*) *canaliculatus* Fairmaire, 1888.

31. Ventral, distal edge of fore femora with a large tooth. Edge of the pygidium strongly emarginate. Length: 13–17 mm. Namib Desert Dune Fields, SW Namibia, NW South Africa ... *Scarabaeus* (*Scarabaeolus*) *rubripennis* (Boheman, 1860)

- Ventral, distal edge of fore femora without tooth. Edge of the pygidium simple. Length: 9–10 mm. Arid coast; SW Angola, NW Namibia ... *Scarabaeus* (*Scarabaeolus*) *knobeli* Ferreira, 1958

Notes on some of the currently valid species

Scarabaeus (*Scarabaeolus*) *palemo* Olivier, 1789 and *Scarabaeus* (*Scarabaeolus*) *bohemani* (Harold, 1868), Figure 5, 10.

Depending on the author, these two species have been classified either as valid taxa or as synonyms. Early authors first described *Scarabaeus palemo* Olivier, 1789, citing a wide distribution from “Sénégal au Cap de Bonne- Espérance” [Senegal to the Cape of Good Hope] and then *Ateuchus* (*Sebasteos*) *cicatricosus* Boheman, 1857, citing a regional distribution in “Caffraria tota” [all of southeast South Africa or, perhaps, all of southern Africa]. Harold (1868) subsequently identified *A. cicatricosus* Boheman as a pre-occupied name and renamed the species as *Ateuchus bohemani*. After transfer of this *Ateuchus* species to *Scarabaeus*, later authors cited *S. bohemani* as a synonym of *S. palemo* (Péringuey 1901, Janssens 1940, Ferreira 1953, zur Strassen 1961). However, zur Strassen (1967) raised *S. bohemani* back to valid species status separate from *S. palemo*.

As opinion has clearly differed over time, and type localities (Olivier 1789, Boheman 1857) suggest overlapping ranges between the two species in southern Africa, we have examined morphological differences between specimens from different localities. In southern Africa, there is a southeast to northwest geographical cline in interstitial macro-sculpture on the elytra of *S. (S.) bohemani*. Specimens from the Upper Karoo of South Africa (Britstown) bear large punctures on the elytra with clear basal micro-granulation. Specimens to the north (Soutpansberg) show similar basal micro-granulation but the pits are smaller. Specimens from the Namib Desert region of Namibia (Hoheacht) have even smaller pits, no visible micro-granulation at macro-scale, and approach the condition of virtually effaced pitting in the larger-bodied *Scarabaeus* (*Scarabaeolus*) *obsoletopunctatus* Balthasar, 1940 that is found primarily in arid Southwest Angola. Specimens of *S. (S.) palemo* Olivier from Ghana also lack visible micro-granulation from the base of the pits at macro-scale. Furthermore, the inner margin of the front tibiae shows proximally-pointing, cone-like projections in Britstown and Soutpansberg *S. (S.) bohemani*. However, the small cone-like or

triangle-like projections point inward in Hoheacht *S. (S.) bohemani* and Ghanaian *S. (S.) palemo*. Although geographical variation in macro-sculpture suggests a species complex, electron micrographs (Fig. 10) show that the bases of large or smaller pits in all individuals bear strong or weak microgranulation thus eliminating a major presence or absence character used to separate *S. (S.) bohemani* from *S. (S.) palemo* by zur Strassen (1967). The other character regarding denticles on the fore tibia is asymmetrically represented across examined material of the two species. In view of the morphological and distributional evidence, we feel that it would be justified to, again, synonymize *S. (S.) bohemani* with *S. (S.) palemo*. However, any final decision would best be supported using molecular techniques. It would also be useful to simultaneously evaluate the status of *S. (S.) obsoletopunctatus*.

Scarabaeus (Scarabaeolus) gracai Ferreira, 1952

The holotype is on permanent loan from Museu Dr. Álvaro de Castro, Lourenço Marques (Maputo, Mozambique) in the TMSA.

Scarabaeus (Scarabaeolus) anderseni Waterhouse, 1890

Although the locality label with the type specimen (Fig. 11) reads as “Lake Ngami” [20°30’S 22°45’E], the type locality was cited as “Lake Nyassa” [11°45’S 34°30’E] (Waterhouse 1890). The reasons for this error are unknown to us. The type was collected by Karl Johan Andersson, a naturalist and explorer who never went near Lake Nyassa (Péringuey 1901) but who did undertake an expedition from Walvis Bay that reached Lake Ngami in 1853 (Andersson 1875). In a listing of collectors (Johnston 1903), we were unable to locate any information on the “Andersen” for whom the species was apparently named, neither to confirm his identity nor to determine if he sampled at Lake Nyassa [Lake Malawi].

Scarabaeus (Scarabaeolus) lucidulus (Boheman, 1860)

This species has a widespread distribution in South Africa, Zimbabwe, Botswana and Namibia. However we could not see any notable difference between specimens from Namibia [18°44’S 18°36’E] and the Nylsvlei [24°39’S 28°41’E] area.

Scarabaeus (Scarabaeolus) flavicornis (Boheman, 1860)

The recorded range of this species is from Lamberts Bay [32° 5'S 18°19'E] in the south (South Africa) to Liuwa plains [14°38'S 22°37'E] in the north (Zambia). Interstriae of specimens from the farm Florida [28° 09' S 21°40'E] in the Northern Cape are strongly shagreened along the edge of the striae, giving them a dull appearance (Fig. 12). In contrast, specimens from the Liuwa Plains are very smooth and relatively shiny (Fig. 12). We believe that this is merely a cline as a specimen seen from Karibib [21°56'S 15°51'E] (Namibia) shows intermediate sculpture (Fig. 12). There is very little difference between aedeagi from Zambian and Northern Cape specimens.

Scarabaeus (Scarabaeolus) gilleti Janssens, 1940

The locality label on the type specimen reads “Bite Angola” = Bitu very close to Luanda (W. Dekoninck, Personal Communication). *S. (S.) damarensis* Janssens 1940, *S. (S.) gilleti* and *S. (S.) kwiluensis* Janssens 1940 are a group of closely related species with distributions centred, respectively, from south to north across the Mega-Kalahari deep sands between northern South Africa and eastern Congo (DRC).

Scarabaeus (Scarabaeolus) scholtzi Mostert & Holm, 1982

This species is only included in *Scarabaeolus* on the presence of the second mesotibial spur (Mostert & Holm 1982). Forgie *et al* (2005) proposed to move it to *Scarabaeus (Scarabaeus)* as it consistently falls outside their “*Scarabaeolus* clades”.

Acknowledgements

Ruth Muller (TMSA) and Riaan Stals (SANC) are thanked for the loan of specimens. Simon Van Noordt (SAMC), Johannes Bergsten (NHRS), Jiri Zidek, Antoine Mantilleri (MNHN) and Helena Maratheftis (BMNH) are thanked for sending photographs of types. Paul Schoolmeesters is thanked for sending taxonomic papers from his extensive collection. We wish to gratefully acknowledge the JRS Biodiversity Foundation for funding the project that led to the recognition of the taxonomic issues addressed in this paper.

References

Andersson, C.J. (1867) *Lake Ngami: or, Explorations and discoveries, during four years' wanderings in wilds of south-western Africa*. Struik, Cape Town, 521 pp.

- Balthasar, V. (1940) Einige neue Scarabaeiden-Arten. *Casopis Ceskoslovenske Spolecnosti Entomologicke*, 37 (3–4), 67–76. Balthasar, V. (1965) Eine neue Undergattung und neue Arten der Familie Scarabaeidae (Col). (121. Beitrag zur Kenntnis der Scarabaeoidea). *Acta entomologica bohemoslovaca*, 62 (1), 14–23.
- Boheman, C.H. (1860) Coleoptera Caffraria annis 1838–1845 a J. A. Wahlberg collecta. *Öfversigt Kongliga Svenska Vetenskapsakademiens Förhandlingar*, 17 (3), 107–120.
- Fabricius, J.C. (1801) *Systema Eleutheratorum secundum ordines, genera, species: adiectis synonymis, locis, observationibus, descriptionibus. Tomus I*. Impensis bibliopoli academici novi, Kiliae, 506 pp.
- Fairmaire, L.M.H. (1884) Diagnoses des Coléoptères de l'Afrique orientale (Suite). *Annales de la Societe entomologique de Belgique. Comptes Rendus des seances Bruxelles*, 28, 121–125 (cxxi–cxxxv).
- Fairmaire, L.M.H. (1888) Enumération des Coléoptères recueillis par M. le Dr. Hans Schinz dans le Sud de l'Afrique. *Annales de la Société entomologique de France*, 6 (8), 173–202.
- FAO/IIASA/ISRIC/ISSCAS/JRC (2012) Harmonized world soil database (version 1.21). FAO, Rome, Italy and IIASA, Laxenburg, Austria. ESRI shapefile downloaded. Available from: <http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116> (accessed 18 August 2014)
- Ferreira, M.C. (1952) A new species of Scarabaeus. *Annals of the Transvaal Museum*, 22 (1), 73–77.
- Ferreira, M.C. (1953) Contribuicao para o estudo dos Escarabaeideos da Africa do Sul. *Memorias Museum Dr. Alvaro de Castro*, 2, 23–26.
- Ferreira, M.C. (1954) Some Scarabaeina in the Durban Museum and Art Gallery. *Durban Museum Novitates*, 4 (7), 91–95.
- Ferreira, M.C. (1958) A new species of *Scarabaeus* from South West Africa. *Novos Taxa Entomológico*, 5, 3–4.
- Ferreira, M.C. (1968) Contribuicao para o estudo dos Escarabideos de Moçambique. Descrição de

- uma espécie nova do subgénero *Scarabaeolus* Balthasar. *Novos Taxa Entomológicos*, 58, 3–9.
- Ferreira, M.C. (1972) Os escarabídeos de África (sul do Saara) I. *Revista Entomologia Mocambique*, 11, 1–1088. [1968–1969/ 1972]
- Forgie, S.A., Grebennikov, V.V. & Scholtz, C.H. (2002) Revision of *Sceliages* Westwood, a millipede-eating genus of southern African dung beetles (Coleoptera: Scarabaeidae). *Invertebrate Systematics*, 16, 931–955. <http://dx.doi.org/10.1071/IT01025>
- Forgie, S.A., Kryger, U., Bloomer, P. & Scholtz, C.H. (2006) Evolutionary relationships among the Scarabaeini (Coleoptera: Scarabaeidae) based on combined molecular and morphological data. *Molecular Phylogenetics and Evolution*. 40, 662–678. <http://dx.doi.org/10.1016/j.ympev.2006.04.018>
- Forgie, S.A., Philips, T.K. & Scholtz, C.H. (2005) Evolution of the Scarabaeini (Scarabaeidae: Scarabaeinae). *Systematic Entomology*, 30, 60–96. <http://dx.doi.org/10.1111/j.1365-3113.2004.00273.x>
- Gillet, J.J.E. (1911) Coprophaga Africana. Descriptions d'espèces nouvelles et remarques diverses. *Annales de la Société entomologique de Belgique*, 55 (11), 308–312.
- Griffith, E. & Pidgeon, E. (1831) The Class Insecta arranged by the Baron Cuvier, with Supplementary Additions to each Order. Notices of New Genera and Species by G. Gray. Volume the first. In: Griffith, E. *et al.* (Eds.), *The Animal Kingdom arranged in conformity with its Organisation by the Baron Cuvier, with Supplementary Additions to each Order. Vol. 14.* Whittaker, Treacher & Co., London, 570 pp., 102 plates. [dated 1832]
- Harrison, J. Du G., Scholtz, C.H. & Chown, S.L. (2003) A revision of the endemic, south-western African dung beetle subgenus *Scarabaeus* (*Pachysoma*) Macleay, including notes on other flightless Scarabaeini (Scarabaeidae: Scarabaeinae). *Journal of Natural History*, 37, 305–355. <http://dx.doi.org/10.1080/713834683>
- Harold, E. von (1868) Diagnosen neuer Coprophagen. *Coleopterologische Hefte*, 3, 80–86.
- Janssens, A. (1940) Monographie des *Scarabaeus* et genres voisines. *Mémoires du Musée royal d'Histoire naturelle de Belgique*, Série 2^e, 16, 1–81, 3 plates.

- Johnston, H.H. (1897) *British Central Africa; an attempt to give some account of a portion of the territories under British influence north of the Zambezi*. Methuen & Co, London, xix and 544 pp.
- Linné, C. (1758) *Systema naturae per regna tria naturae secundum classes, ordines, genera, species cum characteribus, differentiis, synonymis, locis*. Salvii, Holmiae, 824 pp.
<http://dx.doi.org/10.5962/bhl.title.542>
- Macleay, W.S. (1821) *Horae entomologicae, or essays on the annulose animals*. Bagster, London, 524 pp.
- Monaghan, M.T., Inward, D.J.G., Hunt, T. & Vogler, A.P. (2007) A molecular phylogenetic analysis of the Scarabaeinae (dung beetles). *Molecular Phylogenetics and Evolution*, 45, 674–692.
<http://dx.doi.org/10.1016/j.ympev.2007.06.009>
- Mostert, L.E. & Holm, E. (1982) Notes on the flightless Scarabaeina (Coleoptera: Scarabaeidae) with a description of a new Species. *Cimbebasia*, 5, 273–284.
- Mostert, L.E. & Scholtz, C.H. (1986) Systematics of the subtribe Scarabaeina (Coleoptera: Scarabaeidae). *RSA Department of Agriculture & Water Supply, Entomological Memoir*, 65, 1–25.
- Olivier, A.G. (1789) Entomologie, ou histoire naturelle des insectes, avec leurs caractères génériques et spécifiques, leur description, leur synonymie, et leur figure enluminée. *Coléoptères*, 1, 1–190.
- Péringuey, L. (1908) Descriptive catalogue of the Coleoptera of South Africa. Additions and corrections. *Transactions of the South African philosophical Society*, 13, 547–752. [Cape Town]
- Sato, H. (1998) Male Participation in Nest Building in the Dung Beetle *Scarabaeus catenatus* (Coleoptera: Scarabaeidae): Mating Effort Versus Paternal Effort. *Journal of Insect Behaviour*, 11, 833–843. <http://dx.doi.org/10.1023/A:1020860010165>
- Tribe, G.D. (1976) *The ecology and ethology of ball-rolling dung beetles*. M.Sc. thesis, University of Natal, Pietermaritzburg. [total page number unknown]
- Waterhouse, C.O. (1890) New Scarabaeidae in the British Museum. *The Annals and Magazine of natural History, including Zoology, Botany and Geology*, 29, 365–373.
- Westwood, J.O. (1837) Characters and descriptions of some new coleopterous insects belonging to the

family of sacred beetles. *Proceedings of the Zoological Society*, 5, 12–13.

Zidek, J. & Pokorny, S. (2004) Checklist of the genus *Scarabaeus* Linné. *Animma.X*, 5, 1–30.

Zur Strassen, R. (1961) Einige seltene Südafrikanische *Scarabaeus* arten im Museum. *Frey mit einer Neu-beschreibung Entomologische Arbeiten aus dem Museum G. Frey*, 12 (1), 236–241.

Zur Strassen, R. (1963) *Scarabaeus andreaei*, ein neuer Pillendreher aus Mozambique. *Senckenbergiana biologica*, 44 (2), 107–110.

Zur Strassen, R. (1967) Arten-Übersicht der Gattung *Scarabaeus* Linnaeus (Scarabaeidae) mit besonderer Berücksichtigung der äthiopischen Formen. *Entomologische Blätter für Biologie und Systematik der Käfer*, 63 (3), 129–173.

Figures and legends.



FIGURE 1. Dorsal views of (A) *S. (S.) vansoni*, (B) *S. (S.) lucidulus*, (C) *S. (S.) xavieri* and (D) *S. (S.)*

andreaei with associated labels to show synonymies.



FIGURE 2. Dorsal and ventral views of *S. (S.) canaliculatus* with associated labels and dorsal and lateral views of *S. (S.) reichei* with associated labels.

