RODENT DIVERSITY AND HABITAT ASSOCIATION IN HANDENI HILL FOREST RESERVE, NORTH EASTERN TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN WILDLIFE MANAGEMENT AND CONSERVATION OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

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ABSTRACT

The distribution and diversity of rodents is influenced by various factors such as vegetation characteristics, climatic conditions, disease, predation and habitat modification due to anthropogenic activities and food abundance. This study was conducted in Handeni Hill Forest Reserve from November 2018 to March 2019 with the aim of assessing the influence of habitat characteristics on the abundance and distribution of rodent species. Four permanent grids of 70 m by 70 m with 49 Sherman live traps were established in miombo woodland and evergreen forest habitats respectively. In each habitat type one pitfall drift fence was also established. A total of 102 individuals of 8 rodent species from 4704 traps nights were captured namely *Praomys sp, Gerbilliscus vicinus, Grammomys dolichurus, Rattus rattus, Mastomys natalensis, Acomys wilsonii, Lemniscomys rosalia* and *Mus minutoides*. Species such as *G. dolichurus* were restricted to the thickets in the evergreen forest and *Praomys sp* was restricted in a higher altitude of the Miombo woodland habitat. The canonical correspondence analysis (CCA) was used in showing a relationship among species, grids and habitat characteristics. The CCA ordination plot revealed factors such as shrub height, moisture and ground cover to have influence in species diversity and distribution. The study concludes that habitat factors such as ground cover and shrub height have strong influence on the species abundance in the area followed by moisture content.

DECLARATION

I, Bayo Martin J, do hereby declare to the Senate of Sokoine University of Agriculture that this thesis is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

______________________ ____________________

Bayo Martin J. Date

(MSc. Candidate)

The above declaration is confirmed by:

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Dr. Robert Byamungu Date

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DEDICATION

My first dedication goes to the Almighty God. I also dedicate my work to my lovely family for love, encouragement and support during my studies, not forgetting Neema and Christine Joseph, for their support. I have seen God through you; therefore, I dedicate this work to you.

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LIST OF ABBREVIATIONS AND SYMBOLS

CCA	Canonical correspondence analysis
CMR	Capture Mark Release
PAST	Paleontological Statistical Software
Q-GIS	Quantum Geographic Information System
TFS	Tanzania Forest Service

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Among mammals rodents form the most diverse group comprising of about 40% of the mammalian orders (Wilson and Reeder, 2005). They show a great diversity in their morphology, ecology and life history, occupying a wide range of terrestrial habitats except Antarctica (Nowak, 1999). Rodents are distinguished from other mammals due to their prominent gnawing characteristics with two continuous growing incisors in each jaw with a long space or diastema before the cheek teeth. In Tanzania rodents predominates at about 111 species compared to other mammalian orders (Senzota *et al*., 2012). The distribution and abundance of rodents is influenced by various factors such as vegetation, climatic conditions, disease, predation and habitat modification due to anthropogenic activities and food abundance (Johnson and Horn, 2008; Mesele and Bekele, 2012). In Tanzania rodent has been studied in different aspect from zoogeographic, ecology, taxonomy and diseases (Makundi, 1983; Leirs, 1994; Odhiambo *et al.*, 2008), to distribution and diversity (Stanley *et al*., 1998, 2005; Mulungu *et al*., 2008; Sabuni *et al.*, 2015; Stanley and Kihaule, 2016). However, the coastal forests are underrepresented.

The coastal forests of Tanzania form part of the greater East Africa coastal forests which are a chain of aged forest and undergrowth patches set within savannahs, woodlands, wetlands and agricultural lands (Clark, 2000). The forests extend from Southern Somalia to Southern Mozambique and west to Malawi (White, 1983). These forests are generally found inland from the coast of the Indian Ocean to about 200 - 300 km (Moll and White, 1978). Many of the remnant patches of these forests are transitional or composed of a mixture of Miombo woodlands (Ekblom *et al*., 2014) and are recognized as being of global importance (WWF, 1998; Rodgers, 2000) due to the high levels of biodiversity and endemism. Therefore, the results of this study are expected to increase knowledge on the conservation status of rodents in these renown forests of eastern Tanzania.

1.2 Problem Statement and Justification

The coastal forests in Tanzania exist as disjointed patches varying in sizes, community structure and species composition (Bloesch and Klötzli, 2004). They are highly threatened due to anthropogenic activities including agriculture, livestock grazing and tree felling (Burgess *et al.,* 2000). These activities pose negative impact on both flora and fauna including rodents. Lemos (2014) point out that livestock grazing practices do not only cause loss of ground vegetation but also lead to decrease in rodent diversity due to increasing predation risk. However, irrespective the fact that Tanzania has about 84 coastal forests patches (Burgers and Clarke 2000), a few studies on rodent distribution and diversity have been mainly concentrated in the Gendagenda, Kwamsisi. Mbulizaga and Zaraninge coastal forests (Kiwia, 2006; Sabuni, 2008; Sabuni *et al.,* 2015) with scarce information on other forest patches. It is therefore anticipated that the ecological data generated from this study will enhance understanding of diversity and distribution of rodents in relation to the influence of habitats within the Handeni Hill coastal forest.

1.3 Objectives

1.3.1 General objective

To assess the influence of habitat characteristics on rodent species diversity and distribution in Handeni Hill Forest Reserve in Tanzania.

1.3.2 Specific objectives

i. To determine rodent species abundance and diversity in different habitat types.

ii. To establish the distribution pattern of rodent species.

iii. To examine the influence of habitat factors on abundance of the rodent species.

