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Original Research Paper

Spatial Dynamics of Rodent Population Trends in the Afro-Alpine Moorlands of the Bale Mountains National Park, South-Eastern Ethiopia

Anteneh Shimelis, Afework Bekele and Simon Thirgood*
Department of Zoological Sciences, College of Natural Sciences, Addis Ababa University, Addis Ababa, Ethiopia
*Macaulay Institute, Craigiebuckler, Aberdeen, AB15 8QH, United Kingdom
Corresponding Author: Anteneh Shimelis

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ABSTRACT

The main objective of this paper is explaining the spatial dynamics of rodent population in the Afro-alpine moorlands of the Bale Mountains National Park (BMNP). While assessing patterns of rodent abundance, species-specific relationships of abundance with habitat features were evaluated. The habitat variables were percent cover of vegetation and other structural features of the environment. The importance of habitat variables in explaining species-specific patterns in abundance was evaluated using regression modelling. The models were also used to make predictions and corroborate predictions. Percent cover of *Alchemilla* herbs came out to be the only habitat feature with significant contribution to the predictive value of each model built separately for *Arvicanthis blicki, Lophuromys melanonyx* and *Stenocephalemys albocaudata.* Each model then was used to produce estimates of abundance of each species using habitat data collected in 2007 and 2008. The resulting estimates correlated at high statistical significance with what was observed on the ground in both the years.

INTRODUCTION

The research was undertaken with the expectation of forming the basis for a broader understanding of the Afro-alpine ecosystem and using the knowledge to help underpin some conservation and management activities in the Bale Mountains National Park. Spatio-temporal variations in species abundance and distribution reflect the extent to which local environments meet the current niche requirements of a species (Sutherland 1996a, Pulliam 2000, Norris 2004, Sergio et al. 2004). In order to explain patterns in abundance and distribution, three main categories of predictors must be considered. These include, resource variables that represent consumed matter and direct gradients, which represent variables those have some physiological influence on the organisms and indirect gradients that include variables that do not have direct effect on the organism but have strong correlation with direct or resource attributes (Ricklefs 1990, Begon et al. 1996, Morrison et al. 1998, Krebs 2001, Meynard & Quinn 2007). Ecological studies often face difficulties in having complete data on species abundance and distribution. This may be because, the process of collection of ecological data is an expensive venture. To overcome such a hurdle, ecologists determine explanatory habitat variables that can be used to build statistical models to predict abundance or distribution of species to fill gaps in data availability. Usually, predictive modelling of species distribution utilizes presence/absence data as abundance data are absent in many cases (Meynard & Quinn 2007). In this study, data on abundance of species that are potential prey to raptors were collected along with habitat features in the Afro-alpine moorland ecosystem of the BMNP to explain, predict and corroborate predictions regarding abundance patterns. Rodents are the dominant herbivores on the Ethiopian Afro-alpine meadows with total biomass reaching 29 kg/ha (Yalden 1988, Yalden & Largen 1992, Sillero-Zubiri et al. 1995). Previous research has highlighted the importance of environmental constraints such as soil depth and temperature as factors explaining spatial variation in rodent density (Yalden 1988, Yalden & Largen 1992, Sillero-Zubiri et al. 1995). This research aims at explaining variation in rodent density by considering factors such as vegetation and other structural attributes of the environment in the Afro-alpine moorland ecosystem of the BMNP. Statistical models were used to predict the abundance of the common rodent species of the ecosystem to be compared with what was observed on the ground.

