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**ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES**

**SPECIES COMPOSITION, DISTRIBUTION AND POPULATION
DYNAMICS OF RODENTS OF ENTOTO NATURAL PARK**

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DYNAMICS OF RODENTS OF ENTOTO NATURAL PARK**

**A Thesis submitted to the School of Graduate Studies
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**In Partial Fulfillment of the Requirement for the Degree of Master of Science in
Biology**

By

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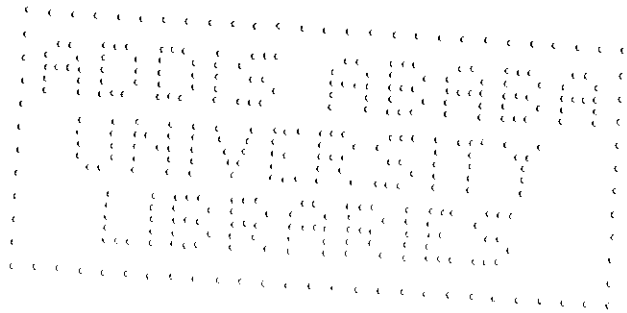
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DEDICATION

This work is dedicated to my late father and founder of my avenue to education who passed away in a land mine accident while I was engaged in this study.

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ABSTRACT

An ecological study of rodents was carried out in the different habitat patches of Entoto Natural Park, northern outskirts of Addis Ababa, from February 1998 to January 1999. Twelve species were found comprising the rodent fauna of the park. A total of 572 individual rodents belonging to nine species were captured from two 0.36 ha grids using a mark-release-recapture technique. The species were *Arvicanthis abyssinicus* (57%), *Myomys albipes* (15.73%), *Lophuromys flavopunctatus* (7.17%), *Mus mahomet* (5.8%), *Otomys typus* (5.24%), *Muriculus imberbis* (4.9%), *Desmomys harringtoni* (2.27%), *Dendromus lovati* (1.75%) and *D. mystacalis* (0.17%) together with the subterranean mole rat (*Tachyoryctes splendens*). Presence of two other rodent species (*Rattus rattus* and *Hystrix cristata*) was confirmed from survey trapping and indices like droppings and spines.

Both temporal and spatial differences in species number were apparent. Species number on the two grids fluctuated between five in the wet season and eight during the dry season and 'small rains'. Disappearance of the small-sized and rare species of rodents accounts for the lower number of species in the wet season and subsequent months. The number of species of rodents sampled using survey trapping was half of that obtained on the grids.

Monthly numbers of small rodents that are known to be alive on both grids varied between 93 at the end of the wet season (October) and 172 during the 'small rains' (April). Population size peaks on both grids appeared during the 'small rains' and in the middle part of the first half of the dry season.

Reproductive peaks occurred mainly during and immediately after both the 'small and big rains'. *A. abyssinicus*, *M. albipes*, and *M. imberbis* had their reproductive peaks after the 'big' and 'small rains'. *Lophuromys flavopunctatus* and *O. typus* on the other hand had their reproductive peaks during the 'big rains'. Hence, reproductive peaks were associated with precipitation be it 'big' or 'small'.

Adults dominated monthly population structures. Juveniles and subadults were better represented in captures made after the main breeding season of each species. More juvenile

L. flavopunctatus and *O. typus* were seen just after the end of the wet season while those of *A. Abyssinicus* and *M. albipes* were seen two months later.

The wet season survival rate was the lowest for most of the species. Very few members of some populations survived for 11 months and the more common species had about 37% survival probability for three months.

Distribution of small rodents in habitats and microhabitats of the mountain was patchy and related to occupation of suitable places. Shrubby grasslands, bushes on brook bank and sloppy hillsides were places of high species number. Swampy grasslands, eucalyptus plantation and grazed woodlands had none or the least species number of small rodents. Man-made microhabitats like stone fence line and heaped stones together with bushy fragments and herbaceous grassland hosted the greatest number of species and individuals on the grids. Trap stations with very short grass and located on sloppy hillsides, rocky out crops and adjacent eucalyptus plantations had the least species number and capture success.

INTRODUCTION

Rodents represent one of the widely distributed and successful groups of vertebrates. Their evolutionary success can be easily seen from their species number that accounts for more than 40% of mammalian species. This success is attributed to their higher reproductive potential and young age in evolutionary terms — between 26 and 38 million years (MacDonald, 1984). Utilisation capability of a wide-ranging food is the other reason for their success.

The economic and ecological significance of rodents is far-reaching. Some rodents cause damage to agricultural crops, pasture, forest nursery and household furniture. Some others are involved in disease transmission and destruction of insects. Rat-borne diseases have taken more lives than all wars and revolutions put together in the last millennium (MacDonald, 1984). Rodents like moles, voles and ground squirrels help in changing texture of soils. Genetic and biomedical researches use rodents as guinea pigs, rats and mice as their principal laboratory animals. Still some others form prey base to carnivores, birds, and snakes. Guinea pigs and edible dormice are deliberately bred for food. Both pest and non-pest field rodents (37 species in Africa) serve as human food source in some parts of the world (Fiedler, 1994).

Being usually secretive, nocturnal and highly mobile, rodents are seldom seen even when present in a given area in great numbers (Williams, 1993). Therefore, trapping is the most employed method in studying them since many species enter traps readily (Sutherland, 1996). Although used frequently, trapping is not free from difficulties such as acquired aversion to being trapped (Tew et al., 1994) and interspecific differences in susceptibility to being captured (Yu, 1994). Moreover, some rodents like whistling rats (*Parotomys brantsii*) never enter Sherman live traps (Kerley, 1992).

Other problems regarding use of traps are determination of distances between traps and the arrest of mobility of the animals. Some proposed trap spaces include 10 or 15 m taken as standard (Montgomery, 1985), 5 – 20 m (Sutherland, 1996), and even distances exceeding these are recommended depending on conditions at hand. Generally, productivity of habitats, mobility of animals, and number of traps available are considered as major variables to deal with in deciding trap spaces (Tew et al., 1994). According to Flowerdew and Gurnnell (1982) and Gurnnell and Gipps (1989), there cannot be satisfactory reason to relate movement to true

home range size because traps restrict animal movement. Despite these problems, trapping provides basic information concerning many aspects of populations like reproduction, feeding, habitat selection, abundance, and distribution.

Distribution of rodents is worldwide, covering most habitats of the earth except the sea (Prasad and Kashyap, 1995). Rodents occur in every habitat from the high arctic tundra, where they live and breed under the snow (lemmings), to the hottest and driest of deserts (gerbils). Since the distribution and abundance patterns of animal populations is the result of their past colonization history and ongoing interactions with their respective environment, the reason for restricted or wider distribution of any given species needs to be viewed accordingly.

Vegetation provides food, shelter and cover to small mammals. The structure and composition of vegetation, therefore, in general determine the distribution, abundance, and diversity of the small mammals. In other words, the diversity and demographic conditions of small mammals are reflections of habitat variables. In general the more diverse the habit, the more diverse is the small mammalian fauna, and the better the habitat, the better is immigration, survival, abundance, recruitment, length of breeding season, and body weight of the small mammals (Rogers and Gorman, 1995).

A reciprocal relationship is also reported to exist between small mammal community type and plant structure dynamics. Rodents have been shown to influence the abundance, structure and dynamics of plant communities as seed consumers and dispersers (Brown et al., 1986; cited in Kerley, 1992).

Altitude wise distribution of animals including small mammals is reported to follow different patterns in different parts of the world. Generally, high altitude communities are believed to have decreased species number by virtue of their occupation of smaller areas than lowlands at equivalent latitudes; and their isolation from similar communities than lowland sites, which will often form part of a continuum (Begon et al., 1996). According to Happold and Happold (1989), such situation is well demonstrated by the small mammalian fauna of the montane habitats of Africa and small mammals of the area appear in small numbers with numerical dominance of a single species.

Decreased number of species and individuals and numerical dominance of a single species with increase in altitude is not a phenomenon observed anywhere. Yalden, (1988b) and Owen,

(1990) reported increase in species number with increasing altitude. Based on results of studies from different areas in the world, Happold and Happold (1992) came to a more comprehensive conclusion regarding altitude wise distribution of small mammals. According to the tentative conclusion, species number, increases, decreases or remains unchanged with altitude increase. Habitat complexity is given more emphasis than mere altitude increment in determining distribution and abundance of small mammals.

Population dynamics of animals is dealt with by investigating factors affecting birth, death, immigration and emigration. The factors are of both biotic and abiotic and some of these include competition, predation, diseases, climate and soil. The impact of each factor in changing population density of a given area is variable. Consequently, population dynamic processes operating in a given habitat should be studied so as to have better understanding of population size change patterns.

The seasonal distribution and quantity of rain is considered as the major climatic variable in determining population dynamics of small mammals in East Africa. This is so because seasonal changes in temperature and day length are small in the region (Delany & Monro, 1986). Similarly, Neal (1986) regarded water and food as dominant factors controlling reproductive cycles throughout much of Africa. The closer correlation observed between rainfall and breeding activity of small mammals is the reason for the conclusion. A notable exception to this conclusion is the breeding pattern of *Arvicanthis abyssinicus* on Semien Mountains (3700 m), Ethiopia, where the species stops breeding during the rain (cold season) (Müller, 1977).

Population explosions (outbreaks) in some species of small mammals are induced by optimum conditions of rainfall and other environmental factors. Recurrent outbreaks of Nile rat (*Arvicanthis niloticus*) and multimammate rat (*Mastomys natalensis*) have been reported from many countries in Africa. Most outbreaks were preceded by extensive drought periods which were accompanied by protracted rain (Fiedler, 1994). The lack of rain for a longer time but not rain *per se* is taken as the key factor in the causation of outbreaks (Leirs, 1995). Repeated plague formation of house mouse (*Mus domesticus*) in Australia demonstrated this phenomenon (Singleton, 1989). Such animals display an r-selected survival strategy during explosions by taking advantage of changing conditions (Chapman and Reiss, 1997). Nevertheless, some other populations of small rodents control their size before maximum number is achieved.

Intrapopulation population regulation mechanisms are well known in rodents. Absorption of fetuses is commonly undertaken under unfavorable environmental conditions. Restriction of reproduction to single alpha females in a colony of *Cryptomys* is the other way of coping with problems that could arise due to overpopulation (Bennet and Jarvis, 1988b; Bennet, 1989). Pre-saturation dispersal of young mice by aggressive territorial males is also reported as the other population size regulation strategy (Anderson, 1970; Fitzgerald et al., 1981).

Many workers have dealt with East African small mammals' ecology. Some of the works include Southern and Hock (1963), Delany, (1964, 1972), Nandwa (1973), Neal (1970, 1984), Kingdon (1974), Field (1975), Taylor and Green (1976), Cheeseman (1977), Martin and Dickinson (1985), Delany and Monro (1986), and Happold and Happold (1987, 1989, 1990, and 1991). Most of these studies were, however, carried out mainly in Kenya, Uganda and Malawi and similar studies in Ethiopia are meager compared to those in Kenya or Uganda.

The mammalian fauna of Ethiopia is composed of 277 species out of which rodents have the greater share both in diversity, distribution and endemism (Hillman, 1993). The higher prevalence of mammalian endemism in Ethiopia is attributed to the unique topography (extensive high ground) and associated climate and vegetation. Despite the availability of extensive high ground in the country, the ecology of the mountain fauna is little known.

A few of the ecological studies on small mammals of Ethiopia are those of Müller (1977), Rupp (1980), Shimelis Beyene (1986), Yalden (1988a and 1988b), Sillero-zubiri et al., (1995) and Afework Bekele (1996a, 1996b). The areas where these researchers carried out their studies are mainly relatively pristine sites such as national parks or places with comparatively less human disturbance. Entoto Mountain is one of the several highly affected highland regions of Ethiopia where the diversity, distribution and abundance of small mammals are little known.

Understanding the factors that determine the diversity, distribution, abundance and population dynamics of the small mammalian community of an area provides information that is vital for the design and implementation of management strategies to attain a specific management

objective. Conducting such studies on small mammals of disturbed areas like the present study site, however, has remained a difficult task to accomplish. Any attempt designed for studying small mammals along this line would be of some economic and ecological importance and so does this study.

Consequently, this paper presents results of an ecological study made on the rodent fauna of some selected sites of the Entoto Natural Park, northern outskirts of the city of Addis Ababa. The main objectives of the study are:

1. To determine the species composition, distribution and abundance of small mammals of Entoto Natural Park.
2. To identify the major factors that influence small mammals abundance in different habitat patches, and;
3. To study population dynamics of rodents over a period of one year on two permanent grids.

1.2. The study area

Entoto Natural Park (also called Entoto herein) represents the northern outskirts of Addis Ababa and is delimited by a track encircling it along its rural boundary. The area is located between $9^{\circ}4' - 9^{\circ}7'N$, and $38^{\circ}45' - 38^{\circ}48'E$ and its altitude ranges from 2600 - 3100 m a.s.l. This study site covers an area of 1308 hectares and faces the city of Addis Ababa. The southern extreme of the land abruptly ascends from the moderately sloping northern urban boundary of the capital. This is the heavily eroded and more impoverished area, which is marked by bare land, and rocky outcrops. A gently sloping and flat intermediate land follows the sloppy area. The former region ends around the foot of the upper most site, which is the southern ridge of the mountain, (Fig. 1).

Small seasonal and permanent streams and various springs are found interspersed along the terrain of the Entoto Mountain. Two brooks flow towards south, traversing the western part of the study site. Three other brooks and their tributaries intersect the eastern area of the mountain.

landscape and ultimately converge at some point in the intermediate region before coming to a rocky gully, Nib Gedel, which literally means 'Bee's Cliff'. Honeycombs are seen hanging from the surface of the sloppy ravine after the wet season. Abundance of *Medicago* (*Trifolium acuale*) in the area facilitates honey production around the mountain. Nib Gedel is also a roosting site for one of Ethiopia's endemic birds (Thick-billed raven) during the dry season.

1.2.1. Geology and climate

The bedrock underlying the whole of Ethiopia is a Pre-Cambrian rock composed of metamorphic and igneous rocks. It is strewn with more recent Mesozoic rocks, mainly sandstone and limestone in central Ethiopia. The Mesozoic rocks in turn are covered by flood lava that extruded during Tertiary period in most parts of the country. Rhyolites, trachytes, tuffs and ignimbrites constitute the flood lava of which basalts are the most important components (Mohr, 1971). The main rock type of central Ethiopia is thus composed of these rocks.

Volcanic extrusion of the Tertiary period also had its impact on the formation of soils of the central plateau. Most soils of the region are thus of volcanic origin and mixed with sandstone and limestone. The soil around Entoto is a reddish-brown and heavy loam that is found on

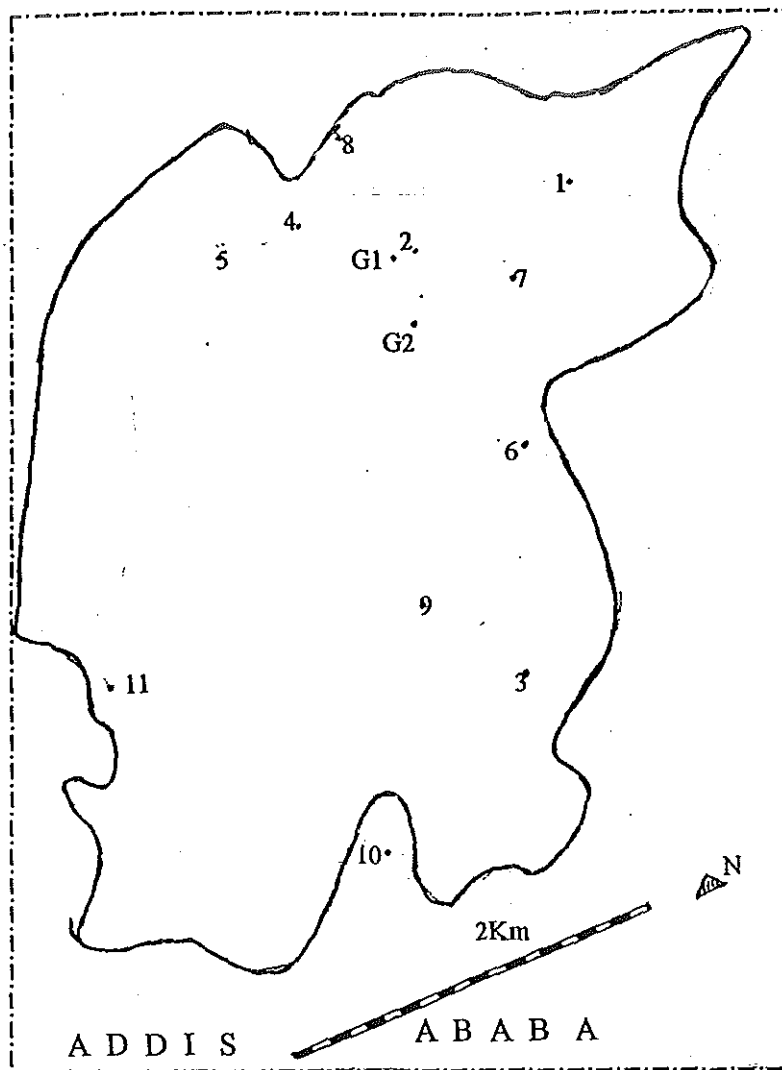


Figure 1. Location of habitats surveyed (1-6), permanent live-trapping grids (G1 & G2), residential area (7) and other important sites within and around the study area.

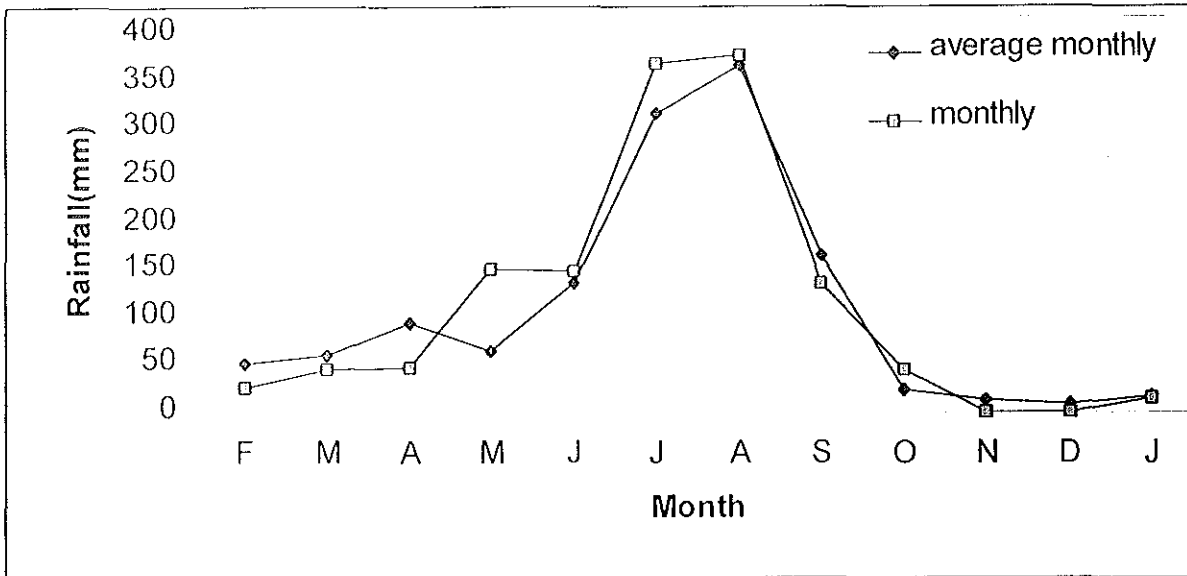
1. Bush on sloppy hillside
2. Bush on brook bank
3. Juniperus-Myrica woodland
4. Eucalyptus bush
5. Eucalyptus woodland
6. Open grassland
7. Residential area
8. Tajeb Kella (Guards' room)
9. Nib Gedel
10. Entoto Kidane Mihiret Church
11. Entoto Mariam Church

mountain and valley slopes and better- drained plateaus. Ustalf is the suborder of the soil type on the mountain and cultivation of this soil causes serious erosion during heavy rains (Englund and Blank, 1995).

