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Dung Beetles (Scarabaeidae: Scarabaeinae, Aphodiinae) of Selous Game Reserve, Tanzania

Trond Trovåg

Tropical Ecology (Ecology)

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Master thesis

Trond Trovåg

Department of Ecology and Natural Resource Management
Norwegian University of Life Sciences
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Abstract

Dung Beetles (Scarabaeinae, Scarabaeidae) are important participants in binding huge amounts of carbon. In Africa these Beetles have been specializing for millions of years, since there have been no "Ice-ages". Today, much of Africa's fertile lands is being "developed" or exploited ether by the local population or foreign investors. As a result, only fragments of the habitats are pristine.

Selous Game Reserve in Tanzania is one of the very few places where habitats and wildlife populations are relatively intact, because of strict protection of the reserve by a high number of armed rangers. In the work with this thesis I have looked in to the number of species of dung beetles present in dung from different species of plant-consuming large mammals present in the reserve. Moreover I have compared the different species of dung beetles utilizing the dung in different habitats in Selous Game Reserve. The finding is an astonishing number of species, 105 in all (including 3 species of Aphodiinae, Scarabaeidae). The species were grouped as morphospecies based on their external morphology. Probably many of the species have not yet been described by science. The species of dung beetles were found to be highly specialized on dung of different mammal dung producers. Also, there was very little overlap between habitat types by the different species of dung beetles. This emphasizes the importance of protection of both Mammal species and habitats for preserving biodiversity of dung beetles.

1. Introduction

Africa south of Sahara is, together with the Amazon basin in South America, one of the very few places on the planet where no Ice-age/ colder periods has driven mass-extinctions during the last few million years. During this very long time span, the specialization of species driven by high competition has resulted in an incredible wildlife from the huge Mammals such as Elephants and Buffalos down to the smallest Dikdiks. The high numbers of Mammals for millions of years has probably in part shaped the landscape.

Africa is now transforming very rapidly, due to very high Human population increase and large international interest for developing the African countries. This is also a fact in Tanzania. It is a high risk that large areas of wilderness will disappear or at least be exploited and thereby be transformed.

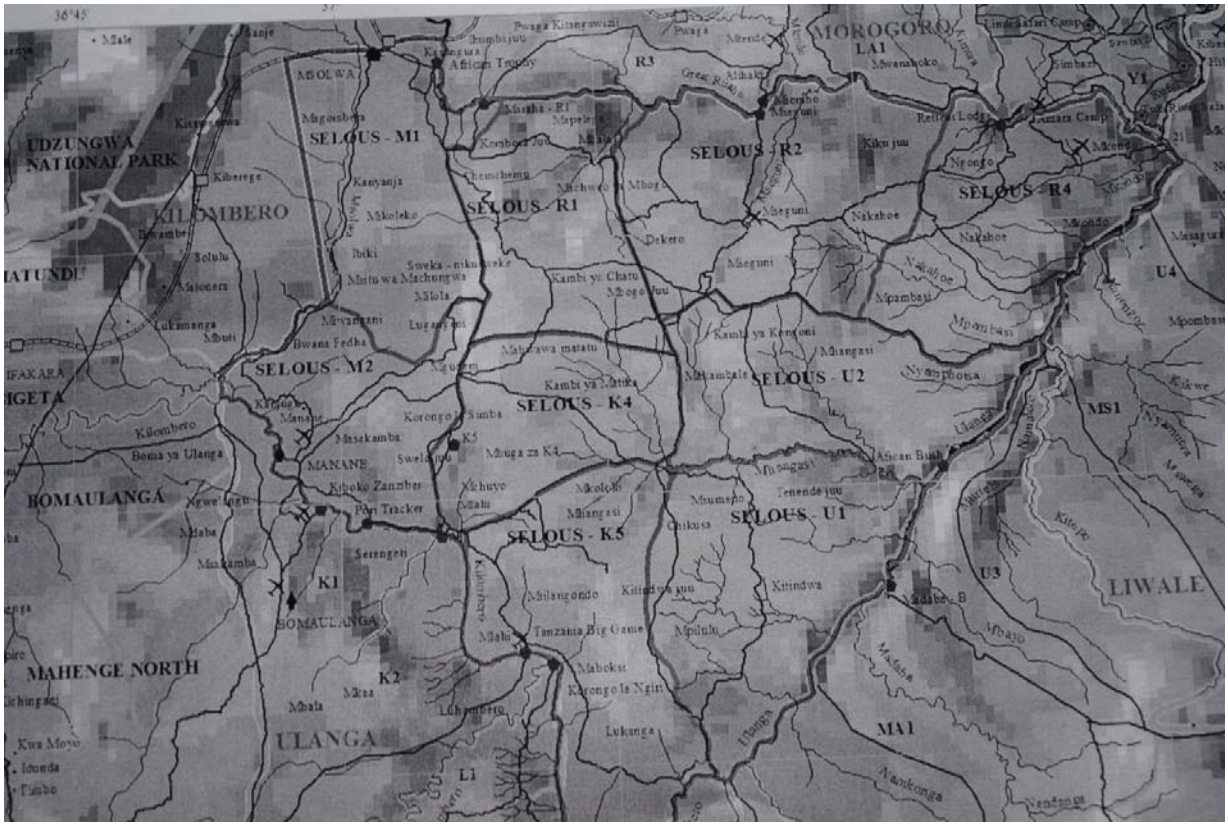
One of the groups that probably is very important in binding carbon to the soil, and thereby fertilize the land is the dung beetles (Scarabaeinae, Scarabaeidae). In Africa we find the largest number of Mammal herbivores in the world. However, because of poaching and habitat loss populations of these herbivores are becoming increasingly smaller during the last century. Particularly during the last few decades, many herbivore populations have decreased rapidly. The dung beetles play an important role in degrading the dung produced by the Mammals. I wanted to study how restricted the dung beetle species were to different dung producers and to different habitats in an undisturbed environment. For this purpose I therefor studied dung beetles in Selous Game Reserve (SGR). In this reserve both habitats and the population of large mammals is still more or less pristine and untouched, because the public is prohibited from entering.

Crossing a channel. The armed guards let me go first to check for Crocodiles. Photo Fred Midtgaard

2. Material and Methods

2.1. Study area

The Selous Game Reserve (SGR) is situated in the East African coast in Tanzania, Morogoro, Lindi, Mtwara and Ruvuma Regions, all in the south of the country at South 9^0 0' 0" and East 37^0 23' 60". With its 54600 km^2 and has additional buffer zones, it is one of the largest undisturbed wilderness areas in Africa, that is free of human settlement, domesticated grazing animals or cultivation. It is located within a wider ecosystem of adjoining protected areas and community Wildlife Management Areas allowing free movement of Elephants and other large herbivores over an area of some 90,000 km^2, with further connectivity to the Niassa Game Reserve (42,000 km^2) in northern Mozambique. Adjoining protected areas Mikumi National Park and Kilombero Wildlife Management Area in the west. Udzungwa Mountains National Park is also just west of Selous GR. The size and complexity of this extensive protected area ensures high diversity of Mammals and large populations.



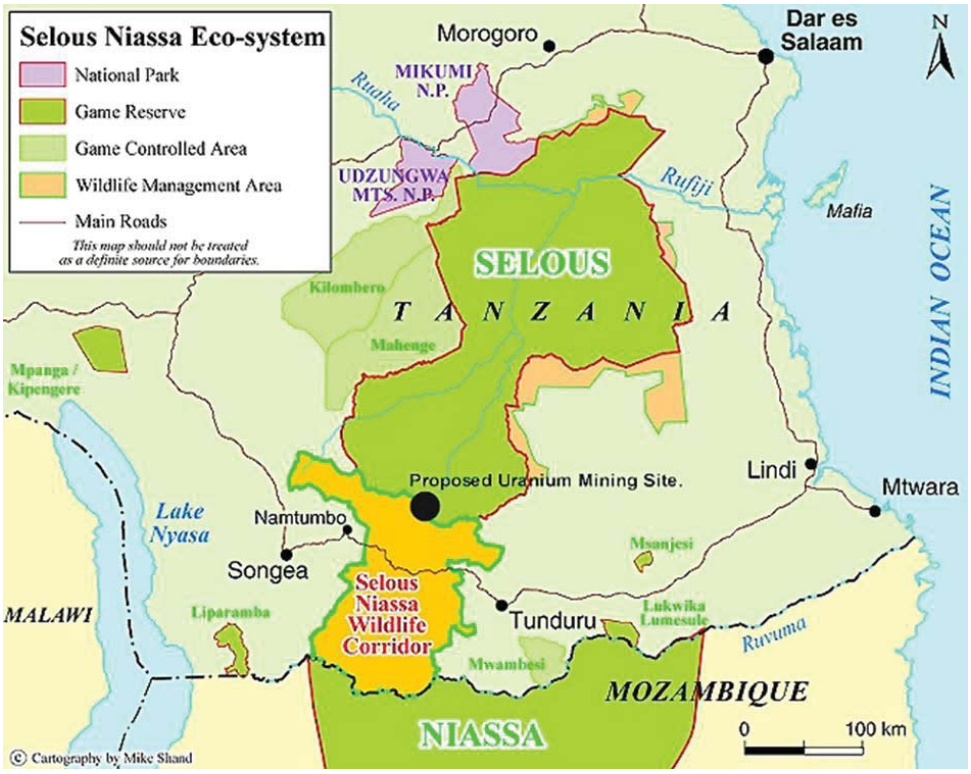
Map of North Western Selous Game Reserve. Photo: Trond Trovåg

The park has a variety of habitats such as miombo forest, grassy woodlands and savanna, as well as seasonally flooded swamp forests, *Acacia* woodland and riverine forest (Lillesøe et al., 2014). The Rufiji and Ruaha Rivers run through the northern part of SGR. Several minor rivers crisscross the park forming a network of lakes, marsh land and swamp forests. Most of the park ranges from 400-600 m. a. s. l., but some areas are as low as 80 m. a. s. l. and mountain peaks may reach 1,300 m. a. s. l.).

The Rufiji river. Photo: Trond Trovåg

Because SGR is a game reserve hunting is allowed in the southern, central and western parts, while the northern-eastern sector is reserved for photo safaris. The reserve is still rarely visited, and the trophy hunting harvest less than 10% of populations and have none or close to no negative impact on wildlife populations (Caro et al., 1998).

The park is named after the English hunter and explorer Frederick Selous (1851-1917). It was first designated as a protected area in 1896 by the German Governor Hermann von Wissmann and became a game reserve in 1905 (Wikipedia).



Map of Selous Game Reserve

Source: http://safaritalk.net/topic/7037-dr-rolf-d-baldus-selous-game-reserve-tanzania/

The Ranger headquarter at Msole. Photo: Trond Trovåg.

SGR is closed for the public and is administrated by The Ministry of Natural Resources and Tourism. There is a sector head quarter in each of the sectors of the reserve. In the North-West sector, where the current study was done, the head quarter is in Msole at the entrance road from Kilombero. To enter the sector, and to do research here, a permit was given by the ministry. A 4x4 land cruiser was rented from Sokoine University of Agriculture. A certified game driver was hired to drive the vehicle, which is mandatory. It is also required to hire an armed game warden to follow on the whole sampling while in SGR. In order to sample on different localities on the flood plain, a small boat was hired with a boat man.

A Landcrusier with a certified game driver was hired from Sokoine Universety. Photo Trond Trovåg

THE UNITED REPUBLIC OF TANZANIA

MINISTRY OF NATURAL RESOURCES AND TOURISM

MALIASILI DAR ES SALAAM
PHONE: +255-2123688, 255 22 2866408, 2868376
Telex: 42741 MALIASILI
Fax: +255-2123688
Email: dw@mnrt.go.tz
Email: ps@mnrt.go.tz

Mpingo House
40 Julius Nyerere Road
15472- DAR ES SALAAM.

Ref. HA.403/583/01/83

24/10/2014

Director,
Research and Postgraduate Studies,
Sokoine University of Agriculture,
P.O. Box 3151,
MOROGORO.

RE: **PERMIT TO ENTER AND CONDUCT NON-DESTRUCTIVE RESEARCH IN SELOUS GAME RESERVE**

Free entry permit into Selous Game Reserve (North West and Southern Sectors) for Prof. Seif Madoffe of Sokoine University of Agriculture; Prof. Fred Midtgaard and Mr. Trond Trovag from University of life Sciences, Norway has been granted to conduct wildlife research titled "Carbon an nutrient circulation from animal dung".

