

New and little known species of the Afrotropical dung beetle genus *Sarophorus* (Coleoptera, Scarabaeidae) and a phylogenetic analysis of the genus

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ABSTRACT

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A new species, *Sarophorus angolensis* sp. n., is described from Angola. New data on the rarely collected species *S. bidentatus* Frolov & Scholtz, *S. carinatus* Frolov & Scholtz, and *S. nitidus* Frolov & Scholtz are given. Phylogenetic relationships of *Sarophorus* species are studied through cladistic analysis.

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INTRODUCTION

The Afrotropical scarabaeine genus *Sarophorus* Erichson was recently revised and consisted of nine known species distributed primarily in South Africa (Frolov & Scholtz 2003). After the revision had been published, I examined additional specimens which were previously unavailable or only collected recently. This material includes a new species from Angola and series of *S. bidentatus* Frolov & Scholtz, *S. carinatus* Frolov & Scholtz, and *S. nitidus* Frolov & Scholtz (all of which were described from single specimens). The new species is described and notes on morphology and distribution of the other species are given.

The material used for the revision of the genus (Frolov & Scholtz 2003) was adequate to describe new species but was inadequate for a thorough phylogenetic analysis of the group because some species were known from only single specimens. With the additional specimens I examined, both sexes of all *Sarophorus* species are now known and a phylogenetic analysis is performed.

Aedeagi were prepared using common technique, air-dried and photographed. The internal sacs were mounted on a slide and photographed in glycerol. Within the species treatments, additional information and comments on the label data are given in square brackets. Most of the characters mentioned in the phylogenetic analysis section are illustrated in Frolov and Scholtz (2003).

SYSTEMATICS

Sarophorus angolensis new species

Figures 1-3, 8

Type material *Holotype*: ♂: ANGOLA, "Tchivinguire Huila [15°10'S 13°21'E], SE 1513 Ab", 14-17.XI.1974 (NMW H22368). *Paratypes*: 6♂ 12♀: same data as holotype.

Description *Holotype* (Fig. 1). Upper side of body densely punctate, feebly shagreened, blackish brown, elytra slightly paler. Body length 8.1 mm, width 4.6 mm.

Head Anterior margin of clypeus sinuate medially, obtusely rounded laterally, very finely bordered. Genae obtuse, faintly separated from anterior clypeal margin. Frontoclypeal and genal sutures indistinct. Dorsal surface regularly, coarsely punctate with adjoining punctures becoming larger laterally. *Pronotum* Surface coarsely punctate with adjoining punctures without smooth areas or tubercles. Punctures rounded on disc becoming elongated laterally. *Elytra* Striae 1-9 distinct, punctate, with margins not carinate. Stria 10 visible only in the middle of elytron and adjacent to epipleuron. Elytral intervals densely punctate and shagreened, flat on disc. Interval 9 convex in the anterior 2/3, intervals 5-8 convex apically. *Wings* fully developed. *Underside* Base of propleura with deep concavities for apices of retracted middle femora. Disc of pygidium densely, regularly punctate with adjoining punctures. Abdominal and prothoracic sternites coarsely and almost regularly punctate. Disc of metasternum concave. *Legs* Spurs of anterior tibiae short, slightly curved downwards.

Apices of middle and posterior tibiae with relatively sparse, unequal setae. *Aedeagus* Parameres with strongly sclerotized, acute apices (Fig. 3). Internal sac with sub-symmetrically located spinules, lacking larger sclerites (Fig. 8).

Paratypes. Body length varies between 6.6-8.0 mm, width between 3.8-4.3 mm. Setae on the body surface are abraded to a different degree in some individuals, otherwise variation among specimens is slight. Female (Fig. 2) differs from male in having smooth and shiny, angulate anterior part of clypeus with less distinct punctuation, and longer, somewhat acute spur of anterior tibiae.

Diagnosis This species belongs to the group *costatus* and can be separated from other species of the group by the pronotum with elongated punctures but without smooth areas, elytra with densely punctate and shagreened intervals, and by the shape of the parameres. From the South African species (*S. costatus* (Fåhraeus in Boheman), *S. striatus* Frolov & Scholtz, and *S. latus* Frolov & Scholtz) it also differs in having sparsely setose apices of the middle and posterior tibiae in both sexes.