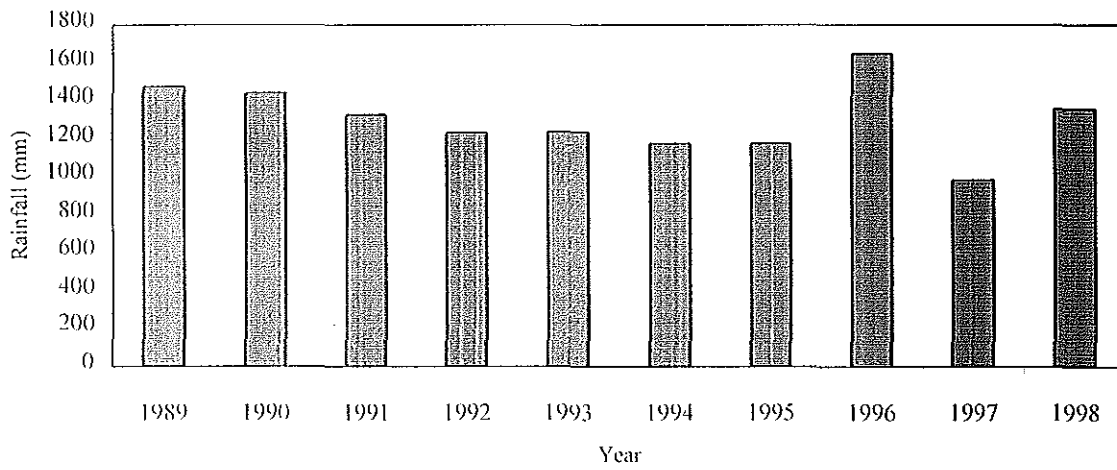
Entoto Mountain has seven months of rain from March to September as part of central Ethiopia. The 'small rains' fall during March to May and the 'big rains' occur from June to September. July and August are months of high and very high rainfall concentration, respectively (Daniel Gamachu, 1977).

According to meteorological data taken from a station at 2900 m a.s.l, located about 1 km west of the study area, the mean annual rainfall of the surrounding area is 1304.78 mm (n=10). The annual precipitation during the study time was 1356.2 mm, with no rain during November and December (Fig. 2). The two rainy seasons (the 'big and small rains') had 92.9% of the annual precipitation, 75.8% during the 'big rains' and 17.2% during the 'small rains'.

The mean monthly temperature minima ranged between 7.5 and 11°C and that of the maxima ranged between 15.8 and 21.1°C. The lowest temperature record of a day was in January (5°C) and the highest temperature record of a day was in April (23.5°C). Monthly minima and maxima temperatures of the study area during the study are shown in Fig. 3.



a)



b)

Figure 2. a) Mean monthly rainfall (n=10) and monthly rainfall during the study period (February 1998- January 1999) on Entoto Mountain.

b) Annual precipitation on Entoto Mountain from 1989-1998.

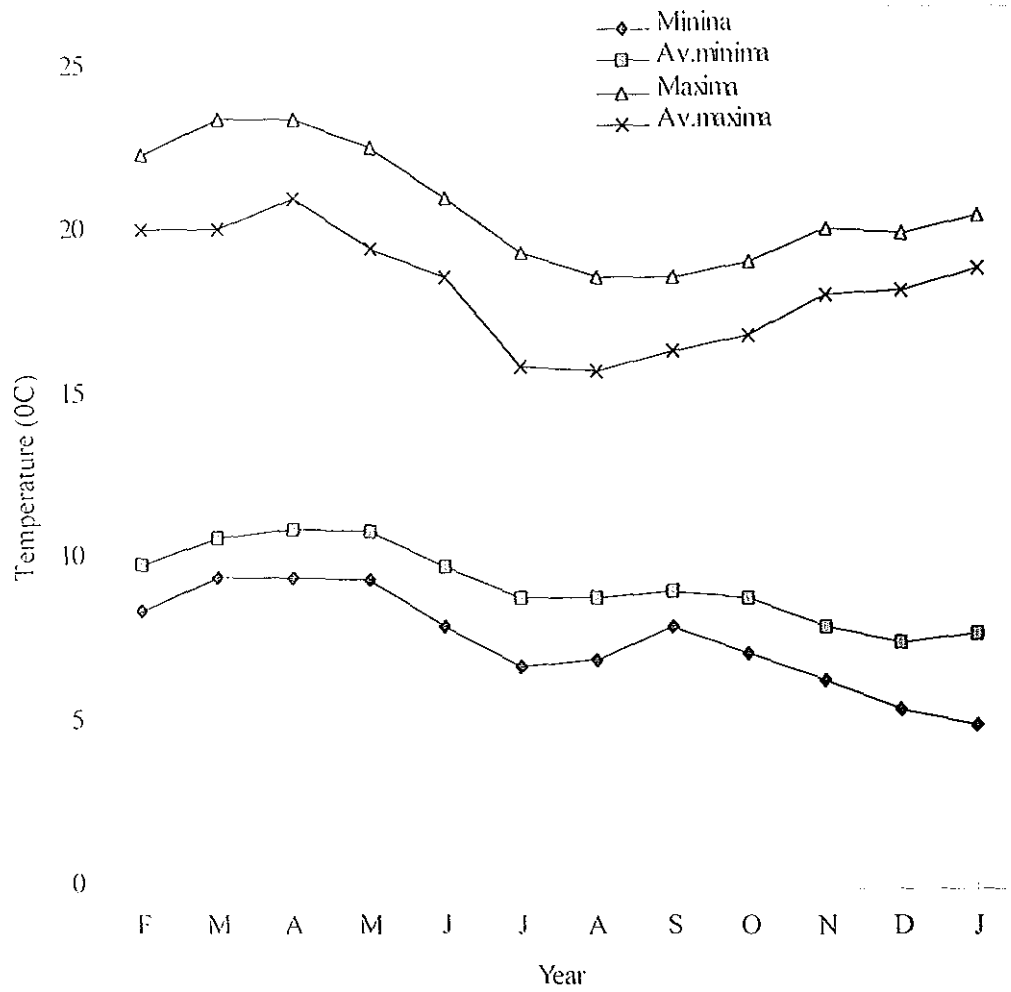


Figure 3. Monthly temperature minima, average minima, maxima and average maxima of Entoto Mountain (February 1998- January 1999).

1.1.2. Land use history and vegetation

The reign of Emperor Menelik (1889-1914) is characterized by urbanization in several places in Ethiopia and was accompanied by depletion of forest resources utilized extensively as fuelwood and construction material. Relocating the state capital from place to place, therefore, temporarily solved the recurrent problems of obtaining necessary forest products in cities (Pankhrust, 1989).

Entoto was one of the places chosen as a capital mainly for strategic reasons. But the chosen fortress had inhospitable climate to the royalty, was hardly accessible, and lacked sufficient water. These factors ultimately brought about Entoto's failure to continue as an appropriate capital. The capital thus had to be moved to a place with sufficient water, easily accessible and hospitable area. Addis Ababa was then taken as the best choice. Introduction of the exotic plant, *Eucalyptus globulus* mitigated problems associated with fuelwood and timber (Hancock et al., 1983).

Land ownership at Entoto continually shifted between private and state until the land was handed over to Addis-Bah, a fuelwood plantation project funded by the World Bank and African Development Fund in 1984 (Fikirte, 1992). The project had undertaken an extensive plantation in the area and finally the land was leased to Ethiopia Heritage Trust (EHT). The latter is a private self-help organization established with the aim of conservation, preservation and restoration of old historic buildings and lands of natural beauty (EHT, undated).

The Trust is now in charge of managing most of Entoto Mountain with a future plan of converting it into a natural park. It is because of this that the largest portion of the Entoto Mountain (the study area) is designated as Entoto Natural Park (ENP) since 1995. The

agroclimatic zone of Entoto is Dega (cool temperate) according to the classification based on altitude, temperature and evapotranspiration (Daniel Gamachu, 1977). The altitude range places the study area under Afro-montane region. The natural vegetation is a mixed shrubland (Edwards, 1976). This is supplemented with some scattered trees like *Juniperus*, *Hagenia*, and others.

Most of Entoto Mountain is currently covered by eucalyptus plantation, mainly *Eucalyptus globulus*. Eucalyptus is favored for its fast growth, high utility and adaptability. It is also believed to cast less shade compared to other broad-leaved trees owing to the way its leaves are oriented on twigs. As a result, eucalyptus tree is grown in 80 countries outside its natural range. Nevertheless, the plant is not free from curses by many others. Eucalyptus plantation is known for its inhibition of growth of other plants near it (allelopathic effect) and poor faunal species number. Because of these and other factors or shortcomings, planting eucalyptus is banned in some countries (Poore and Fries, 1985).

The eucalyptus plantation on Entoto Mountain is exploited by different sectors of the people in and around Addis Ababa. The litter and branches are regularly taken away by children and women coming from urban areas. Men from both urban and rural areas cut wood that serves as both fuelwood and construction material illegally. A large number of people in one way or another earn their living by selling eucalyptus products. The greater fuelwood and construction material demand in and around Addis Ababa combined with Entoto's easier accessibility aggravate the exploitation pressure on both the eucalyptus plantation and patches of relict natural vegetation of the mountain.

A number of species of grasses, herbs, shrubs and trees constitute the natural vegetation of Entoto. The grassland (meadow) is mainly composed of grasses like *Sporobolus africanus*, *Andropogon abyssinicus*, *Themeda triandra*, *Rytiosperma subulata* and *Cyprus rigidifolius*.

The herbs include *Plectocephalus varians*, *Alchemilla abyssinica*, *Alchemilla pedata*, *Saturia abyssinica*, *Trifolium acuale*, *Trifolium schimperi*, *Bidens biternata*, *Bidens macranta*, and *Thymus serrulatus*. A tough creeping herb (*Oldenlandia monanthos*) is found covering the surface of the ground in regularly grazed grasslands. The herb has tiny star-like flowers (4 petals) that flower at any time of year, but in masses during the rain (Edwards, 1976). The flower of this herb is chosen as an emblem of Ethiopia Heritage Trust.

The shrubby vegetation of the mountain is composed of mainly *Hypericum revolutum*, *Discopodium penninervium*, *Buddleja polystachya*, *Rubus steudineri*, *Rosa abyssinica* and *Leonotis velutinia*. *Erica arborea* is found on eroded sloppy areas along the height of the mountain starting from around 2800 m a.s.l. in stunted and scattered condition. The noticeable trees include *Juniperus procera*, *Hagenia abyssinica*, *Myrica salicifolia*, *Maesa lanceolata*, and *Acacia abyssinica*.

The natural and plantation vegetation of Entoto provides protection and food for some large mammals and birds. Large mammals include Spotted hyena (*Crocota crocuta*), Civet (*Civettictis civetta*), Grivet Monkey (*Cercopithecus aethiops*), Bush Duicker (*Sylvicapra grimmia*), Menelik's Bushbuck (*Tragelaphus scriptus meneliki*) and others (**Appendix 1**).

The avian community of Entoto Mountain includes endemic species like Wattled Ibis (*Bostrchia carunculata*), Abyssinian Catbird (*Parophasma galinieri*), Banded Barbet (*Lybius undatus*), Black headed Siskin (*Serinus nigriceps*), Thick-billed Raven (*Corvus crassirostris*) and many other nonendemic ones (**Appendix 2**).

Plantation and agro-pastoralism characterize the land use practice on Entoto. Both of these practices are further encroaching on the relict natural vegetation of the area. The demand for more arable land is threatening even the very steep slopes and rocky outcrops. Children of the area are not engaged in schooling and only aspire to build their hut near their parents. This enhances the need for more land acquisition and eventual exacerbation of the existing pressure on the relict natural vegetation.

Entoto is very important for historical, recreational, religious and biological reasons. Its historical places and National Museum, the famous Entoto Mariam Church together with the Mariam holy water ('Tsebel') are renowned. The mountain provides many vantage points to view over the spectacular landscape around Addis Ababa and the surrounding mountains like Wochecha, Furi, Yerer, Ziquala, and Menagesha.

As a result, people coming for various reasons from allover the country regularly visit these facilities and expatriate tourists enjoy bird watching on the mountain. Both professional and amateur athletes engage in training themselves on Entoto in order to promote their running skills and get acclimatized to higher altitude performance. The biological importance of Entoto lies on its montane fauna and flora. All these factors might have their own contribution to qualify the area as a proposed natural park.

1.1.3. Habitat description

Entoto Mountain can be described as a man-made environment with fragmented natural vegetation composed of open grasslands (meadows), bushes on sloppy hillsides and brook banks, grasslands with scattered bushes and trees (montane savanna), and *Juniperus-Myrica* woodlands (Fig. 1). The extensive eucalyptus plantation, cultivated areas and residential sites represent the highly modified parts of the mountain.

Open grasslands (meadows) are mostly found bordering farmlands. Some of these are arable lands that probably remained uncultivated due to their very steep slope or poor drainage. The bush habitat on the other hand is found on sloppy hillsides and brook banks. It consists of different shrubs without apparent dominant species. The shrubs and the woodlands that are found in scattered and fragmented situation represent natural vegetation of the mountain. Bushes are confined to very narrow strips of land and harbor a few vertebrates especially carnivores. The extensive use of eucalyptus plantation by the people contributed to the survival of the fragmented bushes.

The *Juniperus-Myrica* woodland is found in the southeastern edge of the study area and it is totally encircled by eucalyptus plantation. Plants like *Salix subserata*, *Olinia rochetiana*, *Carisa edulis* and *Allophylus abyssinicus* are also common in addition to the two prominent trees. The area is regularly grazed and has intermittently grown tussocks. The thick vegetation within the woodland provides dens for spotted hyena.

Vegetative growth on the Entoto Mountain occurs mainly during and shortly after the wet season. The 'small rains' and even sporadic rain contributed further growth. Grasses and herbs growing in set-asides and grazing lands showed different growth pattern during the wet season. Both grasses and herbs of the set-asides grew continuously. Grasses in such areas attained height of 40-50 cm, while selective grazing of grasses in grazing areas promoted growth of herbs such as *Alchemilla pedata* and *Alchemilla abyssinica*. Grass height in grazing areas hardly exceeded 15 cm.

Wilting and subsequent drying of the herbs prior to grasses follows the onset of the dry season. However, herbaceous plants found around brook banks, under trees and bushes remain fresh for a long time. Some poorly drained grassland areas keep their vegetation fresh and lush for relatively longer time. Further progress of the dry season is accompanied by drying of grasses with eventual ground vegetation cover decline.

The eucalyptus plantation is viewed as bush or woodland based on the stage of its development. Trees at later stages of their growth have crowns away from the ground and provided no ground cover. Plantation of this sort is referred to as woodland. The ground under the woodland is covered with stunted grass when individual trees are grown far apart. Some herbs and moss are also available during the wet season. The ground under closely grown trees was found either

bare or with scarce vegetation cover. The situation is worsened by erosion around sloppy areas. Fallen leaves of the woodland trees have greater demand by the people and regularly removed unlike the litter found under younger eucalyptus bushes. Eucalyptus bush provides better cover to the nearby ground compared to the woodland.

The habitats in which the two live-trapping grids set are different to those already described with respect to their vegetation structure and can generally be described as grassland with scattered herbs, shrubs and trees. There are, however, differences between the vegetation of the two grids that are reflections of the different system of land use practice in the two sites.

Grid 1 is usually kept as set-aside and grazing is allowed for only two months (May and June). Grid 2, on the other hand is a dry land that is grazed throughout the year. A stone fence line runs along three-quarter length of one marginal row of Grid 1. Various heaped stones of wide ranging sizes (6- 60 m²) characterize grid 2. The stone fence line and heaped stones serve as artificially created microhabitats of the two grids, which are about 400 m apart.

II. MATERIALS AND METHODS

2.1. Live-trapping grids

Two permanent live-trapping grids were established on places representing shrubby grasslands of Entoto. Both grids were set on sloping hillsides of uniform topographic aspect (facing west). Each grid had 49 aluminium Sherman traps (7.6 x 8.9 x 22.9 cm) arranged along seven columns and rows of equal distance between traps and trap lines (10 m). The total area of each grid was thus 0.36 ha.

Choice of grid sites was based on some factors: First, the places had to be wider so as to accommodate the proposed number of traps. Secondly, since low-lying and flat areas of Entoto become swampy or flooded during the rain, places of good drainage were indispensable. Disturbance minimization and dealing with natural vegetation were also points to be considered.

Grid 1 can be regarded as a habitat epitomizing the less affected natural shrubby grasslands of Entoto because of its set aside status. The other grid (Grid 2) was grazed by livestock throughout the year and most frequented by people.

Trapping was conducted monthly for three days starting from February 1998 and ending in January 1999. There was, however, no trapping during December 1999. Total numbers of trap nights utilized monthly and in the year were 294 and 3234, respectively. Sprung and stolen traps were not included in computing trap success rates and associated factors.

Traps were kept covered with hay mainly to avoid excess heat during the day and cold during colder nights. But this was also found important in preventing people from being attracted by

shiny and glittering objects from afar. Trap locations were also easily obtained during trap checking. The usual bait (peanut butter) was used during all trapping operations. Bait and hay replenishing was done as necessary.

Traps were normally checked around 0700 and 1700 hr. Early morning checks, however, were necessary mainly because diel activity of the species were certainly recognized by earlier morning visits (around 0630 hr) and that some species of rodents were found torpid in traps during colder months and had to be released earlier before they die.

Handling captured small mammals was done following Gurnell and Flowerdew (1990). Toe clipping (one toe per foot) was used for marking individual captures. Catches were released at point of capture after recording information pertaining to weight, sex, reproductive status and any other unusual or striking feature observed. Only trap station and individual animal's code was recorded for recaptures within one trapping occasion.

Reproductive status of the captured rodents was determined using genitalia and palpable embryos. In males, size of scrotum and position of testes were used to determine reproductive maturity or immaturity. Large visible scrotum and testes descended into scrotum indicate sexual maturity. Females were checked for onset of breeding, pregnancy or lactation. Size of nipples was used as clues for recent or current lactation. Observation of enlarged abdomen and palpable embryo was carried out for detection of pregnancy of the later stage.

Species identification was accomplished using distinguishing taxonomic characters listed in Yalden et al. (1976), Kingdon (1974) and Nowak (1991). This was also supplemented by

specimens available at the Zoological Natural History Museum, Biology Department, Addis Ababa University where voucher specimens prepared during this investigation are lodged.