1.4 Hypothesis

Habitat heterogeneity has no influence on rodent abundance, diversity and distribution.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 East African Coastal Forests

The East African coastal forests are small remnant patches with sizes ranging from 0.5-50 km^2 of a once large Pan-African forest block (Burgess *et al*., 2000). The forests are found at elevations between 0 and 1000 m, with many of them situated between 100 and 300 m above sea level. They are generally complex in their formation and are influenced by various factors, including rock types, landscape topography, soil composition and hydrology (Burgess *et al.*, 2000; Clarke, 2000; Clarke and Burgess, 2000; Lowe and Clarke, 2000). The forests are part of the Zanzibar-Inhambane regional mosaic and stretches as a strip from Southern Somalia through Kenya and Tanzania to Southern Mozambique (Burgess *et al.,* 2000). However, they are scarcely known scientifically as there are a very few detailed studies conducted so far especially on small mammals. Some examples of scientific studies and publication on rodent and other small mammals include that of Burgess *et al.* (2000), Clarke and Dickinson (1995), Hawthorne (1984), Clarke (2000), Kiwia (2006) and Sabuni *et al*. (2015).

The coastal forest patches are surrounded by a matrix of different types of habitats including miombo woodland, wooded grassland and cultivation areas. According to White (1983), the coastal forests are in transition to miombo savanna-woodlands. The study by Werger and Coetzee (1978) in South Africa viewed the expansion of Miombo habitats to coastal forests as an invasion process, of which the evidences are vivid in the coastal forest patches of East Africa (Ekblom *et al.,* 2014). The major drivers that causes the expansion of Miombo woodlands to the Coastal forests is the use of fire and agriculture activities (Clarke, 2000). Makundi *et al*. (2003) pointed out that increase in human population causes destruction in natural forest which threatens the life of native species; and this is accelerated by replacement of native species by other exotic tree affecting species distribution and abundance.

2.2 Biology and Ecology of Rodents

Rodents represent a huge taxonomical group in the order Rodentia (Wilson and Reeder, 2005) with many species sharing biological and ecological features. Most of rodents are nocturnal and few are diurnal. They use this strategy for self-defense as most of their enemies are inactive during night hours with a few exceptions such as owls and nocturnal small carnivores (Delany, 1994). Most rodents are omnivorous and opportunistically forages on a variety of food items such as grains, fish and fruits (Waggoner, 2000; Connior, 2011). According to Single *et al.* (2001) the characteristics of continuously growing paired incisors help rodent during feeding, burrowing, and defending themselves in time of danger. Rodents also occupies an array of habitats, thus can be fossorial, semiaquatic and/or arboreal (Single *et al.*, 2001).

Being most easily adaptable mammals, rodents are found in different environments and on all continents except Antarctica (Nowak, 1999). The largest rodent species morphologically is the capybara, whereby its weight is estimated to reach 66 kg, while most rodents are no more than 100 g and the smallest being around 3.75 g (Waggoner, 2000). Rodents are more influenced by feeding materials on their distribution and abundance (Makundi *et al.*, 2008). Diet also plays a crucial role in the breeding activity on many rodent species. This is due to the fact that diet activate the reproductive physiology of rodents after assimilation of food materials (Leirs, 1994). There are about 2200 living species of rodents out of the 5416 species of living mammals (IPM, 2016). Ecologically, rodents play vital role in ecosystems including their dynamic influence on vegetation regeneration (Garshong *et al.*, 2013). They are distributors of flora and fungal spores (Gupta, 2011), pollination agents and biological control of pest (Cook *et al.*, 2007), bio-engineer of soils and mediator of energy flow and nutrient cycling. Rodents also play a key role in connecting links between trophic levels (Ofori *et al.*, 2015) as they are key prey for many carnivores and raptors (Davidson *et al.*, 2012). Moreover, the rodents are host of parasites and reservoir of zoonotic pathogens (Karuaera, 2011) and biological indicators (Avenant, 2011).

2.3 Influence of Habitat Factors on Rodent Diversity and Distribution

Habitats conditions are believed to be crucial factors influencing the diversity of rodents' communities and their abundance (Canova and Fasola, 2000). Biological association such as competition, parasitism and predation, and environmental parameters such as rainfall has much influence on rodent ecology in different habitats (Danielson, 1991; Villafañe, 2012). By the aforementioned factors, rodents have adapted to live in wild areas, human settlements, and in plantations and they live and feed in closer proximity to humans than most of other mammals (Kosoy, 2015). Rodents have fairly a minimum habitat and distribution ranges, thus can be studied and monitored easily (Barrett and Peles, 1999). Some of the rodent species especially generalist for example *Mastomys natalensis* prefers habitat that are disturbed and degraded (Linzey *et al.*, 2012). Due to their sensitivity and well adopted feeding ecology, rodents are used as indicator of habitat quality and can be used in monitoring and measuring the quality of different habitats (Morris, 1987; Bowland and Perring, 1994). A study by Monadjem (1997) showed that both biomass and diversity of small mammals correlates positively with vegetation density particularly in tall grasslands. Also, microhabitat parameters such as moisture and plant cover, density and height influence seasonal variation in numbers of small mammal species distribution (Neal, 1984; Martin and Dickson, 1985) including rodents. However, ecological disturbances caused by human activities such as agriculture, forest conversion to farm and settlements well as urbanization commonly affect community composition, and demographic pattern of rodents (Matson *et al.*, 1997). Generally, in the coastal forests belt human activities have resulted in increasing reduction in size of forest remnant - ecologically hindering movements and distribution of rodents (Clarke and Burges, 2000).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

3.1.1 Location of the study area

This study was carried out in Handeni Hill Forest Reserve which is located in Handeni District, Tanga, Tanzania. The reserve lies between 5° 25′ and 5° 27′ S and 5° 1′ and 5° 3′ E. It is located 1.5 km east of Handeni Township at an elevation of about 1030 m.a.s.l (Holmes, 1995). This forest covering about 3500 ha was established in 1974 and is owned by the Central Government through Tanzania Forest Service Agency (TFS) Figure 1.