MATERIALS AND METHODS

The present study was carried out in the Bale Mountains National Park (BMNP) in the southeast plateau of Ethiopia. It is in the Bale Zone of Oromiya Region with the zonal capital, Goba, on the northeast side of the Park. The headquarters for the Park is on the northern border at Dinsho, which is 400 km by road from Addis Ababa. BMNP is located between 6°29' and 7°10'N, and 39°28' and 39°58'E. The area of BMNP covers 2200 km^2 varying in altitude from 500 to 4377 m above sea level (Hillman 1988). The Bale Mountains National Park is part of the Eastern Afro-Montane Biodiversity Hotspot and harbours the highest extent of protected Afro-alpine habitat on the African continent (Williams et al. 2004). It also includes the Harena Forest on the southern slopes which is the highest intact block of forest left in the country. Despite the extremes of temperature, exposure to high isolation and drying winds, the range of species in this habitat is high with the percentage of endemic well over the national figure of 12 percent. For example, of the seven species of stonecrop (*Sedum,* Crassulaceae) known in Ethiopia, five occur in Bale out of which three are endemic. As shown recently for Afro-alpine grasses, endemism is around 20 percent. However, grasses are open-pollinated plants and have widely dispersed species as compared to groups requiring insects or other animal pollinators. Within the moorland, two unique disturbed habitats exist for which special adaptations are required. These are patches of solifluction on the slopes, and areas inhabited by the giant molerat. The most striking plants are Giant Lobelia (*Lobelia geberroa*), and cushions of everlasting flowers (*Helichrysum* spp. particularly *H. citrispinum* and *H. splendidum*). There is a shrubby Lady's mantle, *Alchemilla haumannii,* which is an endemic to mountains of South Ethiopia. The ground between possesses an open vegetation with tussock grasses, sub-shrubs and herbs and up to thirty percent bare ground. The plants associated with the temporary and permanent lakes are similar at the generic level, with the species complements found in these alpine lakes in Europe and, to some extent, the Himalayas. The crevices and cracks in the lava flows at over 4,000 m providing shelter for several plants, including *Erica trimera,* which is well above its normal altitudinal limit of 3,800 m above sea level. The pockets between and in the rocks have soil, which is almost pure humus. An assemblage of minute herbs, most of which remain shorter than five cm grow here. The rocks themselves are covered by many different kinds of lichens.

The Afro-alpine rodent community in BMNP is diverse with 15 species, of which 10 are endemic to Ethiopia. The giant mole rat *Tachyoryctes macrocephalus* and several species of murid rodents including *Arvicanthis blicki* and *Lophuromys melanonyx* are endemic.

To carry out census, the Afro-alpine moorland ecosystem was divided into three 100 km^2 study sites each with 5 random circular counting stations of 1 km radius that reflected the habitat stratification of the moorland ecosystem. It was in these stations that data on rodent abundance and habitat structure were collected for three dry and wet seasons. The collection of data on rodents involved the use of 60 snap traps per sample that were set in three rows of 20 traps ensuring a 10 m minimum distance of separation between any two. The rodent data analysed here did come from a total effort of 2880 trap nights. The vegetation assessment involved visual estimation of percent cover of vegetation classes, rock formations and the open ground by setting up six 50 m × 50 m square quadrats in each of the circular counting stations (Table 1). Data on the structural attributes of the environment were collected repeatedly for three dry and wet seasons. For each circular census station, the average percentage cover for vegetation classes and other structural parameters were estimated. The aim was relating rodent abundance with habitat attributes. Vegetation data collected repeatedly during 2002, 2007 and 2008 across census areas were used to estimate rodent abundance using the predictive equations, the reliability of which was assessed using observed abundance data.

To evaluate the importance of habitat parameters useful to predict rodent abundance in the Afro-alpine moorland ecosystem of the BMNP, it was important to determine whether samples had differences in habitat features that were measured. Samples were grouped according to where they were located (valley plains or rocky cliffs) and differences in habitat attributes were evaluated using Univariate ANOVA. Once the grouping of samples was established with habitat data, mean differences between groups of samples in the abundance of rodent was conducted. Simple correlation analysis was conducted to determine that which habitat variables may have significant potential in explaining the abundance of each of the rodent species that were encountered during the census. Linear regression analysis was conducted to establish the relationship of the habitat variables with the abundance of each of the common rodent species. Analysis up to this stage was done using the rodent abundance data collected in November 2007. Once this was done, data collected in 2002 were used to build linear regression models to predict rodent abundance using habitat features that were determined to have significant explanatory effect. The results were compared with what was observed on the ground in 2007 and 2008 by simple correlation analysis.