Population size and density estimation was carried out using the minimum number of animals known to be alive (MNA) method (Kreb, 1966; Kreb et al., 1969; Petrusiewicz, 1983). Paucity of recaptures during each trapping period did not allow the use of the stochastic Jolly-Seber model for the populations; as the model is imprecise when number of monthly recaptures is less than 10 (Sutherland, 1996).

Density and biomass of the rodents were obtained after finding the area from which animals were supposed to be trapped (effectively trapped area). Boundary strip method, which deals with addition of a strip that is one half-intertrap distance to all sides of a quadrat, was employed to estimate the area. Home ranges of some regularly trapped species were estimated using the minimum area method.

Numbers of new or unmarked individuals entering a population every trapping occasion were utilized in finding recruitment rates. The latter was computed by finding the ratio of rodents entering a population from trapping occasion t to $t-1$ to the population present at period t (MNA).

Survival rate was calculated using data from all individuals of some species captured during the study period. Two different approaches of estimating survival were employed. The first involved finding the monthly population survival and mortality rates of some regularly trapped species and computed following Kreb 1989. The other approach involved finding survival rates of populations using the length of time each individual survived on the grids (Happold and Happold, 1989).

Casual observations around the grids and surveyed habitats were undertaken in order to secure information that may not be obtained through trapping alone. Distant visual observation of diurnal rodents' activities using binocular was the main method. Observations without the visual aid were also employed when found appropriate.

2.2. Assessment of distribution and abundance

The distribution and abundance patterns of rodents in different vegetation types or habitats was also looked at during the wet and dry seasons of 1998. The wet season survey was done using live traps set in line at 10 m intervals. Live trapping was meant not to trap out vulnerable rodent species presumed to exist around Entoto. However, the dry season trapping occasion was carried out using commercial break-back rat-traps. Use of snap traps was found inevitable in order to avoid the frequent damage and removal of traps by scavenging carnivores. Spotted hyena (*Crocuta crocuta*) was found to be the remarkable problem posing animal and threatened the viability of the trapping program by removing and demolishing traps.

Traps were arranged in lines so as to sample animals coming from both sides of trap lines. Number of trap lines required in each trapping area was determined on the basis of width or length of the area. One longer trap line was enough for a long narrow stripped habitat. Square shaped habitat fragments were provided with more than one-trap lines.

Since sizes of habitats surveyed were not of equivalent areas, number of traps utilized were also variable. Hence per cent trap success was appropriate in comparison of abundance.

Sample areas were chosen after deciding the available number of habitat types in the study site. Open grasslands (meadows), bushes beside brooks and on sloppy hillsides, Eucalyptus woodland and bushes, and *Juniperus - Myrica* woodland were the major ones together with farmlands and human residence.

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Table 1. Species composition, numbers of individuals of each species on each grid (Grid 1 and Grid 2), and total number of individuals of both grids, on Entoto Mountain. Percentages of individuals of each species in the respective category are shown in parentheses.

Species	Number of individuals and their proportion		
	Grid 1	Grid 2	Total
<i>Arvicanthis abyssinicus</i>	79 (35.8)	247 (70.4)	326 (57)
<i>Myomys albipes</i>	46 (20.8)	44 (12.5)	90 (15.7)
<i>Lophuromys flavopunctatus</i>	20 (9.1)	21 (6.0)	41 (7.2)
<i>Mus mahomet</i>	31 (14.0)	2 (0.6)	33 (5.8)
<i>Otomys typus</i>	10 (4.5)	20 (5.7)	30 (5.2)
<i>Muriculus imberbis</i>	21 (9.5)	7 (2.0)	28 (4.9)
<i>Desmomys harringtoni</i>	6 (2.7)	7 (2.0)	13 (2.8)
<i>Dendromus lovati</i>	8 (3.6)	2 (0.6)	10 (1.8)
<i>Dendromus mystacalis</i>	---	1 (0.3)	1 (0.2)
<i>Tachyoryctes splendens</i>	*	*	*
Total	221	351	572

* Molehills used as indices

Table 2. Monthly numbers of rodents that are known to be alive (MNA) on Grid 1 and Grid 2, Entoto Mountain, from February 1998 – January 1999. There are no data for December 1998. Aa=*A. abyssinicus*, Ma= *M. albiges*, Lf=*L. flavopunctatus*, Ot= *O. typus*, Mi= *M. imberbis*, Mm= *M. mahomet*, Dh= *D. harringtoni*, Dl= *D. lovati*, Dm= *D. mystacalis*

Species	Grid	Months											
		F	M	A	M	J	J	A	S	O	N	J	
Aa	1	8	15	21	17	26	26	29	23	20	30	19	
	2	63	78	90	93	80	71	49	40	32	49	64	
Ma	1	17	22	17	12	10	10	11	6	3	8	17	
	2	13	16	20	15	6	11	4	-	1	4	9	
Lf	1	1	1	6	6	5	7	6	15	11	10	10	
	2	-	-	2	8	8	9	5	4	5	3	5	
Ot	1	--	3	2	3	3	3	-	2	2	1	-	
	2	-	1	2	-	3	4	4	1	2	6	6	
Mi	1	2	1	2	8	7	5	2	2	3	10	2	
	2	-	-	-	3	-	--	--	--	--	--	4	
Mm	1	11	8	6	--	--	--	--	--	--	6	7	
	2	1	--	--	--	--	--	--	--	--	--	1	
Dh	1	1	1	1	1	--	--	--	--	--	--	3	
	2	3	4	1	1	1	--	--	--	--	--	3	
Dl	1	2	--	2	3	--	--	--	--	--	--	1	
	2	--	2	--	--	--	--	--	--	--	--	--	
Dm	2	1	--	--	--	--	1	--	--	--	--	--	
Total		124	152	172	170	149	147	110	93	79	127	151	
No. spp.	1	7	7	8	7	5	5	4	5	5	6	7	
	2	5	5	5	5	5	5	4	3	4	4	7	
	1 and 2	8	8	8	7	6	6	5	5	5	6	8	

The total number of captures of small rodents from the two grids during the study period was 2030; of which 572 were first catches (Table 1). A mean capture success of 62.8% was obtained by utilizing an overall capture effort of 3234 trap nights. Thus about 132 recaptures were obtained during each monthly trapping occasion. Trap success for both grids catch combined ranged between 41% in October and 76.2% in April. However, trap success differed substantially between the two grids, and hence the monthly average trap success for Grid 1 and Grid 2 were 52.9% and 72%, respectively.

Monthly number of animals known to be alive on each grid and the way these numbers changed during the study period varied on both grids, though similar patterns were seen in some situations. The numbers of Grid 1 rodents showed alternating increase and decrease until May and this was followed by slight variations until September. The number then declined to its annual minimum in October. Both grids were similar regarding the last event and the accompanying population size increase in November. Populations of Grid 2 showed progressive increase during the 'small rains' with subsequent decline during the wet season (Fig.4).

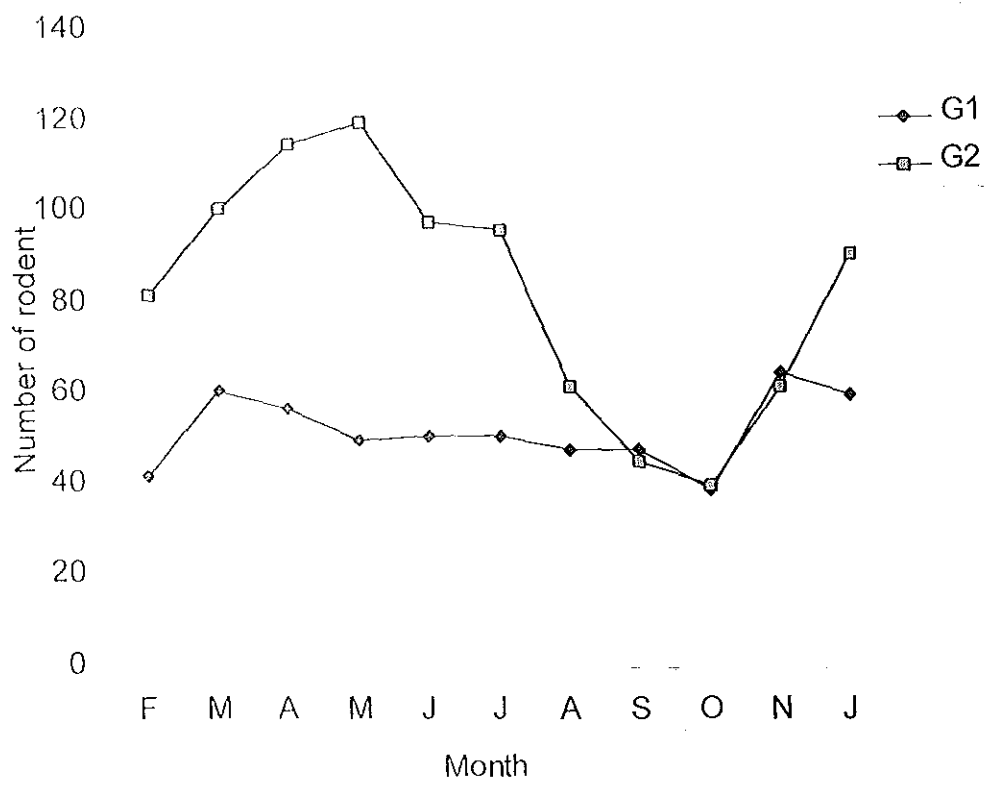


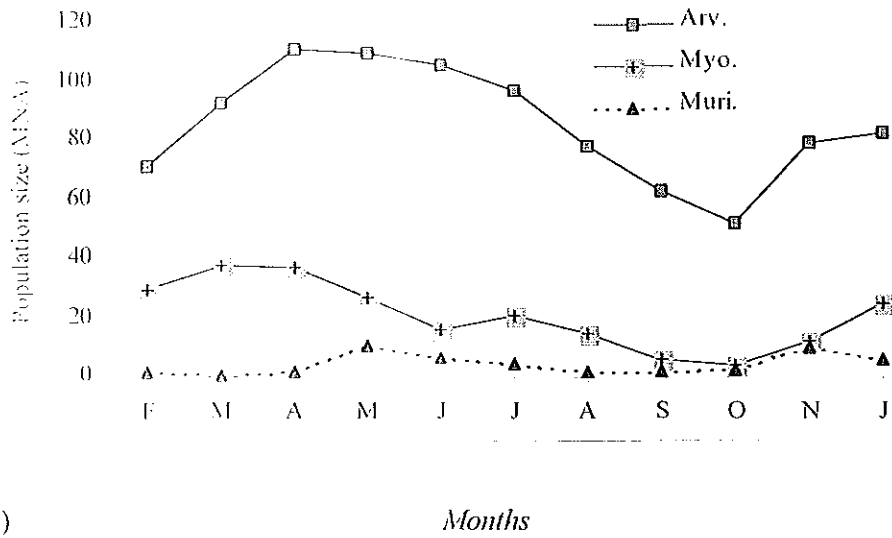
Figure 4. Total number of rodents known to be alive (MNA) on Grid 1 and Grid 2, Entoto.

Population size fluctuation patterns of each species on the grids appeared to be influenced by seasonal factors. *A. abyssinicus* had similar fluctuation pattern as the two rodent communities of the grids. Nevertheless, the population size on Grid 1 was not affected during the rainy season like that of Grid 2. Increase in population size was seen even in August on Grid 1. Decline in number of individuals occurred after November while number of members of the other population on Grid 2 was increasing (Table 2). Total number of monthly captures of the species were positively correlated with monthly temperature average minima ($r = 0.57$) but very weak positive correlation with monthly rainfall ($r = 0.17$).

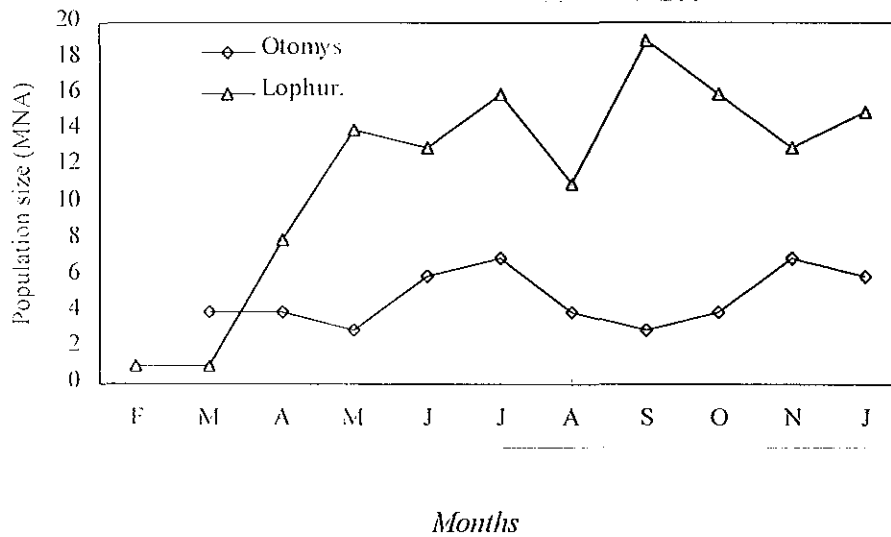
Highest population size for *Muriculus imberbis* was recorded around the onset of the wet season or at the end of the 'small rains' and around the middle of the first half of the dry season. Lower records were those of the 'small rains' and the 'big rains' (Fig. 5a). The main difference observed between populations of the two grids was related to rarity rather than seasonal abundance (Table 2).

Myomys albipes did not show impressive difference in population size between the two grids. The species had higher number of individuals during the 'small rains' on both grids. Lower numbers were captured during the wet season. The lowest record of the year was that of the end of the wet season and beginning of the dry season. The middle part of the first half of the dry season was time of population size recovery for the species (Fig. 5a). The species had shown positive correlation with monthly temperature average minima ($r = 0.63$) but negative correlation with monthly rainfall ($r = -0.19$).

Lophuromys flavopunctatus had quite different population size fluctuation pattern. The general trend was increasing throughout the wet months as of March during the 'small rains'. Decrease in population size was observed after the beginning of the dry season (Fig. 5b). The total monthly captures from both grids were negatively correlated with monthly temperature average minima ($r = -0.53$) but had weak correlation with monthly rainfall ($r = 0.30$). Populations of the two grids showed some differences in the time of maximum and minimum numbers of individuals recorded. The wet season and the first part of the dry season were times of population peaks for Grid 2 and Grid 1, respectively (Table 2).



a)



b)

Figure 5. Population size fluctuation patterns across months and seasons of the five relatively common species of rodents on Entoto Mountain. MNA of G 1 and G 2 combined. a) Arv. (*A. abyssinicus*), Myo. (*M. albipes*) and Muri. (*M. imberbis*) b) Otomys (*O. typus*) and Lophur (*L. flavopunctatus*)

Otomys typus and other species that disappeared for some time during the year can be viewed differently. Highest numbers of *O. typus* were recorded during the wet and the beginning of the dry season in populations of both grids. Lower population sizes marked the latter part of the dry season (Fig.5b). *Mus mahomet* and *D. lovati* disappeared and reappeared in similar seasons (wet season and the first half of the dry season). Population peaks of both species occurred during and at the end of the 'small rains'. Reappearance of *D. mystcalis* was not seen after the wet season. *D. harringtoni* was not captured during the wet season and even its number was lower when captured in the dry season (Table.2).

Density and biomass changes during the study period were found related generally to changes seen in population sizes. Density on Grid 1 ranged between 75/ha during the second half of the dry season (February) and 131/ha during the first half of the dry season (November). The density on Grid 2 was 81/ha at the beginning of the dry season (October) and 235/ha at the end of the same season (May). Generally, densities of both rodent communities peaked during the 'small rains' and were lowest at the end of the wet season or beginning of the dry season (Fig. 6).

Table 3. Mean densities and density ranges of some regularly occurring rodents of Grid 1 and Grid 2, Entoto Mountain. Species for which sufficient data obtained are included.

Species	Grid	Mean density (MNA/ha)	Density ranges and months (MNA/ha)
<i>A. abyssinicus</i>	Grid 1	43	16-61 (February, November)
	Grid 2	132	65-190 (October, May)
<i>M. albipes</i>	Grid 1	25	6-45 (October, March)
	Grid 2	20	2-41 (October, April)
<i>L. flavopunctatus</i>	Grid 1	14	2-31 (March, September)
	Grid 2	10	4-18 (April, July)
<i>O. typus</i>	Grid 1	5	2-6 (November, May & July)
	Grid 2	6	2-12 (March, November & January)
<i>M. imberbis</i>	Grid 1	7	2-20 (March, November)

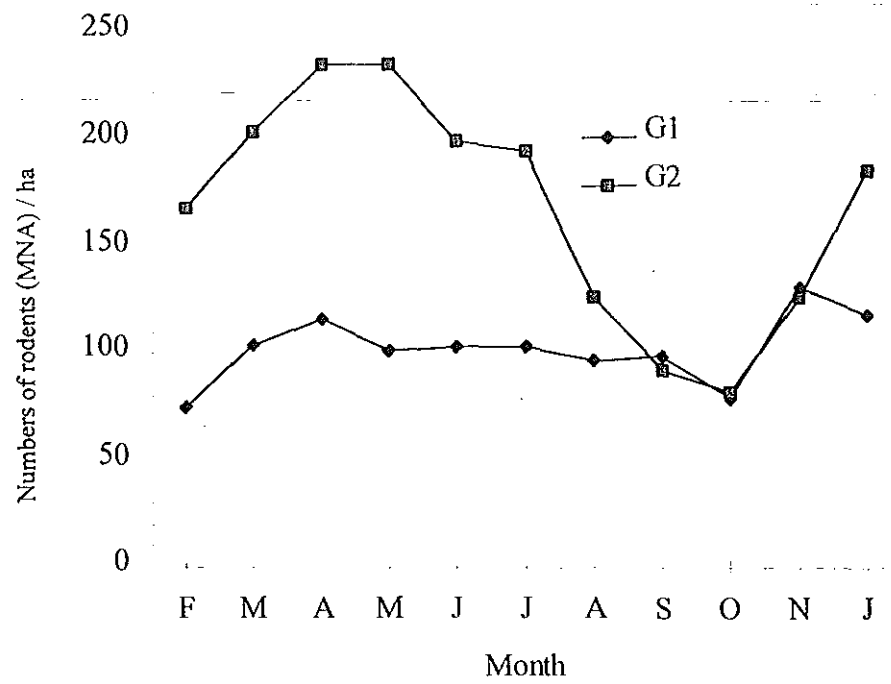


Fig.6 .Density of small rodents on Grid 1 and Grid 2, Entoto mountain.

The mean densities of the five common species of rodents on both grids ranged between 5 and 132/ha. No significant differences in mean population densities of the same species was observed on the two grids, except for *A. abyssinicus*. Density range of each population on its respective grid was the function of population size of the monthly captured rodents. Regular seasonal density patterns were discernable in many populations except *O. typus*. November was found as time of least density for Grid 1 but period of peak density for Grid 2 populations (Table 3). Peak densities for the majority of the common species occurred mostly in months following the 'small rains' and the wet season except October.

