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Species Composition, Distribution, Relative Abundance and Habitat Association of Small Mammals in Denkoro Forest, South Wollo, Ethiopia

By

Eshetu Moges

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Advisors: - Prof. Afework Bekele

Dr. Zelealem Tefera

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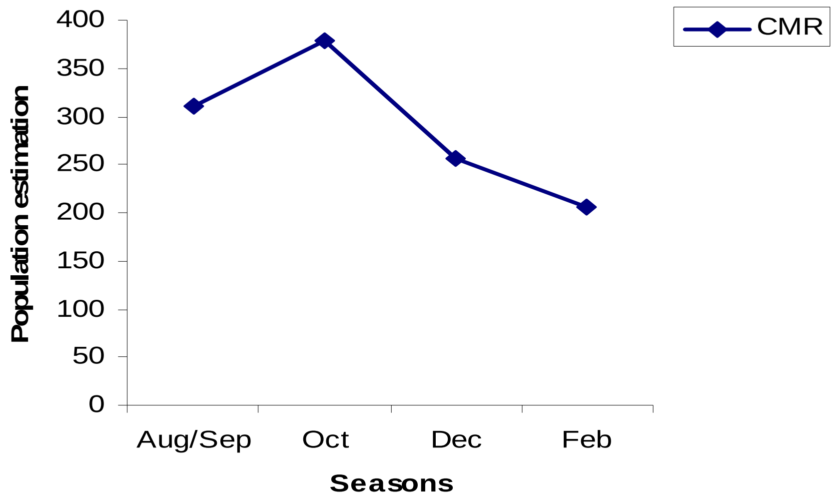

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ABSTRACT

A study on the ecology of small mammals was carried out in Denkoro Forest Priority Area from August 2007 to February 2008. Five trapping grids were randomly selected based on the representative habitat types; open grassland, moorland, *Lobelia* with *Hypericum,* montane forest and farmland. Both live and snap traps were used to capture small mammals. Seven hundred and Ninety three live trapped individuals were captured in 2,940 trap nights. Moreover, a total of 78 individuals of snap trapped small mammals were also captured in 1,500 trap nights. Ten species of small mammals belonging to rodents and insectivores were captured. Additional two rodent species were sighted but not captured. The small mammals trapped were: *Lophuromys flavopunctatus* (35.7%), *Otomys typus* (28.5%), *Stenocephalemys griseicauda* (14.6%), *Arvicathis dembeensis (*9.1%), *Stenocephalemys albipes* (1.9%), *Pelomys harringtoni* (0.8%), *Mus mahomet* (0.6%), *Dendromus lovati* (0.3%), and insectivores represented, *Crocidura flavescens* (5.9%) and *Crocidura fumosa* (1.4%). Population abundance and species composition of small mammals varied from habitat to habitat and from season to season. *L. flavopunctatus* and *O. typus* were the most widely distributed and abundant species, whereas *S. albipes*, *C. fumosa* (in the forest), *P. harringtoni*, *D. lovati* and *M. mahomet* (in the farmland) were restricted. Reproduction was high during the wet season. Analysis of the stomach contents of snap trapped small mammals showed plant matter was the common food items. Out of the ten rodent species recorded in the study area, *A. dembeensis, M. mahomet* and *Hystrix cristata* were recognized as pest rodents on wheat farm.

Key words: Denkoro Forest, habitat association, insectivores, rodents, species composition, Wollo

1. INTRODUCTION

Mammals are diverse group of vertebrates and range in size from whales to mice (Kingdon, 1971; Delany and Happold, 1979). Small mammals form a major proportion of the mammalian fauna and among them rodents comprise approximately 43% with 29 living families, 443 genera and about 2004 species (Vaughan *et al*., 2000; Danell and Aava–Olsson, 2003). Rodents are an old group, dating back from the late Paleocene, but at present, they comprise a very successful group with cosmopolitan distribution from the coldest to the driest area of the world (Kingdon, 1997). Rodents show considerable diversity in morphology, habitat utilization, behaviour, and life-history strategies (Sewnet Mengistu and Afework Bekele, 2003)

Rodents have influenced humans more than other groups of mammals, and are often in close association with man (Macdonald, 1984). However, the systematic and many aspects of the biology of these animals are unknown or inadequately documented (Afework Bekele, 1986, 1995; Capula *et al.,* 1997).

The extent of abundance and distribution of rodents depends mainly upon the nature and density of vegetation for food and shelter (Gubista, 1999). The pattern of movement of rodents changes from time to time based on seasons and on the availability of essential resources (Taylor and Green, 1976). Seasonal movements of small mammals are mostly in search of food, and also it may be in relation to the breeding patterns (Delany, 1964).

The reproductive pattern of rodents generally follows seasonality in relation to variations in rainfall and peaks at the end of the rainy season when resources are plenty (Workneh Gebresilassie *et al*., 2005). As a result, the nature and density of vegetation determine the abundance and distribution of small mammals and in line with this, rodent density in a given area correlates with the availability of food resources (Cole and Batzli, 1979; Workneh Gebresilassie *et al*., 2006). In general, the seasonal changes can have important effect on demography and population dynamics of small mammals (Merritt *et al*., 2001).

Although Africa is impoverished in many taxa, compared with other tropical regions, it hosts the highest number and diversity of mammalian species in the world. Currently over 1,150 species of mammals are listed for Africa (Clausnitzer, 2000) belonging to 13 orders and 50 families. The fauna is more diverse than that of any other continent except South America (Delany and Happold, 1979). The continent possesses high diversity of small mammals as well. In Africa, rodents are among the most ubiquitous and numerous mammals, in both species and individual numbers. These are grouped in 89 genera and 290 species. In East Africa, they account for about 28% of the total mammal species (Clausnitzer, 2000), with 62 genera and 161 species. In this region, the occurrence of several new cryptic species has been recorded, showing the genetic diversity linked with little morphological variation (Kessing, 2000; Fadda *et al.,* 2001).

Rodents are important components of the earth's terrestrial ecosystem (Ecke *et al*., 2002). Some are important herbivores that aerate the soil by burrowing activities and assist plant propagation by consuming and disseminating seeds (Rosi *et al*., 1996). Others form the most important food base for many mammals and birds (Moore *et al*., 2003). However, rodents are also important vectors or reservoirs of numerous diseases that infect human, domestic animals and other wild life species (Sewnet Mengistu and Afework Bekele, 2003; Tobin and Fall, 2004). Specifically, rodents are the most important group of mammals in agriculture, horticulture, forestry and public health. They also show a wide range of adaptation, enabling them to successfully colonize and inhabit almost any type of habitat (Makundi *et al*., 1999). Although there are about 2000 species of rodents, only a few of them are agricultural pests (Manyingrew Shenkut, 2006).