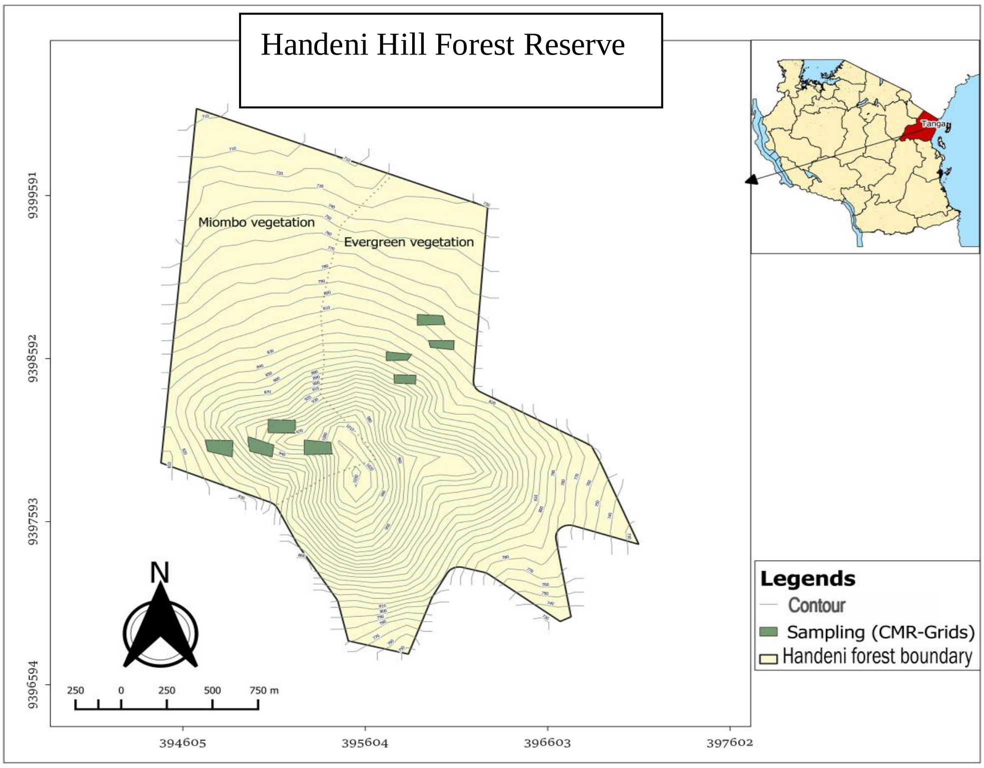

Figure 1: Map of Handeni Hill Forest Reserve

3.1.2 Vegetation

According to Malimbwi and Mugasha (2002), Handeni Hill Forest Reserve has two distinct vegetation types namely; miombo woodland and semi-evergreen coastal forest. Whereas the miombo woodland covers the drier southwest, west and northwest slopes of the reserve, and the semi-evergreen forest covers the wetter northeast, east, south and southeast slopes. The miombo woodland is dominated by *Brachystegia spiciformis, B. bussei, B. boehmii, B. microphylla*, *Julbernardia globiflora* and *Pterocarpus angolensis*. The dominance of Julbernardia and Brachystegia is an indication of typical miombo vegetation (TFS, 2018). The herbaceous layer is composed of a dense grass layer of *Hyparrhenia rufa*, *Panicum maximum* and *Themeda triandra.* The evergreen forest is dominated by *Commiphora zanzibarica, Lecaniodiscus fraxinifolia, Manilkara mochisia, L. vaughariae, Haplocoelum foliolosum, Sterculia appendiculata, Combretum mombazense, Manilkara sulcata, Drypetes natalensis, Milicia excelsa* and *Pteleopsis myrtifolia* (TFS, 2018).

3.1.3 Climate

The climate is characterized by oceanic rainfall with continental temperatures. The estimated annual rainfall in the miombo woodland is 1000 mm with dry season starting from June to September. The mean temperature is 24 ^{o}C maximum in February and 20 ^{o}C minimum in July (Clark, 2000).

3.2 Rodent Sampling

3.2.1 Rodent trapping

The study area was stratified into two habitat types based on the dominant vegetation i.e. evergreen forest habitat and miombo woodland habitat. In each habitat 4 grids were established and rodent trapping was executed between November, 2018 and March, 2019 covering the evergreen forest and miombo woodland habitats. In each of the two habitat types Capture-Mark-Recapture (CMR) technique was employed using permanent trapping grids of 70 × 70 m. Each 70 × 70 m grid consisted of 7 parallel lines spaced 10 m apart each with 7 trap station also placed 10 m apart. Thus, each grid had a total of 49 traps (Makundi *et al.*, 2008). Traps used were Sherman live trap measuring 23 x 9.5 x 8 cm baited with a mix of peanut butter and maize flour (Mulungu *et al.* 2008). Also, in order to capture shy and small rodents that might not be captured in the Sherman traps, pitfall traps were used. In each habitat type one drift-fence was established along pitfall lines, each comprising of 11 buckets, placed 5 m apart, and buried in the ground so that the top of the bucket levels with the ground. Each of these buckets was 36 cm high and with upper and lower diameter of 26 cm and 24 cm, respectively (Stanley and Kihaule, 2016). Each pitfall line had a 50 cm high black plastic drift fence running over the center of each bucket for leading the rodents into the traps.

3.2.2 Trap inspection and maintenance

Traps were checked daily between 0700h and 1000h for three consecutive trapping nights in each trapping grid for inspection and re-baiting. Traps were scraped clean of any old food or feces, and new bait were added and returned to their positions. Traps were washed with water only between uses at different sites as smell of certain species may discourage other species from entering (Barnett and Dutton, 1995). The newly trapped individuals were marked by toe clipping and got released to the point where they have been captured.

