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THE INFLUENCE OF AGRICULTURAL ACTIVITIES ON THE DIVERSITY OF RODENTS IN KINDOROKO FOREST RESERVE AND SURROUNDING AREAS, NORTH PARE MOUNTAINS, TANZANIA

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ABSTRACT

The patterns of richness, diversity and similarity in rodent communities in agricultural areas and in adjacent Kindoroko Forest Reserve in the North Pare Mountains, Tanzania were assessed. By using a capture-mark-recapture method, 289 individuals of nine rodent species in March and May 2011 were captured. Seven species were recorded in agricultural area and 5 species in the Forest Reserve. Multimammate Rat (Mastomys natalensis) was abundant in agricultural area while soft-furred mouse (Praomys delectorum) was dominant in the Forest Reserve. Species diversity was greater outside than inside the forest, supporting results of earlier studies. Species similarity between the two habitats was high indicating that the species were generally evenly distributed across the landscape. The results showed the importance of agricultural land to the rodent community. Differences in rodent diversity between the two areas could be attributed to the availability of food and the heterogeneous environment in agricultural areas. While the factors causing lower diversity in the Forest Reserve are not yet understood, reduced food availability and competition with herbivores could be a contributing factor. Further work to understand the factors determining habitat preferences of species for conservation and ecosystem function is recommended.

Keywords: Diversity, Kindoroko, North Pare Mountains, Rodents, Tanzania

INTRODUCTION

Rodents are important components of a variety of habitats in the Pare Mountains, which are part of the Eastern Arc Mountains (EAM) that extend from southern Kenya to southern Tanzania. Some of the rodents are considered pests due to the economic losses caused to agriculture (Makundi et al. 1999, Mulungu et al. 2002, Magige 2012) and the spread of disease from them (Fiedler 1988, Stenseth et al. 2003, Makundi et al. 2008). However, they also play an important ecological role as prey of various medium sized predators (Pearson 1964, Moehlman 1986, Kitchener 1991, Sillero-Zubiri and Gottelli 1995). They also affect the composition and structure of their environment through consumption and distribution of foliage and plant seeds (Aschwanden 2005). Although existing literature includes some reports of rodent assemblages in the EAM (Carleton and Stanley 2005, Stanley et al. 1998), information on species richness and diversity is lacking in the Pare Mountains, particularly in relation to anthropogenic disturbance. Located in the North Pare Mountains, Kindoroko Forest Reserve is relatively unaffected by human activities, except for some agriculture in the lower areas of the mountains. Earlier surveys have shown that some rodent populations perform well in slightly disturbed habitats (Estrada et al. 1994, Struhsaker 1997, Caro 2001) whereas others might be habitat specific and intolerant of disturbance (Diffendorfer et al. 1995). Therefore, diversity can be analysed at different levels of disturbance within a landscape, and the study of the components of diversity can be useful for measuring and monitoring the effects of human activities on biodiversity (Halffter 1998). The aim of this study was to determine and compare the rodent species richness, diversity and similarity between Kindoroko Forest Reserve and adjacent agricultural land. This study will provide a basis for future studies of the biodiversity of East Arc Mountains.

MATERIALS AND METHODS

Study area

The North Pare Mountain range (03°35´- 03°46´S; 37°33´- 37°40´E) is one of the northernmost elements of the Eastern Arc Mountains, being located in Mwanga District, Kilimanjaro Region, Tanzania (Lovett and Pócs 1993). They extend for 40 km, with an altitude ranging from 730 m in the lowlands to 2,113 m amsl at Kindoroko Hill in Kindoroko Forest Reserve. The North Pare Mountains have an area of 453.4 km^2 of which the Kindoroko Forest Reserve comprises 8.9 km^2 (Figure 1). A relatively dense human population surrounds the forest reserve, and the natural habitat has been altered as a result of agricultural activities and logging. The agricultural activities involve small-scale farming where coffee (*Coffea arabica*), sugar cane (*Saccharum officinarum*), maize (*Zea mays*), beans (*Phaseolus vulgaris*), cassava (*Manihot esculenta*) and banana (*Musa* sp.) crops are planted mainly for subsistence and commercial purposes.