In Africa, only 77 species are reported to cause damage to agriculture and most of the harmful rodents are members of the family Muridae (Ducroz *et al*., 1997; Workneh Gebresilassie *et al*., 2006). The family Muridae alone consists of 267 recent genera and 1,138 species, by far the largest mammalian family (Nowak, 1991). In East Africa, several rodent species are responsible for substantial damage to food, cash crops, structures, industrial and domestic property (Leirs, 2003; Tsegaye Gadisa and Afework Bekele, 2006).

Rodent damage is a major cause of harvest loss, mainly in cereal crops, and most of the damage occurs during the sensitive young seedling stage and just before harvest (Stenseth *et al*., 2001). Reliable quantitative assessments of crop losses caused by pests are required to quantify the magnitude of pest problems. Many sampling techniques have been employed for rodent damage estimation at different locations and for different crops (Mulungu *et al*., 2007).

In Ethiopia, comprehensive studies on the effect of rodent damage to agricultural crops are lacking, and there are limited or few quantified estimates of the crop yield that is lost to rodents (Afework Bekele *et al*., 2003)

Despite the often negative effects of rodents in natural and modified ecosystems, many species have been shown to contribute to ecosystem function and to have value as indicators of environmental changes (Dickman, 1999; Mahlaba and Perrin, 2003). For example, microtine rodents are important at times in the cycling of carbon, nitrogen and other elements (Fiedler, 1990). Beavers cause alteration of hydrological regimes. Other species may be important as pollinators or vectors of fungal spore (Bpatist and Mensah, 1986).

Rodents comprise a substantial portion of the wild game as human diet (Assogbadjo *et al*., 2005). In the United States, mostly squirrels but also muskrat (*Ondatra zibethicus*), particularly in the Midwest, porcupine (*Erethizon dorsatum*), and ground hog (*Marmota monax*) are eaten by humans (Den Hartog and De Vos, 1973). Muskrat is also eaten in the Netherlands and Belgium, and elsewhere in Europe, squirrels, beavers, marmots and dormice are consumed (De Vos, 1977).

About 75% of the African population below the Sahara depends on traditional source of protein. In West Africa, as much as 73% of meat comes from wild animals of which the grasscutter is the most popular rodent (Baptist and Mensha, 1986). In southern Africa, Zimbabwe, Zaire, Zambia, Botswana, and South Africa, different species of rodents are consumed such as cane rats, porcupines and yellow-footed squirrels, (Fiedler, 1990). In Ethiopia along the western border, mice and giant rats are consumed (De Vos, 1977). In the Sudan, Nile rats (*Arvicanthis niloticus*) and field mice are important food items (Den Hartog and De Vos, 1973).

Rodents also play a role in seed dispersal. Many seeds and nuts are dispersed by seed-catcheing rodents (Vanderwall, 2003). In the temperate forests, rodents hoard seeds of woody plants as food for wintering and some of the seeds can over-winter without predation by the hoarders and subsequently establish seedlings in the following year (Wada and Uemura, 1994). Moreover, in the Neotropical forests, seed dispersal and recruitment of some plants depend to a large extent on large caviomorph rodents such as Acouchies and Agoutis (Forget, 1990).

Thus, seed-eating rodents affect forest regeneration considerably by dispersing seeds and determining the micro-distribution of some plant species.

Small mammals consume plants, lichens, fungi, and invertebrates (Ecke *et al*., 2002), and they mainly consume animal matter, roots, tubers, fruits, seeds, and cereals (Kingdon, 1997). Compared to other rodents, multimammate rats are the most successful seed and cereal feeders (Green *et al*., 1980; Leirs *et al*., 1993; Workneh Gebresilassie *et al*., 2004).

Diets are extremely significant for determining evolution, life-history strategies, and ecological roles of animals (Kronfeld and Dayan, 1998). 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 (Krebs, 1989). Also study of diets of animals is crucial for understanding relationships between species and between an animal and its environment. This relationship mainly determines community structure, species diversity, relative abundance, and resource partitioning among species and individuals.

A characteristic topographical feature of eastern Africa is the chain of isolated mountains and plateaux, which stretch from Ethiopia in the north to the Drakensberg Mountains in the south. The high plateux of Ethiopia are over 4000 m asl with extensive high peaks (Happold and Happold, 1989). The Abyssinian plateau constitutes the northern end of the highlands of eastern Africa and it is largely cut off from the highlands of Kenya by a semi-desert. In general, in sub-Saharan Africa, at least 80% of the land above 3000 m occurs in Ethiopia. This altitudinal variation has an important effect on temperature, rainfall and vegetation, playing a major role in determining the mammalian fauna distribution (Sillero-Zubiri *et al*., 1995a; Afework Bekele *et al*., 2003).

The Ethiopian region possesses a diverse fauna and contains 23% of all the mammalian species (Danell and Aava-Olsson, 2002). At present, 284 mammalian species have been recorded from Ethiopia, of which 11% are endemic. Ethiopia is second only to Madagascar for mammalian endemism in Africa (Yalden and Largen, 1992; Hillman, 1993). The small mammal fauna is particularly diverse. So far, 84 species of rodents have been recorded from Ethiopia of which 21% are endemic (Afework Bekele, 1996a; Sewnet Mengistu and Afework Bekele, 2003). Among the nine families of rodents that occur in Ethiopia, the family Muridae comprises 57 species (84%) and 93% of the total endemic rodents. In general, 50% of the Ethiopian endemic mammals are rodents (Afework Bekele and Corti, 1997). This is mainly determined by the diversity characterizing the country, as a consequence of high altitudinal ranges, from below sea level upto more than 4620 m asl.

The central highlands of Ethiopia are parts of these highlands, mainly confined in south Wollo and north Shewa, and the present study site Denkoro forest is a parcel of the central highlands.

This area harbours different species of avian and small mammal fauna (Lakew Berhanu *et al*., 2007). In this area, studies on small mammal fauna are non-existant. The aim of the present study is to identify the species composition, distribution and habitat association of small mammals.

2. OBJECTIVES OF THE STUDY

2.1 General objective

The general objective of the study is:

- ❖ To carry out studies on species composition, distribution, abundance and habitat association of rodents in Denkoro Forest.

