EFFECTS OF VEGETATION DISTURBANCE ON SMALL MAMMALS DIVERSITY AND DISTRIBUTION IN OLOOLUA FOREST, KENYA

By Abdullahi Hussein Ali

A thesis submitted in partial fulfilment for the award of Master of Science in Biology of Conservation, School of Biological Sciences, University of Nairobi, Kenya.

July, 2010

Declaration

I, Abdullahi Hussein Ali, declare that the work herein reported is to the best of my knowledge, original and has not been submitted for a degree in any other University.

Signed...

Date.........30/11/2009.........................

This thesis has been submitted for examination with our approval as the University Supervisors.

Dr. Robert Chira

Signed... ....

Date ....30/11/09...........................

Dr. Evans Mwangi

Signed..

Date.....30/11/09..................................

Dedication

This work is solely dedicated to my late brother **Muhumed Hussein Ali** who lost his life in theatre room, Garissa General Hospital while undergoing treatment, just a month before his long awaited Kenya Certificates of Secondary Education (KCSE) at the Maseno High School. May the Almighty GOD (Allah S.W.A) rest his soul in eternal peace and grant him *Janatul firdowsa. Amen.*

TABLE OF CONTENTS

List of Figures

List of Tables

List of Appendices

Acknowledgements

All praise is to God (Allah SWA), most gracious most merciful. Even though this piece of work is a product of my efforts and time, the dream of accomplishing it could not have been realized without the hands of numerous people to whom I owe credit. Special thanks go to my supervisors; Dr. Robert Chira and Dr. Evans Mwangi of the University of Nairobi, for their persistent encouragement and criticism throughout the period of writing this thesis. I am very grateful to Professor Michael Stokes of the University of Western Kentucky, USA, for allowing me to use his traps for capture of the small mammals. I acknowledge the support of the Institute of Primate Research, in particular, the assistance and direction provided by Mr. Stanislaus Kivai and Dr. Mbaaruk Suleiman during data analysis. Further, I am greatly indebted to my field assistants Mr. Alex Momanyi, Mr. Jotham Muyonga, Mr. Nicholas Kioko and Laboratory Technician Mrs. Ross Kavurani, for their enormous assistance during the data collection phase. I am highly beholden to the Mammalogy Department, National Museums of Kenya for providing technical support, equipment and secondary data that were essential for this study. I would like to express my profound appreciation and gratitude to the Kenya Wildlife Service (KWS) and Kenya Forestry Service (KFS) for offering me access to their libraries and facilitating the implementation of the research work. Sincere thanks also go to my former classmates: Boru Hassan, Adams Gakuo, Simon Kasaine and Francis Opiyo for their advice and support during data collection. Finally, I extend my cordial gratitude to immediate family members, Father (Hussein Ali), Mother (Hayi Hassan) and wife (Zamzam Mohamed) for encouraging me all along, while enduring long spells of my absence during the entire period of data collection and Thesis write-up.

Abstract

This thesis describes investigations carried out from October 2008 to March 2009 to asses the effects of vegetation disturbance on diversity and distribution of small mammals in Oloolua forest, Kenya. Four different forest habitats with various anthropic interference levels were assessed for vegetation and small mammals. Small mammals were sampled by trapping on square grids with 16 live traps, set out in a plot of 25m x 25m plot in every habitat. Overall, 67 woody species and 79 species of herbs were recorded in Oloolua forest. There was significant difference in woody species density among habitats ($F_{3, 204} = 2.78$, $p < 0.05$) in the forest. Similarly, there was significant difference in herbs density among habitats ($F_{3, 420} = 18.97$, $p < 0.05$) in the forest. Diversity index of woody plants was highest in the natural forest (2.7), followed by woodlands (2.5) and the eucalyptus plantation forest (1.9). Nine species of small mammals were recorded in the forest and they represented four main orders: Rodentia, Erinacemorpha, Primates and Carnivora. The Giant rat (*Cricetomys gambianus*) was most abundant species in the entire forest, while the hedgehog (*A.albiventris*) and cane rat (*T.swindderianus*) recorded the lowest numbers. Diversity index of small mammals was highest in the woodland (0.6), followed by the natural forest (0.35) and these two habitats provided greater diversity of small mammals than disturbed habitats. Giant rat (*C. gambianus)* and Tree squireel (*P. ochraceus)* were found to prefer areas with high plant cover and diversity while slender mongoose (*H. sanguineus)* and white tailed mongoose (*I. albicauda)* were dominant in open woodland habitat. This study has shown that there is lower small mammal species richness in disturbed habitats compared with undisturbed habitats. Finally, this study recommends further studies to quantatively assess specific responses of each species of small mammal to quarrying and plantations. The conservation of the forest will be key to future survival of the species and enhanced ecosystem functioning.

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

There are major concerns towards the loss of biodiversity in rich tropical forests around the equator resulting from anthropogenic disturbance (Myers *et al.*, 2000; Beck *et al.*, 2002). The unprecedented levels at which many known and countless unknown species of plants and animals are being lost due to human-influenced habitat degradation has led to 'the biodiversity crisis' (Wilson, 1985; Wilson & Peter, 1988; Wilson, 1992). Monitoring ecosystem viability as a whole is favourable in theory, but quantifying forested ecosystem disturbance is difficult (Simberloff, 1998). Using indicator species to reflect overall ecosystem health offers solution to this problem (Howard *et al.*, 1998). Species within various regions have been used to indicate the health of ecosystems on which they depend. The ability of such landscapes to conserve a region's biota is of concern to all those interested in biological conservation. While the total land area contained in large, continuous tracts of tropical forest is diminishing, remnant forest fragments are rapidly increasing in number because of incomplete deforestation. Such fragments form a mosaic of small habitat islands embedded in a human-modified matrix in which both abiotic and biotic processes are greatly altered. As a result, the within-fragment and among-fragment dynamics of populations will largely determine which tropical forest species can maintain themselves in disturbed landscapes.

Oloolua forest is one such fragmented tropical dry forest in an urban setting and currently provides increasingly important link to nature conservation mainly to Nairobi national park, Ngong hills and other adjacent wildlife areas (Gatheru *et al.*, 2000). The forest is situated on the northern lowlands of Ngong Hills forming part of the belt of dry forests of 1300-2000 m above sea level. The other remnant forests in the belt include Langata, Dagoreti, Maguga, City Park, Karura and Kamiti forest (Gatheru *et al.*, 2000). Most of these are increasingly important refuges for plants and animals as they provide vital corridors for nature conservation. They are also treasures for socio-economic and cultural values for surrounding communities as they provide a wealth of non-timber products including fibres, wild fruits and vegetables, chewing sticks and medicinal plants These forests are characterised by a rich mixture of tree species dominated by *Brachylaena hulliensis*, *Olea europae*, *Calodendrum capense*, and *Croton megalocarpus* species (Gatheru *et al.*, 2000). Quarrying activities within the forest have left areas devoid of vegetation cover and cast out very ugly scenery of unflattened heaps of bare soils. Some section of the forest is completely altered and other areas settled with evidence of household accessibility and use. In order to reveal the extent of human influence, this study sought to establish the effects of vegetation disturbance on diversity and distribution of small mammals in four habitats types with different levels of human influence.

Small mammals are among the animals highly affected by these and are most often used as indicator animals to assess levels of habitat fragmentations. In this study small mammals refer to a heterogeneous group from a taxonomic point of view, as they include species in the Orders insectivora, rodentia, hyracoidea and even order carnivora. Generally species within this group share biological and ecological features related to their small size including relatively small home ranges, short-live span and dispersal from their natal areas when they reach adulthood. Some small mammal populations can be monitored easily to determine their structure (proportion of age classes, sex ratio, etc.), reproductive activity, survivorship, home range size, etc. This offers a new insight on processes like rates of colonization, extinction, dispersal and persistence (Barrett and Peles, 1999). At this point, small mammal demography may vary at small spatial scales, and this variation may be a consequence of the ecological processes that occur at a local rather than at the landscape scales (Krohne and Burgin, 1990).

1.2 Literature Review

1.2.1 Habitat loss and selection by small mammals

Loss of habitat is one of the primary threats of maintaining biological diversity (Harris, 1984; Wilcox & Murphy, 1985) creating isolation and diminishing size of available habitats increasing the probability of species extinction through demographic, environmental or genetic stochasticity (Wiens, 1976; Harris, 1984; Goodman, 1987; Adren, 1994; Wilcove *et al.*1986; Noss & Cooperrider, 1994). Direct loss of species may result from altered habitat conditions or when animals move out into remaining habitats, where competition for resources is likely to intensify. Measuring patterns of habitat variation is critical in understanding their ecological consequence on the demography of small mammals. Data on habitat factors enable us to monitor changes occurring as a result of anthropogenic influence and the impacts these changes have on population dynamics of both plant and animal communities living there. In theory, animals optimize utilization of resources and will select those habitats whose resource base is wide. According to the marginal value theorem, a species will leave a given habitat when critical resources drop to the average for that habitat, this change may be gradual such that the number of individual animals decreases as resources diminish (Charnov, 1976).

Small mammals must obtain sufficient energy, nutrients and vitamins, and must escape predators to survive and reproduce. Their patterns of distribution may thus be influenced by the distribution and abundance of habitat resources. Food, location of burrows, water association and interaction between conspecifics,, territoriality and weather conditions (Ajayi, & Tewe, 1978), are some of these factors. An excellent example was reported by (Ajayi,1977) who observed that the distribution of African giant rat (*Cricetomys gambianus*) is strongly influenced by occurrence of burrows in its environment. Other studies have reported correlations of varying extent between habitat condition and distribution of species. In birds for instance, vertical distribution of sympatric species was observed to correspond with canopy strata (Wiens & Rotenberry, 1985) while distribution and abundance of resources explained group densities in primates (Kingdon, 1982; Cords, 1987; Butynski, 1990).

In view of the fact that small mammals are faced with an array of potential habitats, their choice will largely depend on habitat characteristics (Kincaid & Cameron, 1985; Odhiambo, 2000). As the availability of preferred habitat decreases, less favoured habitat is taken up in accordance with the resource optimization hypothesis (Hilbert *et al.*, 1981). However, the choice of habitat by species is not always pegged to a particular habitat attribute as a species may be present in widely varying habitats.

Consequently, the overall diversity and distribution of small mammal species may vary markedly across habitats with different resources and level of anthropogenic disturbances. Surveys on distribution of populations of small mammals demonstrate that patterns of population change associated with the disturbance of habitat are complex and difficult to assess (Hooven & Black, 1976). This is because data concerning the unknown variables are often missing (Odhiambo, 2000).

1.2.2 Population dynamics of small mammals

The study of population dynamics addresses the causes of the variation in population density, including limiting and regulatory factors that account for these variations (Krebs, 2002). The central theme in population dynamics is to understand how and why a population fluctuates in space and time (Lima and Jaksic, 1999). Dynamics of natural populations are a mixture of deterministic and stochastic factors, and the main objective of population dynamics studies is to determine the roles of the density-dependent and density-independent factors that affect population processes (Lima and Jaksic, 1999). These dynamics have been the subject of human curiosity during the last two decades (Krebs, 2002). From tropics to poles, small mammals populations experience seasonal, inter-annual and multi-annual fluctuations in numbers (Leirs *et al.*, 1996, Lima and Jaksic, 1999), being either regular or not. These fluctuations are a result of the basic demographic processes of reproduction, survival, mortality, emigration and immigration. The role played by regulatory factors and their effects on population dynamics still remains as an open and "hot" debate for most investigators. Small mammal species select habitats as a function of the resources such as (food availability, antipredatory refuges, etc.), but many other factors like their evolutionary history, their degree of specialization and the influence of behaviour on population distribution has influence on the spatial and temporal distribution of individuals and populations (Wolff, 1999).

1.2.3. Vegetation cover and structure.

The composition of small mammal's communities and the abundance of particular species in forest ecosystems are related to the carrying capacities of the habitat (Mazurkiewiz 1991). The abundance and species richness of small mammals that a given habitat can maintain depends on microhabitat features which provide food and shelter against predators (Yahner, 1982; Lin and Batzli, 2001). Small mammals in many communities show preference for habitats with high amount of vegetation cover (Kotler and Brown, 1988), a fact that is closely related with perceived predation risk (Bowers, 1988; Díaz, 1992, Lagos *et al.*, 1995). The selection of thick vegetation is considered to be an antipredatory strategy against both aerial (Longland & Price, 1991) and terrestrial (Jedrzejewska & Jedrzejewski, 1990) predators. Nevertheless, vegetation cover also provides food resources for small mammals, either as leaves, fruits, seeds or insects (Mappes & Ylönen, 1997, Hanski *et al.*, 2001).

Many studies showed strong relationships between small mammal's distribution and abundance and habitat characteristics at two spatial scales: at the landscape scale (macrohabitat) and at the patch scale (microhabitat). Small mammal responses to such scales rely on the degree of habitat specialization of the species. There is a non-specific response of generalist species to macrohabitat gradients (changes between habitats) but a sharp relationship with microhabitat structure, and opposite patterns can be found in specialist species. Data on habitat factors also provide a basis for assessing whether observed population pattern is actually regulated by these environmental factors. Deaths and low density of some small mammal population are reported to coincide with severe conditions of habitat (Cheeseman, 1977; Neal, 1984). In order to compensate for fluctuating resources, some species of small mammals are reported to alter reproductive behaviour (Neal, 1984) or switch to alternative habitats of poor quality (Gurskey, 2000). Finally, measurement of habitat factors may provide critical information in designing conservation management plans for small mammals and other animals.

One approach of assessing habitat quality is by determining densities of populations across the site. Distribution of burrows and vegetation cover are important aspects of habitat that may influence densities and distribution of small mammals (Ajayi & Tewe, 1978; Martin & Dickinson, 1985; Spencer *et al.*, 1990; Monadjem, 1997). For instance, removal of vegetation cover through quarrying or agricultural cultivation reduces the species diversity of small mammals (Ajayi, 1978). Many studies have investigated the diversity and distribution of small mammals (Delany & Neal, 1966; Cheeseman, 1977; Martin & Dickinson, 1985; Monadjem, 1997) but few of them have investigated the influence of vegetation disturbance on small mammal diversity and distribution.

1.2.4. Human disturbance on small mammal populations

There is a growing realization that the ecological consequence of anthropogenic effects on a wide range of habitats has direct influence on the diversity and distribution of vertebrate species (Wiens & Rotenberry, 1985; Hill *et al.*, 1991), and mammals (McAthur & Pianka, 1966; Chanov, 1976; Clutton-Brock *et al.*, 1977; Wrangham, 1980; Crompton, 1984; Harcourt, 1986; Boinski, 1987; Chapman and Chapman, 1990; Spencer *et al.*, 1990; Remis, 1997). These events can remove biomass, creating free substratum, and competition. Besides that, disturbances can be considered as events that promote alterations in systems structures, reduce species competition, and change resource availability (Sher *et al.*, 2000). Variations in frequency and intensity may result in an increase or decrease of biological diversity (Connell, 1978), making them key factors in community structures (Lavorel *et al*, 1994; Armesto & Pickett, 1985).

The degradation of natural environments (*e.g.*, deforestation) and fragmentation substantially modifies these structures and wild population parameters and, consequently, may affect species diversity (Lovejoy *et al.*, 1986; Terborgh, 1992; Noss *et al.*, 1994; Laurence & Bierregaard, 1997; Law & Dickman, 1998). It is also known that, in some cases, disturbances causes increased environmental heterogeneity which in turn may reduce the effects of interspecific competition, and enable coexistence of a larger number of ecologically similar species (Dueser & Shugart, 1979; Price, 1978; M'Closkey, 1976; Rozensweig, 1995). This is especially true among small mammals, for which habitat is the most important niche dimension by which species segregate (Schoener, 1974).

A major cause of loss of species is the alteration of the ecosystems in which they live, causing behavioural changes, particularly on population dynamics and distributions. Small mammals are likely to respond to changing habitats (Cheeseman, 1977; Neal, 1984). While variation in food types, activity patterns and dispersion in response to resources have been reported, few researchers have attempted to assess quantitatively the effects of habitat disturbance on the behaviour of small mammal species. This information would be used for a variety of conservation purposes, for example allocating conservation effort (Hefner and Fasola, 1997), investigating impacts of development or human-induced habitat changes (McCathy *et al.*, 1999), habitat fragmentation (Luke & Zack, 2001) and determining sustainable use levels (Forsyth, 1999). This information is also vital for establishing long term monitoring programmes, a key component of determining population trends (e.g. Ottichilo *et al.*, 2000; Ottichilo *et al*, 2001).