RESULTS

Spatial variation in habitat: Based on the mean percentage of habitat parameters, two clusters of samples (samples located in valley and cliff habitats) were determined (Fig. 1). Between these groups of samples, the mean percentage cover of shrubs of *Lobelia jibiro* ($P = 0.5$), *Erica* ($P = 0.3$), *Helichrsum* ($P = 0.9$) and *Kniphofya* ($P = 0.3$) did not vary significantly. Despite the insignificance of the differences, the first group of samples could be considered as areas with markedly high coverage of Ericaceous woodlands located within the confines of the rocky cliff habitats (Fig. 1). The only shrub that had significantly differing percent coverage between the two groups of samples was *Artemisia* (F = 13.6, P = 0.01). The mean coverage of this shrub in the first group was negligible (Fig. 1). The difference between the two groups in the mean percentage cover of short meadow grasses was not significant (P = 0.9) (Fig. 2). In the second group of samples, significantly higher (F_{14} = 27.1, P = 0.002) amount of *Alchemilla* herbs was recorded. The first group of samples had significantly higher amount of rocks (F_{14} = 19.5, P = 0.004). The second group of samples did have significantly higher amount of open ground with no vegetation and rock cover (F_{14} = 44.1, P = 0.001).

***A. blicki*:** The mean abundance of the species differed significantly between the two groups of samples (F_{14} = 8.2, P = 0.001). The highest mean abundance of the species was documented in the second group of samples, which represented the valley habitats of the Afro-alpine moorlands of the BMNP (Fig. 3). Correlation of the species abundance with most of the habitat parameters was not significant (Table 1). The only significant correlation was with the percentage coverage of *Alchemilla* herbs (Table 1). The linear regression model that used percentage cover of *Alchemilla* herbs as significant (P < 0.001) predictor explained 92 % of the variation in the data set (F_{14} = 69.4 , P <0.001). Abundance of *A. blicki* in November-December 2002 had significant positive (P = 0.004) relationship with percentage of *Alchemilla* herbs. This model explained 84 % of the variation in the species abundance significantly (F_{14} = 25.8, P = 0.004). Abundance estimated for the year 2007 using this model correlated with what was observed on the ground with very high significance (Table 2). The abundance of *A. blicki* estimated for 2008 was also correlated with what was observed on the ground. The correlation was positive and highly significant (Table 2).

***L. melanonyx*:** The groups of samples differed significantly (F_{14} = 9.8, P = 0.02) in the mean abundance of *L. melanonyx* with more individuals in the second group of samples located in the valley habitats (Fig. 3). The species abundance was correlated significantly with the percentage of *Alchemilla* herbs only (Table 1) that had a positive increasing effect. A linear regression model that used percent cover of *Alchemilla* as a significant predictor (P < 0.001) explained 96 % of the variation in the data set (F_{14} = 110.9, P < 0.001).

The percent cover of *Alchemilla* herbs linearly explained 88 % of the variation in the 2002 abundance of *L. melanonyx* significantly (F_{14} = 28.4, P = 0.006). Using the same equation percentage of *Alchemilla* herbs documented in 2007 was used to estimate the species abundance. The result significantly correlated with what was observed (Table 2). The abundance of the species estimated using the 2002 equation correlated significantly with what was observed on the ground in April 2008 (Table 2).

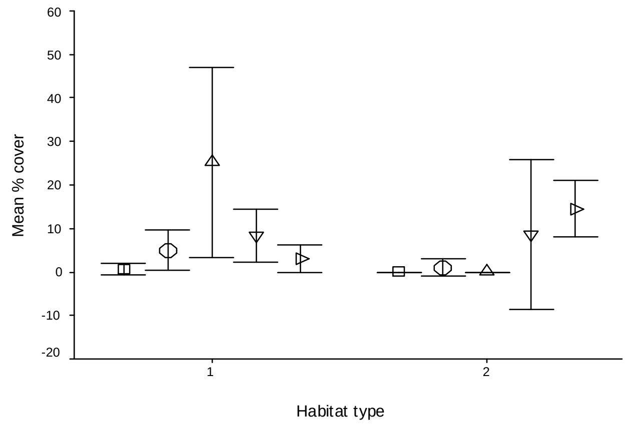

Fig. 1: Variation in the mean percentage cover of shrubby vegetation across groups of samples (1 = Cliff habitats, 2 = Valley habitats, Open square = *Kniphofya*, Open circle = *Erica*, Inverted open triangle = *Helichrsum*, Right slant open triangle = *Artemisia*).