2.2 Specific objectives

The specific objectives of the study are:

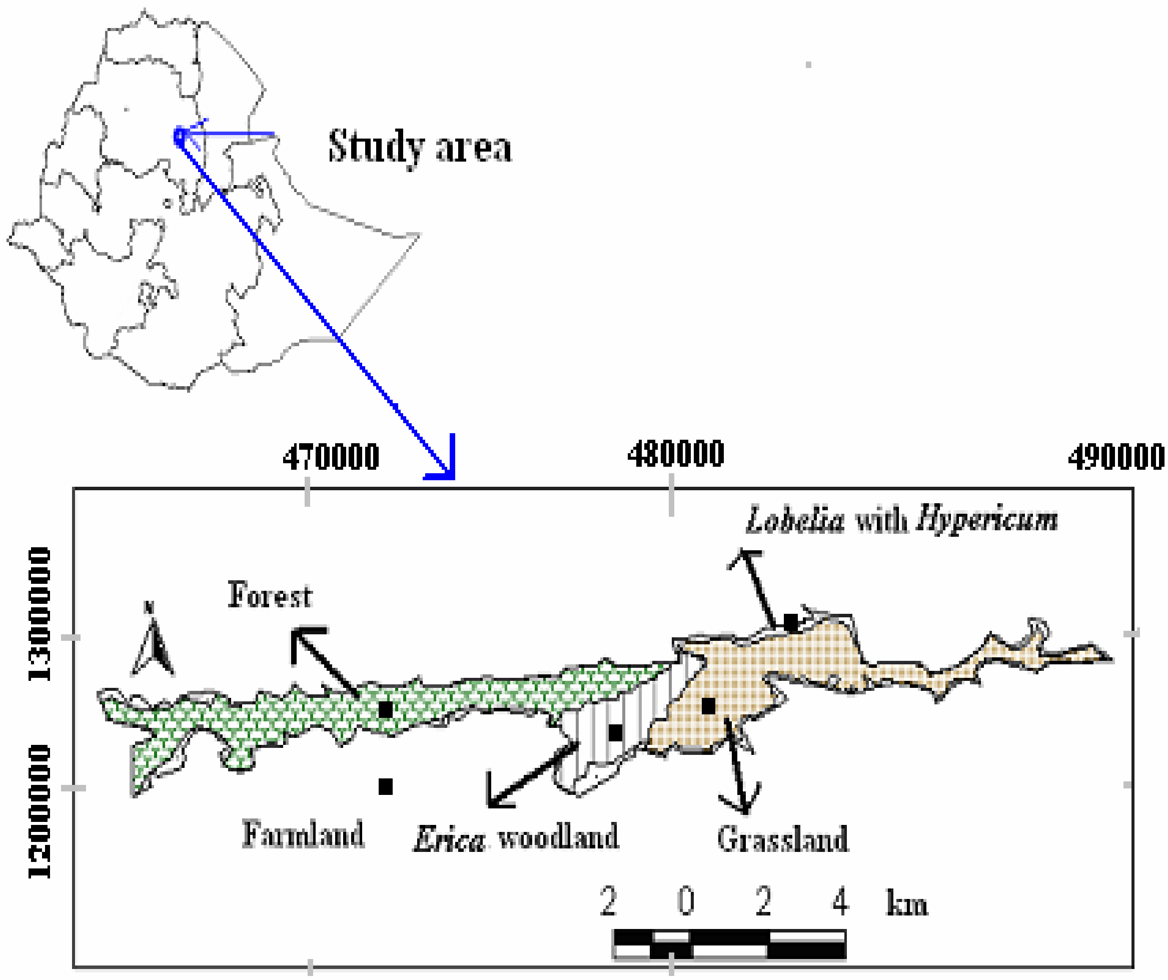
- ❖ To identify the species composition of rodents in the study area.

- To determine the relative abundance of rodents in relation to seasonal variation.
- To describe the distribution and habitat association of rodents in the study area.
- To describe population density of rodents in different habitats.
- To determine the feeding activities and the composition of the diet in relation to seasons.
- To suggest possible and sound management options on the status of the area.

3. DESCRIPTION OF THE STUDY AREA

3.1 Location and Area

The study was carried out in the Amhara Regional State, South Wollo located between two Woredas of Debersina and Densa. It is located about 596 km north of Addis Ababa and 196 km from Dessie via Mekaneselam. Geographically, the study area (Denkoro Forest) is bounded by 10^0 50' 25"-10^0 54' 27" N latitude and 38^0 40' 41"-038^0 53" 39' E longitude (Fig.1).



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

Most of the study area lies in Debresina Woreda and the elevation of the area extends from 2,300 to 3,642 m asl. The total area is estimated to be 4,375 ha an area of . Denkoro Forest was originally recognized and proposed to be protected as natural resources during the reign of Emperor Zera-Yakob (1428-1462). It was legally recognized as an important biodiversity area or priority forest area in 1952 during Emperor Haile Selassie (PaDPA, 1999). The protection of the forest continued during the military regime (Derg) as a State Forest. There was a lot of destruction in 1991, mainly on the side of Saint Woreda formerly but now on the side of Densa Woreda. Part of the forest was cleared and is being used for agriculture and grazing as a result the forest has shrunk from its former size 5,500 ha to the present 4,375 ha (PaDPA, 1999).

3.2 Geology and Topography

Geologically, Ethiopia lies towards or along the northern end of the continental part of the eastern rift. Tertiary volcanic rocks occupy a large part of the country along the Rift Valley (Ethiopian Institute of Geological Survey, 2000). The central highlands extend in a great arc for about 600 km to the north and east and descend to the Somali plateau (Brooke and Robinson, 1959).

The study area (Denkoro Forest) geologically lies on Tertiary volcanic deposits, which are extremely thick, and the soils are principally lithosols (McGinley, 2007). These highlands were volcanic formation over 75 million years ago and were glaciated. The surrounding areas were covered with montane vegetation (British Geological Survey, 2001). Generally, the study area is characterized by rough topography with mountains, deeply incised valleys, escarpments and plateau mostly covered by volcanic rocks mainly basalts of Tertiary age (Abate Ayalew *et al*., 2006).

3.3 Climate

The climate of the central highlands is characterized by a tropical type. Denkoro Forest has a wide range of altitude, and therefore, embraces three climatic zones,´Woinadega', 'Dega' and 'Wurch' (PaDPA, 1999). The distribution of rainfall in the area is characterized by a bimodal pattern. The first wet season mostly occurs from June to the end of September (long rainy season), while the second short rainy season is from mid-January to April. The periodical records of temperature during the dry season extend from 20^0C – 25^0C and 10^0C – 15^0C during the wet season. The monthly mean minimum and maximum temperature of Denkoro Forest from Debresina Woreda (Mekaneselam Station) is given in Figure 2.

Figure 2. Monthly mean minimum and maximum temperature and rainfall from 1999 to 2007 (Source: Mekane Selam Metrological Station)

3.4 Floristic composition and Habitat classification

One of the most attractive features of Ethiopia is the diversity of its vegetation. The various parts of the country with varied topography, altitude, rainfall distribution have resulted in a unique vegetation (Leykun Abune, 2000). The abundance and distribution of the small mammals depend mainly upon the nature and density of vegetation (Taylor and green, 1976). Denkoro forest priority area represents rich biodiversity with high number of endemic species and attractive bio-physical features (Keiner, 2002). Eventhough the forest is small in size it has higher species diversity due to the characteristics of moist evergreen forest (Abate Ayalew *et al*., 2006). The study area, in general encompasses three vegetation zones: Afro-alpine-belt, sub-afroalpine-belt and Afro-montane-belt.

3.4.1 Afro-alpine Belt (>3200)

The belt consists of an area higher than 3,200 m asl. These form the slopes and top of the highest mountains. The rocks are volcanic, mostly basalts and trachytes. The mountains attract much rain and the basaltic and trachytic bed-rock precludes excessive internal drainage. High on the mountain, in the afroalpine belt, the soil temperature is very low (near freezing) (Tewolde Berhan Gebre-egziabher, 1988).

