BRILL
Terrestrial Arthropod Reviews 7 (2014) 81–91
TAR
brill.com/tar

Cetoniinae (Coleoptera, Scarabaeidae) diversity of Bwindi Impenetrable National Park, Uganda and surrounding areas

Daniel C. Moore[1,*] and Jesús Orozco[2]

[1]2140 Dar es Salaam Place, Dulles, Virginia 20189-2140, USA
[2]Sebastian Kolowa Memorial University, Usambara Mountains, P.O. Box 370, Lushoto, Tanzania
*Corresponding author; e-mail: beetlemanx@yahoo.com
Received on June 6, 2014. Accepted on July 28, 2014. Last revisions received on August 21, 2014.

Summary
During the period of October 1996 to September 1999 cetoniine beetles were collected directly from the vegetation and using fruits traps and flight intercept traps in Bwindi Impenetrable National Park (BINP) and surrounding farmland. Additional records were obtained from collections. A total of 52 species were recorded. Information on collecting locality, distribution, ecology, seasonality, and collecting methods is presented for each species. Two species, *Eudicella allardi* (Marais & Holm) and *Pachnoda alluaudi* Bourgoin, are recorded for Uganda for the first time.

Keywords
Beetles; conservation; East Africa; endemics; fruit chafers; insects

Introduction

Bwindi Impenetrable National Park (BINP) is located within the Kigezi highlands of southwestern Uganda on the eastern edge of the Albertine Rift. The park is 330.8 km^2 in area and lies within the administrative districts of Kanungu, Kabale, Kisoro, and Rukungiri. With an elevation range of 1190-2607 m, BINP encompasses both lowland and afromontane forests (Fig. 1).

The park can be considered a moderate conservation success despite it being an isolated patch of forest and the political instability of the region within which it is located. Community involvement in conservation and government protection, even when only on paper, has proved to be a good combination for the protection of the park (Hamilton *et al.*, 2000).

Most of the zoological research conducted at the park is concentrated on mammals, especially chimpanzees and mountain gorillas, with little known for most insects. Some exceptions are Byarugaba 2004 (bees); Kajobe 2007 (bees); and Mutebi *et al.* 2012 (mosquitoes).