The mean biomass records of the rodent communities on the live-trapping grids were not closer to each other as the proximity of the two grids. Grid 1 had a mean biomass of 6318g/ha while that of Grid 2 was 13667g/ha. The oscillation patterns of the two rodent communities were partially different from those seen in density. Peak biomass of Grid 1 occurred during the wet season and shortly after the onset of the dry season. The corresponding time for Grid 2 was during the 'small rains'. Another difference pertaining to biomass of the two grids was that seen after November in which that of Grid 2 continued rising while that of Grid 1 was declining. Lowest records of the two grids' communities occurred at the same time around the beginning of the dry season (Fig. 7).

Biomass ranges were 3480-7630g/ha (February, July) for Grid 1 and 7026-20538g/ha (October, May) for Grid 2. The ranges for the more common species on both grids were functions of the individual rodent's weight and population size. It is not thus surprising to see least values for the small-sized and relatively common species (*M. imberbis*). Mean biomass and ranges of the most abundant species of the grids (*A. abyssinicus*) were substantially different between the two grids (Table 4).

Table 4. Mean biomass and biomass ranges of the common species of rodents from both grids (Grid 1 and Grid 2) of Entoto Mountain. Species with insufficient data are not included.

Species	Grid	Mean biomass (g/ha)	Biomass ranges and months of their registration (g/ha)
<i>A. abyssinicus</i>	Grid 1	3331	914-5090 (February, August)
	Grid 2	11,290	5943-17272 (October, May)
<i>M. albipes</i>	Grid 1	1372	478-2290 (September, March)
	Grid 2	1018	163-2288 (October, April)
<i>L. flavopunctatus</i>	Grid 1	1002	714-1704 (June, September)
	Grid 2	1498	367-1884 (April & November, July)
<i>O. typus</i>	Grid 1	510	153-796 (November, July)
	Grid 2	630	184-1077 (March, January)
<i>M. imberbis</i>	Grid 1	168	74-449 (February, November)

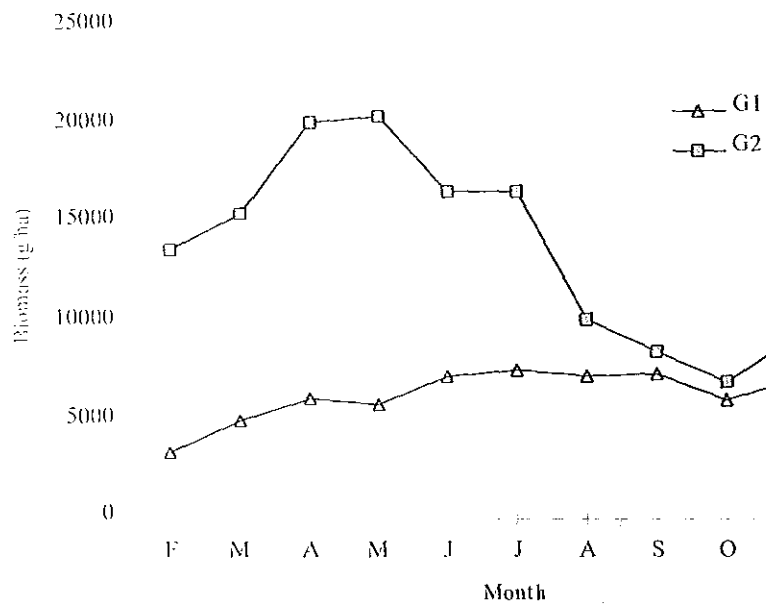


Figure 7. Biomass of the small rodents captured during the study period (February 1998- January 1999) on Entoto Mountain.

3.1.2. Reproductive season, recruitment and population structure

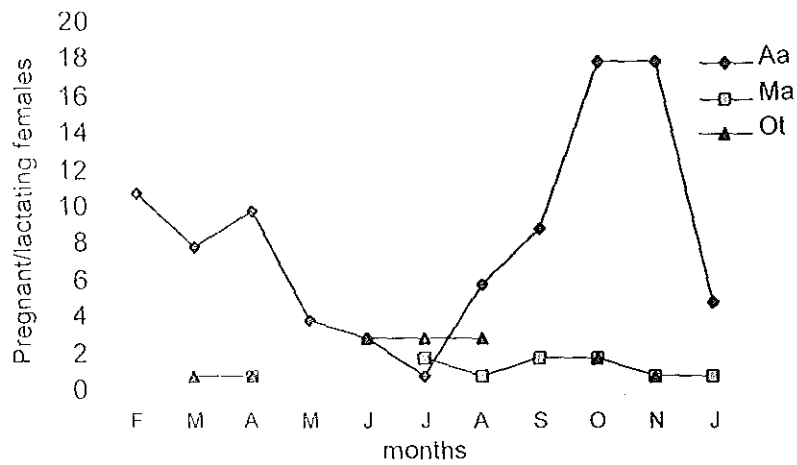
Pregnant and lactating females (reproductively active) of *A. abyssinicus* were captured in all the months of the study period. The highest number of reproductively active females of this species, however, were caught in October and November, while the lowest numbers were recorded during the wet season. The species, therefore, breeds throughout the year with maximum reproductive output in the first two months of the dry season.

Myomys albipes and *O. typus*, in general, showed similar period of reproduction. The peak of their reproductive activity, however, occurred in different months. *O. typus* had the maximum number of actively breeding females during the first three months of the wet season (June, July and August); while the corresponding period for *M. albipes* was around the end of the wet season and beginning of the dry season (Fig. 8a).

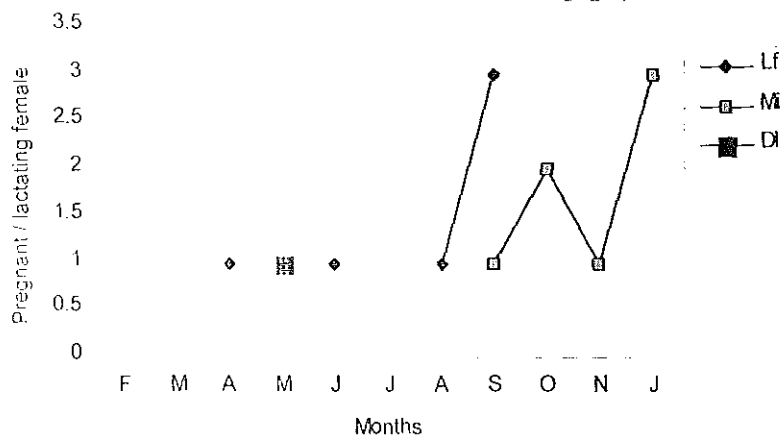
Lophuromys flavopunctatus bred during the wet months of the year (April to September). There is no evidence of reproduction in the rest months of the dry season. *Muriculus imberbis* bred starting from September, with reproductive peaks in and perhaps shortly before January. There was no evidence of reproduction in the wet season months prior to September. Data pertaining to reproduction in the rare and intermittently occurring species were not available in the present study. The only information obtained was that of *Dendromus lovati* in which a pregnant female was encountered in May (Fig. 8b).

Recruitment rates of the five common species of small rodents showed consistent decline between 0.51 in March to 0.13 in October. This was followed by a remarkable increase in November (Fig. 9a). This increase was a result of the cumulative increase in new individuals of four of the five species. Three of the species, however, contributed less than half that of the numerically dominant species (*A. abyssinicus*).

Continuous recruitment was evident in *O. typus*. The species had high population turnover rates in June, July, October and November. *Lophuromys flavopunctatus* was similar to *A. abyssinicus* with regard to its non-zero rates. Some of the recorded rates were higher compared to other months (April, Fig. 9a). The comparatively higher recruitment rate during



a)



b)

Figure 8. Number of reproductively active female rodents recorded monthly from live trapping grids on Entoto.

a) Aa (*A. abyssinicus*), Ma (*M. albipes*), Ot (*O. typus*)

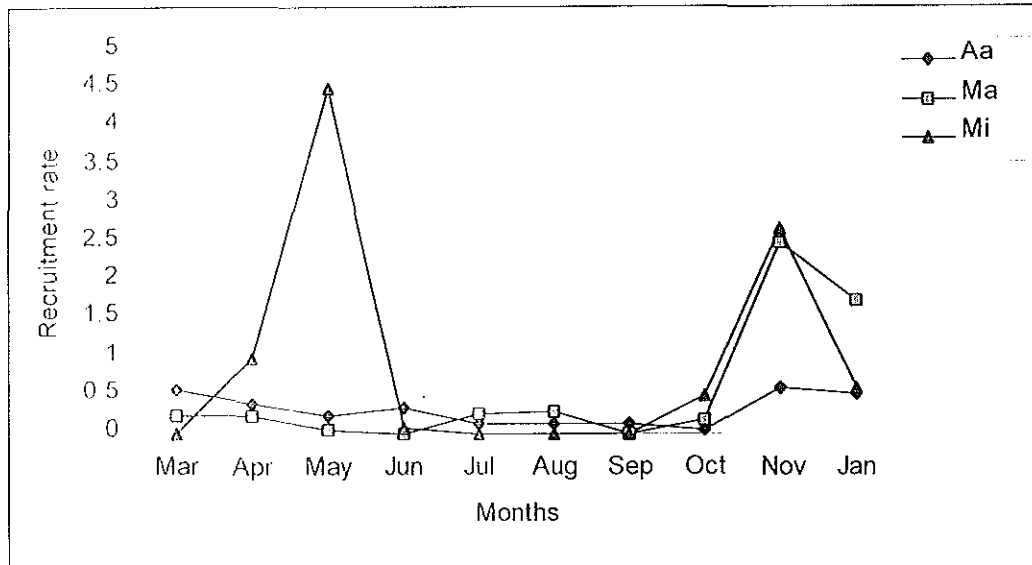
b) Lf (*L. flavopunctatus*), Mi (*M. imberbis*) and Di (*D. lovati*)

July, August and September makes *Lophuromys* different from the other species described herein except *O. typus*.

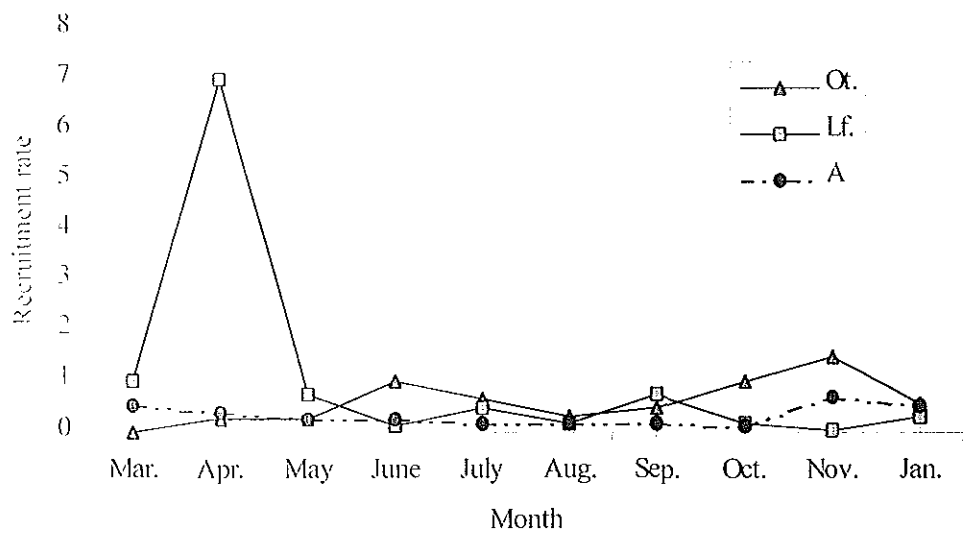
Arvicanthis abyssinicus revealed the highest recruitment rates during the dry season (November and March). The wet season rates were, however, lower. *M. albipes* had shown similar pattern of recruitment changes as *A. abyssinicus*, but with repeated and remarkable fluctuation. The turnover rate seen during November and January was unprecedented in the preceding months. Juveniles had 80% of the November and 38% of the January recruitment. In January 21 of the 25 captured rats were new captures. *M. imberbis* had two recruitment peaks (Fig. 9b).

Arvicanthis abyssinicus had smaller number of juveniles compared to both adults and sub-adults during most of the study period, except in November when the number of juveniles approached that of the sub-adults. The same relationship existed among the sub-adults and adults, with the latter having twice as many individuals as the former. January was the only month when sub-adults surpassed adults and even this seems momentary as seen from results obtained at the beginning of the study period (Fig. 10a). The numbers of adults in *Myomys albipes* were greater from May to January. Sub-adults' dominance lasted for only four months starting from January. November was very remarkable for its very high proportion of juveniles (Fig. 10b).

Otomys typus and *L. flavopunctatus* showed similar population structure in November during which sub-adults were predominant. This time was two months ahead of the time when the other two species (*Arvicanthis* and *Myomys*) displayed such population structure. This did not, however, continued beyond January. The numbers of adults became higher after January and until October (Fig. 11a & 11b).

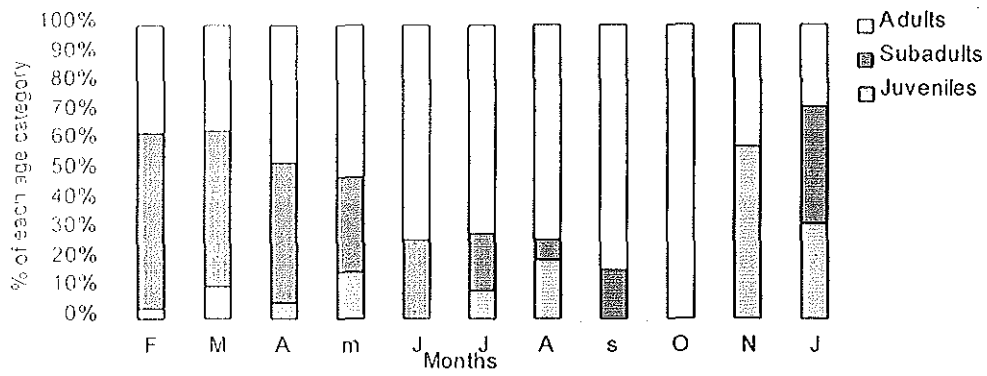


a)

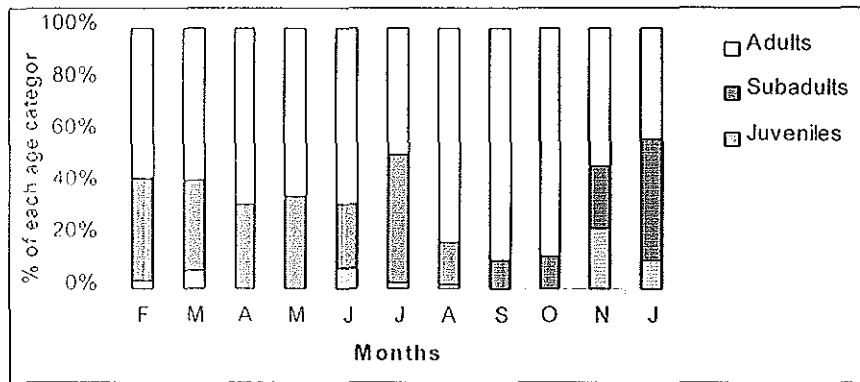


b)

Figure 9. Recruitment rates of a) *O. typus* (Ot), *L. flavopunctatus* (Lf) and the five species combined (A), b) *A. abyssinicus* (Aa), *M. albipes* (Ma), *M. imberbis* (Mi)

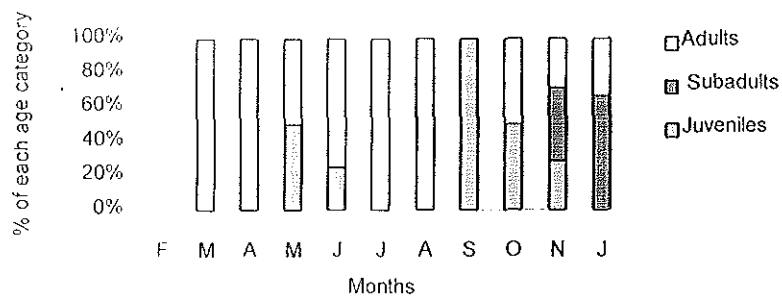


a)

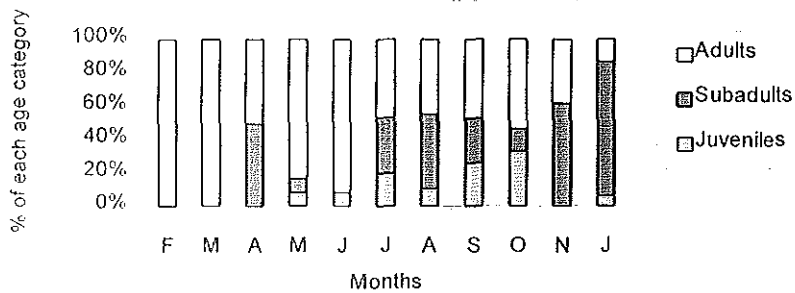


b)

Figure 10. Population structures of *Arvicanthis abyssinicus* (a) and *Myomys albipes* (b) across months of the study period. Proportion of each age group is shown by the relative percentage. Adults were determined by reproductive maturity.



a)



b)

Figure 11. Population structures of *L. flavopunctatus* (a) and *O. typus* (b) across months of the study period on Entoto. Relative abundance of each age category is shown by a percentage and adults were determined by reproductive maturity.

3.1.3. Survival

The maximum potential survival time for those captured during the first trapping occasion was 11 months when all age groups of the small rodents belonging to the more abundant species were treated together. Minimum numbers known to be alive (MNA) in December without the actual catches were used since there was no trapping in the month. Each species had a survival rate characteristic to its population. Nevertheless, some aspects of the survival rates were similar among different populations. A few individuals of *A. abyssinicus* (2%), *M. albipes* (3%), and *L. flavopunctatus* (5%) were able to survive the maximum potential time (11 months).

Survival rates of *A. abyssinicus* and *M. albipes* showed greater similarity towards each other than to any other species and the differences each month were not greater than 0.05 for 10 of the 11 months (Fig. 12a)

No monthly survival rate value of *L. flavopunctatus* was less than corresponding monthly values of any other species. Differences can be better perceived by taking one particular chance of survival for the species. The 37% probability of survival in *L. flavopunctatus* was about five months. The corresponding duration for *A. abyssinicus* and *M. albipes* was three months (Fig. 12a). This is even about one month for *M. imberbis* and *O. typus* (Fig. 12b).