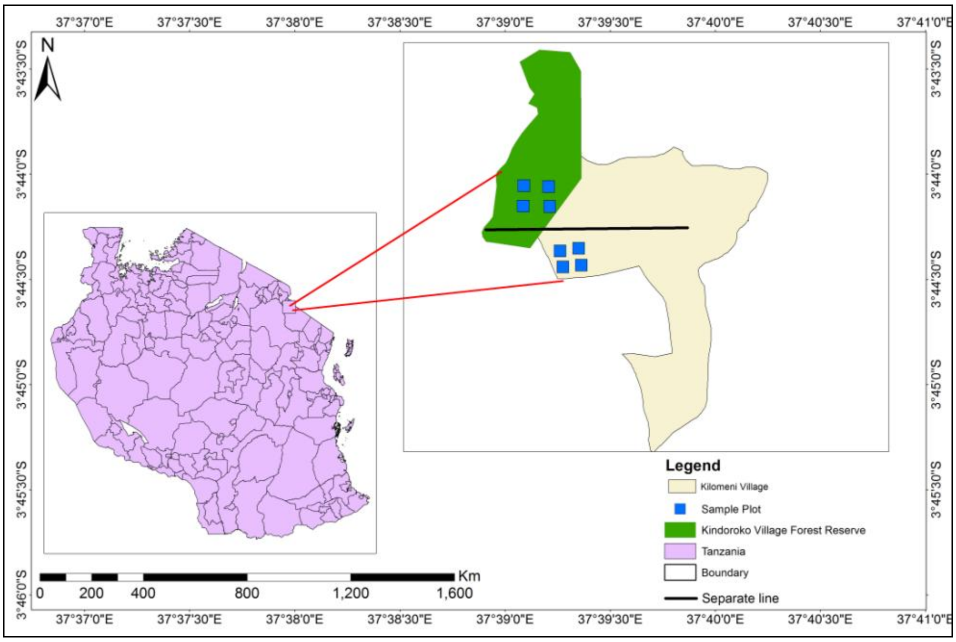

Figure 1: Map of Kindoroko Forest Reserve in Kilimanjaro Region, Tanzania.

Rainfall ranges between 700 and 1,400 mm.yr^{-1} with mist from clouds occurring at higher altitudes (Doggart et al. 2008). Since the North Pare Mountains, particularly their eastern slopes, intercept a significant amount of precipitation, they originally supported an extensive forest cover on the windward side. The dry season extends between June and October and temperatures vary from 16 °C min (July) to 25 °C max (March) (Doggart et al. 2008). The forest habitat ranges from wet montane forest to dry montane forest, dry woodlands and heathlands, including tree species such as *Prunus africana*, *Albizia gummifera* and *Newtonia buchananii* (Doggart et al. 2008).

Data collection

Data were collected in March and May 2011 in the Forest Reserve and agricultural area, respectively. Sampling plots were established at two sites, within the Kindoroko Forest Reserve at the southern part of the forest and in agricultural lands at Kilomeni Village. Eight sampling plots were established along an altitudinal gradient (from 1655 m to 1950 m amsl); four plots were in each of the Forest Reserve and agricultural land (Figure 1).

Pitfall lines were set following the procedures of Stanley et al. (1996). Pitfalls were placed on narrow trails cut for their installation. Each pitfall line comprised 20L buckets that were buried in the ground with the top of the bucket flush with the ground. The bottoms of the buckets were pierced with small holes to allow water drainage. Each line had a 60 cm polythene sheet as a drift fence running over the center of each bucket. These passive and non-baited traps captured animals moving on the surface that encountered the drift fence and followed it until they fell into a bucket. Although the pitfall lines were generally set along straight trails, logs occasionally forced deviation.

Trap lines were set along the established transects and consisted of three different types of traps: Sherman traps (23x9.5x8 cm, H.B. Sherman trap Inc. Tallahassee, Florida), Tomahawk traps (59x15x15 cm, Tomahawk Live Trap Co., Tomahawk, WI) and wire mesh traps. Wire mesh traps consist of an oval frame of steel wire, with wires stretched around it. The mesh wraps around the frame and then tapers into the inside of the trap. When an animal gets inside through the opening, it cannot get out, as the opening bends back into its original narrowness. The traps were baited with freshly fried coconut coated with peanut butter and were largely set on the ground along existing trails. Traps were checked twice a day, early morning and late evening and were re-baited in the evening.