1.3 Justification

Expansion of human activities and the resulting habitat fragmentation affect several biological processes and factors, such as population size, species dispersal, structure and quantity of available habitats. However, research emphasis has often been placed on the study of the effects of patch size and isolation on species abundance and richness. Analyses of the responses of small mammal populations and communities to the effects of disturbances on these proximate factors at the relevant spatial and temporal scales will thus be a promising way to ascertain the relative roles of food and predation on small mammal populations and communities. In addition, a proper understanding on how human-induced changes in habitats and landscapes affect small mammal populations is crucial to undertake the management and conservation of forest ecosystems, considering the important role of small mammals in their dynamics as both food resources for several carnivores and raptors, as predators of insects, plants or seeds, even as seed dispersers of keystone plant species (Torre *et al.*, 2002).

Oloolua forest has been in the past one decade experienced the extraction of building materials and illegal exploitation of plants. The impacts of these activities have raised concerns among the surrounding communities and authorities interested and affected by these manipulations. This has also attracted the attention of the media and hence made Oloolua forest an issue of national and international concern. A second important change in this natural forest is the replacement of natural forest with exotic eucalyptus. Many of these exotic species are planted in Africa to provide quick growing timber and fuelwood. These manipulations of natural ecosystems by it constitute habitat alterations, which may be termed as disturbance. Such alterations have profound impacts on the ecology of the flora and fauna of the affected habitats resulting in change in vegetation cover, structure, and composition, population dynamics, and soil physical and chemical properties.

Because of these factors, small mammals have been identified as potential indicators of sustainable forest management (Carey and Harrington, 2001; Pearce and Venier, 2005). They contribute to forest succession, canopy closure and biodiversity recovery following clearing, burning, or even fragmentation. Disturbance has therefore direct or indirect bearing on populations of small mammals, some of which are important agricultural pests and vectors of diseases.. Until now, knowledge on the effects of deforestation and habitat fragmentation on the presence and abundance of small terrestrial mammals in East African forests is still limited. In order to elucidate the extent of human influence, this study sought to establish diversity and distribution of small mammals in four habitats types with different levels of human influence and assess how patterns of vegetation disturbance influenced diversity and distribution of small mammals.

1.4 Objectives

1.4.1 Overall objective

The overall objective of the study was to determine vegetation characteristics and the effects of disturbance on small mammal diversity and abundance in Oloolua forest.

1.4.2 Specific objectives:

- To determine changes in plant species diversity and densities across habitats in the forest
- To determine the diversity of terrestrial small mammals in different habitats within the forest.
- To determine the role of vegetation characteristics in the distribution and diversity of small mammals

1.5 Study Hypotheses

This study tested the following hypotheses:

Ho: The effect of vegetation disturbances on small mammal diversity is not different across habitats

CHAPTER TWO: STUDY AREA AND METHODS

2.1 Study area

2.1.1 Brief history and location of Oloolua Forest

Oloolua forest is located partly in Ngong division of Kajiado district and in Nairobi city (Figure 1). The Mbagathi River forms the border between Nairobi province and Kajiado district. Apart from Oloolua which covers a total area of 661.6 hectares, Ngong division, also houses the Ngong hills forest with an estimated size of 3077.0 ha. Oloolua is a tropical dry forest at 01^0 22' S, 36^0 42' E. The forest is gazetted and managed by both the Kenya Forestry Service (KFS) and National Museums of Kenya (NMK).

It consists of a variety of habitats with both indigenous and exotic patches, with the indigenous forest covering a total of 479.6 ha while 182 ha are under poorly managed eucalyptus plantation. To the north, the forest extends to Bul Bul location and spreads southwards for about 4 Kilometres, along the Mbagathi River to Rongai Township. To the west of the forest, are found the Olepolos, Oloolua and Ol Keri locations. Stone quarrying has been a major activity in Oloolua forest for the past two decades (Gatheru *et al.*, 2000).

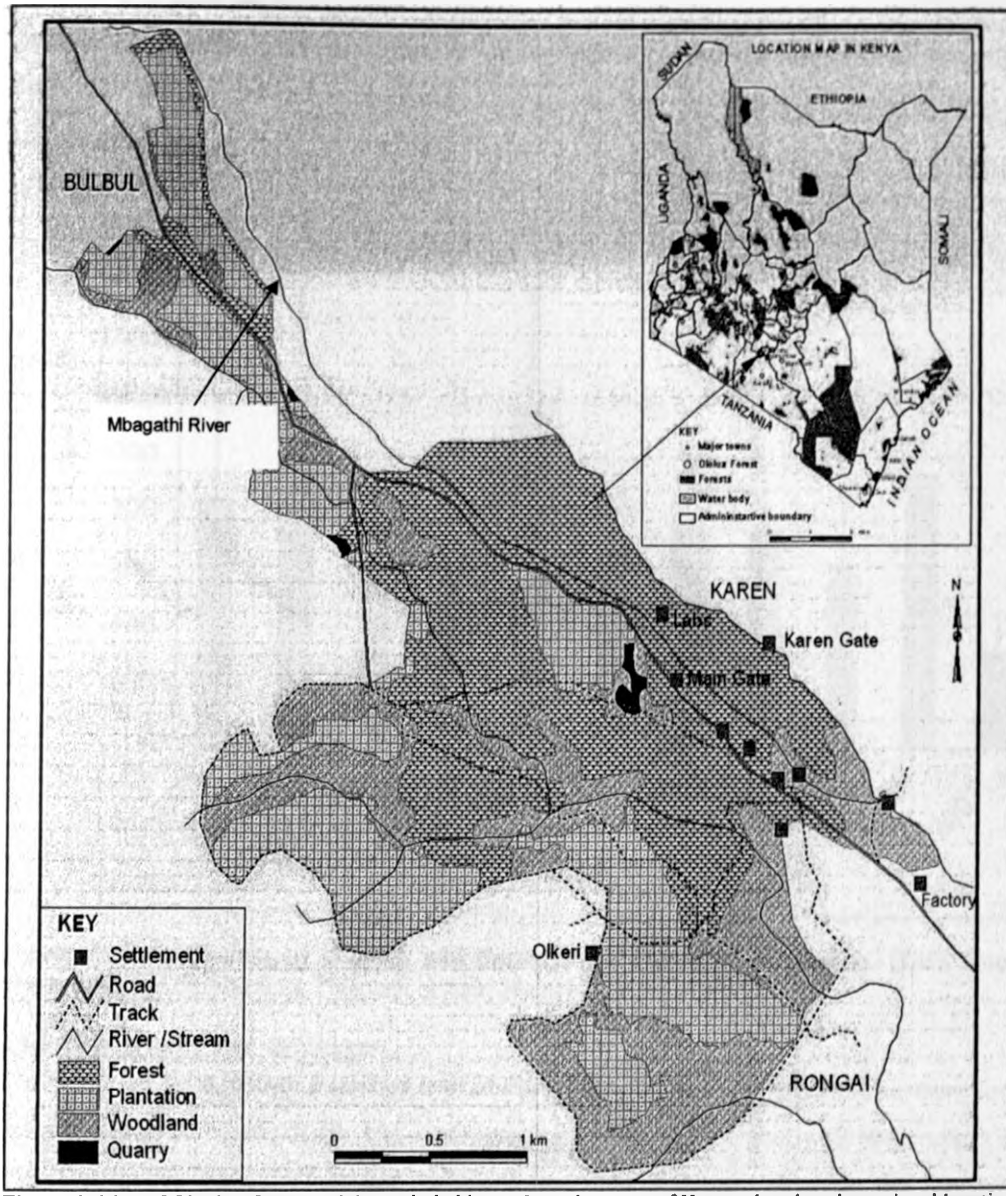

Figure 1: Map of Oloolua forest and the main habitats. Inset is a map of Kenya showing the national location.

2.1.2 Rainfall and Temperature:

Oloolua forest lies within 1300 – 2000 m above sea level (Lind & Morrison., 1974), with mean annual rainfall range of 875 – 1000 mm. Mean temperatures are in the range of 18 to 25 degrees Celsius with the greatest diurnal variation during the dry season (Figure 2). Potential evapotranspiration varies between 1400 mm in the higher and wetter parts to 1800mm in the lower, drier zones.

Meteorological data from 1986-2005 indicates a bimodal rainfall pattern with long rains from March to June, while the short rains start in September and end in November. Mean monthly potential evaporation and evapotranspiration lag behind precipitation all year round except in January, February and December, which represent the hottest and driest months of the year in the area (Figure 2).

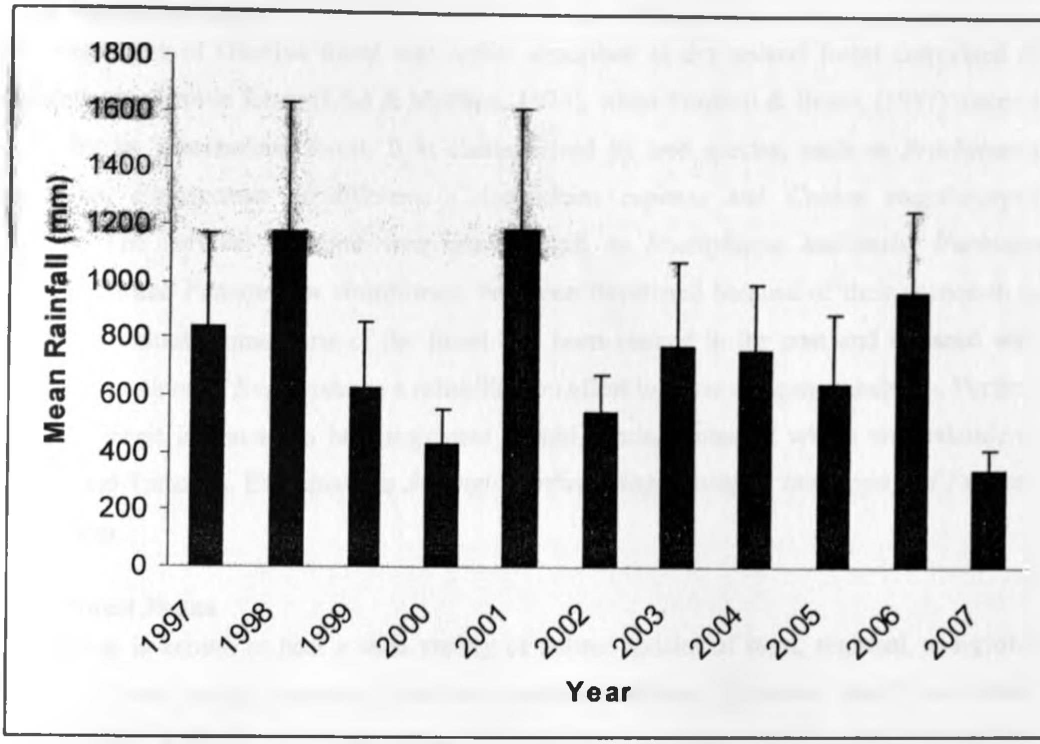

Figure 2: Rainfall data of Oloolua and the adjacent Ngong forest station. (Data source: Meteorological department, Dagoreti corner, Nairobi)

2.1.3 Topography and drainage:

The forest lies on undulating landscape of about 2000m above sea level at the northern lower volcanic plains of Ngong Hills. The landscape is characterised by gently sloping valleys and wide flat topped ridges. There are numerous intermittent streams draining the forest into Mbagathi River. The main drainage pattern is shaped by sloppy volcanic rocks which generally incline towards the east.

2.1.4 Geology, soils and mineral resources

Oloolua and it environs is characterised by shallow volcanic soils. The geological history of the area and its surroundings has been dominated by volcanic activity whereby a thick succession of alkaline lavas and associated tuffs began accumulating in the mid Miocene time and continued into the upper Pleistocene (Gatheru *et al.*, 2000). Practically, these volcanic rocks derived from the Rift Valley region cover the entire Nairobi area. The Oloolua forest contains a variety of rock types, the most important being the devitrified welded tuffs (the Nairobi stone) used extensively for building purposes.

2.1.5 Vegetation types

The vegetation of Oloolua forest was earlier described as dry upland forest comprised of Brachyleana- Croton forest (Lind & Morison, 1974), while Trapnell & Brunt, (1987) mapped it as dry an intermediate forest. It is characterized by tree species, such as *Brachylaena huillensis*, *Pittosporum viridiflorum*, *Calodendrum capense* and *Croton megalocarpus* species. The survival of some tree species such as *Brachylaena huillensis*, *Warbugia ugandensis* and *Pittosporum viridiflorum*, has been threatened because of their economic or medicinal values. Some parts of the forest had been cleared in the past and replaced with exotic plantations of *Eucalyptus* as a rehabilitation effort to cover old quarry habitats. Further, Oloolua forest is known to host important orchid species, some of which are endemic to Kenya and Tanzania. Examples are *Aerangis confusa, Angaraecopsis brevilopa and Psilopus longifolius.*

2.1.6 Forest Fauna

The forest is known to host a wide variety of animal species of local, regional, and global interest. These include leopards (*Panthera pardus)*, buffaloes (*Syncerus cafer*) bush bucks (*Tragelaphus scriptus)*, red forest duiker (*Cephalophus natalensis*) Grey duiker (*Sylvicapra grimmia*), Dik-dik (*Madoqua kirkii*), Warthog (*Phacochoerus aethopicus*), bush pigs (*Potamochoerus larvatus)* Giraffes *(Giraffa camelopadalis tippelskirchi)*, Spotted Hyenas (*Crocuta crocuta*), Sykes monkey (*Cercopithecus albogularis*), Vervet monkey (*Cercopithecus aethiops)* and the Greater Galago (*Otelemur garnettii*) (Gatheru *et al*., 2000). Oloolua also is rich in forest birds, holding around 102 bird species altogether. Of these 87 are completely forest dependent and their current status remains unknown. Of the 87 species, 15 are forest specialists, and are at great risk, as they have very low tolerance to any habitat disturbances. Six birds of regional importance,(i.e where the East African countires hold bulk of the population) also present in Oloolua forest. There are also two regionally vulnerable species; Ayres hawk eagle (*Hieraaetus ayresii*) and African crown eagle (*Stephanoaetus coronatus*).

2.1.7 Land use and socioeconomic environment

The human settlements around Oloolua forest comprises of a mixture of people from different ethnic background. While the Massai were the earlier settlers, mixed group of people have immigrated into Ngong from various part of the country. Some have established permanent residence while others live in rental houses around shopping centres neighbouring the forest. These forest adjacent communities are mainly involved in intensive quarrying and subsistence agriculture around the forest. In the drier areas, more mixed agro pastoral land uses are found (Gatheru *et al.*, 2000). Three quarters of these people use the forests for basic subsistence needs, including firewood, poles, forest fibres, honey collection, game meat, food plant and medicinal plants (Gatheru *et al.*, 2000). A key economic activity is stone mining from Oloolua forest and neighbouring private farms. Stone mining business is owned by few individuals and groups. However, the mining industry employs many people comprising of casual labourers, drillers, stone dressers and blasters. These groups further support food vendors, brokers and transporters within the same localities. Infrastructure development (schools, churches, and market centres roads) also continue to encroach within the forest boundaries contributing to the loss in forest cover (Gatheru *et al.*, 2000). These threats have profound impacts on the ecology of the flora and fauna of the affected habitats through habitat destruction, grazing, quarrying and illegal plant extractions.

2.2 Material and Methods

Different forest habitats showing a mosaic of different successional forest stages and various anthropic interference levels were assessed for vegetation characteristics and small mammal diversity. These habitats included the natural forest (H1), Woodlands (H2), Plantation forest (H3), and Open quarry (H4). The plantations and the quarry habitats represented disturbed habitats with evidence of human manipulation, household accessibility and use.

2.2.1 Woody species characterisation

The woody species characterisation was conducted from October 2008 to March 2009. Using the topographical map of the study area, square grids measuring 25m X 25m were demarcated and numbered. Five sampling grids in each habitat were then selected randomly using random numbers to minimize biasness (Cochran, 1977). Random selection was done independently in each habitat to ensure comprehensive coverage and adequate representation of each habitat. The above plots were used for assessment of vegetation where all individual plants within each plot were counted and identified to species level. Vegetation characteristic data collected was based on diversity, cover, density, basal area and composition. The data generated was used to calculate the following vegetation parameters (Cox, 1990):

$$\text{Density} = \frac{\text{Total number of each species}}{\text{Size of habitat (hectares) sampled.}}$$

$$\text{Relative density} = \frac{\text{Density for a species}}{\text{Total density for all species.}} \times 100$$

$$\text{Dominance} = \frac{\text{Total of Basal Area}}{\text{Area Sampled}}$$

$$\text{Relative dominance} = \frac{\text{Dominance for a species}}{\text{Total dominance for all species}} \times 100$$

$$\text{Frequency} = \frac{\text{Number of plots in which species occurs}}{\text{Total number of plots sampled}}$$

$$\text{Relative frequency} = \frac{\text{Frequency value for a species}}{\text{Total of frequency values for all species}} \times 100$$

Importance value = relative density + relative dominance + relative frequency

2.2.2 Species Diversity

Species diversity of was determined using Shannon Wiener diversity index (H') (Shannon and Wiener, 1963). Species diversity was used with the assumptions that randomness in sampling was achieved. The index combines two quantifiable measures that include the species richness S (the number of species in the community) and abundance N (is the total number of individuals in the sample). The index is termed H' with higher values indicating increased diversity.