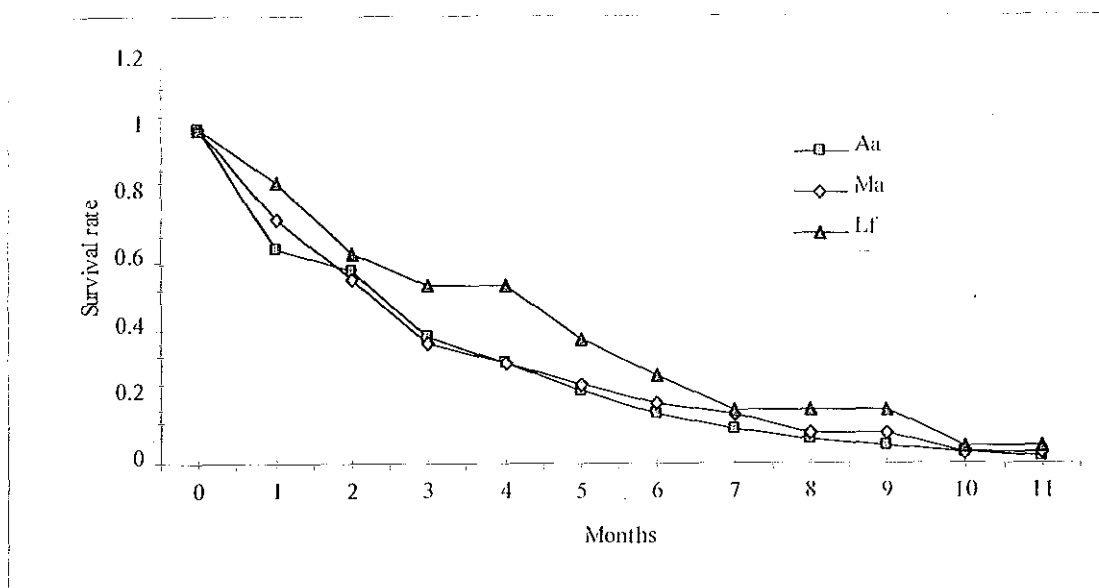
Muriculus imberbis and *O. typus* displayed shorter duration of survival compared to those described above. Observed maximum survival periods were five months for *O. typus* and seven months for *M. imberbis*. The latter had greater survival rates in four of the five months during which the two species could be compared.

Data for computing survival rates of the rare and intermittently appearing species were limited. No single *Dendromus loyati* was recaptured during two trapping occasions. *Mus mahomet* had better recapture data; but its disappearance during May reduced the maximum possible survival time to two months. Five individuals of the species survived for a month, which was the maximum survival period recorded for members of the species in this study. The rest (19) were seen only during one trapping occasion. A better survival rate result might have been recorded had the trapping operation started since November; in which a maximum of five survival

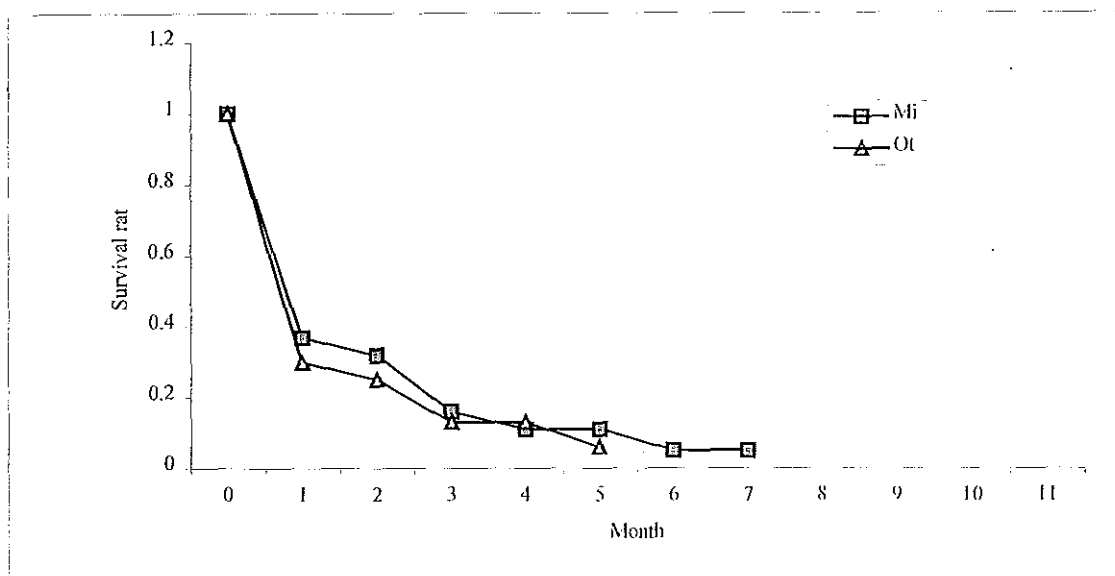
months could have been provided. The reason for this situation is the disappearance of *Mus mahomet* from the grids for about six months as of May or June.

Finite mortality rates of each species of rodents can be viewed from finite survival rates, as the two are complements to each other. Thus the finite survival rates of each species was computed to see monthly finite population survival and mortality rates. The three common species (*A. abyssinicus*, *M. albipes* and *L. flovopunctatus*) had lower survival rates during the wet season. However, their survival rates were not lower than 0.4 throughout the year (Fig. 13a).

O. typus and *M. imberbis* were species with lower survival rates compared to the other rodents just described. *O. typus* was exceptionally different from the other common species in having the least survival rates almost throughout the year. The wet season finite survival rates of *M. imberbis* were very low compared to its dry season (Fig. 13b).



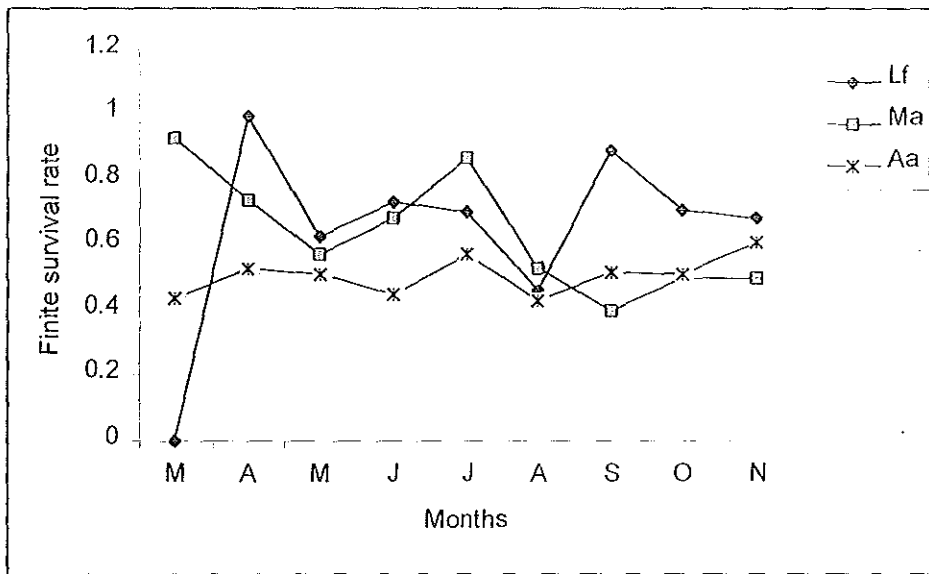
a)



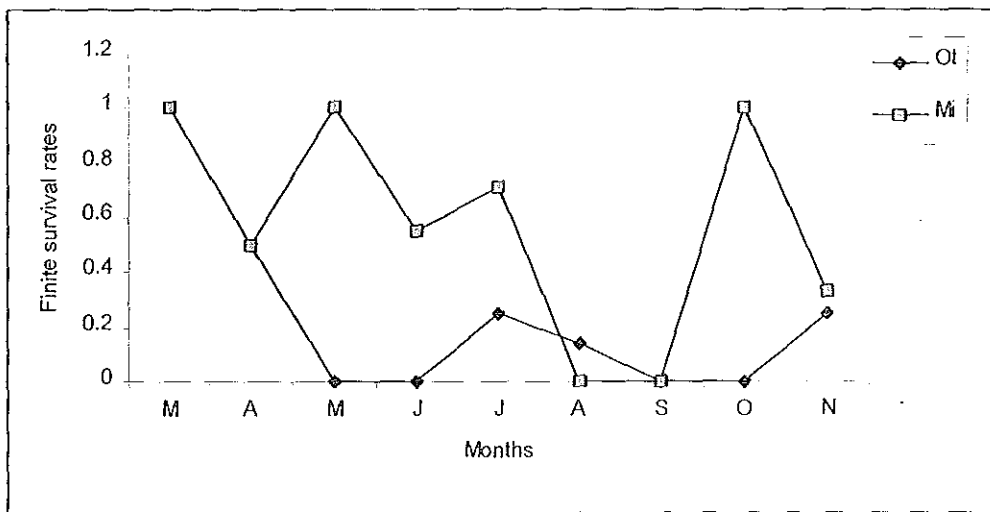
b)

Figure 12. Population survival rates of the five common rodent species of Entoto.

a) *A. abyssinicus* (Aa), *M. albipes* (Ma), and *L. flavopunctatus* (Lf). b) *M. imberbis* (Mi), and *O. typus* (Ot).



a)



b)

Figure 13. Monthly population survival rates of the five regularly appearing species of small rodents on Entoto Mountain, February 1998 – January 1999. Results for each month were obtained using the enumeration estimator ($\Phi = N_{x+1}/N_x$)

Where Φ = probability of survival of a given population, N_x = Number of population at time X and N_{x+1} = number of survivors from the previously sampled population.

a) Aa = *A. abyssinicus* Lf. = *L. flavopunctatus* Ma = *M. albipes*

b) Mi = *M. imberbis* Ot = *O. typus*

3.1.4. Predation and flooding

The rodent fauna of Entoto form the prey base to many avian and mammalian predators. Nocturnal rodents like *M. albipes*, *M. mahomet*, *D. lovati* and even those appearing during both the night and the day time, like *L. flavopunctatus*, and *M. imberbis* fall victim to an attack waged by owls. The call of the Verraux's Eagle Owl (*Buto lacteus*) is one of the characteristic sounds heard during the night on Entoto. There can also be other species of owls in the area, though not possible to confirm their presence.

Augur buzzards (*Buteo rufofuscus*) are the diurnal counterparts of owls in preying upon rodents daily. Rodents are captured by directly diving from the air or waiting for surfacing preys while perching on top of juniper trees or on a boulder. In one occasion, a partially trapped rodent was taken away by a buzzard with the Sherman trap that held the prey.

Arvicanthis abyssinicus keeps on watching augur buzzards from afar or that perched on top of a nearby tree. The rats never leave the mouths of their burrows as long as the bird is around. The rodent is thus extremely wary of buzzards and their arrival is announced to the rest potential victims by the characteristic call. Sitting on haunches or standing erect like Meercats (*Suricata suricata*) or Alpine marmota facilitates improved predator detection. Members of other species of rodents are kept on alert by the call of *A. abyssinicus*.

Mammalian predators include a canid, a viverrid and felid carnivores. Common (Golden) jackal (*Canis adustus*) and Egyptian mongoose (*Herpestes ichneumon*) were observed around meadows and bush of the two grids. Mongooses were frequently seen hunting rodents. Their appearance and hunting rate increased as grasses and crops grew during the wet season.

Caracal (*Felis caracal*) and wild cat (*Felis sylvestrus*) were seldom seen attempting to stalk their preys (rodents). The caracal was once trying to seize a duiker by stalking until the latter darted and both animals fled the area. Serval (*Felis serval*) was seen in shrubby grassland around densely vegetated brook banks. There were no data regarding reptilian predators.

Low-lying and flat areas of Entoto are usually flooded or become swampy during the wet season. The compact loamy clay soil became even more compact due to regular grazing by domestic animals and was more susceptible to flooding. Moreover, drainage ditches made

around and through ploughed fields to prevent flooding of farmland, flood the grassland below with subsequent eradication of the rodents that took refuge in the area. As a result of these factors, flooding was acting as the major factor in determining the fate of some rodents. Since burrows in such places were susceptible to flooding, rodents inhabiting the places had to leave the area and look for elevated and safer places.

Arvicanthis abyssinicus is seen digging new burrows with the onset of the wet season on relatively elevated ground with grasses available nearby. Dry grass is carried to newly dug burrows for making nests. These two phenomena (digging new burrows and collecting dried grass) are indicators of activity center changes at the beginning of both the wet and the dry seasons.

Beginning of the dry season is marked by return of *A. abyssinicus* from its wet season refuge. Places with good drainage were preferred sites in the wet season. But these places become quickly drier and provide little food and cover. Hence digging new burrows or coming to those already abandoned was inevitable. Digging burrows at the beginning of the wet and dry season months is advantageous because of the ease at which burrows dug.

Dry season refuge can be places that are artificially modified (such as heaped stones or stone fence lines) or low-lying patches. The latter accumulate water during the wet season and grasses grown there remain green and fresh for a long time. Sporadic rain can easily induce grass growth in such areas. The places also provide better condition for predator evasion and detection.

Flooding tended to confine movement of the small rodents in general and *A. abyssinicus* in particular. This incidence was clearly visible around the two rows of Grid 2 (row 'A' and 'B'). Only two of the seven traps of row 'A' and three of row 'B' were some times catching rodents during the wet season. The corresponding catch during the dry months was from 5-7 for both rows.

3.1.5. Home range

There were no sufficient data for computing home ranges to some of the small rodents. Six or more recaptures per animal were taken into consideration. But even some of these were not utilized as most of the capture points lie on a line or on a point.

An average home range of 300 m² (n=50) was obtained for *A. abyssinicus*. The range was 100-1100 m² and males displayed relatively wider home ranges. Females home range was about 291 m² while that of the males was 315 m² with n =31 and n =19, respectively.

Lophuromys flavopunctatus had a home range of about 371 m² (n=14), ranging between 150 and 700 m². The average home range value for females was 414 m² and that of males around 329 m² (n=7).

Trap revealed home range of *M. albipes* was about 285 m² (n=17) with a range of 100-600 m². Males had wider home range (306 m², n=8) than females (267 m², n =9). The rodents were restricted to their preferred microhabitats (a bush fragment, stone fence-line or heaped stones) and tended to have narrower home ranges.

Muriculus imberbis tended to exploit resources along the same contour or row with subsequent linear home range. Capture points of two animals revealed a more or less 300m² home range.

3.2. Distribution and abundance

The relative abundance and distribution of rodents in different habitat patches of Entoto was obtained by survey trapping. A total of 130 small rodent individuals belonging to five species was captured after utilizing 380 trap nights during both seasons. The species were *M. albipes* (61.5%), *D. harringtoni* (13.9%), *A. abyssinicus* (13.1%), *L. flavopunctatus* (10.8%), and *M. mahomet* 0.8% (Table 5).

Traps set in guards' room located on the north west corner of the study area (No. 8, Fig. 1) caught two individuals of the synanthropic rodent, *Rattus rattus* Linnaeus 1758. This rat was not found in captures collected from traps placed in human residences. The rats might have

come from villages located outside the study area or might be wild resident (Rupp, 1980; Nowak, 1991; Goodman, 1995).

The spines of porcupines, *Hystrix cristata* Linnaeus 1758, were found scattered in many places in the study area including the grids. Its droppings were also seen on a small track traversing the southeastern part of the eucalyptus plantation.

Different habitats had wide ranging capture success rates. Eucalyptus woodland and open grasslands were found devoid of any small mammal after using 50 trap nights in each site. Traps set in younger eucalyptus stand (bush) captured a single female *M. albipes* and a male *M. mahomet*. Similarly, the *Juniperus-Myrica* woodland's trap success was not far better than this (6.6%).

Bushes of the natural vegetation (hillsides and brook banks) had the peak trap success of the mountain (75.8%). Presence of grasslands and scrub adjacent the bushes had some contribution in maximizing the capture rate. This can be seen from capture of the grass-loving rat (*A. abyssinicus*) in traps set around the bush margin.

Table 5. Distribution and abundance of small rodents in different habitat types of Entoto Mountain surveyed by trapping in the wet and dry seasons of 1998. Species number and trap success of each habitat type and that of the whole area surveyed are also shown. *Ma* = *M. albipes*, *Aa* = *A. abyssinicus*, *Lf* = *L. flavopunctatus*, *Dh* = *D. harringtoni*, *Mm* = *M. mahomet*.

Habitats and their altitude	Species of small rodents					Trap success and species number		
	Ma	Aa	Lf	Dh	Mm	Total capture	Relative trap success (%)	Species number
1. Bush/grass on sloppy hillside 3030m	63	5	5	18	--	91	75.8	4
2. Bush/grass of a brook bank 2940m	12	12	9	--	--	33	66	3
3. Juniperus-Myrica woodland 2830m	4	--	--	--	--	4	6.6	1
4. Coppice of eucalyptus stand 3020m	1	--	--	--	1	2	4	2
5. Eucalyptus woodland 3000m	--	--	--	--	--	--	--	--
6. Open grassland 2900m	--	--	--	--	--	--	--	--
Total	80	17	14	18	1	130	T*=34.2	5
% of each species in the overall catch	61.5	13.1	10.8	13.9	0.8			
Number of habitats each species trapped from	4	2	2	1	1			

* Serial numbers designated to habitats correspond to those used for indicating location of trapping sites (Fig. 1).

T* = overall trap success

Variations in species number were obvious between habitats. Most of the trapping sites had either very few numbers of individuals, (one or two) or without any species. The bushes were habitats with the maximum number of species recorded during this trapping period.

Myomys albipes was the widely spread and abundant species of the bushy areas of the mountain. It was found in four of the six habitats surveyed. The 61.5% abundance share in the overall catch and 60.5% of the capture from the bush witnesses the rat's fitness and numerical dominance in the different sites (Table 5).

Abundance and distribution of small rodents in shrubby grassland of the Entoto Mountain can be seen from captures carried out on the live-trapping grids; and thus, there was no need to run trapping in other similar habitats. Combining results from both trapping operations (on grids and outside grids) showed the general picture of distribution and abundance pattern of rodents in the study area. *A. abyssinicus* was found numerically dominant and distribution wise ubiquitous on the grids and similar habitats of the mountain. *M. albipes* had similar role around bushy patches.

Some of the rodents that were captured from the wild were also found around human habitations. *M. albipes* is the most remarkable animal in this regard. It was regularly captured from peasants' residential houses while feeding on stored grain and gleaning crumb. It was not as notorious, however, as the black rat in destroying a wide range of food, cloth and other items. Soap and flour seem most preferred by *M. albipes* when available.

The rats come into houses from hedges grown nearby where appropriate refuge is not available around human dwellings. Holes made at the base of walls or spaces between roofs and wall tips serve as entrance. Thus they are efficient climbers of earth plastered walls like those found in the study area.

Mus mahomet was the other species of wild rodents that was captured in a room where the black rat was caught. The mice were caught at the time when the wild conspecifics were available on the grids and the black rats disappeared from the place once observed. Traps placed in other residential sites caught no individual of *M. mahomet*.

3.2.1. Habitat and microhabitat selection

The distribution and abundance patterns of the small rodents in the habitats and microhabitats recognized for this study gave impression of the habitat requirements of the animals. *M. albipes* and *D. harringtoni* were observed having closer association with bush since there were no forests on the mountain. *M. albipes*, however, differs from *D. harringtoni* in appearing in stone fence line, heaped stones and being captured some distance away from its residential microhabitats.

Other rodents like *A. abyssinicus*, *O. typus*, and *L. flavopunctatus* utilized stone fence line and heaped stones as permanent sheltering sites. Capture rates of traps set near these man-made microhabitats were among the highest recorded during the study period. Traps set along the fence line of Grid I (row 'A') was accountable for the maximum capture of the traps in the row. This capture rate was greater than those of the three adjacent rows added together.

Lophuromys flavopunctatus and *O. typus* were frequenting herbaceous grasslands and bushy patches. *L. flavopunctatus* was also common in more bushy fragments of the hillsides. It was observed moving from one preferred microhabitat to the other crossing less dense scrubs and also trapped by traps placed in comparatively open herbaceous grassland. *O. typus* preferred denser grassy shrubs and was not seen or captured even about 3 m away from these spots. *Mus mahomet* was found around open grasslands with interspersed stones and grassy bushes. It was the more likely species to be trapped in grassy patches around eucalyptus trees.

