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Species Composition, Distribution, Relative Abundance and
Habitat Association of Rodents in Arbaminch
Forest and Farmlands, Ethiopia.

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ABSTRACT

A comparative study of species composition, distribution and habitat association of pest rodents was carried out in Arbaminch Forest and nearby farmlands from August, 2005 to April, 2006. Six different types of habitats, four from natural forest and two from farmlands were randomly selected. These samples were from ground water forest, riverine forest, deciduous bushland, Lake Abaya shore, maize plantation and cotton plantation. In each habitat type, one representative trapping grid was randomly selected for live trapping. In addition, rodents were also surveyed from each habitat by snap trapping. Sixteen species of small mammals that including two shrews were recorded from the study area. Thirteen small mammals trapped were *Mastomys natalensis* (32.9%), *Arvicanthis dembeensis* (30.6%), *Acomys cahirinus* (10.3%), *Lemniscomys striatus* (8.3%), *Mastomys erythroleucus* (5.7%), *Tatera robusta* (3.4%), *Arvicanthis niloticus* (2.9%), *Stenocephalemys albipes* (2.1%), *Grammomys dolichurus* (1.3%), *Mus musculus* (1.3%) and *Mus tenellus* (0.3%), *Crocidura flavescence* (0.6%) and *Crocidura fumosa* (0.3%). The distribution of species varied from habitat to habitat and season to season. Eleven and seven rodent species were trapped from natural habitats and farmlands, respectively. Among trapped rodents, *M. natalensis* was the most widely distributed species, whereas *T. robusta* and *L. striatus* were the least. The population was also varied from season to season, high during the dry season and less during the wet season. Four rodent species (*M. natalensis*, *A. dembeensis*, *M. musculus* and, *Hystrix cristata*) were recoded as pests species of maize crops in farmlands.

1. INTRODUCTION

Mammals are the highest evolved group of the animal Kingdom (Ghose & Manna, 2003). Among the mammals, rodents (Order Rodentia) constitute the most diverse group (Carrington, 1963; Davis, 1963; Kingdon, 1997; Nowak, 1999; Vaughan *et al.*, 2000). They range from tiny pigmy mice to big *Capybaras*; from arboreal flying squirrels to subterranean mole rats and from opportunistic omnivores to specialist feeders. Nearly 40% of all mammal species belong to this one order. Traditionally, rodents have been grouped into three suborders (Lawlor, 1979; Nowak, 1999; Vaughan *et al.*, 2000), based largely on jaw musculature and associated structure of the skull. These are Sciuromorpha (squirrel-like rodents), the Myomorpha (rat-like rodents) and Hysticomorpha (porcupine-like rodents). Recent studies indicate that the systematics of rodents is more complex. These sub-orders are grouped into 29 recent living families, 426 genera, and 1,814 species. So, rodents have more members than any other orders of mammals (Wilson & Reeder, 1993; Nowak, 1999). Among these, most of the rodent species belong to sub-order Myomphora and two-third of the living rodent species belong to the family Muridae (Kingdon, 1997). The number of rodent species has been increasing from time to time as a result of the development of new techniques of identifying sibling and cryptic species.

The distribution of the Rodentia is nearly worldwide (Davis, 1963; Kingdon, 1997; Nowak, 1999). The habitats and behavior of rodents are highly diversified, as expected from the large number of species (Wilson and Reeder, 1993; Prasad & Kashay, 1995). According to Stoddart (1984), they occur in every habitat from the high Arctic Tundra, where they live and breed under the snow to the hottest and driest region. Therefore, rodent habitats are extensive and varied. Relatively little is known of the factors that determine the distribution and abundance of

small mammals. Tropical grasslands often support a rich and varied assemblage of small mammals in comparison to their temperate counterparts (Martin & Dicknson, 1985; Shanker, 2001). The distribution and pattern of relative abundance of animals depend largely on the seasonal availability of food and water (Taylor and Green, 1976; Obsom & Parker, 2003). In addition, vegetation density affects the micro-climate and also provides protection for small mammals against predators. The number of rodents and their dynamics usually depend up on cover provided by extensive vegetation (Adler, 1985; Hansson, 1999). Therefore, species distributional patterns are not random (Hagmeier & Stults, 1964) and follow geographic patterns that reflect both recent ecology and physiogeographic history (Krytufek & Griffiths, 2002). In addition, many environmental factors have some effects on the timing of reproduction in rodents. Among these temperature, energy and nutrition are probably of prime importance (Vaughan *et al.*, 2000). Seasonal variation is an important factor regulating populations of rodents.

A number of rodents are terrestrial and spend a large part of their time underground (Davis, 1963). Others such as ground squirrels dig extensive burrows system used for resting and caring for their young, while few are largely arboreal. Some can glide, and some are adapted for semi-aquatic life (Stoddart, 1984; Nowak, 1999). They occur in most habitats and show great diversity in their ecology, morphology, physiology, behavior and life history strategies (Delany & Happold, 1979; Nedbal *et al.*, 1996). However, weather has a distinct influence on the reproduction of rodents (Happold & Happold, 1989a). Habitat selection has been considered as an important factor in community dynamics of small mammals (Shurchild's, 1997; Shanker, 2001).

Compared to other continents and other tropical regions, Africa is rich in many taxa. It has a high diversity of mammalian species in the world

(Kingdon, 1997). Delany & Monoro (1986) stresses that in Africa, rodents are among the most ubiquitous and numerous among mammals in both species and in numbers. More than 1150 species of mammals are currently listed from Africa (Kingdon, 1997). In East Africa, rodents account for about 28% of the total mammal fauna (Delany 1986; Kingdon 1997; Clausintzer, 2003). The most common rodents in sub-Saharan Africa belong to the genus *Mastomys* (Stenseth *et al.*, 2001). They occur all over the continent in natural grasslands, thickets, cultivated areas and in human habitations.

According to Singleton *et al.* (2003), rodents have ecological, economical, social and cultural values. Rodents play an important part in natural communities, and provide the main supply of living food for many of the predatory mammals, birds and reptiles (Hvass, 1961; Linzey & Kesner, 1997; Ray, 1998; Davies, 2002). They are valued as important food sources in many regions of Africa. They also comprise as an important component of the diet of the Gumuz indigenous people in Ethiopia (Tadesse Habtamu, 2005). In addition to these, rodents have served as model organisms for studying the effect of tropical forest fragmentation (Adler, 1994; Lambert *et al.*, 2003). They are also useful in the study of environmental gradient (Heaney, 2001; Mena & Vazque-Dominguez, 2005), and good indicators of habitat change. Some of these are considered as pioneer species of ecosystem succession (Davis, 2002). Generally, rodents play important structural roles in different ecosystem services (Kingdon, 1997) For example, by pruning or eliminating vegetation types, aerating soil through their digging and burrowing activities, spreading seeds, pollen and competing with other animals.

On the other hand, some rodents are nuisance in agriculture, forestry and public health (Fiedler, 1994), causing severe economic losses (Tristian & Murakami, 2003). Their damage is an important cause of

harvest loss worldwide. For instance, in Ethiopia eleven species of rodents consume or destroy up to 20% of the cereal crops in some years (Afework Bekele & Leirs, 1997). Farmers often list rodents as one of their most significant crop pests (Singleton *et al.*, 1999; Stenseth *et al.*, 2001). They cause direct damage to various crops or commodities by gnawing and feeding, and indirect damage by spoiling and contamination. More than 25 species (5-10%) of rodents have been recorded as pests in agriculture causing a wide range of damage and losses in cereals, legumes, vegetables, root crops, cotton and sugarcane (Davies, 2002). Among these rodents, *Mastomys* are important pests in agriculture (Leirs *et al.*, 1993; Gratz, 1997). Most damage occurs during the sensitive young seeding stage and just before harvest. However, the pattern and levels of rodent infestation, and the extent of damage, vary in different crop and geographical regions. In addition, they are also reservoirs and carriers of zoonotic diseases that can infect both humans and livestock. As humans and livestock are in regular contact with rodents, their potential for transmission of zoonotic diseases is very high. These diseases are of great social and public health importance. Therefore, by considering their economic importance, controlling rodent population using appropriate pest management methods such as Integrated Pest Management (IPM) approach is important to reduce crop damage by rodents (Gratz, 1997; Stenseth *et al.*, 2001).

Diets are extremely significant for determining evolution, life-history strategies and ecological role of animals (Krebs, 1989). Food is one of the most important dimensions of the niche and, therefore, information on diets of animals is virtually a prerequisite for most ecological research. Study of diets of animals is crucial for understanding relationships between species (Zimmerman, 1965; Bar *et al.*, 1984), and between an animal and its environment. These relationships may determine community structure, species diversity, relative abundance and resource

partitioning among species and individuals. Diets of rodents usually are evaluated by analyzing stomach contents or less frequently fecal materials (Cole *et al.*, 1995), whether they feed on fruits, seeds or arthropods (Davies, 2002). Generally, many rodents are opportunistic feeders. They can feed on a variety of food items (green plant materials, seeds, fruits and insects) and thus survive in many different types of crops that become available in large amounts (Leirs *et al.*, 1994). Mole rats are specialized on root and tubers of different plants (Sidorowicz, 1974).

Compared to other African countries, Ethiopia is both physically and biologically one of the most diverse countries of the world (Lekun Abunie, 2000). This is believed to be as a result of the large diversity of ecological conditions determined by a topography ranging from 110 meters below sea level at Kobar sink in the Afar depression to a peak of 4620 meters above sea level at Ras Dejen in the Simen Mountains (Shibiru Tedla, 1995; Tesfaye Hundessa, 1996).

More than 277 mammalian species have been recorded from Ethiopia (Yalden *et al.*, 1996; Afework Bekele & Corti, 1997; Shibiru Tedla, 1995; Lekun Abunie, 2000). Of these, 31 mammal species (11%), are currently believed to be endemic (Yalden & Largen, 1992). The rodent fauna of Ethiopia consists of 70 species (Yalden and Largen, 1992, Hillman, 1993, Afework Bekele (1996a, b), among these 15 are endemic. Generally, according to Afework Bekele (1996b), rodents comprise 25% of the Ethiopian mammal fauna and contribute about 50% of the total endemic species. More recently, this figure has been elevated to 84 as a result of additional collection (Lavernchenko *et al.*, 1998).

According to Yalden & Largen (1992), limited areas of the country are extensively surveyed for small mammals (rodents). Therefore, there is a need for further survey as more and more of the habitats are affected as

a result of human activities in the ecosystem. Few ecological studies of rodents of Ethiopia have been carried out by Shymelis Beyene (1986); Yalden (1988a); Afework Bekele (1996a, b); Sillero-Zubiri *et al.* (1995); Bekele Tsegaye (1999); Corti *et al.* (1999); Tilaye Wube (1999); Alemu Fetene (2003); and Tadesse Habtamu, 2005). However, studies on population ecology, habitat selection, habitat use, and population dynamics of the rodent community are still poorly known for many regions of Ethiopia. The same is true of rodents in Arbaminch forest (Nechisar National Park) and nearby farmlands (State Farm).

Therefore, extended ecological surveys in this area is essential to determine the species composition, spatial and temporal distribution, relative abundance, habitat association and their impacts on agricultural productivity. These studies will provide important information on the population status of the rodents and their effect on agriculture.

2. OBJECTIVE

2.1. General objective: the general objective of the present study is to conduct ecological survey and assess the current species composition, distribution, and abundance and habitat association of rodents in Arbaminch Forest and nearby farmlands.

2.2 Specific objectives

- To determine the species composition of rodents in the area.
- To estimate the density of rodents in different vegetation zones.
- To determine the relative abundance of rodents and to characterize their seasonal variation, relating to the habitat association.
- To describe the distribution and habitat association of rodents in the area.
- To determine the feeding activities of rodents in both the forest and State Farm.
- To estimate the rodent impact on agricultural products and identification of pest species of rodents associated with maize crops.
- Assessment of the extent of damage caused by rodents on maize crops.

3. Description of the Study Area

3.1. Location and Area

The study area, Abraminch Forest and farmlands (State Farm) is located in southern Ethiopia near Arbaminch town (Fig. 1). Arbaminch Forest is part of Nechisar National Park (NNP), at present administered by African Parks (AP). It is located about 270 km and 510 km South of Awassa and Addis Ababa, respectively (Duckworth *et al.*, 1993). The Park was established in 1974 with an area of 514 km² (Duckworth *et al.*, 1993), of which 85% is land and 15% is water (EWCO, 1999). The park lies within the floor of the Great Rift Valley in the Southern Nations Nationality and Peoples Regional State (SNNPRS) of Ethiopia. Thirty-eight mammal species have been recorded from the Park. The Park is situated at 5°51' - 6°00'N, 37°32' - 37°48' E with an elevation varying from between 1,108 to 1,650 m asl. Previously, the Park was administered by the Southern Nations Nationalities and Peoples Regional Government (Duckworth *et al.*, 1993). But, at present, it is administrated under private sector.

Abraminch Forest, which is part of the Park, covers about 2120 ha. It also includes the strip of riverine forest habitat that lays along the southwestern shore of Lake Abaya as well as the western most section of the Rift Valley. Its territory extends between 05°59'-06°30'N latitude and 37° 32'-37° 48'E longitude (Mateos Ersado, 2003).

The State Farm (farmlands) is located about 1 km to the north of the forest. The boundaries of the study area include in the north Chano Chalba Kebele to the south Lake Chamo, to the east Lake Abaya, to the southeast Gida Bonke Hill and to the west, Arbaminch town (Fig. 1).