DOI 10.1163/18749836-07021076

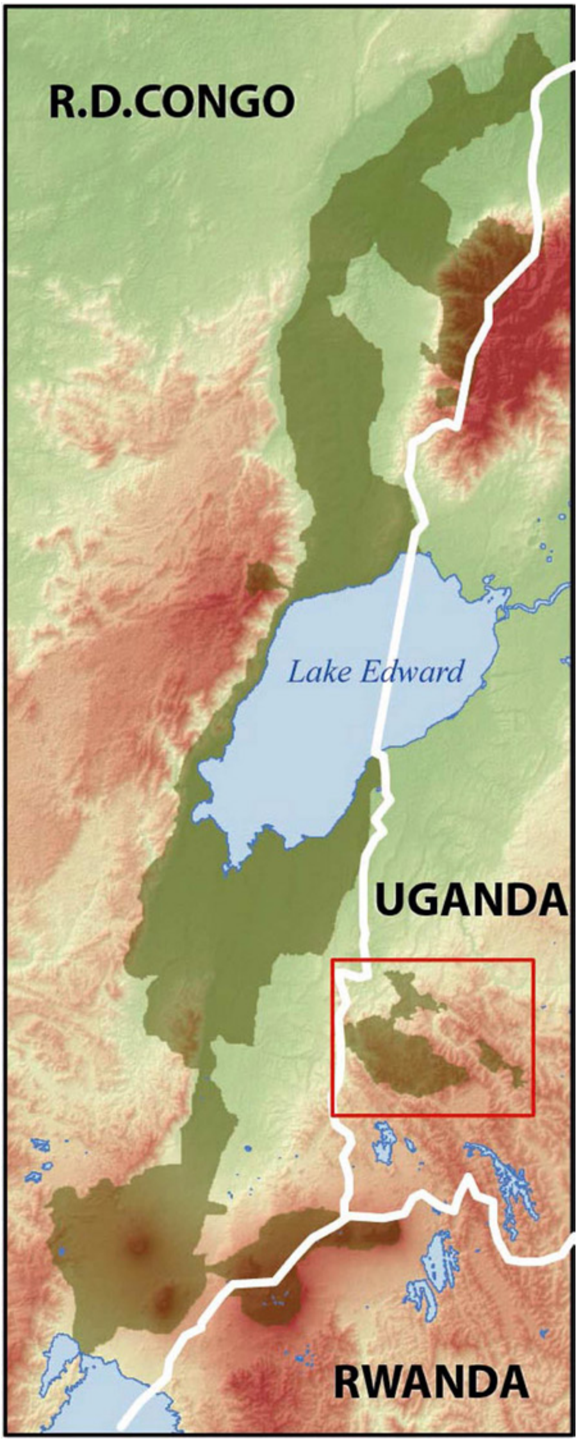

Figure 1. Location of the area of study. This figure is published in color in the online version.

As part of the ongoing biological inventory of the park coordinated by the Institute of Tropical Forest Conservation (ITFC), we designed a protocol to collect these beetles in the area. In addition to data on distribution, we also present ecological information related to feeding preferences, abundance, and precipitation.

Methods

Fruit traps baited with ripe banana were the primary method of collection. Traps consisted of 1 liter clear plastic bottles (either mineral water bottles or tennis ball containers) with drainage holes at the bottom and suspended from trees by fishing line. The fermenting bait was replaced as needed, sometimes staying in the trap for up to a month. Frequency of checking was different for each location due to practical limitations and is indicated below. Specimens were also collected in flight intercept traps (FIT) near Nteko and by direct inspection of vegetation. Hand collection was made by an ITFC field assistant and by the first author during periodic visits to Ruhija and Buhoma. Additional specimens were obtained from locals at various locations within the surrounding districts of Kabale, Kisoro, and Rukungiri (Kanungu District was split from Rukungiri District in 2001).

The fruit traps, 49 in total, were distributed as follows:

- Mubwindi Swamp Trail: Sixteen traps over approximately 5 km along the trailhead at Ruhija; ranging in elevation from 1500–2200 m; suspended from random trees at heights of 2–5 m; and checked every three days from October 1996 to August 1998. Ten additional traps were added in June 1997.
- Ruhija Road Trail: Six traps over 1 km descending from behind the field station into the park; ranging in elevation from 2100–2200 m; suspended from *Prunus africana* (Hook. f.) Kalm (Rosaceae), *Maesa lanceolata* Forssk (Primulaceae), *Albizia* sp. (Fabaceae), and *Croton macrostachys* Hochst. ex A. Rich (Euphorbiaceae) (tree species known to be visited by cetoniines), at heights of 5–10 m; and checked weekly from October 1998 to September 1999.
- ITFC Field Station: Five traps over 200 m along the Ruhija entrance; ranging in elevation from 2200–2250 m; suspended from random trees at heights of 1–3 m; and checked weekly from October 1996 to May 1997.
- Buhoma: Three traps near the Peace Corps Volunteer residence; at elevation 1200 m; suspended from random trees at heights of 2–3 m; and checked weekly during October 1996.
- Ruhija Road: Nine traps over approximately 10 km between the park boundary and Ruhija gate; ranging in elevation from 2200–2500 m; suspended from random trees at heights of 2–5 m; and checked monthly from October 1996 to February 1997.

Additional collection records were obtained from National Museums of Kenya, Entomology Collection (KNM) in Nairobi and from the Uganda Forestry Research

Institute Entomology Lab (FORI) at Forest Department Headquarters in Nakawa/Kampala (Table 1).

All collected and examined material was identified by the authors. Vouchers of all collected material are deposited in the authors' collections.

