Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(2): 2637-2640

Received: 15-01-2018
Accepted: 19-02-2018

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Dung beetle distribution, abundance, and diversity along an elevation gradient in Nyungwe National Park, Rwanda: A preliminary survey

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Abstract
This study presents a preliminary assessment of the abundance, distribution, and diversity of dung beetles in different elevation bands of Nyungwe National Park, Rwanda. Baited pitfall traps were used on transects at each elevation band from 1800m to 2800m. During this study 162 individuals were recorded in over 90 traps. Individuals were placed into eight different species categories based on morphological traits. Dung beetle species richness was highest at the lower elevations sampled and declined with higher elevation samples. These findings support the previous studies showing that dung beetles are not evenly distributed along an evelational gradient.

Keywords: Elevational gradient, Scarabaeidae

1. Introduction
Dung beetles are among the diverse array of insects that play a significant role in tropical rain forest ecology [1]. They are classified in the order Coleoptera, family Scarabaeidae and subfamily Scarabaeinae, which comprise a well-studied and widely distributed group. Dung beetles (Scarabaeidae: Scarabaeinae) represent excellent focal organisms for studying the effects of anthropogenic disturbance on diversity and ecosystem function in tropical forests [2]. They help reduce larval populations of parasitic flies present in fresh dung of mammals. Secondary to primates and other seed dispersers, dung beetles play a role in seed dispersersal and their behavior of burying dung along with the seeds defecated by frugivorous vertebrates is ubiquitous in tropical and subtropical regions [3]. They participate in natural processes of forest regeneration around the world because they consume and bury large amounts of dung and seeds as adults and larvae [4].
Several surveys have shown that elevation, mountain ranges, and structure of vegetation, frequently relate to changes in species composition of large mammals, and this can be a primary factor that affects the organization of dung beetle communities in tropical rainforests [5]. The Nyungwe National Park in Rwanda is a tropical mountain forest rich in endemic species and high in biodiversity. It no longer has an assemblage of large mammals such as buffalo and elephant [6] and the associated loss of dung production may negatively affect the number of dung beetle species present in the community. The diversity of forest types across elevation gradients may also affect the distribution, diversity and abundance of dung beetles in Nyungwe National Park (NNP). Understanding the influence of elevation on species distribution is a key issue in the study and conservation of tropical forest [7].
The main purpose of this study was to carry out a preliminary assessment of the diversity and distribution of dung beetle communities in different elevation bands of NNP. The specific objectives were to compare the influence of elevation on the abundance, diversity, and distribution of dung beetles species. The hypotheses of the study are the following: i**)** Forest types have an effect on the dung beetle distribution. ii**)** Dung beetles are more abundant in low elevation bands than medium and high elevation sites; iii**)** The low elevation band contains a higher variety of dung beetle species than higher elevations.

2. Material and Methods
This study was conducted in mountain rainforest of Nyungwe National Park located in southwestern Rwanda between 2˚15'-2˚55' S and 29˚00' -29˚30'E. Nyungwe National Park covers about 1013 km^2, and ranges in elevation from about 1600m up to almost 3000m.

It is in continuity with Kibira National Park, Burundi, making it the largest contiguous block of montane tropical forest in Africa [8, 9]. The Nyungwe forest is located in the Albertine Rift, a biodiversity hotspot, and has a wide diversity of fauna and flora [9]. It is thus a priority for conservation in Africa. We sampled along three elevation bands in Nyungwe National Park (Figure 1).

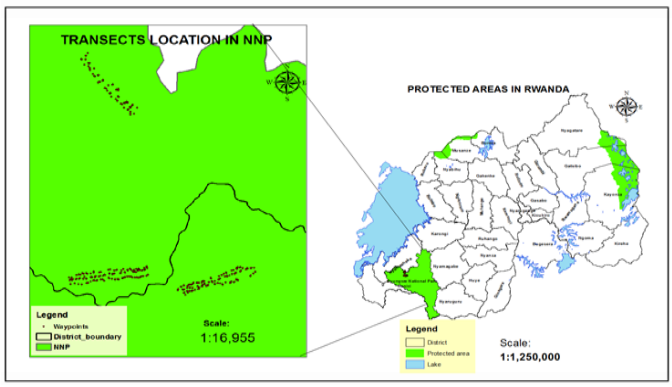

Fig 1: Map of study areas in Nyungwe National Park, Rwanda

Dung beetles were sampled using baited pitfall traps laid along three different elevation bands in NNP for capturing dung beetles during the long rainy season from April to May 2015. Sampling was carried out in three different elevation bands which were classified as Low Elevation Band (LEB) 1800-2000 m; Medium Elevation Band (MEB) 2000 m- 2400 m and High Elevation Band (HEB) up to 2800m. We sampled along three 1km transects at each elevation band which were placed parallel along contour lines, each transect separated by 50m.