Some of the plants include *Kniphofia* spp., *Crassula* spp., *Helichrysum citruspinum, Alchemilla* spp. *Lobelia rhynchopetallum*, *Agrostis quinquesta*, *Festuca*, *Trifolium acaule, Erica arborea*, and in the cervices various herbs, mosses and lichens.

3.4.2 Sub-afroalpine Belt (3000 -3200 m)

The vegetation composition at lower altitudes in the sub-afroalpine zone is most extensively ericaceous scrub, consisting of *Erica-arborea*, shrubs, *Hypericum revolutum* interspersed with tussock grass (*Festuca* spp.), and *Lobelia rhynchopetalum.*

3.4.3 Afro-montane Belt (1900–3000 m)

This belt is characterized by very complex vegetation type. This afro-montane forest is a narrow strip forest situated on steep slopes along Denkoro River on the side of Debresina Woreda. Currently, its coverage is 1,960 ha which has dwindled from its original size of 3,400 ha. However, this area accounts to nearly 100 percent of the indigenous forest trees and shrubs. This remnant afro-montane forest appears to be similar with the Harenna Forest of the Bale Montains National Park both in vegetation structure and composition rather than the Simien Mountains National Park (Woldgebriel Gebrekidan, 2003). This afro-montane forest is purely composed of trees and shrubs of dry evergreen montane forest, evergreen montane woodlands, scrubs and moist evergreen montane forest. The evergreen montane woodlands and scrubs occur at the upper altitudinal range. These include *Juniperus procera, Prunus africana, Domboya torrida, Croton macrostachyus, Bersema abyssinica*, *Nadia congesta and Erica arborea.* The dry evergreen montane forest type occurs in the lower altitude of the forest and is dominated by *Podocarpus falcatus, Croton macrostachyus, Celits africanus, Allophyllus abyssinicus* and

Syzgium guineense. Whereas, the high elevation of wet and humid area of the montane forest possesses *Syzgium guineense, Prunus africanus, Albizia schimperiana and Galineiro saxifrage (*Abate Ayalew *et al*., 2006*)*.

3.5 Habitat types (Grid site) of the study area

3.5.1 Open grassland (*Festuca abyssinica*) type

This grid site (habitat type) occurs at altitudes of 3,293 m asl and coordinates of 10^0 51.277" N latitude and 038^0 47.649" E longitude. The habitat was formerly called by the local people "Bezu-gemera" and the characteristic plant species is dominantly *Festuca abyssinica* with very sparsely associated *Hypericum quartinianum.*

Plate-1. Open grassland (*Festuca abyssinica*) habitat type.(Photo: Eshetu Moges, August, 2007)

3.5.2 *Erica arborea-Festuca abyssinica* type

This site is found in the area locally known as "Mentaw-Gora". It has an altitude of 3,413 m asl and a coordinate of 10^0 51.889" N latitude and 038^0 47.789" E longitude. The characteristic species in this site are dominantly *Erica arborea* with *Festuca abyssinica*.

Plate-2. **Moorland (*Erica* with *Festuca*) habitat type.** (Photo: Eshetu Moges, August, 2007)

3.5.3 *Lobelia rhynchopetalum - Hypericum revolutum* type

This habitat type (grid site) is found around the area, locally called "Leme meske" and it has an altitude of 3,490 m asl and a coordinate of 10^0 52. 329" N latitude and 038^0 48.554" E longitude. The characteristic plant species in this site are *Lobelia rhynchopetalum*, *Hypericum revolutum* associated with *Festuca abyssinica.*

Plate - 3. *Lobelia* with *Hypericum* habitat type. (Photo: Eshetu Moges, August, 2007)

3.5.4 Forest type

This habitat type (grid site) is found in Denkoro Chaka around the area locally called "Gosh-bert". The site has an altitude of 3,114 m asl and coordinates of 10^0 52. 295" N latitude and 038^0 47.790"E longitude. The forest site is characterized by: *Rubus volkensii, Hypericum quartinianum*, *Rubus steudneri*, *Myrsine melanophloeos, Hagenia abyssinica* (dominant), *Discopodium penninervium*, *Cynoglossum coeruleum, Conzya hypoleuca, Convolvulus kilimandschari and Conyta spinosa.*

Plate - 4. Montane forest habitat type. (Photo: Eshetu Moges, August, 2007)

3.5.5 Farmlands

This comprises cultivated open land outside and south-west of the forest. It has an altitude of 2,848 m asl and coordinates of 10^0 51. 410" N latitude and 038^0 46. 988" E longitude. The crop variety cultivated in this site includes wheat (*Triticum aestivum*) and barely (*Hordeum vulgare* subspp. *vulgare)*. Wild grown weed species were also commonly found in association with the crops.

Plate - 5. Farmland (Wheat farm) habitat type. (Photo: Eshetu Moges, August, 2007)

3.6 Fauna

Denkoro Forest is a central highland forest that is rich in biodiversity. It harbours various species of wild animals including, mammals, birds, invertebrates and amphibians. According to the inventory performed by the South Wollo Department of Agriculture, the area harbours 44 species of mammals and 232 species of birds that occur around and inside the forest proper.

4. MATERIALS AND METHODS

4.1 Materials

In the present study, Sherman live-traps, snap-traps, Pesola spring balance, GPS, polythene bags, rulers, metres, dissecting kits, gloves, bait (peanut butter mixed with wheat or barely scraps), digital camera, permanent marker, register and notebook, and 70 % ethyl alcohol to preserve the stomach contents were used.

4.2 Method

4.2.1 Preliminary study

A reconnaissance survey of Denkoro Forest was conducted during the last week of August, 2007 to obtain relevant information about the area. Moreover, the vegetation distribution, types and representative habitat sites were identified and the representative grids were selected randomly based on the vegetation types and altitudes. The actual study was conducted after the required information was obtained to cover both wet (September and October, 2007) and dry seasons (December and February, 2007/2008).

4.2.2 Sampling design

Based on the topography and physiognomy of the vegetation, five sample grids were selected randomly in different vegetation types based on the total area cover of the vegetation. Open grassland (*Festuca abyssinica*), *Erica* with tussock grass (*Erica arborea-Festuca abyssinica*), *Lobelia rhynchopetalum* with *Hypercum revolutum*, dense forest, wheat and barely farm were taken as grids and represented as 1, 2, 3, 4 and 5, respectively. Permanent sampling grids were used during both seasons having 49 Sherman live-traps per grid, and the trapping stations were marked by using yellow plastic tags. Permanent trapping stations of each grid were placed randomly with separation distance of 10 m. To obtain additional information for instance, external body measurements, number of embryos and stomach samples, 25 snap-traps placed at 20 m interval were used. These traps were placed at a distance of 200 m from the live-trapping grids.