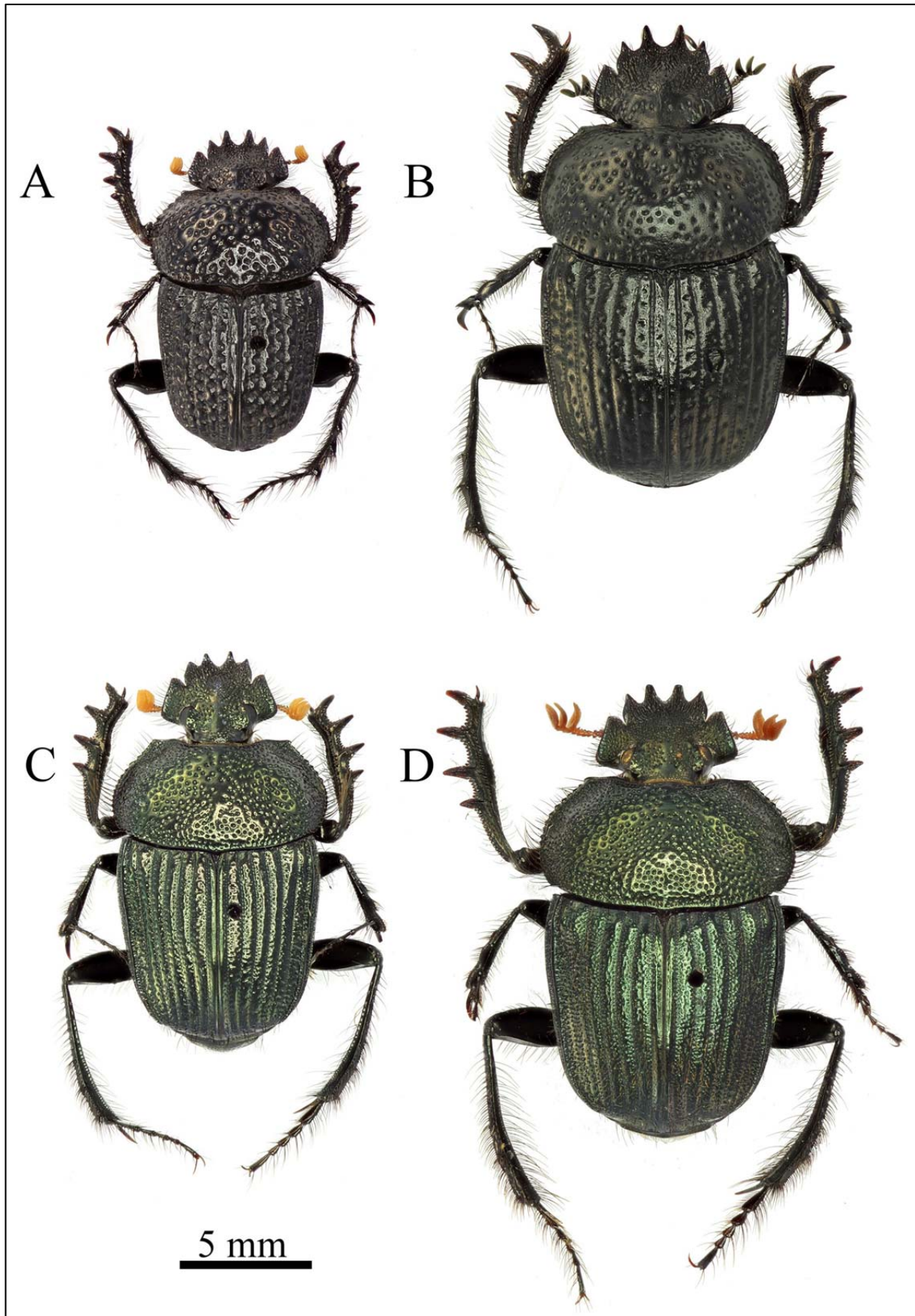


FIGURE 3. A. *S. (S.) soutpansbergensis*. B. *S. (S.) megaparvulus*. C. *S. (S.) niemandi*. D. *S. (S.) carniphilus*.

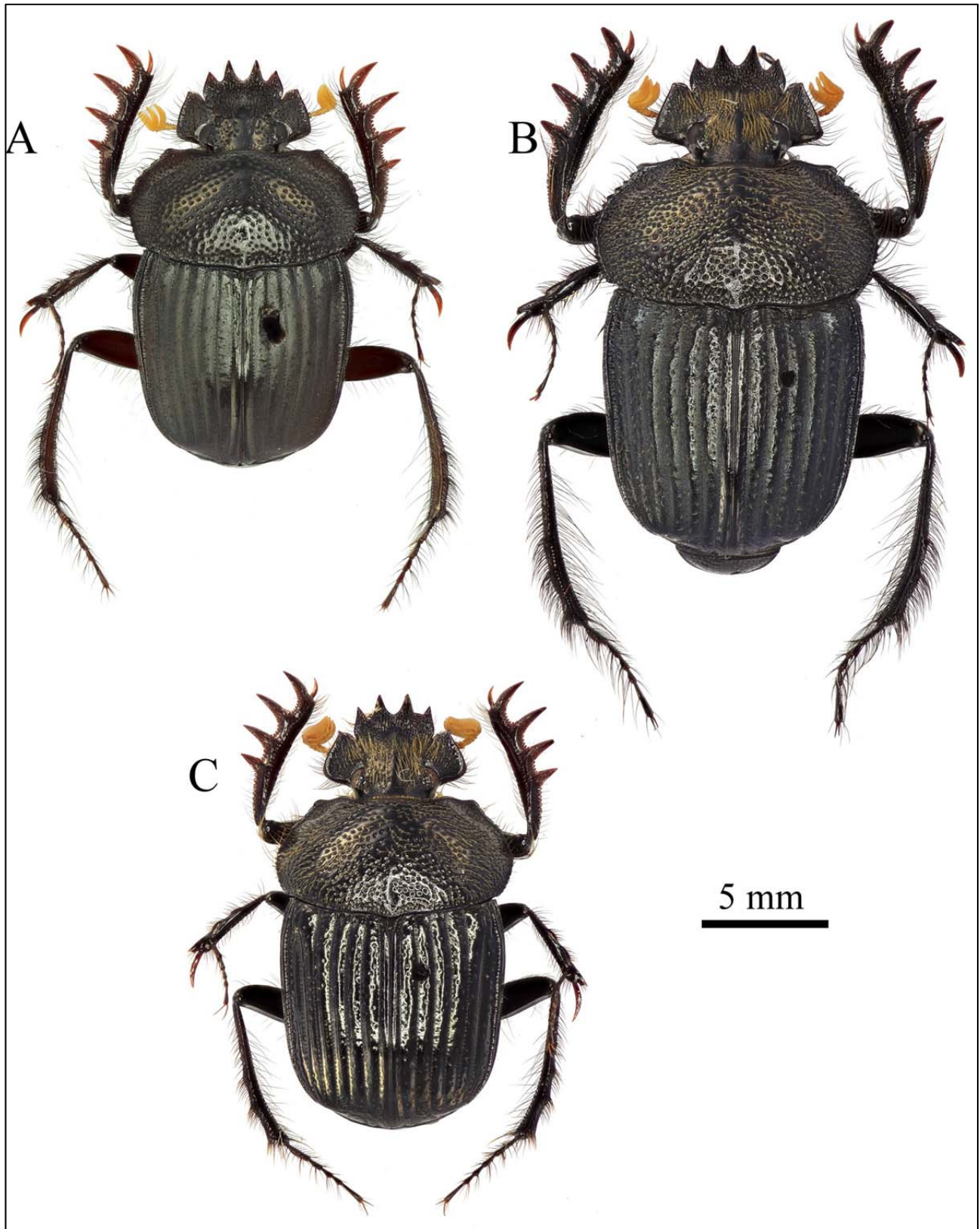


FIGURE 4. A. *S. (S.) planipennis*. B. *S. (S.) ermienae*. C. *S. (S.) nitidus*.

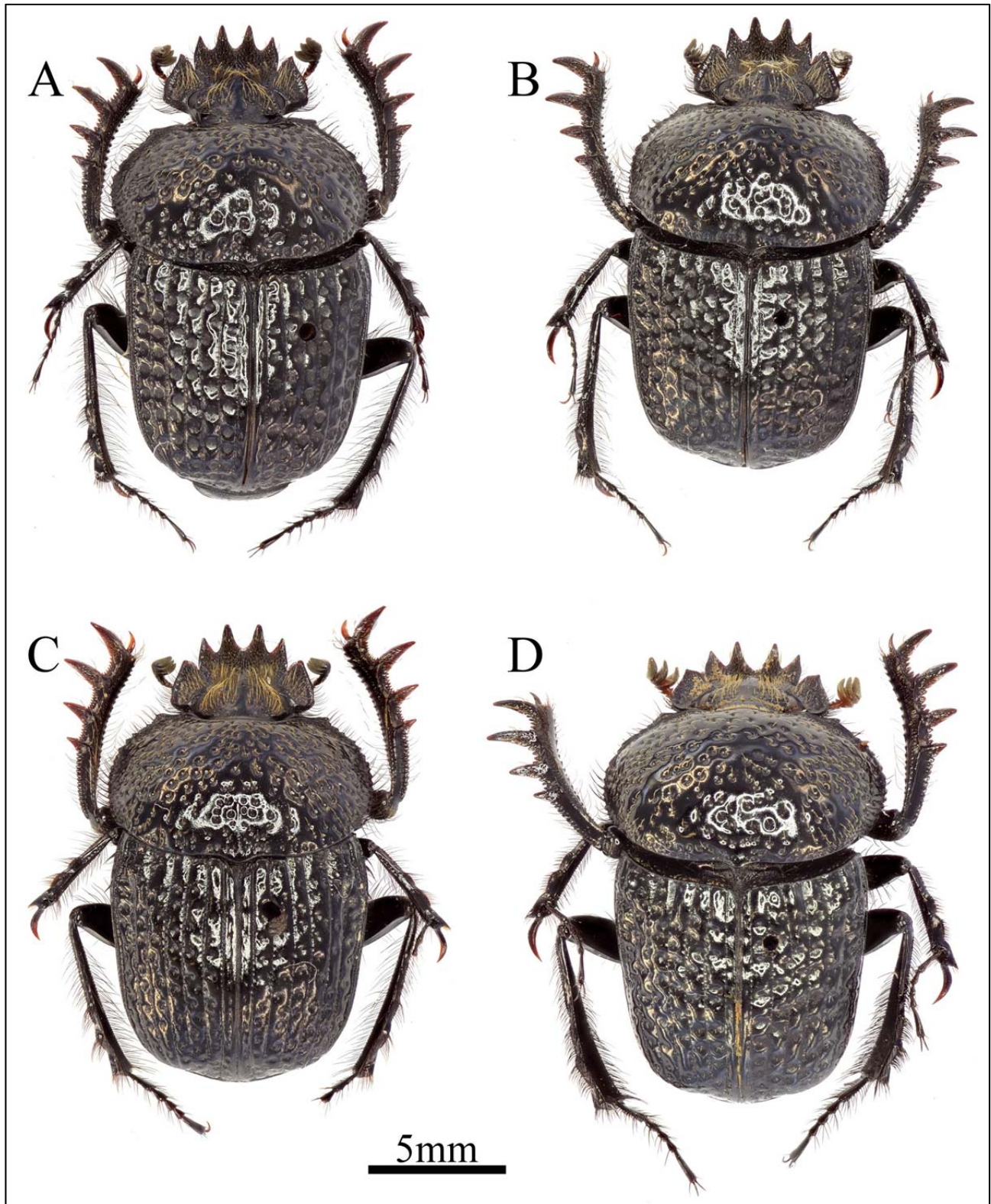


FIGURE 5. *S. (S.) bohemani* from: A. Hoheacht (24.40[°]S 16.23[°]E) (TMSA). B. North of Soutpansberg (S22.87561°E29.73128°) (UPSA). C. Britstown (30.51124°S 23.51983°E) (UPSA). D. *S. (S.) palemo* from Ghana, Damongo (N 9°04' W 1°48') (TMSA).

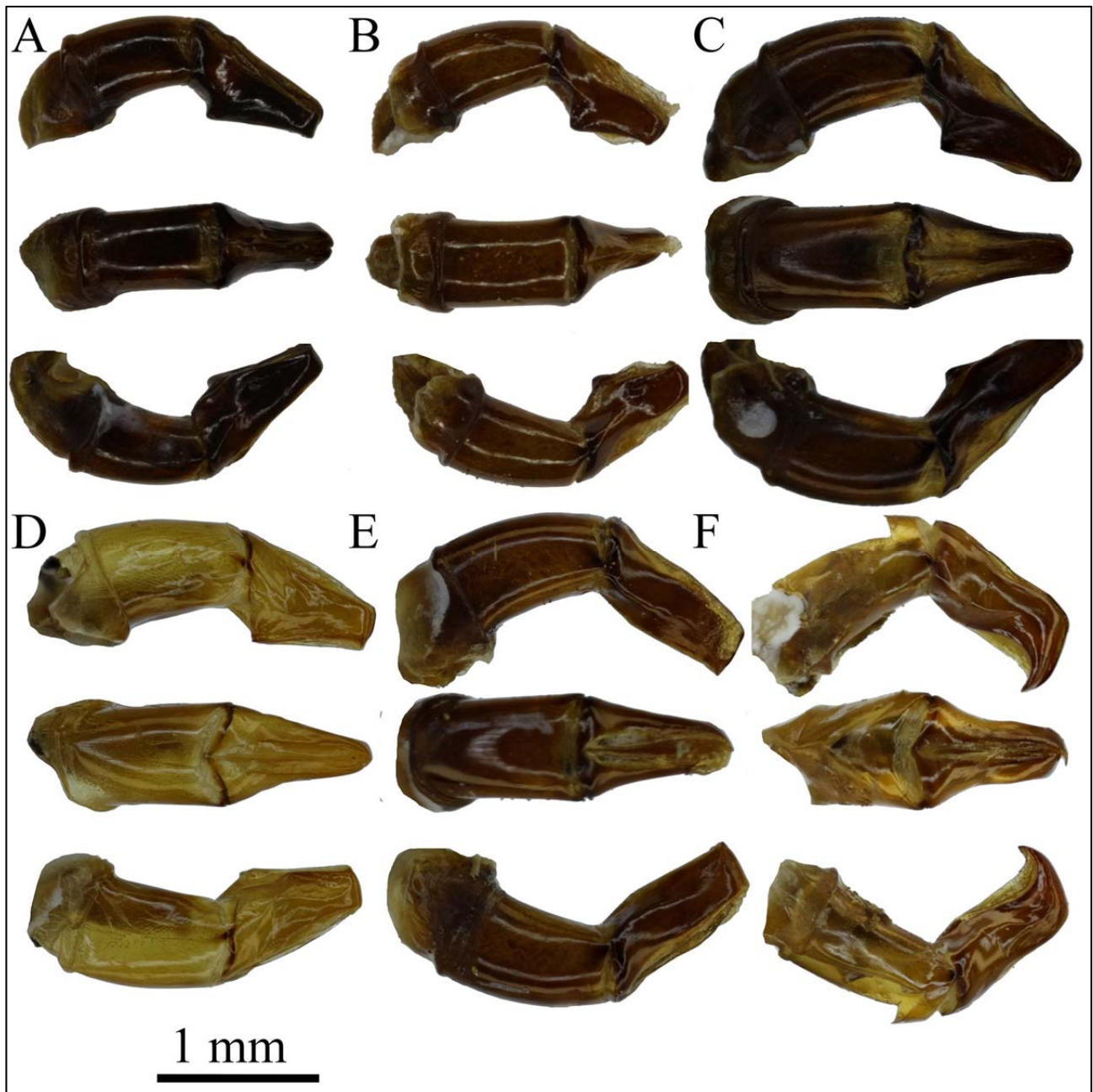


FIGURE 6. Aedeagi of: A. *S. (S.) megaparvulus*. B. *S. (S.) niemandi*. C. *S. (S.) carniphilus*. D. *S. (S.) ermienae*. E. *S. (S.) planipennis*. F. *S. (S.) nitidus*. From top to bottom, photographs of aedeagi are of the left, dorsal and right view for each species.