Baited pitfall traps consisted of a plastic basin (210 mm in diameter and 150 mm in depth), buried to its rim (15cm depth) in soil and containing a water-formalin-liquid soap mixture in the bottom of the trap, and 20-30 g of fresh human or cattle dung which was placed on a strip of wire grid (2.5 cm × 2.5 cm) at the top of the basin [10, 11].

The baited pitfall traps were placed every 100 m along each transect for a total of 10 traps per transect, 30 traps per elevation, and 90 traps in total across all study sites of the three elevation bands. Traps were set out in the morning and trapped individuals were extracted from traps during the following morning, 24 hours later. At each trap site, we recorded the forest habitat type covering the trap location, using these general forest type categories: closed canopy, open canopy, wet valley bottom, and fern opening.

The collected beetles were oven dried and then identified using morphological differences and placed into species categories based on their visible morphological differences with the help of identification keys and previous studies from other forests [12, 13, 14]. The Shannon index was used to calculate species richness [15]. We also calculated the Evenness index which shows how species are distributed in a community and ranges from 0-1[16].

3. Results

In total, 163 individuals were recorded during the study and all individuals captured were grouped into a morphological category, resulting in eight morphological species groups. Each different species captured based on morphological differences was given an alphabetic letter as a code name, which helped in the analysis. The eight categories with possible species names are A (*Canton tringularis*), *B (Diplognatha gagates), C (Scarabaeus confus), D (Kheper nigroaeneus), E (Scarabaeus galenus), F (Scarabaeus laticollis), H (Galerita orientalis)* and G (*Padabrus pruinososus*). These species identifications have not been confirmed.

Out of the nine transects and 90 traps spanning four different forest types, the majority of traps (51%) were in closed-canopy forest. All evelations had traps in each forest type expect low elevation which had no traps in fern openings (Table 1).

Table 1: Distribution of traps in the different forest types by elevation in Nyungwe National Park. Rwanda

Forest type	Low	Medium	High	Totals/ traps	%
Closed canopy	23	8	15	46/90	51%
Fern opening	0	15	4	19/90	19%
Open canopy	5	3	9	17/90	9%
Wet valley bottom	3	2	3	8/90	21%
Grand Total	31	28	31	90	100%

Certain species (B, D, and F) were found only in closed canopy forest type, while species E was found in all habitat types sampled (Figure 2). The lowest elevation band had six different species with a higher number of individuals compared to the medium and high elevation bands (Figure 3). The dung beetles were more abundant at low (50% of all collected beetles) and medium (43%) elevations than at high (7%) elevation. Species E had the highest number of dung beetles (62.3%) of all individuals found (Figure 3). The Medium and Low elevation bands showed higher similarity (Figure 4) and high diversity of species (Table 2) compared to the High elevation band.

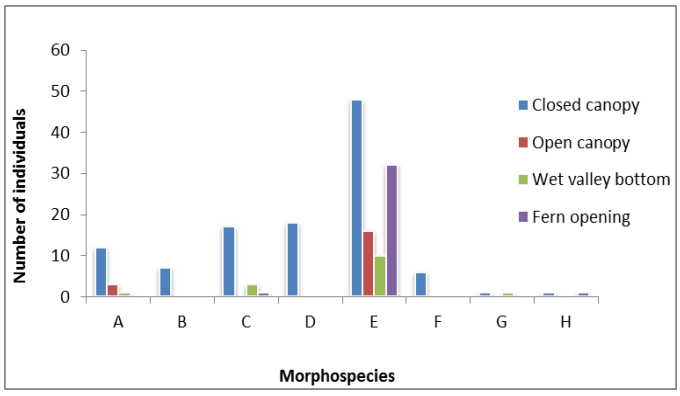

Fig 2: Dung beetle distribution in different forest types sampled in Nyungwe National Park, Rwanda.