Each sampling plot had 66 traps (50 Sherman traps, 4 wire mesh traps, 11 pitfalls, 1 tomahawk). Pitfall traps were set 5m from each other while Sherman traps were spaced 10m apart. In order to maximize capture probability tomahawks and wire mesh traps were set at sites deemed likely to be frequented by small mammals rather than at a fixed distance or in a grid system. Therefore the distance varied between traps.

A Capture-mark-recapture method was also used. Rodents were marked by toe clipping and released at the site of capture. Voucher specimens were fixed in 10% formalin and later transferred to 70% ethanol. Traps were left at each location for seven consecutive nights. A bucket- or trap night refers to one bucket or trap in operation for a 24-hour period (0600 to 0600h).

Data analysis

Diversity index

Two different diversity indices were used: first the Shannon–Wiener diversity index (Shannon and Wiener 1948) measured diversity in the habitat and this was compared between habitats using the Student's *t*-test (Hutcheson 1970).

The Shannon-Wiener diversity index is defined as:

$$H' = \sum(p_i)(\ln p_i)$$

where *H'* is the diversity index and p_i is the proportion of the total sample belonging to each species *i*.

Secondly, Rényi diversity profiles were used to determine which habitat was more rodent-diverse than the other (Tóthmérész 1995). As one of several methods for diversity ordering, the Rényi diversity profiles consider richness and evenness and are a function of the proportional abundance for each species. Diversity profiles are plotted by changing the value of α in the scale parameter using the Renyi's index family. Diversity profiles rank communities according to differences in diversity. The community is considered to have higher diversity if the curve of that community lies above that of the other community over the entire range. However, when the curves intersect, particularly if the intersection occurs when α is between 1 and 2, then the samples are said to be non-comparable. Shannon's index is a limiting function of this measure as α approaches 1.

The Rényi entropy

The Rényi entropy is important in ecology as an index of diversity. It is defined as:

$$H_\alpha = \frac{\log \sum p_i^\alpha}{1 - \alpha}$$

where p_i is the proportion of the observations found in category *i* and α is the value of the scale parameter ($\alpha \geq 0$, $\alpha \neq 1$) (Appendix 1). All calculations were performed with the programme R 3.2.2 (R Development Core Team 2006).

Species similarity

To quantify rodent species similarities between agricultural land and the Forest Reserve the Sørensen similarity index (CCs) was calculated (Sørensen 1948). It reflects both the number and abundance of species the two areas have in common.

Sørensen Similarity index:

$CCs = 2c/(S_1+S_2)$

where S_1 and S_2 are the number of species caught in two different sampling habitats and *c* is the number of species common to both habitats. Values of the index vary from 0 to 1, with 0 indicating that species assemblages are dissimilar and 1 that they are identical.

RESULTS

Species composition

The overall sampling effort (the number of trap-nights and bucket-nights) was 3,696 trap-nights where each study site was trapped only once. A total of 289 individual rodents comprised 155 individuals from the Forest Reserve and 134 individuals from the agricultural land from 9 genera in 4 families. In total, 9 species were recorded; 7 species in the agricultural land and 5 species in the Forest Reserve. *Mastomys natalensis* (Multimammate Rat), *Mus minutoides* (Pygmy Mouse), *Otomys anchietae* (Tanzanian Vlei Rat) and *Cryptomys hottentotus* (Common Mole Rat) were found in the agricultural land only, whereas African Woodland Dormouse (*Graphiurus murinus)* and Soft-furred Mouse (*Praomys delectorum*) were found only in the Forest Reserve (Table 1). The remaining four species were common to both sites (Table 1). *M. natalensis* was the most abundant species, accounting for 73.9 % of all the rodents collected in the agricultural land. In the Forest Reserve, the most common species was *P. delectorum* and it accounted for 93.5% of the total rodents collected in the Reserve (Table 1).

Table 1: Species composition and number of individuals caught in each of the sampling plots in agricultural area and Kindoroko Forest Reserve, North Pare Mountains, Tanzania, 2011.