4.2.3 Data collection

Data were collected in the wet and dry seasons by using a standard trapping technique using Sherman live–traps (7.6x8.9x22.9 cm. size) and snap-traps, and the traps were randomly laid at different trap sites of the habitats.

4.2.3.1 Data collection from live–traps

For live-trapping, five grids were randomly identified to represent different vegetation zones. The area of each live-trap grid was 70x70 m. Each of the grids consisted of seven lines, 10 m apart, with a trap station at every 10 m. A total of 49 Sherman traps was set in each grid, for 3 consecutive days (Fig.3). Peanut butter mixed with wheat or barely scraps were used as bait. The grid was checked twice a day; early morning from 7:00 to 9:00 a.m. and late in the afternoon 4:00 to 6:00 p.m. The trapped animals were marked by toe clipping and released after recording the required data, like location of capture, weight, species identification code, sex and reproductive conditions (Happold and Happold, 1991; Afework Bekele, 1996a ; Clausnitzer, 2003). The weight of the animals was recorded by a Pesola spring balance and each species was identified as juvenile, sub-adult, or adult based upon weight and pelage colour. Sexual condition of males was noted based upon the relative size and position of the testes, whether it is scrotal or inguinal, whereas for females, the condition of the vagina either perforated or non-perforated, and also size of nipples, whether they are lactating or not. Although the species were identified by using morphological characters, activity patterns and referenced using the Museum of Addis Abeba University

4.2.3.2 Data analysis

SPSS version (14.0) computer programme and appropriate stastical methods, like chi-square, Simpson's Similarity Index (SI) were used to compute the species composition, distribution and habitat association of small mammals, and the population size of small mammals in each season was estimated by using Capture-Mark-Recapture (CMR) method.

4.2.3.3 Data collection from snap-traps

In each trapping session, snap-traps were also set at the interval of 20 m and a distance of 200 m away from live-traping sites for 3 consecutive days in each site. The snap traps (n=25) were shifted randomly in order to include other types of habitat on a daily basis. Peanut butter mixed with either wheat or barely scraps were used as baits and traps were checked twice a day, early morning and late afternoon hours from 7:00 to 9:00 a.m. and 4:00 to 6:00 p.m., respectively. The trapped specimens were removed from the trap. The sex, sexual condition, age, the number of embryos and rate of reproduction were noted from the trapped specimens (Workneh Gebresilassie *et al*., 2004; Nicolas and Colyn, 2006). The vegetation types of all the areas used for snap trapping were recorded. Dissection of all the snap-trapped specimens was carried out for stomach content analysis.

4.2.4 Diet analysis

Diets of snap trapped rodents were analysed following the methods of Reichman (1975) Kronfeld and Dayan (1998) and Workneh Gebresilassie *et al*. (2004). Dissection of all the snap-trapped animals was carried out for stomach content analysis. The stomach contents from the dissected animals were removed and preserved in 70% alcohol until further microscopic examination (Leirs, 1994). The stomach contents were dried at 50^0C for 24 hours in the oven. The samples were washed by distilled water to remove fine particles for proper identification, and five slides were prepared for each samples and observed under dissecting light microscope with 60x magnification power. The stomach contents were grouped into leaves, seeds, roots, invertebrates and undifferentiated food fragments. Other food particles and invertebrates were identified with the aid of a reference collection and results were expressed in terms of percentage frequency of occurrence of different food types, and the percentage dietary occurrence of food type or fragments was calculated.

4.2.5 Estimation of wheat crop damage by rodents

In order to estimate the damage and yield loss by rodents in wheat field (farmland) around Denkoro Forest, 12 experimental plots, each 1x1m were taken from two randomly selected hectares of wheat farm to estimate the damage at the seedlings stage and at harvest. In all the plots seedlings were counted, the shoots were assigned as damaged and undamaged. The damage proportion of each sampled seedlings was estimated (Rennison, 1979).

$$\% \text{ of cut tillers} = 100(a/b)$$

Where:

a = number of cut tiller in sample.

b = total number of tillers in sample.

5. RESULTS

5.1 Species composition

A total of 871 individuals of small mammals were trapped out of the 4440 trap nights. These comprised eight species of rodents and two species of insectivores both of them shrews. From the total number of small mammals trapped, 808 (92.8%) were rodents and 63(7.2%) were shrews. The list of large mammals observed is given in Appendix.

The eight species of rodents were represented by *Lophuromys flavopunctatus* Thomas, 1888 (35.7%), *Otomys typus* Heuglin, 1877 (28.5%), *Stenocephalemys griseicauda* Petter, 1972 (14.6%), *Arvicanthis dembeensis* RÜppell, 1842 (10.3%), *Stenocephalemys albipes* Rüppell, 1842 (1.9%), *Pelomys harringtoni* Thomas, 1903 (0.8%), *Mus mahomet* Rhoads, 1896 (0.6%), *Dendromus lovati* De Winton, 1899 (0.3%), The insectivores were represented by *Crocidura flavescens* I. Geoffroy, 1827 (5.9%) and *Crocidura fumosa* Thomas, 1904 (1.4%). (Table 1). Among the insectivores species, *Crocidura fumosa* was highly restricted in the forest habitat during the present study. Whereas, *Crocidura flavescens* has a relatively wider distribution occurring in habitats like, open grassland, *Erica* moorland, and *Lobelia* with *Hypericum* sp. In addition, other small mammals, like *Tachyoryctes splendens* Rüppell, 1836, *Hystrix cristata* Linnaeus, 1758 were noted as observed species in the study area.

Table 1. Species composition of small mammals captured from different habitats of Denkoro Forest using snap and live-trap

Species	Total capture	Relative abundance (%)
L. flavopunctatus	311	35.7
O. typus	248	28.5
S. griseicauda	127	14.6
A. dembeensis	90	10.3
S. albipes	18	1.9
P. harringtoni	7	0.8
M. mahomet	4	0.6
D. lovati	3	0.3
C. flavescens	52	5.9
C. fumosa	11	1.4
T. splendens	*	*
H. cristata	*	*
Total 12	871	100

* = non- captured, but observed species

5.2.1 Abundance of live-trapped rodents and insectivores

Lophuromys flavopunctatus comprised the largest percentage and it was by far the most abundant species that contributed 298 (37.6%) of the total rodents and insectivores caught, followed by *O. typus* 227 (28.5%), *S. griseicauda* contributed 115 (14.5%), *A. dembeensis* 72 (9.1%), *C. flavescens* 47 (5.9%), *S. albipes* 15 (1.9%), *C. fumosa* 7 (0.9%), *P. harringtoni* 6 (0.8%). *M. mahomet* 4 (0.5%) and *D. lovati* 2 (0.3%) were the least abundant species. The captured rodents and insectivores with their relative abundance are given in Table 2.

Table 2. Total catch and abundance of live trapped rodents and insectivores from different grid sites.