This entry and research permit will be used in three phases, notably; **24th October, 2014 to 5th November, 2014**; **1st August, 2015 to 30th September, 2015** and **1st - 30th November, 2015.**

Before the exercise, the team should report to the Management of Selous Game Reserve for notification and any necessary assistance. Likewise compliance with Wildlife Conservation Act, No. 5 of 2009 is crucial.

Best regards.

Alex Choya
For: **DIRECTOR OF WILDLIFE**

Copy:
1. Manager,
   Selous Game Reserve
2. Prof. Seif Madoffe
   Sokoine University of Agriculture

A very happy professor who finally got the research permit after 16 months of application process. Photo Trond Trovåg

To be able to conduct the study of dung beetles we had to drive between 180 to 350 km a day on very simple roads or tracks in order to get to different habitat types. The sampling itself was conducted on foot. We stayed in a tent overnight for the duration of the sampling period.

Sampling were undertaken in pristine miombo forest, dry savanna, riverine forest and on floodplains.

The roads of Selous. Photo: Trond Trovåg.

As a result of the huge effort to get permit and difficulty in getting acces to the park, as well as formidable costs for getting permit, hiring of staff, accomoidations, supplies and transport, it was aboslutely crusial to limit the numer of days in field to an absolutely minimum in order to make this possible economically.

Tetse flies were constantly a challenge. Photo: Trond Trovåg

2.2. Study species

Dung beetles (Scarabaeinae, Scarabaeidae) are the most numerous dung feeders in Africa. There are 2120 species in 101 genera in Africa (Scholtz et al., 2009).

We divide dung beetles in to three functional groups (Scholtz et al., 2009):

1. Tunnellers:

This group of dung beetles makes a dung-ball and burrows a tunnel down in the soil where they bring the dung ball to the bottom of the tunnel. Here the dung ball is left in a chamber with one or a few egg in it and this will result in a new generation of dung beetles.

Tunnels made by Dung Beetles under a pile of Elephant dung. Photo: Trond Trovåg

2. Rollers:

This group of dung beetles rolls off with a dung part, or a dung ball, depending on the type of dung. Then the Beetle hide the dung, lay an egg or maybe a few egg in this dung. Thereafter, the beetle usually repeats this process several to many times.

Ball of dung made by a Roller Dung Beetle. Photo: Trond Trovåg

3. Dwellers:

This is usually relative small beetles, and they are mostly found in big dung piles and ruminant dung with few fibers. They stay in the dung, lay eggs and feed of their "home".

Dweller, specie SS with length: 7 mm. Photo: Trond Trovåg

2.3. Dung beetle identification

The collected specimens were identified to morphospecies and the numbers of each morphospecies were counted. Due to the high number of species found in this study, each species was given one or more capital letters or a number for all the species found. The sorting of specimens, preparation, identification and classification in the laboratory was a very time-consuming and demanding task. All specimens were sorted with the help of microscope. Most specimens were mounted on pins and stored in collection boxes. When a high numbers of specimens of the same morphospecies were found in one sample, they were counted and only four individuals were mounted. The rest were stored on alcohol. All beetles – both those stored in alcohol and the ones mounted on pins are stored. This way it is possible to find back the series of species in the future and hopefully identify the morphospecies to species with latin names later. .

Fresh dung of Waterbuck in Manane. Photo: Trond Trovåg

2.4. Study design

During this study, dung beetles were collected in the northeastern part SGR. We collected dung beetles in four different habitat types:

1. Riverine Forrest:

This is usually a relatively narrow strip of dense and thick forest with high biological diversity between the river and the behind laying landscape.

Riverine forest. Photo Trond Trovåg

2. Miombo Forrest:

Miombo forest in Selous Game Reserve. Photo Trond Trovåg

This is the dominating forest-type of East Africa. The forest is arid, and is formed by seasonal drought and repeated forest fires. The forests type is relatively low in nutrients and grow relativly slow. The repeated fires in these waste forests also form the habitat considerable. The number of different tree-species found in this habitat is around 300 (Lillesøe et al., 2014).

Typical pristine Miombo forest. Mark the relatively green herbal layer. Photo: Trond Trovåg

3. Savanna:

Savanna contains a thin layer of nutrient-rich layer of soil often on top of a hard-pan. Some trees or bushes are common such as Acacia. Some of the grasslands in SGR were experiencing seasonal flooding (personal observation).

The Savanna habitat of K1 sector with some Impala gazelles. Photo Trond Trovåg.

4. Floodplain:

This is low altitude areas, often close to the rivers. Usually this is extremely fertile areas, since the soil contains silt, most nutrition-rich particles, which has been accumulated during thousands of years. During the rain season the plains are flooded. As a result of this seasonally flooding,

there are no trees in the floodplains. The plants in this habitat contain mainly grasses and similar plants like *Papyrus* or *Typha* that can survive being partly both over and under water.

Herd of Elephants in the Floodplain habitat near Manane Ranger Station. Photo Trond Trovåg

Dung beetles from dung from nine different species of Mammals

Samples were taken to observe if there is any difference between these habitats and observed dung beetles in dung at the study-species of animals. We observed and collected specimens of dung beetles from the following Mammals:

1. Liechtenstein's Hartebeests (*Alcelaphus lichtensteinii*), also called Kongoni.

Small heard of Kongoni in a Termite clearing. Photo Trond Trovåg

2. Waterbuck (*Kobus ellipsiprymnus*)

Group of Waterbucks in Floodplanin. Photo: Trond Trovåg

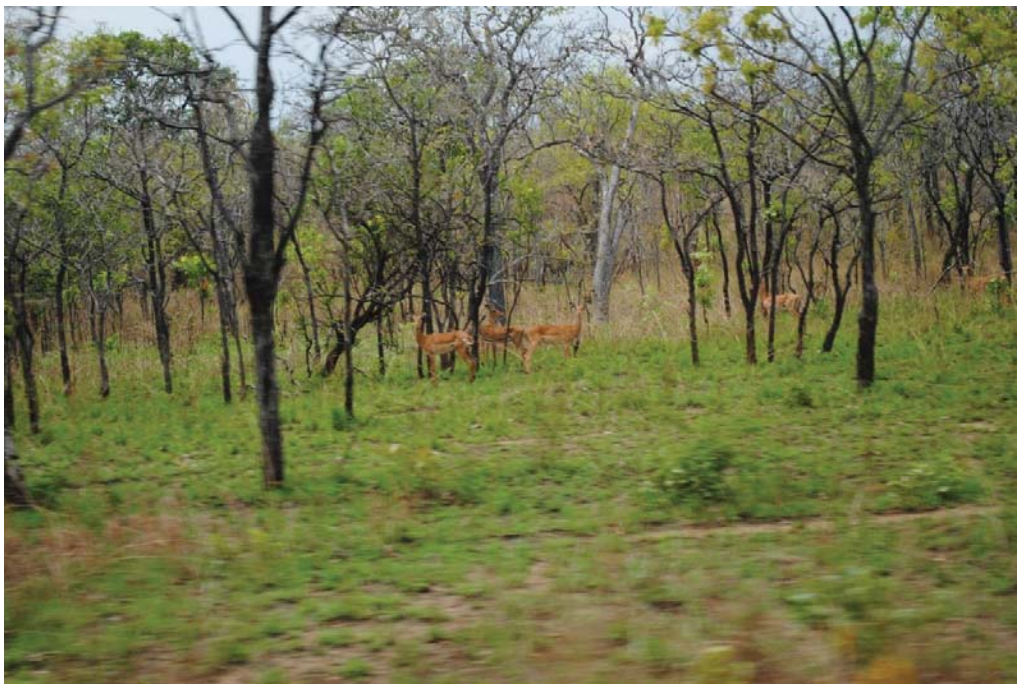
3. Elephant (*Loxodonta*)

Elephant bull in Miombo forest. Photo: Trond Trovåg

4. Hippo (*Hippopotamus amphibious*)

A young male Hippo has found a nice spot to live. Photo: Trond Trovåg

5. Impala (*Aepyceros melampus*)



A group of Impala. Photo: Trond Trovåg

6. Warthog (*Phacochoerus africanus*)

Group of Warthog in Miombo forest. Photo: Trond Trovåg

7. Hyena (*Hyaenidae*)

Dung from Hyena. Photo: Trond Trovåg

8. Buffalo (*Syncerus caffer*)

A group of Buffalo in a thicket. Photo: Trond Trovåg

9. Zebra (*Equus quagga*)

These species were distributed according to their preferred habitat. It was therefor only possible to collect from fresh dung in habitats where the species occurred naturally. In riverine forest I did not find fresh dung. Traps were therefor used in this habitat.

Kongoni on the run. Photo Trond Trovåg

2.5. Sampling methods

Timeframe from fresh droppings until it is too late

During the fieldwork, the humidity was low and the temperature during day quickly passed +40 ^{o}C. In that climate, dung is not fresh more than a few hours. This means that the dung beetles must find the dung more or less immediately to make the most of it. We could repeatedly observe how the beetles came very short time after dung was “produced”, seemingly out of nowhere. For instance, we observed a herd of Impala crossing a section of savanna. 10 minutes later, a lot of their small droppings were rolled away in different directions.

Rollers take off with a fresh dung “pie” of Impala just minutes after it was produced. Photo Trond Trovåg

As described, travelling was very time-consuming. Wildlife in Selous is in many ways similar to our wildlife in Europe, when they are hunted. After observing all different species of wildlife just walking beside cars and people as we passed Mikumi National Park, it was a different experience to see the wild game of Selous run of just with the glimpse of our Landcrusier at long distance. As the game had their normal skepticism towards humans as well as to other predators, most of the species were mostly night-active, or active at dusk or dawn. Therefore, we had to travel very early in the morning to reach the habitats while droppings from the night were still fresh. We also had to walk a lot to get close enough to take fresh samples.

Going through dung to collect Dung Beetles. Photo: Fred Midtgaard

Traps

In Riverine Forest along the Ruaha River we did place out some traps (8), mainly because the soil was challenging and because the vegetation was very dense. In addition 4 traps were placed out in the adjacent miombo forest. The traps were made of a wide plastic bucket that was buried into the ground. Inside the bucket, it was filled with soil up until about 10 cm from the rim. The soil was compressed to be similar to surrounding soil. On top of this we placed dung. The traps were set for 24 hours, and then emptied and all beetles collected and identified.

Trap ready to catch Dung Beetles. Photo Trond Trovåg.

Movement of dung from one habitat to another

Since we did not find dung from all species in all different habitats, we did retrieve some dung from one location to the next. When we did this, we did try to find the very fresh dung and we also added water the dung so it would appear as just dropped. The dung was examined in detail to be sure it was without beetles before placing it out.

Moving dung from one location to another. Photo: Ranger Angella.

2.6 Dung Beetles in different habitats and different dung

I have compared the numbers of species of dung beetles in dung found in different habitats. Also, the number of dung beetles species found in dung from the different Mammal species is counted. Finally, for the species that I have enough data – I have looked into if there are different dung beetles in dung from same Mammal in different habitats.

Labratoie work, sorting and pinning the different species of Dung Beetles. Photo Kristine Trovåg

2.7 Laboratory work

As already mentioned in 2.3, the work in the lab after coming back with this enormous number of beetles – has been time-consuming. Though, - it has of course also been very exciting to clean all the samples, sorting all the samples by species, pinning four of each species and finally photograph each and every species.

Pinning four of each specie in to a monter. Photo Kristine Trovåg

3. Results and discussion

3.1 The number of dung beetles in different Mammal dung:

In total, we found 105 species of dung beetles during this fieldwork distributed among 1369 number of specimens. There are considerably differences in number of species of dung beetles in dung from different Mammals. Samples of dung from Zebra and Hyena was low and gave uncertain results. I therefor choose not to include data from these two species in the thesis.

Dung Beetles found in a pile of dung from Elephant.. Photo: Trond Trovåg

Only one species, C, was found in dung from all 7 Mammal species. Three species (P, NNN and QQQ) were found in three Mammal species' dung. 16 dung beetle species were found in dung from two Mammal species, but the waste majority were found in only one dung type. 41 species were found only in Elephant dung. 22 species were only found in Waterbuck dung. 6 species only in Warthog dung, 5 species only in Buffalo dung, 6 species only in Kongoni dung. 2 species only in impala dung and 3 species only in Hippo dung.