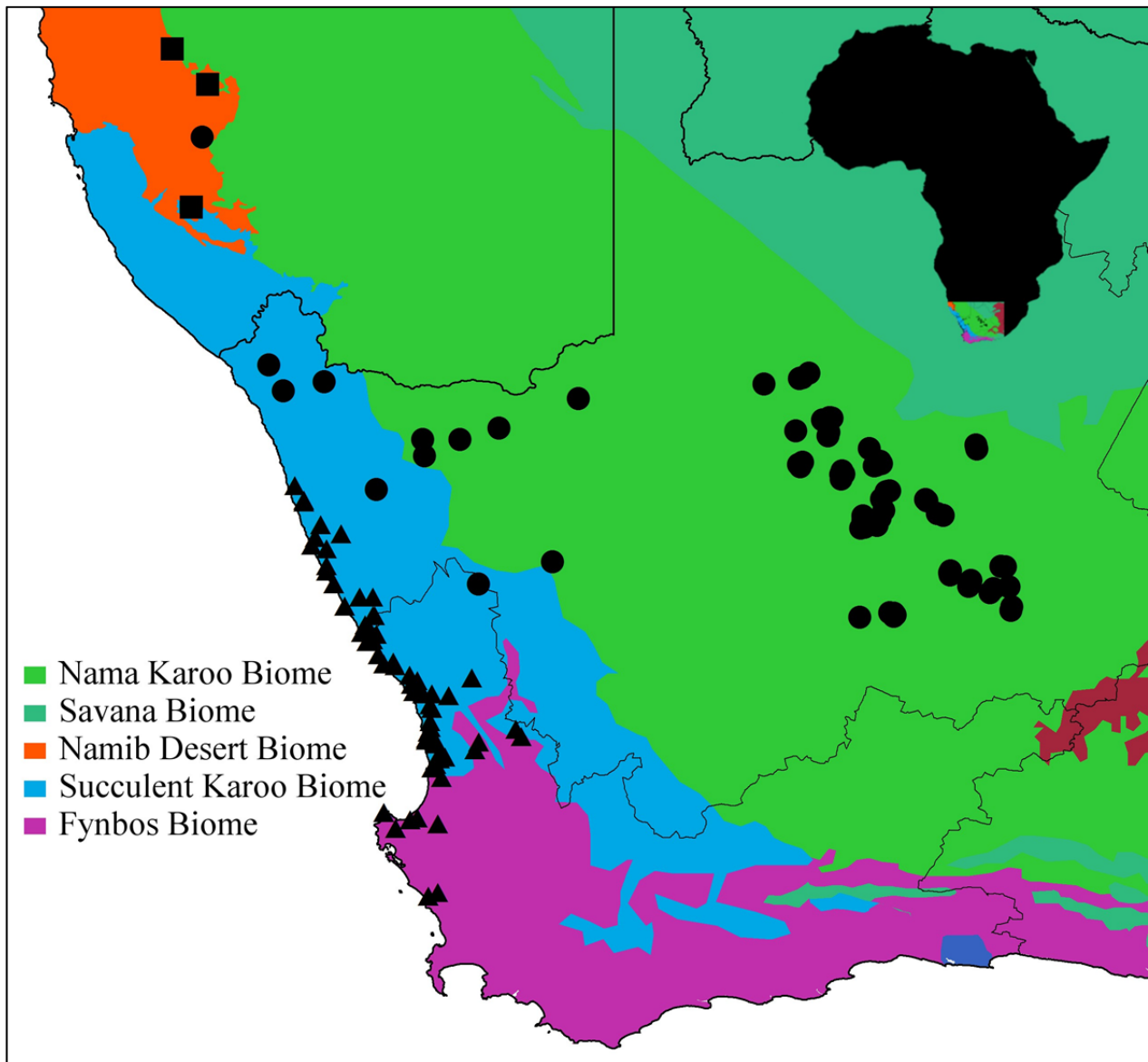


FIGURE 7. Map showing the collecting localities of specimens of (•) *S. (S.) canaliculatus*, (◼) *S. (S.) fritschi* and (▲) *S. (S.) reichei* in SANC, TMSA and UPSA collections.

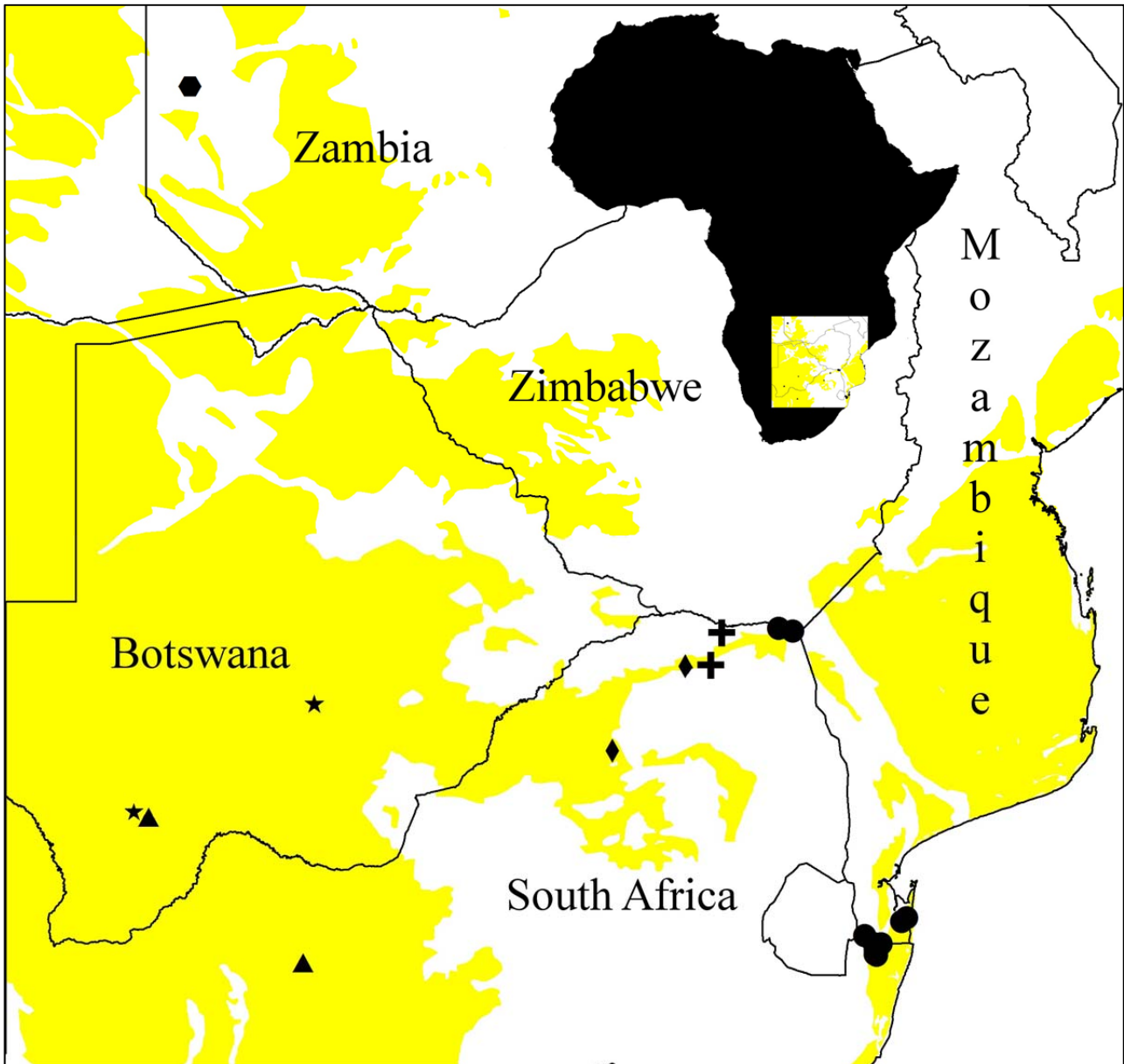


FIGURE 8. Map showing the collecting localities of (+) *S. (S.) soutpansbergensis*, (+) *S. (S.) niemandi*, (6.) *S. (S.) carniphilus*, (•) *S. (S.) ermienae*, (•) *S. (S.) planipennis* and (*) *S. (S.) nitidus*. The yellow highlighted areas show the distribution of Arenosols (Soils that appear to be without any profile development other than an A horizon which consists mostly of unconsolidated sand deposits). Source: FAO digital soil map of the world (FAO/IIASA/ISRIC/ISSCAS/JRC2012).

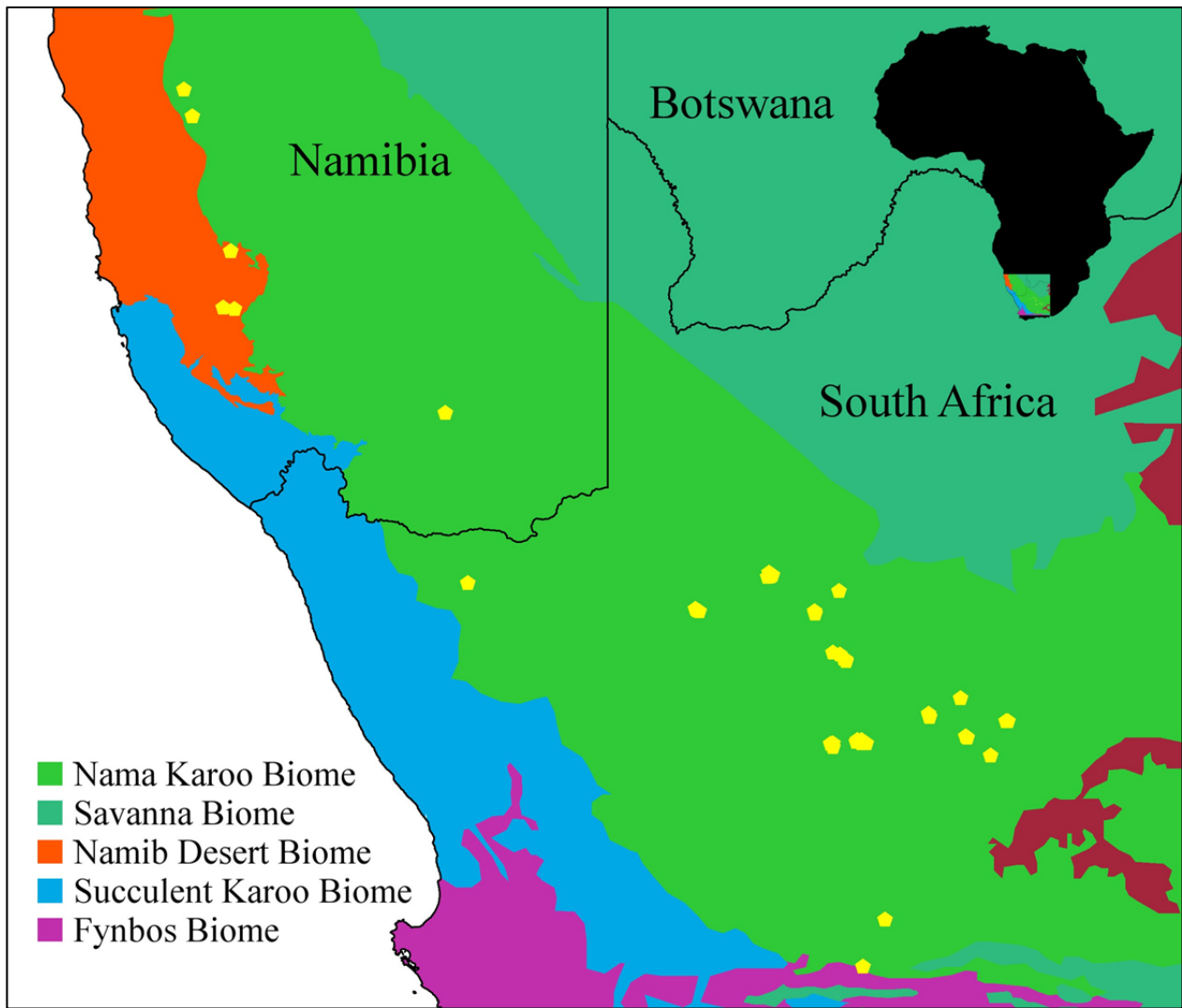


FIGURE 9. Map showing the collecting localities of *S. (S.) megaparvulus* within the Nama Karoo Biome.

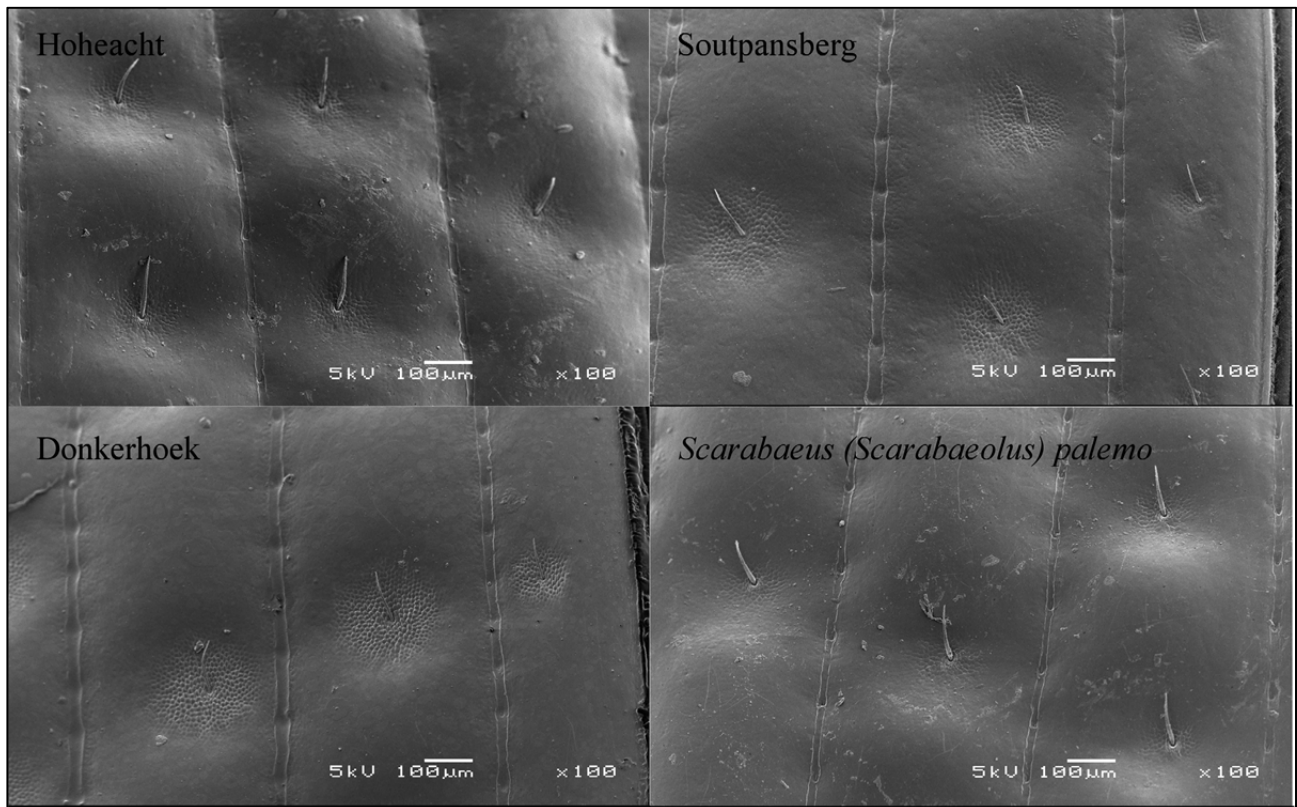


FIGURE 10. Electron micro-graphs showing the microgranulation that is present in the elytral pits of *S. (S.) bohemani* and *S. (S.) palemo*.