Species	Total capture	Relative abundance in (%)
L. flavopunctatus	298	37.6
O. typus	227	28.5
S. griseicauda	115	14.5
A. dembeensis	72	9.1
S. albipes	15	1.9
P. harringtoni	6	0.8
D. lovati	2	0.3
M. mahomet	4	0.5
C. flavescens	47	5.9
C. fumosa	7	0.9
Total	793	100

5.2.1.1 Distribution of rodents and insectivores in different habitat types

Rodents as well insectivores were not uniformly distributed in all habitat types, and variation in species and population number of rodents and insectivores was observed from habitat to habitat. *L. flavopunctatus* is the most widely distributed species in the study area; moreover, its population was also very high. The other widely distributed species was *O. typus,* and it occurred in all habitats (Table 3). However, the population size was less dominant than *L. flavopunctatus.* On the other hand, the less distributed species in the study site were: *S. albipes* and *C. fumosa*. These were highly restricted in the montane forest habitat type (MF). *P. harringtoni, D. lovati* and *M. mahomet* were also the other less distributed species that were confined in the farmland of Denkoro Forest. The range of habitat types of each species of rodents and insectivores is given in Figure 4.

Table 3. Number and percentage (in bracket) of rodents and insectivores in different habitat types

Species	Habitat types					
	OGL	ML	LH	MF	FL	Total catch
S. griseicauda	42(36.5)	35(30.4)	29(25.2)	-	9(7.8)	115
L. flavopunctatus	78(26.2)	12(4.0)	125(41.9)	67(22.5)	16(5.4)	298
A. dembeensis	60(83.3)	-	-	-	12(16.7)	72
O. typus	41(18.1)	36(15.9)	129(56.8)	14(6.2)	7(3.1)	227
S. albipes	-	-	-	15(100)	-	15
P. harringtoni	-	-	-	-	6(100)	6
D. lovati	-	-	-	-	2(100)	2
M. mahomet	-	-	-	-	4(100)	4
C. flavescens	31(65.9)	5(10.6)	11(23.4)	-	-	47
C. fumosa	-	-	-	7(100)	-	7
Total 10	252	88	294	103	56	793

OGL= open grassland, ML= moorland, LH= *Lobeli*a with *Hypericum*, MF= montane forest, FL=farmland

Figure 4. Species distribution of lived-trapped rodents and insectivores.

5.2.1.2 Habitat association and abundance of species in different habitat types

More than 70% of the small mammal species were captured from the farmland and the remaining species were from the open grassland (OGL), moorland (ML), *Lobelia* with *Hypericum revolutum* (LH), and montane forest (MF) (Table 3). *S. griseicauda* was dominant in open grassland and accounted 36.5% of the captures followed by moorland 30.4%. However, the species was not trapped in the montane forest. *L. flavopunctatus* dominantly occurred in the habitat of *Lobelia* with *Hypericum revolutum* type and its abundance was 41.9%, followed by open grassland 26.2%. *A. dembeensis* contributed 83.3% in open grassland and 16.7% in the farmland. *O. typus* was also trapped mostly in *Lobelia* with *Hypericum revolutum* habitat (LH) that contributed 56.8% of the catch followed by open grassland 18.1%. *C. flavescens* accounted 65.9% of the catch in open grassland, followed by 23.4% in *Lobelia* with *Hypericum revolutum* habitat. The abundance of *S. albipes, P. harringtoni, D. lovati, M. mahomet, and C. fumosa* was uniform because the species were restricted only to a particular habitat during the study period. Habitat association of *S. griseicauda, L. flavopunctatus, A. dembeensis, O. typus, C. flavescens* was statistically significant (χ^2_1=22.4, p<0.001, χ^2_1 = 66.2, p<0.001, χ^2_1 =35.7, p<0.001, χ^2_1= 72.4, p<0.001, χ^2_1 = 23.3, p<0.001, respectively). However, *S. albipes, P. harringtoni, D. lovati, M. mahomet* and *C. fumosa,* showed no significant difference between habitats (p>0.05).

The farmland and open grassland harboured the largest number of species with 7 and 5, respectively, while the lowest species richness was recorded in the montane forest (MF), moorland (ML) and *Lobelia* with *Hypericum revolutum* habitat (LH) with 4 species each. By using Simpson's Similarity Index (SI), the similarity between different habitats with reference to the composition of species was 0.42. This indicates that they are below half-similar in species composition.

5.2.1.3 Seasonal variation

Lophuromys flavopunctatus, *S. griseicauda, C. flavescens*, *and C. fumosa* were abundant during the wet season. Whereas that of *P. harringtoni, D. lovati* and *M. mahomet* were recorded only in the dry season. *A. dembeensis* was highly dominant and the population reached peak at the end of the wet season and the beginning of the dry season (Table 4). The difference in population of small mammal species (*S. griseicauda*, *L. flavopunctatus, A. dembeensis, O. typus, S. albipes, M. mahomet, C. flavescens, and C. fumosa* between seasons was significant (χ^2_1= 69.5, p<0.001, χ^2_1=34.8, p<0.001, χ^2_1=38.9, p< 0.001, χ^2_1 = 22.2, p<0.001, χ^2_1 =2.3, p<0.05, χ^2_1 = 1.0, p<0.05, χ^2_1 = 22.9, p<0.001, χ^2_1 = 1.3, p< 0.05, respectively). However, *S. albipes* and *P. harringtoni* showed no significant difference between wet and dry seasons (χ^2_1= 0.7, p>0.05, χ^2_1 = 0.3, p>0.05). The overall abundance of the small mammals between wet and dry seasons was 64.4% and 35.6%, respectively and it showed statistical significance (χ^2_1 =7.8, p<0.05).

Table 4. Distribution of live trapped rodents and insectivores in relation to seasonal variation.

Species of small mammals	Wet season Aug/Oct 2007		Dry season Dec/Feb 2008		Total capture	
	M	F	M	F	M	F
S. griseicauda	50	41	13	11	63	52
L. flavopunctatus	113	103	35	47	148	150
A. dembeensis	19	21	15	17	34	38
O. typus	48	57	51	71	99	128
S. albipes	4	3	2	6	6	9
P. harringtoni	-	-	3	4	3	4
D. lovati	-	-	2	-	2	-
M. mahomet	-	-	3	1	3	1
C. flavscens	20	25	-	2	20	27
C. fumosa	3	4	-	-	3	4
Total 10	257	254	124	158	381	412

S. griseicauda, L. flavopunctatus and the insectivore species were captured more during the wet season while the others were trapped more during the dry season (Fig. 5).