Shannon Wiener diversity index

$$H' = -\sum_{i}^{n} (pi \log pi)$$

Where

H' = Information content of sample, Index of species diversity, or degree of uncertainty.

p_i = Proportion of total sample belonging to i_{th} species

Finally, woody species basal area was estimated for each habitat, based on the basal diameter measured for individual trees within each habitat. Basal areas were subsequently used to estimate the distribution of tree basal areas ($m^2/625m^2$) in each habitat. Tree Basal Area (TBA) which is the cross-sectional area (over the bark) at breast height (1.3 metres above the ground) measured in metres squared (m^2). TBA was used to estimate tree volumes and stand competition. To determine Tree Basal Area, I measured the diameter at breast height in centimetres and calculated the basal area in (m2) using an equation based on the formula for the area of a circle (area = p r2 where r = radius and p = 3.142) and the formula for radius (r=diameter/2 = DBH/2).

Therefore:

$$\text{Tree Basal Area (TBA) } (m^2) = \pi r^2$$
$$= 3.142 \times (DBH/200)^2$$

Where DBH is the diameter at breast height in centimetres and this formula also converts the diameter in centimetres to the basal area in square metres.

2.2.3 Herbaceous layer characterisation

Herbaceous layer sampling was carried out in nine 1m x 1m quadrats, placed at 6m intervals within the larger plots. Overall, 45 micro plots of 1m x 1m were sampled for each habitat. Starting points of the sampling plots were randomly selected from the lager plot. Sampling plots were used in each habitat to estimate herbaceous species richness and diversity, cover and density across the habitats. All individuals within each sub plot were counted from which the total density was determined. Herbaceous layer specimens along with woody specimens were also prepared and submitted to Chiromo herbarium, University of Nairobi, for identification. The herbaceous layer cover was estimated for each habitat based on mean percentage ground cover of herbs in each plot. This was subsequently used to estimate the overall mean herbaceous cover within the habitats.

2.2.4 Comparison of herbaceous layer similarity across habitats in Oloolua forest

Habitat similarity in herbaceous layer was measured by pair wise comparison of the habitats using Sørensens similarity coeffiecient (Ss). The computation of similarity index was done using the following formula;

$$(Ss) = \frac{2a}{2a + b + c}$$

Whereby;

Ss= Sørensens similarity coeffiecient

a= Species common in both habitats

b= Total number of species in habitat 1

c = Total number of species in habitat 2

The interpretation of the similarity coefficient is that, the higher the coefficient the more similar the habitats are, and the coefficient ranges from 0-1, where 1 implies perfect similarity.

2.2.5 Small mammals sampling

Sherman live traps 23 x 9.5 x 7.5 cm (H.B. Sherman traps Inc. Tallahassee, USA) and collapsible double door live Tomahawk Traps (Model 203) were used to sample small mammals across the habitats. . Sampling was done from October 2008 to March 2009 in 4 different habitats, which involved setting up of traps in 25x25m square grids. Every sampling point contained 4 trap-stations laid at 5 m intervals, each with 4 traps, baited with fried coconuts mixed with peanut butter. Each trap station had 3 Sherman traps and one Tomahawk trap and the traps remained open for three consecutive days and nights. These were inspected twice every day, and rebaited daily i.e. that is early in the morning and just before dusk. Captured animals were identified to species level, weighed to the nearest 0.5 g using a Pesola spring balance (PESOLA, Switzerland).

For every captured animal, the following information was recorded into a standard sheet: date, trap station (or trap-number), species identity, sex, age class, body mass, reproductive condition and any other detail observed and deemed important, e.g. injury. Sex was determined by examining primary reproductive organs, e.g. penile organ or vagina. This was used to determine the reproductive state through examination of testes for males, and vagina for females i.e closed or open; teats visible, enlarged or small. Age was assessed by examining fur texture, size etc. Further, individual body measurements (head - body length in mm, tail length in mm, left hind foot length, Left Ear length to the nearest mm) were recorded (Happold & Happold 1990, Keesing 1998). Specimens were prepared as scientific voucher specimens in the form of skins and skulls, or as fluid preserved specimens. Skulls were removed from the latter to aid in identification. The identification of all specimens followed (Kingdon., 2004, and National Museums of Kenya mammalogy collection).

2.3: Data analysis

All statistical analysis was performed by use of GraphPad InStat 3.0 statistical program. Data were tested for normality and heteroscedasticity before parametric analysis. Where parametric requirements were slightly not met i.e proportions, the data was arcsine-transformed before using Analysis of variance (ANOVA) analysis.

Analysis of Variance was also performed to test for significant differences between vegetation types in the four habitats. Chi-square analysis was performed to assess the distribution of small mammals in different habitats of Oloolua. Finally, the observed sex structure of small mammals was tested for differences from 1:1 ratio using Chi-square test. All statistical analysis were evaluated at $p = 0.05$ level of significance.

CHAPTER THREE: RESULTS

3.1. Vegetation characterisation

Vegetation assessment was done for the four habitats of the forest that comprised the natural forest (H1), Woodlands (H2), Plantation forest (H3), and Open quarry (H4). The assessment characterized the woody species and the herbaceous layer. The following are the results of the vegetation assessments.

3.1.1 Woody species richness and composition across the habitats

The woody vegetation of natural forest was dominated by Brachylaena-Croton stands that are characteristic of a dry tropical lowland forest (Appendix 1). A total of 51 woody species were recorded in this habitat mainly comprising of five major families that included Compositae, Euphobiaceae, Rutaceae, Rubiaceae and Ochnaceae. The key species with higher relative density (the density of one species as a percent of total plant density) in this habitat are trees such as *Brachylaena huillensis (10.7)*, *Croton megalocarpus* (10.1), *Clausena anisata (9.5) Teclea simplicifolia (7.9), and Ochna ovata (5) as shown in (Appendix 2)*. The *Brachylaena huillensis* had the highest importance value (21*)* in this habitat, closely followed by *Croton megalocarpus* (20) and *Clausena anisata* (13)

The woodland habitat mainly comprised of Rutaceae, Tiliaceae, Sterculaceae and Umbeliiferae families. This was the second most diverse habitat registering a total of 41 woody species (Appendix 3). The key species with higher relative density in this habitat are trees such as *Clausena anisata (17.1), Teclea simplicifolia (7.6), Heteromorpha trifoliata (6)* and *Grewia similis (6%)*. Other species with higher relative density in this habitat included the following: *Heteromorpha trifoliata (6) Strychnos henningsii (6)* and *Olea Africana (5)* as shown in Appendix 3. In this habitat *Clausena anisata* had the highest importance value of 32, followed by *Heteromorpha trifoliata (16) and Grewia similis with (13) as* shown in *Appendix* 3.

The eucalyptus plantation forest was characterised by pure eucalyptus stands mixed with secondary vegetation. A total of 148 woody plants comprising of 14 species were recorded in this forest. The most common families in this habitat included the Myrataceae and

Thymelaceae. The key species with higher relative density in this habitat are trees such as *Eucalyptus botryoides (35), Lanta camara (25) and Clausena anisata (13) as detailed in Appendix 4. Eucalyptus botryoides* had the highest impotance value of 87.51 within this habitat, followed by *Lantana camara (57) and Clausena anisata (34) (Appendix 4)*

The quarry habitat had the lowest number of species (13) across all the habitats (Appendix 5). The area is characterised by heaps of bare soils, with few secondary coloniser/ invasive species. The main families in the quarry include Luganiaciae, Labiatae, Solanaceae, Polygonaceae and Verbanaceae. The key species with higher relative density in this habitat are trees such as *Buddleia polystachgia (38), Lantana camara (16) and Solanum indicum* (14) as detailed in Appendix 5. All these are invasive species that colonized the area following initial destruction of the natural vegetation. *Buddleia polystachgia* had the highest importance value (92), followed by *Lanata camara* (56*) and Solanum indicum* (34*)* as detailed in Appendix 5.

Overall, a total of 35 families were recorded in the entire forest for woody species representing 67 different species of trees and shrubs across the study sites (Appendix 1). The Plantation and the Quarry habitats had the highest number of invasive species that included *Eucalyptus botryoides, Gnidia subcordata, Lantana camara, Dombeya burgessiae, Buddleia polystachgia, Solanum indicum* and *Rumex usamabarensis.* All these invasive species have the potential to lead to further habitat degradation. Eucalyptus plantations were earlier introduced in Oloolua as part of rehabilitation effort to increase plant cover in highly degraded areas within the forest. This followed destruction of natural vegetation for mining/quarrying purposes and is currently undergoing natural regeneration and hence invasion by exotic and natural forest species.

3.1.2 Difference in woody species densities across habitats

The mean woody species density in the forest ranged between 1010.24 ± 142.4./ha to 34.56 ± 6.56 /ha as estimates for plantation forest and the quarry habitats respectively (Figure 3). The natural forest and the woodland had a mean density of 632.96 ± 121.6/ ha to 424.96 ± 925.8/ha respectively.

There was significant difference in woody species density among sites ($F_{3, 204} = 2.78$, $p < 0.05$) in the forest (Figure 3). Turkey's Post hoc analysis revealed that the plantation forest had significantly higher density than all others. The quarry recorded the least density among all the habitats, however, differences in densities between the natural and the woodlands were not significant, ($p > 0.05$). Generally, the high density in the plantation forest can be attributed to the exotic eucalyptus plantations which establishes fast.

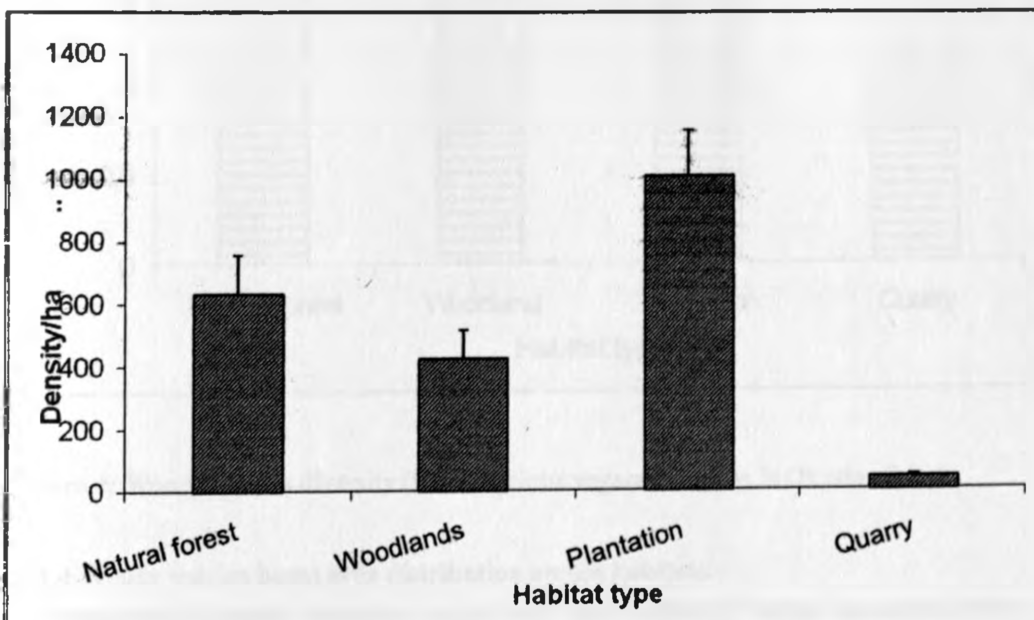

Figure 3: Woody species mean density/ha across habitats in Oloolua forest.

3.1.3 Woody plants diversity across habitats

Figure 4 shows diversity index (H') of woody species in four main habitats of the forest. Diversity index of woody plants was highest in the natural forest (2.7), followed by woodlands (2.5) and the eucalyptus plantation forest (1.9). Lowest H' values were obtained in old quarry habitat (1.8).

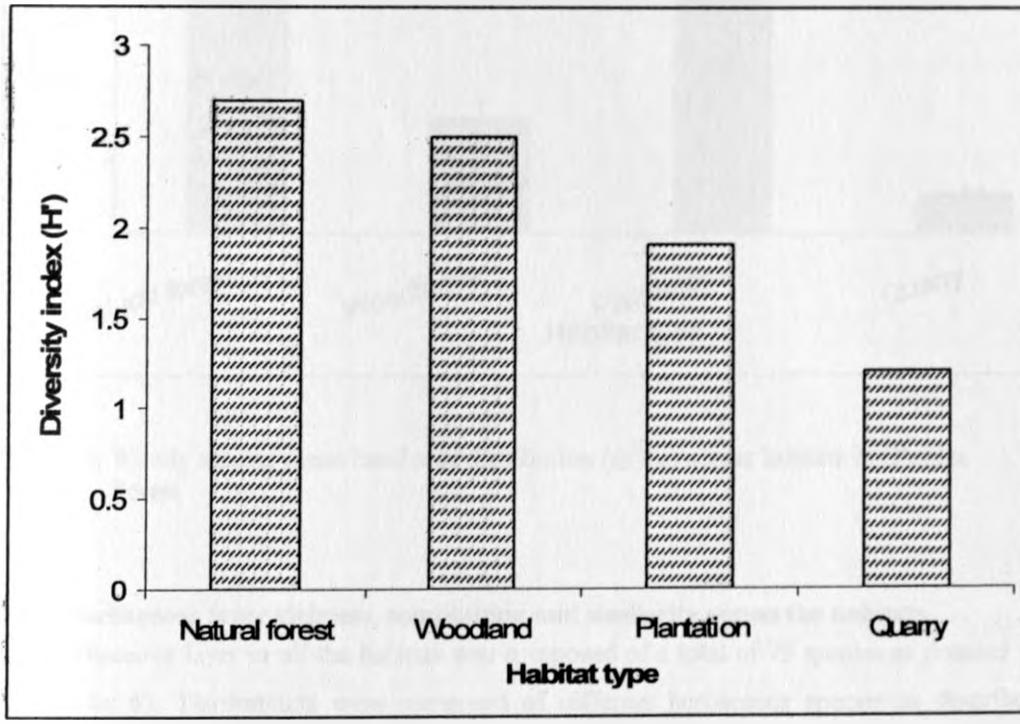

Figure 4: Woody species diversity (H') in various vegetation types in Oloolua forest

3.1.4 Woody species basal area distribution across habitats.

The mean woody species basal area ranged from 960 ± 204.8 m^2 /ha for the natural forest to 320.1 ± 51.2/ha for the quarry habitat as shown in Figure 5 below. Tukey krammer multiple comparison test revealed the value of q as greater than 3.674, $p<0.05$). This means variation of mean basal area was significant across the site. These variations about the mean indicate significant differences particularly between the natural forest and quarry. However, basal area variation between the plantation forest and the woodlands was not significant, ($p>0.05$).

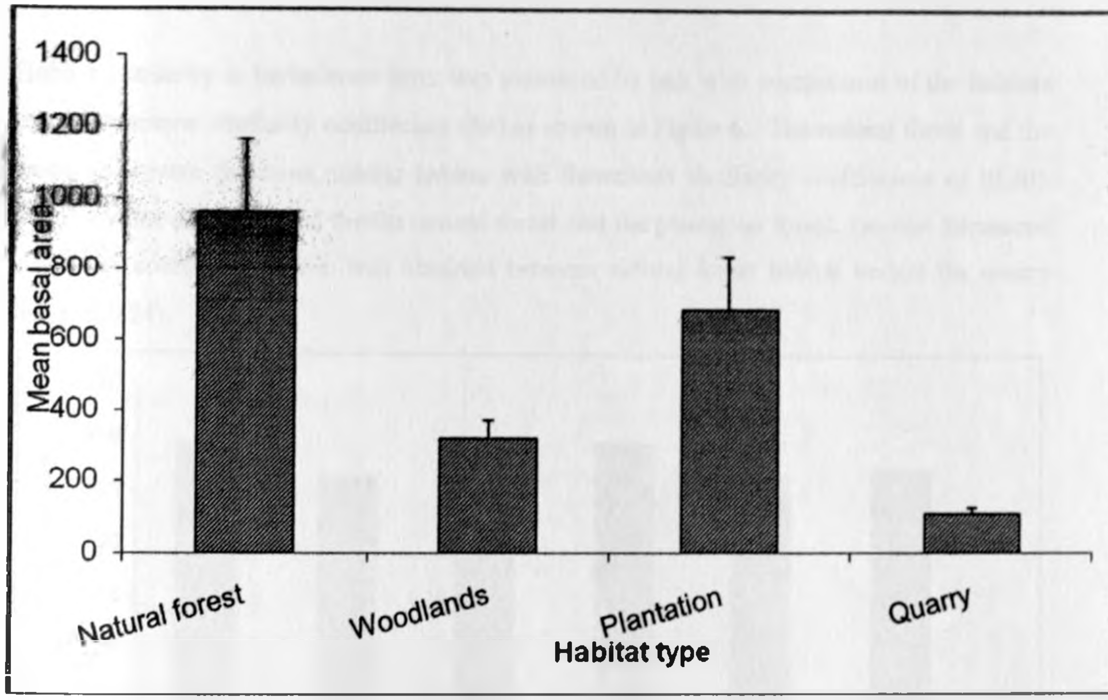

Figure 5: Woody species mean basal area distribution (m^2/ha) across habitats in Oloolua Forest

3.1.5 Herbaceous layer richness, composition and similarity across the habitats

The herbaceous layer in all the habitats was composed of a total of 79 species as detailed in (Appendix 6). The habitats were composed of different herbaceous species as described below.