3.2.3 Handling of captured animals and species identification

The captured rodents were measured in terms of weight (to nearest gram), and assessment was done to their state of the vagina (closed or perforated) or position of the testes (scrotal or abdominal) were noted. Moreover, individuals were identified to species level using morphological measurements such tail length, ear length, and body length, and with the use of field guide books (Kingdom, 2003; Wilson and Reeder, 2005).

3.2.4 Habitat assessment

The habitat features that were assessed under this study followed Mugasha (2004), Burt *et al.* (1993) and Canova and Fasola (2000). These included soil moisture content, texture and bulk density, plant species, density (trees and shrub), cover and heights.

3.2.4.1 Trees and shrubs

In each trapping grid, three 10 m by 10 m quadrats spaced 10 m apart were used to assess tree heights using Suunto-clinometer and canopy cover using canopy densitometer. Plant species were identified and counted (numbers of individual trees and shrubs) following Malimbwi *et al.* (2002) and Mugasha (2004).

3.2.4.2 Grass and leaf cover

Within each 10 m by 10 m quadrats established for trees and shrub, 1 m by l m quadrats were randomly placed for ocular measurement of grass and leaf cover. Whereby, the 1 m by l m quadrats were divided into four squares occupying 25% of the area and the cover of the four portions were compared to get percentage grass/leaf cover of the quadrat (Kamwe, 2010).

3.2.4.3 Soil sample collection

To estimate soil moisture two samples of 250g were collected from 5 corners of the CMR grid whereby the first sample was from 0-15 cm layer and the second was from 15-30 cm. Texture and bulk density were obtained from soil profile of 60cm x 1m x 1m height, width and length respectively. The soil samples were collected from each of the eight study grids. The samples collected were packed and taken to SUA at the soil science laboratory for analysis of soil moisture content, soil bulk density and texture.

3.2.5 Sampling of rodents for assessing the distribution pattern

To assess the distribution pattern of rodents, GPS coordinates on each trapping grid were taken and later used to map the distribution of rodent in each grid based on species abundance.

3.3 Data Analysis

3.3.1 Abundance

The percentage relative abundance of each species per habitat type was estimated using the ratio of total individual species to the total rodents captured.

%Relative abundance = $\frac{No\ of\ individual\ species\ captured}{Total\ No\ rodents\ species\ catputred}$ x 100%.................................(1)

3.3.2 Species Diversity

Species diversity (number of species and numerical contribution of each to the community) were calculated using the Shannon-Wiener diversity index (Krebs, 1999).

H′ = $-\sum_{i=1}^{s} PiLnp_i$……………………………………………………………..(2)

Where pi = S / N

H′ = species diversity index,

S = number of individuals of one species,

N = total number of individuals in the sample,

Pi = is the relative abundance (proportion) of the i^{th} species in the community,

Ln Pi = natural logarithm of Pi.

3.3.3 Establishing the distribution pattern of rodents species

The GPS coordinates of trapped rodents in each habitat types were mapped using Q-GIS software version 2.3, whereby the relative abundance of each species was overlaid on the trapping grids. The result is the map that shows how rodent are distributed on each habitat.

3.3.4 Examining the influence of micro-habitat factors on abundance of the rodent species

Environmental and biotic variables including canopy cover, tree density, shrub height, shrub density, grass cover and grass height were processed in excel spread sheet and the mean values were calculated and used in the analysis for correlation and Canonical Corresponding Analysis. Mean values of each variable were also used in the analysis of the factors influencing rodent distribution and abundance. Then the abundance of rodent species obtained in objective one was related to these environmental and biotic variables using Canonical Correspondences analysis (CCA) in the Program Paleontological Statistics software (PAST), (Hammer *et al.*, 2002). Also, a correlation test was used to find out whether rodent species were affected by habitat factors, by relating the habitat factors (listed above) to abundance of rodents across sites.

CHAPTER FOUR

4.0 RESULTS

4.1 Rodents Abundance and Diversity in Miombo Woodland and Evergreen Habitat

A total of 102 individuals belonging to eight species were captured out of 4704 trap nights. The eight species captured and the associated habitats are shown in Fig. 2. In both habitats *Mastomys natalensis* was the most abundant species with 91.2% and 21.6% of the total species abundance in miombo woodland and evergreen forest respectively. In terms of other species; the miombo woodland was also dominated by *Lemniscomys rosalia* (58.2%) followed by *Acomys wilsonii* (24%) and *Mus minutoides* which contributed 7.4%, Figure 2.

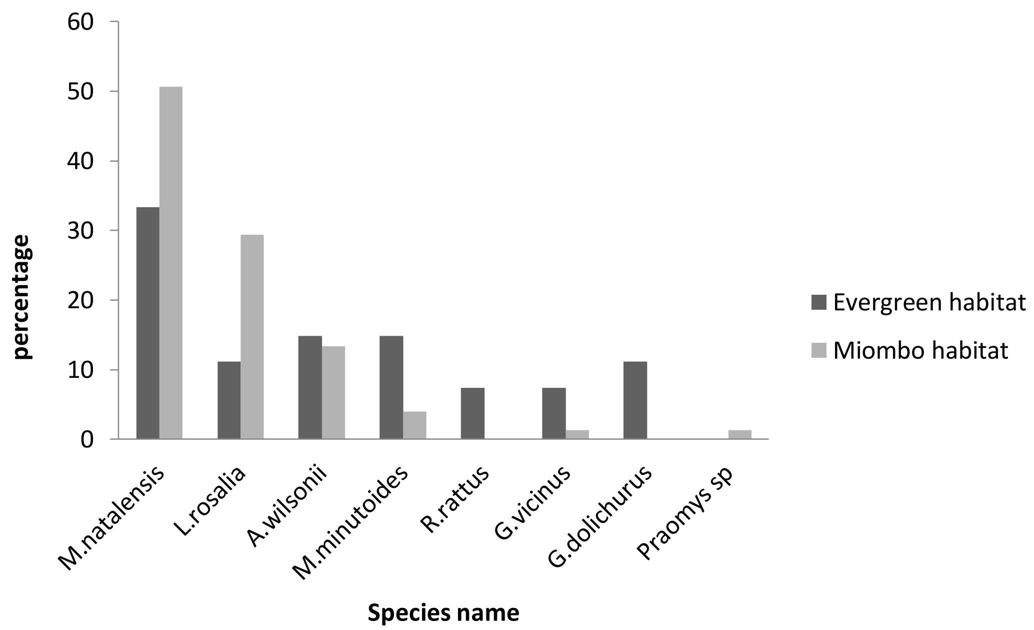

Figure 2: Percentage relative abundance of species in both Miombo and Evergreen habitats