Elephant

A
B
C
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
W
Æ
Ø
Å

AA
FF
GG
JJ
LL

51 species of dung beetles

DDD
EEE
FFF
MMM
QQQ
WWW
ÆÆÆ
ØØØ
ÅÅÅ

A4
B4
F4
M4
N4
O4
P4
Q4
R4
S4
T4
U4
V4

Two armed guards followed us while we collected samples at the Floodplain. Photo: Trond Trovåg

Waterbuck		**27 species of dung beetles**	
C	AA	AAA	D4
	BB	BBB	E4
	CC	CCC	F4
	DD	GGG	G4
	JJ	JJJ	H4
	PP	KKK	I4
	SS	LLL	J4
	TT		K4
	ÆÆ		L4
	ØØ		
	ÅÅ		

Collecting Dung Beetles from Waterbuck. Photo: Trond Trovåg

Impala **8 species of dung beetles**

C	GG	OOO	W4
P	NN	UUU	Æ4

Fresh droppings from Impala. Photo: Trond Trovåg.

Warthog **12 species of dung beetles**

B	NN	NNN
C		OOO
		PPP
		QQQ
		RRR
		SSS
		TTT
		UUU
		VVV

Lichtenstein Hartebeast (Kongoni) **10 Species of dung beetles**

C	EE	Ø4
	II	
	KK	
	MM	
	NN	
	OO	
	QQ	
	XX	

Sample of Beetles just caught from dung. Photo: Trond Trovåg

The number of samples were unevenly distributed between the Mammals. There were 10 samples from Elephant, 2 from Buffalo, 3 from Waterbuck, 1 from Kongoni, 2 from Hippo, 2 from Impala, and 2 from Warthog. Totally 22 samples. Originally, the number of samples were at least twice as high, but many samples were too old so the samples were considered inadequate.

Buffalo		**15 species of dung beetles**
A	EE	III
C	HH	MMM
D	UU	
E	VV	
P	YY	
V	XX	
	ZZ	

Buffalo dung. Photo: Trond Trovåg

Hippo		**9 species of dung beetles**
C	PP	C4
D	QQ	
	RR	
	UU	
	VV	
	WW	

Tracks made by Hippos which were walking the same trail night after night in search for food. Photo: Trond Trovåg.

Elephant dung dominates the samples in several ways

As we can observe, the number of dung beetles species is highest in dung from Elephant, both in total number of species (51) and in number of unique species (41). There are three aspects to take in to consideration with this: 1. Elephant has different stomach and is not a ruminant. 2. The size of the dung from Elephant is enormous compared to the other animals in this study. 3. The number of dung samples is highest for Elephant compared to the other animals. Another finding

that is important is that the number of species of dung beetles in dung of Waterbuck is remarkable high. Here there the total number of species were as high as 27, but even more impressive was that 22 of these were unique for Waterbuck only. The droppings from this medium sized antelope is quite small, yet still a lot of species found it of great interest. This could possibly be because of the high quality food it eats on the floodplains.

Fresh dung from a young/ small Elephant. Photo: Trond Trovåg

A study from South Africa, where traps with dung from different domesticated animals (cow, sheep and pig) as well as Elephant and chicken liver, showed similar tendencies (Tshikae et al., 2008). They collected 67 species and found that most species were specialized in only one of these artificial dung types. A few generalists were attracted to several dung types. The results from the present study are even clearer, possibly because of a much higher number of species found, but maybe also because natural dung were used.

3.2 Number of dung beetles in different habitats

Savanna		**29 species**	
B	EE	NNN	C4
C	ii	OOO	W4
D	KK	PPP	Æ4
N	MM	RRR	Ø4
V	NN	SSS	
	OO	TTT	
	PP	UUU	
	RR	VVV	
	UU	QQQ	
	VV		
	WW		
	QQ		
	XX		

Group of Warthog at the Savanna. Photo: Trond Trovåg

Floodplain **45 species**

B	AA	AAA	D4
C	BB	BBB	E4
F	CC	CCC	F4
J	DD	DDD	G4
K	JJ	EEE	H4
M	LL	FFF	I4
N	PP	GGG	J4
R	SS	JJJ	K4
U	TT	KKK	L4
V	ÆÆ	LLL	R4
W	ØØ		S4
Æ	ÅÅ		T4
Ø			U4
Å			

Miombo forest **33 species**

A	AA	DDD	A4
B	FF	MMM	B4
C	GG	QQQ	F4
F	JJ	ÆÆÆ	M4
G	LL	ØØØ	N4
H		ÅÅÅ	O4
I			P4
J			Q4
L			V4
N			
O			
P			
T			
V			
Q			

Riverine forest **11 species**

A	EE	III	V4
P	GG	MMM	
S	LL	WWW	
V			

As we can observe, the number of different species of dung beetles is lowest in riverine Forest, and highest in floodplain. Riverine forest is a relatively narrow strip along the rivers, so it is maybe not that surprising that the numbers of species is a bit low. In addition, we used dung traps in this habitat. The dung could have been less attractive to the beetles than fresh dung in the original habitat where the dung was produced. I also had traps in one miombo habitat, but there were many "natural" samples from that environment too. The fact that the Floodplain contained the highest numbers of dung beetles is maybe a bit surprising. This habitat is flooded one or twice a year and during these flooding's the survival of dung beetles must be difficult. Floodplains is one of the habitats with the highest amount of nutrients – due to the same flooding. Thereby abounded food for grazers likely attracts the high number of grazers which again will produce the highest amount of dung to attract dung beetles. The dung may also be more nutritious in this habitat.

Species that were only found in each one of the four habitats (but with all Mammal dung producers included on at least one of them) were much more common than generalist species. Only one species, LLL, was found in all habitats. Three species were found in three out of four habitats (species B, C and V). 17 species were found in two habitats, while the rest were found in only one habitat: 37 species only on the floodplain, 25 species only in miombo. 20 species only on savanna and 2 species only in riverine forest. This means that 84 out of the 105 species were only found in one habitat type (80% of the species).

Also for the samples in different habitats, sample numbers were uneven. There were 3 samples from riverine forest, 5 from savanna, 8 from miombo and 5 from floodplain. Each of the samples demanded a lot of time to find and collect so it was not possible to get many more samples or have them more evenly distributed.

Floodplain in Manane. The temperature was measured to 46 C degrees. Photo: Trond Trovåg

3.3 Species of dung beetles in different habitats from dung of same Mammal

The number of samples is highest from Elephant, and thereby easier to compare habitats with less uncertainty, because the above comparison included all dung producers.

Elephant	**51 species**		
Floodplain	Miombo Forest	Savanna	Riverine forest
B	A	N	A
C	B	V	S
F	C		V
J	F		LL
K	G		MMM
M	H		WWW
N	I		V4
R	J		
U	L		
V	N		
W	O		
Æ	P		
Ø	Q		
Å	T		
LL	V		
DDD	AA		
EEE	FF		
FFF	GG		
R4	JJ		
S4	LL		
T4	DDD		
U4	MMM		
	QQQ		
	ÆÆÆ		
	ØØØ		
	ÅÅÅ		
	A4		
	B4		
	F4		
	M4		
	N4		
	O4		
	P4		
	Q4		
	V4		

Elephant herd crossing the road. Photo Trond Trovåg

Surprising difference between habitats

There were just two species of dung beetles found in Elephant dung in the savanna. Those two, species N and V, were also found in floodplain as well as in Miombo forest. One of them, species V, was also found in riverine Forest. In riverine forest, I found two distinct species that only occur there; species S and WWW. Miombo and floodplain share some species of dung beetles. However, I found surprisingly many species in just one of the habitats. For instance, In miombo there were 24 species of dung beetles in Elephant dung that I did not find in any other habitat. In the floodplain, I found 14 species in Elephant dung that only occur there. Totally, 41 species were only found in Elephant dung. This is also here 80% of the total number of species on Elephant dung (the same percentage as those found only in one habitat type for all dung types).

Buffalo	**15 species**
Miombo Forest	Riverine Forest
C	A
D	P
E	V
HH	EE
VV	III
UU	MMM
YY	
XX	
ZZ	

Completely different species for Buffalo dung

Also for Buffalo I find that there is significant difference between the habitats. Buffalo dung was found in miombo forest and riverine forest, and none of the species overlap between the two habitats.

The one true generalist, species C, which was found in all different dung types (but not all habitats). Photo: Trond Trovåg

Impala	**8 species**
Savanna	Riverine forest
C	GG
UUU	P
NN	
W4	
Æ4	
OOO	

Completely different species for Impala dung between habitats

For Impala, one of the samples contained only two species of dung beetles. It is of interest to observe that there also in for this type of dung there is no overlap of species of dung beetles between the two types of habitat.

Digging for tunnellers under a dung pile. Photo Fred Midtgaard

Dung is quit complex and may consist of a lot of coarse fibers or be finely grained. Dung beetles particularly feed on the moisture between the fibers (Holter et al., 2002; Scholtz et al, 2009), but dung with fibers is more easy to form into ball to roll away or dig down (Pers. Obs.). Grazing and browsing Mammals often produce different dung types. In addition, it is important if the mammal is a ruminant, producing fine-textured dung, or a non-ruminant producing coarse dung. Some species excreted the dung in a mass form while others excrete in pellet-form. It may also be important what season the dung was produced in, such as high quality rainy season graze compared to poorer quality dry season graze (Edwards 1991). From field observations it seems to me that particularly Buffalo dung have more dwellers (species living inside the dung pile) than species with coarser dung. The dung pellets from gazelles were in the field often observed being rolled away by small rollers using one pellet as food for their eggs. All the field work was done in the dry season and it was thus not possible to compare seasons. Elephant dung is special because it is very coarse and also in very big piles, often consisting of 6-7-8 bowls each one up to 20 cm in diameter. In this study, Elephant dung was found to be particularly rich in species, both rollers and tunnellers, while there seemed to be relatively few dwellers. There may be several reasons for this: Large piles of dung may attract more beetles because of more scent sent out, more species may have evolved to compete over this huge resource of dung, the relatively coarse dung from Elephants is likely easy to roll into balls, and possible the non-ruminant dung may contain more nutrients left than ruminant dung. I did not differentiate between tunnellers and dwellers in the Appendix 1. However, small species without horns in the male are likely to be dwellers.

It is reasonable to assume that the non-ruminant species could have similar communities of dung beetles. The non-ruminant species would be Elephant, Hippo and Zebra. However, there was very little overlap in species composition for the two former species. It should be noted that I had very few samples from Hippo and Zebra though. Zebra was excluded from analysis (as mentioned above) because the quality of the dung seemed inadequate.

Also among the ruminant dung producers, very little overlap was found between the species. Ruminant dung may range from rather large “cakes” produced by Buffalo, to walnut sized pellets by larger gazelles, down to tiny pellets by the smaller gazelles. The different ruminant species

also seemed to prefer different habitats which in turn may have affected the community of dung beetles feeding on their dung.

When the communities of dung beetles were so different as they were between Mammal species, it would be expected that the community could be similar for the same dung producer in different habitats. However, also here there was very little overlap.

The number of species was very high (105 species) and some overlap between either species of dung producer or habitat could be expected. However, the number of specimens were low compared to the high number of species (only 1369 specimens distributed on 105 species). Many species were found in only one or a few specimens. A reason for this could be that the number of species in SGR could be so high that my samples only consisted of a tiny portion of the total number of species. However, the sampling was done in only one sector of SGR and during a relatively short part of the dry season. It thus seems unreasonable that my samples are not at all representative for the actual communities, particularly when many species were found in several samples on the same dung type or in the same habitat.

There are very few studies on dung beetle communities compared between specific dung types (Tshikae et al., 2008), and that study was on artificial dung pats not on natural pats from the wild. I have not found any articles with comparison of the dung beetle communities between different habitat types for the same dung producer. This aspect, as well as the comparison between dung producers for the same habitat type, seems to be unique for this study.

4. Conclusion

The dung beetles in Selous Game Reserve seems to be highly specialized – both due to what type of dung the dung beetles are attracted to, as well as high difference in species composition of in different habitat types.
Is a bit surprising to find that there seems to be a very distinct and "clear-cut" difference between species of dung beetles found in dung from different animals. Similarly it is a bit astonishing to find that different species of dung beetles is found in one type of dung in one habitat, while it is completely absent in similar dung maybe just a stone-throw away in another habitat.
One species differed from this pattern; species C. This species was the only one present in all different types of dung and it was also found in 3 of 4 different habitat types.