Remark The examined material had apparently been partly decomposed and the beetles had fallen apart before they were pinned. In all specimens, the head and the pronotum are glued to the remaining part of the body and some specimens have anterior and posterior parts from individuals that differ considerably in size. One dissected specimen proved to be comprised of a male anterior part and a female posterior part. There is, however, no doubt that the specimens are conspecific.

Sarophorus carinatus Frolov & Scholtz, 2003

Figures 4, 5, 7

This species was described from one female from Ohrigstad (South Africa, Mpumalanga Province). Additional material examined includes 8 specimens (5 males and 3 females) from Goedehoop Farm, 15 km west of Lochiel, 26°10'S 30°38'E, altitude 1400 m, 28.XI.2002, R. Stals leg. (deposited in the National Collection of Insects, Plant Protection Research Institute, Pretoria). This locality is some 110 km south of the type locality of the species. The beetles were collected in grassland under trees and shrubs on a rocky outcrop. They were found in the top 3 mm layer of moist sandy soil under leaf litter. They were not attracted to a pitfall trap baited with cattle dung set up approximately 10 meters away (Riaan Stals, pers. comm.).

The specimens examined are similar to the holotype except that the keels on the elytral intervals 3 and 5

are not interrupted on the disc (Fig. 4). Males have the anterior part of clypeus densely punctate as opposed to being smooth to sparsely punctate in females. Apices of the middle tibiae are somewhat triangular in males and narrow in females. There is no noticeable difference in the shape of apical spur of anterior tibiae between sexes.

Parameres are similar to those of *S. punctatus* Frolov & Scholtz with flat and wide, strongly sclerotized apices (Fig. 5). Internal sac of the aedeagus is without armature (Fig. 7).

Body length of the beetles varies from 6.0 mm to 6.5 mm in males and from 5.0 mm to 6.4 mm in females; width from 3.0 mm to 3.2 mm and from 2.7 mm to 3.4 mm respectively. The smallest exemplar from this series (female with body length 5.0 mm and width 2.7 mm) is the smallest *Sarophorus* specimen known to me.

