Altitudinal variation in small mammal distribution on Mountain Afadjato

Faustina Adu Boahene[1*], Bright O. Kankam[2], Jones Kpakpa Quartey[3] and Daniel K. Attuquayefio[1]

[1]Department of Animal Biology and Conservative Sciences, University of Ghana, Legon
[2]Forestry Research Institute of Ghana (CSIR-FORIG), Kumasi
[3]Center for African Wetlands, University of Ghana, Legon
***Corresponding author:** yaaasantewaa5@yahoo.com

ABSTRACT

The relationship between altitudinal variation and small mammal species composition, abundance and diversity was studied at Mountain Afadjato (~ 885 m) in the Volta Region of Ghana. The study focused on a test to determine if the mid-altitudinal pattern could be applied to Mountain Afadjato. Species composition, abundance and diversity were documented across four altitudinal gradients along the mountain. Forty-five Sherman collapsible live traps were used to capture small mammals in the wet and dry seasons. Two hundred and ten individual rodents belonging to four species, *Praomys tullbergi, Mastomys erythroleculus, Myomys* sp. and *Mus minutoides* were captured for a total of 2,208 trap nights. *Praomys tullbergi* was the most abundant species across the four altitudinal gradients. A decreasing species richness and diversity with increasing altitude pattern prevailed. Principal Component Analysis (PCA) revealed five microhabitat variables; herbaceous species density, diameter at breast height, number of holes on the ground, number of stumps, and soil temperature correlated with the distribution of small mammals.

Key words: Mid domain effect, species abundance, altitudinal gradient, small mammal, Mountain Afadjato

Introduction

The variation of species richness and relative abundance with altitude has been investigated by many ecologists (Bateman *et al.*, 2010; Caceres *et al.*, 2011; Li *et al.*, 2003; McCain, 2004, 2009b).

Hypotheses such as (i) changes in abiotic and biotic factors, (ii) decrease in richness with altitude or (iii) mid elevation peak (i.e. a hump-shaped pattern) (Taylor *et al.*, 2015) have been propounded to explain altitudinal variations in faunal characteristics. Most research has shown that the altitudinal patterns seem to vary among geographical regions and taxonomic groups (Bateman *et al.*, 2010).

Four factors are speculated to explain the small mammals' diversity along altitudinal gradient; thus, climate, habitat heterogeneity, species-area-effect and mid-domain effect (Caceres *et al.*, 2011; Sanchez-Cordero, 2001). This study focused on two of the factors: mid-domain effect and habitat heterogeneity.

The mid domain effect explains that the spatial limitations (e.g. base and top of the mountain) allow more species to overlap towards the centre of an area (McCain & Grytnes, 2010); thus creating a peak in species richness at mid-altitude (Colwell & Hurtt, 1994; Colwell & Lees, 2000). Species diversity increasing with habitat diversity is one of the hypotheses that explain the distributional patterns of small mammal along altitudinal gradients (Bateman *et al.*, 2010).

Most studies on the relationship between altitudinal patterns and small mammal diversity have been undertaken on relatively higher (>1,000 m) mountains (Li *et al.*, 2003; Sanchez- Cordero, 2001) elsewhere, but not in West Africa. Most of the biodiversity research on higher mountains followed the mid-altitudinal pattern in species richness and diversity (hump shape). Thus, species richness increases as altitude increases up to a certain point, creating a “diversity bulge” at middle altitude (McCain, 2005, 2010). Mountain Afadjato is relatively low (= 885 m) in comparison to other mountain areas where research has been undertaken and is therefore ideal for a study to test if the mid-altitudinal pattern applies to mountain Afadjato. Small mammals sometimes occur at one place or habitat but turn to use different habitats in that area (i.e. microhabitat partitioning). However, microhabitat partitioning as a generalize phenomenon requires more research to gain sufficient foundation on the spatial distribution and abundance of small mammals over time (Hodara & Busch, 2010; Jorgensen, 2004; Stapp, 1997) at different altitudes.

Small mammals are bioindicators, understanding their distribution, species richness and habitat variables in relation to altitude would help to improve knowledge of their conservation (Attuquayefio & Wuver, 2003).

Our objectives were to determine (i) whether the mid-altitudinal hypothesis, applies to mountain Afadjato (ii) whether small mammal species composition and diversity decline with increasing altitude, and (iii) which microhabitat variables affect small mammal distribution across different altitudinal gradients. We hypothesize that (i) small mammal diversity and composition will be higher in the mid-altitudinal gradient (hump shape) of the mountain (McCain, 2004, 2009a; Rahbek, 1995), and (ii) all nine microhabitat variables measured will influence small mammals composition and distribution.