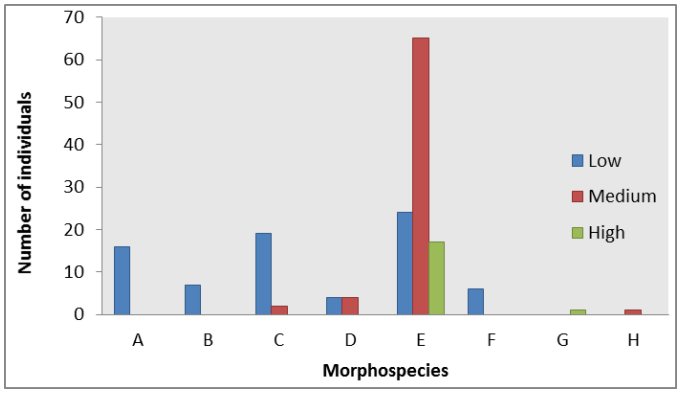

Fig 3: Dung beetle distribution in three elevation bands in Nyungwe National Park, Rwanda

Table 2: Shanonn Index and Evenness Index in each elevation band sampled

Location	Shannon index	Evenness
High	0.0093	0.045
Medium	0.179	0.086
Lower	0.701	0.337

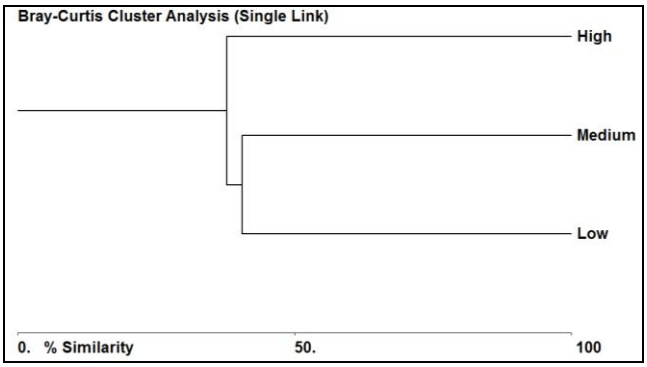

Fig 4: A dendrogram of species similarities among elevation band

4. Discussion

Our preliminary survey showed that dung beetle abundance, distribution, and diversity may be influenced by forest type. The closed canopy forest was most commonly sampled in this study, and had higher dung beetle diversity compared to other forest types sampled across all elevations. Closed canopy forest is often less disturbed forest compared to other forest types and, as well as the greater number of traps set in closed canopy, played a role in dung beetle abundance, which is consistent with a study conducted on rapid turnover and edge effects in dung beetle assemblages at Bolivian Neotropical forest savanna ecotone [17].

Conducting this research during the rainy saison likely has played a significant role in the distribution and abundance of dung beetles; dry season has been shown to have an impact in sampled species richness and abundance [1, 22]. A high abundance of dung beetles was recorded at low and medium elevations, and this may be related to greater primate presence in those two areas compared to higher elevation. Those two areas present a higher abundance of primate food trees such as *Carapa grandiflora*, *Newtonian buchananii*. *Symphonia globulifera*, and *Strombosia schefferi* as well as a higher density of lianes [6].

Overall, we found that dung beetle species richness showed a decrease from low elevation to high elevation. This may be caused by biotic (presence of primates, plants) and abiotic (temperature, humidity, sunlight) factors as well as species environmental tolerances [18]. Dung beetles have been suggested to be more adapted to warmer temperature conditions than to cold temperature conditions [19, 20]. Cluster analysis of species composition showed that the low and medium elevation bands were more similar to each other than those sampled at high elevation. One species was found to be widely distributed across the sampling sites. Other studies have found certain species to be more dominant than others [21]. This may indicate its adaptability to different habitats, environmental conditions, elevation gradients, and biotic factors.

5. Conclusion

This preliminary survey showed that dung beetle species may be distributed differently across elevation gradients in tropical montane forest. Forest types and availability of resources may be the influence on the dung beetle community distribution. The lowest elevation had higher species richness and higher number of individuals, which may be related to the abundance of primates and their feces. Further studies are needed to sample across more forest types and seasonal phases, and to identify species.

6. Acknowledgements

The authors are grateful to the Rwanda Development Board for permission to carry out this research in Nyungwe National Park. Great thanks to Protestant University of Rwanda (PIASS) for the liberal time provided to F.M. for writing up the manuscript for publication.

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