Sarophorus bidentatus Frolov & Scholtz, 2003

Figure 6

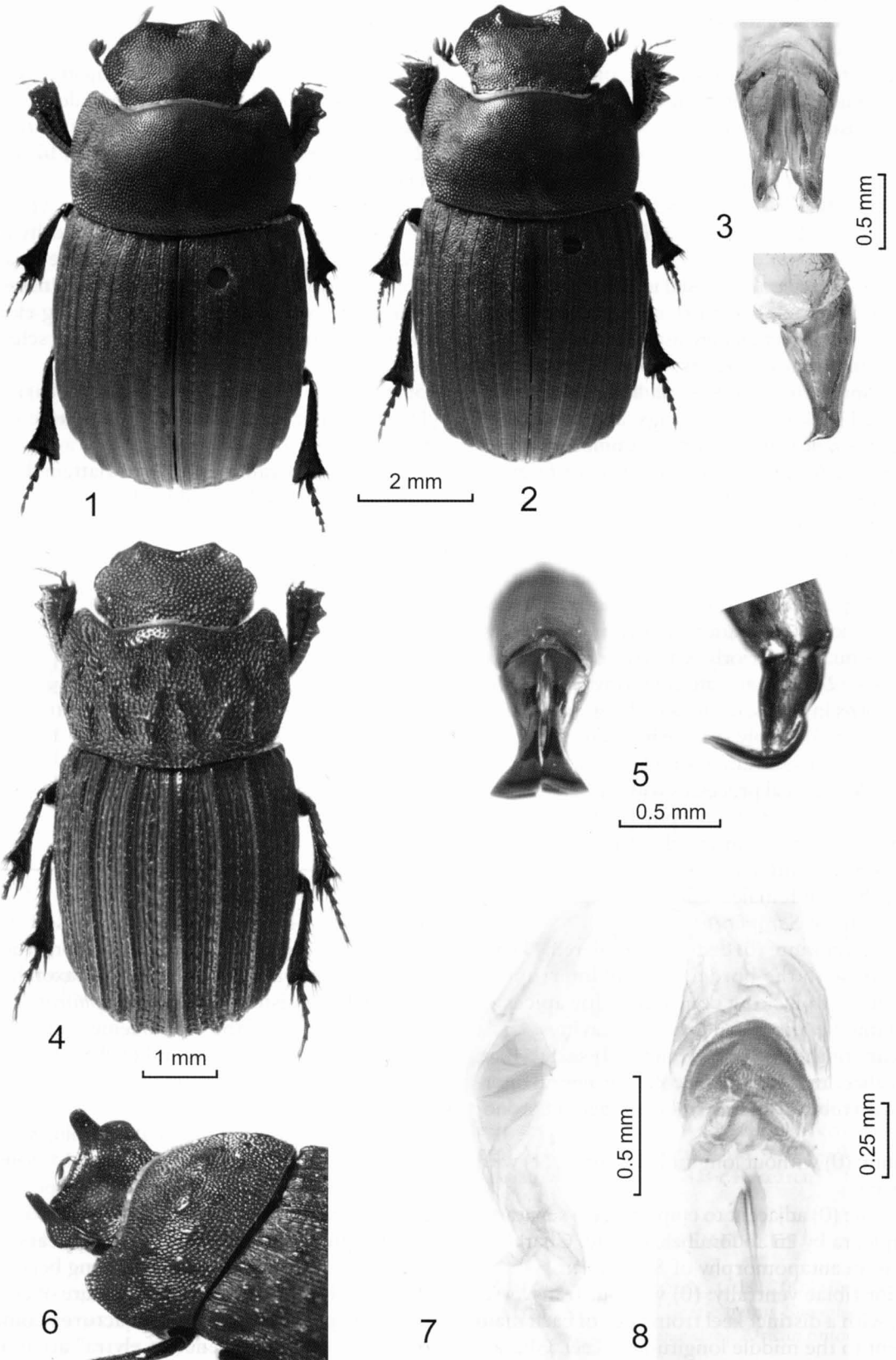
The species was described from one male specimen from Kamieskroon (central Namaqualand, South Africa). Since the original description was published, additional specimens (6 males and 8 females) with the labels "Cap bon Esp [Cape of Good Hope]" were found in the Muséum National d'Histoire Naturelle, Paris.

The peculiar shape of clypeus and the presence of an apical patch of setae on the middle tibiae are sexually dimorphic characters in this species. Females of *S. bidentatus* lack these characters and are similar to females of *S. tuberculatus*. The females of *S. bidentatus* can be distinguished from *S. tuberculatus* females by the absence of propleural fossae in the former species. Most specimens are larger than the holotype and males possess longer clypeal horns (Fig. 6). Body length varies from 7.2 mm to 8.1 mm in males and from 7.0 mm to 8.5 mm in females; width from 3.9 mm to 4.5 mm and from 3.8 mm to 4.5 mm respectively.

The distribution range of this species is still largely unknown since the newly discovered specimens do not have exact locality labels. I was unable to sample this species from vicinity of Kamieskroon in March and September 2003.

Sarophorus nitidus Frolov & Scholtz, 2003

Additional material examined: KENYA: 3 ♂: Kenya, Kiambu [1°10'S 36°50'E], Kikuyu Escarpment, altitude 2000 m, 3.XI.1977, Perret leg. (Muséum d'Histoire Naturelle, Genève); 3 ♂: British



Figs 1-8. 1-3. *Sarophorus angolensis*, sp. n. 1, habitus of male; 2, habitus of female; 3, parameres in dorsal and lateral view; 4-5. *Sarophorus carinatus* Frolov & Scholtz, 4, habitus of male; 5, parameres in dorsal and lateral view; 6, *S. bidentatus* Frolov & Scholtz, head and pronotum of male; *Sarophorus carinatus* Frolov & Scholtz, 7, internal sac of aedeagus; 8, *Sarophorus angolensis*, sp. n. – internal sac of aedeagus.

eastern Africa, Escarpment, IX.1900-IV.1901, W.Doherty (Natural History Museum, London).

These specimens are very similar to the type specimens except for having denser setae on middle tibiae apices. The sparse setae on the holotype tibiae might be a result of abrasion.