4.1.1 Rodent diversity in the evergreen forests and miombo woodland habitats

Fig.3. shows the diversity index of rodents in the two habitats. The Shannon diversity index in the evergreen forest was 1.9 and that in the miombo woodland habitat was 1.2.

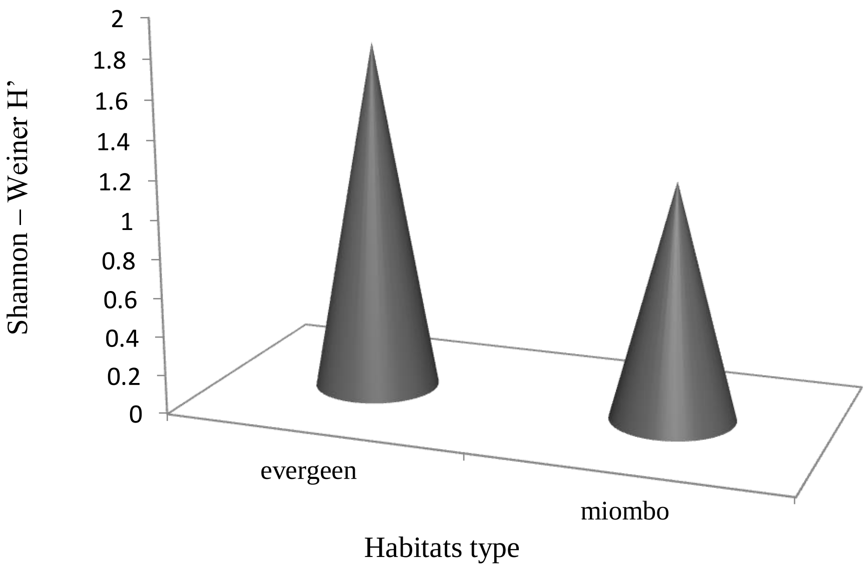

Figure 3: Shannon-Weiner Diversity index of rodent's species in evergreen and miombo woodland habitats

4.2 Rodent Distribution Pattern

The distribution of rodents varied across habitats throughout the study areas. *M. natalensis, L. rosalia, A. Wilson, M. minutoides* and *G. vicinus* were trapped from both habitat types. *G. dolichurus* and *R. rattus* were restricted to the evergreen forest habitat Fig. 4, whereas Praomys sp. was confined to the miombo woodland habitat.