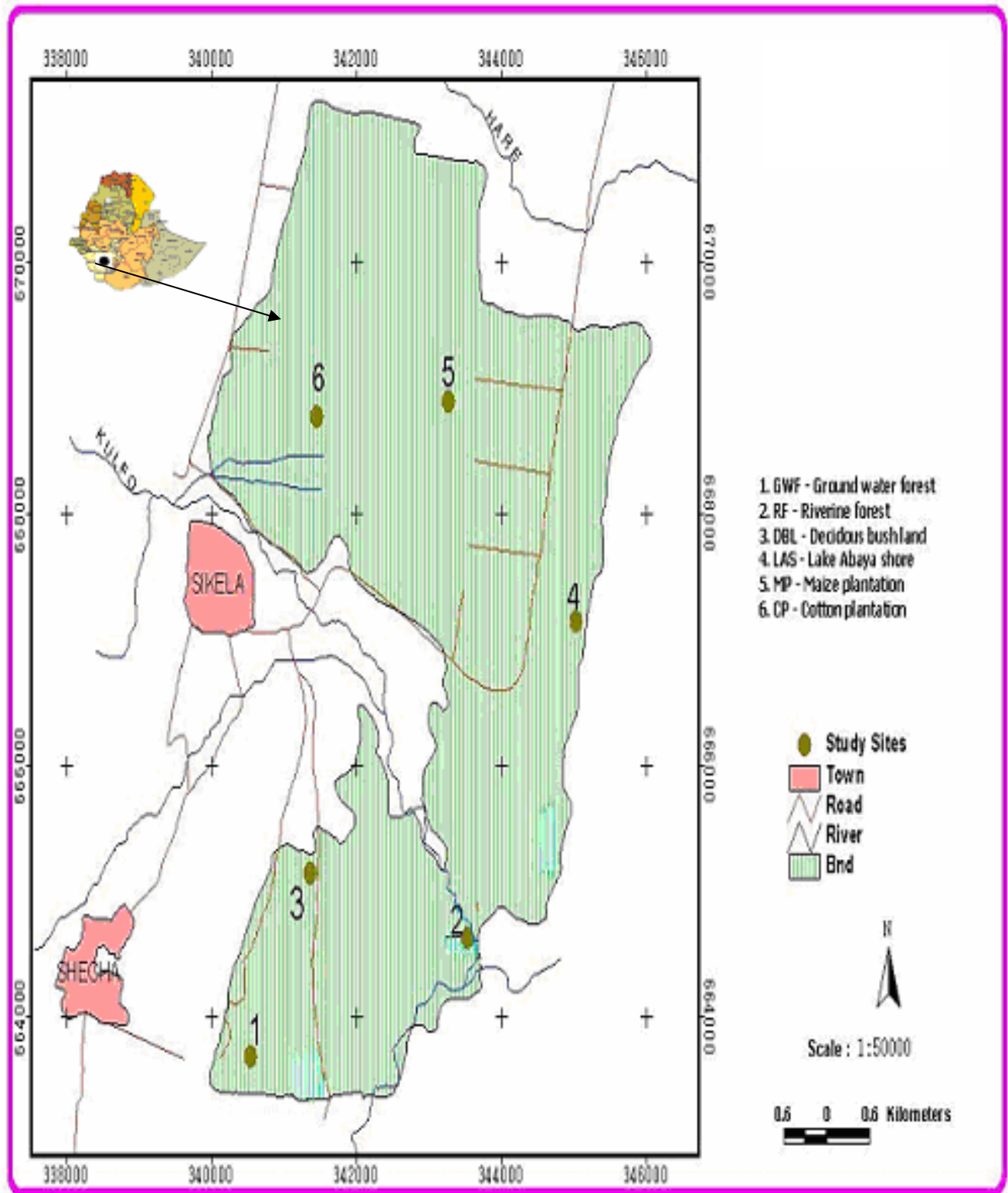


Figure 1. Location of the study area showing the position of grids.

3. 2. Geology and Topography

The underlying geology of the areas falls under the southern Rift Valley, which also includes Arbaminch Forest. It is mainly Quaternary volcanic alluvial deposits and lacustrine clay. Mateos Ersado (2003) states that the soils under the forest and the State Farm are composed of three main types namely: Fluvisols, Gleysols and Vertisols. Fluvisols consist of soil materials developed in alluvial deposits and flood plains. The Gleysols, on the other hand, are associated with depressed valley bottom and with shallow ground water table. It is typical of the area occupied by the ground water forest, following Arbaminch stream. Vertisols or black cracking clays are predominant on the slopes and better drained parts of the Lake shore and agricultural areas. It also covers bushlands and wooded grassland vegetation around the forest.

3. 3. Climate

The climate of the study area (NNP) is characterized by having relatively hotter climatic conditions with lower and unevenly distributed rainfall pattern with regularly higher temperature. The annual rainfall follows bimodal regime characterized by two distinct rainfall peaks during the dry season in between (Fig. 2). Most of the rain is from March to May (long rain season), while the short rain season is between September and November (EWCO, 1999).

The driest season is January to February and the other dry period is from June to August. The temperature ranges from 12.2 to 34.3 °C. The rainfall and temperature (including mean monthly precipitation, mean minimum and mean maximum monthly temperature recorded in Arbaminch town near the study area are shown in Fig. 3.

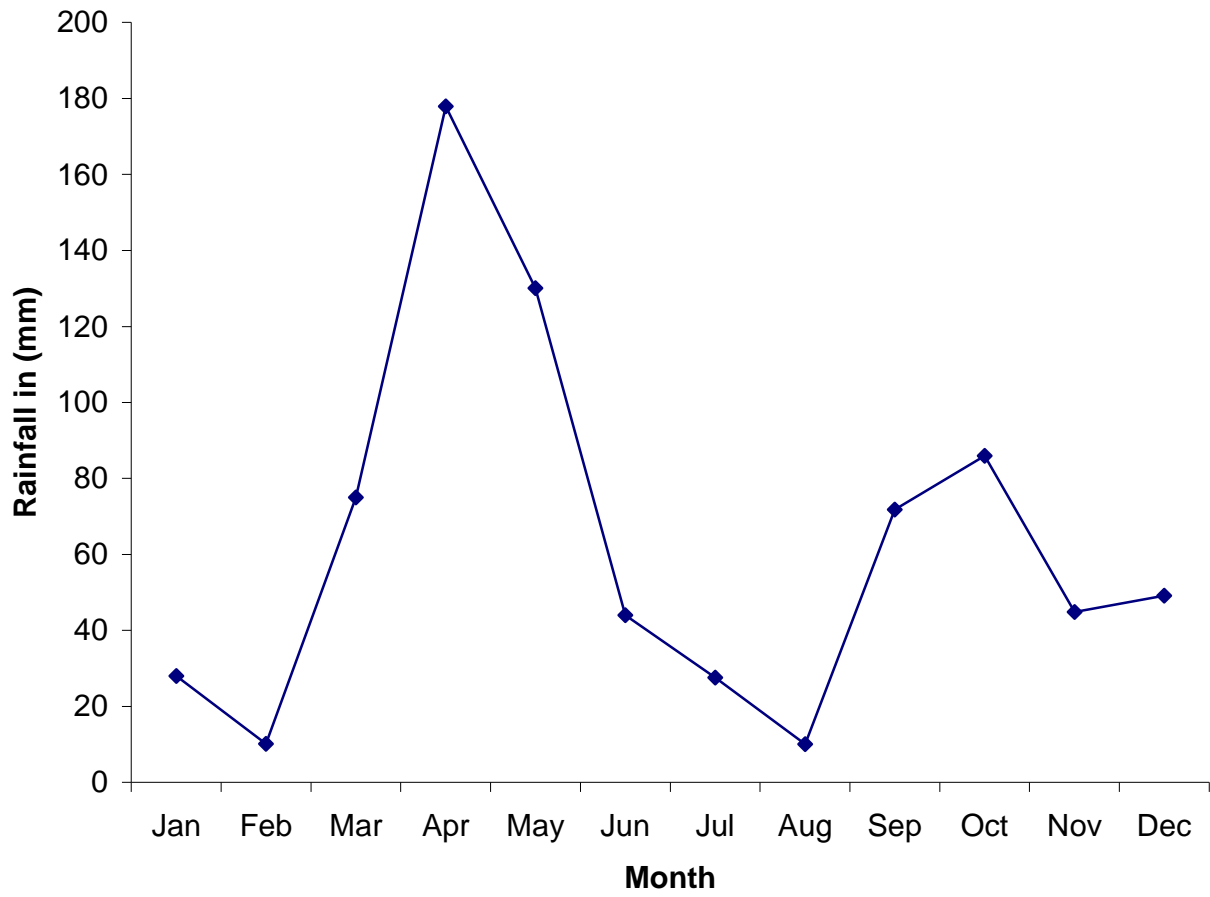


Figure 2. Average rainfall of Arbaminch from 2000 to 2006.

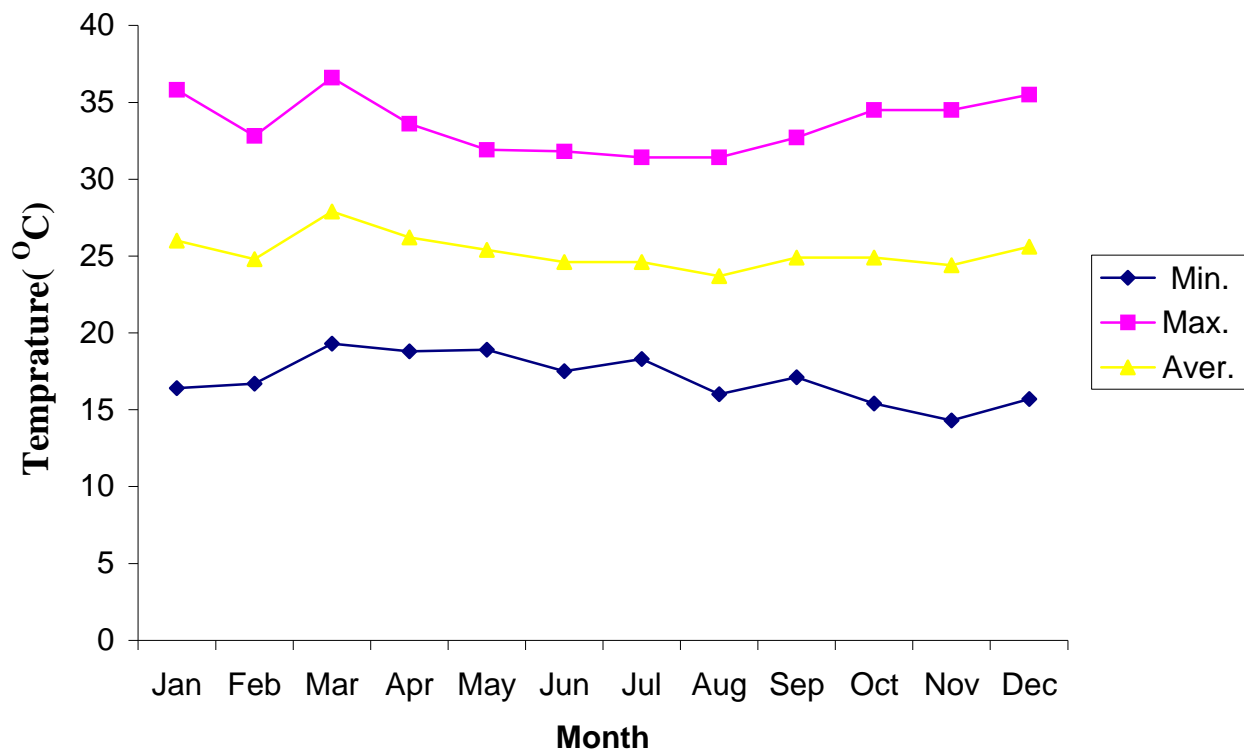


Figure 3. Monthly mean, minimum and maximum temperatures of Arbaminch from 2000 to 2006.

3.4. Vegetation and Habitat Classification

The main factor that determines the distribution and relative abundance of mammalian species is the nature of vegetation through food and cover it provides (Cloudstley-Thomposon, 1969). The interaction of plants and animals had been ignored both by botanists and zoologists until recently (White, 1983). The natural vegetation of Nechisar National Park has been described by White (1983). River Kulufo bisects the forest. The river is less than 10 m in width and rarely deeper than 1 m. It is fringed with

riverine forest and ends within the Park. There are three vegetation types within Arbaminch Forest. These include: ground water forest, riverine forest and deciduous bushland forest (thickets).

3.4.1 Arbaminch Forest

3.4.1.1 Ground water forest

The ground water forest is located in the west near the Park's headquarter with a low ground water table that supports a dense ground water forest, whose floristic make-up is diverse. The habitat consists of evergreen and some deciduous tree species with a canopy exceeding 30 meters. As one moves away from Kulfo River and Arbaminch stream, the high forest becomes rapidly smaller in stature and more dominated by species such as *Diospyros*, *Terminalia bromwni*, *Kigelia pinnata*, *Tamarindus indica* and *Euclia schimperi*. From the forest habitats, the vegetation becomes yet lower in stature and dominated by *Euclia schimperi* before merging in the surrounding bushland/ thicket.