The herbaceous layer for the natural forest was dominated by three main families that included Graminae, Thymeleaceae and Acantheceae. The key dominant species that represented each of these families were *Setteria pelicatilis, Oplismeus hirtellus* and *Gnidia subcordata seedlings, Barleria ventricosa* and *Asastasia spp.* The woodlands habitat was the most unique habitat with distinctive herbs composition that included Graminae, Leguminosae and Verbanaceae. These families were represented by *Panicum maximum, Indigifora swanziensis* and *Aspilia mossambicensis.* The plantations and the quarry had similar species composition and were dominated by three main families that include Graminae, Labiatae and Acantheceae. The dominant species in these two habitats incuded: *Setaria pelicatis, Ocimum suave and Asastasia spp.*

Habitat similarity in herbaceous layer was measured by pair wise comparison of the habitats using Sørensens similarity coeffiecient (Ss) as shown in Figure 6. The natural forest and the woodlands were the most similar habitat with Sørensens similarity coeffiecient of (0.30). Similar value was obtained for the natural forest and the plantation forest. Lowest Sørensens similarity coeffiecient value was obtained between natural forest habitat versus the quarry habitat (0.24).

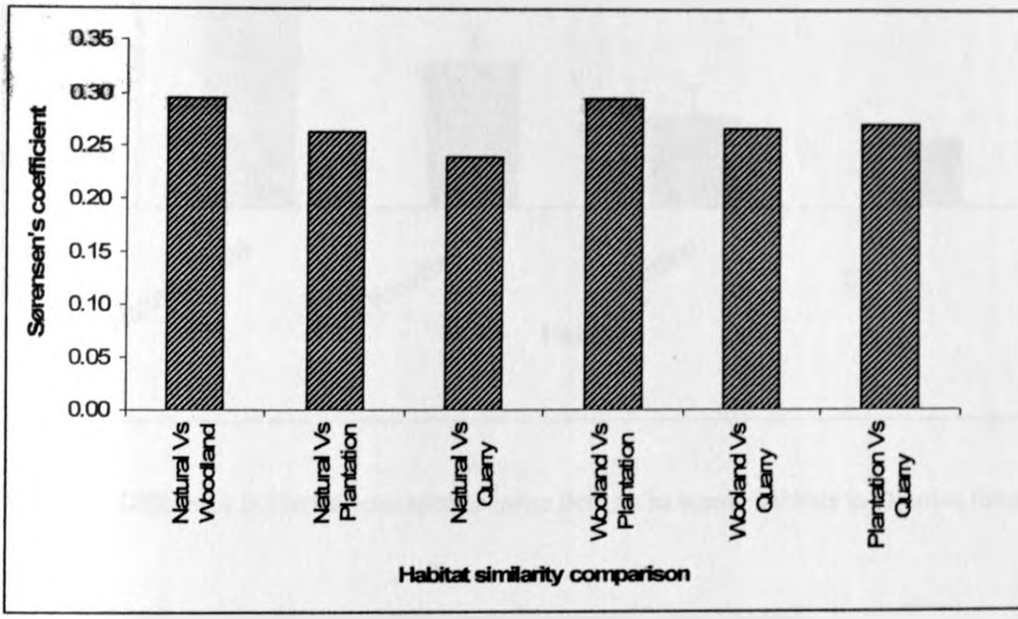

Figure 6: Pair wise comparison of herbaceous layer species diversity across habitats in Oloolua forest.

3.16 Differences in herbaceous layer densities across the habitats

The mean herbaceous species density ranged from 3702.24 ± 445.76/ha to 623.04 ± 169.192/ha as estimated in natural forest and the quarry respectively (Figure 6). The woodlands and the plantation forest had a mean density of 1354.72± 325.28/ha and 840.32 ± 297.6/ha respectively.

There was significant difference in herbs density among habitats ($F_{3, 420} = 18.97$, $p < 0.05$) in the forest (Figure 7). Turkey Post hoc analysis revealed that the natural forest had significantly higher density than all other habitats. However, the differences in densities between the woodlands and the plantation was not significant, ($p > 0.05$). Generally areas that have had some level of human influence recorded the lowest densities, i.e. the plantations and the quarry.

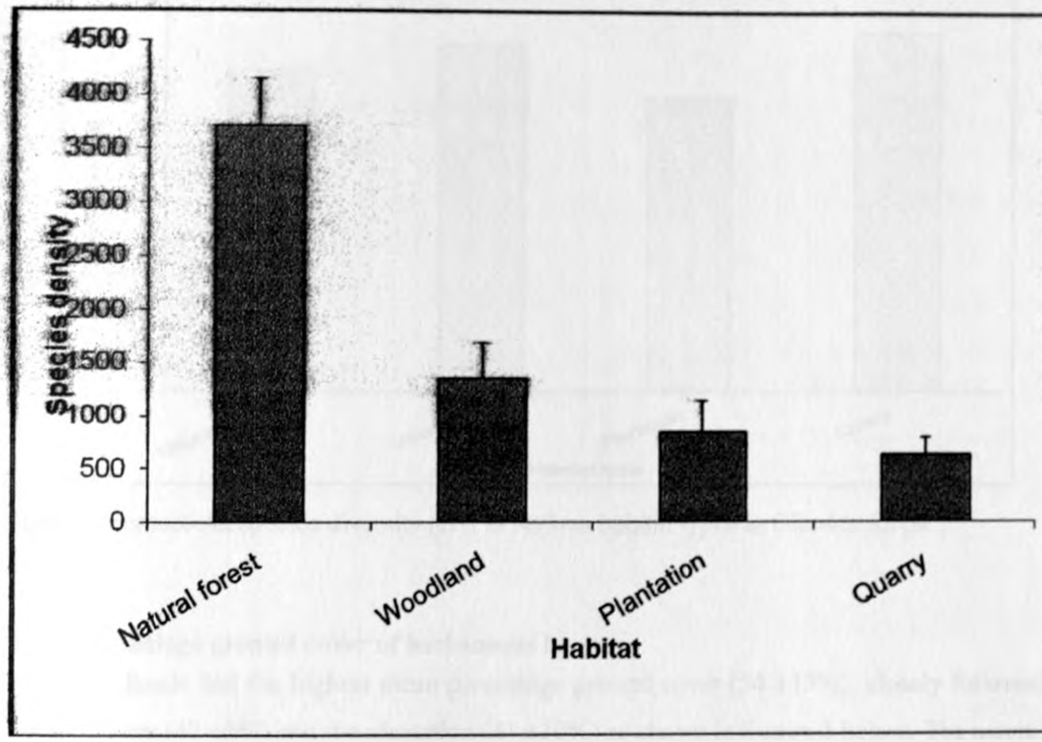

Figure 7: Difference in Herbaceous species mean density/ha across habitats in Oloolua forest

3.1.7 Differences in herbaceous layer species diversity across habitats

Figure 8 show diversity indices (H') for the herbaceous layer in the four habitats of Oloolua forest. Herbs species Diversity was highest in the woodland (2.7), followed by the natural forest (2.5) and the quarry (2.8). The plantations recorded the lowest diversity index (2.3) as shown in Figure 8.

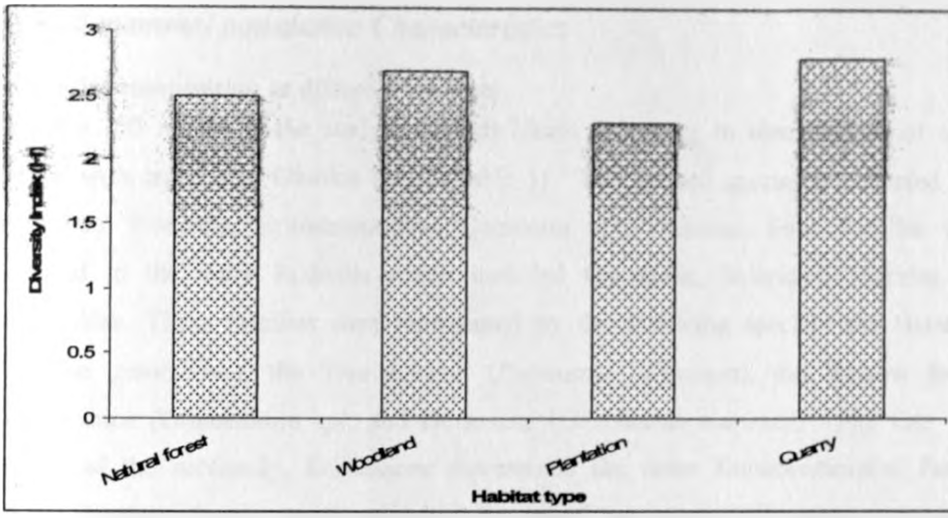

Figure 8: Herbaceous species diversity (H') in various habitat types in Oloolua forest

3.1.8 Percentage ground cover of herbaceous layer

The woodlands had the highest mean percentage ground cover (54 ±15%), closely followed by the quarry (42 ±5%) and the plantation (41 ±10%) as shown in Figure 8 below. The natural forest recorded the least ground cover percentage (38 ±8%). The high mean percentage cover for herbs in the woodlands can be attributed to the penetration of light and minimal level of disturbance that were lacking in all the other habitats. Cover values were arcsine transformed and tested for significance using Anova. However, variations of ground cover were not significant across the habitat with ($F_{3,16} = 1.057$), $p>0.05$.

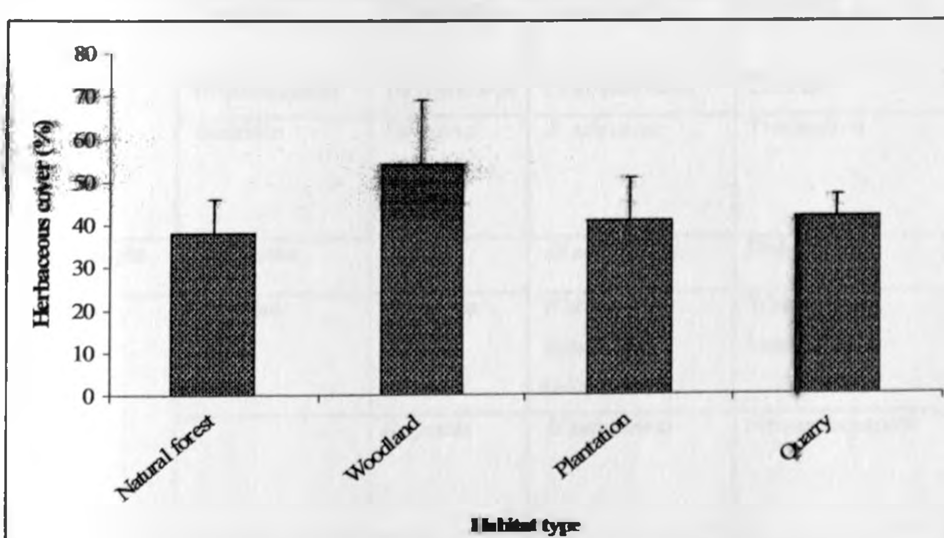

Figure 9: Mean (± SE) percentage herbs cover across the habitats of Oloolua.

3.2 Small mammal population Characteristics

3.2.1 Species composition in different habitats

During the 150 nights of the study, 194 individuals belonging to nine species of small mammals were trapped in Oloolua forest (Table 1). The trapped species represented four main orders: Rodentia, Erinaceomorpha, Carnivora and Primates. Four families were represented in the order Rodentia which included Oricetidae, Sciuridae, Muridae and Muscardinidae. These families were represented by the following species: the Giant rat (*Cricetomys gambianus*), the Tree squireel (*Paraxerus ochraceus*), the Narrow footed woodland mice (*Grammomys sp),* and Dormouse (*Graphiurus murinus).* The four toed hedgehog of the subfamily, Erinaceinae represented the order Erinaceomorpha. Family viveridae represented order carnivora, which registered two species (*Herpestes sanguineus* and *Ichneumia albicauda*). Finally, the order primates registered a single species, the greater Galago (*Otolemur garnettit*) of the family Galagonidae.

Table 1: Species composition and taxa of small mammals recorded in Oloolua forest.

Order	**Family**	**Genus**	**Species** **Scientific name**	 **Common Name**	**Habitat found**
Rodentia	Muridae	*Grammomys*	*G. dolicheurus*	Narrow footed woodland mice	Woodlands
	Muscardinidae	*Graphiurus*	*G.murinus*	Dormouse	Natural forest
	Oricetidae	*Cricetomys*	*C.gambianus*	Giant Rat	All the habitats
	Thryonomyidae	*Thryonononomys*	*T.swindderianus*	Cane rat	Woodlands
	Scuiridae	*Paraxerus*	*P.ochraceus*	Tree squirrel	Natural forest and the woodlands
Erinacemorpha	Erinaceinae	*Atelerix*	*(A.albiventris)*	Hedgehog	Woodlands
Carnivora	Viveridae	*Ichneumia*	White Tailed Mongoose *I.albicauda*	White Tailed Mongoose	Woodlands
		Herpestes	*H.sanguineus*	Slender mongoose	Woodlands and Natural forest
Primates	Galagonidae	*Otolemur*	Bush baby (O.*garnettit)*	O.*garnerttit*	Natural forest

External measurements were taken for the captured individuals for taxonomic identification purpose and determination of the general body conditions. This was compared with documented morphometric measurements of each species as detailed by (Kingdon, 2004). Mean individual body measurements (head - body length, tail length, and weight) for all captured individuals is summarised in Table 2 below. All the species morphological measurements conformed and are within the documented range.

Table 2: External Measurements for Species trapped in Oloolua Forest.

	Species	Mean Tail Length (TL)	Mean Head Body Length (HB)	Mean Weight	Comments
1	Bush baby *(Otolemur garnettii), n=3*	36 cm	26cm	780 g	This lies within the range reported for this species, where HB length ranges from 23-34 cm, T 30-44cm and weight 550-1200g
2	African Dormice *(Graphiurus murinus), n=8*	10cm	8cm	20g	This lies within the range reported for this species, where HB length ranges from 7.5-14 cm, T(1-11cm and weight (18-85g)
3	Giant Rat *(Cricetomys gambianus), n=99*	36	37	1.2kg	This lies within the range reported for this species, where HB length ranges from 28-45 cm, T 36-46cm and weight 1-1.4kg
4	Hedgehog *(Atelerix albiventris) n=1*	2 cm	16	500g	This lies within the range reported for this species, where HB length ranges from 14-25 cm, T 1-5cm and weight 250-600g
5	Slender mongoose *(Herpestes sanguineus)n=27*	25cm	28	500g	This lies within the range for the species, HB 26-34 cm, T 23-31cm, and weight 350-800g
6	Cane rat (Thryononomys Swindderianus) n=1	23cm	48cm	6kg	This lies within the range for the species, HB 43-58 cm, T 17-26cm, and weight 4.5-8.8kg
7	Narrow footed woodland mice (Grammomys sp), n=1	16cm	10cm	30g	This lies within the range for the species, HB 8-14 cm, T 12-22, and weight 28-65g
8	Tree squireel *(Paraxerus ochraceus)n=51*	15cm	15cm	82g	This lies within the range for the species, HB 13-18 cm, T 13-19cm, and weight 80-100g
9	White Tailed Mongoose *(Ichneumia albicauda)n=3*	60 cm	45cm	5kg	This lies within the range for the species, HB 47-71 cm, T 35-50cm, and weight 2-5.2kg

3.2.2 Population structure of small mammal species trapped in Oloolua

Overall, a total of 194 individuals comprising of 111 males and 83 females were captured across all the species of small mammals in Oloolua, (Table 3). The natural forest had the highest number of individuals (122) comprising of four main species. The Giant rat (*Cricetomys gambianus)* was the most abundant species with total number of 60, and this was followed by Tree squirrel (*Paraxerus ochraceus)* and Dormice *(Graphiurus murinus)* each with a total of 44 and 8 individuals respectively. Within this habitat, the giant rat had a total of 33 males and 27 females. The tree squirrel was represented by 30 males and 14 females while the dormouse was represented by three males and five females. The slender mongoose was also well represented in this habitat with a total of seven individuals comprising of three males and four females.