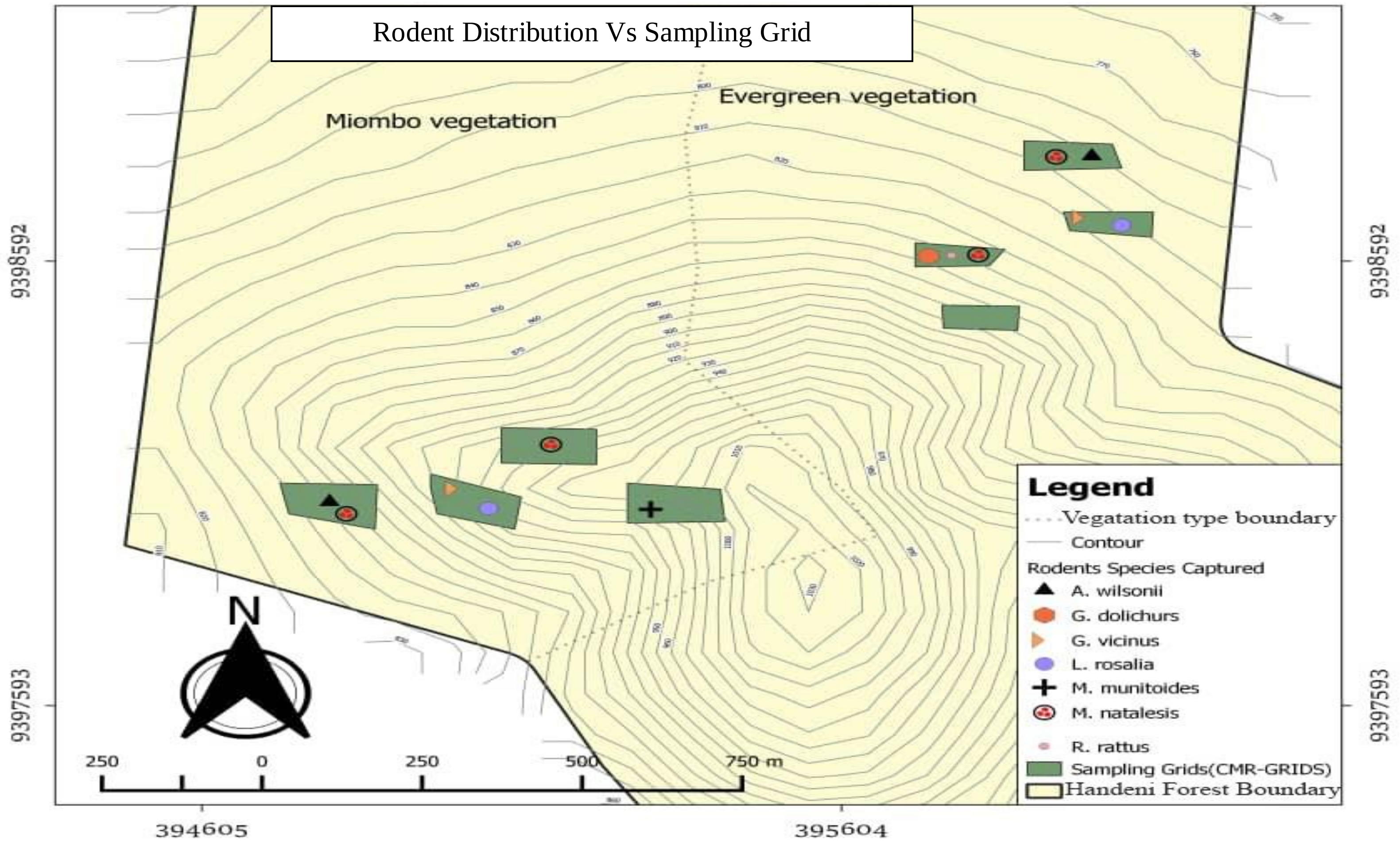

Figure 4: Map showing the species distribution in different elevations and habitat types in Handeni Hill Forest Reserve

4.3 Influence of Micro-Habitat Factors on Abundance of the Rodent Species

The habitat factors analyzed were the log transformed mean values of soil physical characteristics (percentage of soil moisture and bulk density) and vegetation and environmental features involving tree density, percentage canopy cover, shrub density, shrub height, grass height, ground cover and altitude (Appendix 1). Correlation analysis was performed to test for the relationship between habitat and environmental variables with abundance of rodents in both sites (Table 1). *M. natalesis* was positively correlated with altitude, bulk density, shrub density, grass height and percentage ground cover but also the species was negatively correlated with shrub height. *L. rosalia* was positive correlated with bulk density, grass height and ground cover. Moreover, *A. wilsonii* correlated positively with grass height and grass cover and was negatively correlated with shrub height. *M. minutoides, G. vicinus* and *G. dolichurus* showed negative correlation with soil moisture content at 15cm and 30 cm depths. Lastly, Praomys sp. showed positive correlation with altitude, tree density and negative correlation with shrub density. The above described correlations are based on those variables showing significant correlations only.

The Canonical Correspondence Analysis (CCA) showed a relationship among species, grids, and habitat characteristics. The first two axes (1 and 2) explained approximately 71% and 18% respectively (Eigenvalues: CCA1 = 0.70121 and CCA2 = 0.17881). On triplot graphs, normally species close to each other are more similar in abundant and vice versa, therefore species such as *G. vicinus, M. minutoides* and *G. dolichurus* are more-similarly distributed.

Table 1: Correlation analysis between rodent abundance and the habitat factors assessed

Variable	*M natalensis*	*L rosalia*	*A wilsoni*	*M minutoides*	*R rattus*	*G vicinus*	*G dolichurus*	*Praomys sp*
Altitude	0.67772	0.17788	0.43033	0.15685	-0.39367	-0.23934	-0.16607	0.84594
%MOI 15cm	0.28683	0.20255	-0.31278	-0.78215	0.052566	-0.74608	-0.95331	0.2174
%MOI 30cm	0.36125	0.26021	-0.23547	-0.64719	-0.12943	-0.76934	-0.91162	0.35362
BD	0.55697	0.67351	0.2413	-0.2654	-0.517	-0.27401	-0.45423	0.086814
TD	0.2099	-0.27392	-0.07516	-0.0647	-0.24484	-0.31677	-0.20738	0.55183
CC	-0.22641	-0.0601	-0.27899	-0.15395	0.27399	-0.48806	-0.16557	0.25375
SD	0.61461	0.18625	0.28088	-0.05897	-0.54609	-0.01061	-0.31537	0.28886
SH	-0.7653	-0.31172	-0.5698	-0.25805	0.44289	0.0223	0.14659	-0.69126
GH	0.81246	0.52418	0.50001	-0.00698	-0.8416	-0.02393	-0.23182	0.31592
GC	0.7344	0.52305	0.64263	0.27339	-0.47357	0.077155	-0.04777	0.46647

Key: %Moi15 = percentage soil moisture content at 15 cm depth, %Moi 30 = percentage soil moisture content at 30 cm depth,
BD = Bulk density, TD = Tree density, CC = % Canopy cover, SD = Shrub density, SH = Shrub height, GH = Grass height, and GC = Grass/leaf litter cover.

Moreover, site close to a certain species host more individual of that particular species. For example, grid 1 and 3 hosts more *M. natalensis*. The distance between grids (sites) is a result of the chi-square in relative abundance, therefore grid close to each other hosts more similar species than distant ones. For, example in the triplot, the sites (black numbers) are more concentrate at the center hence they do not differ in terms of abundance except grid number 2. The line direction shows correlation between habitat factors (environmental variable) to species or grids, therefore *L. rosalia* is more associated with moisture content in the area. Also, the length of the line indicates how important is the variable in influencing the presence of the species under that direction. Therefore, from the triplot grass height and ground cover influences *M. natalensis*, while the species has negative association with shrub height. Species such as *A. wilsonii* didn't show association or choices between variables that's why it was found in the center. As for the spearman correlation analysis *M. muisitides*, *G. vicinus* and *G. dolichurus* were negatively associated with soil moisture content. *R. rattus* had strong association with shrub height, while negatively associated with grass height and ground cover. In generally grass height, ground cover and shrub height had strong influence on rodent species captured.