3.4.1.2. Riverine forest

The riverine forest occurs as narrow strips along the Kulfo River with dense vegetation and tall trees along the banks of a river. It has a small area of spring-fed ground water forest along the base of the scrap at the eastern edge of Arbaminch stream and also along the better drained parts of the shore of Lake Abaya.

The plant species composition of the Kulfo riverine forest and the ground water forest are more or less similar. The most dominant, 20-30 m high tree species include: *Ficus sycomorus*, *Garcinea livingstonia*, *Teclia nobilis*, *Cordia africana*, *Diospyros abyssinica*, *Vepris danielii* and *Trichillia emetica*. Woody climbers consist of *Hippocratea africana*,

Lumbago zeylanica, *Pergularia daemia*, *Cissus rotundifolia*, *Paullinka Pinnata* as well as *Lantana camera* and *Stephonotis floribunda*.

3.4.1.3. Deciduous bushland (Thicket)

This vegetation type dominates in areas further away from the riverine habitats, with gently slopping terrain, as well as gullies. An abrupt variation in the woody vegetation composition and densities of the bush lands is evident in the southwest of Arbaminch stream and in the east of Kulfo River (Plate 1a).

The dominant tall tree plant species composition in the bushland includes: *Acacia tortilis*, *A. nilotica*, *A. seyal*, *Combretum mole*, and *Balanites aegyptiaca*. The most common and widespread woody plant species include: *A. mellifera*, *Rhus natalensis*, *Candaba farinosa* and *Ximenia caffera*. In addition to these, *A. brevispica*, *A. oerfota*, *A. senegal*, *A. trifolis* and *Terminalia browni* are also common. Others like *Dodonia angustifolia*, *Harrissonia abyssinica* and *Capparid micrantha* with widespread woody shrubs and creepers are widely distributed.

3.4.2. Lake Abaya shore

This study area is part of Nechisar National Park (NNP), to the west of Lake Abaya near the crocodile farm. Creeper shrubs and thick leave grasses (family Poaceae and Cyperaceae) dominate the habitat (Plate 1b).

3.4.3. Farmlands (State Farm)

This comprises cultivated open land outside and north of the Park. It has an altitude of 1212 m asl. The habitat is dominated by settlements and cultivated crops. The crops species cultivated in this site include maize (*Zea mays*)(Plate 2a) and cotton (*Gossypium hirtutum*)(Plate 2b). Wild growing weed species are also common.

4. MATERIALS AND METHODS

4.1. Materials

Materials used for ecological study include: Sherman live-traps, snap-traps, bait (peanut butter and maize flour), polythene bags, spring balance (digital balance), ruler, dissecting kit, camera, GPS, field guides, data sheets and gloves. Monocular microscope was used for stomach content identification. 70-80% ethyl alcohol and 5-10% formalin were used as preservatives.

4.2. Methods

4.2.1. Preliminary Study

Preliminary survey was conducted in Arbaminch Forest (African Parks) and nearby farmlands during August 1 to 7, 2005. During this survey, all the available and relevant information about the area (climatic condition, topography, and approximate size of the area) was gathered. Different vegetation types and representative habitat sites were observed. Grids were selected randomly based on representation of the main vegetation zones in the park and farmlands.

Based on the information gathered during the preliminary survey, continuous field work on ecological study of rodents in the study area was carried out. During the study, both dry and wet seasons were included. The first dry period data collection was carried out in August 2005 and the second main dry season was conducted in January 2006. The first wet season data collection was in October 2005 and the second main wet season data collection was from March to April 2006. Sampling methods of Afework Bekele (1996a, b); Fernandez *et al.* (1996); Ellis *et al.* (1997); Linzey & Kesner (1997); Shanker (2001); and Workneh Gebresilassie *et al.* (2004) were employed.

4.2.2. Sampling design

Based on the topography and habitat type, the total area of the study was classified into 18 grids of approximately 6 km². This provided a pictorial habitat classification of the whole study area. Based on this information, the vegetation type in the forest was identified as ground water forest (GWF), riverine forest (RF), deciduous bushland (DBL) or thicket, and Lake Abaya shore (LAS) at the edge of the forest. Grids with the agricultural area were with maize plantation (MP) and cotton plantation (CP).

The number of sampling grids chosen for different vegetation zones was based on the total size of the area that the vegetation type covers. The representative grids were randomly selected among the vegetation type based upon possible representation of different habitats as well as easy accessibility. Ground water forest, riverine forest, deciduous bushland, Lake Abaya shore, maize plantation and cotton plantation were numbered as Grids 1, 2, 3, 4, 5 and 6, respectively. The same grids were used during both seasons. In each sampling, permanent trapping stations of grid at 10 m intervals were placed at randomly selected areas. To explore the remaining habitats, 25 snap traps at an interval of 20 m were used at least 200 m away from the live trapping sites.

4.2.3. Data Collection

During the study period, both Sherman live-traps (5.5X6.5X16 cm) and snap-traps were used. The traps were randomly placed at different trap sites on each randomly selected grid. Data were also gathered by direct observation in the area.

4.2.3.1. Data collection by live-traps

A permanent 4900 m² live trapping grid was established at different habitat types. In each trapping sites, square trapping (7 rows by 7 columns) (Fig. 4) trapping grid was established during both seasons. A total of 49 Sherman traps were set per grid at 10 m intervals between points during both seasons. The traps were baited with peanut butter and crushed maize. This trapping design is referred to as the standard grid (Linzey & Kesner, 1997). When a unique habitat was observed, few additional traps were set at random to sample the fauna. Traps were covered by hay and plant leaves during the dry season. This provided protection for trapped animals against the strong heat. The traps were checked twice a day early morning (between 07:00 and 09:00 a.m.) and late afternoon (between 05:00 and 06.00 p.m.) for three consecutive days. Each trapped animal was captured alive, identified, marked by toe-clipping (Linzey & Kesner, 1997; Clausnitzer, 2003), and released for future identification. In addition, the following data were recorded: weight, sex, approximate age (juvenile, sub-adult, adult) based on their weight and pelage colour (Afework Bekele, 1996a) and reproductive conditions for female (closed or perforated vagina) and for males the position of testes (scrotal or abdominal).

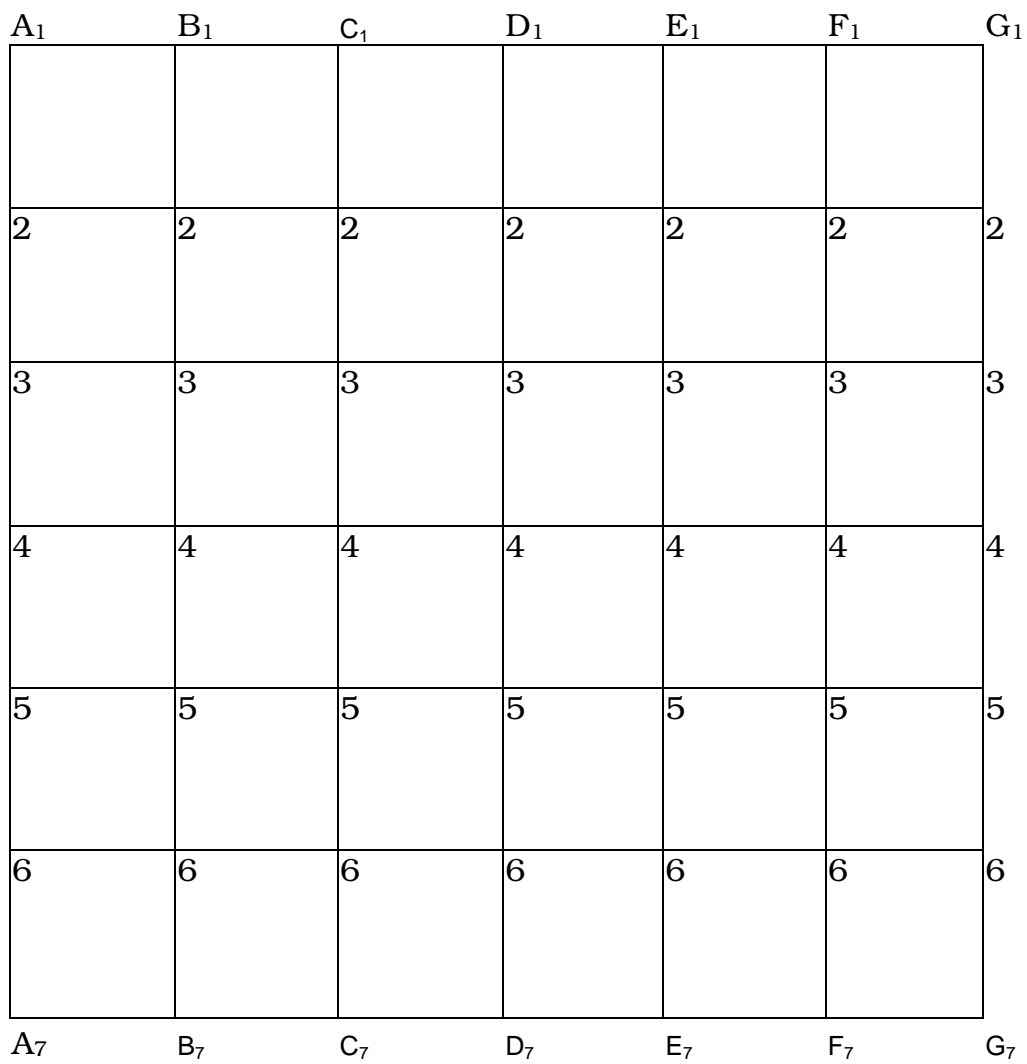


Figure 4. Diagrammatic representation of a live-trapping grid with trap locations.

4.2.3.2. Data collection by snap-traps

During both wet and dry seasons data collection, 25 snap-traps were used. The snap-traps were used along Sherman live-traps at the same time. The aim was to include other types of vegetation for collection of additional rodent species and to obtain stomach contents for diet analysis. During seasonal data collection, animals were caught by snap-traps arranged in two parallel lines. Each line was about 200 m long, separated from each other by about 50 m and from the live trapping grid by about 200 m at each site. Each snap-trap was at an interval of about 20 m. The snap-traps were baited with a mixture of peanut butter and maize scrap and placed at the same field for three days. The traps were checked twice a day early in the morning and late afternoon hours after Sherman live traps were checked. In the case of snap-trapped data collection, in addition to weight, sex, appropriate age additional body measurements like head-body length, length of tail, hind foot, and ear were recorded. Moreover, together with these special remarks of captured animals such as scars on the body, loss or damage on ear, toes, foot and tail as well as fur type and colour, number of mammae and number of embryo from pregnant females were also recorded. Based on the species type, code number was given to each trapped animal by both snap and Sherman live traps. From those animals captured by snap-traps, the skin and skull of representative specimen were prepared and deposited as voucher specimens in the Zoological National History Museum, Biology Department, Addis Ababa University. Then the specimens were compared and identified at species level by referring to additional reference materials deposited in the Museum. In addition, samples of liver were taken for DNA analysis in the future.

4.2.4. Diet analysis

Diet analysis was carried out following the methods of Johnson (1961); Reichman (1975); Kronteld & Dayan, (1998); Campos *et al.* (2001) and Workneh Gebresilassie *et al.* (2004). The trapped rodents were removed from the trap, identified and records on sex; sexual conditions and approximate age, weight, code number (type of species), habitat type, and grid number were recorded. All the representative snap-trapped animals were dissected for stomach content analysis. A few representative individuals from each species in each habitat and from each season were collected. The stomach was removed and preserved in individual containers and preserved in 5-10% formalin solution or in 70% alcohol, until further microscopic examination. The contents were brought to the Department Biology, Zoology Laboratory for diet analysis. The stomach contents were weighed using (digital balance) after drying the moisture content at 50°C for 24 hours. The samples were washed with distilled water to remove fine particles for proper identification and mixed thoroughly. Four slides were prepared for each sample and observed under light microscope to identify the type as well as the proportion of the diet. To quantify the food items (counting the fragments) of the stomach samples, a microscope at 60X magnification was used for all species. The proportion of different food fragments in the diet was carried out by counting the fragments from the entire slide.

4.2.5. Estimation of damage on maize crops

To estimate the damage of maize crop from Arbaminch farmlands the study was carried out in October 2005. Two hectares of maize plantation were randomly selected at pre-harvest stage. One was from central (inside) and the other from peripheral (edge) of the maize plantation. The maize was sowed in a row. In 1 m² about 6 (2 x 3) numbers of individual maize plants were counted. Therefore, about 60,000 individual maize

plants were expected from a hectare. To estimate the loss, direct damage counting (seed cobs) was carried out from 50 randomly selected rows during pre-harvest period (one week prior to the intended date of harvest). Individual damage was recorded as totally damaged, half damaged and one-fourth damaged from each hectare and each randomly selected row. Then, the damage proportion of each sampled cob was estimated.

According to Buckle (1994), there are a number of techniques available to assess rodent damage to crops, The method that seems as best to describe damage of maize crop by rodents was modified from Brown & Singleton (1999).

$$\% \text{ Maize crop damage} = 100(a/b)$$

Where: a= number of damaged individual maize crops in sample

b= total number of individual maize crop in sample

4.2.6. Data Analysis

For species identification taxonomic characteristics listed in Yalden *et al.* (1976), Nowak (1999), Afework Bekele (1996a) and other relevant guidebooks were used. Moreover, the prepared voucher skins and skulls were compared with the specimens deposited in the Zoological Natural History Museum of Addis Ababa University.