PHYLOGENETIC ANALYSIS OF THE GENUS *SAROPHORUS*

Characters The characters used in this phylogenetic analysis are all based on the external morphology of adults. In all, 15 characters were used including 13 two-state and 3 multistate characters. Of the 16 characters, 12 are parsimony informative and 4 are autapomorphic (Table 1). Mouthparts, wings, and sclerotized parts of the female genitalia were examined in a number of specimens of each species but no differences were found that could be used as reliable characters. Characters used are as follows:

1. Clypeus. Shape of the clypeus is diverse and often species-specific. However, four types can be recognized: (0) clypeus feebly sinuate anteriorly, rounded to obtuse at sides of sinuation, similar in both sexes, (1) deeply sinuate anteriorly with two dents, similar in both sexes, (2) feebly sinuate anteriorly with 2 short rounded horns in males; horns with long sparse setae on dorsal side, (3) deeply sinuate in middle, angulate to dentate at sides in females and with long, acute horns in males; clypeal processes without setae. Character state (2) is an autapomorphy for *S. bidentatus*.
2. Sculpture of clypeus anteriorly: (0) densely punctate to rugose, similar in both sexes, (1) sparsely punctate, shiny in females. Character state (1) is an autapomorphy of *Sarophorus*.
3. Sides of pronotum: (0) distinctly bordered, (1) not bordered or with the border broadly interrupted.
4. Propleura: (0) lacking concavities for apices of retracted middle femora, (1) with concavities.
5. Sculpture of the body upper side: (0) surface flat, without tubercles, (1) with tubercles on elytral intervals, (2) with tubercles on elytral intervals and pronotum.
6. Pygidium: (0) without longitudinal carina, (1) with short carina.
7. Metacoxae: (0) adjacent to epipleura, (1) separated from epipleura by an abdominal sternite. Character state (1) is an autapomorphy of *Sarophorus*.
8. Anterior tibiae ventrally: (0) without transversal keels, (1) with a distinct keel from apex of each main lateral dent to the middle longitudinal keel. Character state (1) is an autapomorphy of *Sarophorus*.
9. Apical setation of middle tibia: (0) with setae relatively sparse in both sexes, (1) with setae dense in males.

10. Apices of middle tibia in males: (0) without a patch of setae, (1) with a patch of setae. Character state (1) is an autapomorphy for *S. bidentatus*

11. Apices of middle tibiae: (0) elongated oval, similar in both sexes, (1) triangular in males. Character state (1) is an autapomorphy of *S. carinatus*.

12. Apical spur of anterior tibia: (0) bifurcate in males; (1) not bifurcate in both sexes.

13. Internal sac of aedeagus: (0) with asymmetrical sclerites; (1) with small, subsymmetrically distributed spinules; (2) with larger subsymmetrically distributed spinules; (3) lacking distinct spinules.

14. Internal sac of aedeagus: (0) lacking elongated sclerotized areas, (1) with 2 elongated sclerotized areas.

15. Parameres proximally in lateral view: (0) rounded, (1) with small sinuation. Character state (1) is an autapomorphy of *S. bidentatus*.

16. Apices of parameres: (0) not flattened, (1) flattened and more or less widened.

Table 1

<i>F. opacus</i>	10001	10000	00000	0
<i>F. barratti</i>	30000	00000	00000	0
<i>S. bidentatus</i>	21002	11101	01001	0
<i>S. carinatus</i>	01012	11100	11300	1
<i>S. punctatus</i>	01012	11100	01300	1
<i>S. tuberculatus</i>	01012	11100	01300	0
<i>S. cicatricosus</i>	01010	01100	01100	1
<i>S. nitidus</i>	01110	01110	01210	1
<i>S. striatus</i>	01010	01110	01110	1
<i>S. latus</i>	01010	01110	01110	1
<i>S. costatus</i>	01110	01110	01210	1
<i>S. angolensis</i>	01010	01100	01110	1

Outgroup The outgroup comparison method implies that the sister group to a taxon studied be preferably used as the outgroup. No taxon has been proposed as a sister group to *Sarophorus*. The only cladistic analysis of the scarabaeine which includes the genus is that of Montreuil (1998). He hypothesized that *Sarophorus* is a member of a clade which also includes genera *Demarziella* Balthasar, *Pedaria* Laporte de Castelnau, *Pedaridium* Harold, *Aphengium* Harold, *Bdelelyropsis* Pereira, Vulcano et Martinez, and *Bdelelyrus* Harold. These genera were grouped together merely because they share one homoplastic character, the pubescent elytra, which appears also in *Pseudopedaria* Felsche. However, dung beetles show a great deal of variation in the sculpture of elytra and it is most probable that the structures commonly referred to as "pubescence of elytra" are not really homologous in different taxa. Thus the groups resulting from using the use of this character as a two-state character ("elytra pubescent" vs "elytra not pubescent") are not reliable.