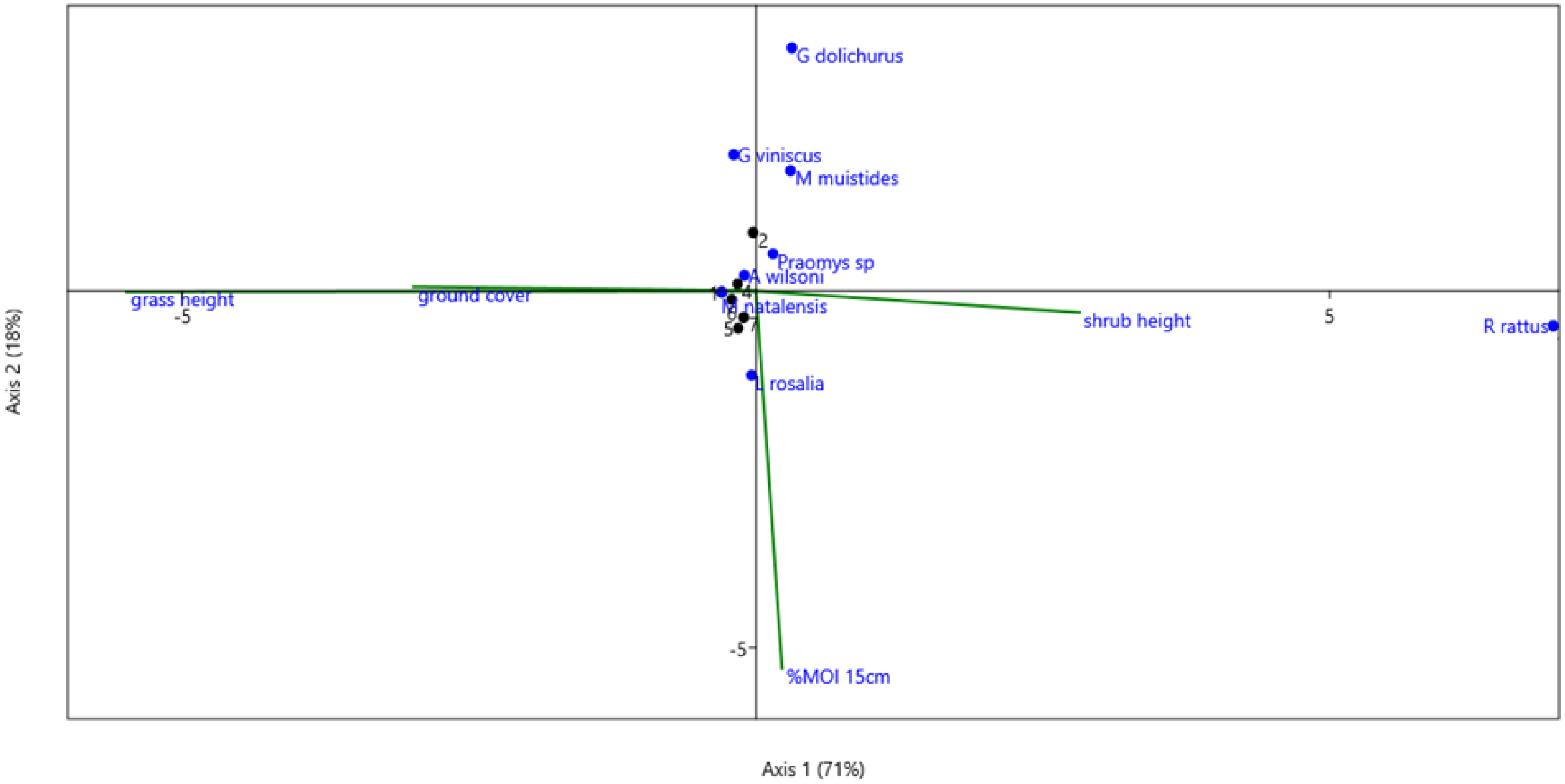

Figure 5: CCA - the associations between species, trapping grids and habitat factors. The numbered dots at the center of the plot are trapping grids, and lines show association of the environmental and biotic variables

CHAPTER FIVE

5.0 DISCUSSION

5.1 Rodent Species Abundance and Diversity in Different Habitat Types

A total of 8 species of rodents were captured namely; *M. natalensis, L. rosalia, A. wilsonii*, *M. minutoides, G. vicinus, G. dolichorus*, Praomys sp, and *R. rattus*. Also, two non-rodent species namely Crocidura sp and *Petrodromus tetradactylus* were trapped. This number of species recorded under the current study is smaller compared to that reported by Kiwia (2006) in Zaraninge forest. This could be due to the fact that the current study covered the wet season alone, thus, those species that are less active during this season were probably missed (see for example Mayamba *et al.,* 2019). For instance, Beamys sp are specialists foraging mainly on fruits (Sabuni *et al.*, 2015); thus, the fact that there were no fruits during the study period, this could be the reason of why this species was not recorded. Perhaps, it could have been trapped upon the extension of trapping period.

Among the eight rodent species recorded in this study, four of them (*G. dolichorus, G. vicinus*, *R. rattus*, and Praomy sp) were underrepresented with no more than three individuals. This may be due to the fact that the study site did not contain their preferable habitats. For example, *R. rattus* and Praomys sp (Kingdon, 1997) are commensals, and the latter prefer high altitude and mountain climate. Comparably, *M. natalensis* relative abundance was the highest in both miombo and evergreen habitats. Makundi *et al.* (1999, 2010) and Mulungu (2003) have reported this trend as well. Perhaps, since *M. natalensis* is a generalist can easily colonize a different habitat types regardless of disturbance levels (Massawe *et al.,* 2005). On the other hand, as this study was conducted during rainy seasons the higher abundance of *M. natalesis* could be due to indirect influence of rainfall (which indicate food availability and good cover), which favors this species reproduction activity and physiology (Leirs 1992, 1994).