SPSS version 11.0 and appropriate statistical methods such as Chi-square test, Simpson's Similarity Index and Correlation Coefficient were used to compute the type of species, distribution, relative abundance and the vegetation association of major rodent species. In addition, Minimum Number Alive (MNA) method was used to estimate the population of trapped small rodents during each season. The analysis of the obtained diet data was carried out using SPSS version 11.0 and chi-square test.

5. RESULTS

The result obtained during the study period in the specified area is given in the following four separate sections:

The first section highlights the general descriptions of trapped and observed small mammals found in the study areas (Arbaminch Forest, Lake Abaya shore and farmlands). Distributions of shrews and observed rodent species were described. The second section deals with the result obtained from Sherman live-trapping surveys. This deals with the species composition relative abundance, distribution, habitat association, seasonal distribution and population estimation of rodent species. The third section deals with the result obtained from snap-trapping surveys. This part covers species composition, distribution, body measurement, embryo number and diet analysis. The fourth section tried to reveal the major rodent pests and their effect on maize crop in the farmlands.

5.1. Species composition of small mammals

From Nechisar National Park (Arbaminch Forest and Lake Abaya shore) and farmlands, a total of 823 individuals of small mammals belonging to the orders Rodentia and Insectivora were trapped in 5328 trap nights. These comprised 14 species of rodents and two shrews. These were trapped by both Sherman and snap traps in six randomly selected sites during both dry and wet seasons. Out of the small mammals trapped, 816 individuals (99.1%) represented 11 species of rodents and 0.9% shrews (Table 1). These were *Arvicanthis dembeensis*, *Arvicanthis*

niloticus, *Mastomys natalensis*, *Mastomys erythroleucus*, *Acomys cahirinus*, *Lemniscomys striatus*, *Tatera robusta*, *Stenocephalemys albipes*, *Grammomys dolichurus*, *Mus musculus* and *Mus tenellus*. The remaining 7 individuals (0.9%) were represented the two species of insectivores (*Crocidura flavescence* and *Crocidura fumosa*). The two shrew species were captured from different habitats by Sherman and snap traps. Among the five individuals of *Crocidura flavescence*, three individuals were captured by live-traps, two individuals from deciduous bushland (DBL) and one individual from Lake Abaya shore (LAS). In addition, two individuals were trapped from maize plantation (MP) by snap traps. Out of the two individuals of *Crocidura fumosa*, one was captured from deciduous bushland (DBL) by live traps and the other one was from cotton plantation (CP) by snap traps.

In addition to the above small mammals, three species (*Paraxerus flavovittis*, *Hystrix cristata* and *Tachyorctes splendens*) of non-trapped rodents were confirmed to occur in the study area and noted as observed species (Table 1). *P. flavovittis* was widely distributed in DBL, MP and CP. *H. cristata* and *T. splendens* were also observed dispersed in the forests and farmlands. *T. splendens* was captured by hand near Lake Abaya shore.

Table 1. Species composition of small mammals captured from Arbaminch forest, Lake Abaya shore and farmlands.

Species	Total catch	Relative abundances(%)
<i>Mastomys natalensis</i>	271	32.90
<i>Mastomys erythroleucus</i>	47	5.70
<i>Arvicanthis dembeensis</i>	252	30.60
<i>Arvicanthis niloticus</i>	25	2.90
<i>Acomys cahirinus</i>	85	10.30
<i>Lemniscomys striatus</i>	68	8.30
<i>Tatera robusta</i>	28	3.40
<i>Stenocephalemys albipes</i>	17	2.10
<i>Grammomys dolichurus</i>	11	1.30
<i>Mus musculus</i>	11	1.30
<i>Mus tenellus</i>	2	0.30
<i>Crocidura flavescence</i>	5	0.60
<i>Crocidura fumosa</i>	2	0.30
<i>Praxerus flavovittis</i>	*	*
<i>Hystrix cristata</i>	*	*
<i>Tachyrcetes splendens</i>	*	*
Total 16	823	100%

* =non-trapped, but observed species

5.2. Species composition

Six hundred and twenty (76%) individual rodents were caught by Sherman live-traps and 196 (24%) snap-traps in 3528 and 1800 trap nights, respectively. They belonged to 11 species of rodents. Ten species were captured commonly by both traps, but one species (*Mus tentellus*) was only collected by snap-traps. Among live-trapped rodents, *M. natalensis* was the most abundant species;

whereas, among snap trapped rodents, *A. dembeensis* was the most abundant.

5.2.1. Sherman live-trapping

5.2.1.1. Species composition and relative abundance of rodents

A total of 620 individual rodents (732 captures) was captured in 3528 trap nights from the six randomly selected grids. The species of rodents identified and recorded were *M. natalensis*, *A. dembeensis*, *A. cahirinus*, *L. striatus*, *M. erythroleucus*, *T. robusta*, *A. niloticus*, *S. albipes*, *G. dolichurus* and *M. musculus*. *Mastomys natalensis* was the most abundant species from study area. The relative abundance of captured rodent species were *M. natalensis* (34.4%), *A. dembeensis* (28.9%), *A. cahirinus* (10.6%) *L. striatus* (9.0%), *M. erythroleucus* (6.1%), *T. robusta* (3.4%), *A. niloticus* (3.1%), *S. albipes* (2.1%), *G. dolichurus* (1.3%) and *M. musculus* (1.1%). The trapped rodent species and their abundance are shown in Table 2.

Table 2. Species composition, total catch and relative abundance of live-trapped rodents from different habitats of the study area.

Species	Total catch	Relative Abundance(%)
<i>Mastomys natalensis</i>	213	34.4
<i>Arvicanthis dembeensis</i>	179	28.9
<i>Acomys cahirinus</i>	66	10.6
<i>Lemniscomys striatus</i>	56	9.0
<i>Mastomys erythroleucus</i>	38	6.1
<i>Tatera robusta</i>	21	3.4
<i>Arvicanthis niloticus</i>	19	3.1
<i>Stenocephalemys albipes</i>	13	2.1
<i>Grammomys dolichurus</i>	8	1.3

<i>Mus musculus</i>	7	1.1
Total 10	620	100

5.2.1.2. Distribution of species

The distribution of species varied from species to species. *Mastomys natalensis* was the most widespread and abundant. It was not only comprised 33.0% of the total rodents captured by live trapping, but also occurred widely in all six habitats (Table 3). In some of the habitats it was more dominant than others. However, it was relatively less common both in ground water forest and riverine forest habitat. The other widely distributed species was *M. erythroleucus*. It occurred in all habitats except in maize plantation. However, in terms of number it was less dominant. *L. striatus* and *T. robusta* were less distributed species in the study area and found only in two habitat types (DBL and LAS). *A. dembeensis* is the most abundant rodent in the farmland followed by *M. natalensis*. These two species are known pests in farmlands.

Table 3. The distribution of live-trapped rodents in six habitat types

Species	Habitat types						Total catch
	GWF	RF	DBL	LAS	MP	CP	
<i>M. natalensis</i>	11	9	35	39	68	51	213
<i>M. erythroleucus</i>	1	4	17	13	-	3	38
<i>A. dembeensis</i>	-	-	19	22	79	59	179
<i>A. nilotiucs</i>	-	-	12	-	3	4	19
<i>A. cahirinus</i>	10	11	31	14	-	-	66
<i>L. striatus</i>	-	-	16	40	-	-	56
<i>T. robusta</i>	-	-	13	8	-	-	21
<i>S. albipes</i>	2	2	5	3	-	1	13
<i>G. dolichurus</i>	3	2	-	3	-	-	8

<i>M. musculus</i>	-	-	2	-	4	1	7
Total	27	28	150	142	154	119	620

GWF = ground water forest, RF = riverine forest, DBL= deciduous bushland
 LAS = Lake Abaya shore, MP = maize plantation, CP= cotton plantation.

The distribution of each rodent species in six randomly selected grids is shown in Figure 5. Comparison of species within the six-habitat types was not statically significant ($P>0.05$).

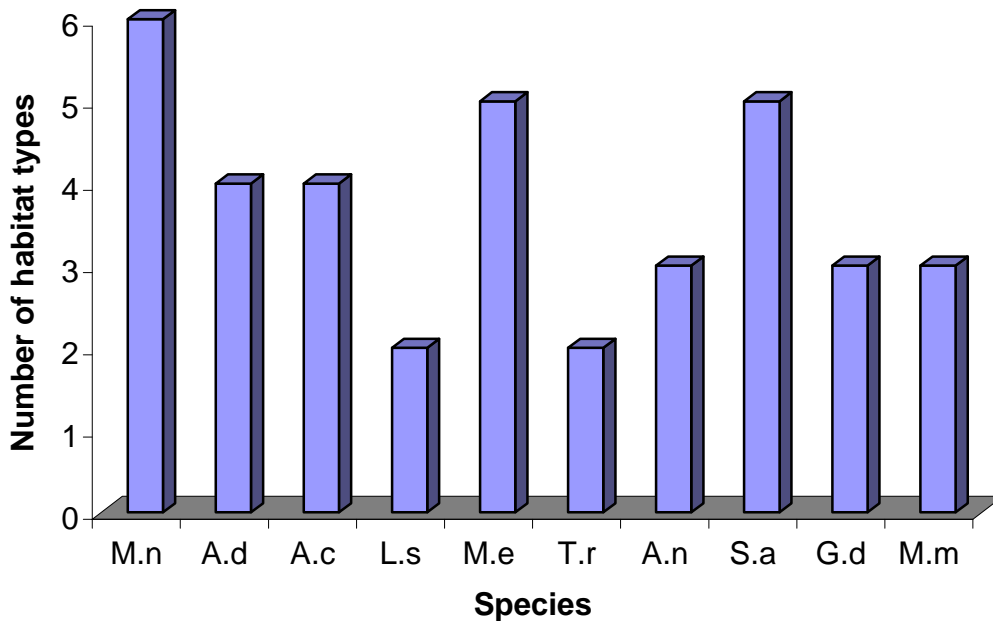


Figure 5. Species distribution of live-trapped rodents from six habitat types. (M.n = *M. natalensis*, M.e = *M. erythroleucus*, A.d = *A. dembeensis*, A.n. = *A. niloticus*, A.c = *A. cahirinus*, L.s = *L. Striatus*, T.r = *T. robusta*, S.a = *S. albipes*, G.d = *G. dolichurus*, M.m = *M. musculus*).

5.2.1.3. Habitat association and abundance

Most of the rodent species trapped were from the deciduous bushland (DBL) habitat and less in maize plantation. *G. dolichurus* was the only rodent not recorded from DBL vegetation (Table 4). The other habitats in the order of preference were Lake Abaya shore (LAS), cotton plantation (CP), ground water forest (GWF), and riverine forest (RF) and maize plantation (Mp)(Fig. 6). The species composition and abundance in deciduous bushland were *M. erythroleucus* (44.7%), *A. niloticus* (63.2%), *A. cahirinus* (47.0%), *T. robusta* (61.9%) and *S. albipes* (38.5%). *M. natalensis* (31.9%) and *A. dembeensis* (44.1%) occurred dominantly in maze plantation. *L. striatus* (71.4%) was mostly captured from Lake Abaya shore. *G. dolichurus* (37.5%) was captured from LAS and CP. Relatively *M. musculus* captured highly from MP (Table 4).

Table 4. Percentage of habitat association of each species in different habitat types. Dash (-) shows absence of trapped individuals (Mn= *M. natalensis*, Me = *M. erythroleucus*, Ad = *A. dembeensis* An.= *A. niloticus*, Ac = *A. cahirinus*, Ls = *L. striatus*, Tr = *T. robusta* Sa= *S. albipes*, Gd = *G. dolichurus*, Mm = *M. musculus*, RA=relative abundance)

Habitat Types	Rodent species									
	Mn	Me	Ad	An	Ac	Ls	Tr	Sa	Gd	Mm
GWF	5.2	2.6	-	-	15.1	-	-	15.4	37.5	-
RF	4.2	10.5	-	-	16.7	-	-	15.4	25.0	-
DBL	16.4	44.7	10.6	63.2	47.0	28.6	61.9	38.5	-	28.6
LAS	18.3	34.2	12.3	-	21.2	71.4	38.1	23.0	37.5	-
MP	31.9	-	44.1	15.8	-	-	-	-	-	57.1
CP	24.0	8.0	33.0	21.0	-	-	-	7.7	-	14.3

The number of rodent species trapped from the different habitat types was statistically significant ($P < 0.1$) among different habitat types (Fig. 6). It Rodent species richness was highest in deciduous bushland (DBL) and Lake Abaya shore (LAS) with 9 and 8 species, respectively. The lowest species richness was attained at the maize plantation with only four species. A regression analysis of species diversity with more or less the same altitudinal variation was negative. Generally, Similarity Index (SI) showed only 0.17 similarities between different habitats with reference to the composition of species.