Dendromus lovati was captured in microhabitats least frequented by the rest species; grass of about 50 cm height like *Themeda thriandra*. The rodent disappeared when grazing commenced and reappeared at a time when grasses attained their maximum height. Contrary to this species, *D. mystacalis* was caught by a trap that captured the maximum number of species (7 spp.). The place was a scrubby area found near a bush.

Muriculus imberbis frequented open grasslands with herbs on gentle slopes. It digs simple burrow usually near stones found interspersed throughout the grassland. In an attempt to obtain wild iris corm (*Moraea schimperii*), it digs shallow perpendicular holes (c. 4 cm deep). The corm is perhaps its favorite food because the rodent was regularly observed while searching for

the herb. Closely set dug holes (honeycombed) and decorned wild iris herbs are characteristic features of places occupied by the rodent during the wet months of the study area.

Avicantthis abyssinicus is the least shy and most exposed diurnal rodent of the short grassland in the study area. Microhabitats preferred by the rat were those with short grasses and that can provide shelter like heaped stones and stone fence lines. Burrows can be found in places with cover or in grassland with little cover. Grass growing near burrows will be the first to be cleared by regular cutting. Hence, foraging is some distance away from sheltering places and the animals move faster or watching a predator while going to feeding places and returning. This behavior enables the species to have burrows around exposed places where other rodents do not usually occur.

Microhabitats that were preferred by individual small rodents on the grids had the maximum number of catches during each trapping occasion. This can be seen from the capture rates of each trap station. Stone fence line, heaped stones, bushy patches and herbaceous grassland had more trap success than open grassland and open areas on sloppy hillsides (Table 6).

The manner microhabitats on both grids used by the small rodents can also be seen from the number of species captured by traps placed in different places. These ranged between one and seven. None of the traps remained without catch or captured the maximum number of species that can be found on each grid (eight species) during the study period (Table 7).

About 88% of the traps set during the year caught more than one species. This means, that proportion of the area on both grids was utilized by species ranging between two and seven. Traps that captured only one species were those placed in open grasslands away from bush, herbs, stone fence line and heaped stones. Such traps were visited both by the most ubiquitous rat of the grids (*A. abyssinicus*) and the rare ones like *D. lovati*, *M. imberbis*, and *M. mahomet*. Maximum numbers of species were trapped by traps placed near man-made microhabitats and densely vegetated stations (Table 6).

Table 6. Comparison of captures of individuals of different species of rodents in the different habitats and microhabitats as compiled from results of captures of traps of the two grids combined.

Habitats & microhabitats	Number of traps	Number of captured rodents	Captures per allocated number of traps
Open grassland	34	230	7
Herbaceous grassland	32	512	16
Bushy patches	20	406	20
Stone fence line/heaped stones	12	309	26
Total	98	1457	15*

* = Average capture

Table 7. Number of species captured by traps of both grids (G1 & G2) during the study period (February 1998 – January 1999).

Number of Species captured	Number of traps		% of the total capture
	Grid 1	Grid 2	
1	4	8	12.2
2	4	11	15.3
3	12	17	29.6
4	14	8	22.5
5	10	4	14.3
6	5	--	5.1
7	--	1	1.0
8	--	--	--
9	--	--	--
Total	49	49	100

IV. DISCUSSION

4.1. Population dynamics

4.1.1. Species composition and population size

The small rodent species number of the study area is comparable to other similar habitats in Ethiopia and eastern Africa (Rüpp, 1980; Yalden, 1988b; Happold and Happold, 1989; Afework Bekele, 1996b). Total number of the small rodent species was found to be the same as that of the Menagesha State Forest, though replacement of three species was seen between the two sites. *Graphurus murinus*, *Stenocephalemys greisicauda* and *Arvicanthis dembeensis* in Menagesha were replaced by *D. lovati*, *M. imberbis* and *A. abyssinicus* on Entoto Mountain. The other species (eight in number) are the same with eventual 72.72% percentage similarity in species of the two rodent communities.

Number of monthly encountered species ranged between three in the wet season and eight in the dry season on the grids. Such monthly or seasonal variations in number of species that can be sampled were due to some rare and intermittently occurring species like *Mus mahomet*, *Dendromus lovati*, and *Dendromus mystacalis* (Table 2) that are comparatively small in size (8-16g).

Dendromus mystacalis (a single male) was captured both in the dry season (February) and wet season (July). Hence it is not possible to ascribe its disappearance during some months to seasonal impacts like that of temperature and rainfall. The likely reasons can be its rarity and non-optimal trapping set up, as it is also arboreal.

Dendromus lovati was not captured for more than six months as of June. Thus, unlike its congeneric, this rodent disappeared with the onset of the wet season and reappeared around the middle of the dry season. Similar results were obtained on Bale Mountains (Sillero-Zubiri et al., 1995). What was found amazing there was the availability of the animal at higher altitude as high as 3900 m a.s.l. and its failure to have burrows (nests under boulders). Consequently, the researchers suggested that the rodent might hibernate or avoid activity during the cold season.

Mus mahomet was the other small rodent species whose disappearance caused species number fluctuation in the study area (Table 2) and was not trapped during the wet season (May to October). The species, however, was captured in May and July in Menagesha State Forest from places below 2580m a.s.l. (Afework Bekele, 1996b) and Harena Forest in August (Yalden, 1988a). Comparatively higher temperature condition that is associated with lower altitude of the area may be the likely reason for appearance of the mouse in the specified months. The extraordinary precipitation in May of the study period may have its impact for disappearance of the animal before the commencement of the wet season (Fig. 2a).

According to Berry (1970), some wild populations of *Mus* exist for only part of the year in Great Britain, disappearing during the winter. Stocks that had sheltered in buildings replenish those disappeared from the wild in spring. The situation in the study area looks similar to this. Where do the mice pass the wet season? This is not an easy question to answer, though possible to speculate that some optimal habitats around or some distance away from their dry season refuge may serve as sanctuary in the wet season.

Generally, disappearance of the small-sized species during the cold season is associated with their high metabolic rate and eventual loss of more energy in humid and colder environmental conditions. The situation is further aggravated by food scarcity due to flooding. Therefore, rodents in such condition have to either hibernate or look for some other optimal habitats where energetic cost of survival is lower.

The other small-sized rodent next to those already described was *M. imberbis* (15-30g). It is one of the rare and endemic rodents of Ethiopia that had not been collected by researchers for more than two decades. Hence, it is also one of the least known species of the country. The rodent's similarity to *Mus* both in size and morphology brought about debate over its taxonomy (Yalden et al., 1976).

Muriculus imberbis ('Wurch rat') was found torpid in traps at times during the morning trap check in spite of its Amharic name connotation (;'Frost rat'). It appeared in almost all the monthly catches despite its apparent susceptibility to cold environmental condition. Nonetheless, it was one heavy weight individual that was captured during the cold weather of the wet season except in August when no catch from the species was recorded.

Desmomys harringtoni ('Dega rat') is a medium-sized rodent that seems large enough to cope with the cold of the wet season. It was not, however, captured during the cold wet season months for reasons that may probably be unrelated to cold condition. Numbers of individuals captured on the grids were very low. The very small bush fragments from which it was captured might be its secondarily inhabited areas. This can be confirmed from the better trap success of the relatively larger bushes of the hillsides during the survey.

The capture pattern of the small rodents on Entoto Mountain suggests that more number of species can be trapped if trapping is carried out during the dry season. No trapping effort of the wet season can reveal presence of species like *M. mahomet* and *D. lovati* on the mountain. Thus detection of presence of small mammal species in a given environment depends on the nature or behavior of species and time of the year in which the study is to be conducted. This view is, however, contrary to Yu (1994) that stated the need to trap at least for five consecutive days in order to detect the presence of all the species found in an area.

Seasonal factors were found effective in changing population sizes of most species of rodents on Entoto Mountain. The wet season had little impact on populations of *O. typus* and *L. flavopunctatus*. The species even had more population sizes during the wet season (Fig.5b). The dry season records of their population sizes were, however, lower than the wet season. Thus these species are the likely ones to be affected by dry season impacts.

Population sizes of *A. abyssinicus*, *M. albipes* and *M. imberbis* were higher during the 'small rains' and around the middle part of the first half of the dry season. The wet season was marked by dramatic decline of their population sizes. November can be regarded as the turning point in the resurgence of the population size after the decrease experienced during and immediately after the wet season. Therefore, this situation demonstrates the resilience that was achieved after the dramatic decline. Such phenomenon was also true to those rodents that disappear for some part of the year. Their population size was approaching the size observed in the previous dry season. Species representation also remained unchanged during the year. This means the dominants remained dominant even when the rare ones reappeared.

The wet season on Entoto Mountain was thus a period during which fewer numbers of species observed and population sizes declined. The plausible explanation for low species number has already been dealt with. The reason for low population sizes in some species can be viewed in

terms of low reproductive, survival and recruitment rates, as individual's survival and reproduction capacity is altered by extremes of temperature, rain or drought, winter or very cold spells (Chapman & Reiss, 1997). The amount of precipitation that fell during the 'big rains' was 75.8% of the annual rainfall (Fig. 2). Thus, such higher concentration of rainfall and the accompanying weather impacts act as intermediate disturbance (Connell, 1978). The disturbance thus would produce asymmetrical relationship between food quality and availability and population density. Fresh and lush vegetation that may not be as nutritious as the fully-grown ones were available during the season which may even not be accessible at ease and safely.

Average minimum temperatures of the study site during the wet season months were not lower than those of the end of the first half of the dry season (Fig.3). It is, therefore, reasonable to relate decline in population size and species number to compounded problems brought as a result of heavy rain and accompanying harsh conditions rather than temperature *per se*. Generally, the 'small rains' can be characterized by highest temperature of the year, second precipitation peak and highest population sizes and species number on the mountain. Contrary to this, the 'big rains' were with highest rainfall, lower temperature and lowest population sizes and species number. Hence warmer temperature and moderate rainfall seem more appropriate conditions for success of many of the rodent species on Entoto Mountain.

The enumeration estimates of population sizes of *A. abyssinicus* were not closer to those predicted by the probabilistic methods of the Jolly-Seber method. This may not be surprising as the enumeration method here only pertains to minimum population sizes and due to lower number of recapture during some months; as temporal variations in capturability produce erroneous results or estimates (Krebs and Boonstra, 1984; Montgomery, 1987). Hence the Jolly-Seber estimates of population sizes may be unrealistic in such circumstances, though more realistic to describe natural events.

Density of *A. abyssinicus* on the present study area was closer to that obtained on the Afroalpine grassland of the Semien Mountain National Parks (Müller, 1977). The density of *A. abyssinicus* on that mountain was 65-250 animals/ha. Grid 2, in the present study had a density of 65-190 animals/ha. The density range for Grid 1 of the present study site was far less than the two density ranges of Grid 2 and Semien Mountain (16- 61 animals/ha). The very low density on the more or less natural and relatively protected area suggests the rodent's better

success around short grassland even when frequented and impacted by humans and large mammals.

The biomass ranges of *A. abyssinicus* on Entoto and Semien Mountains were also closer to each other; ranging between 4900 and 16,500 g/ha on Semien Mountain and 5943 and 17,272 g/ha on Entoto Mountain (Grid 2). The biomass on Grid 1 was also very low as the density range (Table 4).

Similar densities and biomass on the two mountains are attributable to presence of species of rodents that are common to both areas; notably the most abundant one (*A. abyssinicus*) that comprised 75-83% of those on Semien Mountain and 70.3% of the rodents on Grid 2 of Entoto Mountain. The ratio of increase (minimum: maximum) of biomass on both mountains is about 1:3. The two mountains also have other rodent species that are common to both like *L. flavopunctatus*, *O. typus* and *D. lovati*.

4.1.2. Reproductive season and recruitment

Breeding seasons of small rodents studied on Entoto Mountain were similar to some other areas in East Africa, although differences appear in some instances. *A. abyssinicus* bred throughout the year without any sign of seasonality. Reproductive peak immediately followed beginning of the dry season. On Semien Mountains (Müller, 1977) the chilly months of the wet season (June-September) were not times of breeding for the species, unlike the situation in the present study. Most young were also born around the middle of the dry season (January-March). Breeding in *Arvicanthis niloticus* occurred in close association with rainfall (Delany and Monro, 1986) and during the wet season and beginning of the dry season (Taylor and Green, 1976). Thus both the genus and the species show reproductive season plasticity based on climatic condition of their habitat.

In Uganda, *L. flavopunctatus* bred throughout the year in forests, with peaks towards the end of the rainy seasons (Delany, 1971, 1975). A single prolonged breeding season during the rain was reported to occur in the southern parts of the species range (Kingdon, 1974). Happold and Happold (1989) confirmed that parturition in the species is seasonal and lasts only for about four months during the wet season.

The duration of breeding season in *L. flavopunctatus* was found to lie between the longest and shortest periods of the just mentioned reports; six relatively wetter months (April – September) on Entoto Mountain. However, appearance of greater proportion of subadults and larger number of recruits in April (Fig.10a and 12) suggest reproduction prior to April. It is thus possible to say that the species may breed throughout the year in the study area.

Reproductive seasons in *M. albipes* were found to be consistent with results reported by Afework Bekele (1996a) in which the species breeds throughout the year with peaks at the end of the wet and beginning of the dry season. *D. lovati* may have similar reproductive season as its congeneric (*D. mystacalis*) because both species' pregnant females were collected in the same month (May). Pregnant female *D. mystacalis* were obtained in Menagesha State Forest during the month (Afework Bekele, 1996b). The period is very adaptive for *D. lovati* in that the newly born offspring can appear after the wet season (after hibernation or inactive state during the wet season). No individual of the pre-wet season's capture was recaptured during the dry season.

Lower rate of reproduction during the dry months following the peak reproduction months of the beginning of the dry season implies that the dry senescent grass that was readily available on Grid 1 was less nutritious in facilitating reproduction. Thus food quality and peak reproduction are intimately correlated as described by Taylor and Green, 1976, and Delany and Monro, 1986. Some wet and fresh grass found under rocks, stone piles, and fragmented bushes that are not accessible to cattle or large mammals may serve in facilitating limited rate of reproduction during the dry months. Reproduction may also proceed during the dry months because of extension of the wet season, sporadic rain or generally shortening of the dry season.

Rate of addition of new individuals to populations of the relatively common species of the mountain varied seasonally and species wise. Wet season recruitment rates were lowest for *A. abyssinicus* and *M. imberbis*, and lower for *M. albipes*. *L. flavopunctatus* and *O. typus* had better recruitment rate even in the wet season.

The dry season recruitment rate was better for those that were not better off in their wet season recruitment, but less optimal for the other two. The November recruitment boom was due to both *in situ* reproduction and immigration of *A. abyssinicus* and *M. albipes* from certain wet season habitats like stubble, pockets of elevated grounds and dense bush patches. However,

since there was high birth rate some time before November, the main source of the recruitment cannot be accredited to spillover effect, but *in situ* reproduction.

Recruitment of *L. flavopunctatus* was found consistently low (0.2-0.6) on Zomba Plateau (Happold and Happold, 1989). The species had better recruitment rate on Entoto Mountain, like the one observed in April and November (Fig.9a). Recruitment peaks were also seen at different climatic condition of the two places. The general recruitment patterns of the two rodent communities were also different. The immigration rate for all the species studied was highest in the wet season, lower in the dry season, and lowest in the late dry season on Zomba Plateau. On the other hand, recruitment rate was highest around the beginning of the dry season, lower in the latter part of the dry season and lowest in the wet season on Entoto Mountain. The wet and dry seasons thus have different impacts on recruitment rates of the two regions.

Population structure of *A. abyssinicus* is characterized by domination of adults. This is in line with the r-selected or opportunistic strategy of the species that is marked by earlier maturation of young (Delany and Monro, 1986). Such situation was not observed in *M. albipes* in which sub-adults remained immature for comparatively longer time.

Generally, subadults outnumber adults for not more than four months in *A. abyssinicus*, *M. albipes*, *O. typus*, and *L. flavopunctatus*. This time was during early dry season for *O. typus* and *L. flavopunctatus*, whereas in the middle of the dry season for *M. albipes* and *A. abyssinicus*. Juveniles' dominance was observed only in *M. albipes* and *O. typus* for a short time (Fig. 10b & 11b).

4.1.3. Survival and home ranges

In the present study, *L. flavopunctatus* and *O. typus* had the highest and lowest survival rates, respectively (Fig. 13). Reported survival rates of some species include: 50% survival rate for about three months for *L. flavopunctatus* (Happold and Happold, 1989), 18.2% survival rate for six months for *M. albipes* (Afework Bekele, 1996a), and 14% survival rate for about six months for *Arvicanthis niloticus* (Delany and Monro, 1986). Corresponding survival rate values obtained in this study were 53% for about three months for *L. flavopunctatus*, 18% survival for

about six months for *M. albipes*, and 15% survival rate for about six months for *A. abyssinicus* (Fig. 12a). The respective results are generally closer to each other albeit presence of minor deviations in some other months.

Survival rates of the species on Entoto Mountain were not thus lower compared with those reported from other places. The survival rates of the animals in the present study could have become better than the obtained had some factors reducing survival were not operational on the mountain. Factors allied with the heavy rain of the wet season had their contribution in reducing the survival rates of some rodent species on the mountain. The general decrease of the survival rate in August can serve as strong evidence (Fig. 13).

Flooding and other harsh environmental conditions accompanied the heavy rain. Torpor, death, and restriction of foraging activities followed these. The problems were compounded by intensified attack of predators, as the latter require more meal to cope with the very cold condition. Diurnal predators were comparatively free to crop their harvest during this time because of limited human interference and grown vegetation provided cover to predators during searching and stalking preys. Since flooding forced *A. abyssinicus* to occupy a few elevated pocket ground, the predators keep eyes only on these and the rodents had to stay in burrows for a long time. Generally, the clement weather posed intermingled problems that were not easily solved without more sacrifice on behalf of the small rodents.

One feature seen from Figure 13 pertains to the number of null monthly population survival rate scores of *O. typus*. Its reluctance to enter traps is also reported at times (Bond et al. 1980). Consequently the species was monitored from a distant using a binocular and occasionally was not trapped while seen around traps. The rodent sticks to the place it emerged and tends not to explore any other thing around. It only tries to feed on herbs obtained near bush, fence line or heaped stone. Thus, such behavior can reduce capture rate with eventual impact on its computed survival rate. The rodent was also very vulnerable to buzzards because of its darker and poorly camouflaged coat, larger size and sluggish nature. Its use of hearing to escape enemy (Kingdon, 1974) is advantageous as far as the alarm call of *A. abyssinicus* is provided. But its activity around dusk and dawn and during cold and damp conditions (at a time when *A. abyssinicus* is in burrows) makes it more vulnerable.

Highest survival rate of *L. flavopunctatus* during the wet season may be ascribed to its foraging on invertebrate fauna. Wet and damp condition is conducive for availability of invertebrates especially like ants. A large number of ants that infested the trap that caught the species were found killed and the animal unharmed. The ants were successful in killing two *A. abyssinicus* in traps. The partly nocturnal habit of *L. flavopunctatus* may help it get some ants that may come out during the damp night. The species was also found around places that are not flooded.

The survival rates of some individuals of some species were also affected by rodenticides placed around crop fields. *A. abyssinicus* was the main target as it causes heavy damage to crops and set aside grass. One *M. albipes* was also seen killed by rodenticide in barley crop. *M. imberbis* can also be poisoned because it was found near a barley farmland on Grid 2.