Generally, the evergreen coastal forest habitat had a higher diversity index value (1.9) compared to the miombo woodland habitat which scored a diversity index of 1.2. The lower diversity in the miombo woodland could be due to habitat disturbance as fires, logging and firewood collection were commonly noted during data collection; thus, there is a possible impact on some sensitive species (Mulungu *et al.*, 2008).

5.2 Distribution Pattern of Rodent Species in Different Habitat

The highly abundant *M. natalensis* was distributed in both habitats. This is also supported by the study done in Ethiopia which also found *M. natalensis* being most abundant and evenly distributed, probably due to its opportunistic feeding behavior (Datiko and Bekele, 2013). *L. rosalia* was most abundant in the miombo woodland than in evergreen forest, probably due to high ground cover and grass height recorded within miombo. This corroborate with previous findings which indicates that this species is influenced by high grass cover, the feature that characterize the miombo woodland habitats (Smither, 1983). On the one hand, *A. wilsonii* presence in the miombo woodland and evergreen forest habitat was not a surprise. As it is reported by Kingdon *et al.*, (2003), *A. wilsonii* and other members of the genus Acormys can usually colonize many habitats especially in the semi-arid and grassland landscapes. On the other hand, *M. minutoides* preferred both miombo and evergreen habitats, and this could be due to the fact that this species has the ability to occupy a wide range of habitat following its size and the omnivorous feeding habit (Rowe-Rowe, 1986; Kingdon *et al.,* 2003). This species has been recorded in recently burned habitats and in higher altitude up to 2700 m.as.l (Monadjem, 1997; Kingdon *et al.*, 2003). *G. dolichurus* was only recorded in the evergreen forest, and this agrees with the results by

Kingdon *et al*. (2003), Kiwia (2006) and Mulungu *et al*. (2008), that the species is distributed in coastal forest thickets, but sometimes in bushy areas. The species is usually very rare to capture and require intensive survey to increase the number of captures (Stanley *et al.,* 1998). The presence of *R. rattus* in the evergreen forest on the other hand indicates high level of intrusion by humans around the forest which influence this commensal rat in this habitat type (Musser and Carleton, 2005).

Generally, under the current study, some rodents that are typical evergreen forest species such as Beamys spp (Kiwia, 2006; Sabuni *et al.,* 2015) were not captured during the entire capture period. This may be due to low sampling efforts. Therefore, it is anticipated that if we could have increased the trapping period the probability of capturing the species would have increased.

5.3 Influence of Micro-Habitat Characteristics on Abundance of Rodent Species

The results showed that each rodent species correlated with at a least one of the measured habitat variables. *L. rosalia* seemed to prefer moist habitats. These results agree with the previous study by Habtamu and Bekele (2008) who reported the species to also have wide ecological range and preferring forest and farmland with cover. *M. natalensis* which was the most abundant species in both habitats was associated with high ground cover and tall grasses. This species is highly adaptable and hence the preference of high ground cover suggests its association with densely vegetated grounds such as agricultural fallows, and miombo woodlands that are characterized by grasses and short bushes (Habtamu and Bekele, 2008). The species however, avoided tall shrubs. *A. wilsonii, M. minutoides, G. vicinus, G. dolichurous* and Praomys sp seemed to avoid moist areas. *R. rattus* on the other hand, was associated with tall shrubs. Moreover, it was observed that a small part of the evergreen forest was gradually being replaced by the miombo woodland and even the rodent species captured were not typically evergreen forest dwellers but rather many were generalists. According to Canova and Fasola (2000), change in original forests increase rodent richness and diversity, but mostly to the advantage of generalist species, meanwhile the specialized species face difficulties to coup and adopt.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study shows how habitat characteristics affect composition and diversity of rodents in Handeni Hill coastal forests, eastern Tanzania. As reported in previous studies, the alteration of the natural habitat can bring impact on specialist species while favoring the generalist ones (Canova and Fasola, 2000). This scenario was also observed under the current study, e.g. the presence of *M. natalesis* in higher abundance and its even distribution in the study area is an indication of habitat alteration. On the other hand, habitat factors such as ground cover and shrub height were found to have strong influence on species abundance. Lastly, it was observed (during data collection) that the influence of humans on the habitats was high and this was evidenced by the presence of commensal species such as *R. rattus*. This could be due to the fact that human activities have altered the original forest habitats to the extent of favoring these commensals.

6.2 Recommendations

Generally, it was observed that the evergreen forests are being replaced by the miombo woodlands as the rodent species captured were those species that can be found in habitats that are not necessarily coastal forests. Therefore, the management of Handeni Hill Forest Reserve has to consider proper utilization regime, and engage community for conservation and protection of some of the unique species found in the reserve. This study recommends a further research on additional patches of the costal forests in the inland to understand the gradient and movement patterns of rodents. This can give an understanding of whether habitat disturbance is a driver of species distribution in the coastal forests. A long-term study on population dynamics to assess the effect of season and climatic conditions on rodents could also reach at a sound conclusion on sustainable conservation of rodents in Handeni Hill Forest Reserve.

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APPENDICES

Appendix 1: Mean value of the habitat factors measured

Altitude	%MOI 15cm	%MOI 30cm	bulk density	tree density	canopy cover	shrub density	shrub height	grass height	ground cover
830	4.42	5.66	1.04	130.61	0.5	52.45	2.6	0.4	0.65
810	0.68	1.27	1.01	36.69	31.57	48.98	1.8	0.3	0.8
780	5.66	4.94	0.99	34.69	45.67	36.73	2.3	0.05	0.7
958	8.01	11.43	1.2	114.29	44.9	104.08	0.9	1.5	0.94
874	7.36	8.65	1.3	53.1	51.02	55.1	1.6	1.1	0.85
810	10.67	9.09	1.3	34.7	20.41	155.1	1.3	2	0.88
780	8.01	10.85	1.4	22.45	24.5	126.53	1.3	1.3	0.91