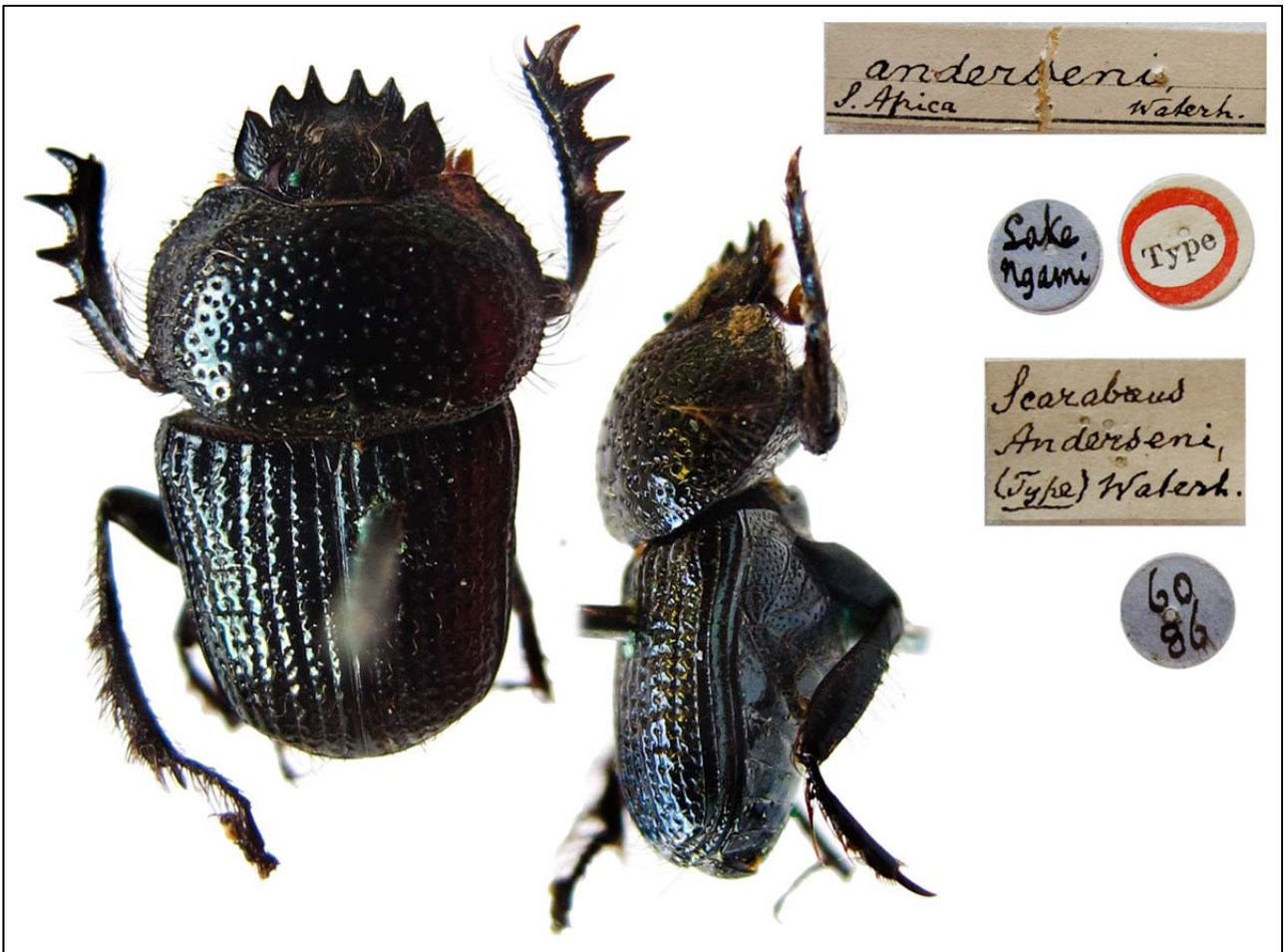


FIGURE 11. Photographs of the type of *S. (S.) anderseni* with its labels.

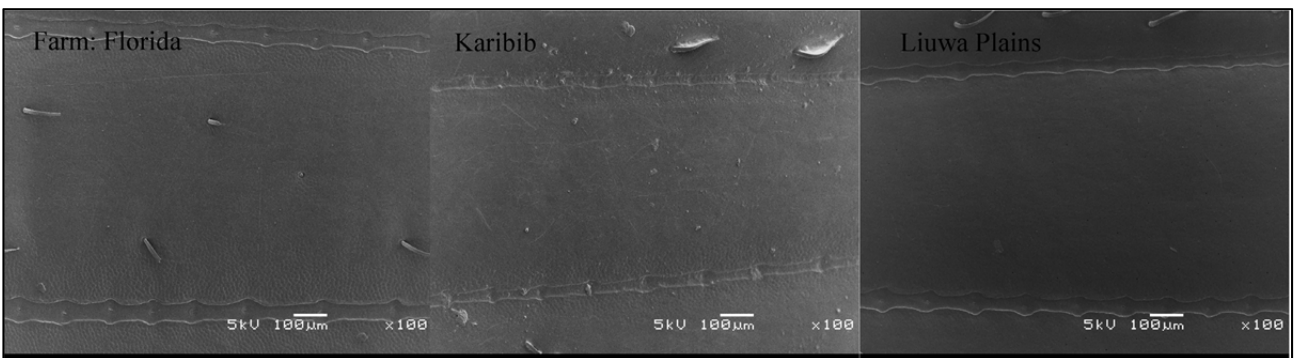


FIGURE 12. Electron micro-graphs showing the microgranulation that is present in the elytral interstriae of *S. (S.) flavicornis* from the Farm Florida, Karibib and Liuwa Plains.

Chapter 3

A new monotypic genus, a species synonymy and nomenclatural corrections in the arid-adapted Canthonini (Scarabaeidae, Scarabaeinae) from the Succulent Karoo Biome of south-western Africa

CHRISTIAN M. DESCHODT^{1,2,3}, ADRIAN L.V. DAVIS² & CLARKE H. SCHOLTZ²

¹*Department of Zoology and Entomology, Rhodes University, Grahamstown, South Africa*

²*Department of Zoology and Entomology, University of Pretoria, Pretoria, South Africa*

³*Corresponding author. E-mail: cdeschodt@zoology.up.ac.za*

Abstract

Although it has been demonstrated that the tribe Canthonini (Scarabaeidae: Scarabaeinae) is polyphyletic, those canthonine genera occurring in arid south-western Africa apparently form a monophyletic group. In this paper we add one new monotypic genus, *Drogo stalsi* gen. et. sp. n. to this group, and synonymize another member, *Byrrhidium namaquense* Scholtz and Howden, 1987 syn. n. with *Byrrhidium ovale* Harold, 1869. We correct the spelling of two species names that were not in agreement with the gender rule. A phylogenetic analysis based on morphology supports the erection of *Drogo* gen. n. An updated key to the genera and species of the *Byrrhidium* group is presented.

Key words: new genus, new species, synonymy, mandatory spelling changes, Richtersveld, Namaqualand, key, South Africa, Namibia, *Byrrhidium* group

Introduction

Although the scarabaeine dung beetle tribe Canthonini (by some authors referred to as Deltochilini) is clearly polyphyletic (Philips *et al.* 2004, Monaghan *et al.* 2008, Tarasov and Génier 2015), it appears that the flightless canthonines of the *Byrrhidium* Harold group are monophyletic (Sole and Scholtz 2010). This group occurs in the arid Succulent Karoo and Nama Karoo Biomes of south-western Africa and is currently represented by *Byrrhidium*, *Namakwanus* Scholtz and Howden, *Dicranocara* Frolov and Scholtz and, probably, *Versicorpus* Deschodt, Davis and Scholtz. All of the group representatives seem to be well adapted to the aridity of their habitat, have localized distributions (Frolov and Scholtz 2003, Deschodt *et al.* 2007, Deschodt *et al.* 2011), and most are strictly associated with rock hyrax (*Procapra capensis* (Pallas, 1766)) dung middens (Frolov and Scholtz 2003, Deschodt *et al.* 2007, Deschodt *et al.* 2011). The only probable exception is the most widespread species, *Byrrhidium ovale* Harold, 1869, which has been recorded at a small distance from hyrax colonies.

Hyrax-associated species of the *Byrrhidium* group are found amongst boulders and in close proximity to their food source. Rock hyrax can be found wherever there are rocky formations that provide a hiding place from predators together with nearby food plant species (Skinner and Chimimba 2005). As suitable rock hyrax habitat is naturally disjunct, its combination with this harsh environment creates islands surrounded by barriers to emigration by the flightless dung beetles. These isolated islands serve as stable refugia where speciation may occur over time. It is thus not surprising to find a new undescribed species that is distinct enough to also accord it new generic status. It is described here as *Drogo stalsi* gen. et. sp. n.

The genus *Byrrhidium* Harold, 1869 currently consists of three hitherto valid species. These are: *Byrrhidium ovale*, *Byrrhidium convexum* Scholtz and Howden, 1987 and *Byrrhidium namaquense* Scholtz and Howden, 1987. All of the species are very similar in appearance and endemic to South Africa. Recently new material was collected and our understanding of the generic distribution became clearer. While reviewing this new information we have recognized that *Byrrhidium namaquense* is a synonym of *Byrrhidium ovale*.

Materials and methods

Locality labels are reported verbatim with our comments in square brackets.

The color images of the habitus of the new genus were made using a Canon 500D camera body mounted with a Canon 65mm MPE 1–5x zoom lens and of the aedeagus using a Leica M165 C microscope and a Leica DMC 2900 digital camera. Image stacking was done using the Helicon remote and Helicon focus software packages. All other images were generated by the various museums curating the type specimens mentioned here, using their own imaging systems. Measurements of specimens were made using a Zeiss dissecting microscope fitted with a reticle. Lineage II in Sole and Scholtz (2010) includes *Byrrhidium* and several other genera that are all exceedingly small-bodied thus making reliable measuring difficult. Therefore, *Epirinus convexus*, the larger-bodied, basal taxon on the sister lineage III, was selected as the outgroup.

All the measurements made for the character matrix were averaged out. These measurements were then plotted on an excel graph and visually separated into the distinct groupings used in the analyses.

List of characters used for the cladistic analysis

1. Relative species length (defined as pronotum length plus elytron length, appendix 2) (0) large (more than 10 mm) (1) big (between 8 and 10 mm) (2) medium (between 4 and 8 mm) (3) small (less than 4 mm)
2. Pronotum area vs. elytron area (0) large (group a on figure 5A) (1) medium (group b on figure 5A) (2) small (group c on figure 5A)

3. Pronotum length, from appendix 2 (0) shorter than 2.5 mm (1) longer than 3 mm
4. Pronotum length vs. pronotum width (0) group a on figure 5B (1) group b on figure 5B
5. Elytron length vs. elytron width (0) group a on figure 5C (1) group b on figure 5C (2) group c on figure 5C (3) group d on figure 5C (4) group e on figure 5C
6. Elytron length, from table 2 (0) longer than 6 mm (1) between 5 and 6 mm (2) between 3.5 and 5 mm (3) between 2.5 and 3.5 mm (4) shorter than 2.5 mm
7. Mesocoxae distance vs. meso-metacoxa distance (0) group a on figure 5D (1) group b on figure 5D (2) group c on figure 5D
8. Elytron width vs. pronotum width (0) group a on figure 5E (1) group b on figure 5E (2) group c on figure 5E (3) group d on figure 5E
9. Visual grouping of clypeal horn size relative to body size (0) big (1) medium (2) small
10. Front tibial teeth (0) two (1) three
11. Serrations on median area of outside fore tibia (0) close together with sharp points (1) long and flat
12. Clypeus with third small median tooth (0) absent (1) present
13. Clypeus (0) bidentate (1) quadridentate
14. Clypeogenal suture (0) straight (1) inward curving
15. Sexual dimorphism in clypeal horns (0) absent (1) present
16. Aedeagus apex in side view (0) acutely downward pointing (around 90° angle) (1) downward pointing (around 45° angle) (2) almost straight
17. Aedeagus apex in frontal view (0) sideways or outwards pointing (1) not sideways or outwards pointing
18. Side protrusions on aedeagus (0) absent (1) present
19. Aedeagus (0) without saw-like structures between parameres (1) with saw-like structures between parameres
20. Edge of aedeagus at outside apex (0) with notch (1) no notch
21. Mesometasternal suture (0) straight (1) forward curving (2) slightly backward curving
22. Mesometasternal suture (0) not well defined (1) clearly defined
23. Prosternal punctures (0) faint (1) clear (2) not punctate
24. Separation of punctures on prosternum (0) close together (1) further apart (2) not punctate
25. Puncture size on prosternum (0) small (1) large (2) not punctate
26. Mesosternal punctures (0) faint (1) clear
27. Separation of punctures on mesosternum (0) close together (1) further apart
28. Puncture size on mesosternum (0) small (1) large
29. Metasternal punctures (0) faint (1) clear
30. Separation of punctures on metasternum (0) close together (1) further apart

31. Sides of pronotum (0) almost parallel (1) clearly converging anteriorly

Morphological relationships between canthonine species of the arid southwest were determined by cladistic analysis using NONA in WinClada (Nixon 2002). We deactivated the four uninformative characters. We then performed Bootstrap analyses running 10000 replicates with number of search reps set at 1000 repeated five times. The resulting cladograms were then submitted to the commands “keep Best trees only (delete suboptimal)” and “Consensus (strict)”. The averages for the bootstraps were calculated.

The nexus file used in the analyses is deposited on Morphobank (O’Leary & Kaufmann 2007) where the study is saved as Project 2443 (<http://morphobank.geongrid.org>).

Institutions mentioned in this paper are:

MNHN	France, Paris, Muséum National d’Histoire Naturelle
SANC	South Africa, Pretoria, South African National Collection of Insects
SAMC	South Africa, Cape Town, Iziko South African Museum
MFNB	Germany, Berlin, Museum für Naturkunde

Systematic entomology

Mandatory changes in spelling. Article 34 of the International Code of Zoological Nomenclature (ICZN 1999) deals with mandatory changes in spelling. According to article 34.2 (and also 31.2) that specifically deal with species-group names, the ending of a species name must agree in gender with the generic name.

Two species names cited in this paper are not in accordance with the abovementioned rules and must be changed.

The species name *Byrrhidium namaquensis* Scholtz and Howden, 1987 should thus change to *Byrrhidium namaquense* Scholtz and Howden, 1987 and *Versicorpus erongoensis* Deschodt, Davis and Scholtz, 2011 must change to *Versicorpus erongoense* Deschodt, Davis and Scholtz, 2011.

These new and correct spellings are followed throughout this paper.

New genus

Drogo Deschodt, Davis & Scholtz, gen. n.

Figs. 1, 2 and 4

Type species: *Drogo stalsi* Deschodt, Davis & Scholtz, sp. n.

Head. Clypeus quadridentate, with two relatively well-developed slender forward-pointing teeth, and two outside teeth that are right angled at ends. One very small tooth on lower clypeal margin between dorsal teeth. Clypeogenal suture distinct and inward curving.

Pronotum. Convex.

Elytra. Convex. Striae visible.

Sterna. Meso- and metasternum fused, mesometasternal suture well defined, somewhat curved anteriorly.

Protibia. Two teeth at apical outside margin.

Pygidium. Surface shagreened with big shallow punctures.

Aedeagus. Symmetrical. Medial sclerotized plate serrated ventrally (Fig. 1B, C).

Diagnosis. *Drogo* clearly falls within the tribe Canthonini by being strongly convex, having no more than three protibial teeth, the lateral margin of elytra being entire and by having fore tarsi present. It falls within the *Byrrhidium* group as described above. This genus and *Byrrhidium* are the only genera in the group that have a quadridentate clypeus. However *Drogo* can be separated from *Byrrhidium* by having longer clypeal horns and the mesometasternal suture being well defined. The body shape of *Drogo* is also more rounded whereas it is slightly elongate in *Byrrhidium*. *Drogo* can be separated from *Namakwanus* by having two protibial teeth instead of three and having the clypeus quadridentate instead of bidentate as in *Namakwanus*. None of the other species in the *Byrrhidium* group has the saw-like serrations on the medial sclerotized plate of the aedeagus (note that the aedeagus of *Versicorpus* is unknown).

Etymology. The gender is masculine. The aedeagus of *Drogo* reminds us of a sword thus the name is from contemporary fantasy after a powerful warlord known for his swordsmanship.

New species

Drogo stalsi sp. n.

Figs. 1, 2 and 4

Description. Holotype ♂: Medium sized beetle. Measurements with head inflexed, 7.34 mm (long) ×5.60 mm (wide) ×4.21 mm (high).

Head. Clypeus quadridentate, with two well-developed teeth, area between inside teeth more or less straight. Outside teeth are right-angled. One very small tooth on lower clypeal margin between dorsal teeth. Clypeogenal suture distinct and curving markedly inward. Clypeal surface clearly punctate.

Pronotum. Convex, small punctures completely covering pronotum, punctures separated by about one and a half lengths of their own diameter.

Elytra. Convex. Striae very shallow but visible, faintly punctate. Irregular and very faint punctures on interstriae.

Sterna. Prosternum with large shallow punctures. Meso- and metasternum fused, mesometasternal suture slightly curved anteriorly. Surface of mesosternum shagreened with clear, medium-sized shallow punctures. Surface of metasternum shagreened with a few very faint punctures.

Protibia. Inner margin more or less straight with no denticles. Line of punctures with associated tan setae along dorsal inside margin, deviating onto margin at apex, setae forming a small brush at apical tip. Tibial apex blunt with small spatulate outside-curving spur next to setal brush. Tarsi attached under spur close to inner margin of tibia. Setae on inner margins of tarsi short. Three very short thick and dark, spine-like setae on dorsoapical margin, parallel with apical margin. Two teeth at apical outer margin. First half of outer margin serrated from joint. Mesotibia. Outer margin sinuous with small and closely arranged serrations and with short tan setae all along edge. Inner margin relatively smooth except last fifth which is somewhat serrated. Setae short and sparse at regular intervals. Ventromedially and dorsomedially with a dense regular line of tan setae. Apically with two spurs. Tarsi with short tan setae, ending with two claws.