Taxonomy

The taxonomy of African Cetoniinae is a very dynamic field. Genera and species are constantly being synonymized or resurrected and new subgenera, species, and subspecies are continuously being described. Synonymized genera frequently come back as a subgenera, and species as subspecies. Most of these changes, seen from a positive perspective, and as unnecessary as some might seem, contribute towards the understanding of the morphological complexity of the group.

In this work we avoid as much as possible the use of subspecies as we consider most of them to be only color forms or part of the normal intraspecific variation. In contrast, our decision of not using subgenera in many cases does not reflect on their validity but to what we consider to be redundancy in a non-taxonomic paper. In some cases we make explicit the authority used when it does not correspond to the latest trend.

Results

Species diversity

A total of fifty-two species were recorded from BINP and neighboring areas (Table 1). Thirty-two species were collected in the park itself and thirty-eight species were collected from the three surrounding districts of Kabale, Kisoro, and Rukungiri.

Several species may be of conservation importance due to their limited distribution or rarity. Of special note are six afromontane species endemic to the Albertine Rift: *Caelorrhina babaulti* (Bourgoin), *Eudicella allardi*, *Eudicella ducalis* Kolbe, *Leucocelis abdita* Kolbe, *Diplognatha subaenea* Duvivier, and *Heteropseudinca arrowi* Valck Lucassen. Six species: *Caelorrhina gracilipes* (Moser), *Eudicella cupreosuturalis* (Bourgoin), *Eudicella ducalis, Pachnoda alluaudi, Phonotaenia tigrina* (Arrow), and *Heteropseudinca arrowi*, are not known from any other location in Uganda, and may be limited to BINP and surrounding areas in their distribution in the country. Two species had not been previously recorded in Uganda and constitute new country records: *Eudicella allardi* and *Pachnoda alluaudi.*

Abundance

During the duration of the study, 341 specimens were collected in the park. Additional specimens were collected from neighboring areas of the surrounding districts of Kabale, Kisoro, and Rukungiri but since there was no systematic collecting effort in those areas, data on abundance of the species were not recorded.

Most of the species were represented by only a few specimens, in most cases less than 10 (Table 1). The most abundant species was *Tmesorrhina runsorica* Arrow with 165

Table 1. Annotated species list of Scarabaeidae: Cetoniinae for BINP and surrounding districts.

TRIBE Species	Habitat[a]	Collecting locality[b]	Distribution[c]	Collecting method	Total
CETONIINI					
Leucocelis abdita Kolbe	U	Ruh	1?	manual	1
Leucocelis haemorrhoidalis (F.)	W	Ruh//Kit/RU	5, 6	manual	1
Leucocelis plebeja Kolbe	W	Buh/KA	8	manual	7
Pachnoda aemula Bourgoin	W	Kit/RU/KA/KI	6	manual	1
Pachnoda alluaudi Bourgoin	U	Ruh	2	fruit trap	1
Pachnoda cincticollis Moser	f	RU	3, 6	manual	x
Pachnoda ephippiata Gerstaecker	W	KI	6	manual	x
Pachnoda helleri Moser	f	Ruh/RU/KA	6	manual	8
Phonotaenia tigrina (Arrow)	FH	Ruh	1	manual	1
Polystalactica cf. *P. conspergata* Csiki	U	RU	3, 5, 6	manual	x
Rhabdotis sobrina (G. & P.)	W	RU	8	manual	x
Oxythyrea picticollis Kraatz	U	RU/KA	6	manual	x
Tephraea sternalis Moser	U	RU	3, 6	manual	x
CREMASTOCHEILINI					
Campsiura cf. *C. congoensis* (Bates)	U	Kig	3	KNM	x
DIPLOGNATHINI					
Diplognatha gagates (Forster) *	W	Ruh, RU/KI/KA	3, 4, 5, 6	manual	1
Diplognatha subaenea Duvivier	FL?	Nte	1, 7	FIT	1
Diplognatha viridula Janson	FL?	RU	6	manual	x
Heteropseudinca arrowi Valck Lucassen	FH	Ruh	1, 7	fruit trap	5
Niphetophora carneola Burmeister	W	Kit?/RU	8	manual	x
Porphyronota maculatissima (Boheman)	W	RU	3, 5, 6	fruit trap	x
Pseudinca marginicollis Valck Lucassen	FH	Ruh	3, 7	fruit trap	67
Pseudinca plicatus Kolbe	f	Nte/RU/KI	3	FIT	1
Pseudinca rufulus Kolbe	f	Ruh/KI/RU	3, 7?	fruit/manual	15