The woodland habitat registered higher diversity of species though with lower numbers. The more dominant species included the Giant Rat *(Cricetomys gambianus)*, which registered a total 21 individuals comprising of 11 males and 10 females. Slender Mongoose (*Herpestes sanguineus)* had a total of 20 individuals comprising of 13 males and seven females, while the Tree squirrel *(Paraxerus ochraceus)* had a total seven individuals comprising of four males and three females. The White Tailed Mongoose *(Ichneumia albicauda)* was also fairly represented in this habitat registering a total of three individuals consisting of one male and two female. Other species that were recorded in this habitat, which were represented by single enteries included the Cane rat (*Thryononomys swindderianus*), Narrow footed woodland mice (*Grammomys sp*), and Hedgehog *(Atelerix albiventris)*.

The plantation forest and the quarry were represented by a single species, the Giant Rat (*Cricetomys gambianus*). A total of nine individuals were captured within the plantation forest and this consisted of three males and six females. The quarry also registered a similar numbers with total of nine captures comprising of three males and six females. All other species were absent from these two habitats probably due to their levels of disturbance as shown in table 3 below. Chi-square analysis indicated that distribution of small mammals in different habitats in Oloolua was significantly different than expected by chance ($\chi^2 = 134.39$, d.f = 4, $P<0.05$).

Table 3: Total numbers and sexes of small mammals trapped across habitats in Oloolua.

Habitat Type	Species	Total number captured	Sexes	
			Males	Females
Natural Forest	Bush baby *(Otolemur garnettii*	3	2	1
	African Dormice *(Graphiurus murinus)*	8	3	5
	Giant Rat *(Cricetomys gambianus)*	60	33	27
	Tree squirrel *(Paraxerus ochraceus)*	44	30	14
	Slender mongoose *(Herpestes sanguineus)*	7	3	4
	Sub total	**122**	**71**	**51**
Woodlands	Cane rat (Thryonomys Swindderianus)	1	0	1
	Narrow footed woodland mice (Grammomys sp)	1	1	0
	Hedgehog *(Atelerix albiventris)*	1	1	0
	White Tailed Mongoose *(Ichneumia albicauda)*	3	1	2
	Slender mongoose *(Herpestes sanguineus)*	20	13	7
	Giant Rat *(Cricetomys gambianus)*	21	11	10
	Tree squirrel *(Paraxerus ochraceus)*	7	4	3
	Sub total	**54**	**31**	**23**
Plantation Forest	Giant Rat *(Cricetomys gambianus)*	9	6	3
	Sub total	**9**	**6**	**3**
Quarry	Giant Rat *(Cricetomys gambianus)*	9	3	6
	Sub total	**9**	**3**	**6**
Overall total for all the habitats		**194**	**111**	**83**

3.2.3: Seasonal variation in species composition and sex structure

The most abundant species in both seasons was *Cricetomys gambianus* (Table 4) with a total of 99 captures comprising of 60 males and 39 females (Table 4). This was followed by *Paraxerus ochraceus* with a total of 51 captures comprising of 28 males and 23 females. This was closely followed by *Herpestes sanguineus* with total capture of 27 individuals consisting of 20 males and seven females. All other species were represented in low numbers in both seasons as shown in table 4 below.

Table 4: Seasonal variations in small mammal species composition in Oloolua forest

Species	Males		Females	
	Wet	**Dry**	**Wet**	**Dry**
Bush baby *(Otolemur garnettit)*	2	0	1	0
Dormouse *(Graphiurus murinus)*	2	1	0	5
Giant Rat *(Cricetomys gambianus)*	27	33	17	22
Hedgehog *(Atelerix albiventris)*	0	1	0	0
Slender mongoose *(Herpestes sanguineus*	11	9	4	3
Cane rat (Thryononomys Swindderianus)	0	0	0	1
Narrow footed woodland mice (Grammomys sp)	0	1	0	0
Tree squireel *(Paraxerus ochraceus)*	16	12	18	5
White Tailed Mongoose *(Ichneumia albicauda)*	1	0	0	2
Totals	**59**	**57**	**40**	**38**

3.2. 4: Differences in age structure and sex ratios of small mammals in Oloolua forest.

Three age classes; adults, sub adults and young were utilized to describe the age classes of small mammals in Oloolua forest. This definition is based on body weight and sexual maturity stage as described in the preceding chapter. Of the total captures within the 4 habitats, 74% of the individuals were adults, 24% sub adults and 3% young individuals (Table 5).

For the natural forest, adults and sub adults of the Giant rat and the Tree squirrel were the frequently captured individuals while adults and sub adults of the slender mongoose and the Giant rat individuals were frequently captured in the woodlands. Only adults and sub adults of one species, the Giant rat, were captured within the plantation forest and the quarry habitats (Table 5). The observed trend of high percentage of adults' capture as shown in Table 5 could be attributed to adult's wider daily dispersal range during foraging for food for themselves and their young ones.

Table 5: Age structure of small mammals across the habitats in Oloolua forest

Habitat Type	Species	Totals	Adults	Sub-adults	Young
Natural Forest	Bush baby *(Otolemur garnettii)*	3	1	2	0
	African Dormice *(Graphiurus murinus)*	8	4	3	0
	Giant Rat *(Cricetomys gambianus)*	60	50	10	0
	Tree squirrel *(Paraxerus ochraceus)*	44	30	12	2
	Slender mongoose *(Herpestes sanguineus)*	7	5	1	1
	Sub total	**122**	**90**	**28**	**3**
Woodlands	Cane rat *(Thryononomys Swindderianus)*	1	1	0	1
	Narrow footed woodland mice (Grammomys sp)	1	1	0	0
	Hedgehog *(Atelerix albiventris)*	1	1	0	0
	White Tailed Mongoose *(Ichneumia albicauda)*	3	2	1	0
	Slender mongoose *(Herpestes sanguineus)*	20	13	5	2
	Giant Rat *(Cricetomys gambianus)*	21	13	7	1
	Tree squirrel *(Paraxerus ochraceus)*	7	5	2	0
	Sub total	**54**	**36**	**15**	**4**
Plantation Forest	Giant Rat *(Cricetomys gambianus)*	9	6	3	0
	Sub total	**9**	**6**	**3**	**0**
Quarry	Giant Rat *(Cricetomys gambianus)*	9	8	1	0
	Sub total	**9**	**8**	**1**	**0**
		194	**140**	**47**	7

Sex ratios were calculated based on seasons for three main species namely Giant Rat *(Cricetomys gambianus)*, Slender Mongoose *(Herpestes sanguineus)* and Tree squirrel *(Paraxerus ochraceus)*. All other species were not considered for sex ratios due to their low numbers in both seasons in the forest.

The sex ratio for the giant rat for the dry and wet seasons did not differ and returned the same chi-square value ($\chi^2 = 0.9$, d.f = 1, $p > 0.05$). This means there is no significant departure from 1:1 ratio in both seasons. Sex ratio for Slender mongoose for the wet season was ($\chi^2 = 1.2$., d.f = 1, $p > 0.05$), while the dry season returned chi-square value of ($\chi^2 = 1.4$, d.f = 1, $p > 0.05$). This also means that there were no significant departures from 1:1 ratio in both seasons. Finally, sex ratio for tree squirrel during the wet season was ($\chi^2 = 1.3$., d.f = 1, $p > 0.05$), while dry season returned chi square value of ($\chi^2 = 1.05$., d.f = 1, $p > 0.05$). This also means there were no significant departures from 1:1 ratio and therefore all sex ratios for all the species was not affected by season.

Further sex ratios were also calculated for the above species based on habitats. The sex ratio for the giant rat in the natural forest did not differ from unity ($\chi^2 = 0.616$, d.f = 1, $p > 0.05$). This means there was no significant departure from 1:1 ratio within this habitat. Similar results were obtained for the Slender mongoose, in the same habitat ($\chi^2 = 0.285$., d.f = 1, $p > 0.05$), However sex ratio for the Tree squirrel in the natural forest was biased toward males and did differ from unity ($\chi^2 = 5.84$, d.f = 1, $p < 0.05$).

In the woodlands, the sex ratio for the giant rat did not differ from unity, ($\chi^2 = 0.095$, d.f = 1, $p > 0.05$). This means there is no significant departure from 1:1 ratio within this habitat. Similar results were obtained for Slender mongoose, in the same habitat ($\chi^2 = 1.85$., d.f = 1, $p > 0.05$), while the same was obtained for Tree squirrel and did differ from unity ($\chi^2 = 0.285$, d.f = 1, $p > 0.05$).

The giant rat was the only species in the plantations habitat and the sex ratio did not differ from unity ($\chi^2 = 1.1$. d.f = 1, $p > 0.05$). Similarly, the giant rat was the only species represented in the quarry habitat and the sex ratio did not differ from unity ($\chi^2 = 1.11$., d.f = 1, $p > 0.05$).

In general, both season and habitat types did not affect sex ratio for most species except for the tree squirrel in which the ratio was biased towards males in the natural forest where it was well represented.

3.2.5 Differences in small mammal diversity and evenness in Oloolua Forest

Diversity index (H) of small mammals species were analysed for only two main habitats which registered more than one species. These are the natural forest and the woodlands (Figure 9). The highest species diversity (H') was recorded in the woodlands (0.6.) and was followed by the natural forest (0.35).

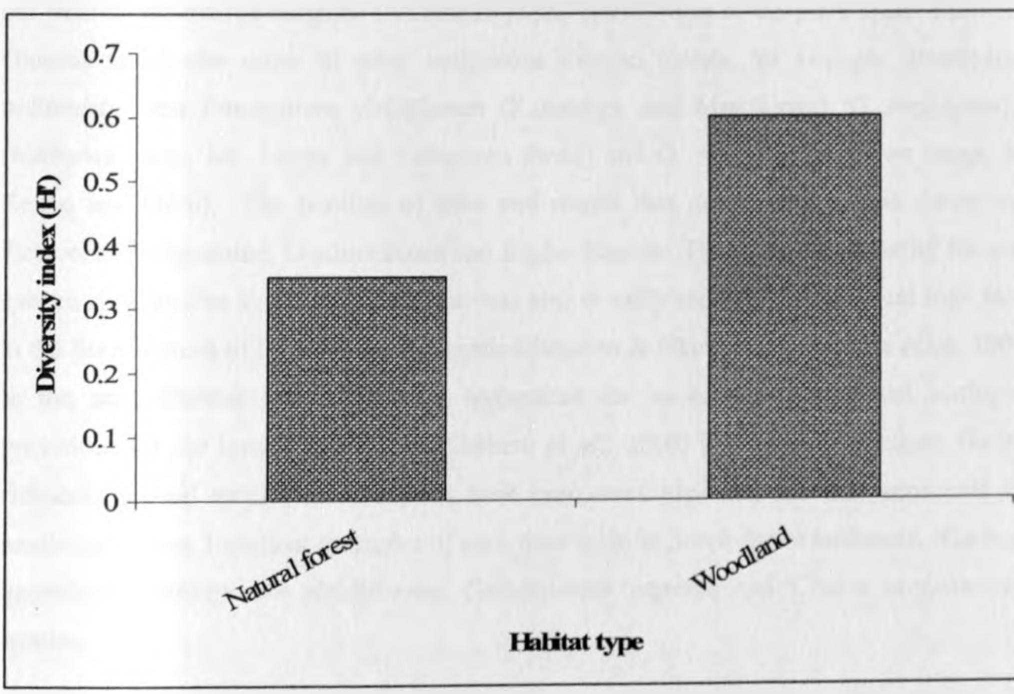

Figure 10: Small mammal diversity index (H") in different habitats in Oloolua forest.

CHAPTER FOUR: DISCUSSION, CONCLUSION AND RECOMMENDATIONS

4.1 Discussion

The floristic species richness recorded for Oloolua forest lies within the range reported for tropical forests, often higher than 50 (Lind & Morrison, 1974), but was much lower than most East African forests (Linder, 2001, Eunice *et al.*, 2008). Species richness in Oloolua forest was lower than in the other well-known and studied indigenous forests in Kenya. For example, (Mutangah *et al.*, 1992) recorded 147 plant species in Kakamega tropical rainforest whereas Blackett (1994) recorded 161 species in Mt. Kenya moist montane forest. The highest documented species richness in any of Kenya's indigenous forests was 280 plant species for the Mau forest reserve complex (Mutangah *et al.*, 1993). Most of the plant species found in Oloolua forest also occur in other indigenous Kenyan forests, for example, *Brachyliana hullienisis* and *Pittosporum viridiflorum* (Kakamega and Mau forest), *C. megalocarpus* (Mathews range, Mt. Kenya and Kakamega forest) and O. europaea (Mathews range, Mt. Kenya and Meru). The families of trees and shrubs that dominated Oloolua forest were Rutaceae, Composiatae, Leguminaceae and Euphorbiaceae. These are often among the most species rich families in tropical forests, as was also recently reported for a tropical high forest in the Ssese islands of Lake Victoria, Uganda (Ssegawa & Nkuutu, 2006, Eunice *et al.*, 2008). In the past, Oloolua forest had been recognized for its socio-economic and ecological provisions for the local communities (Gatheru *et al.*, 2000) but not for its unique floristic richness. Several species of rare plant have been over exploited for their economic and medicinal values. Excellent examples of such trees include *Brachylaena huillensis*, *Warbugia ugandensis*, *Pittosporum viridiflorum*, *Calodendrum capense* and *Croton megalocarpus* species.

In this study, nine species of small mammals were recorded. This may not represent all the species present in the study area but it gives a current account of the small mammal species occuring in the forest. Giant rat (*Cricetomys gambianus)* and Tree squireel (*Paraxerus ochraceus)* were the most abundant and were found to prefer areas with high plant cover (natural forest and the woodlands). Slender mongoose (*Herpestes sanguineus) and* White tailed mongoose *(Ichneumia albicauda)* as expected occurred in open woodland habitats. Small mammal species composition in this site is comparable to that of other areas with similar ecological conditions in the East Africa region, for example, *Cricetomys gambianus* and *Paraxerus sp* have been reported in Kahawa area, 25 km to the North of Nairobi (Martin & Dickinson.., 1985).

The data obtained suggests that Giant rat (*Cricetomys gambianus)* has the widest range of distribution among the species captured, having been recorded in all habitats. The species may be highly flexible and adaptable to both disturbed and undisturbed habitats or has a wide range of tolerance to microhabitat variations. Nevertheless, it was affected negatively by human land use and its abundance was low in the quarry and the plantations (most disturbed habitats). Tree squirrel (*Paraxerus ochraceus)* occurred both in the woodlands and the natural forest but was absent in the plantation and quarry further suggesting intolerance to levels of disturbace. Variations in frequency and intensity of disturbance may result in an increase or decrease of biological diversity (Connell, 1978), making them key factors in community structures (Lavorel *et al*, 1994; Armesto & Pickett, 1985). The degradation of natural environments (*e.g.*, deforestation and fragmentation) substantially modifies these structures and wild population parameters and consequently, may affect species diversity (Law & Dickman, 1998; Laurence & Bierregaard, 1997; Lovejoy *et al.*, 1986; Noss *et al.*, 1994; Terborgh, 1992). Overall, the natural forest and the woodlands area (perhaps a complex of habitat attributes) was most suitable habitats and hosted the greatest diversity of small mammal species than any other site in both seasons.

African small mammal populations generally exhibit seasonal variations in numbers and usually decline during the dry season (Monadjem, 1997) and this was the case in this study (Table2). Such seasonal variations have been reported by others; (David & Jarris, 1985). In this study the highest small mammal diversity was recorded woodlands and the natural forest; which were the least disturbed habitats and with more favorable conditions for most species. Inter-site variation in distribution of *Cricetomys gambianus* and *Paraxerus ochraceus is* due to the differences in cover arising from plant species diversity and disturbance levels which in turn determine distribution and availability of resources. Quarrying and plantations have reduced native vegetation cover and consequently the diversity of small mammals. The ecological response of small mammals to changes in the environment is a potentially useful indicator of alteration in local environmental conditions such as habitat modifications caused by man.. This is especially true among small mammals, for which habitat is the most important niche dimension by which species segregate (Schoenner, 1974). With the increase in human activities, it would be expected that diversity of small mammal species would decrease. Therefore, a brief regular survey of the diversity and distribution of the small mammals (as indicator species) in forest ecosystems would help one to detect whether the ecosystem is stable or not (Seddon & Tattersfield, 1996). The separation of species with apparently similar environment requirements can largely be explained in terms of current land use practices and biology of species (Neal, 1984).