			Forest Reserve		**Agricultural Area**	
Family	**Scientific name**	**Common name**	**Frequency**	**%**	**Frequency**	**%**
Bathyergidae	*Cryptomys hottentotus*	Common Mole Rat	-	-	1	0.7
Cricetomydae	*Cricetomys gambianus*	Giant-pouched Rat	3	1.9	5	3.7
Gliridae	*Graphiurus murinus*	African Woodland Dormouse	1	0.6	-	-
Muridae	*Grammomys ibeanus*	East African Thicket Rat	3	1.9	23	17.2
Muridae	*Praomys delectorum*	Soft-furred Mouse	145	93.5	-	-
Muridae	*Mastomys natalensis*	Multimammate Rat	-	-	99	73.9
Muridae	*Mus minutoides*	Pygmy Mouse	-	-	4	3
Muridae	*Otomys lacustris*	Tanzanian vlei Rat	-	-	1	0.7
Nesomyidae	*Beamys hindei*	Lesser Pouched Rat	3	1.9	1	0.7
TOTAL			**155**	**100**	**134**	**100**

Species diversity

The species diversity was significantly higher in the agricultural area (H' = 0.37) than in the Forest Reserve (H' = 0.14) (t = 4.415, df = 274, p<0.001). Figure 2 provides Rényi diversity profiles for the two habitats. The profiles show that there is diversity ordering for which the curve for agricultural area lies above the curve of the Forest Reserve over the entire range signifying that the agricultural land is more diverse than Forest Reserve.

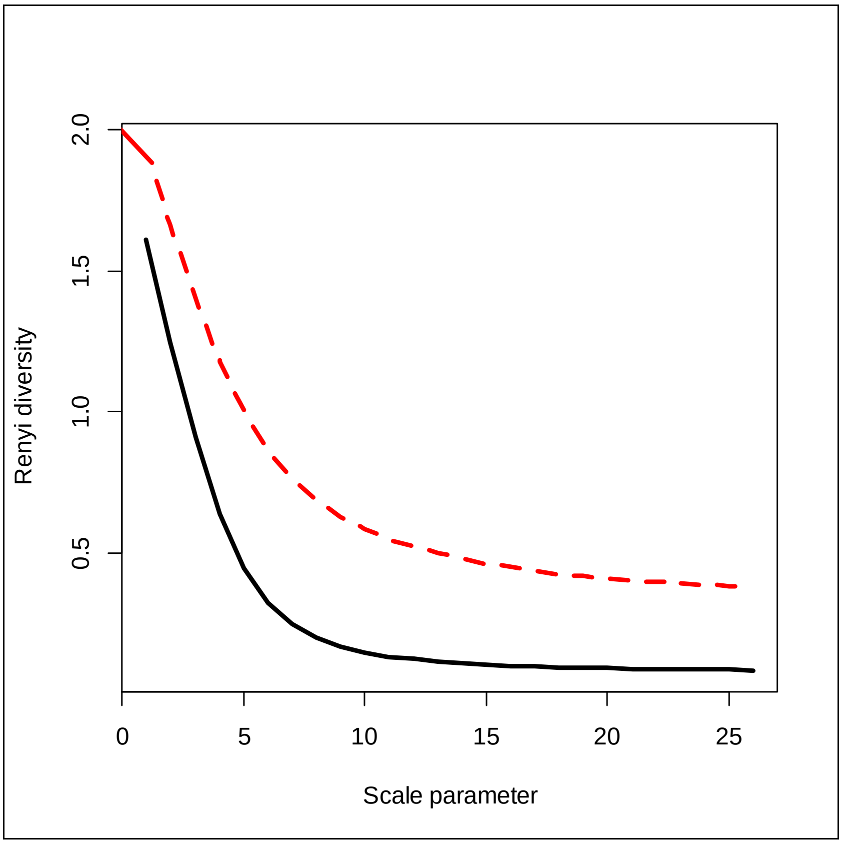

Figure 2: Rényi diversity profiles of the agricultural area and Kindoroko Forest Reserve assemblages, North Pare Mountains, Tanzania, 2011 (Dashed line denotes agricultural area and Solid line denotes the forest reserve).

Species similarity

The coefficient of species similarity between agricultural area and Forest Reserve was 0.75. Values in the range between 0.51-0.75 reflect high similarity (Ratliff 1993). This high similarity indicates that the species diversity is somewhat similar across the landscape.