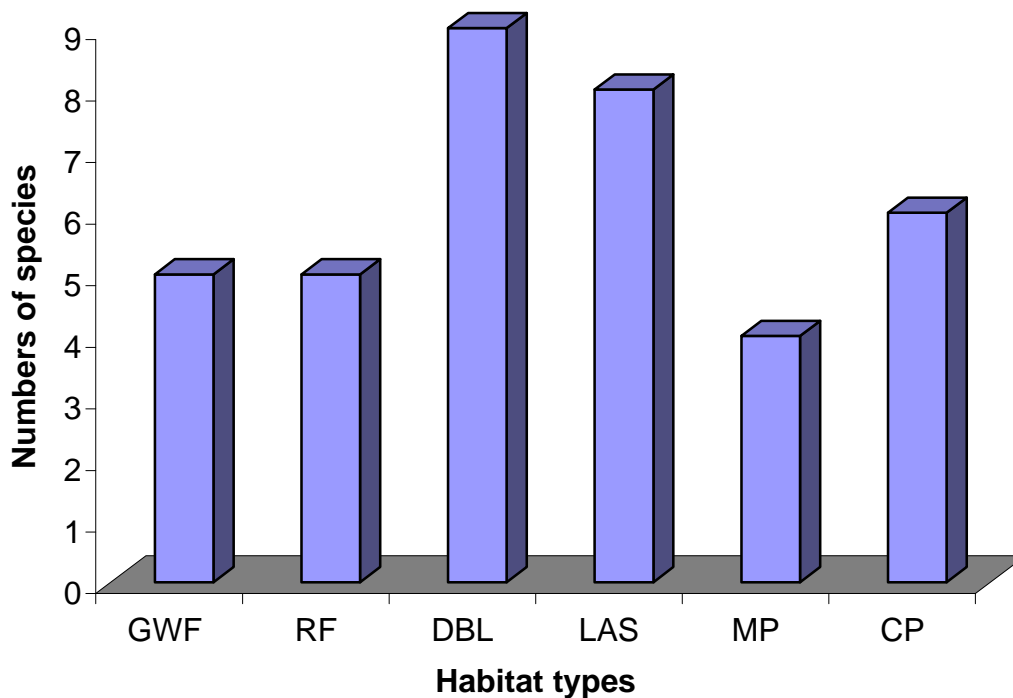


Figure 6. The diversity of species in six habitat types (GWD = ground water forest, RF= riverine forest, DBL= deciduous bushland, LAS = Lake Abya shore, MP = maize plantation, CP = cotton plantation)

5.2.1.4. Seasonal variation

A total of 10 rodent species was trapped in wet and dry season trappings. The overall number of species between the two seasons was not statistically significant ($p>0.01$). However, some species that were captured during the wet season were not trapped during the dry season (Table 5). The rodent abundance between the wet and dry seasons is 44.7% and 55.3%, respectively. During the dry season more individuals were recorded than the wet season. However, more number of species was collected during wet season.

Table 5. Seasonal variation and sex distribution of each species of rodent trapped by live-trapping (M= male, F= female)

Species	Aug/2005		Oct/2005		Jan/2006		Mar-Apr/2006		Total catch	
	dry season		wet season		dry season		wet season		M	F
	M	F	M	F	M	F	M	F		
<i>M. natalensis</i>	35	37	20	23	28	33	18	19	101	112
<i>M. erythroleucus</i>	6	3	3	5	6	7	5	3	20	18
<i>A. dembeensis</i>	23	29	20	20	23	24	19	21	85	94
<i>A. niloticus</i>	-	-	3	1	4	3	5	3	12	7
<i>A. cahirinus</i>	6	4	11	14	6	9	7	9	30	36
<i>L. striatus</i>	9	11	4	5	6	5	8	8	27	29
<i>T. robusta</i>	4	2	3	5	4	1	-	2	11	10
<i>S. albipes</i>	3	2	3	2	-	-	2	1	8	5
<i>G. dolichurus</i>	1	1	2	-	1	2	-	1	4	4
<i>M. musculus</i>	2	2	-	2	-	-	1	-	3	4

<i>Total</i>	89	91	69	77	78	84	65	67	301	319
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5.2.1.5. Sex ratio and age distribution

The sex ratio of trapped rodents from different habitats was given in Table 5. Out of the 620 individuals of rodents captured by live-traps in all trapping occasions, females comprised 319 (51.4%) and males 301 (48.6%). The difference in the rate of capture of females and males was not statistically significant ($p > 0.05$). However, as the number of individuals (abundance) increased the number of females also increased.

Different age groups were represented in the population of trapped rodents during both dry and wet seasons (Table 6). Out of 95 individuals of young rodents captured from different habitats during both seasons, 75 (79%) were captured during the wet and 20 (21%) were captured during dry seasons. The difference in the total capture of the number of young rodents during the different seasons varied significantly ($P < 0.001$). The number of pregnant females recorded was also high during the wet season. However, species such as *M. musculus* and *G. dolichrus* with only few individuals trapped do not have the young trapped during both seasons. Generally, Pearson's Correlation Coefficient shows high positive association between young individuals and wet season ($r = 0.87$) and low negative association during dry season.

Table 6. Composition of different age groups of live-trapped rodents

Month/season	Age groups			
	Adult	Sub-adult	Young (juvenals)	Total
Aug /2005 (dry season)	131	37	12	180
Oct/2005 (wet season)	90	20	36	146
Jan/2006 (dry season)	133	21	8	162
Mar-Apr / 2006 (wet season)	82	11	39	132
Total	436	89	95	620

5.2.1.6. Distribution of catches and trap success

Differences in the number of capture of rodents were recorded from live-trap surveys at three sites (Arbaminch Forest, Lake Abaya shore and Farmlands). Arbaminch Forest and Farmlands were further divided into three and two habitat types, respectively (Table 7). The number of captured and trapping success varied from habitat to habitat. It shows statistically significant variation ($P < 0.001$) between different habitat types (Table 7). The highest catch was recorded from maize plantation (154) and the lowest from ground water forest (27). The trap success was also maximum from maize plantation (26.2%) and minimum from ground

water forest (4.6%). The altitudinal ranges are more or less the same in all habitats (Table 7).

Table 7. Distribution of rodent catches from live-trapping surveys in each habitat types (AF= Arbaminch forest, LAS= Lake Abaya shore, FL= Farmlands).

Study site	Habitat type	Altitudel (m)	Total catch	Trap nights	Trap success
AF	Ground water forest	1223 m asl	27	588	4.6
	Riverinne forest	1221 m asl	28	588	4.8
	Deciduous bushland	1203 m asl	150	588	25.5
LAS	Lake Abaya shore	1183 m asl	142	588	24.1
FL	Maize plantation	1199 m asl	154	588	26.2
	Cotton plantation	1206 m asl	119	588	20.2

Seasonal catch of rodents and their success rate in each habitat type were recorded. Variations in number of rodent catch between different habitats (grids) and seasons were statistically significant ($P < 0.01$). Seasonally, maximum numbers of individuals were trapped from the maize plantation during the dry season (August, 2005) in which 49 individuals were trapped (Table 8). The lowest number of individual was captured from the riverine forest (3) during the wet season (October, 2005). There was variation in trap success between different habitats in the same type of seasons. For instance, the maximum trap success (33.3%) and minimum trap success (6.1) were recorded during the dry

season (August, 2005) from maize plantation and riverine forest, respectively (Table 8).

Table 8. Number of rodents, trap nights and success rate during wet and dry seasons in different habitats (GWF=ground water forest, RF= riverine forest, DBL= deciduous bushland, LAS= Lake Abaya shore, MP= maize plant, CP= cotton plantation).

Grid (Position)	Habitat types	Seasons	Month	Total Catch	Trap Nights	Trap Success (%)
G1 06° 01' N 37° 33' E	GWF	dry	Aug, 2005	10	147	6.1.7
		wet	Oct, 2005	4	147	2.70
		dry	Jan, 2006	5	147	3.40
		wet	Mar-Apr, 2006	8	147	5.40
G2 06° 00' N 37° 34' E	RF	dry	Aug, 2005	11	147	7.50
		wet	Oct, 2005	3	147	1.40
		dry	Jan, 2006	6	147	4.10
		wet	Mar-Apr, 2006	8	147	4.80
G3 06° 59' N 37° 34' E	DBL	dry	Aug, 2005	43	147	29.30
		wet	Oct, 2005	30	147	20.40
		dry	Jan, 2006	39	147	26.50
		wet	Mar-Apr, 2006	38	147	25.9
G4 06° 01' N 37° 36' E	LAS	dry	Aug, 2005	42	147	28.60
		wet	Oct, 2005	31	147	21.10
		dry	Jan, 2006	36	147	24.50
		wet	Mar-Apr, 2006	33	147	22.40
G5 06° 03' N 37° 35' E	MP	dry	Aug, 2005	49	147	33.30
		wet	Oct, 2005	43	147	29.30
		dry	Jan, 2006	38	147	25.90
		wet	Mar-Apr, 2006	24	147	16.30

G6 06° 03' N 37° 34' E	CP	dry	Aug, 2005	25	147	16.30
		wet	Oct, 2005	35	147	23.10
		dry	Jan, 2006	40	147	27.20
		wet	Mar-Apr, 2006	22	147	14.30

5.2.1.7. Activity pattern

The activity pattern of six relatively more abundant species and the two observed species of rodents were recorded from Arbamnich Forest, Lake Abaya shore and farmlands. *A. dembeensis* is exclusively diurnal. All others, *M. natalensis*, *A. cahirinus*, *L. striatus*, *M. erythroleucus* and *T. robusta* were collected from early morning check (nocturnal). However, few individuals of *M. natalensis*, *A. cahirinus* and *L. striatus* were collected from late afternoon check. *Paraxerus flavovittis* was only observed only during the day (exclusively diurnal) while *Hystrix cristata* was observed during night (recorded as exclusively nocturnal).

5.2.1.8. Estimation of population

The estimated population numbers of all rodent species in the live-trapping grid using Minimum Number Alive (MNA) is given in Fig. 7. The present study showed that there is statistically significant difference ($P < 0.05$) in numbers of population size between seasons. Except *A. cahirinus*, all other rodent species showed a high population estimates during dry season than wet seasons.

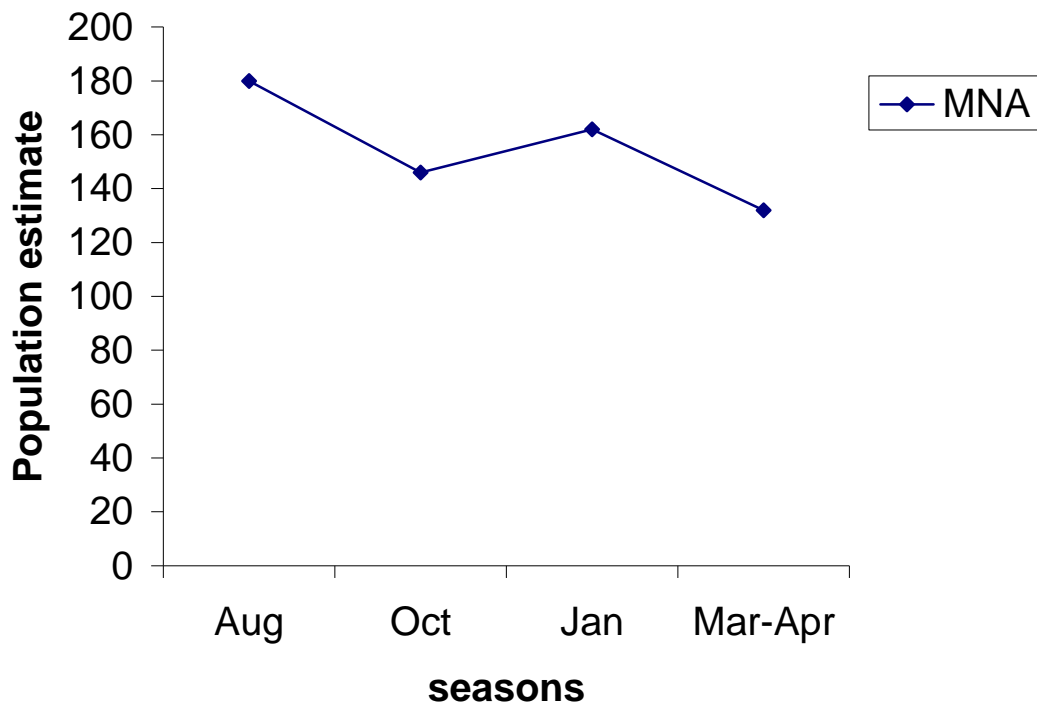


Figure 7. Population estimates of trapped rodents from live-trapping grids using MNA (Minimum Number Alive) (Aug = dry season, Oct = wet season, Jan = dry season, Mar-Apr = wet season, MNA=minimum number alive)

5.2.2. Snap trapping

5.2.2.1. Species composition, distribution and abundance

Snap trapping surveys yielded 11 species of rodents from six randomly selected sites (Table 9). A total of 196 individual rodents were captured in 1800 trap nights. The 11 recorded species from the study area were *Arvicanthis dembeensis*, *Arvicanthis niloticus*, *Mastomys natalensis*, *Mastomys erthroleucus*, *Acomys cahirinus*, *Lemniscomys striatus*, *Tatera*

Table 9. Species composition, abundance and distribution of snap trapped from different habitats (GWF=ground water forest, RF=riverine forest, DBL=deciduous bushland, LAS=Lake Abaya shore, MP=maize plantation, CP= cotton plantation)

Species	Total catch (%)	GWF	RF	DBL	LAS	MP	CP
<i>A. dembeensis</i>	73(37.3)	-	-	10	17	25	21
<i>D. natalensis</i>	58(29.6)	1	2	8	6	29	12
<i>A. cahirinus</i>	19(9.7)	3	5	9	2	-	-
<i>L. striatus</i>	12(6.1)	-	-	5	7	-	-
<i>M. erythroleucus</i>	9(4.6)	2	-	3	3	-	1
<i>T. robusta</i>	7(3.6)	-	-	5	2	-	-
<i>A. niloticus</i>	5(2.6)	-	1	1	-	1	2
<i>S. albipes</i>	4(2.0)	1	-	1	2	-	-
<i>M. musculus</i>	4(2.0)	-	-	-	-	3	1
<i>G. dolichurus</i>	3(1.5)	-	1	-	2	-	-
<i>M. tenellus</i>	2(1.0)	-	-	1	-	-	1
Total	196(100)	7	9	43	41	58	38

robusta, *Stenocephalemys albipes*, *Grammomys dolichurus*, *Mus musculus* and *Mus tenellus*.