Results in this study compare with those of (Dublin, 1995 & Salvatori *et al.*, 2001) that vegetation disturbance limits the natural regeneration of woody plants and negatively affects the diversity and distribution of animal species. Most of the woody plant species found in the old quarry and the eucalyptus habitats are either planted/exotic species such as *Eucalyptus botryoides,* or colonizer/invader species *Ocimum suave, Buddleia polystchga, Gnidia subcordata and Crotolaria sp.* indicating signs of land degradation in these two habitats. Degradation of habitat (based on plant species diversity, densities and cover estimates) occurred with greater incidence in the old quarry and the eucalyptus habitat than the rest of the habitats. This outcome suggests that activities across pairs of these land use categories result in more or less similar vegetation variability. Overall, vegetation alteration activities across habitats had greater impacts on density of woody plants compared to that of herbaceous species. This may be associated with the different growth patterns of the two groups i.e. woody plants are perennials while herbs species are mostly annuals. Both groups of plants must have different habitat requirements and are likely to respond differently to similar land use activities.

The low numbers of small mammals in the quarry and the plantation areas is probably as a result of human activities which have resulted in the destruction of burrows and elimination of subterranean and herbaceous plants species in many of the habitats surveyed. These changes may have both direct and indirect effects on small mammals as disturbance removes vegetation, destroys nest habitats and is also associated with alteration of soil environment and leads to exposure to predators (Wiens & Rotenberry, 1985; Hill *et al.*, 1991, Sher *et al.*, 2000). In this regard qualitative changes in the small mammal communities occur when land is cleared for various human activities. For instance species such as *Cricetomys gambianus* which are associated with burrowing, were largely absent in old quarry site. Thus the consequence of land use that leads to the removal of trees and herbaceous vegetation cover affects the survival of small mammal species. Habitats with dense plant cover (Natural forest and the woodlands) supported a higher diversity of small mammal species. Similar results have been reported in other ecosystems, for instance, in desert habitats, small mammal diversity tend to increase with increase in plant cover (Kerley, 1992). Similarly, Monadjem, (1997;) found that species diversity tended to be highest at intermediate values of plant cover. This response is probably representative of any community of small mammals in Africa. Moreover it shows that African small mammals are similar in this respect to small mammals in other parts of the world in their inability to survive in disturbed areas.

4.2 Conclusion and recommendations

Anthropogenic activities that foster fragmentation and modification of natural habitats continue to pose serious threats to biological diversity. In this study, indices of habitat diversity across habitat types were related to diversity of both plant and small mammal richness. My survey across the four habitats of Oloolua forest suggests that patterns of population changes associated with disturbance are complex. Several factors have been found to influence diversity and distribution of small mammals as discussed in the preceding chapters. If these factors indeed influence the study species in different ways, then the observed variability in diversity and distribution would be clearly explained. Since the study species were in the same locality, it is possible they experienced similar ecological factors like interspecific competition, predation and weather conditions and therefore the observed demographic variation was solely as a result of habitat disturbance and fragmentation. The well being of these populations is dependent on the quality of the habitats. Mammals in general and small mammal in particular, being highly dependent on natural habitat as demonstrated in this study, are threatened with reduction of their diversity, if not with extinction, due to the rapid and irreversible degradation of habitats occurring throughout most of the habitats. More importantly, vulnerable are those species with low numerical abundance for example the African hedgegog (*Atelerix albiventris*) or those restricted to one or a few habitats e.g. white tailed mongoose (*Herpestes sanguineus)* and the cane rat *(Thryonomys Swindderianus)*.

The ability of mammals to survive in remnant fragmented forest such as Oloolua is of great importance given the continuous challenges facing it. The surrounding local communities (Gataka and Bulbul residents) should be left to reap direct benefits from fauna / flora conservation, which will enhance people's perceptions. In order to succeed in this, strong local support should be marshalled, which means listening to their concerns and working closely with locals to ensure conservation benefits trickle down to avoid resentment and lack of grassroots commitment. The government through the Ministry of Wildlife and Forestry and it is relevant institutions are charged with the sole responsibility of managing Kenyan forest resources. Hence, they have the authority and responsibility of coordinating, enforcing and regulating the use of forest reserve resources. These are embedded in the new forest law of 2005 which advocates for participatory management of forest resources. The trend of forest management devolution has been practised in many tropical countries, for example, in Bolivia, which has brought benefits to many poor rural communities in heavily forested areas, including greater access to forest resources, restricted encroachment by large timber companies and ranchers, and a greater voice in policy making (CIFOR, 1999). Funding, enforcement and political goodwill remain the main challenges in Kenya. An even greater challenge is the inclusion of all relevant stakeholders in the management of the forest. The potential of integrating the local people's knowledge and skills in the management of the forest reserve is yet to be tapped. The above will ensure erosion of suspicion when introducing new ideas in the management of the forest reserve, hence creating a sense of belonging and trust. Finally, this study makes the following specific recommendations for the management of Oloolua forest.

- The checklist of plants and small mammals will provide valuable information for developing management plans to utilize the forest resources sustainably.
- Re- planting of indigenous trees along old quarry habitats is vital in reviving the forest especially at the block outside the Institute of Primate Research (I.P.R).
- A strategic management plan for Oloolua forest is lacking and is of highest priority given the location and the extent of habitat modification in the forest. Human activities within the forest should be regulated and the local communities should be involved and empowered to manage the forest through participatory forest management approaches.

4.3 Suggested areas for further research

Small mammals play an important role in ecosystems. An in-depth, detailed study is necessary to examine quantitatively the responses of each species of small mammals to quarrying and exotic plantations.

REFERENCES

Adren, H., 1994. Effects of habitat fragmentations on birds and small mammals in landscapes with different proportions of suitable habitat: A review. *Oikos*. **71**: 355-436

Ajayi, S. S., & Tewe, O. O., 1978. Distribution of burrows of the African giant rat (Cricetomys gambianus Waterhouse) in relation to soil characteristics. *E. Afr. Wildl.* J. **16**: 105-111.

Ajayi, S. S., 1977. Live and carcass weights of giant rat (Cricetomys gambianus) Waterhouse and domestic rabbit (Oryctolagus cuniculus l). *E. A. Wildl. J.* **15**: 233-227

Armesto, J. J. & Pickett, S. T. A., 1985, Experiments on disturbance in old-field plant communities: Impact on species richness and abundance. *Ecology*, **66**: 230-240.

Barrett, G. W. and J. D. Peles. 1999. Small-mammal ecology: A landscape perspective. Pp 1–8. In Barrett, G. W. and J. D. Peles, editors. (Eds). *Landscape Ecology of Small Mammals. Springer*. New York, NY. 347. pp.

Beck J, Schulze CH, Linsenmair KE, Fieldler K (2002) From forest to farmland: diversity of geometrid moths along two habitat gradients on Borneo. *J Trop Ecol* **18**:33–51.

Blackett, H.L. (1994) Forest Inventory Report No. 6 Mount Kenyaand Thunguru Hill. Kifcon, Nairobi.

Boinski, S., 1987. Habitat use by squirrel monkeys (Saimiri oerstedi) in Costa Rica. Folia *Primatol.* **49**: 151-167

Bowers, M.,1988. Seed removal experiments on desert rodents: the microhabitat by moonlight effect. *J. Mammalogy* **69**: 201-204.

Butynski, T. M., 1990. Comparative ecology of blue monkeys (Cercopithecus mitis) in high and low-density subpopulations. *Ecol. Monogr*. **600**: 1-26

Carey, A. B. & C. A. Harrington. 2001. Small mammals in young forests: implications for management for sustainability. For. *Eco. Manag.*, **154**:289–309.

Centre for International Forestry Research (CIFOR).,1999). CIFOR AnnualRep ort, 1998. CIFOR, Bogor, Indonesia.

Chapman, A. C., and Chapman, L. J., 1990. Dietary variability in primate populations. *Primates*, **31**:121-128.

Charnov, E. L., 1976. Optimal foraging theory, the marginal value theorem. *Theor. Popl. Biol.* **9**:129-136.

Cheeseman, C. L., 1977. Activity patterns of rodents in Rwenzori National Park, Uganda. *E. Afr. Wildl. J.*, **15**: 281-287.

Clutton-Brock, T. H., and Harvey, P. H., 1977. *Species differences in feeding and ranging behaviour in primates. In Clutton-Brock, T. H., (ed.) Primate ecology, Academic press, New York.*

Cochran, W.G. (1977). *Sampling techniques.* 3rd ed. New York: Wiley.

Connell, J. H., 1978, Diversity in Tropical Rain Forests and Coral Reefs - High diversity of Trees and Corals is Maintained Only in a Non-Equilibrium State. *Science*, **199**: 1302-1310.

Cords, M., 1987. Mixed species association of Cercopithecus monkeys in the Kakamega Forest, Kenya. University of California Press, Berkeley.

Cox, G.W. (1990). *Laboratory Manual of General Ecology. 6th Edition. WCB Publishers, Dubuque, Lowa.*

Crompton, R., 1984. Foraging habitat structure and locomotion in two species of galago; In Rodman, P. and Cant, J., (eds), Adaptation for foraging in non human primates. Columbia university press, New York.

Delany, M. J., and Neal, B. R., 1966. A review of the Muridae (order Rodentia) of Uganda. British Museum (Nat. Hist.). London.

Dublin, H. T., 1995. Vegetation dynamics in the Serengeti-Mara Ecosystem: the role of elephants, fire and other factors: *Ecol.* **33**: 937-943.

Dueser, R. D. & Shuggart, H. H., 1979, Niche Pattern in Forest-floor in Small Mammal Fauna. *Ecol.* **60**: 108-118.

Eunice W. G., Mins Chuah-P., John K. M., and David W. O., 2008. A botanical inventory and diversity assessment of Mt. Marsabit forest, a sub-humid montane forest in the arid lands of northern Kenya, *Afr. J. Ecol.*, **46**, 39–45

Ferreira, S. M. and Van Aarde Jr. 2000. Habitat associations and competition in Mastomys saccostmys – Aethomys assemblages on coastal dune forests. *Afr. J. Ecol.* **37**: 121 – 136.

Forsyth, D.M., 1999. Long-term harvesting and male migration in a New Zealand population of Himalayan tahr Hemitragus jemlahicus. *J. Appl. Ecol.* **36**, 351–362.

Gatheru, S., Mutangah J. & Kariuki J., 2000. Environmental Impact Assessment for Quarrying Activities in Oloolua Forest – Kajiado district, Kenya. A report for Forestry Department, Ministry of Environment & Natural Resources.

Goodman, D., 1987. *The demography of chance extinction.* Cambridge University Press, Cambridge, England.

Gurskey, S., 2000. Effects of seasonality on the behavior of an insectivorous primate, (Tarsius spectrum). *Int. J. Primatol.* **21**: 477-495.

Hamilton, A. C., 1974. The significance of patterns of distribution shown by forest plants and animals in tropical Africa for the reconstruction of upper Pleistocene paleoenvironments: *a review paleaeoecology of Africa* **9**: 63 – 97.

Hanski, I., Henttonen, H., Korpimäki, E., Oksanen, L. and Turchin, P., 2001. Small-rodent dynamics and predation. *Ecol.* **82**: 1505–1520.

Happold, D.C.D & Happold M., 1990. An Ecological Study of Small Rodents in the Woodland Savannah of Liwonde National Park, Malawi. *J. Zool.*, London **221**: 219-235.

Harcourt, C. S., 1986. Seasonal variation in the diet of South African galagos. *Int. J. Primatol.* **7**: 491-506.

Harris I. D., 1984. The fragmented forest. University of Chicago Press, Chicago.

Hefner, H. & Fasola, M., 1997. Long-term monitoring and conservation of herons in France and Italy. Colon. *Waterbirds* **20**, 298–305.

Hilbert, D. W., Swift, D. M., Detling, J. K., and Dyer, M. I., 1981. Relative growth rates and the grazing optimization hypothesis. *Oecologia* **51**: 14-18.

Hill, D. A., Lambtons, S., Proctor, I., and Bulloc, I., 1991. Winter bird communities in woodland in the forest of Dean, England, and some implications of livestock grazing. *Bird study* **32**:56-70.

Hooven, E. F., and Black, H. C., 1976. Effects of some clear cutting practices on small mammals populations in Western Oregon. *Northwest Science* **50** (4): 189-208.

Howard, P.C., Viskanic P., Davenport T.R.B., Kigeny F.W., Baltzer M., Dickinson C.J., Lwanga J.S., Mathews R.A., & Balmford A.,1998. Complementarity and the use of indicator groups for reserve selection in Uganda. *Nature* (London) **394**: 472 -475.

Jedrzejewska, B. and Jedrzejewski, W., 1990. Antipredatory behaviour of bank voles and prey choice of weasels – enclosure experiments. *Ann. Zool.* Fenn. **27**: 321-328.

Keesing, F., 1998. Impact of Ungulates on the Demography and Diversity of rodents in Central Kenya. *Oecologia* **116**: 381 – 389.

Kerley, G. I. H., 1992. Ecological correlates of small mammals community structure in the semi – arid Karoo, South Africa. *J. Zool.* Lond. **227**: 17 – 27.

Kincaid, W. B. & Cameron, G. N., 1985. Interactions of cotton rats with a patchy environment: dietary responses and habitat selection. *Ecol.* **66**: 1769-1783.

Kingdon, J. 1982. *East African Mammals.* An atlas of Evolution in Africa. Vol. 111D, Bovids.

Kingdon, J. 2004. *The Kingdon pocket guide to African mammals.* A & C Black Publishers Ltd. London.

Kotler, B.P. and Brown, J.S., 1988. Environmental heterogeneity and the coexistence of desert rodents. Ann. Rev. *Ecol. Syst*. **19**: 281-307.

Krebs, C.J., 2002. Beyond population regulation and limitation. *Wildlife Research* **29**: 1-10.

Krohne, D.T. Burgin, A.B., 1990. The scale of demographic heterogeneity in a population of Peromyscus leucopus. *Oecologia* **82**: 97-101.

Lagos, V.O., Contreras, L.C., Meserve, P.L., Gutiérrez, J.R., and Jaksic, F.M., 1995. Effects of predation risk on space use by small mamals, a field experiment with a Neotropical rodent.*Oikos* **74**: 259-264.

Laurence, W. F. & Bierregaard, R. O.., 1997, Tropical forest remnants. The University of Chicago Press, pp. 502-514.

Lavorel, S., Lepart, J., Debussche, M., Lebredon, J. D. & Beffy, J. L., 1994, Small scale disturbance and the maintenance of species diversity in a Mediterranean old field. *Oikos* (Berl.), **70**: 455-473.

Law, B. S. & Dickman, C. R., 1998. The use of habitat mosaics by terrestrial vertebrate fauna: implications for conservation and management. *Biodivers Conserv,* **7**: 323-333.

Leirs, H., Verhagen, R., Verheyen, W., Mwanjabe, P. y Mbise, T., 1996. Forecasting rodent outbreaks in Africa: an ecological basis for Mastomys control in Tanzania. Journal of Applied *Ecology* **33**:937-943

Lima, M. y Jaksic, F.M., 1999. Population rate of change in the leaf-eared mouse: The role of density-dependence, seasonality and rainfall. *Australian Journal of Ecology* **24**: 110-116.

Lin, Y.K., and Batzli, G.O., 2001. The influence of habitat quality on dispersal, demography, and population dynamics of voles. *Ecological Monographs* **71**: 245-275.

Lind, E. M. & Morrison, M. E. S.,1974. *East African Vegetation*, Longman Scientific and Technical, New York.

Linder, H.P., 2001. Plant diversity and endemism in sub-Saharan tropical Africa. *J. Biogeogr.* **28**, 169–182.

Longland, W.S. and Price, M.V., 1991. Direct observations of owls and heteromyd rodents, can predation risk explain microhabitat use. *Ecol.* **72**: 2261-2273.

Lovejoy, T. E. R., Bierregaard, R. O., JR., Rylands, A. B., Malcolm, J. R., Quintela, C. E., Harper, l. H., JR., Brown, K. S., Powell, A. H., Powell, G. U. N., Schubert, H. O. R. & Hays, M. B., 1986. Edge effects and other effects of isolation an Amazon forest fragments. pp. 257-285. In: Soulé, ME (ed). Conservation Biology: The science of scarcity and diversity. Sinauer, Sunderland, Massachusetts.

Luke, G.T. & Zack, S.,2001. Spatial and temporal considerations in restoring habitat for wildlife. *Restor. Ecol.* **9**, 272–279.