Materials And Methods

Study Area

Mountain Afadjato, the highest mountain in Ghana, is about 885 metres above sea level (Owusu *et al*., 2005). This mountain is part of the Agumatsa range (0^0 15’-0^0 45’E; 6^0 45’-7^0 15’N) and has an area of about 12 km^2 (Figure 1). The area is locally under the management of the Gbledi and Fodome-Ahor Traditional Councils in the Hohoe District of the Volta Region of Ghana (Ofori *et al*., 2015).

Live-trapping and handling of captured small mammals

Small mammals were trapped live for four months, June to July 2016 and November to December 2016. Forty-five Sherman collapsible traps (23 cm x 9 cm x 7.6 cm) were set at the four altitudinal gradients:

- Base (< 200 m).
- Lower (200 m, 250 m and 350 m)
- Middle (400 m, 450 m, and 550 m)
- Upper (600 m, 650 m and 750 m)

Thirty-three traps were each set at the Lower, Middle and Upper altitudinal gradients (Figure 2) for four consecutive nights, whiles 12 traps were set at the base of the mountain for 13 consecutive nights. An eTrex Global Positioning System (GPS) was used to measure the transect distances, pick coordinates and altitudes. Captured individuals were weighed, sexed, aged, checked for reproductive condition, and marked by toe-clipping before release at the point of capture (Ofori *et al*., 2015). Captured small mammals were identified using Kingdon (2015) and Rosevear (1969) guide. The ano-genital distance, which is longer in males, was used to sex the animals. After weighing captured animals with Pesola light-line spring scales (10, 100 and 1000 g) with ± 0.3% accuracy, they were examined for reproductive condition (using the presence or absence of scrotal testes in males, and perforate/imperforate vagina, pregnancy and lactation in females). Photographs of the species were also taken. Standard morphometric measurements taken for each specimen were: the total body and tail length, head and body length, hindfoot length, ear length and weight (Hoffmann *et al*., 2010). Live trapping was important in this research because it allowed consistent monitoring of more than one species including elusive species at the same time (Flowerdew *et al*., 2004).

Measurement of Microhabitat Conditions

Selection of areas where species can potentially occur is important in small mammals microhabitat partitioning (Dalmagro & Vieira, 2005; Freitas *et al*., 2005; Price, 1978); therefore, data on nine microhabitat variables were collected and analyzed using Principal Component Analysis (PCA) to infer their influence on small mammals distribution (Table 1).