This study is made out of a fieldwork in a relatively short timeframe in October and November in a dry period. I would suggest a similar study during the peak of the wet season in March-April to find if there are any other species, or – if the species found in this study have the same preference to habitat and type of dung also at this time. It is likely that a much higher number of specimens would be found in the wet season.

Though the species of dung beetles in this study are just classified as morphospecies, most likely many species have not yet been described. To identify and describe the morphospecies found in this study would be an interesting future task.

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https://en.wikipedia.org/wiki/Selous_Game_Reserve

Attachment 1
Catalog with photos of the 105 different Dung Beetle species that were found during this study. 102 species are subfamily Scarabaeinae and 3 are subfamily Aphodiinae (Scarabaeidae). They are classified as morphospecies and named by an alphabetical code. For each species it is described in which type of dung they were found, in which habitat(s) they were found as well as if I assume it is a tunneling/dwelling species or a roller. In the description "Tunneller" means "Tunneller/dweller" as it is not easy to see the difference morphologically. It is assumed that most are tunnellers though.

Species A

Tunneller found in three samples of dung from Elephant in Miombo forest, and in one sample of dung from Buffalo in Riverine forest. Length: 8 mm.

Species B

Tunneller found in dung from Elephant in Miombo forest and in Floodplain and in dung of Warthog at the Savanna. Length: 12mm.

Species C

Tunnelling beetle that were among the species which was found in most different habitats and dung from several different Mammals. Found in two samples of dung from Elephant in Miombo forest and in one sample from Floodplain. It was also found in dung of Buffalo in Miombo forest. At the Savanna it was found in dung of Warthog, Kongoni, Impala and Hippo. At the Floodplain it was found in dung from Elephant as mentioned above as well as in dung from Waterbuck. Length: 12 mm.

Species D

Tunneller found in dung of Buffalo in R1 sector, rich Miombo forest, and we also found them in dung of Hippo at K4, Savanna habitat. Length: 8 mm.

Species E

Roller found in dung of Buffalo in R1 sector, rich Miombo forest.

Species F

Tunneller species found in dung from Elephant at A1-R1 road in Miombo woodland. Length 30 mm.

Species G

Tunneller found in dung from Elephant at A1-R1 road in Miombo woodlands. Length between 22 and 29 mm.

Species H

Tunneller species found in dung of Elephant on a dry hill in sector M1 – MiomboWoodlands. Male and female in photo. Length: 24 mm.

Species I

Roller found in dung of Elephant in M1 – Dry Hill – Miombo forest. Length: 25 mm

Species J

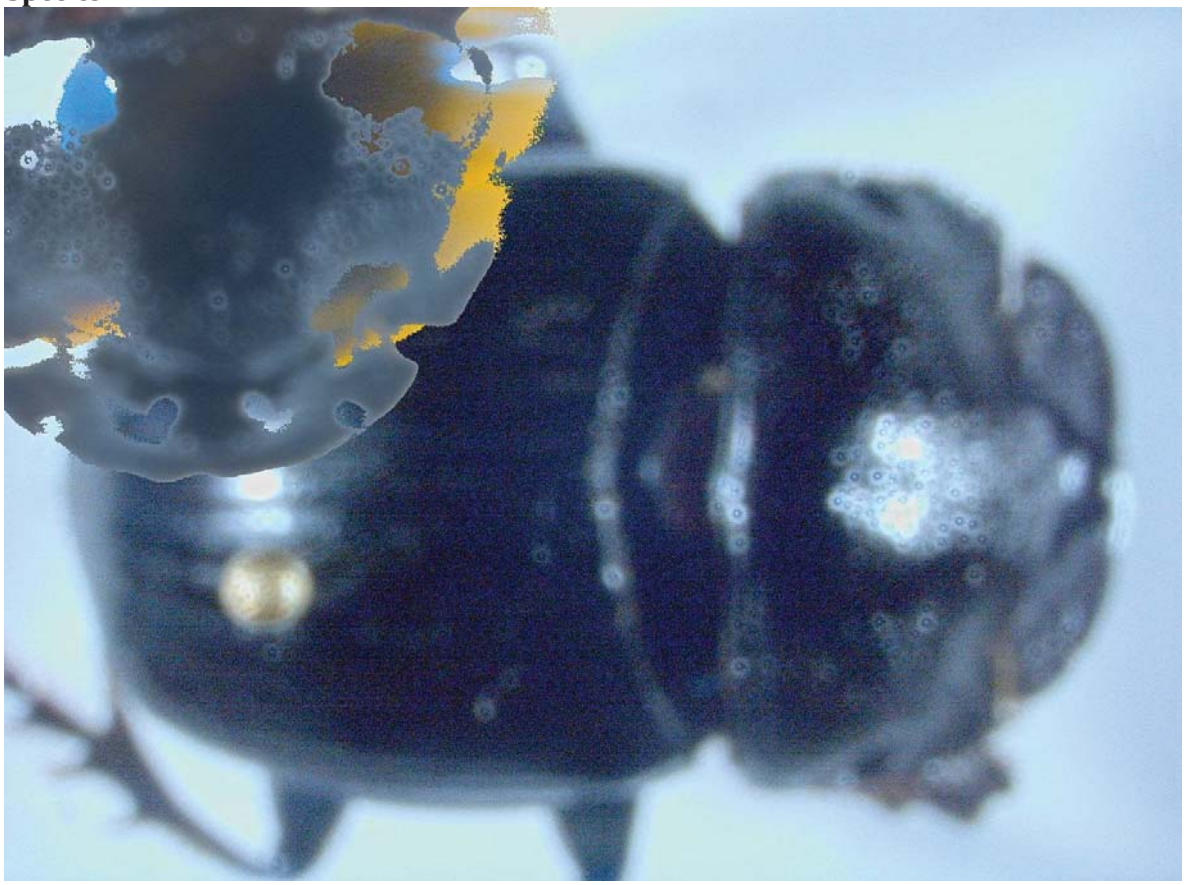
Front part of specimen found in dung of Elephant in Manane, Floodplain habitat.

Back part of specimen found in dung of Elephant in Manane.
Tunneller with length: 20 mm

Species K

A large Beetle, shining in green metallic color when wet. It was found in dung of Elephant in Manane – Floodplain habitat. Length: 27 mm. Roller.

Species L



Tunneller found in dung of Elephant in M1 dry hill, Miombo forest. Length: 16 mm.

Species M

Found in dung of Elephant in Manane, Floodplain habitat. Length: 9 mm. Roller

Species N

Found in dung of Elephant in Manane, Floodplain habitat and we also found the same species in dung of Elephant on R1 road, Savanna habitat. Length: 14 mm. Tunneller.

Species O

Found in dung of Elephant at A1-R1 road, Miombo forest. Length: 12 mm. Tunneller

Species P

Found in dung of Buffalo, M1 camp – Riverine forest, also found in dung of Impala in M1 camp – Riverine forest. Furthermore, we found them in dung of Elephant in M1 dry hill – Miombo forest, and in dung of Elephant in A1-R1 road – Miombo forest. Length: 14 mm. Tunneller.

Species Q

Tunneller found in dung of Elephant in Miombo forest. Length: 19 mm.

Species R

Back-part of the specimen found in dung of Elephant in Manane

Front-part of the specimen found in dung of Elephant in Manane. Length: 19 mm. Tunneller.

Species S

Found in dung of Elephant in M1, Riverine forest habitat. We also found them in dung of Waterbuck in Manane in Floodplain habitat. Length: 15 mm. Tunneller.

Species T

Tunneller species found in dung of Elephant at A1-R1 road, Miombo forest. Length: 11 mm.

Species U

Tunneller found in dung of Elephant in Manane in a Floodplain habitat. Length: 17 mm.

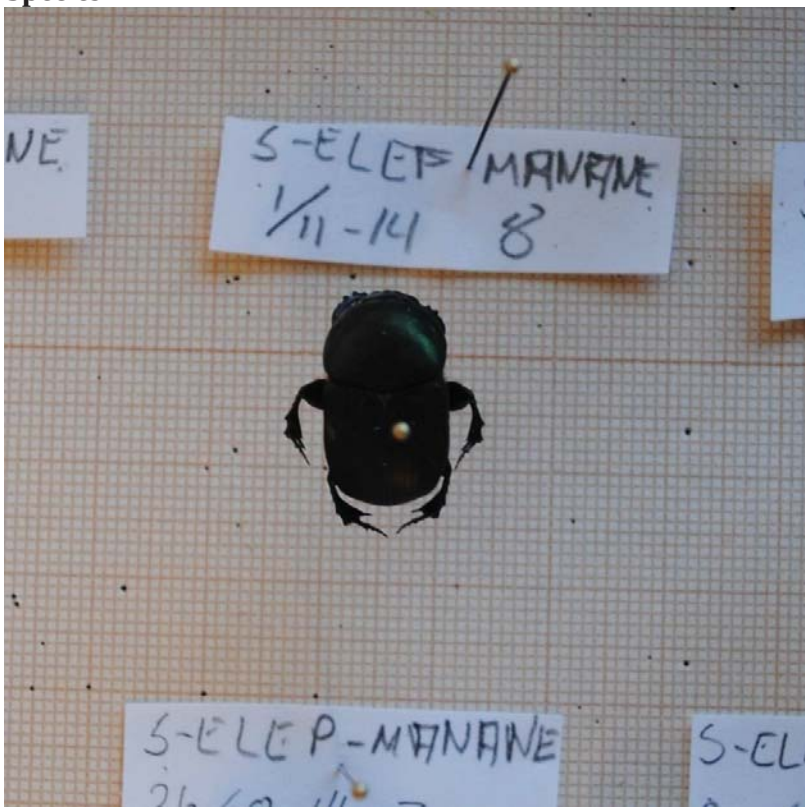
Species V

Tunneller found in dung of Elephant in A1-R1 road, Miombo forest and beetles were found in dung in Manane, Floodplain habitat. We also found them in dung of Elephant in M1 sector at a dry hill in Miombo forest, and finally the beetles was found in dung of Elephant in M1 sector in Riverine forest. Length: 18 mm

Species W

Tunneller found in dung of Elephant in Manane, Floodplain habitat. Length: 19 mm.

Species Æ



Tunneller found in dung of Elephant in Manane – Floodplain habitat. Length: 29 mm.

Species Ø

Found in dung of Elephant in Manane – Floodplain habitat. Length: 22 mm. Tunneller.

Species Å

Tunneller found in dung of Elephant in Manane – Floodplain habitat. Length: 17 mm.