Figure 5. Abundance of rodents and insectivores during the wet and the seasons

5.2.1.4 Age structure and sex ratio

Out of a total of 793 individuals of live-trapped small mammals juveniles comprised 100 (19.9%), sub-adult 70 (13.9%) and adult 333 (66.2%) during the wet season, whereas during the dry season, juveniles contributed 52 (17.9%), sub-adult 23(7.9%) and adults 215(74.2%) (Table 5). The difference in the total capture of juveniles during the two seasons varied significantly (χ^2_1 = 22.3, p<0.001). In addition, the difference in total capture of both sub-adult and adult was also statistically significant (χ^2_1 = 31.8, p<0.001, χ^2_1 = 109.1, p < 0.0001, respectively). From the total caught, males comprised 381 (48.1%) and females 412 (51.9%). Moreover, seasonally males comprised 257 and females 254 during wet season whereas, during the dry season, males comprised 124 and females comprised 158. Hence, the sex ratio was not significantly different (χ_1^2= 0.16, p> 0.05).

Table 5. Age groups of live-trapped rodents and insectivores

Month/season	Age Structure			
	Juveniles (young)	Sub-adult	Adult	Total
Aug/Sep/2007 (1st – wet season)	60	44	153	257
Dec/2007(1st–dry season)	32	15	133	180
Oct/2007(2nd–wet season)	40	26	180	246
Feb/2008(2nd–dry season)	20	8	82	110
Total	152	93	548	793

5.2.1.5 Biomass of small mammals

The highest small mammal biomass was revealed in the *Lobelia* with *Hypericum* grid, followed by open grassland (Table 6). *O. typus* constituted the highest proportion of biomass in all grids. The small mammal biomass varied between grids and between trapping sessions. In *Lobelia* with *Hypericum* grid, the maximum biomass recorded per hectare was 9,744 g during the second trapping session (wet season) and the minimum was 40 g/ha during the third session (dry season). The minimum small mammal biomass was obtained from the wheat grid. In the wheat grid the maximum biomass recorded per hectare was 784.8 g and the minimum was 60.2 g/ha in the same (fourth) trapping session. The biomass of small mammal in relation to seasonal variation in *S. griseicauda* and *L. flavopunctatus* was significantly different ($\chi^2{}_1$ = 2.0, p<0.05, $\chi^2{}_1$ = 1.6, p<0.05, respectively).

Table 6. Number and biomass (g ha^{-1}) of small mammals captured at different trapping sessions

Session	Grid	S.g Mbw=68.3 N=233	L.f Mbw=59.1 N=611	A.d Mbw=83.7 N=146	O.t Mbw=116.0 N=463	S.a Mbw=48.0 N=30	P.h Mbw=58.0 N=12	D.l Mbw=25.0 N=4	M.m Mbw=30.1 N=8	C.fl Mbw=20.5 N=95	C.f Mbw=20 N=14
1	1	55(3756.5)	86(5082.6)	8(669.6)	8(928)	0	0	0	0	39(799.5)	0
	2	37(2527.1)	14(827.4)	0	6(696)	0	0	0	0	4(82)	0
	3	29(1980.7)	116(6855.6)	0	47(5452)	0	0	0	0	12(246)	0
	4	0	29(1713.9)	0	2(232)	6(288)	0	0	0	0	8(176)
	5	4(273.2)	10(591)	6(502.2)	4(464)	0	0	0	0	0	0
2	1	22(1502.6)	59(3486.9)	65(5440.5)	29(3364)	0	0	0	0	22(451)	0
	2	16(1092.8)	8(472.8)	0	18(2088)	0	0	0	0	8(164)	0
	3	14(956.2)	76(4491.6)	0	84(9744)	0	0	0	0	6(123)	0
	4	0	35(2068.5)	0	10(1160)	8(384)	0	0	0	0	6(132)
	5	8(546.4)	8(472.8)	2(167.4)	6(696)	0	0	0	0	0	0
3	1	6(409.8)	24(1418.4)	20(1674)	22(2552)	0	0	0	0	0	0
	2	14(956.2)	0	0	33(3828)	0	0	0	0	0	0
	3	10(683)	49(2895.9)	0	82(9512)	0	0	0	0	4(40)	0
	4	0	31(1832.1)	0	8(928)	12(576)	0	0	0	0	0
	5	2(136.6)	10(591)	10(837)	2(232)	0	8(464)	4(100)	6(180.6)	0	0
4	1	8(546.4)	14(827.4)	31(2594.7)	31(3596)	0	0	0	0	0	0
	2	4(273.2)	6(354.6)	0	20(2320)	0	0	0	0	0	0
	3	4(273.2)	20(1182)	0	37(4292)	0	0	0	0	0	0
	4	0	12(709.2)	0	6(696)	4(192)	0	0	0	0	0
	5	0	4(236.4)	4(334.8)	8(928)	0	4(232)	0	2(60.2)	0	0
	Total	233	611	146	463	30	12	4	8	95	14
		15, 913.9	(36, 110.1)	(12,220.2)	(53,708)	(1,440)	(696)	(100)	(240.8)	1905.5	305

Numbers in parentheses show biomass, Session 1 and 2 are wet season, and Session 3 and 4 are dry season

Grid 1= open grassland, Grid 2= moorland, Grid 3 = *Lobelia* with *Hypericum,* Grid 4 = montane forest, Grid 5 = farmland

5.2.1.6 Total catch and trap success of small mammals based on the types of habitat

The number of captures and trapping success varied among habitat types. Table 7 shows the number of captures in different habitat types. The capture rate significantly differed between different types of habitat (χ^2=47.8, p < 0.001). The highest catch was recorded from *Lobelia* with *Hypericum revolutum* habitat (294), followed by open grassland (252). The lowest capture was from wheat farm (56). The maximum trap success was recorded in *Lobelia* with *Hypericum revolutum* grid (50%) and the minimum was from wheat farm or farmland (9.5%).

Table 7. Distribution of small mammals capture and trap success among the five habitat types

Habitat types	Altitude (m)	Total capture	Trap nights	%Trap success
Open grassland	3293 m asl	252	588	42.9
Moorland	3413 m asl	88	588	14.9
Lobelia with *Hypericum*	3490 m asl	294	588	50.0
Montane forest	3114 m asl	103	588	17.5
Farmland	2848 m asl	56	588	9.5

Seasonally, the total catch and trapping success between different habitats was also varied. The maximum number of individuals was recorded from open grassland and *Lobelia* with *Hypericum revolutum* habitat during the wet season (Aug/Sep/2007 and Oct/2007) and the least in the wheat farm. And in the dry season.

The trap success between habitats (OGL, ML, LH, MF and FL) at different seasons was significantly different ($\chi^2{}_1$ = 39.6, p< 0.001, $\chi^2{}_1$ = 4.4, p< 0.05, $\chi^2{}_1$ = 14.7, p< 0.001, $\chi^2{}_1$ = 10.6, p<0.01, $\chi^2{}_1$ = 11.9, p< 0.01, respectively) (Table 8).