DISCUSSION

Species composition

M. natalensis, one of the highly distributed and abundant species across much of Sub-Saharan Africa, is ubiquitous in lowland agricultural areas across Tanzania, and is considered a crop pest due to its highly specialised herbivorous/granivorous nature (Mulungu et al. 2014). This study also found a high abundance of *M. natalensis* in the agricultural areas of the North Pare Mountains. This observation supports other studies (De Graaf 1981, Leirs 1992, 1995, Leirs et al. 1993, Makundi et al. 1999). The high number of *P. delectorum* in the Forest Reserve is expected because it is a forest specialist (Kingdon and Howell 1993, Stanley et al. 1998). The occurrence of *G. murinus* in the Forest Reserve only could be ascribed to its habitat and feeding habit. They prefer areas with high canopy cover and depend on wooden corridors for their movement (Kingdon 1997), however, the species can also be found in agricultural land (Skinner and Chimimba 2005). Four species were caught only outside the Reserve: *M. natalensis*, *M. minutoides*, *O. anchietae* and *C. hottentotus*, whereas *G. murinus* and *P. delectorum* were trapped only inside the Forest Reserve.

Species Diversity

Significantly more species were trapped in the plots outside the Forest Reserve resulting in higher rodent species diversity in agricultural areas. This study confirms findings from earlier work showing that areas which are disturbed by various human activities have a high number of rodent species (Avenant 2002, Jeffrey 1997, Konečny et al. 2010) which results in higher species diversity in these areas compared to that in protected areas (Happold and Happold 1997, Caro 2001, Caro 2002). The high diversity in the agricultural land may result from a greater number of microhabitats with their diverse resources (Kasangaki et al. 2003). This is true for other small species like bats (Williams-Guillen and Perfecto 2011). It is now becoming evident that moderate alteration of some ecological aspects of landscapes creates favourable conditions for survival of some rodent species (Primack 1993). However, these alterations might have a negative effect on other groups of animals like birds (Sinclair et al. 2002).

Other factors contributing to the lower diversity of rodents in the Forest Reserve are not yet known. However, Caro (2002) reported that herbivores and carnivores might have a significant effect on the small mammal community by reducing grass biomass and through predation respectively. In the Kindoroko Forest Reserve, medium to large sized herbivores such as African buffalo *Syncerus caffer,* Bushbuck *Tragelaphus scriptus,* Suni *Neotragus moschatus and* Harvey's duiker *Cephalophus harveyi* (Cordeiro et al. 2005) and birds of prey (Doggart et al. 2008) have been recorded and their impacts need to be studied. Moreover, in the forest, rodent species may be habitat specialists or less used to human presence, which may make them more hesitant to enter traps and hence less attracted to the baits. Longer periods of trapping or alternative means of detection such as track counts are recommended.

CONCLUSION

The results of this study suggest that agricultural areas harbour a greater richness and diversity of rodent species compared to that of the Kindoroko forest reserve. Both the soft furred rat, *Praomys delectorum* and *Mastomys natalensis,* were dominant in the North Pare Mountains. The high abundance of *Mastomys natalensis,* which is an indicator of disturbance in agriculture, should be monitored since this species is destructive of crops and property, and is also a vector of disease. Other species such as *Cryptomys hottentotus, Graphiurus murinus, Otomys lacustris* and *Beamys hindei* occurred at very low abundance and they need to be documented in more detail than just richness and diversity so that their conservation status can be monitored. It is important, particularly for wildlife managers, to understand the parameters that determine the presence of some species in a particular area and protect and control them to maintain both ecosystem function and conservation of natural habitats.

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Appendix 1: The R-code used in this study

C1= Forest reserve and C2=Agricultural area

```
> C1<- c(3,3,3,1,145,0,0)
> C2<- c(1,5,1,23,99,4,1)
> xm<-rbind(C1,C2)
> library(DiversitySampler)
> library(vegan)
> scales<- seq(0,5, by<- 0.2)
> (renyi(xm, scales=scales))
>matplot(t(renyi(xm, scales=scales)), type="l", lwd="3", xlab="Scale parameter",ylab="Renyi diversity")
```