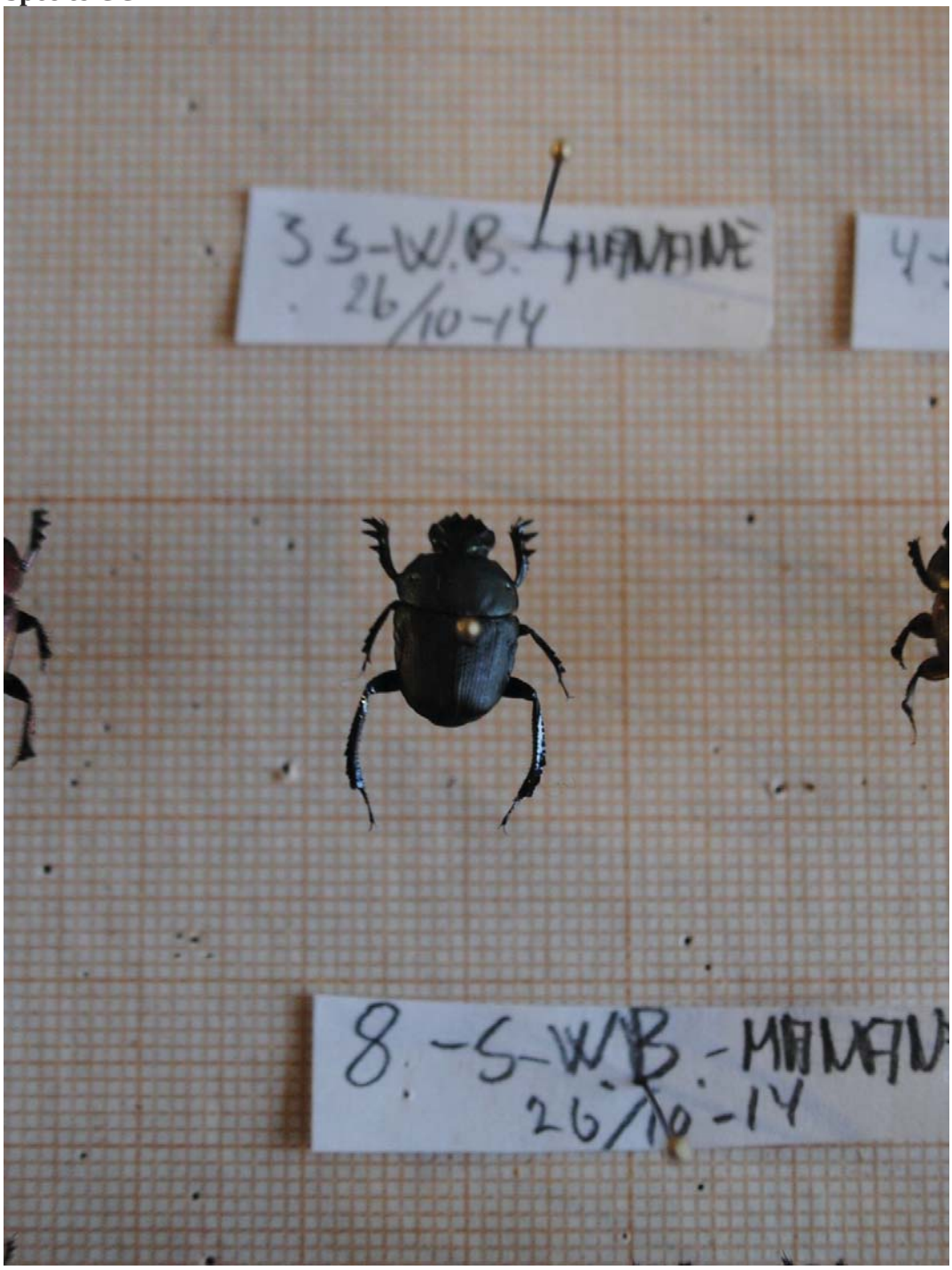
Species AA

Roller found in dung of Waterbuck in Manane, Floodplain and found in Elephant dung on Manane road which is Miombo forest. Length: 14 mm.

Species BB

Colorful roller, found in dung of Waterbuck in Manane – Floodplain habitat. Length: 12 mm.

Species CC



Roller found in dung from Waterbuck in Manane – Floodplain. Length: 13 mm.

Species DD

Roller found in dung of Waterbuck in Manane, Floodplain. Length: 8 mm.

Species EE

Tunneller Found in dung of Kongoni in K4, Savanna. Length: 21 mm.

Species FF

Tunneller found in dung of Elephant in M1 at a dry hill, Miombo forest. Length: 11 mm.

Species GG

Tunneller found in dung of Elephant in M1 on a dry hill, Miombo forest. Also found in dung of Impala in M1 – Riverine Forest. Length: 14 mm.

Species HH

Colorful Tunneller found in dung of Buffalo at R1 30.10.-14 – Miombo woodlands. Length: 15 – 18 mm.

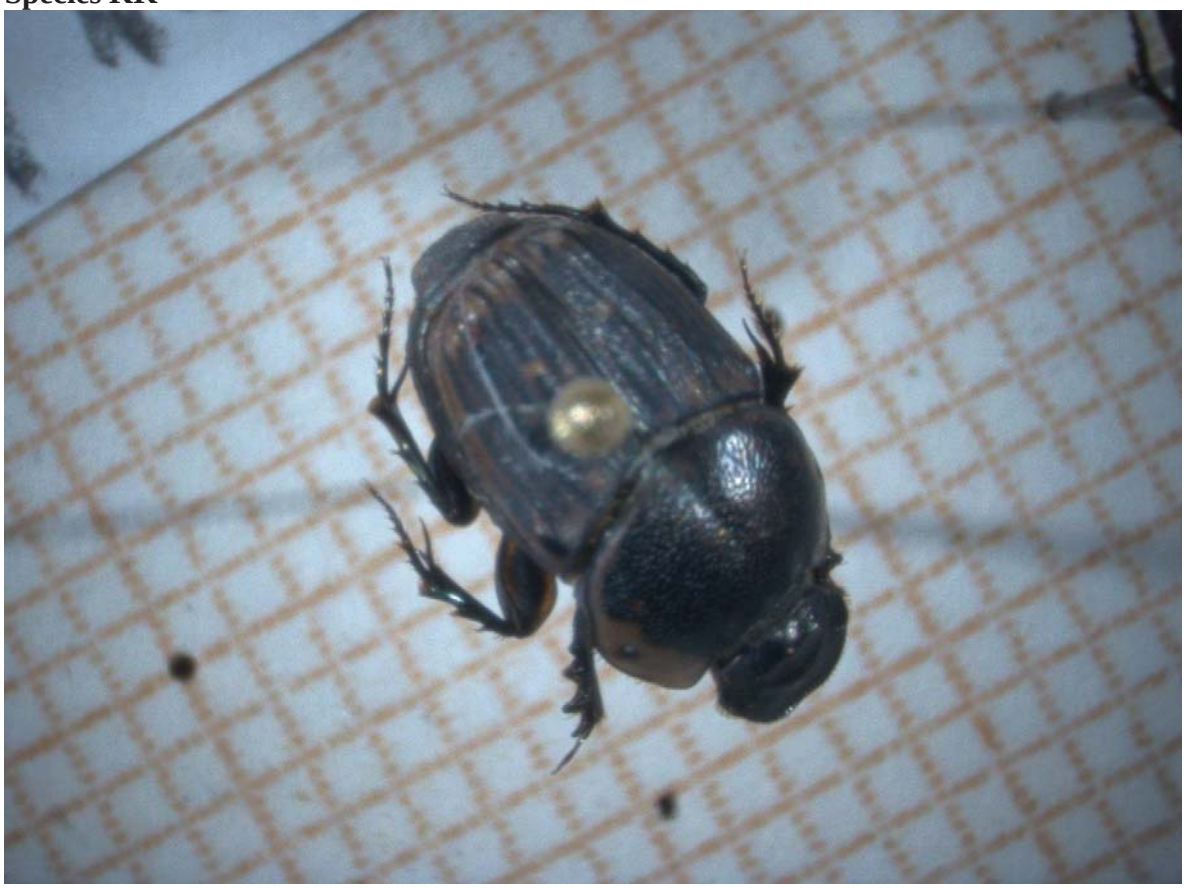
Species II

Roller found in dung of Kongoni in K4 sector, Savanna habitat. Length: 9 mm

Species JJ

Tunneller found in 3 specimens in dung of Waterbuck in Manane, Floodplain and found in dung of Elephant at Manane road, Miombo woodland. Length: 10 mm

Species KK



Found in dung of Kongoni in K4, Savanna. Length: 9 mm.Tunneller.

Species LL

Tunneller found in dung of Elephant in Manane, Floodplain habitat. Also found in dung of Elephant in dry hill in M1 – Dry Miombo forest. Also found in dung of Elephant in Riverine forest at M1 sector and finally found in Manane road in habitat between Miombo forest and Savanna. Length: 9 mm.

Species MM

Tunneller found in dung of Kongoni in K4, Savanna habitat. Length: 11 mm.

Species NN

Roller found in dung of Kongoni and in dung of Impala and Warthog in sector K4, Savanna habitat. Length: 8 mm.

Species OO

Tunneller found in dung of Kongoni in sector K4, Savanna habitat. Length: 11 mm.

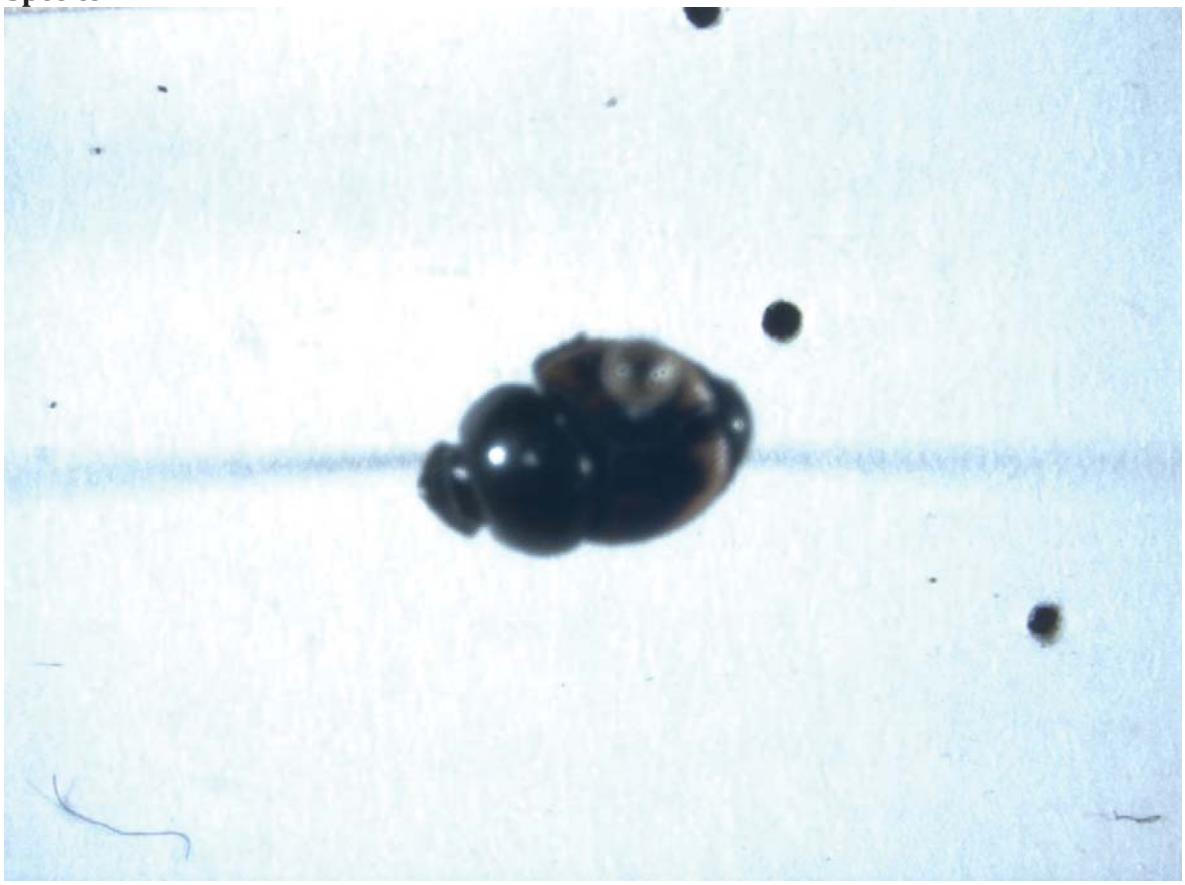
Species PP

Roller found in dung of Waterbuck in Manane, Floodplain habitat. Also found in dung of Hippo in sector K4, Savanna habitat. Length: 8 mm.