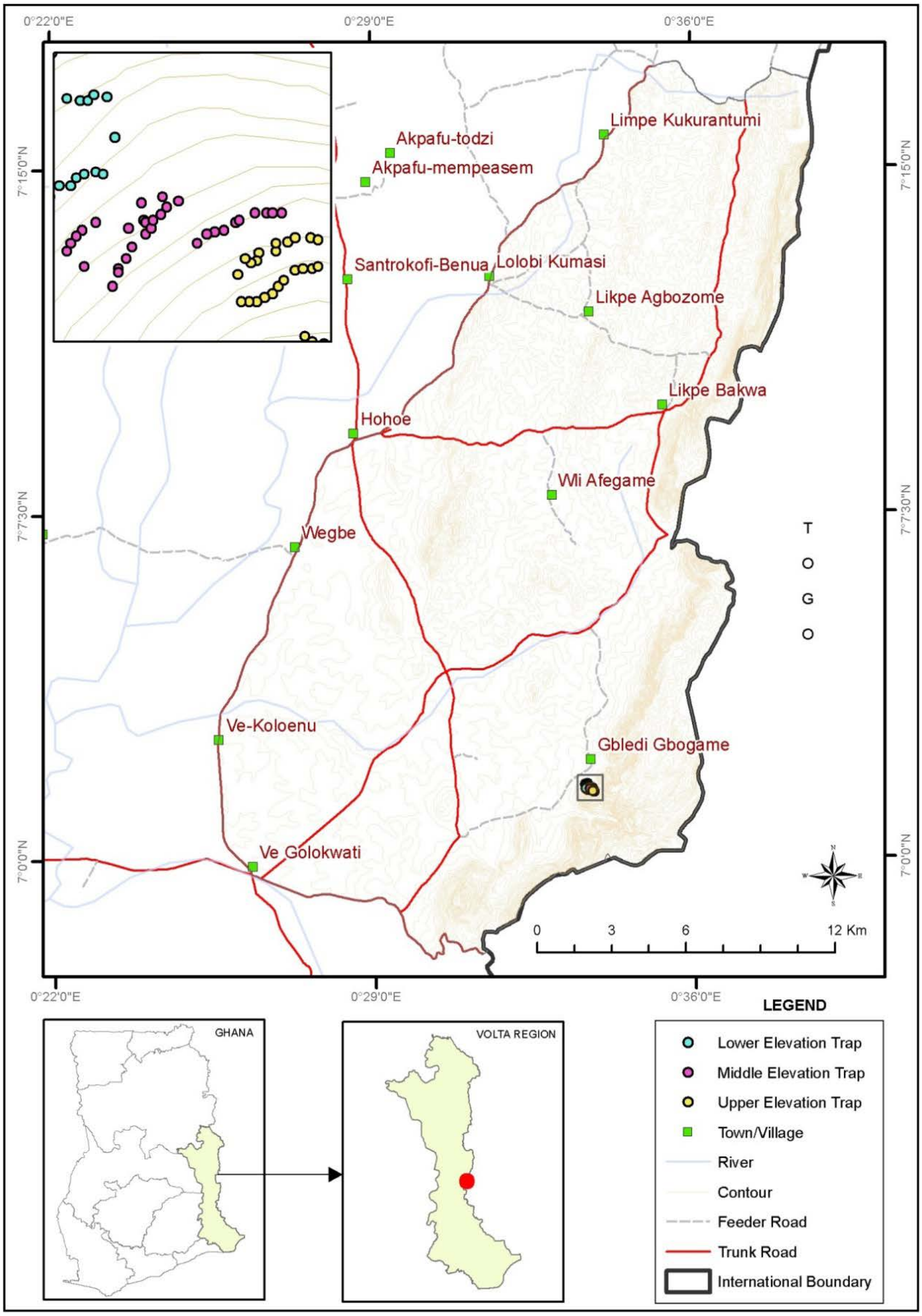

Fig. 1. Map of the study area, Afadjato
Source: Centre for Remote Sensing and Geographical Information System (CERGIS), University of Ghana (2017).

Table 1. Nine microhabitat variables recorded and used in the Principal Component Analysis

Variables	Computation
Woody Species Density (WSD)	Number of woody plants counted in a 5 m × 5 m quadrat per trap-station.
Herbaceous Species Density (HSD)	Number of herbaceous plants counted in a 5 m × 5 m quadrat per trap-station.
Distance to the Closest Tree (DIST):	Measure of tree dispersion, or the distance from a trap-station to the closest tree, measured within a circle of 5 m radius.
Diameter of Trees at Breast Height (DBH)	Measurement of the circumference of all trees within a 5-metre radius per trap-station, using a tape measure, and determination of the diameter using the equation d = C/π, where C = circumference of tree.
Leaf Litter Depth (LLD)	Measurement of average depth of litter from the surface of the leaf litter to the bare ground within a 5 m × 5 m quadrat, calculated using three replicates taken within the demarcated area.
Number of Holes (NOH)	Number of holes (burrows) in the ground, counted within a 5 m × 5 m quadrat per trap-station.
Number of Cavities on Fallen Logs (NOC)	Number of hiding places such as cavities in logs or trees and fallen logs, estimated within a 5 m × 5 m quadrat per trap-station.
Number of Stumps (NOS)	Number of stumps as a result of logging or natural tree fall, determined within a 5 m × 5 m quadrat per trap-station.
Temperature	Measurement of the mean ambient temperature at each trap station within a 5 m x 5 m quadrat, calculated using three replicates within the demarcated area.

Data Analyses

The relative abundance of small mammals was estimated as the number of animals caught per 100 trap-days. Capture success was also obtained by multiplying the total captures by 100 and dividing it by the sampling effort in trap-nights. The trap night was calculated as the total number of nights multiplied by the total number of traps and the number of days. The Shannon (H) index and the Simpson (D) index (Balčiauskas & Juškaitis, 1997; Krebs, 1999) were used to characterize species diversity of small mammal communities. Species richness was estimated based on the captured data using estimators (Chao 1, Chao 2) (Chao *et al*., 2000) from the program EstimateS version 13 (Colwell, 2013). Plymouth Routines In Multivariated Ecological Research (PRIMER) version 6.0 (Clarke & Gorley, 2005) was used to carry out a Principal Component Analysis (PCA) to examine the association between microhabitat variables and small mammals' species distribution. Spearman correlation was used to determine the relationship between the microhabitat variables measured and small mammal species richness at each altitudinal gradient. The criterion for statistical significance was $P < 0.05$.