M'Closkey, R. T., 1976. Community structure in simpatric rodents. *Ecol.* **57**: 728-739.

MacAthur, R., and Pianka, E.,1966. An optimal use of patchy environment. *Am. Nat.* **100**: 603-609.

Mappes, T. and Ylönen, H.,1997. Reprodcutive effort of female bank voles in a risky environment. *Evolutionary Ecol.* **11**: 591-598.

Martin, G. H. G., and Dickinson, N. M., 1985. Small mammal abundance in relation to habitat in dry sub-humid grassland in Kenya.

Mazurkiewicz, M.,1991. Population dynamics and demography of the bank vole in different tree stands. *Acta Theriologica* **36**: 207-227.

McCarthy, M.A., Webster, A., Loyn, R.H. & Lowe, K.W., 1999. Uncertainty in assessing the viability of the Powerful Owl Ninox strenua in Victoria, Australia. Pac. *Conserv. Biol.* **5**:144–154.

Monadjem, A., 1997. Habitat preferences and biomasses of small mammals in Swaziland. *Afr, J. Ecol.* **35**: 555-559.

Mungai, G.M & Beentjee H.J (1989). Checklist of the plants of Oloolua

Mutangah, J.G., Mwangangi, O. & Mwaura, P.K. (1993) Mau Forest Complex Vegetation Survey. Kenya Indigenous Forest Conservation Programme (KIFCON). Karura Forest Station, National Museums of Kenya, Nairobi.

Mutangah, J.G., Mwangangi, O. & Mwaura, P.K., (1992). Kakamega Forest Vegetation Survey. Kenya Indigenous Forest Conservation Programme (KIFCON). Karura Forest Station, National Museums of Kenya, Nairobi.

Myers N, Mittermeier RA, Mittermeier CG, Da Fonseca G, Kent J (2000) Biodiversity hotspots for conservation priorities. *Nature* **403**:853–858

Neal, B. R., 1984. Relationship between feeding habits, climate and reproduction of small mammals in Meru National Park, Kenya. *J. Anim. Ecol.* **52**: 731-744

Norton-Griffiths, M., 1978. Counting animals. African Wildlife Foundation. Nairobi.

Noss, R. F., and Cooperrider, A. Y., 1994. Saving nature's legacy: Protecting and restoring biodiversity. Island Press, Washington DC

Odhiambo, O. R., 2000. An ecological study of Praomys taitae (Rodentia: Muridae). Msc Thesis, Kenyatta University.

Ottichilo, W. K., J. de Leeuw, A. K. Skidmore, H. H. T. Prins, and M. Y. Said., 2000. Population trends of large non-migratory wild herbivores and livestock in the Maasai Mara ecosystem, Kenya, between 1977 and 1997. *Afr. J. Ecol 38*:202-216.

Ottichilo, W.K., de Leeuw, J. & Prins, H.H.T., 2001. Population trends of resident wildebeest Connochaetes taurinus hecki (Neumann) and factors influencing them in the Masai Mara ecosystem, Kenya. *Biol. Conserv.* **97**: 271–282.

Pearce, J. & L. Venier. 2005. Small mammals as bioindicators of sustainable boreal forest management.For. *Eco. Manag.*, **208**:153–175.

Price, M.V.,1 978. The role of micro habitat in structuring desert rodent communities. *Ecol*: **59**:910-921

Remis, M., 1997. Western lowland gorilla (gorilla gorilla gorilla) as seasonal frugivores: Use of variable resources. *Am. J. Primatol.* **43**:87-109

Rosenzweig, M. L., 1995, *Species diversity in space and time*. Cambridge University Press, Second edition, 436 p.

Salvatori, V., Egunyu, E., Skidmore, A. K., De Leeuw, J. and Van Gils, H. A. M. 2001. The effects of fire and grazing pressure on vegetation cover and small mammal populations in the Maasai Mara National Reserve. *Afr. J. Ecol.* **39**: 200-204.

Schoenner, T. W., 1974, Resource partitioning in ecological communities. *Science*, **185**: 27-39.

Seddon, M. and Tattersfield P., 1996. Molluscan biodiversity in East African forests. Unpublished project paper, National Museums of Wales.

Shannon CE and Wiener W (1963). The mathematical theory of communication. University of Illinois Press, Urbana USA

Sher, A. A., Marshall, D. L. & Gilbert, S. A., 2000, Competition between native Populus deltoides and invasive Tamarix ramosissima and the implications for reestablishing flooding disturbance. *Cons Biol*, **14**: 1744-1754.

Simberloff, D. (1998). Flagships, umbrellas, and keystones: Is single-species management past in the landscape era? *Biol Cons* **83**: 247 – 257.

Soul'e, M. E.,1991. Conservation: tactics for constant crisis. *Science* **25**: 744-750.

Sousa, W. P., 1984, The role of disturbance in natural communities. Annual Review in *Ecology and Systematic, 15*: 353-391.

Spencer, R., Cameron, G. N., and Swihart, R. K., 1990. Operationally defining home range: temporal dependence exhibited by hispid cotton rats. *Ecol.*, **71**(5): 1817-1822.

Ssegawa, P. & Nkuutu, D.N., 2006. Diversity of vascular plants on Ssese islands in Lake Victoria, central Uganda. *Afr. J. Ecol.* **44**: 22–29.

Stenseth, N.C., 1985. Models of bank voles and wood mouse populations. In: The ecology of woodland rodents. Bank voles and Wood mice (ed by J.R. Flowerdew, J. Gurnell y J.H.W. Gipps). *Symposia of the Zoological Society of London* **55**: 339-376.

Stenseth, N.C., R.A., 1993. *The Biology of Lemmings*. Academic Press, London.

Struhsaker, T. T., 1975. The red colobus monkeys. University of Chicago press, Chicago.

Terborgh, J., 1992, Maintenance of tropical forests. *Biotropica*, **24**: 283-292.

Torre, I., Arrizabalaga A, Díaz, M., 2002. Ratón de campo Apodemus sylvaticus (Linnaeus, 1758).*Galemys* **14** (2): 1-26.

Trapnell, C. G. and Brunt, M. A. 1987. *Vegetation and climate maps of South West Kenya* (1:250, 000) Surbiton: Survey.

Wiens, J. A., 1976. Population responses to patchy environments. *Animal review of ecology and systematics*. 7: 81-120.

Wiens, J. A., and Rotenberry, J. J.,1985. Habitat associations and community structure of birds in shrubs steppe environments. *Eco. Manog* **5**:21-41.

Wilcove, D. E., McLellan, C. H., and Dobson, A. P., 1986. Habitat fragmentation in the temperate zone. In Soule (ed) 1991, Conservation: tactics for constant crisis. *Science* **25**: 744-750.

Wilcox, D. A., and Murphy, D. D., 1985. Conservation strategy: the effects of fragmentation and extinction. *American naturalist* **125**: 879-887.

Wilson, E. O.& Peter, M. F. (Eds.)., 1988. Biodiversity. National Academy Press, Washington DC.,

Wilson, E. O., 1985. The biological diversity crisis. *BioSc.* **35**: 700-706.

Wilson, E. O., 1992. *The diversity of life*. Harvard University Press, Cambridge, M.A

Wolff, J.O., 1999. Behavioral Model Systems. In: Landscape Ecology of Small Mammals (Ed by G.W.Barrett y J.D.Peles), pag. 11-40. Springer, New York.

Wrangham, R., 1980. An ecological model of female primate groups. *Behav.*, **75**:262-300.

Yahner, R. H.,1982. Microhabitat use by small mammals in farmstead shelterbelts. *J. Mammalogy* **63**: 440-445.

APPENDIXES

Appendix 1: Checklist of trees, shrubs and Lianas in Oloolua forest

Species	Family	Growth form
Abutilon mauritianum (Jacq.) Medic Sensu lato	Malvaceae	Shrub
Acokanthera oppositifolia (Lam) Codd	Apocynaceae	Tree/shrub
Acokenthera schimperi	Sapinadaceae	Tree/shrub
Allophylus kilimandscharicus Taub	Composiatae	Tree/shrub
Aspilia mossambicensis (Oliv.)Wild	Compositae	Shrub
Brachylaena huillensis O. Hoffm	Composiatae	Tree
Buddleia polystachya Fres.	Luganiaceae	Trees /shrub
Calodendron capense(L.f) Thunb	Verbanaceae	Tree
Canthium keniense Bullock	Rubiaceae	Tree/shrub
Carissa edulis (Forssk.) Vahl	Apocynaceae	Shrub
Warbugia ugandensis Sprague	Canelleceae	Tree
Celtis africana Burm.f	Ulmaceae	Tree
Clausena anisata (Willd.) Benth	Rutaceae	shrub
Crotolaria goodiiformis Vatke	Leguminaseae	shrub
Croton megalocarpus Hutch.	Euphorbiaceae	Tree
Cyphostemma nieriense (Th.F.r.jr.) Dese	Vitaceae	Liana
Diospyros abyssinica (Hiern) F.White	Ebeneceae	Tree
Dombeya burgessiae Gerrard	Sterclaceae	Tree/shrub
Dovyalis macrocalyx (Oliv.) Warb.	Flacourtiaceae	Tree/ shrub
Drypetes gerrardii Hutch	Euphorbiaceae	Tree
Elaeodendron buchananii (Loes.)Loes	Celastraceae	Tree
Erythrococca bongensis pax	Euphorbiaceae	Tree
Eucalyptus botryoides	Myrtaceae	Tree
Euclea divinorum Hiern Hiern	Ebenaceae	Tree/shrub
Gnidia subcordata Mesin	Thymeleaceae	Shrub
Grewia similis K.Schum.	Tiliaceae	Shrub/liana

Heteromorpha trifoliata (Wendl.) Eckl. &Zeyh	Umbelliferae	Tree/shrub
Hibiscus fuscus gareke	Malvaaceae	Shrub
Indigofera swanziensis Bolus	Leguminosaae	shrub
Jasminum fluminense Vell.	Oleaceae	Shrub/climber
Lantana camara L.	Verbanaceae	shrub
Lantana trifolia L.	Verbanaceae	Shrub
Lippia kituiensis vatke.	Verbanaceae	shrub
Maytenus heterophylla (Eckl.&zeyh.) Robson	Celastraceae	Tree/shrub
Maytenus senegalensis (Lam)Exell	Celastraceae	Tree/shrub
Maytenus undata (Thunb). Blake lock	Celastraceae	Tree/shrub
Meineckia phyllanthoides Baill.	Euphorbiaceae	shrub
Mystroxylon aethopicum (Thunb.) Loes	Celastraceae	Shrub
Newtonia buchananii (Bak.)Gilb.&Bout	Leguminaceae	Tree
Ochna ovata F. Hoffm	Ochnaceae	Tree
Pittosporum viridiflorum	Pittosporaceae	Tree
Olea capensis L.	Oleaceae	Tree
Olea europae L. ssp africana (Mill.) P.G. Green	Oleaceae	Tree
Opuntia Vulgaris L.	Cactaceae	Succulent
Ocimum suave Willd	Labiatae	shrub
Phylanthus sepiallis	Euphorbiaciaceae	shrub
Psidia Punctulata (D.C) Vatke	Composiatae	shrub
Pterolobium stellatum (Forssk.) Brenan	Leguminosae	shrub
Rhus natalensis krauss	Anacardiaceae	shrub
Rumexs usambarensis (Dammer) Dammer	Polygonaceae	shrub
Sarcostemma viminale (L.) R.Br.	Asclepiadaceae	Shrub
Schrebera alata (Hochst.) Welew.	Oleaceae	Tree
Scutia myrtina (Burm.f.) Kurz	Rhamanaceae	Tree/Shrub
Sesbania keniensis Gillett	Leguminosae	Tree/shrub
Solanecio angulatus (Vahl). C.Jeffrey	Compositae	Climber
Solanum indicum L.	Solanaceae	Shrub
Solanum incanum L.	Solanaceae	shrub

Strychnos henningsii Gilg	Loganiaceae	Tree
Tarenna graveolens (S.moore) Brem	Rubiaceae	Tree/shrub
Teclea simplicifolia (Engl.) Verdoorn.	Rutaceae	Tree
Teclea trichocarpa (Engl.). Engl.	Rutaceae	Tree
Tinnea aethopica Hook.f.(Sensu lato)	Rutaceae	Tree
Trichilia emetica vahl.	Meliaceae	Tree
Trimeria grandifolia (Hochst.) Warb	Flacourtiaceae	Tree/Shrub
Turraea mombassana C.DC	Meliaceae	Shrub
Vangueria infausta Burch.ssp. Rotunda (Robyns) Verdc.	Rubiaceae	Tree/Shrub
Vernonia brachycalyx O.Hoffm	Compositae	Shrub
Zanthoxylum usambarense (Engl.) Kokwaro	Rutaceae	Tree

Appendix 2: Showing the relative frequency, density, doimance and importance value of woody species for H1

Natural Forest (H1)						
Species	Relative frequency	relative density	Basal area	dominace	Relative dominace	Importance Value
Allophylus kilimandscharicus Taub	0.606060606	0.31152648	36.11	0.0115552	1.252442193	2.170029279
Acokenthera schimperi	0.606060606	0.15576324	85.065	0.0272208	2.950401416	3.712225262
Brachylaena huillensis (O. Hoffm)	3.03030303	10.74766355	228.3475	0.0730712	7.920023363	21.69798994
Caledendron capense(L.F)	1.818181818	2.336448598	101.54825	0.03249544	3.522107807	7.676738223
Canthium keniense Bullock	2.424242424	5.140186916	47.6345	0.01524304	1.652158893	9.216588233
Warbugia ugandensis	2.424242424	3.894080997	182.905	0.0585296	6.343891977	12.6622154
Celtis africana Burn.F	0.606060606	0.934579439	77.416	0.02477312	2.685102875	4.22574292
Clausena anisata (Willd.) Benth	3.03030303	9.501557632	26.88125	0.008602	0.932351473	13.46421214
Crotolaria goodiiformis (Vatke)	1.818181818	0.46728972	86.346	0.02763072	2.994831725	5.280303263
Croton megalocarpus Hutch.	3.03030303	10.12461059	210.345	0.0673104	7.295623181	20.4505368
Cyphostemma nierense (Th.F.r.jr.) Dese	1.212121212	0.31152648	102.625	0.03284	3.559453892	5.083101584
Diosperus abyssinica (Hiern) F.White	1.212121212	0.31152648	120.823	0.03866336	4.190634812	5.714282504
Dombeya burgessiae Gerrard	2.424242424	3.271028037	107.235	0.0343152	3.719347509	9.414617971
Dovyalis macrocalyxs(Oliv.) Warb	0.606060606	0.15576324	58.765	0.0188048	2.038210066	2.800033911
Drypetes gerrardii Hutch	0.606060606	0.46728972	129.72	0.0415104	4.499219088	5.572569414
Elaeodendeon buchananii(Loes.)Loes	1.212121212	0.62305296	126.972	0.04063104	4.403907231	6.239081403
Erythrococca bongensis pax	0.606060606	0.31152648	36.6575	0.0117304	1.271431728	2.189018813
Eucalyptus botryoides	0.606060606	0.31152648	37.55	0.012016	1.302387271	2.219974356
Euclea divinorum	1.212121212	1.246105919	171.915	0.0550128	5.962713918	8.42094105
Gnidia subcordata Mesin	3.03030303	4.828660436	13.735	0.0043952	0.476385863	8.33534933
Grewia similis K.Schum.	3.03030303	2.647975078	107.185	0.0342992	3.717613305	9.395891413
Hybiscus fuscus Gareke	0.606060606	0.62305296	48.081	0.01538592	1.667645336	2.896758901
Jasminum fluminense Vell.	0.606060606	0.62305296	90.275	0.028888	3.131105482	4.360219048
Maytenus heterophyla	1.212121212	0.62305296	4.261	0.00136352	0.147788872	1.982963044