Species QQ

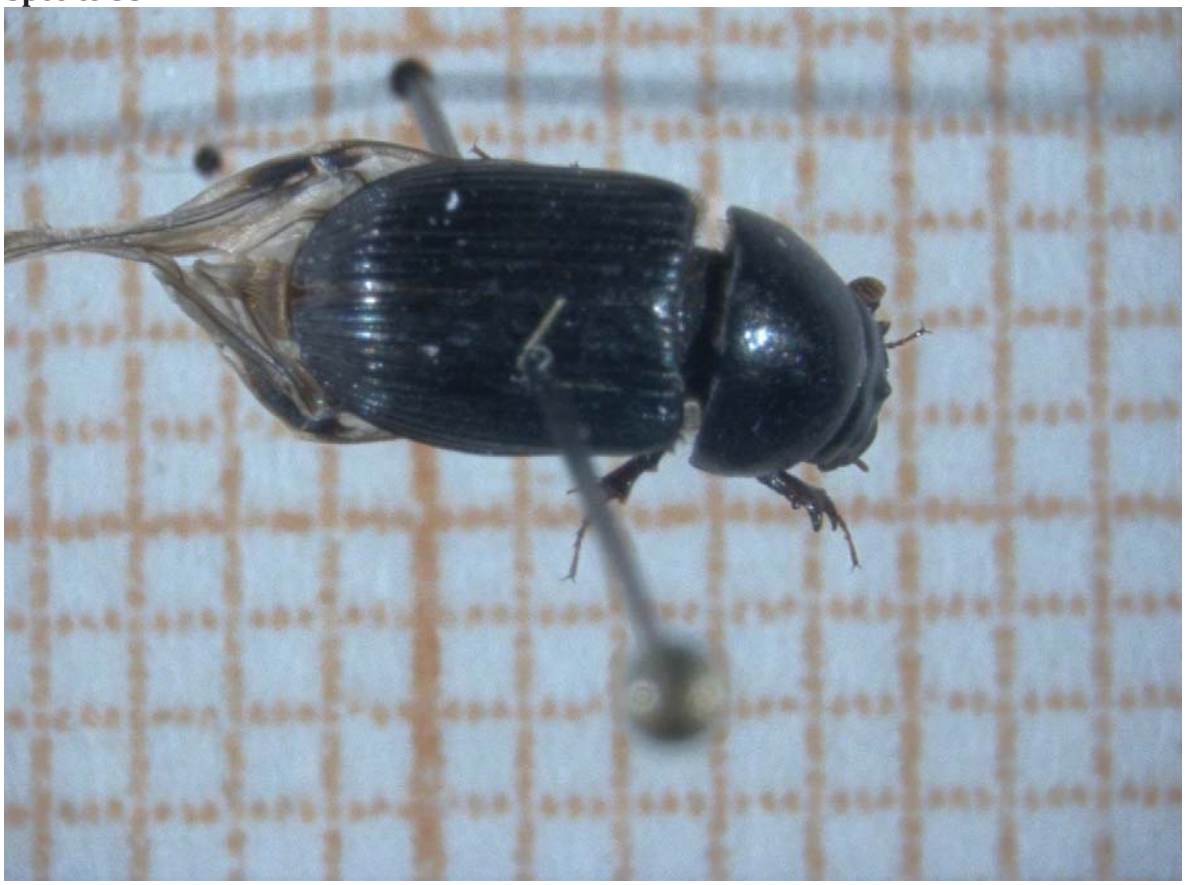
Tunneller found in dung from the two species Hippo and Kongoni in sector K4, Savanna. Length: Length: 6 mm.

Species RR



Tunneller found in dung of Hippo in sector K4 – savanna. Length: 5 mm.

Species SS



Tunneller found in dung from Waterbuck in Manane – Floodplain habitat. Length: 7 mm

Species UU

A small tunneller found in dung of Buffalo in sector R1 – Miombo forest and in dung of Hippo in sector K4, Savanna. Length: 4 mm

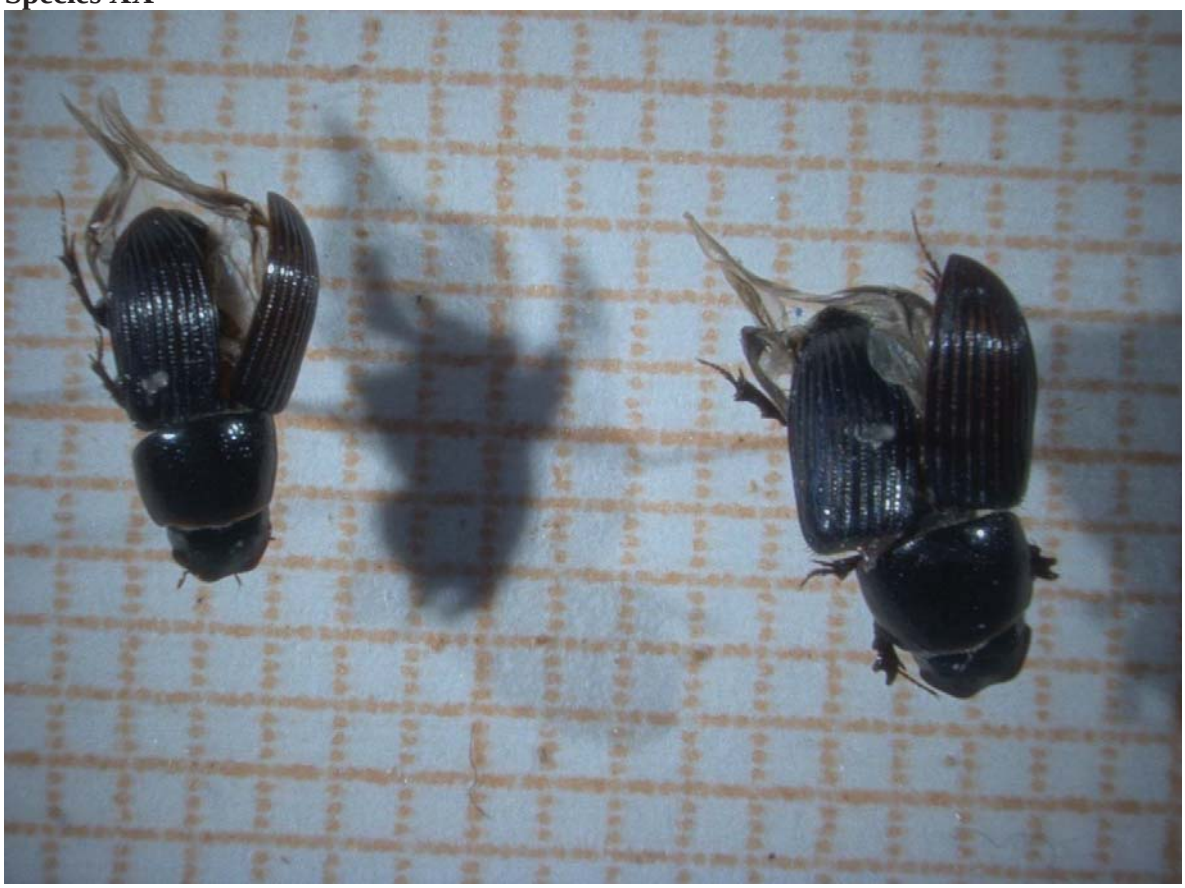
Species VV

Tunneller found in dung of Hippo in sector K4 – Savanna, and in dung of Buffalo in sector R1 - Miombo forest. Length: 4 mm.

Species WW

Tunneller found in dung of Hippo in sector K4, Savanna habitat. Length: 3 mm

Species XX



Tunneller found in dung of Kongoni in sector K4 – Savanna, and in dung of Buffalo in sector R1 – Miombo Forest. Length: 6 mm

Species YY

Tunneller found in dung of Buffalo in sector R1 – Miombo forest. Length: 3 mm

Species ZZ

Tunneller found in dung of Buffalo in R1 – Miombo Woodland habitat. Length: 8 mm.

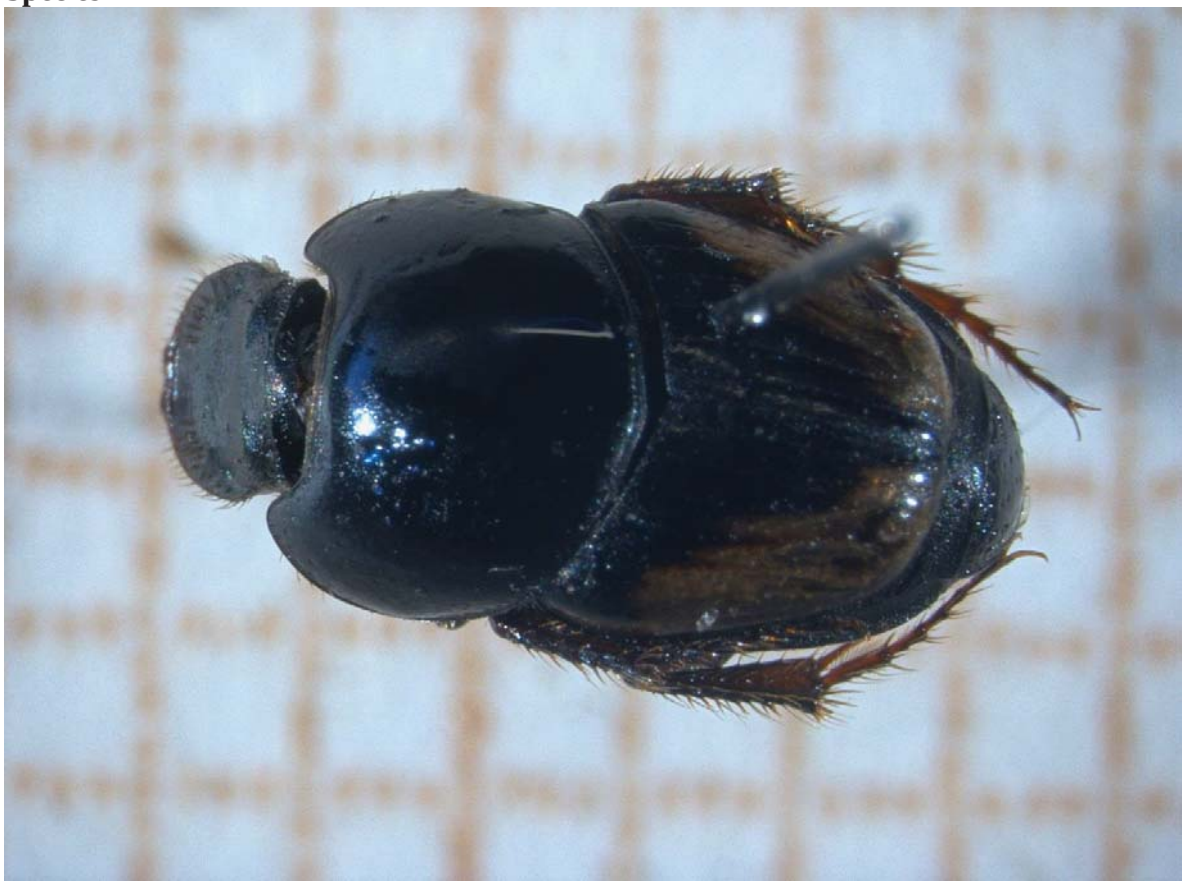
Species ÆÆ

Found in dung from Waterbuck in Manane – Floodplain habitat. Length: 5 mm. Tunneller.

Species ØØ

Tunneller found in dung of Waterbuck in Manane – Floodplain habitat. Length: 5 mm.