The most abundant species from all snap trapping occasions was *A. dembeensis*. It comprised 37.3% of the total 196 rodents collected during all trapping occasions. *M. natalensis* was the second abundant

species, comprising 29.6% of the total catch. However, *M. tenellus* was rare. The percentage composition of trapped rodents was: *A. dembeensis* (37.3%), *M. natalensis* (29.6%), *A. cahirinus* (9.7%), *L. striatus* (6.1%), *M. erytholeucus* (4.6), *T. robusta* (3.6%), *A. niloticus* (2.0%), *S. albipes* (2.0%), *M. musculus*, *G. dolichurus*, and *M. tenellus* (1.0%).

5.2.2.2. Body measurements

The body weight and external measurements of 11 species of rodents trapped are given in Table 10. Only scrotal males and perforated females were included. Variation in body weight is statistically significant ($p < 0.1$) between seasons within a species. However, in other external body measurements, there was not statistically significant difference ($p > 0.01$) between seasons. There was also no sexual dimorphism in body weight and other external measurements.

Table 10. Body weight (g) and measurements (cm) (mean \pm SD) of rodents snap-trapped during dry and wet seasons.

Species	Season	No. of individuals (adult)	Body measurements				
			BW	HB	TL	HF	ER
<i>A d</i>	Dry	8	68.8 \pm 12.11				
	Wet	8	76.2 \pm 14.20	13.7 \pm 1.50	19.7 \pm 1.21	2.6 \pm 0.14	1.5 \pm 0.11
<i>M n</i>	Dry	10	51.4 \pm 13.80				
	Wet	10	63.5 \pm 12.25	11.4 \pm 1.42	10.9 \pm 1.25	2.4 \pm 0.11	1.6 \pm 0.13
<i>A c</i>	Dry	5	34.2 \pm 10.33				
	Wet	5	35.1 \pm 8.11	9.8 \pm 1.40	7.3 \pm 1.13	1.7 \pm 0.12	1.1 \pm 0.09
<i>L s</i>	Dry	3	37.0 \pm 7.99				
	Wet	3	40.2 \pm 8.64	10.5 \pm 1.33	11.6 \pm 1.22	2.1 \pm 0.16	1.4 \pm 0.11
<i>M e</i>	Dry	3	48.4 \pm 10.70				
	Wet	3	51.3 \pm 9.76	11.1 \pm 1.46	9.8 \pm 1.11	2.3 \pm 0.12	1.5 \pm 0.12
<i>T r</i>	Dry	2	52.7 \pm 9.90				
	Wet	2	55.6 \pm 8.89	12.5 \pm 1.51	14.2 \pm 1.23	3.1 \pm 0.21	1.6 \pm 0.14
<i>A n</i>	Dry	2	62.6 \pm 11.60				
	Wet	2	62.3 \pm 13.51	13.2 \pm 1.27	11.5 \pm 1.22	2.6 \pm 0.13	1.2 \pm 0.10
<i>S a</i>	Dry	1	50.9				
	Wet	2	53.1 \pm 7.51	11.7 \pm 1.54	14.4 \pm 1.20	2.5 \pm 0.19	2.1 \pm 0.13
<i>M m</i>	Dry	3	10.7 \pm 4.92				
	Wet	1	9.8	6.4 \pm 1.44	5.9 \pm 1.00	1.1 \pm 0.14	0.7 \pm 0.80
<i>G d</i>	Dry	2	47.9 \pm 8.77				
	Wet	1	46.5	7.5 \pm 1.52	12.1 \pm 1.10	2.5 \pm 0.11	1.6 \pm 0.10

Mt	Dry	-	-	-	-	-	-
	Wet	2	11.8±3.80	5.6±1.10	3.5±0.10	1.2±0.08	0.8±0.07

(BW = body weight, TL = tail length, ER = ear length, HB = head + body length, HF = hind foot length, Mn= *M. natalensis*, Me = *M. erythroleucus*, Ad = *A. dembeensis*, An.= *A. niloticus*, Ac = *A. cahirinus*, LS = *L. striatus*, Tr = *T. robusta*, Sa= *S. albipes*, Gd = *G. dolichurus*, Mm = *M. musculus*, Mt= *M. tenellus*).

5.2.2.3. Embryo size

The number of embryos in 20 captured pregnant females of 7 different species is given in Table 11. The number of embryos of pregnant females was varied from species to species. This also varied among individuals of the same species as well as between left and right horns. The highest number of embryos was recorded from *M. natalensis* (5-12) and the least from *L. striatus* (3-5).

Table 11. Number of embryos recorded from pregnant females of seven rodent species.

Species	No. of pregnant	No. of embryos
<i>A. dembeensis</i>	5	4-6
<i>M. natalensis</i>	6	5-12
<i>A. cahirinus</i>	3	4-6
<i>L. striatus</i>	2	3-5
<i>M. erythroleucus</i>	2	9-11
<i>A. niloticus</i>	1	10
<i>S. albipes</i>	1	4

5.2.2.4. Diet analysis

Table 12. Shows food fragments obtained from stomach samples for six rodent species from the study area. Food items were grouped into plant seeds, plant leaves, plant roots, earthworms and arthropods. Plant matters were most the common food items identified. Few root fragments were also observed in some species.

Table 12. Food fragments from stomach samples of six rodent species from the study area (Ad=*A. dembeensis*, Mn=*M. natalensis*, Ac=*A. cahirinus*, Ls= *L. striatus*, Tr=*T. robusta*, Mm= *M. musculus*).

Species	Plant seeds		Plant leaves		Plant roots	Earth Worms	Arthropod		
	Monocot	dicot	Monocot	dicot			Termites	Ants	Un different -tiered
<i>Ad</i>	*	*	*	*	*	-	*	*	*
<i>Mn</i>	*	*	*	*	*	*	*	*	*
<i>Ac</i>	*	*	*	*	*	*	?	?	*
<i>Ls</i>	*	*	*	*	?	-	*	*	*
<i>Tr</i>	*	*	*	*	*	-	*	*	*
<i>Mm</i>	*	*	*	*	-	*	*	*	*

* = Presence of fragments, - = no fragments, ? = Uncertain

5.2.2.4.1. Diet during wet and dry seasons

Even though the six rodent species studied mostly depended on plant matters, the relative proportion of the food items differed significantly among seasons and among species (Table 13). Statistically significant difference ($p < 0.05$) in consumption of seeds, leaves, roots and arthropods were observed among rodent species during the two seasons. The consumption of earthworms was more during the wet season; whereas, consumption of root was more during the dry season. Arthropods were used more during the wet season than during the dry

season. Except *L. striatus* and *T. robusta*, the other four species mostly depended on seeds of monocot and dicot plants during the dry season (Table 13). The stomach analysis from the snap trapped rodents did not show any significant seasonal variation in types of food items. However, there was a significant variation ($p < 0.05$) in proportion of the diet of each species.

Table 13. Composition of stomach contents (mean % frequency) of six rodent species in relation to seasons, (- =absence of data) (MS=monocot seed, DS= dicot seed, ML= monocot leaf, DL= dicot leaf, PR = plant root, EW= earthworm, A (T) = arthropod (termites), A(A) = arthropod (ants), A(u) = Arthropod (undifferentiated).

Species	Season	Percentage frequency of food fragment observed								
		MS	DS	ML	DL	PR	EW	TA	A(A)	A(U)
<i>A.d</i>	Dry	17.2	17.3	21.5	18.5	17.5	-	9.7	2.0	6.3
	Wet	17.4	18.1	22.6	29.0	-	-	1.6	4.8	6.5
<i>Mn</i>	Dry	24.5	20.4	16.3	18.4	4.1	1.0	4.1	5.1	6.1
	Wet	13.1	15.2	19.6	23.9	4.3	10.9	3.3	4.3	5.4
<i>Ac</i>	Dry	21.1	23.7	21.1	18.4	2.6	5.2	-	-	7.9
	Wet	20.7	20.7	13.8	17.2	3.5	17.2	-	-	6.9
<i>Ls</i>	Dry	19.4	18.6	29.7	24.0	-	-	-	-	8.3
	Wet	21.2	19.7	22.7	24.3	-	-	3.0	6.1	3
<i>Tr</i>	Dry	25.9	29.6	3.17	7.4	11.1	-	5.6	9.3	7.4
	Wet	26.7	31.1	8.9	4.4	13.3	-	4.5	4.4	6.7
<i>Mm</i>	Dry	19.4	23.5	15.8	19.6	-	3.9	5.9	7.8	3.9
	Wet	17.8	15.6	22.2	13.3	-	11.1	6.7	4.4	8.9

5.2.2.4.2. Diet composition during different sexual status

Data on the composition of stomach contents of four rodent species in relation to sexual status from the study area are given in Table 14. The stomach samples of females (non-pregnant and lactating) show not statistically significant ($p>0.01$) difference in their diet composition and percentage proportion of stomach contents. However, the stomach samples of most adult male rodents revealed the presence of a wide diversity of diet compared with pregnant and lactating females. Earthworm

Table 14. Composition of stomach contents (% frequency) of four rodent species in relation to sexual status (Ms= monocot seed, DS= dicot seed, ML= monocot leaf, DL= dicot leaf, PR= plant root, EW= earthworm, AP= arthropod).

Species	Sex	Age group	MS	DS	ML	DL	PR	EW	AP
<i>A. dembeensis</i>	M	Adult	19.7	25.4	22.5	2.8	2.8	-	8.5
	F	Pregnant	16.7	20.8	25	-	-	-	8.3
		Lactating	19.2	21.9	17.8	2.7	2.7	-	13.7
<i>M. natalensis</i>	M	Adult	21.1	15.8	18.4	2.6	2.6	5.3	10.5
	F	Pregnant	30.1	19.2	15.1	-	-	8.2	11
		Lactating	24.5	20.4	26.5	-	-	4.1	8.2
<i>A. cahirinus</i>	M	Adult	15.7	23.5	19.6	11.8	11.8	3.9	9.8
	F	Pregnant	22.2	29	24.1	2.1	2.1	8.9	6.7
		Lactating	20.7	24.1	13.3	1.7	1.7	5.2	6.9
<i>L. striatus</i>	M	Adult	13.6	18.2	33.8	29.8	-	-	4.6
	F	Pregnant	29.1	25.5	20.0	21.8	-	-	3.6
		Lactating	18.7	21.3	26.1	19.7	-	-	14.2

fragments were not observed from stomach samples of *A. dembeensis* and *L. striatus* in all the three sexual conditions. Pregnant females of most species showed relatively narrow range of diet diversity except *A. cahirinus*, which fed on all described food items. In lactating females of *A. dembeensis*, *L. striatus* and *M. natalensis* more percentage of seeds and leaves of both dicot and monocot plants were observed, whereas in *A. cahirinus* arthropods were the most common components of the diet, especially during the wet season.

5.3. Rodents as pests

A total of 4 rodent species (three trapped and one observed) were recorded as pests of maize crops on the farmlands (Arbaminch State Farm of maize plantation) (Table 15). The trapped rodent pests were *Mastomys natalensis*, *Arvicanthis dembeensis* and *Mus musculus*. The non-trapped but observed rodent pest was *Hystrix cristata*., which was the major rodent pests of the area. The most abundant species was *A. dembeensis* 106 (51.0%), followed by *M. natalensis* 97 (46.6%) and *M. musculus* 5 (2.4%)the trapped ones. Table 15 shows the species composition of rodent pests and their relative abundance in maize farm.

Table 15. Species composition and relative abundance of rodent pests in maize plantation.