Metatibia. Angulate in cross section. with six rows of short tan setae that are densely spaced.

Pygidium. Surface shagreened with large shallow punctures.

Aedeagus. Symmetrical, see Figure 1.

Female. Unknown.

Specimen examined. Holotype male: NAMIBIA, Zebrafontein, ca 30km, NNE of Rosh Pinah, 27°45'S 16°53'E 2–6.iv.,2002 E.Holm & H.Gebhardt. (SANC).

Etymology. This species is named after Riaan Stals (SANC), who first identified it as new.

Discussion and support for generic status

Five trees with the same topology but with different bootstrap support were recovered in the analyses (Fig. 4). The bootstrapping for the constructed tree is not very well supported. This is probably due to the use of only morphological characters for a group of genera and species with the same general appearance that occupy similar niches in different locations in a very stable environment. Therefore, the classification of the presented tree needs to be supported by a molecular study.

Despite similarity in habitus between *Byrrhidium* and *Drogo*, the size differences, divergent characters of the aedeagi (Figs. 1, 3), and allopatry across the Orange River Valley suggest that they are sufficiently distant to be separated at generic level. Furthermore, erection of the new genus is supported by the topology of Figure 4 where the branches for *Namakwanus* lie between those for *Drogo* and *Byrrhidium*, suggesting separate histories of derivation.

Topology of Figure 4 may also go some way towards supporting the separation of *Namakwanus*

streyi from other *Namakwanus* species at generic level. However the limited observed morphological differences and close similarities in geographical distribution suggest that a molecular study is required as additional support for such a decision.

New synonymy

Byrrhidium ovale Harold, 1869

Figure 3

Elassocanthon brevipes Kolbe, 1908

Byrrhidium namaquense Scholtz and Howden, 1987 new synonym

Harold (1869) described the genus *Byrrhidium* with *Byrrhidium ovale* Harold, 1869 as the only constituent species. The very doubtful type locality was cited as “Port. Natal” by Harold (1869) although the label reads only “Natal”. Kolbe (1908) later described a new genus and species, *Elassocanthon brevipes* Kolbe 1908 (see figure 3B, E and H) from Brit. S.W. Africa, Kl. Namaland, Kamaggas [=Komaggas S29.80° E17.50°], vii. [19]04, L. Schultze S. This locality is consistent with the travels of L. Schultze during August 1904 from Steinkopf to Port Nolloth [S29.26° E16.87°], Henkries [S28.97° E18.09°] and Ka[o]maggas (Schultze 1908). In 1938, Janssens noted that *Elassocanthon brevipes* Kolbe, 1908 is most likely a synonym of *Byrrhidium ovale*. However the two species were only formally synonymized by Scholtz and Howden (1987), who also added two new species to the genus, *Byrrhidium convexum* and *Byrrhidium namaquense*. However, following the reasoning in Table 1, where we compared images of the three type specimens, we are of the opinion that *Byrrhidium namaquense* syn. n. is a junior synonym of *Byrrhidium ovale*. Consequently, we synonymize the two species.

Key to the genera and species in the *Byrrhidium* group

Note: Some species can only reliably be separated by examination of the male genitalia. The females and fragmented body parts may thus not be identifiable. In those cases, identity may be obtained from geographical distribution, which is included in the key, and may suggest an identity.

1. Fore tibia with three external denticles ... 2

- Fore tibia with two external denticles ... 6

2. Habitus fairly elongate; Erongo Mountain ... *Versicorpus erongoense* Deschodt, Davis and Scholtz

- Habitus convex ... *Namakwanus* Scholtz and Howden ... 3

3. Clypeal horns as long as, or longer than, distance between them; Windhoek and Gobabeb ... *N. irishi* Scholtz and Howden
 - Clypeal horns shorter than distance between them ... 4
4. Apices of aedeagus not curving outwards terminally, with rows of long setae; Remhoogte Mountains to the south of the Tsondab River canyon ... *N. streyi* Frolov
 - Apices of aedeagus curving outwards terminally, without rows of long setae ... 5
5. Tips of parameres with two notches in frontal view; Naukluft Mountains to the south of the Tsondab River canyon ... *N. endroedyi* Deschodt, Davis and Scholtz
 - Tips of parameres without notches in frontal view; Hardap Dam ... *N. davisii* Deschodt and Scholtz
6. Clypeus clearly bidentate with clypeal horns long ... *Dicranocara* Frolov and Scholtz ... 7
 - Clypeus quadridentate, with short medial clypeal horns ... 9
7. Aedeagus with lateral clypeal horns on parameres that extend forward; punctures on pronotum fewer, faint and shallow; Richtersveld south of Orange River, in South Africa ... *D. tatasensis* Deschodt and Scholtz
 - Aedeagus without lateral clypeal horns on parameres; punctures on pronotum numerous and obvious; Richtersveld north of Orange River, in Namibia ... 8
8. Apex of parameres bulky; northern Richtersveld and Fish River Canyon ... *D. inexpectata* Deschodt and Scholtz
 - Apex of parameres slender; southern Richtersveld: Boom River ... *D. deschodti* Frolov and Scholtz
9. Clypeal horns short, mesometasternal suture not well defined; south of Orange River *Byrrhidium* Harold ... 10
 - Clypeal horns medium length, mesometasternal suture well defined; north of Orange River ... *Drogo stalsi* gen. et. sp. n.
10. Aedeagus with side protrusions, fore tibia with outer teeth parallel; Richtersveld in South Africa ... *B. convexum* Scholtz and Howden
 - Aedeagus plain with no side protrusions, fore tibia with outer teeth diverging; Namaqualand ... *B. ovale* Harold

Acknowledgements

We wish to thank the following curators: Riaan Stals (SANC) for taxonomic discussions, critically reading an earlier draft of the manuscript and for the specimen loan, Dr. Antoine Mantilleri (MNHN) for photographs of the *Byrrhidium ovale* holotype, Dr. Joachim Willers (MFNB) for photographs of the *Elassocanthon brevipes* holotype and Dr. Simon van Noort (SAMC) for images of the *Byrrhidium namaquense* holotype.

We also wish to gratefully acknowledge the JRS Biodiversity Foundation for funding the project that

led to the recognition of the taxonomic issues addressed in this paper.

References

- Deschodt, C., Kryger, U. & Scholtz, C.H. (2007) New taxa of relictual Canthonini dung beetles (Scarabaeidae: Scarabaeinae) utilizing rock hyrax middens as refuges in south-western Africa. *Insect Systematics & Evolution*, 38, 361–376. <http://dx.doi.org/10.1163/187631207788784067>
- Deschodt, C.M., Davis, A.L.V. & Scholtz, C.H. (2011) New dung beetle (Coleoptera: Scarabaeidae: Scarabaeinae) taxa from arid south-western Africa. *Insect Systematics & Evolution*, 42 (3), 277–294. <http://dx.doi.org/10.1163/187631211X568173>
- Frolov, A.V., Akhmetova, L.A. & Scholtz, C.H. (2008) Revision of the obligate mushroom-feeding African "dung beetle" genus *Coptorhina* Hope. *Journal of Natural History*, 42 (21–22), 1477–1508. <http://dx.doi.org/10.1080/00222930802002535>
- Frolov, A.V. & Scholtz, C.H. (2003) A new genus and species of dung beetle from southern Namibia. *African Entomology*, 11 (2), 297–299.
- Harold, E. von (1868) Diagnosen neuer Coprophagen. *Coleopterologische Hefte*, 3, 80–86.
- ICZN (1999) International Code of Zoological Nomenclature. Fourth Edition. The International Trust for Zoological Nomenclature, London, 306 pp.
- Janssens, A. (1938) Scarabaeini, Coleoptera Lamellicornia, Fam. Scarabaeidae. *Exploration du Parc National d'Albert, Mission G.F. de Witte (1933-1935)*, Fascicle 21, 1–76.
- Kolbe, H.J. (1908) *Dynastidae, Cetoniidae und Scarabaeidae. Schultze L.: Zoologische und Arthropologische Ergebnisse einer Forschungsreise im westlichen und zentralen Südafrika. Bd. I.* Denkschrift Medizinisch-Naturwissenschaftlichen Gesellschaft zu Jena, 13, 121–132.
- Monaghan, M.T., Inward, D.G., Hunt, T.H. & Vogler, A.P. (2007) A molecular phylogenetic analysis of the Scarabaeinae (dung beetles). *Molecular Phylogenetics and Evolution*, 45, 674–692. <http://dx.doi.org/10.1016/j.ympev.2007.06.009>
- Nixon, K.C. (2002) WinClada ver. 1.00.08. Published by the author, Ithaca, NY.

- O'Leary, M.A. & Kaufman, S.G. (2007) MorphoBank 2.5: Web application for morphological phylogenetics and taxonomy, Available from: <http://www.morphobank.org> (accessed 15 Jun. 2016)
- Philips, T.K., Pretorius, E. & Scholtz, C.H. (2004) A phylogenetic analysis of dung beetles (Scarabaeinae: Scarabaeidae): unrolling an evolutionary history. *Invertebrate Systematics*, 18, 53–88. <http://dx.doi.org/10.1071/IS03030>
- Scholtz, C.H. & Howden, H.F. (1987) A revision of the southern African Cathonina [sic] (Coleoptera: Scarabaeidae: Scarabaeinae). *Journal of the Entomological Society of Southern Africa*, 50, 75–119.
- Schultze, L (1908) *Zoologische und anthropologische Ergebnisse einer Forschungsreise im westlichen und zentralen Südafrika: ausgeführt in den Jahren 1903-1905. Erster Band, Systematik und Tiergeographie / mit Unterstützung der Kgl. Preussischen Akademie der Wissenschaften zu Berlin, 1e Lieferung.* Jena, Fischer, 646 pp.
- Skinner, J.D. & Chimimba, C.T. (2005) *The Mammals of the Southern African Subregion, 3rd ed.* Cambridge University Press, Cambridge, 874 pp. <http://dx.doi.org/10.1017/CBO9781107340992>
- Sole, C.L. & Scholtz, C.H. (2010) Did dung beetles arise in Africa? A phylogenetic hypothesis based on five gene regions. *Molecular Phylogenetics and Evolution*, 56 (2), 631–641. <http://dx.doi.org/10.1016/j.ympev.2010.04.023>
- Tarasov, S. & Génier, F.(2015) Innovative Bayesian and Parsimony Phylogeny of Dung Beetles (Coleoptera, Scarabaeidae, Scarabaeinae) Enhanced by Ontology-Based Partitioning of Morphological Characters. *PLoS ONE*, 10 (3), 1–86. <http://dx.doi.org/10.1371/journal.pone.0116671>

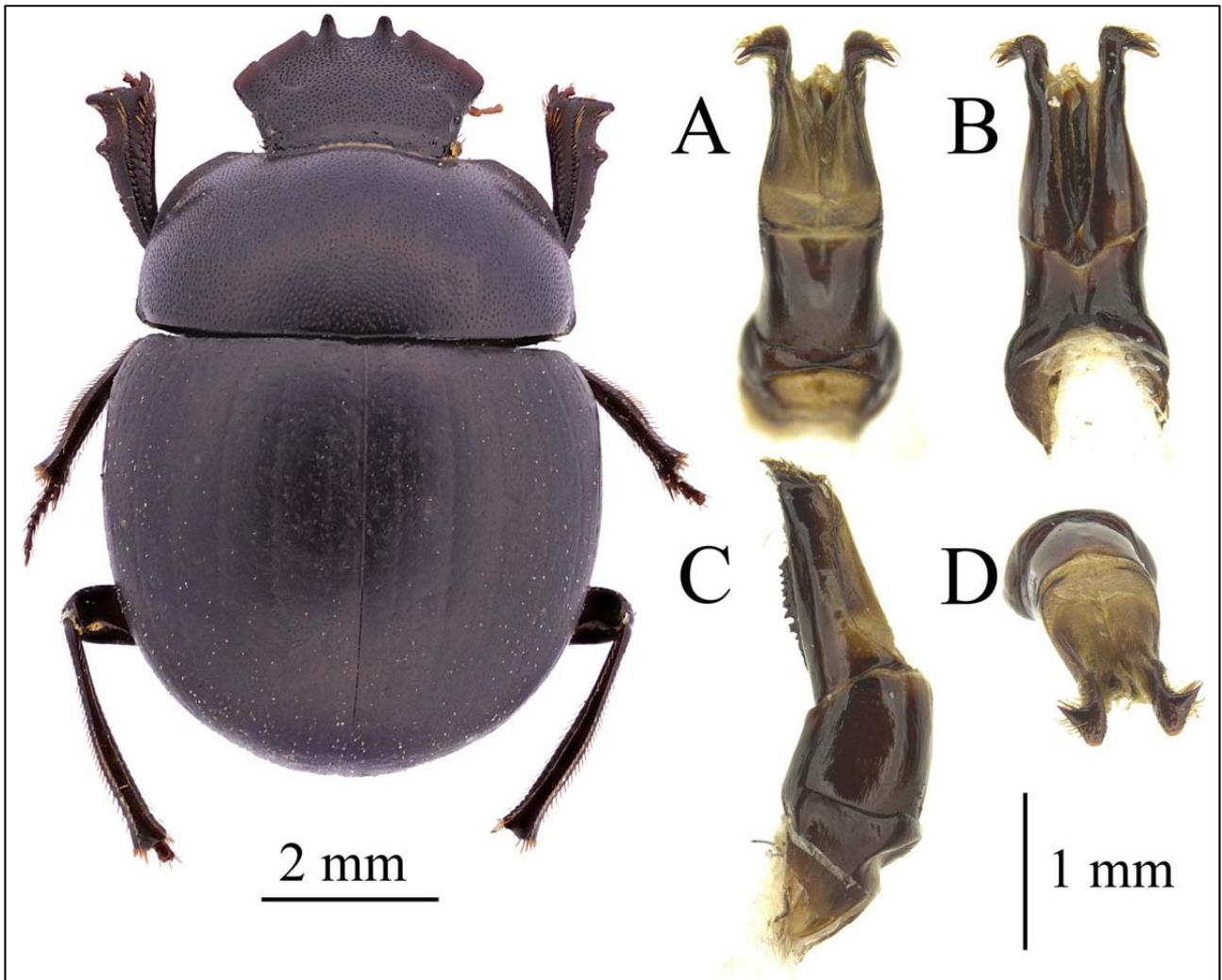


FIGURE 1. Habitus and aedeagus of *Drogo stalsi* gen. et. sp. n. Dorsal (A) ventral (B) left lateral (C) and (D) frontal views of aedeagus.