Species ÅÅ

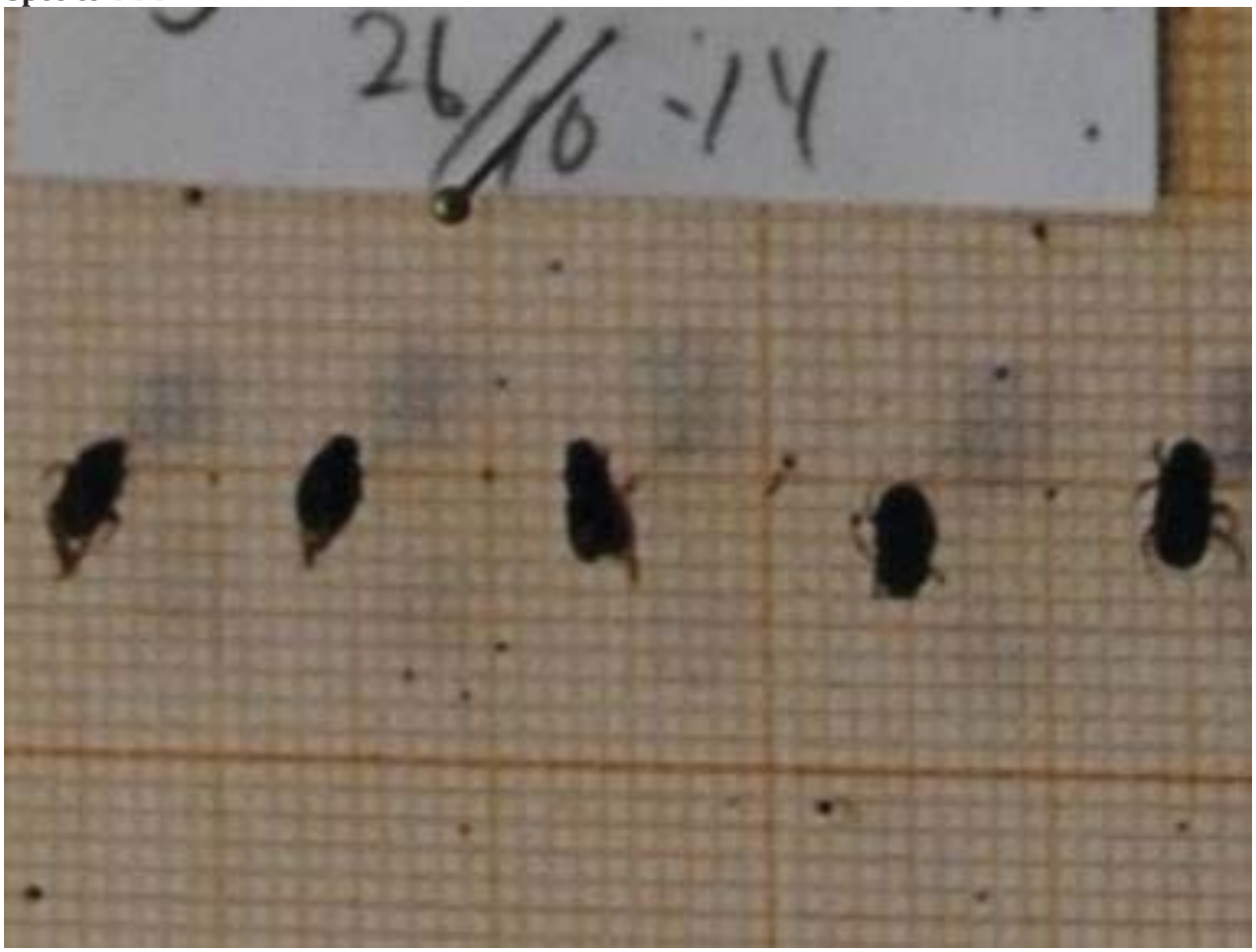


Tunneller found in dung from Waterbuck in Manane – Floodplain habitat. Length: 4 mm.

Species AAA

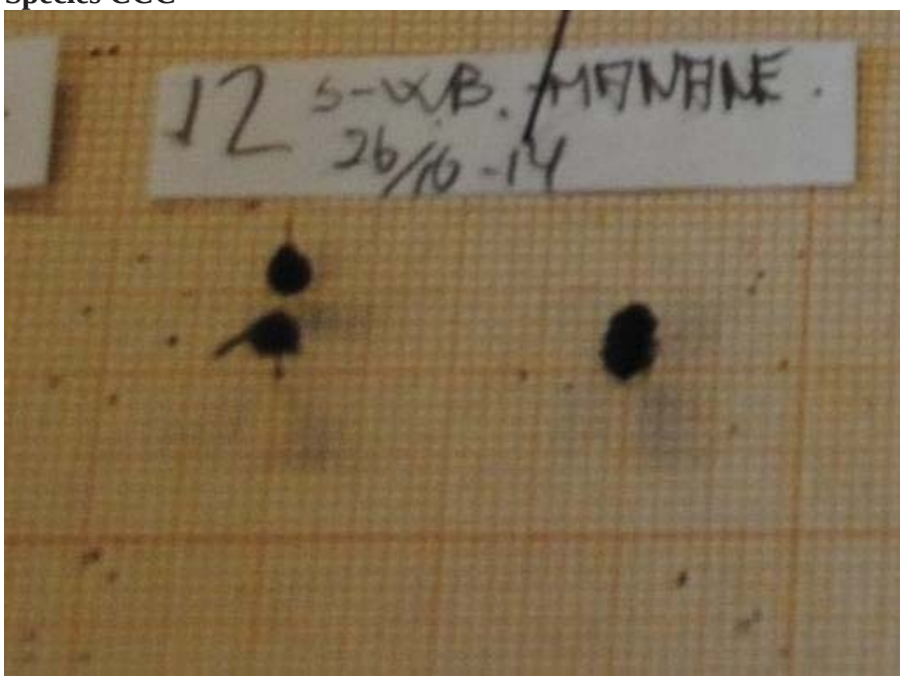
Tunneller found in dung from Waterbuck at Manane – Floodplain habitat. Length: 4 mm.

Species BBB



Tunneller found in dung of Waterbuck in Manane – Floodplain Habitat. Length: 4 mm.

Species CCC



Tunneller found in dung of Waterbuck in Manane – Floodplain Habitat. Length: 4 mm.

Species DDD

Tunneller found in dung from Elephant at Manane road – Miombo forest, and in Manane – Floodplain habitat. Length: 7 mm

Species EEE

Tunneller found in dung of Elephant in Manane – Floodplain habitat. Length 10 mm

Species FFF

Tunneller found in dung from Elephant in Manane, - Floodplain habitat. Length: 11 mm.

Species GGG

Roller found in dung from Waterbuck in Manane – Floodplain habitat. Length 10 mm.

Species HHH

This Tunneller was found in dung from a carcass of an Elephant in Manane road – Miombo forest. Length: 19 mm.

Species III

Tunneller found in dung from Buffalo in M1 sector - Riverine forest. Length: 14 mm.

Species JJJ

Tunneller found in dung from Waterbuck in Manane – Floodplain habitat. Length: 12 mm.

Species KKK

Roller found in dung of Waterbuck in Manane – Floodplain Habitat. Length: 9 mm.

Species LLL

Tunneller found in dung of Waterbuck in Manane – Floodplain Habitat. Length 14 mm.

Species MMM

This beetle we found in 3 different habitats; in dung of Buffalo in M1 – Riverine forest, and in dung of Elephant both in M1 – riverine forest and at A1-R1 road – Miombo forest. Length: 9 mm. Tunneller.

Species NNN

This tunneller was found only in dung from Warthog in sector K4 – Savanna habitat. Length: 5 mm.

Species OOO

This beetle we found in 3 different samples, one in dung from Impala and two from dung of Warthog. All tree samples were found in sector K4 – Savanna habitat. Length: 5 mm. Tunneller.

Species PPP

This tunneller was found in two samples of dung from Warthog in sector K4 – Savanna habitat. Length: 5 mm.

Species QQQ

Aphodiinae (Scarabaeidae) with length between 4 and 5 mm. This is another subfamily from the rest of the beetles presented here. They also feed on dung, but is a mainly Holarctic group with few representatives in Africa. This species were found in totally four samples, two in samples from dung of Warthog – both in sector K4 – Savanna habitat. In the same habitat, we also found this beetle in dung from Hippo. In the Miombo forest of Manane road we also found this specie in one sample of Elephant dung.

Species RRR

This species of tunneller was only found in dung from Warthog in sector K4 – Savanna habitat. Length: 6 mm.

Species SSS

This species of tunneller was found in two samples of dung of Warthog in sector K4, Savanna Habitat. Length: 4 mm.

Species TTT

This tunneller was found in one sample of dung from Warthog in sector K4 – Savanna habitat. Length: 11 mm.

Species UUU

This species were found in two samples from sector K4 – Savanna habitat. One of the samples came from dung of Warthog; the other came from dung of Impala. Length: 9 – 11 mm. Tunneller.

Species VVV

Species found in dung of Warthog in sector K4 – Savanna habitat. Length: 9 mm.Tunneller.

Species WWW

Found in dung of Elephant in sector M1 – Riverine forest. Length: 12 mm. Tunneller.

Species ÆÆÆ

Found in dung of Elephant at A1-R1 road – Miombo forest. Length: 11 mm. Tunneller.

Species ØØØ

Tunneller found in dung of Elephant at A1-R1 road – Miombo forest. Length: 11 mm.

Species ÅÅÅ

Tunneller found in dung of Elephant at A1-R1 road – Miombo forest. Length: 11 mm

Species A4

Tunneller found in dung of Elephant at the A1-R1 road – Miombo Woodlands. Length: 8 mm.

Species B4

Tunneller found in two samples in dung from Elephant at A1-R1 road – Miombo forest. Length: 7 mm.

Species C4

Tunneller found in one sample of bones of a Hippo in Miombo forest. Length: 4,5 – 5,5 mm.

Species D4

Aphodiinae (Scarabaeidae) with length between 4 and 5 mm. This is another subfamily from the rest of the beetles presented here. They also feed on dung, but is a mainly Holarctic group with few representatives in Africa. The species was found in one sample of dung from Waterbuck in Manane – Floodplain habitat. Length: 4 mm.

Species E4

Tunneller found in dung from Waterbuck in Manane – Floodplain habitat. Length: 4 mm.

Species F4

Tunneller found in two samples of dung from Waterbuck in Manane – Floodplain habitat, and in one sample of dung from Elephant at Manane road – Miombo forest. Length: 4,5 mm

Species G4

Tunneller found in dung from Waterbuck in Manane – Floodplain habitat. Length: 3,5 mm

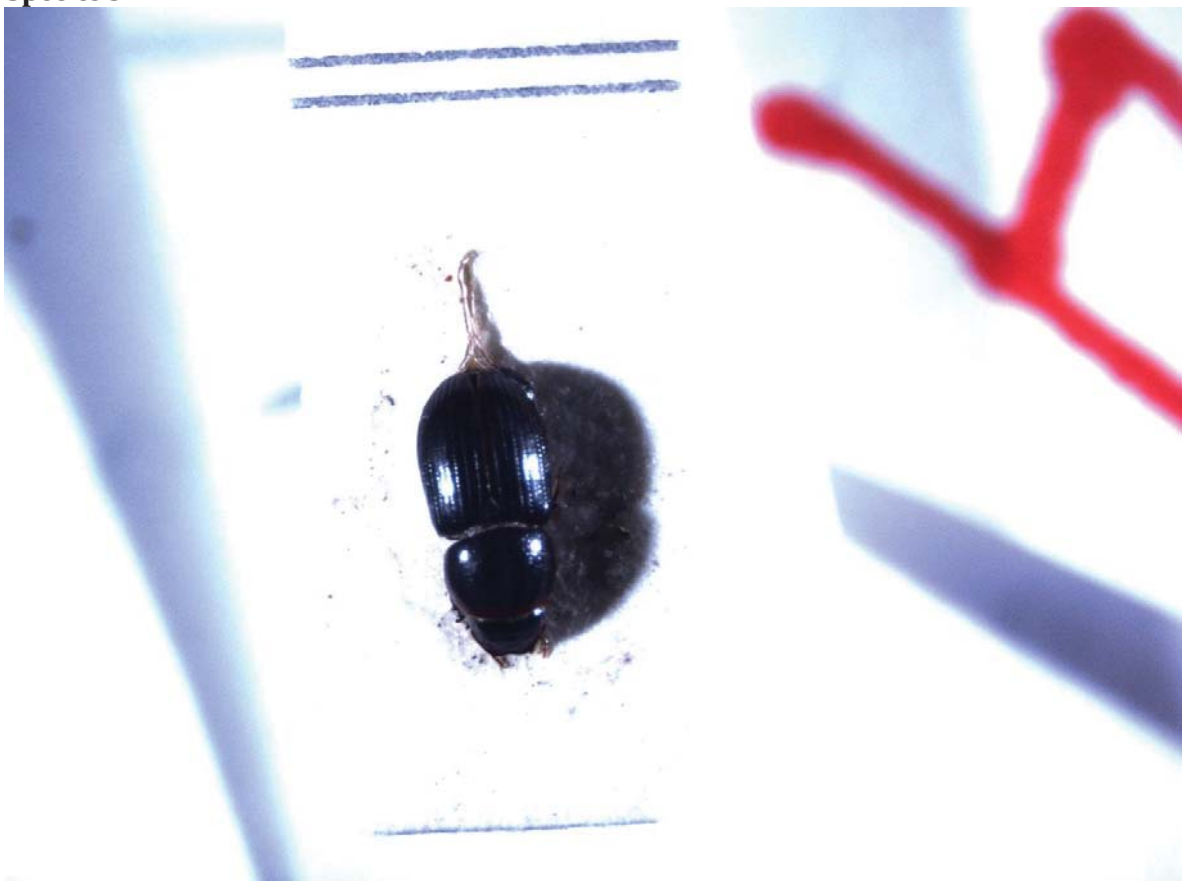
Species H4

Tunneller found in one sample of dung from Waterbuck in Manane – Floodplain habitat. Length: 8 mm.