Results

Species accumulation and sampling effort

Four species of small mammals were identified during the sampling period. The species accumulation curves plotted for the base of the mountain and the lower band showed a species richness of 4 and 3 respectively (Figure 2). The Chao1 and Chao2 estimators for these altitudinal zones levelled off. However, the curves plotted for the middle and upper bands did not level off (Figure 2).

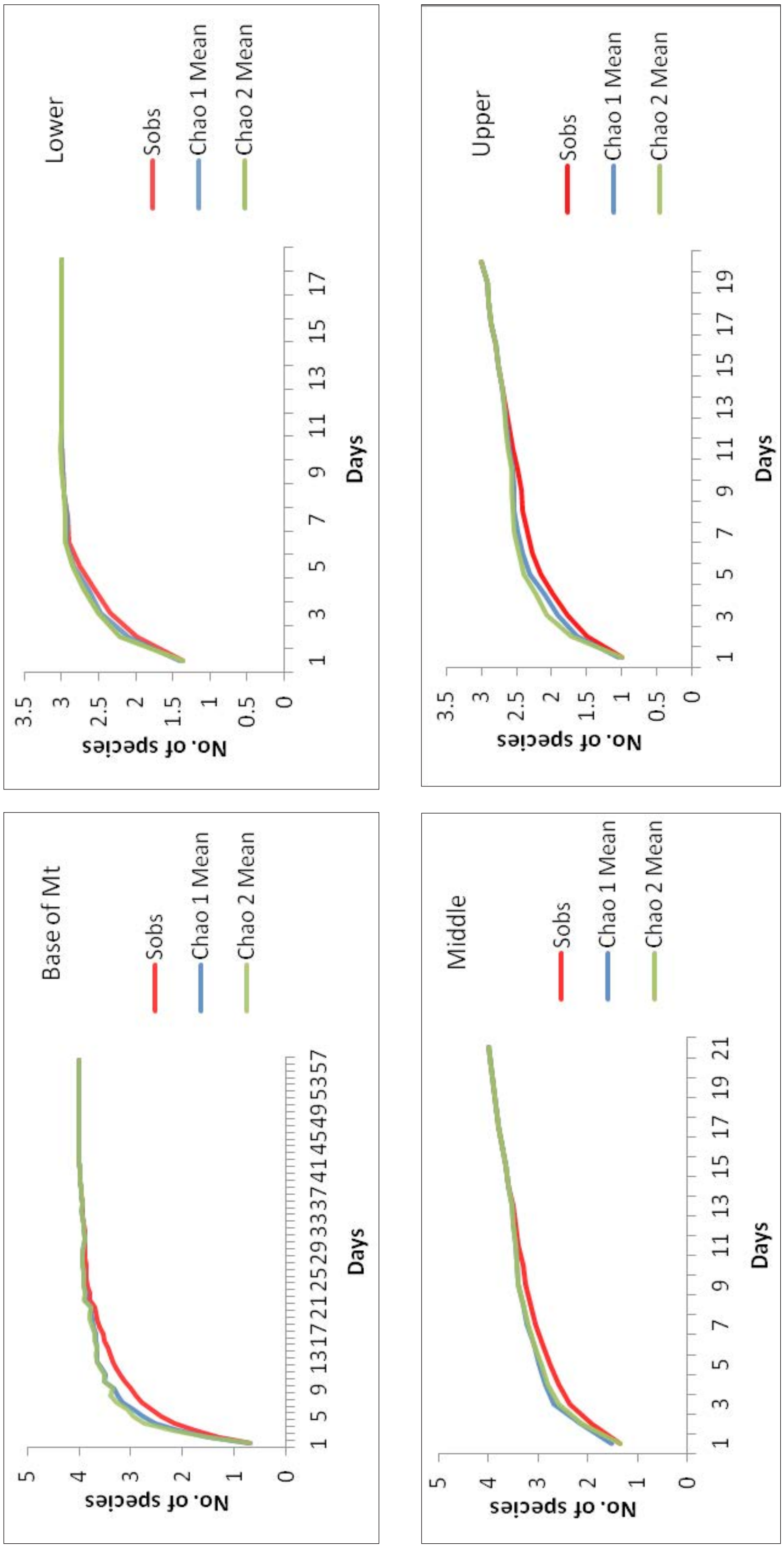

Fig. 2. Species accumulation curves for small mammal composition on each altitudinal gradient sampled