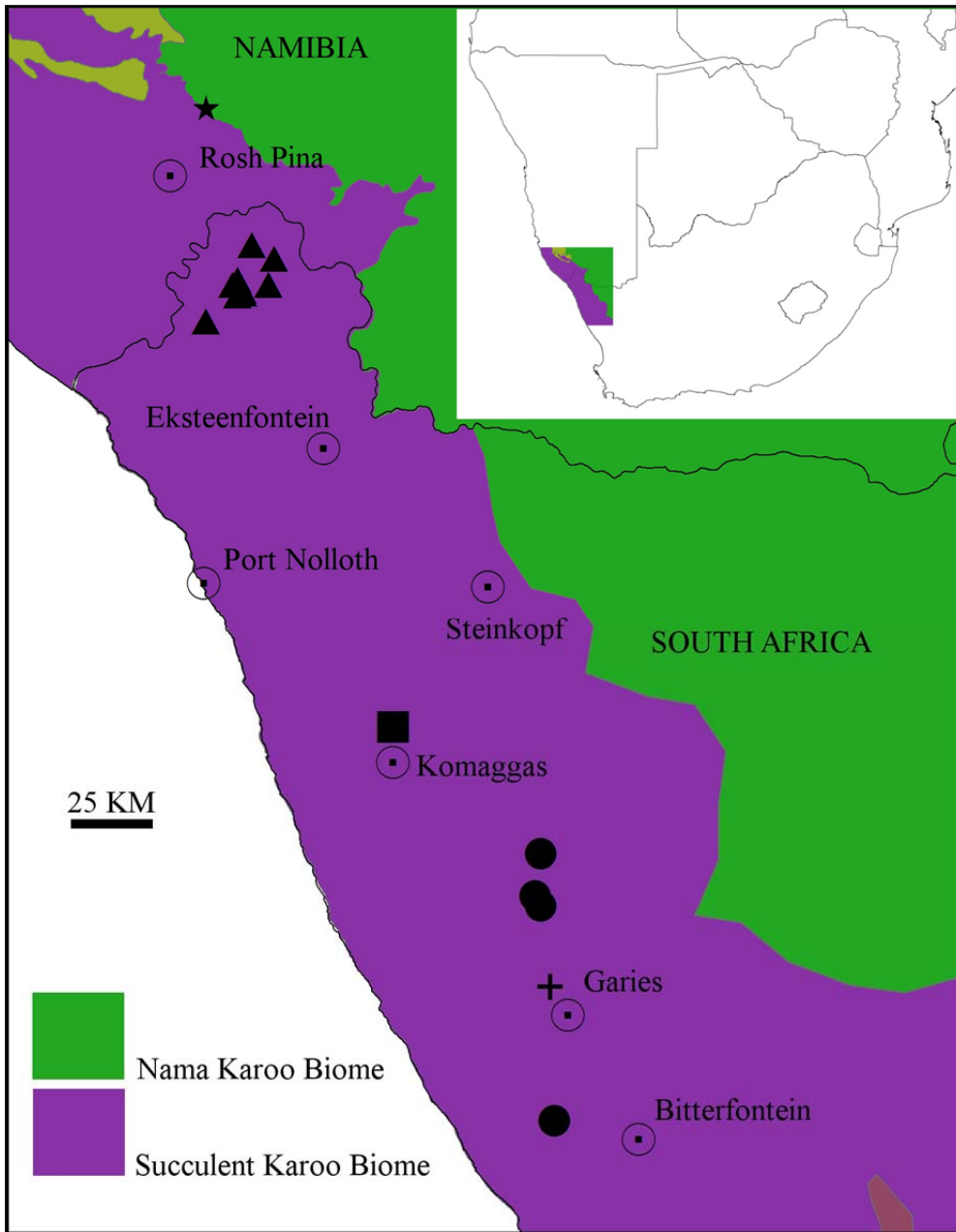


FIGURE 2. Map showing the type localities of *Drogo stalsi* gen. et. sp. n (★) and *Elassocanthon brevipes* Kolbe, 1908 (■) together with the type locality (+) and recent collecting localities (●) for *Byrrhidium namaquense* Scholtz and Howden, 1987 and *B. convexum* Scholtz and Howden, 1987 (▲).

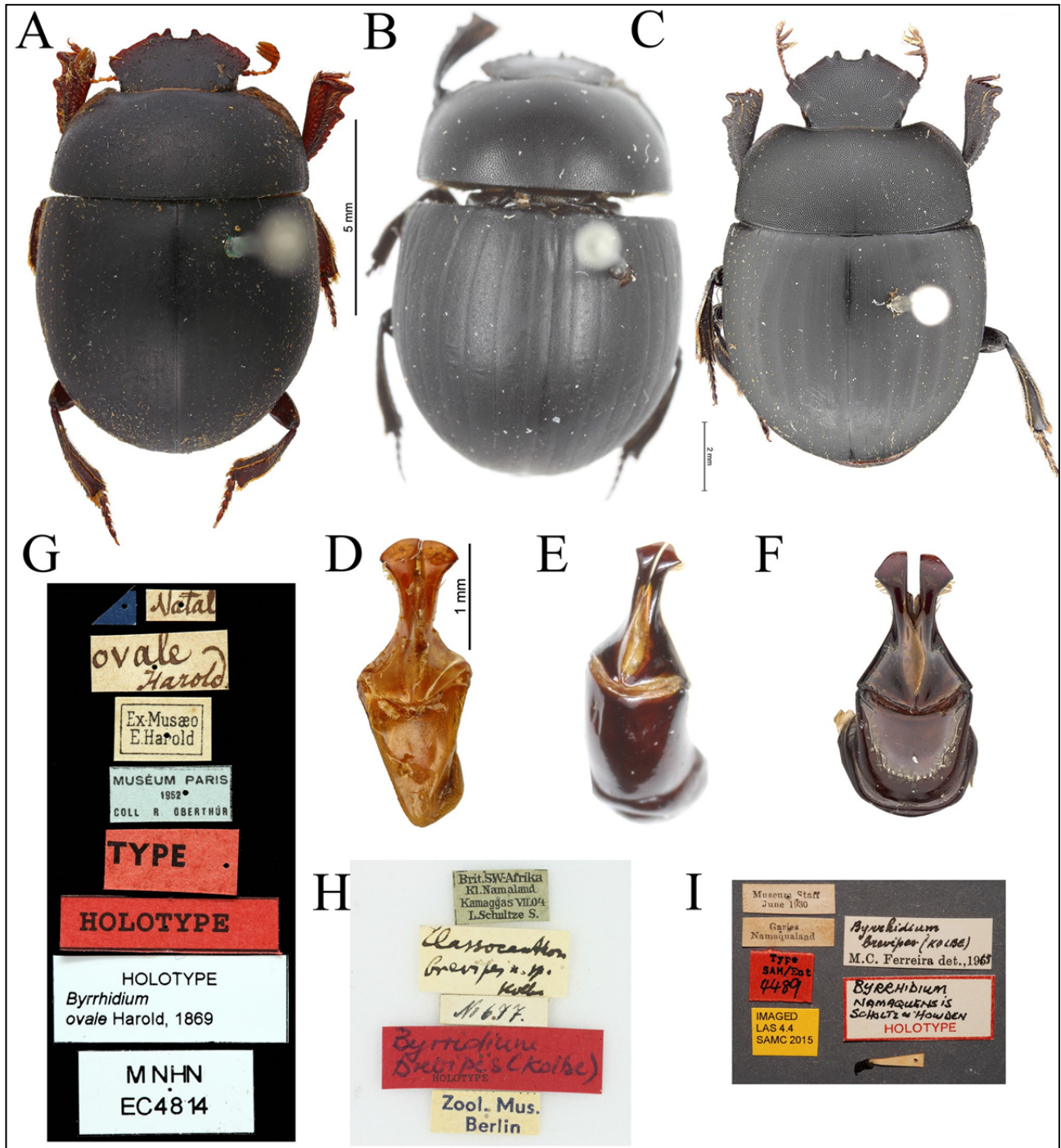


FIGURE 3. Habitus, aedeagus and specimen labels of the holotype specimens of *Byrrhidium ovale* Harold (A, D and G) *Elassocanthon brevipes* Kolbe (B, E and H) (no scale) and *Byrrhidium namaquense* Scholtz and Howden (C, F and I).

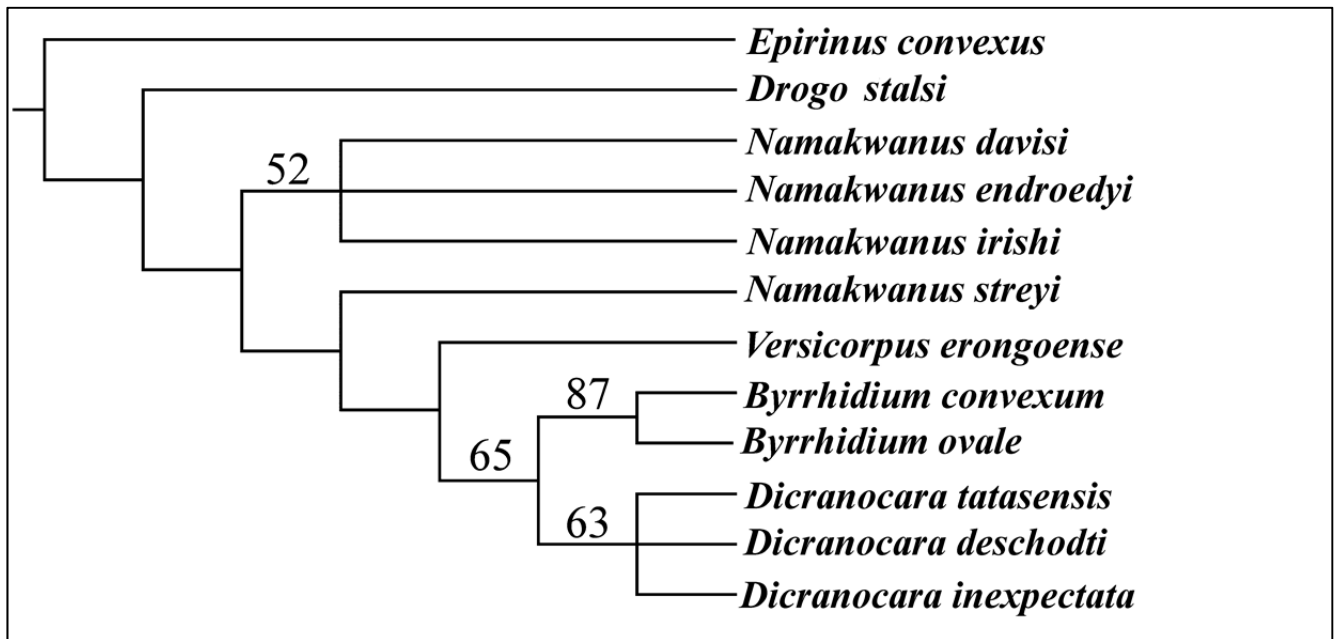


FIGURE 4. Strict consensus tree showing support for the currently recognized genera of the *Byrrhidium* group based on 31 morphological characters. Bootstrap percentages above nodes (percentages lower than 50% not shown) L=66, CI=68, RI=73.

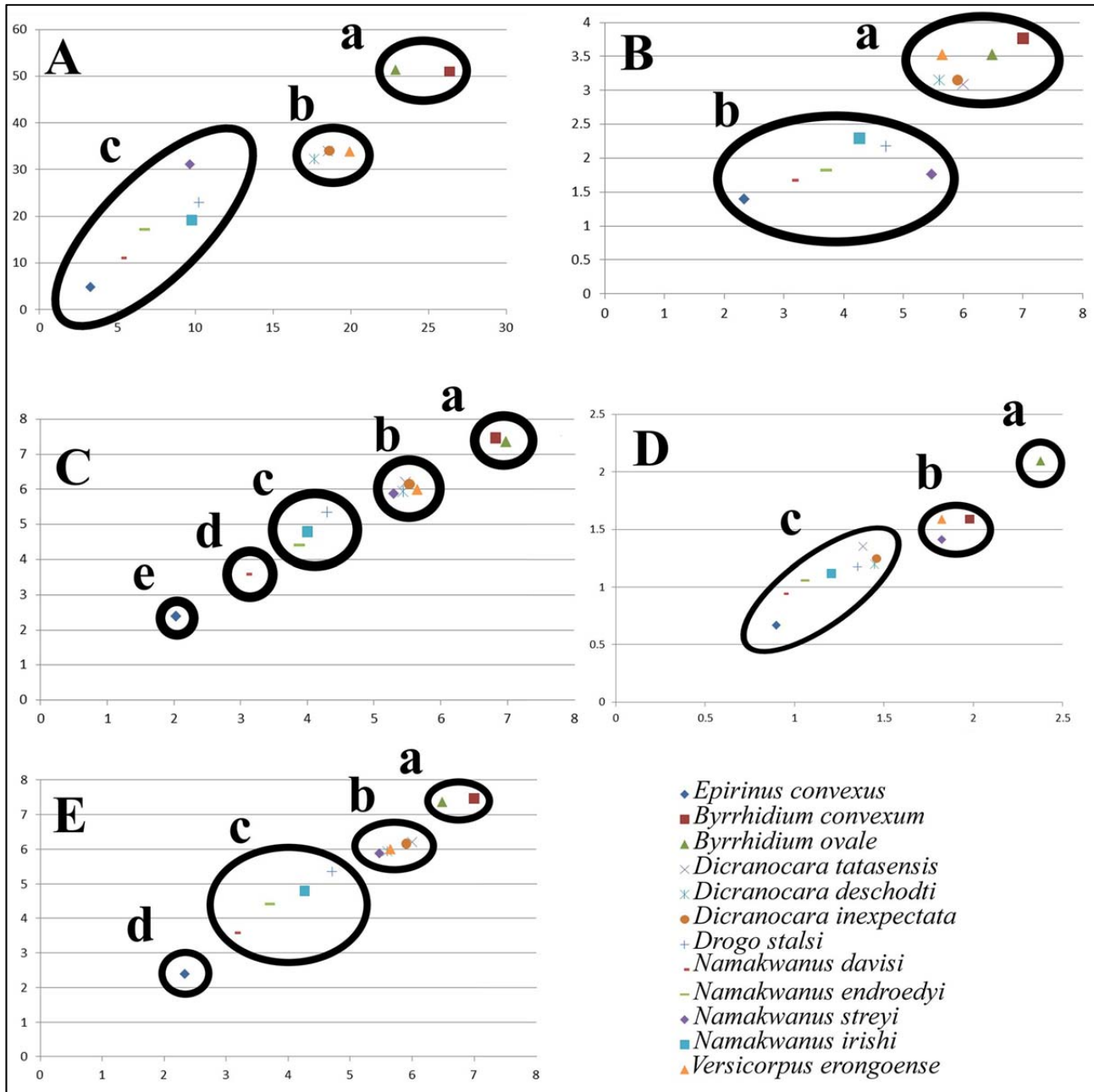


FIGURE 5. Graphs from measurements of characters: (A) pronotum area vs. elytron area, (B) pronotum length vs. pronotum width, (C) elytron length vs. elytron width, (D) mesocoxae distance vs. meso-metacoxa distance and (E) elytron width vs. pronotum width.

Table and appendix

Table 1. Table showing the differences between *Elassocanthon brevipes* and *Byrrhidium namaquense* according to Scholtz and Howden 1987 with characters for *Byrrhidium ovale* included from images of the holotype.

	<i>Byrrhidium ovale</i>	<i>Elassocanthon brevipes</i>	<i>Byrrhidium namaquense</i>	Our remarks made from images of types
	Not seen by Scholtz and Howden	Seen by Scholtz and Howden	Seen by Scholtz and Howden	
Fourth clypeal tooth	Absent	Present	Absent	Absent in all three specimens
Genal margin	Straight	Sinuate	Straight	More or less straight in all
Granules on the elytral interstriae	Absent	Present	Absent	Absent in all three specimens.
All elytral striae	Distinct	Distinct	Only some visible	Relatively distinct in all three specimens
Size of apical piece of each paramere	Slightly smaller than <i>Byrrhidium namaquense</i> type	Smaller [from fig. 15 in Scholtz and Howden 1987]	Larger [from fig. 17 in Scholtz and Howden 1987]	All aedeagi within normal species-group size variation
Locality	Natal [Erroneous]	Kl. Namaland, Ka[o]maggas	Garies Namaqualand	

Appendix 1. Data matrix for all the species of the *Byrrhidium* group and one outgroup species, used in the cladistic analysis (description of characters is included in the text).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
<i>Epirinus convexus</i>	3	2	0	0	4	4	2	3	2	1	0	0	0	0	2	1	0	0	1	2	1	2	2	2	2	1	0	1	1	0	0	
<i>Byrrhidium convexum</i>	0	0	1	1	0	0	0	0	1	0	1	1	1	0	0	0	1	1	0	1	1	1	1	0	1	1	0	0	1	0	1	
<i>Byrrhidium ovale</i>	0	0	1	1	0	0	1	0	1	0	1	1	1	0	0	1	1	0	0	1	0	0	1	0	1	1	0	0	1	0	1	
<i>Dicranocara tatasensis</i>	1	1	1	1	1	1	2	1	0	0	1	0	0	0	1	0	1	1	0	1	1	1	0	1	0	1	1	1	1	0	1	0
<i>Dicranocara deschodti</i>	1	1	1	1	1	1	2	1	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1	0	1	0
<i>Dicranocara inexpectata</i>	1	1	1	1	1	1	2	1	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0	1	1	0	1	0	0	1	0	
<i>Drogo stalsi</i>	2	2	0	0	2	2	2	2	1	0	1	1	1	1	?	2	1	0	1	1	1	1	1	0	1	1	1	0	0	1	1	
<i>Namakwanus davisi</i>	2	2	0	0	3	3	2	2	1	1	0	1	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	0	1	1	0	
<i>Namakwanus endroedyi</i>	2	2	0	0	2	2	2	2	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	0	
<i>Namakwanus streyi</i>	2	2	0	0	1	1	1	1	1	1	0	1	0	0	0	0	1	0	0	1	0	1	1	0	1	1	1	0	1	1	0	
<i>Namakwanus irishi</i>	2	2	0	0	2	2	2	2	0	1	0	1	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	0	1	1	0	
<i>Versicorpus erongoense</i>	1	1	1	1	1	1	1	1	1	1	0	1	0	1	?	?	?	?	0	1	1	1	1	0	0	1	1	0	1	0	0	

Appendix 2. Average of all measurements made. Number of specimens measured are shown after each species name.