Maytenus undata(Thunb).	0 606060606	0 15576324	15 185	0 0048592	0.526677782	1 288501628
Meineckia phallanthoides(Baill.) Webster	3.03030303	1 246105919	157.87	0.0505184	5.47557599	9 751984939
Mystroxylon aethopicum (Thunb.) Loes	3.03030303	0.778816199	51.091	0.01634912	1.772044422	5 581163652
Newotonia buchananii (Bak.)Gilb.&Bout	1.212121212	0.62305296	116.375	0.03724	4.036360017	5 871534188
Newotonia buchananii (Bak.)Gilb.&Bout	3.03030303	2.024922118	57.697	0.01846304	2.001167466	7.056392615
Ochna ovata F. Hoffin	3.03030303	5 919003115	12.556	0.00401792	0 435493331	9.384799476
Olea africana	2.424242424	2.336448598	3.14	0.0010048	0.108908017	4 869599039
Olea capensis	0.606060606	0.15576324	0.98	0 0003136	0 0339904	0 795814246
Olea europea	0 606060606	0.15576324	3.14	0 0010048	0.108908017	0 870731863
Psaidia Punctulata(D.C) Vatke	0.606060606	0 15576324	3.92	0.0012544	0.135961601	0.897785446
Pterolobium stellatum(Forsk.) Brenan	0.606060606	0 15576324	10.2	0.003264	0.353777634	1 11560148
Rhus natalelenis	0 606060606	0.15576324	0.785	0.0002512	0.027227004	0 78905085
Sarcostemma vimnale	0 606060606	0.15576324	40.42	0 0129344	1 401930585	2.163754431
Schrebera alata (Hostch.) Welew.	2 424242424	2.180685358	31.79	0 0101728	1.10260696	5 707534742
Scutia myritina (Burm.F.) Kurz	3 03030303	1 401869159	0.392	0 00012544	0 01359616	4 445768349
Solanecio angulatus (Vahl). C.Jeffreys	1.212121212	1 246105919	3.53	0 0011296	0 122434809	2 58066194
Solanum Mauritiunum	3 03030303	0 778816199	3.14	0 0010048	0 108908017	3 918027246
Solanun incanum L.	1 818181818	1 401869159	42.782	0 01369024	1 483854387	4 703905364
Strychnos henningsii Gilg	2 424242424	3 271028037	3.336	0 00106752	0 115706097	5 810976558
Tarenna graveolens (S.moore) Brem	0 606060606	0 15576324	31 88	0 0102016	1 105728527	1 867552373
Teclea simplicifolia (Engl.)Verdoon	3 03030303	7 943925234	0.785	0 0002512	0.027227004	11 00145527
Teclea tricocarpa	1 818181818	5 140186916	0.196	0 00006272	0 00679808	6 965166814
Tinnaea ethopica Hook.f.	0 606060606	0 15576324	3.925	0 001256	0 136135021	0 897958867
Trichilia sp	1 212121212	0 934579439	32 185	0 0102992	1 116307172	3 263007823
Trimeria grandifolia (Hostch.)	1 212121212	0 62305296	6 28	0 0020096	0 217816034	2 052990205
Vangueria infausta Burch.ssp. Rotudata(Robyns) Verdc.	1.212121212	0 62305296	7 068	0 00226176	0 24514709	2 080321262
Zanthoxylum usambarensis	0 606060606	0 15576324	4 121	0 00131872	0 142933101	0 904756947
	100	100	2883 167	0 92261344	100	300

Appendix 3: Showing the relative frequency, density, doimance and importance value of woody species for H2

Species	Relative frequency	Relative density	Basal area	Dominace	relative dominace	I.v
Acokanthera oppositifolia (Lamb)	2.02020202	1.145038195	18.315	0.0058608	2.21668706	5.381927276
Aspilia mossambicensis (Oliv.)Wild	1.01010101	0.763358797	6.276	0.00200832	0.759592028	2.533051835
Canthium keniense Bullock	4.04040404	2.671755789	13.732	0.00439424	1.662000913	8.374160742
Carissa edulis (Forssk.) Vahl	1.01010101	0.381679398	34.535	0.0110512	4.179813685	5.571594093
Celtis africana Burn.F	1.01010101	0.381679398	15.121	0.00483872	1.830113297	3.221893706
Clausena anisata (Willd.) Benth	5.050505051	17.17557293	81.236	0.02599552	9.832093368	32.05817135
Crotolaria gooditiformis (Vatke)	1.01010101	0.381679398	5.255	0.0016816	0.636019137	2.027799546
Croton megalocarpus Hutch.	4.04040404	6.870229172	31.002	0.00992064	3.752210333	14.66284354
Cyphostemma nierense (Th.F.r.jr.) Dese	1.01010101	0.381679398	31.985	0.0102352	3.871184036	5.262964445
Dombeya burgessiae Gerrard	3.03030303	3.816793984	5.69	0.0018208	0.688667724	7.535764739
Erythrococca bongensis pax	1.01010101	1.526717594	52.592	0.01682944	6.365274686	8.90209329
Gnidia subcordata Mesin	1.01010101	0.381679398	21.391	0.00684512	2.588979138	3.980759546
Grewia similis K.Schum.	3.03030303	6.106870375	35.215	0.0112688	4.262114924	13.39928833
Heteromorpha trifoliata (Wendl.) Eckl.&Zeyh	3.03030303	6.106870375	58.635	0.0187632	7.096666437	16.23383984
Hybiscus fuscus Gareke	1.01010101	1.908396992	14.521	0.00464672	1.757494557	4.675992559
Indigifora swaziensis	1.01010101	0.381679398	9.83	0.0031456	1.189737035	2.581517444
Jasminum fluminense Vell.	2.02020202	1.908396992	2.415	0.0007728	0.292290431	4.220889444
Lippia ukambensis Vatke	2.02020202	2.290076391	1.641	0.00052512	0.198612256	4.508890667
Maytenus heterophyla	3.03030303	3.816793984	18.254	0.00584128	2.209304155	9.05640117
Maytenus senegalensis (Lam)Exell	2.02020202	0.763358797	36.306	0.01161792	4.394160001	7.177720818
Maytenus undata(Thunb)	5.050505051	3.816793984	10.785	0.0034512	1.305321864	10.1726209
Mystroxylon aethopicum (Thunb.) Loes	3.03030303	0.381679398	7.452	0.00238464	0.90192476	4.313907188
Ochna ovata F. Hoffm	5.050505051	3.053435187	30.418	0.00973376	3.681528092	11.78546833
Olea africana	6.060606061	5.343511578	86.35	0.027632	10.4510471	21.85516474

Olea capensis	1.01010101	0.381679398	22.176	0.00709632	2.683988657	4.075769065
Opuntia Vulgaris	1.01010101	0.381679398	26.69	0.0085408	3.23032365	4.622104058
Ocmum suave	2.02020202	0.763358797	1.79	0.0005728	0.21664591	3.000206727
Phylanthus	2.02020202	0.763358797	26.69	0.0085408	3.23032365	6.013884467
Psaidia Punctulata(D.C) Vatke	1.01010101	0.381679398	1.176	0.00037632	0.142332732	1.53411314
Rhus natalelenis	1.01010101	0.381679398	0.981	0.00031392	0.118731641	1.51051205
Scutia myritina (Burm.F.) Kurz	1.01010101	0.381679398	0.196	0.00006272	0.023722122	1.41550253
Sesbania keniensis Gillet	2.02020202	1.526717594	33.558	0.01073856	4.061566168	7.608485782
Strychnos henningsii Gilg	5.050505051	6.106870375	0.785	0.0002512	0.095009519	11.25238494
Tarenna graveolens (S.moore) Brem	7.070707071	2.671755789	14.32	0.0045824	1.733167278	11.47563014
Teclea simplicifolia (Engl.)Verdoon	4.04040404	7.633587968	0.785	0.0002512	0.095009519	11.76900153
Teclea tricocarpa	2.02020202	0.763358797	42.099	0.01347168	5.095293943	7.87885476
Tinnaea ethopica Hook.f.	1.01010101	0.381679398	4.52	0.0014464	0.54706118	1.938841589
Trichilia	3.03030303	1.145038195	6.81	0.0021792	0.824222707	4.999563933
Turraea mombasana	1.01010101	0.381679398	6.819	0.00218208	0.825311988	2.217092397
Vangueria infausta Burch.ssp. Rotudata(Robyns) Verdc.	3.03030303	3.816793984	2.676	0.00085632	0.323879584	7.170976598
Vernonia brachycalyx O Hoffin	1.01010101	0.381679398	5.21	0.0016672	0.630572732	2.02235314
262 individuals representing (41 species)	100	100.0000024	826.233		100	300.0000024

Appendix 4: **Showing the relative frequency, density, doimance and importance value of woody species for H3**

Eucalyptus Plantation	**Relative frequency**	**Relative density**	**Basal area**	**Dominace**	**Relative dominace**	**I.V**
Caledendron capense(L.F)	3.333333333	0.507614729	0.098	0.00003136	0.014614692	3.855562754
Canthium keniense Bullock	3.333333333	0.507614729	21.19	0.0067808	3.160054289	7.001002351
Clausena anisata (Willd.) Benth	13.33333333	13.70559767	50.0981	0.016031392	7.471105039	34.51003604
Croton megalocarpus Hutch.	6.666666667	4.568532557	30.176	0.00965632	4.500132054	15.73533128
Dombeya burgessiae Gerrard	10	10.15229457	75.36	0.0241152	11.23839977	31.39069435
Eucalyptus botryoides	16.66666667	35.533031	235.098	0.07523136	35.06004923	87.2597469
Gnidia subcordata Mesin	6.666666667	5.076147285	80.74625	0.0258388	12.04164859	23.78446254
Grewia similis K.Schum.	3.333333333	0.507614729	18.153	0.00580896	2.707147971	6.548096033
lantana camara	16.66666667	25.38073643	100.785	0.0322512	15.03001753	57.07742063
Maytenus undata(Thunb).	6.666666667	2.030458914	35.30375	0.0112972	5.264830892	13.96195647
Ochna ovata F. Hoffin	3.333333333	0.507614729	2.355	0.0007536	0.351199993	4.192148055
Olea africana	3.333333333	0.507614729	8.635	0.0027632	1.287733308	5.128681369
Teclea simplicifolia (Engl.)Verdoon	3.333333333	0.507614729	6.28	0.0020096	0.936533315	4.777481376
Trimeria grandifolia (Hostch.)	3.333333333	0.507614729	6.28	0.0020096	0.936533315	4.777481376
14	**100**	**100.0001015**	**670.558**		**100**	**300.0001015**

Appendix 5: Showing the relative frequency, density, doimance and importance value of woody species for H4

Quarry Habitats	Relative frequency	Relative density	basal area	Dominance	relative dominance	Importance Value
Abutilon mauritianum (Jacg.)Medic	3.5714286	1.851851852	0.196	0.00006272	0.199765174	5.623045597
Acokenthera schimperi	7.1428571	3.703703704	0.196	0.00006272	0.199765174	11.04632602
Buddleia polystachga	17.857143	38.88888889	35.128	0.01124096	35.80281139	92.54884314
Croton megalocarpus Hutch.	3.5714286	1.851851852	1.766	0.00056512	1.799924986	7.223205409
Grewia similis K.Schum.	7.1428571	7.407407407	1.37	0.0004384	1.396317798	15.94658235
lantana camara	17.857143	16.66666667	21.195	0.0067824	21.60215746	56.12596699
lantana mauritiunum	3.5714286	1.851851852	0.785	0.0002512	0.800079906	6.223360329
Lippia ukambensis Vatke	3.5714286	1.851851852	0.1962	0.000062784	0.199969016	5.623249439
Olea africana	10.714286	5.555555556	0.196	0.00006272	0.199765174	16.46960644
Rumexs usamabarensis	3.5714286	1.851851852	6.675	0.002136	6.803227227	12.22650765
Schrebera alata (Hostch.) Welew	3.5714286	1.851851852	25.316	0.00810112	25.80232217	31.22560259
Solanum Indicum L.	14.285714	14.81481481	4.9	0.001568	4.99412935	34.09465845
Tarenna graveolens (S.moore) Brem	3.5714286	1.851851852	0.196	0.00006272	0.199765174	5.623045597
13 species	**100**	**100**	**98.1152**	**0.031396864**	**100**	**300**

Appendix 6: Checklist of the herbaceous layer (diversity) in Oloolua forest

SPECIES	Family	Growth form
Aspillia mossambicensis	Compositae	Herb
Abutilon mauritiunum (Jacq.) Medic	Malvaceae	Herb
Achyranthes aspera L.	Amaranthaceae	Herb
Ageratum conyzoides L.	Compositae	Herb
Albizia gummifera (J.F. Gmel.) C.A sm seedling	Leguminosaae	Seeedling
Asparagus spp.	Asparagaceae	Herb
Assstasia musorensis	Acantheceae	Herb
Barleria ventricosa Nees(Roth)T. Anders	Acantheceae	Herb
Basella alba L.	Basellaceae	Herb
Brachyliana hulliensis	Compositae	Tree seedlings
Buddleia polystachya	Longinaceae	Herb
Caleodendron seedling	Verbanaceae	Seedlings
Combretum molle G.Don	Combretaceae	Seedlings
Canthium keniense Bullock seedling	Rubiaceae	Seedling
Clausena anisata seedling (Willd.) Benth	Rutaceae	Seedling
Clematis sinensis Fres.	Ranunculaceae	Herb
commelina sp	Commelinaceae	Herb
Crotolaria goodiiformis Vatke	Leguminosae	Herb
Cyperus maranguensis K. Schum	Cyparaceae	Herb
Diospyros abyssinica (Hiern) F.White seedling	Ebenaceae	Seedlings
Dombeya burgessiae Gerrard	Sterculaceae	Herb
Elaeodendron buchananii seedling (Loess.)	Cellastraceae	Seedling
Erythrococa bongensis Pax	Euphorbiaceae	Seedling
Erythrococa fischeri seedling Pax	Euphorbiaceae	Seedling
Eucalyptus botryoides seedling	Myrtaceae	Seedling
Euphorbia gospypina Pax	Euphorbiaceae	Seedling
Gnidia subcordata seedling Mesin	Thymalaceae	Seedling
Grewia similis seedling K.Schum.	Tiliaceae	Seedling

Hibiscus Calyphyllus Cav.	Malvaceae	Herb
Hibiscus fuscus	Malvaceae	Herb
Indigofera swanziensis	Leguminosae	Herb
Jasminum fluminense	Oleaceae	Herb
Lantana camara	Verbanacee	Herb
Leucas grandis Vatke	labateae	Herb
Maytenus heterophylla (Eckl.&zeyh.) Robson	Celastaceae	Seedling
Meineckia phyllanthoides (Baill.) Webster	Euphorbiaciae	Seedling
Mosses(Brachythecium spp.)	Moss	Moss
Solanum nigrum L.	Solanaceae	Herb
Ochna insculpta seedling Sleumer	Ochnaceae	Seedling
Ochna ovata F. Hoffin seedling	Ochnaceae	Seedling
Pittosporum viridiflorum seedling	Pittosporaceae	Seedling
Oplismenus hirtellus (L.) P. Beauv	Gramminae	Grass
Ocimum suave Willd	Labiatiae	Herb
Pallaea adiantoides (Willd.) J.sm	Adiantaceae	Fern
Panicum maximum L.	Graminae	Grass
Pavonia patens (Andr.) Chiov	Malvaciae	Herb
Pentas lanceolata (Forsk) Deflers.	Rubiaciae	Herb
Phyllanthus Odontadenius Muell.Arg	Euphorbiaciae	Herb
Psiadia punctulata D.C)	Composiate	Herb
Pterobium seed	Leguminoceae	Seedling
Rhus natalensis seedling Karauss	Anarcanthacae	Seedling
Rumexs usambarensis	Polygonaciae	Seedling
Sarcostemma Viminalle (L.)R.Br.	Ascleapiadiacae	Herb
Schrebera alata seed	Oleceae	Seedling
Scutia myritina seedling (Burm.F.) Kurz	Rhamnaceae	Seedling
Senecio discifolius Oliv	Compositae	Herb
Senecio lyratiparititus A.Rich	Compositae	Herb
Senecio stuhlmanii Klatt	Compositae	Herb
Sesbania sesban (L) Meril var nubica	Leguminosae	Herb

Setaria plicatilis (Hochst.) Engl.	Graminae	Grass
Smilax aspera	Similaceceae	Herb
Solanacio angulatus	Compositae	Herb
Solanum incanum seedling	Solanaceae	Seedling
Sphaeranthus bullatus Matt.f	Compositae	Herb
Strychnos seedling	Longaniceae	Seedling
Tarenna graveolens seedling S.More) Brem.	Rubiaceae	Seedling
Teclea simplicifolia seedling	Rutaceae	Seedling
Teclea tricocarpa	Rutaceae	Seedling
Tephrosia hildebrandtii Vatke	Leguminocae	Herb
Terenna graveolens S.More) Brem, seedling.	Rubiaceae	Seedling
Themda triandra	Graminae	Grass
Thunbergia alata Sims	Acantheceae	Herb
Torilis arvensis (Huds.) Link	Umbiliferae	Seedling
Tragia brevipes pax	Euphorbiaceae	Herb
Trichilia emetica vahl. seed	Meliaceae	Herb
Vangueria infausta Burch. Ssp. Rotundata seedling	Rubiaciae	Herb
Venonia brachycalyx seedling O.Hoffins	Compositae	Herb
Venonia Holstii O.Hoffm seedling	Compositae	Herb
venonia lasiopus O.Hoffm seedling	Compositae	Herb
Vigna membranacea A. Rich	Leguminosae	Herb