(*Continued*)

Table 1. (*Cont.*)

TRIBE Species	Habitat[a]	Collecting locality[b]	Distribution[c]	Collecting method	Total
GOLIATHINI					
Compsocephalus bayeri (Moser)	U	KA/RU	3, 7	FORI	x
Caelorrhina babaulti (Bourgoin)	FH	Ruh	6, 7	fruit trap	9
Caelorrhina gracilipes (Moser)	U	Buh	3, 7	fruit trap	1
Caelorrhina superba (Gerstaecker)	f	Buh	3	fruit trap	1
Chlorocala africana (Drury)	W	RU	8	fruit/ manual	x
Chlorocala inermis (Burgeon)	f	RU	3, 6	manual	x
Eudicella allardi (Marais and Holm)	f	RU	1, 7	fruit trap	9
Eudicella cupreosuturalis (Bourgoin)	FH	Ruh	3, 7	fruit trap	7
Eudicella ducalis Kolbe	U	Ruh	1, 7	fruit trap	1
Eudicella gralli (Buquet)	f	Buh/RU	3	fruit trap	1
Eudicella selene (Kolbe)	f	Buh	3, 6	fruit trap	1
Eudicella hornimani quadripunctata (Allard)	f	Buh/RU/KI/ KA	3	fruit trap	4
Eudicella tetraspilota euthalia (Bates)	f	Ruh/RU/KA/ KI	2, 3	manual	16
Dicronorhina johnstoni Waterhouse	f	RU	3	fruit/ manual	x
Goliathus goliatus (Drury)	f	Kit	3, 4	manual	1
Lophorrhina overlaeti (Burgeon)	FL	RU	6, 7?	manual	x
Mecynorhina mukengiana (Kolbe)	f	Ruh	3	fruit trap	1
Taurhina stanleyi (Janson)	f	RU/KA	3, 6	manual	x
Pedinorrhina septa (Harold)**	f	Buh/KA/RU	3, 4	fruit/ manual	2
Pedinorrhina subaenea (Harold)**	f	RU	3	manual	x
Pedinorrhina cinctuta (Voet)**	f	RU	3, 4, 6	manual	x
Pedinorrhina plana (Wiedemann)**	f	RU	5, 6	manual	x
Pedinorrhina watkinsiana (Lewis)**	f	Buh	3	fruit	1

(*Continued*)

Table 1. (*Cont.*)

TRIBE Species	Habitat[a]	Collecting locality[b]	Distribution[c]	Collecting method	Total
Stephanorrhina adelpha Kolbe	f	RU	3, 6	manual	x
Stephanorrhina guttata (Olivier)	f	Buh	4	fruit	9
Stephanorrhina tibialis (Waterhouse)	f	RU	3, 6, 7?	manual	x
Tmesorrhina iris (F.)	U	Ruh	3, 4	fruit trap	1
Tmesorrhina laeta Moser	FL	Buh/RU	3, 4	fruit trap	1
Tmesorrhina runsorica Arrow	FH	Ruh/Buh/RU	6, 7?	fruit trap	165