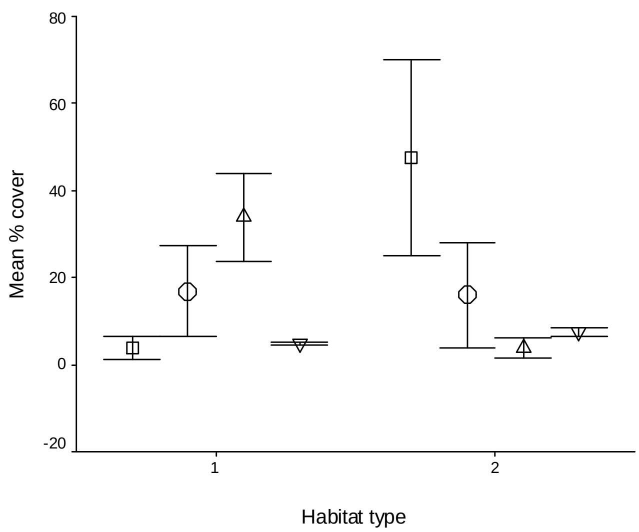

Fig. 2: Variation in the mean percentage of herbaceous vegetation and other land cover types (1 = Cliff, 2 = Valley, Open square *Alchemilla*, Open circle = Meadow grass, Open triangle = Rock, Inverted open triangle = Open ground).

***S. albocaudata*:** Like the preceding rodent species, the abundance of *S. albocaudata* was also higher in the valley habitat (Fig. 3) and this difference was significant (F_{14} = 10.3, P = 0.02). Again, the species had significant positive correlation with the percent cover of *Alchemilla* herbs like the previous two species (Table 1). At the same time, its abundance also showed significant correlations with proportions of rock and open ground. The correlation with proportion of *Alchemilla* and open ground were positive while the species abundance declined as the percentage of rocky structures

Table 1: Pearson coefficient correlations of abundance of rodents encountered during the census with percent cover of different habitat variables (one asterisk represents significance < 0.05 and two asterisks indicate < 0.001 significance).

Rodent species	*Lobelia*	*Kniphofya*	*Erica*	*Helichrysum*	*Artemisia*	*Alchemilla*	Grass	Rock	Open ground
A. blicki	-0.3	-0.4	-0.5	-0.3	0.5	0.96**	-0.2	-0.6	0.6
L. melanonyx	-0.3	-0.4	-0.5	-0.1	0.5	0.98**	-0.3	-0.7	0.7
S. albocaudata	-0.3	-0.4	-0.5	0.2	0.4	0.9**	-0.3	-0.7*	0.8*
S. grisecauda	-0.1	0.3	0.1	0.1	-0.4	-0.2	0.03	0.2	-0.2

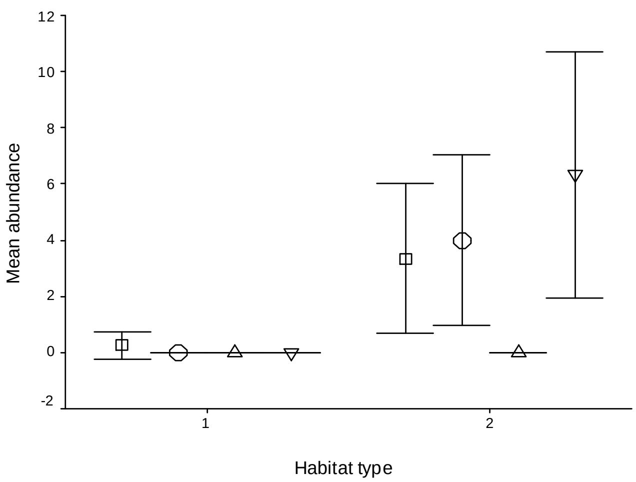

Fig. 3: Variation in the mean abundance of the common rodent species across groups of samples (open square = *A. blicki*, open circle = *L. melanonyx*, open triangle = *S. grisecauda*, inverted open triangle = *S. albocaudata*)