	Pronotum width	Pronotum length	Elytron length	Elytron width	Mesocoxae distance	Diagonal meso-to metacoxa distance	Pronotum area	Elytra area	pronotum length + elytron length
<i>Epirinus convexus</i> (5)	2.33	1.40	2.03	2.40	0.90	0.67	3.26	4.86	3.43
<i>Byrrhidium convexum</i> (2)	7.00	3.76	6.82	7.47	1.98	1.59	26.35	50.98	10.59
<i>Byrrhidium ovale</i> (5)	6.48	3.53	6.98	7.36	2.38	2.09	22.88	51.38	10.51
<i>Dicranocara tatasensis</i> (2)	6.00	3.09	5.47	6.21	1.38	1.35	18.53	33.95	8.56
<i>Dicranocara deschodti</i> (5)	5.60	3.15	5.44	5.94	1.45	1.20	17.66	32.29	8.59
<i>Dicranocara inexpectata</i> (5)	5.91	3.15	5.53	6.15	1.46	1.25	18.62	34.02	8.68
<i>Drogo stalsi</i> (1)	4.71	2.18	4.29	5.35	1.35	1.18	10.24	22.99	6.47
<i>Namakwanus davisii</i> (2)	3.15	1.68	3.09	3.59	0.94	0.94	5.28	11.08	4.76
<i>Namakwanus endroedyi</i> (1)	3.71	1.82	3.88	4.41	1.06	1.06	6.76	17.13	5.71
<i>Namakwanus streyi</i> (1)	5.47	1.76	5.29	5.88	1.82	1.41	9.65	31.14	7.06
<i>Namakwanus irishi</i> (2)	4.26	2.29	4.00	4.79	1.21	1.12	9.78	19.18	6.29
<i>Versicorpus erongoense</i> (1)	5.65	3.53	5.65	6.00	1.82	1.59	19.93	33.88	9.18

Chapter 4

Two allopatric synonyms of *Epirinus davis* Scholtz and Howden 1987 (Coleoptera: Scarabaeinae: Canthonini), a forest dung beetle endemic to Kwazulu-Natal, South Africa.

CHRISTIAN M. DESCHODT^{1, 2, 3}, ADRIAN L.V. DAVIS² & CLARKE H. SCHOLTZ²

¹*Department of Zoology and Entomology, Rhodes University, Grahamstown, South Africa*

²*Department of Zoology and Entomology, University of Pretoria, Pretoria, South Africa.*

³*Corresponding author: E-mail: cdeschodt@zoology.up.ac.za*

Abstract

Using comparisons based on DNA sequences and morphology we studied the taxonomic status of three morphologically allied species of *Epirinus* Reiche, 1841 that occupy isolated forest patches in northeast KwaZulu-Natal, South Africa. On the basis of these comparisons we synonymize *Epirinus hlhluwensis* Medina & Scholtz 2005 and *Epirinus ngomae* Medina & Scholtz 2005 with *Epirinus davis* Scholtz & Howden 1987.

Key words: Scarabaeidae, Scarabaeinae, endemic, new synonymies, four gene region sequences, morphological observations, *Epirinus*.

Introduction

The genus *Epirinus* Reiche, 1841 is thought to have radiated from the south western part of Africa (Davis *et al.* 2008). All the species are restricted to cooler habitats within southern Africa, including the winter rainfall shrubland, arid Upper Nama Karoo shrubland, Highveld grassland and forest habitat (Davis *et al.* 2008). Currently the genus consists of 29 described species, 10 of which are flightless.

In the genus *Epirinus*, most of the known flightless species are relict species (Mlambo *et al.* 2011). This group is most often found in undisturbed and mostly disjunct forest patches, which are often very small (Mucina & Rutherford 2006). As isolation within such forest patches has driven many speciation events (see Deschodt and Scholtz 2008 for other examples in Canthonini (referred to as Deltochilini by some authors)) within this tribe and flightless beetles have a higher speciation rate than their flight-capable counterparts (Ikeda *et al.* 2012), it is interesting, although not unknown, to find that some species remain conserved. Examples of forest-restricted species that occur widely are *Epirinus silvestris* (Cambefort,

1978), *Bohepilissus subtilis* (Boheman, 1857), *Gyronotus pumilus* (Boheman, 1857) and *G. carinatus* Felsche, 1911 (all flightless) and *Frankenbergerius armatus armatus* (Boheman, 1857) and *Frankenbergerius armatus tuberculatus* Frolov and Scholtz, 2005 that are presumably weak fliers.

Recently specimens of *Epirinus davisii* Scholtz and Howden, 1987 were collected from Maphelane (S28.408383° E32.420508°) and Nkandla forests (S28.745338° E31.134180°) in Natal. This expanded the area of occurrence for this species, that was previously only known from Dlinza forest (S28.895958° E31.450886°) and Ngoye forest (S28.842743° E31.705159°), significantly. The revised distribution raised our suspicion about the possible synonymy of *Epirinus hluhluwensis* Medina and Scholtz, 2005 and *Epirinus ngomae* Medina and Scholtz, 2005 with the morphologically very similar *E. davisii*. Previous attempts to extract DNA from museum specimens of *E. davisii* failed but the new specimens of *E. davisii* collected from Maphelane (the Nkandla specimens did not produce usable sequences) gave us the opportunity to make molecular comparisons between the three species, *E. hluhluwensis*, *E. ngomae* and *E. davisii*. Using both molecular and morphological results, we conclude that they are synonymous.

Materials and Methods

The sequences used in the present analyses were either selected from those of Mlambo *et al.* (2011) available on GENBANK (see method below) or were new sequences produced using the same protocol. The sequences are from the following gene regions: two from mitochondrial genes, cytochrome c oxidase I (COI) and 16S (16S rRNA), one portion of the nuclear rRNA large subunit 28S (28S rRNA) domain 2 and also the CPSase region of carbamoyl-phosphate synthetase-aspartate transcarbamoylase-dihydroorotase (CAD). The sequences were then aligned and cut to the same length using Clustal (Larkin *et al.* 2007) and thereafter concatenated to form one long sequence using SequenceMatrix (Vaidya *et al.* 2010). The evolutionary history was inferred using the Maximum Likelihood method based on the Tamura-Nei model (Tamura *et al.* 2004). The analysis involved 29 nucleotide sequences. Codon positions included were 1st+2nd+3rd+Noncoding. All positions containing gaps and missing data were eliminated. There were a total of 1414 positions in the final dataset. Evolutionary analyses (Maximum likelihood molecular phylogenetic analysis shown in Figure 2) were conducted in MEGA6 (Tamura *et al.* 2013). Specimens that had less than 80% of the base pairs in the concatenated dataset were deleted from the original data and not used in the final analyses.

The same dataset was used for the estimates of evolutionary divergence over sequence pairs between the groups.

Specimens from the following institutions were morphologically examined.

TMSA: South Africa, Pretoria, Ditsong National Museum of Natural History

UPSA: South Africa, Pretoria, University of Pretoria

Labels are reported verbatim.

Synonymy

Epirinus davisi Scholtz and Howden 1987 Figs 1 and 3

Epirinus hluhluwensis Medina and Scholtz 2005 syn. n.

Epirinus ngomae Medina and Scholtz 2005 syn. n.

Molecular analyses

The weak support in the molecular phylogenetic analysis (Figure 2) for the node between *E. hluhluwensis* and *E. ngomae* collapse to form a polytomy for the *E. davisi* complex (although the different populations are strongly separated) within the Natal Drakensberg and forest group of analysed *Epirinus* species. This polytomy supports the *E. davisi* complex as a single species.

Two sets of observations emerge from the table of evolutionary divergence distances (Table 2). Those between the three Natal Drakensberg and forest group of species are low compared to most other paired comparisons which are mostly greater than 0.1: *E. davisi* and *E. hluhluwensis*, 0.096; *E. davisi* and *E. ngomae*, 0.098; *E. hluhluwensis* and *E. ngomae*, 0.029. The short evolutionary divergence distances, suggesting synonymy, between the clearly morphologically dissimilar species pairs remain unexplained.

Distances between specimens of some other species fall between 0.029 and 0.096 (Table 2). Some of these results may warrant further synonymies whilst some may be anomalous. The species cited as *Epirinus sulcipennis* has been misidentified. It is, in fact, close to *E. striatus* Scholtz & Howden, 1987, which is, in turn, close to *E. obtusus* as reflected by a distance of 0.042. The distances of 0.022 and 0.040 between the morphologically dissimilar *E. flagellatus* and, respectively, the misidentified taxon and *E. obtusus*, seem anomalous. Similarly, the distances of 0.064 and 0.066 between *E. comosus*, the misidentified taxon and *E. obtusus* require further investigation.

Morphological variation

Only minor differences were observed between specimens from all localities (table 1). The most notable difference is seen in the indentation between the clypeal teeth where the base is almost straight in *E. davisi* specimens from Maphelane and rounded in all others. Also some slight variation was observed in the depth of the median depression at the base of the pronotum.

Material visually examined

E. davisi: 1 paratype specimen Z.A. 33 Dhlhiza For. Eshowe Dist., humus, x.1960, Leleup leg. (UPSA), 1 specimen Ngoye forest Ruth Muller 2010/12/04 E-Y:3890 sifting forest litter, (TMSA) 10 specimens, Maphelane, 28°24'30.18"S 32°25'13.83"E, 16-18.x.2011, C. Deschodt. Pig dung baited pitfall traps. (UPSA), 4 specimens, Nkandla Forest Reserve, Inside forest, S28.745338° E31.134180°, 1070m, 10-12.xii.2014, Deschodt and Davis, pig dung baited pitfall traps (UPSA).

E. hlulhluwensis: 4 paratype specimens, S. Afr. Zululand, Hlulhluwe Game Res. 28.05S – 32.04E, 20.11.1992; E–Y: 2837, ground traps with feces bait for 8 days, leg. Endrödy–Younga (UPSA)

E. ngomae: 2 paratype specimens S. Afr. KZN Ngome State Forest 27.49S – 31.25E pitfall trap, indigenous forest 17.11.1992– 6.01.93 1100m, leg. M.v. de Merwe (UPSA), 4 paratype specimens, S.Afr. Zulu Drakensberg Ngome For. Sta. 27.49. S – 31.25E 24.2. 1997; E–Y: 3283, ground traps with faeces bait, leg. Endrödy–Younga. (UPSA).

Distribution

The current combined Extent of Occurrence (EOO) shown in figure 3 is about 8900km². This area size falls well within the EOO of *E. hilaris* (29550km²), *E. silvestris* (1175km²) and *E. convexus* (2300km²) (Davis *et al.* unpublished red data atlas). Published literature on the genus shows that it might be unlikely for more than two different species occupying that same area.

Conclusion

Epirinus davisi, *E. hlulhluwensis* and *E. ngomae* show strong external morphological and molecular similarities within a limited distribution. The differences noted by Medina and Scholtz 2005 in the internal sack of the aedeagus and the difference seen in the indentation of the clypeus observed by us should be interpreted as intraspecific variation. This has led us to the conclusion that *Epirinus hlulhluwensis* Medina and Scholtz 2005 syn. n. and *Epirinus ngomae* Medina and Scholtz 2005 syn. n. are both junior synonyms of *Epirinus davisi*

Scholtz and Howden 1987.

Acknowledgements

Special thanks to Sukoluhle Mlambo for doing the original molecular work. We thank Ezemvelo KZN Wildlife for the permit (No: OP 5434/2014) to collect dung beetles in their forest reserves.

We also wish to gratefully acknowledge the JRS Biodiversity Foundation for funding the project that led to the recognition of the taxonomic issues addressed in this paper.

References

- Boheman, C.H. (1857) *Insecta Caffraria annis 1838-1845 a J.A.Wahlberg collecta amici auxilios sultus descripsit*. Coleoptera Officina Norstedtiana. Holmiae 2:1-395
- Cambefort, Y. (1978) *Canthonina nouveaux ou peu connus d'Afrique continentale*. Journal of the entomological Society of Southern Africa 41(2):199-213
- Davis, A.L.V., Deschodt, C.M. & Scholtz, C.H. in press *Conservation Assessment of Scarabaeine dung beetles in South Africa, Botswana and Namibia: IUCN Red List Categories, Atlas and Ecological Notes* Suricata, South African National Biodiversity Institute, Pretoria
- Davis, A.L.V., Frolov, A.V. & Scholtz, C.H. (2008) *The African Dung Beetle Genera*. Protea Book House, Pretoria, South Africa, 274pp.
- Deschodt, C.M. & Scholtz, C.H. (2008) Systematics of South African forest-endemic dung beetles: new genera and species of small Canthonini (Scarabaeidae: Scarabaeinae). *African Entomology*. 16(1):91-106
- Felsche, C. (1911) Coprophage Scarabaeiden. *Deutsche Entomologische Zeitschrift* 2:133-141
- Frolov A.V. & Scholtz, C.H. (2005) Revision of the southern African genus *Frankenbergerius* Balthasar with description of new taxa (Coleoptera: Scarabaeidae: Scarabaeinae). *Journal of Natural History*, 39(25): 2355-2377
- Ikeda, H., Nishikawa, M. & Sota, T. (2012) Loss of flight promotes beetle diversification. *Nature Communications*, 3, 648.
- Larkin, M.A., Blackshields, G., Brown, N., Chenna, R., McGettigan, P.A., McWilliam, H., Valentin, F., Wallace, I.M., Wilm, A., Lopez, R., Thompson, J.D., Gibson, T.J., & Higgins, D.G. (2007) Clustal W and Clustal X version 2.0. *Bioinformatics* 23:2947–2948

- Medina, C.A., and Scholtz, C.H. (2005) Systematics of the southern African genus *Epirinus* Reiche Coleoptera: Scarabaeinae: Canthonini: descriptions of new species and phylogeny. *Insect Systematics and Evolution* 36(2): 145-160
- Mlambo, S., Sole, C.L., Scholtz, C.H. (2011) Phylogeny of the African ball-rolling dung beetle genus *Epirinus* Reiche (Coleoptera: Scarabaeidae: Scarabaeinae). *Invertebrate Systematics*. 25:197-207
- Mucina, L. & Rutherford, M.C. (Eds.) (2006) *The Vegetation of South Africa, Lesotho and Swaziland*. Strelitzia 19. South African National Biodiversity Institute, Pretoria, 807pp.
- Reiche, L. (1841) Tableau d'une division systématique de la tribu des coprophages, dans la famille des Lamellicornes. *Revue Zoologique*: 211-213.
- Scholtz, C.H. & Howden, H.F. (1987) A revision of the southern African genus *Epirinus*. *Journal of the entomological Society of Southern Africa*. 50:121-154
- Tamura, K., Nei, M., & Kumar, S. (2004). Prospects for inferring very large phylogenies by using the neighbor-joining method. *Proceedings of the National Academy of Sciences (USA)* 101:11030-11035
- Tamura, K., Stecher, G., Peterson, D., Filipski, A., & Kumar S. (2013). MEGA6: Molecular Evolutionary Genetics Analysis version 6.0. *Molecular Biology and Evolution* 30: 2725-2729
- Vaidya, G., Lohman, D.J. & Meier, R (2010) SequenceMatrix: concatenation software for the fast assembly of multigene datasets with character set and codon information. *Cladistics*, 27: 171–180

Figures and tables

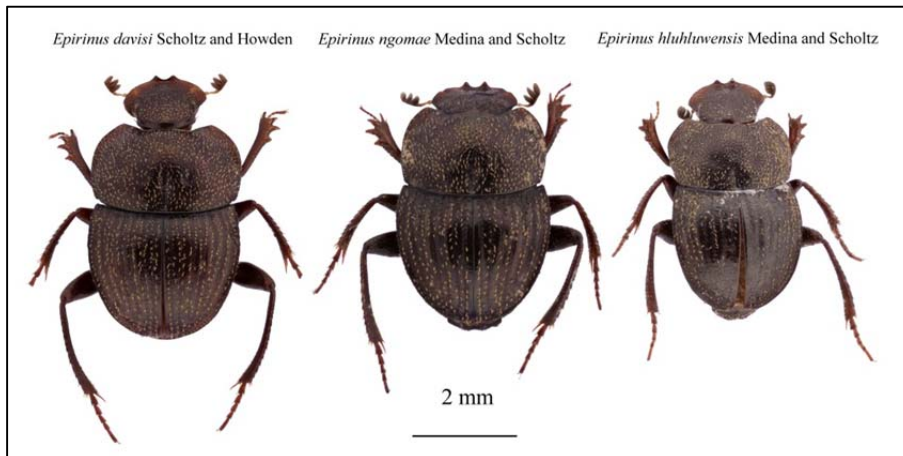


Figure 1. Habitus images for *Epirinus davisii* Scholtz and Howden 1987, *Epirinus hluluwensis* Medina and Scholtz 2005 and *Epirinus ngomae* Medina and Scholtz 2005.