[a] F: Forest, FH: Highland forest, FL: Lowland closed forest, f: Forest edge/woodland, S: Wetland, O: Open habitat, W: Widespread, U: Unknown.
[b] Ruh: Ruhija/BINP, Buh: Buhoma/BINP, Nte: Nteko/BINP, Kit: Kitahurira/BINP, KA: Kabale District, KI: Kisoro District, RU: Rukungiri District, Kig: Kigezi, non-specific.
[c] 1: Albertine Rift Endemic, 2: Lesser East Africa, 3: Central African Forest Belt, 4: West Africa, 5: Southern Africa, 6: Greater East Africa, 7: Afromontane, 8: Afrotropical.
x represents species collected outside the park were data on abundance was not recorded.
* The separation of this species into two subspecies is unwarranted. The presence of 1–2 mesotibial spines frequently used to separate these two together with body size and sculpturing only constitute intraspecific variation. The lack of genitalic differences and their sympatric distribution in our study area, and in other areas of the continent, are important evidence regarding the conspecificity of these two.
** The genus *Pedinorrhina* Kraatz is here considered *sensu* Holm (1994).

specimens, representing almost 50% of all specimens collected. The next more abundant taxa were *Pseudinca marginicollis* Valck Lucassen with 67, *Pseudinca rufulus* Kolbe with 15, and *Eudicella tetraspilota euthalia* (Bates) with 16 specimens. *Pseudinca marginicollis* has been considered rare (Rigout and Allard, 1992) but can be easily collected in the highland closed forest of the park using fruit traps (*Pseudinca marginicollis* is also common in North Kivu, DRC. Sébastien Rojkoff, personal communication).

Seasonality

The park's annual precipitation ranges from 1130–2390 mm, with rainfall peaks from March to May and from September to November. Annual rainfall amounts at Ruhija during the years of the study were 1611 mm (1996), 1402 mm (1997), and 1135 mm (1998). Late 1996 and early 1997 were characterized by higher than normal rainfall due to *El Niño* events.

Adult cetoniines were present during the entire study period and most species were active year-round in the park, with some variation in their abundance. The constantly warm and humid environment and the food availability in these forests can support the year-long activity of the beetles. In addition, cetoniine-preferred flora (Table 2) produces flowers, fruit, or sap at some point during the year. In contrast, we have

Table 2. Plant species where cetoniines were frequently found.

Species	Part
Albizia sp.	sap and flowers
Bothriocline tomentosa (Oliv. & Hiern)	flowers
Crassocephalum sp.	flowers
Croton macrostachys Hochst. ex A. Rich	sap
Maesa lanceolota Forssk	sap and flowers
Pennesetum purpureum Schumach	sap
Prunus africanus (Hook. f.) Kalkman	sap
Syzygium guineense (Willd.)	sap
Vernonia amygdalina Delile	sap and flowers
Vernonia auriculifera Hiern	sap and flowers
Vernonia sp.	sap and flowers

observed that in woodland and savannah ecosystems in Uganda, seasonality is more evident and starts to become less apparent as one moves towards more humid areas.

Abundance versus precipitation at Ruhija during the 27-month period from September 1996 to November 1998 is presented in Fig. 2. No strong correlation was observed between precipitation and number of individuals collected during this 27-month period. Nevertheless, the average number of beetles collected during high (>150 mm) and low precipitation (<60 mm) months was lower (7 and 2.4 respectively) than during months with average precipitation (60–150 mm) (11.7 beetles on average). In general, strong rains or no rains affected negatively the number of specimens collected but we did not find a strong correlation. This same pattern was noted over shorter periods of time (*i.e.* less than one month), where cetoniine activity decreased during periods of constant rainfall as well as during extended dry periods.

In other geographic regions, the situation is known to be different. For example, in southern Benin and Burkina Faso, Cetoniinae abundance is indicated to be higher after the rainy season (Touroult and Le Gall, 2012; Akoudjin *et al.*, 2011), while in Guiana cetoniine abundance appears to be higher during the dry season and correlated with insolation (Touroult and Dalens, 2010). As indicated by Mudge *et al.* (2012), life histories and seasonal phenology of cetoniines are diverse and poorly known. Also, due to only a few specimens being collected for most species, this pattern represents the seasonality pattern of only the species with highest abundance.