Species composition and diversity

A total of 210 individuals of four species of non-volant small mammals was captured from the Order: Rodentia, family Muridae and sub-family Murinae and Genera: *Praomys, Mastomys, Myomys* and *Mus*. Out of the 2,208 trap-nights, *Praomys tullbergi* (154) was the most abundant species (Kruskal – Wallis, H = 21.796; Chi-critical $_{(3, 0.05)}$ = 7.815; $p < 0.05$) accounting for 73.3 % of the total captures (154), followed by *Myomys* sp. (33), *Mastomys erythroleucus* (19), and *Mus minutoides* (4) accounting for 15.7 %, 9.1 % and 1.9 % respectively. The Lower gradient recorded the highest number of captures (Kruskal – Wallis, H = 11.156; Chi-critical $_{(3, 0.05)}$ = 7.815; $p < 0.05$). Overall trapping success was 9.5 %, with the trapping success across the various altitudinal gradients varying from 6.7 % (Base of mountain) to 13.8 % (Lower altitudinal gradient) which recorded the highest trapping success. The Middle altitudinal gradient recorded 11.6 %; while the Upper altitudinal gradient recorded the lowest trapping success (6.4 %) (Table 2).

Table 2: Small mammal capture at various altitudinal bands. (Values in brackets represent capture rate in %).

	Altitudes				
Species	**Base**	**Lower**	**Middle**	**Upper**	**Total**
Mastomys erythroleucus	7 (16.7)	6 (8.2)	5 (8.2)	1 (2.9)	19 (9.1)
Mus minutoides	3 (7.1)		1 (1.6)		4 (1.9)
Myomys sp.	13 (31)	8 (11)	5 (8.2)	7 (20.6)	33 (15.7)
Praomys tullbergi	19 (45.2)	59* (80.8)	50 (82)	26 (76.5)	154* (73.3)
No. of captures	42	73	61	34	210
No. of trap nights	624	528	528	528	2208
Trapping success (%)	6.7	13.8	11.6	6.4	9.5

* Significant differences at P<0.05

The Shannon-Weiner and Simpson's index showed that the Base of the mountain was the most diverse (Table 3). For Shannon-Weiner index, the second most diverse zone was the Middle part of the mountain whereas the least diverse zone was the Lower zone.

Table 3. Spatial variation in diversity of small mammals

	Altitudinal Zone			
Diversity indices	**Base of Mt**	**Lower**	**Middle**	**Upper**
H^I	1.209	0.6198	0.6587	0.6342
1-D	0.6667	0.328	0.316	0.372
Species richness	4	3	4	3
Abundance (N)	42	73	61	34

Relative abundance of small mammals and altitudinal variation

Relative abundance of small mammals was observed to be negatively related to increasing altitude (Figure 3). The relative abundance of *Mastomys erythroleucus* was the same for both the Base of the mountain and the Lower altitudinal gradient (Table 4). *Praomys tullbergi* however had the highest relative abundance (11.2 %) (Table 3). *Mus minutoides* had the lowest overall relative abundance of 0.2 % (Table 4).

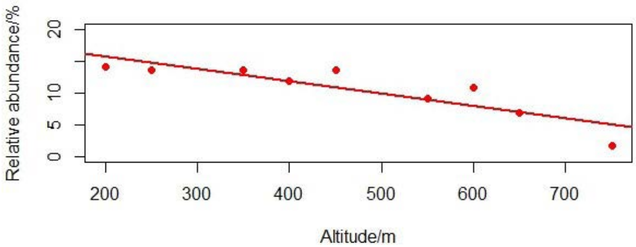

Fig. 3. Altitudinal variation in small mammals distribution.

($R^2 = 0.8$, p = 0.002; Relative Abundance (%) = 19.8 - 0.02 Altitude).