Species I4

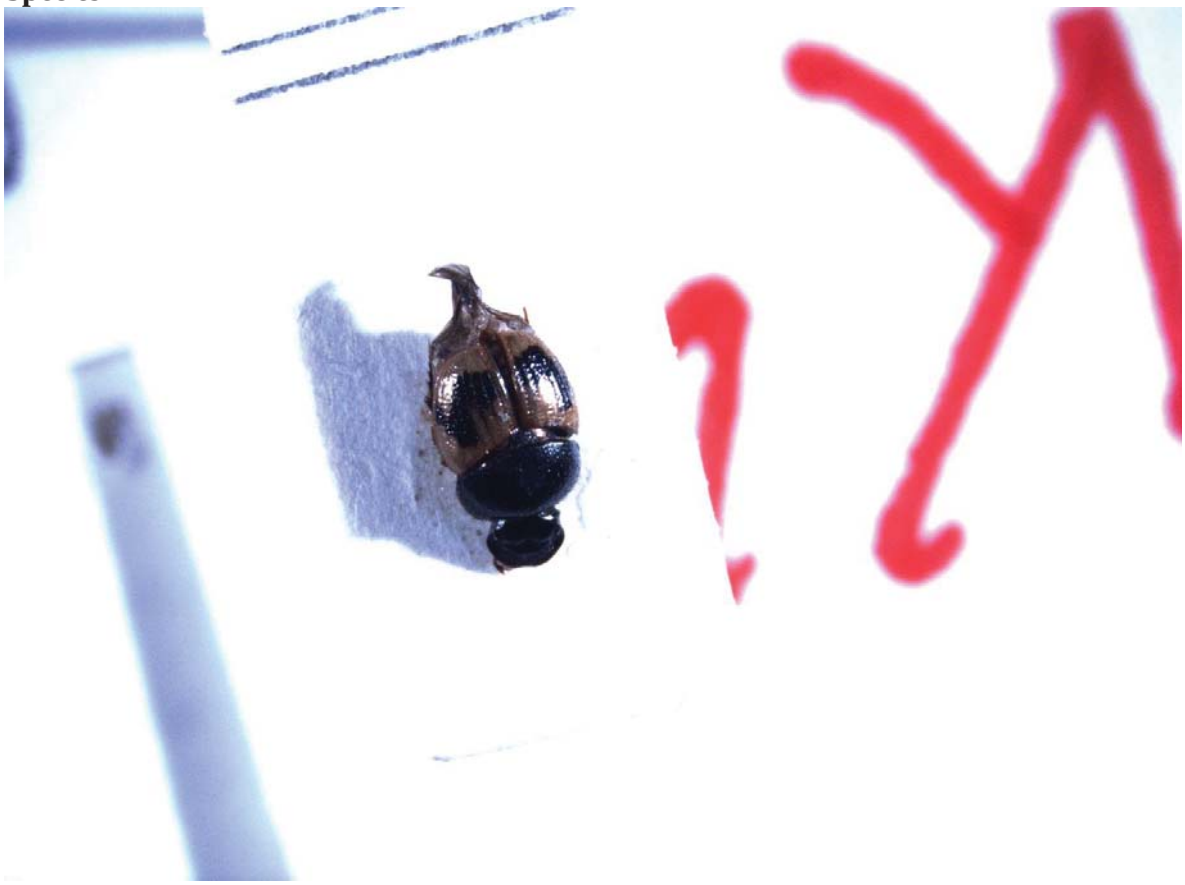
Aphodiinae (Scarabaeidae) with length between 4 and 5 mm. This is another subfamily from the rest of the beetles presented here. They also feed on dung, but is a mainly Holarctic group with few representatives in Africa. Found in one sample of dung from Waterbuck in Manane – Floodplain habitat. Length: 3 mm.

Species J4



Tunneller found in one sample of dung from Waterbuck in Manane – Floodplain habitat. Length: 4 mm.

Species K4



Tunneller found in one sample of dung from Waterbuck in Manane – Floodplain habitat. Length: 3,5 mm.

Species L4

Tunneller found in one sample of dung from Waterbuck in Manane – Floodplain habitat. Length: 6 – 7 mm.

Species M4

Tunneller found in one sample of dung from Elephant at Manane road – Miombo forest. Length: 8 mm.

Species N4

Tunneller found in one sample of dung from Elephant at Manane road – Miombo forest. Length: 3 mm.

Species O4

Tunneller found in one sample of dung from Elephant at Manane road – Miombo forest. Length: 4 mm.

Species P4

This Tunneller was found in one sample of dung from Elephant at A1-R1 road – Miombo forest. Length: 7 mm.

Species Q4

This Tunneller was found in one sample of dung from Elephant at A1-R1 road – Miombo forest.
Length: 10 mm

Species R4

Found in one sample of dung from Elephant in Manane – Floodplain habitat. Length: 6 - 7 mm. Tunneller.

Species S4

Found in one sample of dung from Elephant in Manane – Floodplain habitat. Length 5,5 mm. Tunneller.

Species T4

Found in one sample of dung from Elephant in Manane – Floodplain habitat. Length: 6 – 7 mm. Tunneller.

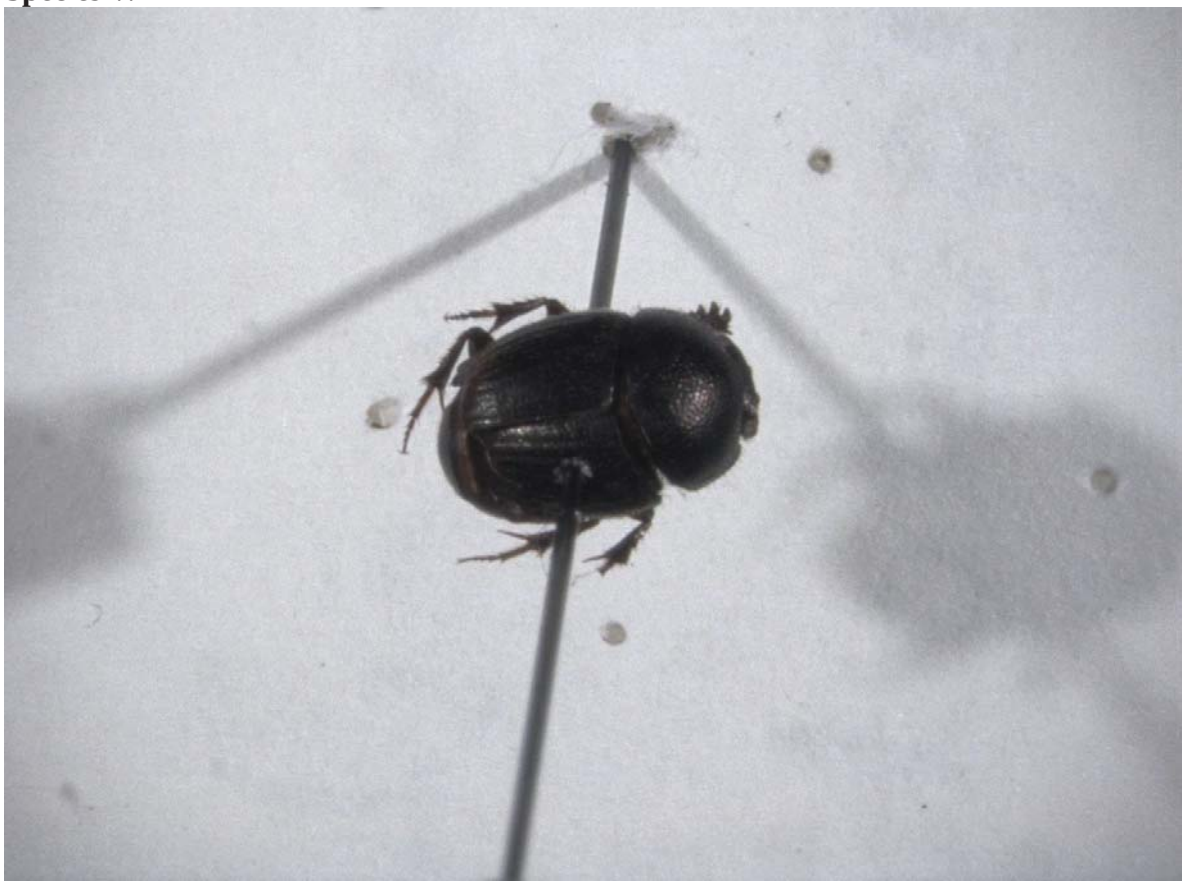
Species U4

Found in one sample of dung from Elephant in Manane – Floodplain habitat. Length: 9 mm. Tunneller.

Species V4

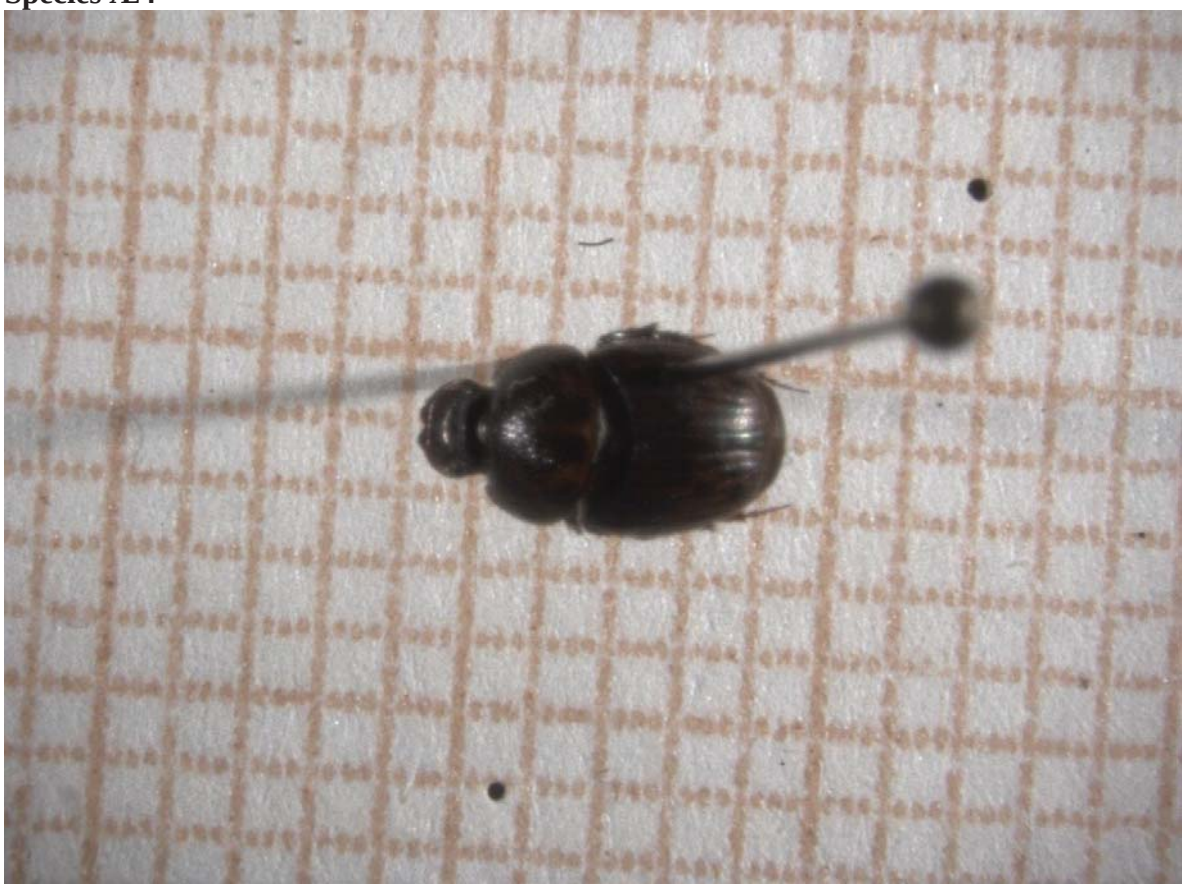
Found in two samples of dung from Elephant. One is in M1 – Riverine forest, the other one is from A1-R1 road – Miombo forest. Length: 7 mm. Tunneller.

Species W4



Found in one sample of dung from Impala in sector K4 – Savanna. Length: 5mm. Tunneller.

Species Æ4



Found in one sample of dung from Impala in sector K4 – Savanna habitat. Length: 6mm. Tunneller.

Species Ø4

Found under stomach content of dead Kongoni in K4 – Savanna. It had dug deep in. Length: 54 mm.