increased. A step-wise Multiple Linear Regression Analysis selected only percent cover of *Alchemilla* as a significant predictor of the species abundance (F_{14} = 20.7, P = 0.004) in a model that explained 78% of the variation in the data set. Regressing *S. albocaudata* abundance documented in November-December 2002 against percentage of *Alchemilla* herbs explained 94.2 % of variation in the data set significantly (F_{14} = 81.2, P < 0.001).

This equation was used to estimate the species abundance using data on the predictor from November 2007 and the result significantly correlated with what was observed on the ground significantly (Table 2). Using the same equation data on the proportion of *Alchemilla* herbs collected in the field in April 2008 was used to estimate the species abundance. This was demonstrated to have significant correlation with the species abundance recorded on the ground in 2008 (Table 2).

***S. grisecauda*:** The abundance of the species did not vary significantly (P = 0.5) between the two types of habitats (Fig. 3). None of its correlations with any of the habitat variables was significant (Table 1).

DISCUSSION

The main objective of the study was to determine patterns in small mammal abundance and relating them to habitat parameters. The premise had elements of the environment that the organism under study uses as cues in its numerical occupancy of different locations within the study area. Such components may have direct relevance to the organism as food sources and/or cover from predator/s (Krebs 2001, Wiens 1989, Morrison et al. 1998, Sutherland 1996). As prey communities are found at the bottom of the trophic layer in a predator-prey system, the use of relevant biotic and abiotic constituents of the environment to explain patterns in their distribution and abundance is highly crucial for understanding the processes that regulate a system such as the one investigated.

The Afro-alpine moorlands of the BMNP support at least 14 species assemblage of rodents of which six are endemic to Ethiopia (Yalden 1988, Sillero-Zubri & Gottelli 1995). The density of rodents in BMNP is the highest of any habitat throughout Africa (Sillero-Zuburi & Gottelli 1995). In the present study, areas such as the Lower Web Valley and the Sanetti Plateau were described as having extensive short grassland habitats (this may refer to the valleys in the context of this study) and high biomass of rodents. Areas such as Tulu Dimtu where *Helichrysum* shrubs were extensive had a lesser biomass of rodents. Sites with high percentage cover of rocks and ericaceous woodland did not have rodents in them and valley pastures with large coverage of *Alchemilla* type herbs had high abundance of three species of rodents. These results were consistent with previous findings (Sillero-Zuburi & Gotelli 1995). Results also showed the spatial variation in the abundance of the common rodent species, which can be explained and predicted with high accuracy using linear models in which the proportion of *Alchemilla* herbs is used as a predictor. Usage of linear models for such purposes demonstrated that the predictions had very high significant correlations with rodent numbers observed on the ground. One of the small rodents studied, *S. grisecauda* had lower abundance throughout the study area and did not have significant relationships with any of the attributes of the Afro-alpine habitat. This was no surprise as

Table 2: Pearson correlation coefficients of the similarity between predicted values of rodent abundance with observations made in 2007 and 2008.

Species	*r*	*P*	*r*	*P*
	2007		2008	
A. blicki	0.96	<0.001	0.96	<0.001
L. melanonyx	0.98	<0.001	0.84	0.01
S. albocaudata	0.88	0.004	0.83	0.001

it was documented early by Yalden (1988) that the species was more numerous in lower altitudinal areas, particularly in the forested areas of the park. The relationships that were established with all four common and endemic rodents with this habitat attribute strongly suggest its importance to all as a food source. These relationships also suggested that along with the impact of the mammalian and avian predators, availability of *Alchemilla* herbs is a very important habitat factor that determines the abundance of *A. blicki, L. melanonyx,* and *S. albocaudata*.

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