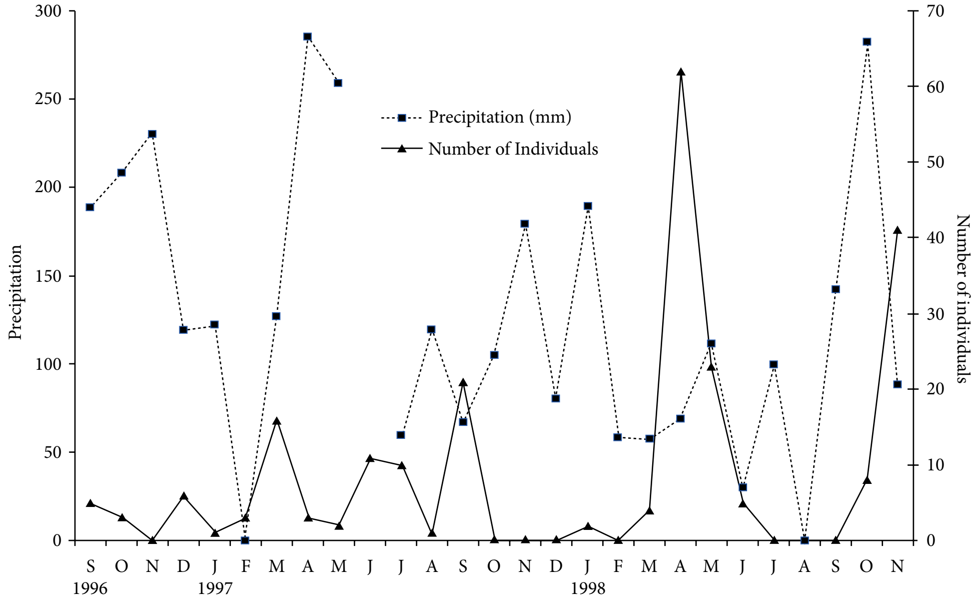

Figure 2. Precipitation *versus* Cetoniinae abundance for BINP/Ruhija from September 1996 to September 1998 (No precipitation data was available for June 1997).

General ecological observations

Inside the park elephants, monkeys, and mice were a constant threat to our collecting effort. Elephants would knock down trees holding the traps while both monkeys and mice would constantly steal the bait from the traps.

Based on their exclusive presence in forested habitats during the three years of sampling, ten species can be considered forest specialists in BINP: *Caelorrhina babaulti* (Bourgoin), *Eudicella cupreosuturalis, Lophorrhina overlaeti* (Burgeon), *Tmesorrhina laeta* Moser, *Tmesorrhina runsorica, Phonotaenia tigrina, Diplognatha subaenea, Diplognatha viridula* Janson, *Heteropseudinca arrowi,* and *Pseudinca marginicollis.*

Cetoniines have been studied as possible bioindicators in several geographic regions (Bouyer *et al.*, 2007; Mudge *et al.*, 2012; Touroult and LeGall, 2012; Puker *et al.*, 2014) but the lack of knowledge on the ecology of most of the species has been one of the limiting factors for the unquestionable application of this idea. Table 1 shows the preferred habitats for the collected species. In BINP, species with code *FH*, or *FL*, including the common *T. runsorica* and *P. marginicollis*, are forest specialists. Species with code *f* are frequently found in the forest edge/woodland. In the park, presence or absence of these species can be correlated with forest health. Areas with a high number of *FH* or *FL* species we consider to be undisturbed, while those with high numbers of *f* species we consider to be fragmented or disturbed. Through time, an increasing number of *F* species can be used as an indicator of recovery/regeneration due to the increasing habitat available for forest-dependent species; while an increasing number of *f* species would indicate forest degradation (due to increasing habitat for forest-edge/

woodland species). Changes in abundance can also be correlated with forest health. However, such changes must necessarily be interpreted over the long term, given the high variability in cetoniine activity, and the interpretation of the data strongly depends on our knowledge of the biology of the species.