Species	Total catch	Total catch by live-trapping (%)	Total catch by snap trapping (%)
<i>A. dembeensis</i>	106	81(53.7)	25(43.8)
<i>M. natalensis</i>	97	68(45.0)	29(50.9)
<i>M. musculus</i>	5	2(1.3)	3(5.3)
<i>H. cristata</i>	*	*	*
Total	208	151 (100.0)	57 (100.00)

* = Observed pest species

The trapped rodents were recognized as a pest as revealed from the stomach content analysis and the damaged maize crops from the field. Figure 8 shows the composition of maize seed fragments in relation to other food items in the stomach content of the three rodents

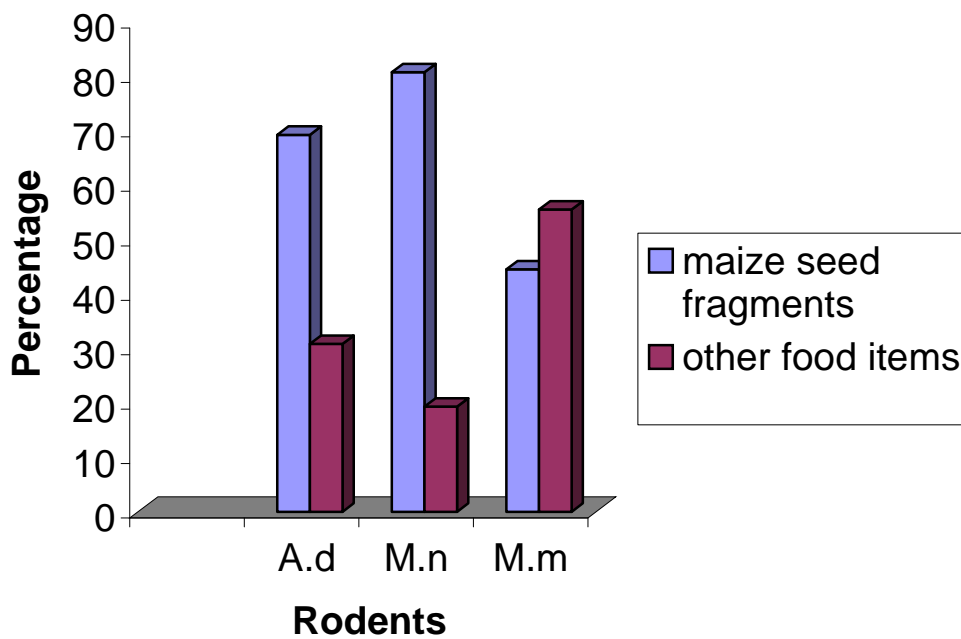


Figure 8. The content of stomach analysis of rodent pests (maize seed fragment and other food items) (*A.d* = *A. dembeensis*, *M.n* = *natalensis*, *M.m* = *M. musculus*)

The percentage of maize seed fragments statistically significant ($p < 0.01$) from species to species. The maize fragment was high in *M. natalensis* (80.7%), followed the stomach content of *A. dembeensis* (69.2%) and *M. musculus* (44.5%). However, maize fragments were less than other food contents in the stomach of *M. musculus*.

5. 4. Assessment of maize crop damage by rodents

Maize crop damage estimate was carried out on the plantation of farmland. Table 16 shows the estimated damage of maize crop from two randomly selected different hectares. Damage frequency was statistically significant ($P < 0.01$). High loss was recorded from the periphery hectare (61.7%) and less from the central sampled area (38.3%) of the maize plantation.

Table 16. Damage estimate from the two hectares of maize plantation.

Damage status	Site of the damaged areas		Total average
	H _{1P} (individuals)	H _{2C} (individual)	
Fully damaged	321(321)	203 (203)	262
Half damaged	817(408.5)	429 (214.5)	311.5
One-fourth damaged	1326(331.5)	957(239.3)	285.4
Total individual damaged	1061	656.8	858.9
Percentage of loss	7.10%	4.40%	5.70%

H_{1P}= hectare₁ peripheral, H_{2C} = hectare₂ central.

6. DISCUSSION

6.1. Species composition and distribution

During the present study, the recorded composition of small mammal fauna of the study area was 14 species of rodents and two species of insectivores. Among the result of trapped rodents, 11 and 7 rodent species were trapped from natural habitats and farmlands, respectively. *A. cahirinus*, *L. striatus*, *T. robusta* and *G. dolichurus* were not recorded from farmlands. However, the remaining species were common to both habitat types. Similar study in NNP (Arbaminch forest) by Duckworth *et al.* (1993) recorded eight species of rodents and two shrews (only from forest). However, *L. striatus* was recorded as observed species in their survey and the absence of *T. nigricauda* in the present study by both snap trap and live-trap surveys was unfortunate. This might be due to habitat variation; types of traps used and related factors. But, additional three species, *T. robusta*, *M. erythroleucus* and *M. musculus* were captured from the forest.

Mastomys natalensis was a common rodent in most parts of west, central and east African countries (Lavernchenko *et al.*, 1998). They also distributed widely over most Ethiopian regions (Buckworth *et al.*, 1993; Yalden *et al.*, 1996; Afework Bekele & Liers, 1997; Bulatova *et al.*, 2002 and Tadesse Habtamu, 2005). Similarly, it was also the most widely distributed and abundant rodent species in the present study area. It occurred in all six surveyed habitat types. This species is the

major rodent pest in African farmlands. It was also recorded as the major rodent pest in the maize crop plantation.

Mastomy erythroleucus is a wide spread rodent in Ethiopia. It was recorded by Afework Bekele & Leirs (1997) from central Ethiopia (Ziway), Bulatova *et al.* (2002) from Gambela and Tadesse Habtamu (2005) from Alatish Proposed National Park. In the present study area, it was the second widely distributed rodent species. This species occurred in all habitat types except in maize plantations.

Arvicanthis dembeensis is a common rodent Ethiopia. Most the studies have revealed the existence of this species in different parts of Ethiopia. Afework Bekele (1996b) from Menagesha Stae Forest usually at 2200 m asl. Afework Bekele & Leirs (1997), from Ziway maize farm and Bulatova *et al.* (2002) from Gambela. During the present study, it was recorded as the abundant species (next to *M. natalensis*). The species occurred in DBL, LAS, MP, and CP. Moreover, it was recorded as the second important rodent pest in the maize plantation. Similar studies by Afework Bekele & Leirs (1997), and Workneh Gebresilassie *et al.* (2004) revealed as a pest rodent in maize farm at Ziway and in Maynugus irrigation field, respectively.

Acomys cahirinus was known to be primarily savannah species by Kingdon (1997). Sokolov *et al.* (1993) also revealed as it was a common rodent in sandy deserts and semi-desert regions from sea level to 1500 m asl. However, during the present study, it was a commonly trapped rodent from natural forests (GWF, RF, DBL, and LAS). The species was not recorded from farmlands (MP and CP).

Stenocephalemys albipes was commonly trapped from GWF, DBL and LAS by both trap types during this study period. But, it was trapped from RF and MP by snap traps only. It was not trapped in the cotton plantation. Similar study by Yalden (1988a) found this species common in the Bale NP, Chenchu and Bulta Bonke near Arbaminch. It was recorded as one of the endemic rodent species of Ethiopia (Yalden, 1988b; Duchworth *et al.*, 1993; Afework Bekele, 1996a, b; Bulatova *et al.*, 2002). It was also noted as a common rodent in Menagesha State Forest and widely distributed in Ethiopia mainly in Montane areas. At the same time, there are also many mapped collection sites close to the Rift Valley Lakes.

T. robusta and *L. striatus* were the least distributed species in the study area. They only occurred in Lake Abaya shore and in deciduous bushland. *L. striatus* was highly abundant in LAS than DBL, whereas *T. robusta* was less abundant in both habitats. Bates (1988) observed the distribution of *T. robusta* from some part of Sudan and Kenya. It was also commonly distributed in southern Ethiopia (Rift Valley and Omo Valley). These mostly occurred in the altitudinal range of 200-1700 m asl. (Yalden, 1988b) and central Ethiopia (Afework Bekele & Leirs, 1997) as well as from Koka (Tilaye Wube, 1990). In the present study, the species was recorded at altitude between 1100 and 1160 m asl.

Arvicanthis niloticus was also common in Ethiopia, mostly recorded from Gambela and lower Omo Valley by Bulatova *et al.* (2002). In the present study, the species was recorded commonly from DBL, MP and CP by both traps. They were also captured by live traps in the riverine forest, but not from GWF and LAS.

Grammomys dolichurus was confirmed to occur in Ethiopia by Yalden *et al.* (1976) and in Arbaminch by Duckworth *et al.* (1993). This study also recognized it as it was less common and with a restricted distribution in the study area. It was only recorded from RF and LAS. Snap traps also trapped it from GWF. But, they were not captured from other surveyed habitat types.

Mus musculus has a wide distribution in Ethiopia. Yalden (1988a) described the occurrence in open habitats between 1510 and 3000 m asl. In the present study, it occurred at an altitudinal range between 1100-1212 m asl. of the study area. The species was recorded mainly from farmland (MP) and few only from CP and DBL. This species was recorded as one of the rodent pests of maize crops in farmlands.

Mus tenellus was the least abundant and least distributed rodent species in the study area. Surprisingly, it was only trapped by snap traps. This might be due to their small size in addition to small population size at different habitat types.

Generally, the distribution of species varied from species to species. *M. natalensis* was the most widely distributed species in all habitat types, whereas *L. striatus*, *T. robusta* and *M. tenellus* were the least distributed and least abundant species in all the habitats.

6.2. Habitat Association

The species composition and abundance varied in different localities and habitat types of the study sites. Most rodent species were recorded from natural habitats than farmlands during the study period. Farmlands usually harbour higher number of rodent pests than natural forests. For instance, *M. natalensis*, *A. dembeensis* and *M. musculus*

were more numerous in farmlands than in natural forests. However, species such as *L. striatus*, *G. dolichurus*, *T. robusta* and *A. cahirinus* were only collected from natural forests during the study period (Table 3). Some species occurred in both habitat types and others are restricted to only natural habitats with variable microhabitats. *M. natalensis* occurred in all habitat types while other are restricted to few habitats with variable number.

Variable species richness in different vegetation zones was revealed by Delany (1964) for Uganda, Bond *et al.* (1980) for South Africa and Afework Bekele (1996b) for Ethiopia. Species richness and their habitat association in the present study area are comparable to similar studies in other regions. The higher preferences of natural habitat by most rodents than farmlands might be due to homogeneity of agricultural habitats, whereas natural habitats are heterogeneous. Happold & Happold (1989b) stated that most small mammals exhibit a well-developed preference for one habitat or combination of other habitats.

For habitat selection and distribution of rodents in the study area, food quality as well as food availability may be an important determining factor, because in this study area there is no significant altitudinal variation between each habitat (Table 7). However, the present study revealed great variation in number of species and abundance of rodents from habitat to habitat types. In addition, cover is also an important regulating factor. Taylor & Green (1976) found that cover removal depleted most species of rodent populations. Increased predation was also an obvious result of cover removal. The place where the species occurred in high abundance was also a place where there is enough cover as well as adequate food. This suggests that species can be rare if their preferred microhabitat or resource is limited, but common if their preferred resources are abundant.

Habitat complexity has been found to influence rodent communities and densities. Similarly, Scott & Dueser (1992); Adler (1995); Shanker (2001) and other studies have shown the role of habitat complexity and heterogeneity in structuring small mammal communities. They stressed that habitat selection may be more important than inter-specific competition. Among the six different habitat types of the study area, the most preferred one is the deciduous bushland. Out of the eleven trapped rodent species by both trap types, all except one species (*G. dolichurus*) were captured from this habitat type. The second preferred habitat with high number of species was Lake Abaya shore. It possessed 8 rodent species (Table 3). The present study shows that habitat selection of these species of rodents was due to diversity of food and microhabitat of the habitats as noted by Fiedler (1994), Delany (1986) and Afework Bekele *et al.* (1993).

The species composition and abundance in the two natural habitats (ground water forest and riverine forest) was very poor. Only few species were captured from these habitats. This shows that they have low species diversity. This might be due to the homogeneous vegetation that is dominated by few species of tall trees. In addition, the underground habitat is open or less covered resulting in shortage of cover, food and diversity of microhabitats.

The farmlands were also less preferred by most rodent species of the study area, except rodent pest species. Because this habitat was fairly homogeneous, commonly dominated by maize or cotton plants. Among the rodent species, *M. natalensis*, *A. dembeensis* and *M. musculus* were recorded in high number from this site, especially before harvest. This may be due to the high productivity of the crops. Farmers attempt to increase soil fertility and water availability by adding fertilizers and

irrigation, respectively. As a result, enough amount of energy rich-food crop and few weeds become available to agricultural pests like *M. natalensis* and *A. dembeensis*. Afework Bekele & Leirs (1997) noted that *T. robusta* was observed in natural habitats but high in number in maize field during the dry season in central Ethiopia. However, during the present study *T. robusta* was not captured agricultural areas during both dry and wet seasons.

Generally, the overall trend shows that densely covered habitats with high diversity of plant species were preferred by most rodent species in the present study area. However, the distribution of *M. natalensis* is unique in occurring in all habitats at variable numbers. This may be due to its natural adaptability as revealed earlier (Taylor & Green, 1976). It was shown that from experimentally removed vegetation, *M. natalensis* was less responsive than other rodent species.

6.3. SEASONAL DISTRIBUTION, SEX RATIO AND BODY MEASUREMENTS

In the present study, most rodents trapped from the study area show that there was a significant variation in population size, sex ratio and body measurements. Each season shows variation in the habitat types. This results changes in food availability, cover and other related factors and overall species composition and ecology of rodents. As noted by many researchers, the effect of habitat change varies between species (Emmons, 1984; Pahl *et al.*, 1988). Therefore, even some species that occur in one season might not show up in the next or other seasons. Some animals might be specialists on a particular vegetation type (Emmons, 1984). For instance, *A. niloticus* was not trapped during the

day season (August, 2005) and *S. albipes* and *M. musculus* during the dry season (January, 2006).

The sex ratio of most species did not vary significantly. However, the present study revealed that the number of females increases along with the increase in the abundance of that species. This shows that population size might follow the pattern of increase in number of fertile females.

For some species, variation in age distribution was observed from season to season during the study period (Table 6). According to Okia (1973), the period following the dry months was characterized by few pregnant females. In the present study, the number of pregnant females and juveniles (young) were high in number during the wet season, and less during the dry season. Even for abundant species (*M. natalensis* and *A. dembeensis*), pregnant and young individuals were rarely trapped during the dry season during the present study period. This shows that breeding of most of the rodent species was during the wet season. However, this is exceptional to *Acomys* species that had more young individuals during the dry season than the wet season. Generally, the common feature of most rodent breeding patterns is that they are centered on a rich food season. Since, rainfall is seasonal, the variability of food varies. Thus, result is consistent with numerous other studies that showed breeding patterns for many African rodents to be related to rainfall (Sicard & Fuminer, 1996).