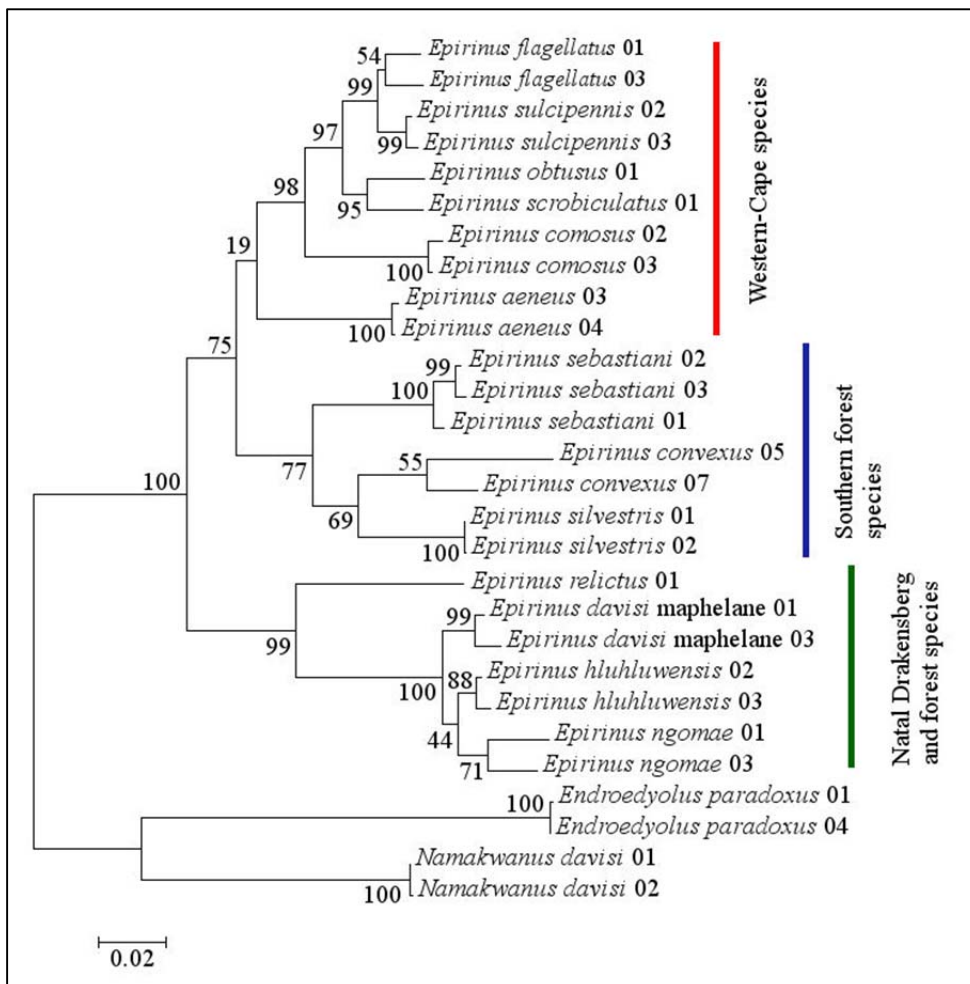


Figure 2. Maximum likelihood molecular phylogenetic analysis.

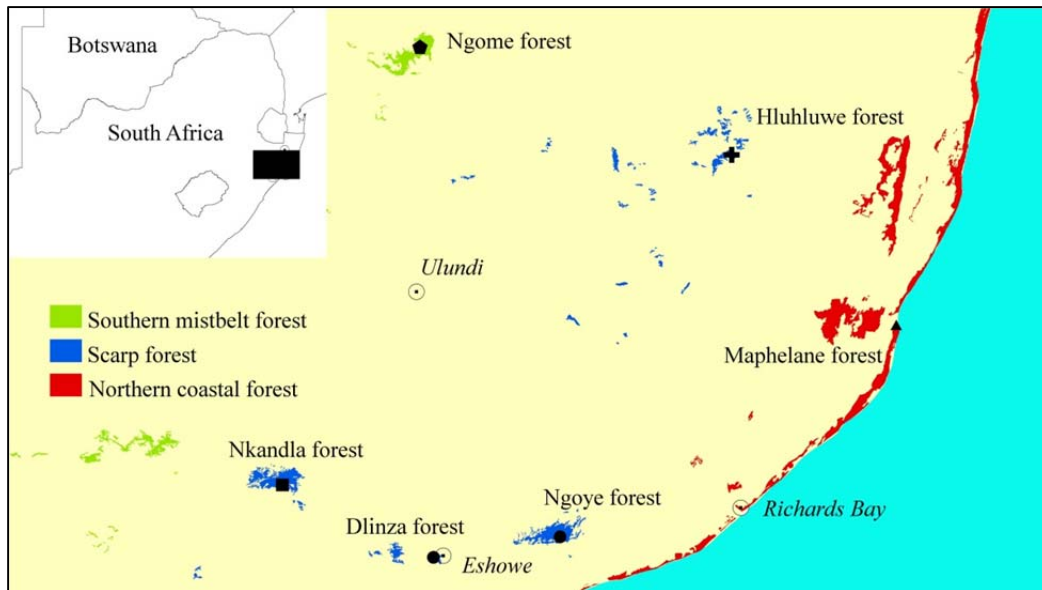


Figure 3. The known distribution of *Epirinus davis* (●) with its synonyms *Epirinus hluhluwensis* (✚) and *Epirinus ngomae* (◆). The new collecting localities for *Epirinus davis* from Nkandla (■) and Maphelane (▲) forests.

Table 1. Table showing the external morphological characters for *E. davisi*, *E. hluluwensis* and *E. ngomae* that Medina and Scholtz 2005 used to separate the three species with comments by the present authors.

		<i>Epirinus davisi</i> Dlinza forest	<i>Epirinus hluluwensis</i> Hluluwe forest	<i>Epirinus ngomae</i> Ngome forest	<i>Epirinus davisi</i> Maphelane forest	<i>Epirinus davisi</i> Nkandla forest
Pronotal lateral foveae	As published by Medina and Scholtz 2005	Absent	Present	Present	Not seen	Not seen
	As seen by current authors	Absent	Absent	Absent	Absent	Absent
Clypeal teeth	As published by Medina and Scholtz 2005	slightly wide indentation	Well developed (bigger), with narrow medial indentation	Smaller with wide indentation	Not seen	Not seen
	As seen by current authors	Well-developed teeth with small indentation, rounded at base	Well-developed teeth with small indentation, rounded at base	Well-developed teeth with small indentation, rounded at base	Well-developed teeth with small indentation, straight at base	Well-developed teeth with small indentation, rounded at base
Pygidium	As published by Medina and Scholtz 2005	One medial tubercle (in cladistic analysis)	One medial tubercle (in text). Two medial tubercles (in cladistic analysis)	Two medial tubercles (in text). One medial tubercle (in cladistic analysis)	Not seen	Not seen
	As seen by current authors	Two medial tubercles	Two medial tubercles	Two medial tubercles	Two medial tubercles	Two medial tubercles

Table 2. Estimates of Evolutionary Divergence over Sequence Pairs between Groups

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	<i>Namakwanus davis</i> Deschodt & Scholtz, 2007														
2	<i>Epirinus sulcipennis</i> Boheman, 1857	0.2549													
3	<i>Epirinus silvestris</i> (Cambefort, 1978)	0.2047	0.1679												
4	<i>Epirinus sebastiani</i> Medina & Scholtz, 2005	0.2502	0.1107	0.1258											
5	<i>Epirinus scrobiculatus</i> Harold, 1880	0.2009	0.1057	0.1013	0.1516										
6	<i>Epirinus relictus</i> Scholtz & Howden, 1987	0.2877	0.1357	0.2113	0.1383	0.1922									
7	<i>Epirinus obtusus</i> Boheman, 1857	0.2694	0.0419	0.1739	0.1151	0.1033	0.1432								
8	<i>Epirinus ngomae</i> Medina & Scholtz, 2005	0.2815	0.1459	0.1977	0.1565	0.1886	0.1279	0.1472							
9	<i>Epirinus davis</i> Scholtz & Howden, 1987	0.2233	0.2124	0.1443	0.1970	0.1387	0.1926	0.2238	0.0977						
10	<i>Epirinus hlhluwensis</i> Medina & Scholtz, 2005	0.2891	0.1416	0.2014	0.1463	0.1962	0.1198	0.1421	0.0293	0.0964					
11	<i>Epirinus flagellatus</i> (Fabricius, 1775)	0.2652	0.0221	0.1772	0.1103	0.1130	0.1352	0.0396	0.1437	0.2225	0.1381				
12	<i>Epirinus convexus</i> Scholtz & Howden, 1987	0.2118	0.1675	0.0736	0.1359	0.1119	0.2130	0.1754	0.2017	0.1552	0.2070	0.1770			
13	<i>Epirinus comosus</i> Péringuey, 1901	0.2336	0.0641	0.1433	0.1119	0.0995	0.1418	0.0659	0.1441	0.1780	0.1399	0.0617	0.1498		
14	<i>Epirinus aeneus</i> (Wiedemann, 1823)	0.1969	0.1448	0.1153	0.1553	0.0961	0.1982	0.1579	0.1994	0.1550	0.2062	0.1555	0.1077	0.1261	
15	<i>Endroedyolus paradoxus</i> Scholtz & Howden, 1987	0.1754	0.2602	0.2117	0.2763	0.2020	0.3018	0.2652	0.2914	0.2306	0.2954	0.2713	0.2153	0.2374	0.2016

Chapter 5

Final Conclusion

The synonymy of *Copris bihamatus* Balthasar, 1965 with *Copris fidius* (Olivier, 1789) has been confirmed. This technique of the distributional function between two body dimensions (lateral horn length and mid-line elytron length) plotted on a two dimensional graph was also used as further support for the erecting of the new species *Copris crassus* Deschodt and Davis, 2015. This technique is a very easy and cheap to apply. However it will only work as in this case where the males in a species are horned (character) and show variation from major to minor (state) character states. In this case females couldn't be used as they do not show the same wide range of character state variation.

Second, my aim with the current Scarabaeinae genus *Scarabaeolus* Balthasar (previously considered a subgenus of *Scarabaeus*) was to use classical taxonomy by comparing the external morphology of different specimens under the dissecting microscope. *Scarabaeus* (*Scarabaeolus*) *vansoni* Ferreira, 1958 was found to be a synonym of *Scarabaeus* (*Scarabaeolus*) *lucidulus* (Boheman, 1860) and *Scarabaeus* (*Scarabaeolus*) *xavieri* Ferreira, 1968 with *Scarabaeus* (*Scarabaeolus*) *andreaei* zur Strassen, 1963. I have also assessed *Scarabaeus* (*Scarabaeolus*) *reichei* Waterhouse, 1890 that was erroneously synonymized with *Scarabaeus* (*Scarabaeolus*) *canaliculatus* Fairmaire, 1888 using pictures of the type. Similarly, by comparing specimens with each other, I recognized several undescribed species and proposed names for them. Although subjective, this commonly used method is very easy to use as images of types from museums across the world can be provided in an instant. Locally available types can also very easily be compared with other specimens.

Third, I found a single and peculiar Scarabaeinae beetle that is housed in the South African National Collection of Insects in Pretoria that fits in the tribe Canthonini. I decided to use statistical methods to support my feeling that it belonged to a new and undescribed genus. I also suspected the synonymy of *Byrrhidium namaquense* Scholtz and Howden, 1987 with *Byrrhidium ovale* Harold, 1869. This method is very tedious and time-consuming. All the specimens have to be examined minutely thus there is always the danger of damage to specimens. Because of the very small distances; accuracy is of the utmost importance. Once all the measurements are complete it can sometimes be difficult to decide what software package to select from the host of currently accepted. Also every program has its own internal settings that must be understood for reliable results.

Last, I suspected the synonymy of *Epirinus hluhluwensis* Medina and Scholtz, 2005 and *Epirinus ngomae* Medina and Scholtz, 2005 with *Epirinus davisii* Scholtz and Howden, 1987. My objective was

to test this synonymy using molecular methods. This conclusion was also confirmed by conventional morphology. Molecular methods reveal what is impossible to see otherwise. Ancient relatedness of very dissimilar morphological appearing species can be proved. Likewise unrelatedness between convergent evolutionary species is just as easily shown. Although this method is expensive it is constantly getting cheaper. Advances in analysing software combined with larger specimen sequence data is undoubtedly making this one of the most supported and widespread methods for future taxonomy.

These are only a few of the methods currently available to the modern taxonomist. Every method has its own advantages above others and there are certainly more methods that will be developed as modern technologies progress.

References

- Balthasar, V. (1965) Eine neue Undergattung und neue Arten der Familie Scarabaeidae (Col). (121. Beitrag zur Kenntnis der Scarabaeoidea). *Acta entomologica bohemoslovaca*, 62 (1), 14–23
- Boheman, C.H. (1860) Coleoptera Caffraria annis 1838–1845 a J. A. Wahlberg collecta. *Öfversigt Kongliga Svenska Vetenskapsakademiens Förhandlingar*, 17 (3), 107–120
- Deschodt, C.M. and Davis, A.L.V. (2015) in Deschodt, C.M., Davis, A.L.V. and Scholtz, C.H. (2015) A new synonymy in the *fidius* group of *Copris* Müller 1764 (Coleoptera: Scarabaeidae: Scarabaeinae) and a new species from the highland grasslands of South Africa. *Zootaxa*. 3949 (3): 431–438 (28 Apr. 2015)
- Ferreira, M.C. (1958) A new species of *Scarabaeus* from South West Africa. *Novos Taxa Entomológico*, 5, 3–4
- Ferreira, M.C. (1968) Contribuicao para o estudo dos Escarabideos de Moçambique. Descrição de uma espécie nova do subgénero *Scarabaeolus* Balthasar. *Novos Taxa Entomológicos*, 58, 3–9
- Ferreira, M.C. (1972) Os escarabideos de Africa (sul do Saara) I. *Revista Entomologia Mocambique*, 11, 1–1088. [1968–1969/ 1972]
- Fairmaire, L.M.H. (1888) Enumération des Coléoptères recueillis par M. le Dr. Hans Schinz dans le Sud de l'Afrique. *Annales de la Société entomologique de France*, 6 (8), 173–202. Harold, 1869
- Medina, C.A. and Scholtz, C.H. (2005) Systematics of the southern African genus *Epirinus* Reiche (Coleoptera: Scarabaeinae: Canthonini: descriptions of new species and phylogeny. *Insect Systematics and Evolution* 36(2): 145-160
- Olivier, A.G. (1789) *Entomologie, ou histoire naturelle des insectes, avec leurs caractères génériques et spécifiques, leur description, leur synonymie, et leur figure enluminée.*

Coléoptères. T. I, N°3 Baudouin, Paris, 190 pp. <http://dx.doi.org/10.5962/bhl.title.49479>

Scholtz, C.H. and Howden, H.F. (1987) A revision of the southern African *Cathonina* [sic]

(Coleoptera: Scarabaeidae: Scarabaeinae). *Journal of the Entomological Society of Southern Africa*, 50, 75–119

Waterhouse, C.O. (1890) New Scarabaeidae in the British Museum. *The Annals and Magazine of natural History, including Zoology, Botany and Geology*, 29, 365–373

Westwood, J.O. (1837) Characters and descriptions of some new coleopterous insects belonging to the family of sacred beetles. *Proceedings of the Zoological Society*, 5, 12–13

Zur Strassen, R. (1963) *Scarabaeus andreaei*, ein neuer Pillendreher aus Mozambique.

Senckenbergiana biologica, 44 (2), 107–110