The home ranges of the more common species in this study were very small compared to some other studies (Müller, 1977; Happold & Happold, 1989). This is mainly due to fragmentation of habitats by encroaching eucalyptus plantation and grazing. Linear home ranges were common. This was because of seeking protection along similar strips of microhabitats and to encompass a number of potential sources of food (Kotzagporgis & Mason, 1996). The smaller area of the grids might also have contributed in minimizing home range sizes of the more mobile species.

Point home ranges were observed in situations where there were no connections between preferred microhabitat patches like bushy fragments. Presence of permanent man-made refuge like heaped stones and stone fence lines on the grids induced individual rodents not to go far from these spots. Consequently, rats living in one heaped stone had greater chance of being captured by the same trap with eventual small home range sizes. Such situations prevented randomness of catches. Hence the home range sizes of the rodents in this particular case depended on availability, distribution and abundance of resources (Kauhala, et al., 1993) and predator avoidance.

4.2. Distribution and abundance

As many natural communities, the relatively natural areas of Entoto Mountain have few common or abundant species and many rare species of rodents. Grouping the species on the mountain as common and rare can show this. A species is considered common if its population size is equal to or greater than the number obtained by dividing the total number of the small rodents community by the species number (Yu, 1994). On this basis, only *M. albipes* was common among those rodents dealt with surveying. *Arvicanthis abyssinicus* and *M. albipes* on Grid 2 and *A. abyssinicus*, *M. albipes* and *M. mahomet* on Grid 1 were the common species. However, *M. mahomet* was temporally rare in not being trapped from the grids for about half a year.

The commonness and rarity of small rodents is determined by factors that constrain distribution and abundance. Eucalyptus woodland and bush were among the habitat types with least, if not nil capture success. As plantations of some other exotic species, eucalyptus plantation provides poor habitat diversity. This would be so at the expense of replacement of natural vegetation, which could have contributed more to the lower end of the animal food chain. Thus, the success of exotic plants including eucalyptus plant in places where introduced emanates from their unpalatability (Poore and Fries, 1985).

After studying small mammals in pine plantations and natural habitats, Happold and Happold (1987) came to the conclusion that the change from natural habitat to plantation caused decline in both total numbers of individuals and species number. Results of the present study are consistent with the conclusion. Even the subterranean rodent, *Tachyorctes splendens* had no mole hills in eucalyptus plantations. The only species that may easily get adapted in such area if forced by some factors is *M. mahomet*. Scarcity of food and cover are the reasons for having impoverished or no small rodent species in eucalyptus plantations.

The *Juniperus-Myrica* woodland was similar to the plantation albeit its better trap success in relative terms. Here too, scarcity of cover at ground level may be the main factor for its lower species number and abundance. Unlike the eucalyptus woodland, however, intensive grazing by large mammals was the reason for the scarce cover.

The greater number of individuals and species of small rodents in the bush on brook banks and sloppy hillsides was due to better provision of food and cover. Bush patches that were bordered by herbaceous grasslands were even richer. Both forest-adapted (bush) and rodents preferring herbaceous grasslands visit the area that is transitional between the two habitat patches.

The numerical dominance and ubiquity of *M. albipes* in the sites surveyed was in conformity with the result obtained in Menagesha State Forest (Afework Bekele, 1996b). The species represented 54.3% of the total rodents captured in all habitats and 70.8% of those in forests in Menagesha and 61.5% of the overall catch and 60.5% of the capture from bushy habitats on Entoto Mountain. The difference in capture proportion between the bushy and forest habitats of the two study sites indicates the greater association the species has with forest habitats (Afework Bekele, 1997).

Many factors might have contributed for the success of *M. albipes* on the Mountain. The most obvious one may be prolonged breeding time. The other pertains to its plastic behavior in occupying habitats. As seen earlier, the species was found occupying bushy patches, woodland, man-modified sites such as stone fence line and heaped stones and even human residence. Its exploitation of open areas away from permanent residence extends the foraging frontier, which is not practiced by *D. harringtoni* and *O. typus*. Similar adaptation plasticity is also seen in its occupation of wider altitude range (low lands to high mountains).

The success of the common species, *A. abyssinicus*, on and around the grids, is attributable to some factors. Kingdon (1974) ascribed its success particularly to its capacity to recoup its number after the end of the dry season. This is the case in lower altitudes or places that have severe dry season. The situation on Entoto Mountain was the converse of that is experienced in such places. Thus, the success in more humid high mountains can be ascribed to its resilience after the wet season is over.

Kingdon (1974) also noted that factors like production of larger number of young, faster movement, and its reliance on good camouflage for safety play the main role for the success of *Arvicanthis*. Hence breeding throughout the year and the accompanying incorporation of many new individuals frequently into the population can be regarded as the major one. Its cryptic coat helps it to feed easily undetected especially around or in drying and dried grass. The animal may be detected as it moves, but it is very swift and agile even in maneuvering. Its

alarm call makes every member of the colony and even other species like *Otomys* to escape a looming danger. This kind of altruism is that remained a challenge to authorities in the field. The advantage of helping (saving) other species?

Diurnal activity is the other factor contributing for the success of the species. The shy mammalian predators rarely hunt rodents during the day around open grasslands. Therefore, the rodent is more successful in places frequented by people such as one of the grid sites in the present study.

Distribution of *M. imberbis* in the study site was found patchy and highly restricted, as it was captured from the two grids only; from one of them (Grid 1) in a better abundance. Yalden et al. (1974) suggested that the species became rare since 1940 because of conversion of its habitat to agricultural land. The suggestion seems reasonable because other similar areas that are cultivated in the surrounding were found devoid of the species. The place where the species was found in better abundance was also a place where its seemingly staple food (wild iris) grows properly. This suggests that species are rare if their preferred microhabitat or resource is rare but common where their preferred resource is abundant (Price, 1978). The likely preferred habitat of *D. lovati* is also vulnerable, since it is required for grazing and farming. The species (like *M. imberbis*) may thus suffer from conversion of its needed habitat to grazed and ploughed land.

The two grids can also be viewed with respect to distribution and abundance of their small rodent fauna. The grids were set on places that represent the natural vegetation in the surrounding area in their species number. Almost all the small rodent fauna species were found on the grids. The proportion of the species captured by the survey in the study area was about 50% of those present on the grids. The situation in Menagesha State Forest was just the reverse of that on Entoto Mountain in this regard. What factors determine such kinds of distribution and habitat occupation? Some probable answers to the question will be forwarded in the next part of the on going discussion.

4.2.1. Habitat and microhabitat selection

One of the most striking features of the results from this study was trapping of many species and large number of individuals from restricted points of the grids. The other refers to accommodation of the maximum number of species by the grids compared to other habitat patches. These situations suggest the preference of appropriate habitats and microhabitats. One may not be able to give one conclusive reason as to why the grids and some places within the grids were preferred to other habitats and microhabitats, respectively. It is more logical, therefore, to deal with as many factors as possible to reveal the general situation on the field.

Since small mammals in a community may differ in their microhabitat preferences (Martin and Dickinson, 1985), habitats providing more microhabitat types or those with more habitat diversity are likely to accommodate more species. A more complex habitat will contain more niches, which may be exploited by many species (Rozenzweig and Winakur, 1969). But the problem here may be how can we be sure that the grids on Entoto had more diverse microhabitats than other areas. This can be seen from the availability of almost all the vegetation types like grassland, scrub, bush, and even man-modified ones on each grid. Hence small rodents of the grids can get their preferred microhabitats from one or more of the available microhabitats.

The fact that small rodents can get their preferred microhabitats on the grids does not mean that resources are not shared among species. The same resource can be utilized by different species at different times. The diel activity differences could serve in elaborating this. *Mus mahomet*, *M. albipes*, *D. mystacalis* and *D. lovati* are nocturnal rodents; *A. abyssinicus* and *O. typus* diurnal, and the rest more of diurnal. Moreover, some of the species were not using resources on the grids for some time in the year (Table 2). Even the most abundant rodent, partially emigrated during the wet season, leaving its dry season refuge unutilized because of flooding.

Use of different sectors of resources was also observed among some species of rodents. *M. imberbis* and *D. lovati* were frequently found around microhabitats not frequented by many others except *A. abyssinicus*. Grass seeds seem to be used by *D. lovati* overwhelmingly.

M. imberbis was seen mainly feeding on the wild iris corm, which is probably monopolized by the species. Kingdon (1997) presumed that *M. Imberbis* might feed mainly on insects owing to the nature of narrow forward pointing incisors. Many insects were found killed in a trap that

held the rat in one occasion, suggesting the possibility that the mouse may use the insects as food, not killing them to defend itself alone. *O. typus* was observed feeding mainly on the herb *Alchemilla abyssinica* when available. It was also seen feeding on the pith of *Echinops steudineri* after debarking it. Other rodents may not utilize such plants. *D. harringtoni* was seen feeding on fallen petals of *Carisa edulis* and known to feed on grass stems and leaves. *L. flavopunctatus* is known for its invertebrate food resources. Such trophic specialization can promote the co-existence of many species on the confined area of the grids.

Inter-specific tolerance might also have facilitated the living together of the rodent species. There seemed to be less agonistic interaction between the different species. Reasons for saying this include the multiple capture of individuals belonging to different species by the same trap and use of more common area (see **Table 7**). The capture of many species by the same trap during the same trapping occasion shows the utilization of more common area. This gives clue for presence of inter-specific tolerance and absence of agonistic or territorial behavior among at least some of the species.

The same trap, without subsequent fight or wounding each other, caught *Mus mahomet* and *M. albipes*, and *A. abyssinicus* and *L. flavopunctatus*. Observation of some of the species that were placed in rat cages revealed the likely interaction that can be executed on the field. *A. abyssinicus*, *L. flavopunctatus*, *O. typus*, and *D. harringtoni* were seen huddling together.

D. lovati never associated with any of them and always looked for hiding places. The adult male *M. imberbis* seemed more aggressive towards conspecifics that was not closely related to it; as it was trying to severely bite upon encounter. Some species of rodents like *Rattus rattus* do not allow other rodents live nearby. It eliminated *praomys natalensis* from human dwellings (Delany, 1975).

Predation can be the other factor that can be considered to contribute to the species number of the two grids. Predators reduce competition between the rodent species by preying upon them. This leads to greater niche overlap between the rodent species, which in turn results in promoting species diversity. The presence of many species of predators in the study area suggests the greater role the rodent community plays in supporting the predators.

Other factors relate to the encroachment of eucalyptus plantation and farmland areas. Rodent communities rarely require the former, and the latter cannot be occupied permanently. These restricted the options rodents could have; had there been wider natural habitat around the grids. Hence some species like *M. albipes* and *D. harringtoni* could have occupied forest or larger bush fragments had these been available around the grids. This means some species might have been forced to occupy secondary habitats as the extensive area gets fragmented.

Certain anthropogenic impacts were also found important in increasing species number; as other impacts like plantation, tilling and mowing decrease it. Presence of stone fence line and heaped stones can be cited as factors that increased habitat heterogeneity. Such man-made or modified environments are also reported to be suitable to certain small mammals elsewhere. Hanley and Page (1982) concluded that grazing in mesic habitats increased the diversity of plant growth forms with subsequent increase in small mammal diversity.

Man-modified and open areas seem to have helped some species of small mammals as the less modified and sheltered environments (Yahner, 1983). He suggested that population dynamics of small mammals in farmstead shelterbelts was generally similar with studies from less modified environments. Densities of the more abundant species in grasslands near Mexico city were largely correlated with more open habitats and higher indices of habitat modification (Fa et al., 1990). The situation on Entoto seems similar to this with respect to especially *A. abyssinicus*.

V. SUMMARY AND RECOMMENDATION

An ecological study dealing with distribution and population dynamics of rodents of Entoto Natural Park was carried out from February 1998 to January 1999. Nine species were found occupying two 0.36ha live-trapping grids set on grazed and set aside shrubby grasslands of the mountain. In addition, the presence of three rodent species was confirmed using survey trapping and indices like molehills, droppings and spines.

The species from the two grids include the most abundant species that comprised 57% of the whole catch (*A.abyssinicus*) and nine others. *M.albipes*, *L. flavopunctatus*, *M. Mahomet*, *O.typus*, *M. imberbis*, *D. harringtoni*, *D. lovati* and *D. mystacalis* were the live-trapped species with descending order of their abundance. Numerous molehills on the grids proved the presence of *T. splendens*. *Rattus rattus* was trapped from human residence while droppings and spines indicated presence of porcupines (*Hystrix cristata*).

One interesting feature seen regarding species composition of small rodents on Entoto is the higher endemic species ratio. About 35% of the small rodent species are endemic to Ethiopia, excluding *A. abyssinicus*, the controversial species with respect to its taxonomy and endemic status. Another feature pertains to the inclusion of one Ethiopia's endemic, rare, vulnerable, and little known rodent, *M. imberbis*, in the list of the present collection. This species had not been collected for more than two decades from any of the places where it was previously reported to be present.

Various aspects of population dynamics of the small rodents revealed spatial and temporal fluctuations in species number and population sizes. Total number of species encountered during each monthly trapping occasion ranged between five in the wet season and eight during the dry season. The decline in species number of the wet season is attributed to the disappearance of the small sized rodent species; evoked by their susceptibility to sustained wet, humid and cold condition.

Population sizes of the rodents that were regularly appearing on the grids were also variable across months of the study period. Monthly number of rodents that are known to be alive on

both grids varied from 79 (October) at the end of the wet season to 172 during the small rains (April).

The decline in population size and related demographic parameters were mainly due to low reproductive, recruitment and survival rates of the more common species during the wet season. There were two peaks of population numbers on both grids during the study period. The first was during the 'small rains' and the second around the middle part of the first half of the dry season. The end of the wet season was not time for population peak appearance as is the case in lowlands where the wet season has less impact on the survival and reproductive status of small rodents. Hence the wet season was marked by appearance of least population sizes on one of the grids. The other grid had shown little change during this time because of addition of new rodents that had been driven from their dry season refuge by flooding.

Density and biomass of rodents on Grid 1 showed less variation compared to those of Grid 2. The main reason for this phenomenon was the greater abundance of *A. abyssinicus* on Grid 2. Consequently, the dramatic decline in density and biomass of this species during the wet season on Grid 2, brought about the fundamental difference in the way densities and biomass of the two rodent communities increased and declined. Hence, density ranges were 75-131/ha on Grid 1 while that of Grid 2 was 81-235/ha. Biomass ranges were 3480-7630 g/ha on Grid 1 and 7026-20538g/ha on Grid 2.

Both reproduction and immigration were important to the resurgence achieved by small rodent populations after the wet season trough (October). This month can be regarded as time for many species on the mountain during which least population sizes registered. The logical explanation for attaining lowest density during the month is the low reproductive, recruitment and high mortality rates in the wet season prior to it and lag of reproductive recruitment and immigration for some time after the wet season is over.

Predation and flooding were among the major factors in stabilising the rodent communities on Entoto Mountain. Presence of many avian and mammalian rodent predators confirms how these check numbers of the more common and vulnerable species and avoid competitive exclusion with an eventual maintenance of diversity. Presence of many predators also suggests the important role that the rodents have in forming the prey base. Flooding had significant impact in destabilising the most abundant species of the grassland (*A. abyssinicus*).

Both seasonal and aseasonal trends in reproduction were observed in some rodent species. *A.abyssinicus* bred throughout the year with reproductive peaks at the beginning of the dry season and during the 'small rains'. *M. albipes* and *O.typus* also bred throughout the year with peaks during the wet season. Reproductive conditions were seen in about six relatively wetter months with peaks during the wet season in *L.flavopunctatus*.

Pregnant and lactating females of *M. imberbis* were trapped immediately after the wet season and through the first half of the dry season. The higher recruitment rate in May suggests presence of reproduction during the 'small rains' though not observed. The small rains may also be very important for reproduction of *D. lovati* as a pregnant female was captured in May. In all the cases, reproductive peaks occur during or immediately following rain (small or big). This is in line with the correlation between breeding and rainfall observed in many African rodents.

Higher proportions of newly captured rodents were registered around the middle part of the first half of the dry season. The other recruitment peak was during the 'small rains'. August and September were months of the wet season during which least recruitment rates obtained. Consequently, the major source of recruitment on the grids was reproduction, as peaks were observed some time after reproductive peaks and seasons.

Adults during most of the year dominated population structures of the more common species. This was more relevant to *A. abyssinicus* in which subadults dominated adults only in January. Subadult *O.typus* and *L. Flavopunctatus* outnumbered adults around the middle part of the first part of the dry season. This happened two months later in *M. albipes* and *A. abyssinicus*. The situation indicates the most probable reproductive peak time of the respective species.

Survival of the rodent species on the mountain was characteristic to each species. A few individuals of *A. abyssinicus*, *L. flavopunctatus* and *M. albipes* survived the maximum potential survival time of this study (11 months). Survival rates of the regularly occurring species ranged between the highest (that of *L. flavopunctatus*) and the lowest survival rates (*O. typus*). Monthly population survival rates have also shown similar trends but with higher mortality rates during the wet season.

Home range sizes of the common rodent species were very small compared to results from other studies. This may be partially due to the small size of the grids. Presence of small patchy microhabitats and man-made refuges like stone fence line and heaped stones induced restricted movement of rodents. Availability of required food resources within the immediate vicinity of residence of rodents could be the other reason for smaller home ranges.

The distribution and abundance patterns of rodents in the different habitats and microhabitats of Entoto Mountain was studied using survey trapping and capture success of different microhabitats within the grids.

A total of 130 individual rodents belonging to five species was captured employing 380 trap nights. *M. albipes* comprised 61.54% of the catch and found distributed widely. The unstriped grass rat (*A. abyssinicus*) comprised only 13.1% and found in half of the number of habitats from which *Myomys* was collected. This suggests absence of numerical dominance of a single species on Entoto where both species were found dominant within their preferred respective habitats. Hence, domination of one species may occur in places or habitats with lower habitat heterogeneity.

Some microhabitats or habitats had scarce or no rodent species. Swampy grasslands and eucalyptus woodland were devoid of any rodent species. *Juniperus-Myrica* woodland and eucalyptus bush hosted very few species and individuals. Higher number of species and individuals were captured from bushes of brook banks and sloppy hillsides.

About half of the species sampled from the grids were trapped from the various types of habitats surveyed. Some reasons can be given to this situation: the grids were set on places that are suitable to many species; the species can coexist; resources were partitioned in space and time; predation facilitated niche overlap and other more optimal microhabitats and habitats were not available near the occupied ones to facilitate dispersal of some species. However, lower species number in some of the surveyed habitats may also mean absence of other species, presence of rare species or very limited trapping effort had been made.

Habitat and microhabitat selection patterns were somehow evident. *D. lovati* and *M. mahomet* tended to frequent taller grasses. *A. abyssinicus* and *M. imberbis* were solely occupying short grassland. *M. albipes* and *D. harringtoni* preferred dense bushes. *O. typus* and *L.*

flavopunctatus were more probable in herbaceous grasslands. Some species, however, were found in many microhabitats exhibiting some degree of microhabitat generalist tendency. These include *M. albipes* primarily and *L. flavopunctatus* to some extent. Dense bushy patches, stone fence line and heaped stones were seen frequented by many species and individuals. This suggests that small mammals' habitat occupation pattern is the function of foraging and predator avoidance. Hence, it is not surprising to see absence of rodents in eucalyptus woodland and other similar habitats that provide little cover and food.