Our research (Frolov & Scholtz, in prep.) shows that the genus *Frankenbergerius* Balthasar or the lineage *Frankenbergerius* + (*Coptorhina* Hope + *Delopleurus* Erichson) should be considered putative sister groups to *Sarophorus*. These taxa share a number of congruent, non-homoplastic characters. Therefore, two *Frankenbergerius* species representing the more basal and the more advanced lineages (Frolov & Scholtz, in press) are included as the outgroup.

Parsimony analysis An exhaustive search was performed in PAUP (Swofford, 1998) and yielded one most parsimonious tree (Fig. 9) with length of 17 steps (4 parsimony uninformative characters were excluded from the analysis but placed on the resulting tree), consistency index 0.88 and retention index 0.93. Because of the relatively small number of the characters involved I did not consider bootstrap or Bremer support values.

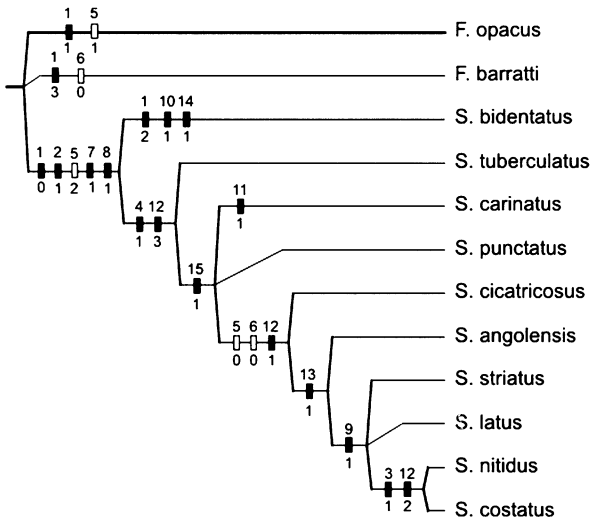


Fig. 9. The most parsimonious tree of *Sarophorus* species resulting from the analysis.

DISCUSSION

Monophyly of the genus *Sarophorus* is supported by 3 synapomorphies: metacoxae separated from epipleura by an abdominal sternite; clypeus densely punctate in males and sparsely punctate, shiny in females; and anterior tibiae with transversal keels ventrally.

S. bidentatus appears to be the sister group to all the other *Sarophorus* species as it retained two plesiomorphic character states but also possess some autapomorphies. In the revision of the genus (Frolov, Scholtz, 2003) we provisionally placed this species in the group *tuberculatus* on the ground of the similar sculpture of elytra and pronotum. This analysis sug-

gests, however, that the three other species of the group (*S. tuberculatus*, *S. punctatus*, and *S. carinatus*) are more closely related to the species group *costatus* than to *S. bidentatus*. Therefore, I propose to consider the later species in a separate monotypic species group with the following diagnosis: internal sac of aedeagus armed with asymmetrical sclerites, and propleura without concavities for apices of retracted middle femora.

It can be noted that genera in the Scarabaeinae, especially those in the tribes Onthophagini and Onitini, are commonly established on the ground of much smaller differences than those found between *S. bidentatus* and other *Sarophorus* species. The new data, i.e. examination of the immature stages and nesting behaviour, may necessitate changes in the nomenclature with elevation of the rank of the group *bidentatus*.

The species group *tuberculatus* appears to be paraphyletic and *S. tuberculatus* is a sister group to other species because it retained the plesiomorphic character state – apices of the parameres not flattened or widened.

On the cladogram, two nodes in the ingroup are unresolved. I did not attempt to resolve these nodes by introducing the species' diagnostic characters because the characters, although distinct, are the minor differences in the body sculpture and the shape of the parameres and therefore they are not reliable enough for phylogenetic reconstructions.

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