Discussion

Half of the species in this study were collected solely by hand, and not by any trapping method. Many species in the Cetoniini and Diplognathini tribes (*v.g. Diplognatha* spp. and *Leucocelis* spp.) are not readily attracted to fruit traps. For these tribes, and for other cetoniines in general, a greater emphasis on hand collection will likely yield additional species. More specialized collection methods like ant and termite nests inspection and light trapping would be required for the Cremastocheilini. Additional species are likely to be found in the lowland parts of the park (e.g. Buhoma, the 'Neck', and northern sector) by the use of alternative collection techniques.

Acknowledgements

We thank Venance Betowabo, ITFC Field Assistant, for maintaining our Mubwindi Swamp trail and Ruhija Road Trail traps. Dan Gallagher, Peace Corps Volunteer, is also thanked for maintaining our Buhoma traps during the study. We thank ITFC and Simon Jennings (ITFC Director during the period of the study) for including this study as part of BINP biological inventory work and for providing the rainfall data for Ruhija. The comments of Jorge Santiago-Blay, Sébastien Rojkoff, and five anonymous reviewers greatly improved the quality of the manuscript.

References

Akoudjin, M., J. César, A. Kombassere and J. Bouyer. 2011. Spatio-temporal variability of fruit feeding insects used as ecological indicators in West Africa. Bois et Forêts des Tropiques 308:21–32.

Bouyer J., Y. Sana, Y. Samandoulgou, J. Cesar, L. Guerrini, C. Kabore-Zoungrana and D. Dilieu. 2007. Identification of ecological indicators for monitoring ecosystem health in the trans-boundary W Regional Park: A pilot study. Biological conservation 138:73–88.

Byarugaba, D. 2004. Stingless bees (Hymenoptera: Apidae) of Bwindi Impenetrable Forest, Ugana and Abayanda indigenous knowledge. International Journal of Tropical Insect Science 24:117–121.

Hamilton, A., A. Cunningham, D. Byarugaba and F. Kayanja. 2000. Conservation in a region of political instability: Bwindi Impenetrable Forest, Uganda. Conservation Biology 14:1722–1725.

Holm, E. 1994. On the Genera of African Cetoniinae 1: The Genus *Pedinorrhina* Kraatz and Related Taxa (Coleoptera: Scarabaeidae). The Coleopterists Bulletin 48:19–29.

Kajobe, R. 2007. Pollen foraging by *Apis mellifera* and stingless bees *Meliponula bocandei* and *Meliponula nebulata* in Bwindi Impenetrable National Park, Uganda. African Journal of Ecology 45:265–274.

Mudge, A. D., J. Orozco, T. K. Philips and P. Antoine. 2012. The cetoniine fauna of the Upper Guinean forests and savannas of Ghana (Coleoptera: Scarabaeidae: Cetoniinae). Terrestrial Arthropod Reviews 5:113–174.

Mutebi, J-P., M. B. Crabtree, R. C. Kading, A. M. Powers, J. J. Lutwama and B. R. Miller. 2012. Mosquitoes of Western Uganda. Journal of Medical Entomology 49:1289–1306.

Puker, A., H. L. Ad'Vincula, V. Korasaki, F. N. F. Ferreira and J. Orozco. 2014. Biodiversity of Cetoniinae beetles (Coleoptera: Scarabaeidae) in introduced and native habitats in the Brazilian Atlantic Forest. Entomological Science: 17:309–315.

Rigout, J. and V. Allard. 1992. Cetoniini 2. Les Coléoptères du Monde. Sciences Nat, Venette, France. Volume 12. 100 pp.

Touroult, J. and P. H. Dalens. 2010. Cétoines de Guyane: variations saisonnières et interannuelles (Coleoptera, Scarabaeoidea, Cetoniinae). In: TouroultJ. (ed.) Contribution à l'étude des coléoptères de Guyane. Tome I, pp. 81–88. Supplément au Bulletin de liaison d'ACOREP-France "Le Coléoptériste". ACOREP-France.

Touroult, J. and P. Le Gall. 2012. Fruit feeding Cetoniinae community structure in an anthropogenic landscape in West Africa. Journal of Insect Conservation 17:23–34.