Certain conclusions and recommendations can follow the yearlong ecological work on Entoto Mountain. Some of these are presented below:

1. The results from the present study are comparable to those from places less impacted by humans. One can learn from this that research workers should not always look for only pristine and remote areas. Even urban surroundings like Entoto can serve as good study sites. Mountainous areas like Entoto can be used as refuge to rare and threatened species beyond serving as mere study area because of their isolation from the surrounding lowlands and from other highlands by human habitation.

2. The relict natural vegetation was found very important in harboring the small rodent species while the eucalyptus plantation was virtually without rodent species. The eucalyptus plantation, however, indirectly guarantees survival of the relict natural vegetation because people primarily exploit eucalyptus for livelihood needs. No natural vegetation could have existed had there not been the eucalyptus plantation. The trend towards re-establishing the indigenous vegetation of the mountain, therefore, shouldn't threaten the eucalyptus plantation that indirectly has a role in at least temporarily maintaining the relict vegetation.

The natural relict vegetation is also maintained by absence of fire on the mountain. Nevertheless, the run off from the sloppy landscape causes severe erosion and subsequent land impoverishment. The intensity of soil erosion can easily be seen from the larger gullies that have been formed and the turbulence of the flood observed during the rainy season. The sloppy areas and cultivated lands lose huge amount of soil annually since the topsoil is the type that can be easily eroded when cultivated. Appropriate remedial measures are thus needed to mitigate impacts of this hazard.

3. Humans are usually known as the principal agent of habitat destruction and modification. However, human activities some times create better and modified habitats to animals though not deliberate. Hedge rows and farmstead shelterbelts are listed as examples elsewhere. Stone fence lines, heaped stones and set aside lands on Entoto Mountain were examples of man-made microhabitats and habitats that provided better refuge to many rodent species.

4. This study should initiate other researches to look into the ecological mysteries of some rare and endemic rodents of Ethiopia. The country is not rich in the information needed pertaining to management of endemic rodents, as it is rich in endemic small mammals. Some of the questions raised here can serve as a springboard for further investigation. It is only through complete understanding of the ecology of the rare, vulnerable, or endangered endemic small mammals of the country that their conservation can be effectively undertaken when time induces their urgent preservation or rescue.

5. Since Entoto Mountain is easily accessible and relatively rural environment, ecological studies of this kind and others can be carried out in the future after establishing good relationship with the Ethiopia Heritage Trust and residents of the mountain. Any attempt that ignored the local people will not be effective. Thus, students of animal and plant ecology and taxonomy can make use of the area and the Biology Department should bear particular responsibility in materialising this.

6. The initiation and idea of studying the ecology of small mammals on Entoto Mountain emerged in accordance with the effort made to convert the area to a natural park by Ethiopia Heritage Trust (a very huge task). Further progress along the line leading to this end will be vital for undergoing other scientific studies that can in turn have contribution in the creation of a natural park. Therefore, any effort to realise the natural park status for Entoto Mountain should be encouraged and supplemented with assistance.

VI. REFERENCES

- Afework Bekele (1996a). Population dynamics of the Ethiopian endemic rodent, *Praomys albipes* in the Menagesha State Forest. *J. Zool., Lond.* **238**:1-12.
- Afework Bekele (1996b). Rodents of the Menagesha State Forest, Ethiopia, with an emphasis on the endemic *Praomys albipes* Rppel 1842. *Tropical Zoology* **9**:201-212.
- Afework Bekele (1997). Forest block and altitude as indicators of *Myomys albipes* (Rüppell, 1842) (Mammalia: Rodentia) distribution in Ethiopia. *Tropical Zoology* **10**: 287-293.
- Anderson, P.K. (1970). Ecological structure and gene flow in small mammals. *Symp. Zool.Soci. Lond.* **26**:299-325.
- Begon, M., Harper, J.L., & Townsend, C.R. (1996). *Ecology: Individuals, populations and communities*. 3rd edn. Black Well Science Ltd: Milan. p.905.
- Bennet, N.C. (1989). The social structure and reproductive biology of the common mole rat, *Cryptomys h. hottentotus* and remarks on the trends in reproduction and sociality in the family Bathyergidae. *J. Zool., Lond.* **219**:45-59.
- Bennet, N.C & Jarvis, J.V.M. (1988b). The social structure and reproductive biology of colonies of the mole rat *Cryptomys damarensis* (Rodentia: Bathyergidae). *J.Mammal.* **69**:293-302.
- Berry, R.J. (1970). The natural history of the house mouse. *Field Studies* **3**:219-262.
- Blank, H. & Englund, P. (1995). Entoto Natural Park: A minor field study. Swedish University of Agricultural Sciences: Uppsala.
- Chapman, J.L. & Reiss, M.J. (1997). *Ecology: Principles and applications*. Cambridge University Press: Cambridge, pp.35 & 48.

- Cheeseman, C.L. (1977). Activity patterns of rodents in Rwenzori National Park, Uganda. *Afr. Wild J.* 15:281-287.
- Cheeseman, C.L. & Delany, M.J (1979). The population dynamics of small rodents in a tropical African grassland. *J.Zool. Lond.* 188:451-475.
- Connell, J.H. (1978). Diversity in tropical rainforests and coral reefs. *Science*, Wash.199: 1302-1310.
- Daniel Gamachu (1977). *Aspects of climate and water budget in Ethiopia*. Addis Ababa University Press: Addis Ababa.
- Delany, M. J. (1964). A study of the ecology and breeding of small mammals in Uganda. *Proc. Zool. Soc. Lond.* 142: 347-370.
- Delany, M. J. (1971). The biology of small rodents in Mayanja Forest, Uganda. *J. Zool., Lond.* 165: 85-129.
- Delany, M. J. (1975). *The rodents of Uganda*. Trustees of the British Museum (Natural History): London.
- Delany, M.J. and Monro, R.H. (1986). Population dynamics of *Arvicanthis niloticus* (Rodentia: Muridae) in Kenya. *J.Zool., Lond.* 209:85-103.
- Edwards, S. (1976). *Some wild flowering plants of Ethiopia*. Addis Ababa University Press: Addis Ababa.
- Ethiopia Heritage Trust (Undated). Entoto Natural Park Project : Addis Ababa.
- Fa, J. E., Lopes-Pianigua, J., Romero, F. J., Gomez, J. L., and Lopez, J. C.(1990). Influence of habitat characteristics on small mammals in a Mexican high-altitude grassland. *J. Zool., Lond.* 221: 275-292.

- Fiedler, L.A. (1994). *Rodent pest management in eastern Africa*. FAO Plant Production and Protection Paper: Rome.
- Field, A.C. (1975). Seasonal changes in reproduction, diet and body composition of two equatorial rodents. *E Afr. wild. J.* 13:221-235.
- Fikirte Haile (Undated). Women fuelwood carriers in Addis Ababa and the peri-urban forest. International Labor Office: Geneva.
- Fitzgerald, B.M., Karl, B.J. & Moller, H. (1981). Spatial organization and ecology of a sparse population of house mouse (*Mus musculus*) in a New Zealand forest, *J. Anim. Ecol.* 50: 489-518.
- Goodman, S.M. (1995). Rattus on Madagascar and the dilemma of protecting the endemic rodent fauna. *Conservation Biology*: 9(2): 450-453.
- Gurnell, J. & Flowerdew, J.R (1990). *Live trapping small mammals: a practical guide*. The Mammal Society: London.
- Gurnell, J. & Gipps, J.H.W. (1989). Inter-trap movement and estimating rodent densities. *J. Zool., Lond.* 217:241-254.
- Hancock, G., Pankhurst, R., and Willetts, D. (1983). *Under Ethiopian Skies*. H & L Communications Ltd: London. pp. 102-103.
- Hanley, T.A. & Page, J.L. (1982). Differential effects of livestock use on habitat structure and rodent populations on Great Basin Communities. *Calif. Fish Game*, 68:160-174.
- Happold, D.C.D & Happold, M. (1987). Small mammals in pine plantations and natural habitats on Zomba Plateau, Malawi. *J. Appl. Ecol.* 24:353-367.
- Happold, D. C. D. & Happold, M. (1989). Demography and habitat selection of small mammals on Zomba Plateau, Malawi. *J. Zool. Lond.* 219: 581-605.

- Happold, D. C. D. & Happold, M. (1990). An ecological study of small rodents in the woodland savanna of Liwonde National Park, Malawi. *J. Zool., Lond.* **221**:219-235.
- Happold, D.C. D. & Happold, M. (1991). An ecological study of small rodents in the thicket - clump savanna of Lengwe National Park, Malawi. *J. Zool., Lond.* **223**:527-547.
- Happold, D. C.D. & Happold, M. (1992). The ecology of three communities of small mammals at different altitudes in Malawi. *J. Zool., Lond.* **228**:81-101.
- Hillman, J.C. (1993). *Ethiopia: a compendium of wildlife conservation information*. New York Zoological Society- The Wildlife Conservation Society & Ethiopian Wildlife Conservation Organization: Addis Ababa.
- Kauhala, K., Helle, E., and Taskinen, K. (1993). Home range of the racoon dog (*Nyctereutes procyonoides*) in southern Finland. *J. Zool., London.* **231**: 95-106.
- Kerley, G.I.H. (1992). Ecological correlates of small mammal community structure in the semi-arid Karoo, South Africa. *J. Zool., Lond.* **227**:17-27.
- Kingdon, J. (1974). *East African mammals. An atlas of evolution in Africa.* 2(B). Hares & Rodents. Academic press: London & New York.
- Kingdon, J. (1997). *The kindgon field guide to African Mammals*. Academic Press: San Diago, etc.
- Kotzagporgis, G.C. & Mason, C.F. (1996). Small mammal populations in relation to hedgerow structure in arable landscape. *J. Zool., Lond.* **242**:425-434.
- Krebs, C.J. (1966). Demographic changes in fluctuating populations of *Microtus alifornicus*. *Ecol. Monogr.* **36**:239-273.
- Krebs, C.J. (1989). *Ecological Methodology*. Harper & Row: New York.

- Krebs, C.J. and Boonstra, R. (1984). Trappability estimates for mark-recapture data. *Canadian J. Zool.* **62**:2440-2444.
- Krebs, C.J., Keller, B.L., and Tamarin, R.H. (1969). *Microtus* population biology: Demographic changes in fluctuating populations of *M. Ochrogaster* and *M. pennsylvanicus* in southern Indiana. *Ecology* **50**: 587-607.
- Leirs, H. (1995). *Population ecology of Mastomys natalensis* (Smith, 1834): *Implications for rodent control in Africa*. Belgian Administration for Development Co-operation: Brussels.
- Marin, G.H.H. & Dickinson, N.M. (1985). Small mammal abundance in relation to microhabitat in a dry subhumid grassland in Kenya. *Afr. J. Ecol.* **23**:223-234.
- Mohr, P. A. (1971). *The Geology of Ethiopia*. 2nd edn. Addis Ababa University Press: Addis Ababa.
- Monro, R.H. (1984). A technique for monitoring changes in small mammal habitats. *J.Zool., Lond.* **294**:566-569.
- Montgomery, W.I. (1985). The effect of recapture and the estimation of *Apodemus* spp. *J. Zool., Lond.* **206**: 267-269.
- Montgomery, W.I. (1987). The application of capture-mark-recapture methods to the enumeration of small mammal populations. *Symp. Zool. Soc. Lond.* No. 58: 25-57.
- Müller, V.J.P. (1977). Populations sokologie von *Arvicanthis abyssinicus* in der Grassteppe des Semien Mountains National Park (Äthiopien). *Z. Säugetirk.* **42**:145- 172.
- Neal, B.R. (1970). The habitat distribution and activity of a rodent population in western Uganda, with particular reference to the effects of burning. *Rev. Zool Bot. Afr.* **81**:29-50.
- Neal, B. R. (1984). Relationship between feeding habitats, climate, and reproduction of small mammals in Meru National Park, Kenya. *Afr.J.Ecol.* **22**:195-205

- Neal, B. R. (1986). Reproductive characteristics of African small mammals. *Cimbebasia* **8**: 113-127.
- Nowak, R.M. (1991). *Walker's mammals of the World*. I. 5th edn. The Johns Hopkins University Press: Baltimore & London.
- Owen, J. G. (1990). Patterns of species number in relation to temperature, productivity, and variance in elevation. *J. Mammal.* **71**: 1-13.
- Pankhurst, R. (1989). Some notes on deforestation and afforestation in Ethiopia prior to World War I. *Walia* **12**: 10-20.
- Petrusewicz, K (1983). Numbers: their concept and definition. *Acta. Theriol.* **28**:89-101.
- Poore, M.E.D.& Fries, C. (1985). *The ecological effects of eucalyptus*, FAO Forestry Paper no. 59. Food and Agriculture Organization: Rome. 88+III PP.
- Prasad, S.N. & Kashyap, V. (1995). *A textbook of vertebrate zoology*. 13th edn. Wiley Eastern Limited: New Delhi. pp. 494-499.
- Price, M. V. (1978). The role of microhabitat in structuring desert rodent communities. *Ecology* **59**: 910-921.
- Rogers, L. M. & Gorman, M. L. (1995). The population dynamics of small mamma living in set aside and surrounding semi-natural and cropland. *J. Zool., Lond.* **236**: 451-464.
- Rozenzweig, M.L. & Winakur, J. (1969). Population ecology of desert rodent communities. *Ecology* **59**: 910-921.
- Rupp, H. (1980). Beiträge Zur Systematik, Verbreitung und Ökologie äthiopischer Nagetiere: Ergebnisse mehrerer Forschungsreisen. *Säugetierk, Mitt*, **28**:81-123.
- Shimelis Beyene (1986). *A study on some ecological aspects of the giant molerat (Tachyoryctes macrocephalus) (Rüppell 1842) in Bale Mountains, Ethiopia*. M. Sc. thesis, Addis Ababa University: Addis Ababa. 90+ xi pp.

- Sillero - Zubiri, C., Tattersal, F. H. & Macdonald, D.W. (1995). Bale Mountains rodent communities and their relevance to the Ethiopian wolf (*Canis simensis*). *Afr. J. Ecol.* **33**:301-320.
- Singleton, G.R. (1989). Population dynamics of an outbreak of house mice (*Mus domesticus*) in the Mallee wheatlands of Australia - hypothesis of Plague formation. *J. Zool., Lond.* **219**:495 -515.
- Southern, H.N. & Hook, O. (1963). Notes on breeding of Small mammals in Uganda & Kenya. *Proc. Zool. Soc. Lond.* **140**: 503-515.
- Sutherland, W.J. (1996). *Ecological census technique*. Combridge University Press: Cambridge.
- Taylor, K.D., & Green, M.G. (1976). The influence of rainfall on diet and reproduction in four African rodent species. *J. Zool., Lond.* **180**:367-389.
- Tew. T.E., Todd, I.A., and MacDonald, D.W. (1994). The effects of trap spacing on population estimation of small mammals. *J. Zool., Lond.* **233**:340-344.
- William. G.M. (1993). *Techniques and fieldwork in ecology*. Collins Educational: London.
- Yahner, R.H. (1983). Population dynamics of small mammals in farmstead shelterbelts. *J. Mammal.* **64**:380-386.
- Yalden, D.W. (1988a). Small mammals in the Hareenna Forest, Bale Mountains National Park. *Sinet: Ethiop. J. Sci.* **11**:41-53
- Yalden, D. W. (1988b). Small mammals of the Bale Mountains, Ethiopia. *Afr. J. Ecol.* **26**: 282-294.

Yalden, D.W., Largen, M.J. & Kock, D. (1976). Catalogue of the mammals of Ethiopia.

2. Insectivora and Rodentia. *Mont Zool. Ital.* (N.S.) (Suppl.) 8:1-118.

Yu, H.J. (1994). Distribution and abundance of small mammals along a subtropical elevational gradient in central Taiwan. *J. Zool., Lond.* 234:577-600.

Appendix I. List of the mammalian species of Entoto Mountain

Scientific name	Common name
A. Rodentia	
1. <i>Arvicanthus abyssinicus</i> (U)	Ethiopian Grass Rat
2. <i>Muriculus imberbis</i> (E G)	Semien Mouse (Wurch Rat)
3. <i>Lophuromys flavopunctatus</i>	Harsh-furred Mouse
4. <i>Otomys typus</i>	Swamp Rat
5. <i>Myomys albipes</i> (E)	White-footed Rat
6. <i>Desmomys harringtoni</i> (E)	Dega Rat
7. <i>Mus mahomet</i> (E)	Mahomet's Rat
8. <i>Dendromus lovati</i> (E)	Lovate's Mouse
9. <i>Dendromus mystacalis</i>	Banana Mouse
10. <i>Rattus rattus</i>	Black Rat
11. <i>Tachyoryctes splendens</i>	Common molerat
12. <i>Hystrix cristata</i>	Crested Porcupine
B. Lagomorpha	
13. <i>Lepus habessinicus</i>	Abyssinian Hare
C. Tubulidentata	
14. <i>Orycteropus afer</i>	Aardvark
D. Artiodactyla	
15. <i>Sylvicapra grimmia</i>	Common Duiker
16. <i>Tragelaphus scriptus meneliki</i> (Es)	Menelik's Bushbuck

E. Primates

- | | |
|-----------------------------------|---------------|
| 17. <i>Cercopithecus aethiops</i> | Grivet Monkey |
| 18. <i>Papio anubis</i> | Olive Monkey |

F. Carnivora

- | | |
|--------------------------------|-------------------|
| 19. <i>Felis sylvstris</i> | Wild Cat |
| 20. <i>Felis serval</i> | Serval |
| 21. <i>Felis caracal</i> | Caracal |
| 22. <i>Herpestes ichneumon</i> | Egyptian Mongoose |
| 23. <i>Civettictis civetta</i> | Civet |
| 24. <i>Canis adustus</i> | Common Jackal |
| 25. <i>Panthera pardus</i> | Leopard |
| 26. <i>Crocuta crocuta</i> | Spotted Hyena |

U---Uncertain endemic status

Es---- Endemic subspecies

E – Endemic to Ethiopia

EG—Endemic Genus

Scientific names	Common names
30. <i>Streptopelia lugens</i>	Dusky Turtle Dove
31. <i>Columba albitorques</i>	White-collared Pigeon
32. <i>Columba guinea</i>	Speckled Pigeon
33. <i>Corvus crassirostris</i> (E)	Thick-billed Raven
34. <i>Corvus capensis</i>	African Rook
35. <i>Corvus albus</i>	Pied Crow
36. <i>Caprimulgus poliocephalus</i>	Montane Nightjar
37. <i>Bubo lacteus</i>	Verreaux's Eagle Owl
38. <i>Milvus migrans</i>	Black Kite
39. <i>Elanus caeruleus</i>	Black-shouldered Kite
40. <i>Buteo rufofuscus</i>	Augur Buzzard
41. <i>Neophron percnopterus</i>	Egyptian Vulture
42. <i>Gypaetus barbatus</i>	Lammergeyer
43. <i>Necrosyrtes monachus</i>	Hooded Vulture
44. <i>Gyps bengalensis</i>	White-backed Vulture
45. <i>Gyps rüppelli</i>	Rüppell's Griffin Vulture