Table 4: Altitudinal relative abundance of small mammals

	Abundance at different altitudes				
Species	**Base**	**Lower**	**Middle**	**Upper**	**Total**
Mastomys erythroleucus	1.1	1.1	0.9	0.2	0.9
Mus minutoides	0.5		0.2		0.2
Myomys sp	2.1	1.5	0.9	1.3	1.5
Praomys tullbergi	3.0	11.2	9.5	4.9	7.0

Microhabitat Variables and Small Mammal Distribution

The first two principal components (PC1 and PC2) with eigen values 5.67 and 2.43 respectively accounted for a cumulative 90.0 % of the total variation of the data (Table 5). Five of the microhabitat variables; HSB, DBH, NOH, NOS and ST explained 96.7 % variation in the distribution of small mammals. However, in a Distance based linear model (DistLM), through a stepwise selection procedure and based on the Akaike Information Criterion (AIC) value (43.689), the most appropriate microhabitat predictors of the distribution of small mammals across the various altitudinal gradients were WSD and Holes (i.e. small mammals ~ holes + WSD; AIC = 43.689, $R^2 = 0.74$).

Table 5. Variables measured on all sampled sites at Afadjato

Variables	PC1	PC2
WSD		-0.355
HSD	-0.395	
DCT		-0.525
DBH		-0.637
LLD	0.386	
NOH	-0.402	
NOC	-0.35	
NOS		
ST	-0.378	
Eigenvalue	5.67	2.43
% variance explained	63.0	27.0
Cumulative % variance	63.0	90.0

Discussion

Species Composition and Diversity

A decreasing species richness and diversity with increasing altitude ($R^2 = 0.8$, p = 0.002) in this study, is consistent with research by Taylor and colleagues (2015) on Mts. Elgon, Rwenzori and Kilimanjaro but inconsistent with the mid-altitudinal peak pattern (Colwell & Hurtt, 1994; Colwell & Lees, 2000). It is likely that the inconsistent results from this study could be due to its relatively low mountain peak as compared to other research areas. The fact that the lower altitudinal gradient recorded the highest number of captures and individuals is due to the species-area relationship (SAR) which predicts that the base of the mountain would have more species than the mountain tops (McCain, 2007, 2010). Thus, there was a positive relationship between the species richness and altitude at Afadjato as predicted by species area relationship.

Mastomys erythroleucus and *Myomys* sp. are for the first time being recorded in the area. Previous small mammal studies recorded *Hylomyscus stella, Mus* sp. (GWS, 1998), *Crocidura crossei* (Ofori *et al.,* 2015). The absence of *Hylomyscus stella* and *Crocidura crossei* in this study is due to changes in the microhabitat condition of the area. The presence of the two new species (*Mastomys* sp and

Myomys sp) could be due to adoption of conservation initiatives such as bushfire prevention by the local people.

The mid altitudinal pattern predicts one pattern of diversity, a curved pattern with maximum diversity at the midpoint of the mountain. However, this study revealed a species decline in diversity with altitude.

Several microhabitat factors have been shown to influence the abundance and distribution of small mammals in different habitats (Cerqueira & Freitas, 1999; Mohammadi, 2010). From PCA results, the distribution of small mammals correlated with five microhabitat variables (HSD, DBH, NOS, NOH on the ground and ST). Corominas (1999) reported that vegetation cover influences the distribution and abundance of small mammals. Although the distribution of *Praomys tullbergi* has been observed to be influenced by leaf litter and dense vegetation (Decher *et al.,* 1999; Van der Straeten & Decher, 2008), it was observed from the PCA that abundance of this species may increase when leaf litter is absent. One of the probable reasons why leaf litter density did not influence small mammal distribution might be the low presence of predators in the study area; for example, only three snakes were recorded during the entire study period. The DistLM showed that the most important predictors of the distribution of small mammals were NOH and WSD. Several studies have also documented the importance of number of holes, especially as nests and hiding places for small mammals (Cerqueira & Freitas, 1999).

Conclusion

Praomys tullbergi, Myomys sp.*, Mastomys erythroleucus and Mus minutoides* were recorded in the study. The relationship between the altitudinal gradient and small mammal distribution at Mountain Afadjato indicated a pattern of declining species richness and diversity with increasing altitude. The study sought to address the question: Are observed patterns of small mammals richness consistent with the mid-domain hypothesis? Our research did not support this prediction. It however suggested that, a mid-domain effect can be linked to food chain length in terms of species richness (Prillwitz & Blasius, 2020). A combination of five microhabitat variables (HSD, DBH, NOS, NOH and ST) correlated with small mammal distribution on Mountain Afadjato.

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