The result of the body measurement (Table 10) shows a significant decrease in body weight for most of the rodents during the dry season. It might be related to shortage of food, both in quality and quantity. Similar result was observed by Taylor & Green (1976). This might be related to the limited availability of food sources during the dry season

than wet season. Similarly, except *Acomys*, the number of embryos of most species decreased during the dry season. For instance, in *M. natalensis* only five embryos (2 from right and 3 from left horns) were counted during the dry season. However, the count was never less than seven during the wet season.

6.4. Trap success and activities

The trap success was significantly different from habitat to habitat and season to season (Table 7 and 8). Different factors might be affecting the trap success of each habitat. The overall trap success of the six habitats varied from habitat to habitat and from season to season. The lowest success was obtained from ground water forest, whereas the highest from maize plantation by both types of traps during the study period. The recorded lowest success was 4.6% and highest was 26.2% from ground forest and maize plantation, respectively. Seasonally, the highest trap-success was recorded from maze plantation (33.3%) and the lowest from riverine forest (1.4%) during the dry season and the wet season, respectively (Table 8). In terms of the study sites, the highest success was from LAS (24.1%), followed by 23.2% from farmlands and 11.6% from Arbaminch Forest. The average total trap success was 17.6% for live-trapped and 10.9% for snap-trapped rodents from the study area. Similar studies in different parts of Ethiopia obtained 19% trap success (Yalden, 1975) from the high altitude locality of south Goba. In addition, Yalden (1988a) achieved 18.7% mean trap success from Haremma Forest, south Ethiopia. There are differences between trap success based on variations of habitats (Sillero-Zubiri *et al.* 1995; Afework Bekele, 1996a).

Trap success is influenced by many factors. For example, rain can significantly increase the capture rate from forest (George, 1984;

Sidorowicz, 1974). However, in the present study, the trap success rate was high during the dry season. This might be due to seasonal fluctuation. Smith & Blessing (1969) stated that food availability could affect trap success. When more food is available in the habitat, capture rates may decrease significantly. Low population density also affects significantly.

The activities of animals also determine trap success. For instance, diurnal activity is one of the factors contributing for the success of the rodent species. The shy mammalian predators rarely hunt during the day in some habitats. Some rodents (*A dembeensis*) are more frequently trapped and observed in human habitation areas and farmlands during the study period. The activity pattern of species should also be considered when setting traps, since some species of rodents are diurnal and others are nocturnal and still some display bimodal patterns.

6.5. Population estimation

Population density estimation of rodents using mark recapture method is given in Figure 7. During the study period, the population of most rodent species declined during the wet season and increased during the dry season. Similar population trend was reported by Gliwicz (1985); Happold & Happold (1991), Linzey & Kesner (1996) and Tadesse Habtamu (2005) from some Africa countries including Ethiopia. The causes of population fluctuation of rodents are variable. As different investigators noted food quality and abundance, habitat cover, weather condition and predation have a great role (Fernandez *et al.*, 1996). During present study, the population fluctuations observed between seasons may be mostly attributed to variation in line with reproductive patterns and related factors (food). During the wet season

trapability of rodents is exceptionally low. This might be due to bait used becoming unattractive as a result of plenty food in the vicinity. Wet period is a season of reproduction for most rodents. The study showed high number of pregnant and young rodents probably limiting trap success as seen in Mozambique (Gliwicz, 1985). This shows that the young rodents may not reach for trapability. Population estimate shows that *M. natalensis* and *A. dembeensis* have high population densities in both seasons.

6.6. Diet analysis

Information obtained from feeding analysis on rodents is the main ecological parameter to study the food preference, habitat association, seasonal fluctuation and the pest status of rodents. Based on the food preferences, one can predict control measures and management programs for the concerned species. However, the feeding ecology of small mammals throughout the world is highly diverse (Campos *et al.*, 2001). Most species of rodents appear to be opportunistic in their feeding habit (Johnson, 1961). The present study also supports this view. The result of this study shows clearly that the six species of rodents studied for stomach contents were omnivorous and granivores. However, differences in the proportion of both major food groups and specific plant and animal species consumed varied temporally and spatially for each rodent species. Studies that attempt to infer diet by analyzing the contents of stomachs or faeces suffer from a number of problems (Campos *et al.*, 2001). For example, the importance of food items that are more rapidly digested may be under estimated (Putman, 1984; Kronteld & Dayan, 1998), while some consumed only in small proportion may be over estimated when consumption is measured in terms of frequency of occurrence (Reynolds & Aebischer, 1991). In addition, more frequency of consumption of a particular food does not necessarily reflect the importance of that food in terms of its nutritional

benefits (Roper & Mickeuicius, 1995). In the present study, only stomach contents were analyzed. Because, some ingested food items (small or soft-bodied arthropods and easily digested plant materials) digest completely, leaving no evidence in the faeces and difficult to identify.

The content for stomach analysis was taken only from snap traps. This is because of the trapped animals die before they consume the bait. However, in live trapping, the bait will be consumed by rodents making it difficult to wash the contents in order to distinguish the natural diet. During the present study, identification of arthropods was carried out from the contents of head, legs and wings. Even though, identification of each part of the content as the whole at a species level was difficult.

The result of the stomach content analysis showed that regardless of the frequency difference, all examined rodents consumed plant matters and arthropods during both seasons. However, earthworms were recorded at high frequency for *A. cahirinus* during the wet season. This was not recorded from *A. dembeensis*, *L. striatus* and *T. robusta*. *A. dembeensis* usually preferred dicot plant matters during the wet season and depended more on monocot plants during the dry season. Taylor & Green (1976) reported that *Arvicanthis* switched its diet dramatically first to dicotyledon plant and then almost completely to grasses during the wet and dry season, respectively. Few root fragments and no earthworms were observed from the stomach contents of *A. dembeensis*. *M. natalensis* mostly preferred monocot plants in both seasons. However, unlike others, they feed on all types of described food items. This might be an indication for its success in being distributed widely. *L. striatus* and *T. robusta* showed similar feeding patterns. Unlike others, both species have more seeds during the wet

season than the dry season. Root was absent from the stomach contents of both species. However, *Lemniscomys* was observed to be highly dependent on insects during the wet season. In *M. musculus*, except the absence of root in the diet, there was no significant change in feeding during both seasons.

In the present study, the result of diet analysis based on reproductive conditions of four abundant species showed that adult males fed on diverse types of food items. In the case of pregnant and lactating females, in both *M. natalensis* and *A. cahirinus*, there was no significant change in food preferences. However, the stomach content of *A. dembeensis* and *L. stiratus* had no earthworms. Generally, seeds, leaves and arthropods were the main diet components of all the rodent species at different reproductive conditions. However, the proportion of contents of each species varied significantly.

6.7. The effect of pest rodents on maize crops

During the present study, crop damage assessment was carried out at the pre-harvest stage (a week before harvest). As shown in Table 16, the common pest rodents of maize crops were *M. natalensis*, *A. dembeensis* and *M. musculus*. The stomach content analysis showed that *M. natalensis* consumed the highest Quantity of the grain followed by *A. dembeensis* and *M. musculus* (Fig. 8). The above rodent species were earlier recorded as major pests in most parts of Africa including Ethiopia. The multimammate rats (*M. natalensis*) and *A. dembeensis* are the most noxious Muridae pests in eastern Africa (Fidler, 1994; Leirs *et al.*, 1996). *Mastomys* as a pest in Ethiopia was documented in maize fields (Afewerk Bekele & Leirs, 1997) from Ziway maize farm. The damage and the dietary results confirm that adjacent non-crop habitats

play an important role in crop damage of maize plantations. The damage as well as the number of the first two pest rodents were mostly seen at the periphery rather than inside the plantation. This might be due to the diverse habitat type (high heterogeneity) of the marginal areas, whereas in the central areas of the maize plantation, the habitat was dominated by maize (highly homogenous) except a few weed species.

These studies also showed that a close relationship exists between the disturbances caused by farming activity in the field and the population dynamics of the rodents in the farmland. Plowing has both direct and indirect effect on animals by destroying their refuge (habitat cover), food resources and exposing the animals to predators. Similarly, some studies have shown that the reduction of shelter exposes small rodents at increased predation risk (Jacob & Brown, 2000; Sheffield *et al.*, 2001). The present study at Arbaminch farmland shows that during land preparation and after harvest, the population of rodents highly decreased. This might be due to the harvesting maize crop and plowing the field that removed much of the food. Generally, the result of damage estimation from the two hectares (one periphery and one inside) shows that pest rodents caused a damage of about 5.7% in maize plantation. However, the damage was high at the periphery (7.1%) and low in the center of maize plantation (4.4%). This shows that rodent distribution is determined by microhabitats rather than macrohabitats. At the same time, heterogeneous cover is a preferred habitat to harbour different species of rodents.

The problem of pest rodents in cotton plantations was not observed as such, unless few cotton seed fragments was counted in the stomach contents of pest species. Therefore, the damage assessment for cotton crops was not carried out from the study area.

7. CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

Sixteen species of small mammals were recorded from six randomly selected habitats. Out of these, fourteen (11 trapped and 3 observed) species were rodents and 2 were shrew species. Except *M. tenellus* all were trapped by both snap traps and live traps. In the present study, three rodent species (*T. robusta*, *M. erythroleucus* and *M. musculus*) were recorded from the forest as new for the area.

Determination of habitat preferences was facilitated by the opportunity to observe the distribution of species at different seasons and habitats. Generally, natural forests (DBL and LAS) harbour more number of species than the others. On the other hand, GWF and RF were less in having few types of species among the surveyed habitats during the study period. Except variation in number, *M. natalensis* differed from the other species in having equal preference for all different habitat types.

Based on stomach content analysis, most species of rodents appeared to be opportunistic in their feeding, subsisting on a variety of different

food items when available. Generally, during the dry season most of the rodent species relied highly on the seeds of plants and arthropods were usually taken during the wet season.

In farmlands four species (*M. natalensis*, *A. dembeensis*, *M. musculus* and porcupine) were recorded as a major pest of maize crops. They caused a total of about 5.7% damage on maize crops. The present study has shown that rodent pests were not uniformly distributed in maize farmlands. Therefore, the pattern of rodent pest distribution may be attributed to proximity to the habitat diversity except in *M. natalensis*. Therefore, the present study is an attempt to obtain information on different parameters of the ecology of rodents in habiting natural forests, and farmlands. Therefore, it provides important information on ecology and effect of rodents in the study area as well as conservation measures of the Arbaminch Forest and farmlands (crops). However, further detailed study with prolonged duration is likely to yield more information on the ecology of specified species. In addition, studies on population ecology of rodent community and their effect on crops are still poorly known for many regions of Ethiopia. Therefore, these also need attention.

7.2. Recommendations

The data collected provide valuable information on the ecology of rodents as well as the pest problems in Arbminch Forest and farmlands. The habitats as well as the species have great biological and social values. Therefore, to maintain the vegetation and the rodent species, the following suggestions are forwarded:

- ◆ Arbaminch Forest is attractive and is part of the ecologically important natural forest of Nechisar National Park (NNP). It plays a

great role for the existence of many animal species and even for the people of Arbaminch town, especially by maintaining the water table of the spring (forty spring) where the people get water for domestic purposes. However, previously the problem of deforestation (for building, fuel and domestic uses) was very high. At present, even if some problems still exist, the work of African Parks (AP) is being appreciated for their good conservation practice. This helps the existence of the species as well as the people around. Therefore, AP should be encouraged and recommended to continue their conservation work through community participation. The people should also realize that there is no further life in Arbaminch town without Arbaminch forest. The forest helps them in maintaining the ecological conditions by reducing temperature, providing fresh air and maintaining the water resource quality. Therefore, the locals should help and work with African Parks in all conservation areas.

- ◆ Since the studied species and others have a great economic value, the need for further work should be emphasized. Additional research should be carried out to get detailed information on the ecology of each species.

- ◆ Management of pest rodents on crops should not rely on a single technique. Therefore, Integrated Pest Management (IPM) such as rodenticides, biological methods of controlling pest rodents is very important. At present, the study investigated the relationship between rodent densities and damage as well as yield loss. However, to decide how and which useful strategy is important, assessment of the cost of control measures with the cost of damage is important. As observed during the present study, the following measures are important:

- Clearing the habitat around the farm areas and removing the weeds in the maize plantation. This will increase the vulnerability of rodents to predation. Therefore, it decreases the effect of high migration of pest rodents from surrounding area to the maize plantation.
- Harvesting the crops earlier on time before touching the ground, which easily exposes the crop to the pest rodent.
- Undergo further continuous research to identify the intensity of damage and predict pre-control measures.
- The damage caused on cotton plantation is immense. This needs further investigation.

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a



b

Plate 1. a & b vegetations of deciduous busland and Lake Abaya shore, respectively.



a



b

Plate 2. a & b Farmland vegetations of maize and cotton plantation ,respectively.



a



b

Plate 3. a & b damaged of maize seeds and illegally collected fire wood, respectively

DECLARATION

This thesis is my work, has not been presented for a degree in any university and that all sources of material used for the thesis have been duly acknowledged.

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