Table 8. Trap nights, total capture and trap success during the wet and dry seasons in different habitats (OGL = open grassland, ML= moorland, LH = *Lobelia* with *Hypericum revolutum*, MF=montane forest, FL= farmland

Habitat types	Grid with altitude	Seasons	Sessions	Trap nights	Total capture	Trap success in (%)
	G 1	Wet	1	147	91	61.9
OGL	(3293 m)	Dry	3	147	36	24.5
		Wet	2	147	97	65.9
		Dry	4	147	28	19.0
	G 2	Wet	1	147	30	20.4
ML	(3413 m)	Dry	3	147	20	13.6
		Wet	2	147	25	17.0
		Dry	4	147	13	8.8
	G 3	Wet	1	147	97	65.9
LH	(3490 m)	Dry	3	147	65	44.2
		Wet	2	147	86	58.5
		Dry	4	147	46	31.3
	G 4	Wet	1	147	28	19.0
MF	(3114 m)	Dry	3	147	32	21.8
		Wet	2	147	34	23.1
		Dry	4	147	9	6.1
	G 5	Wet	1	147	8	5.4
FL	(2848 m)	Dry	3	147	26	17.7
		Wet	2	147	16	10.9
		Dry	4	147	6	4.1

Session one (1) = Aug/Sep/2007, Session two (2) = Oct/2007,
Session three (3) = Dec/2007, Session four (4) = Feb/2008.

5.2.1.7 Activity pattern of small mammals

Stenocephalemys griseicauda, C. fumosa, M. mahomet, S. albipes, D. lovati were nocturnal, whereas, *C. flavescens* was mostly nocturnal but few populations were also caught during the late afternoon checking time. Although *L. flavopunctatus* was diurnal, number of individuals was also caught during the early morning check. *P. harringtoni* was nocturnal. *A. dembeensis* was exclusively diurnal and *O. typus* was arhythmic.

5. 2.1. 8 Estimation of population

The estimated population numbers of all small mammal species in the live-trapping grid using Capture–Mark-Recapture (CMR) method is given in Fig. 6. The present study showed that there is statistically significant difference ($p< 0.05$) in number of population size between seasons.

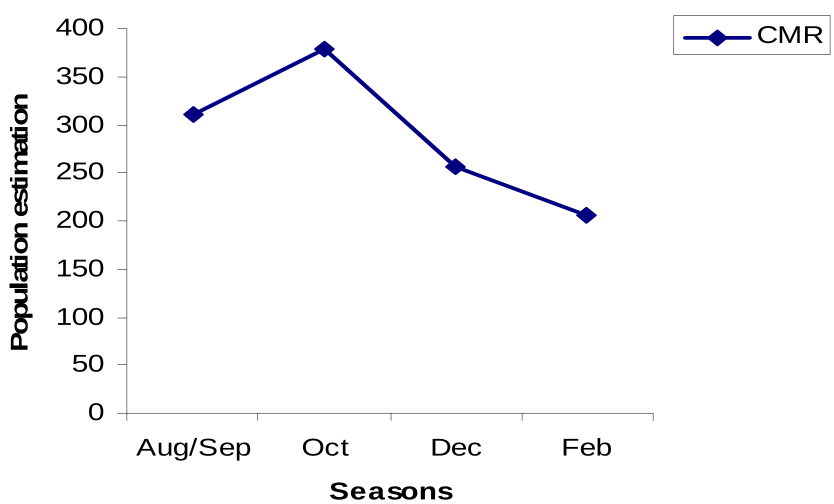


Figure 6. Population estimates of trapped small mammals from live-trapping grids using (CMR) method.

5.2.1.9 Density in different habitats

The lowest density recorded per session at open grassland was 6/ha during the third trapping session, for species, *S. griseicauda*, whereas, the highest density was recorded 86/ha during session one, for *L. flavopunctatus* (Table 9). In the moorland habitat type, the lowest population density was 4/ha, during trapping sessions one and four, for *C. flavescens* and *S. griseicauda*, respectively. Whereas the highest density was recorded (37/ha) during the first trapping session, for *S.griseicauda*.

The lowest density recorded per session at *Lobelia* with *Hypericum revolutum* habitat type was 4/ha, for *S. griseicauda* and *C. flavescens* each, whereas the highest density recorded was 116/ha per session, for *L. flavopunctatus*. In montane forest, the lowest density per session was 2/ha, for *O. typus*, whereas the highest record was 35/ha, for *L. flavopunctatus*. While in wheat farm, the lowest density per session was 2/ha, for *S. griseicauda* and *O. typus,* whereas the highest record was 10/ha per session, for *A. dembeensis* and *L. flavopunctatus* individually (Table 9).

Table 9. Population density of small mammals in Denkoro forest during different trapping sessions

Grid No.	Trapping sessions	Density (no. ha^{-1})										
		S. g	L. f	A. d	O. t	S.a	P.h	D.l	M.m	C.fl	C.f	Total
1	1	55	86	8	8	-	-	-	-	39	-	196
	2	22	59	65	29	-	-	-	-	22	-	197
	3	6	24	20	22	-	-	-	-	-	-	72
	4	8	14	31	31	-	-	-	-	-	-	84
2	1	37	14	-	6	-	-	-	-	4	-	61
	2	16	8	-	18	-	-	-	-	8	-	50
	3	14	-	-	33	-	-	-	-	-	-	47
	4	4	6	-	20	-	-	-	-	-	-	30
3	1	29	116	-	47	-	-	-	-	12	-	204
	2	14	76	-	84	-	-	-	-	6	-	180
	3	10	49	-	82	-	-	-	-	4	-	145
	4	4	20	-	37	-	-	-	-	-	-	61
4	1	-	29	-	2	6	-	-	-	-	8	41
	2	-	35	-	10	8	-	-	-	-	6	59
	3	-	31	-	8	12	-	-	-	-	-	51
	4	-	12	-	6	4	-	-	-	-	-	22
5	1	4	10	6	4	-	-	-	-	-	-	24
	2	8	8	2	6	-	-	-	-	-	-	24
	3	2	10	10	2	-	8	4	6	-	-	42
	4	-	4	4	8	-	4	-	2	-	-	22
Total		233	611	146	463	30	12	4	8	95	14	1616

Grid 1= Open grassland; Grid 2= moorland; Grid 3= *Lobelia* with *Hypericum revolutum;* Grid 4 = montane forest; Grid 5 = farmland.

(S. g - *Stenocephalemys griseicauda*, L. f - *Lophuromys flavopunctatus*, A. d -*Arvicanthis dembeensis*, O. t – *Otomys typus*, S. a - *Stenocphalemys albipes*, P. h - *Pelomys harringtoni*, D. l – *Dendromus lovati*, *M. m - Mus mahomet*, C. fl –*Crocidura flavescens,* C. f -*Crocidura fumosa*)

Lobelia with *Hypericum revolutum* habitat showed the highest density of small mammals (590/ha) followed by open grassland (549/ha). Whereas, the lowest density was recorded in wheat farm or farmland 112/ha in all trapping occasions during the study period (Table 10).

Table 10. Density of each species of small mammals per hectare in each grid (number of individuals/ha).

Grid No	Density (no.ha^{-1})										
	S.g	L.f	A.d	O.t	S.a	P.h	D.1	M.m	C.fl	C.f	Total
1	91	182	124	91	-	-	-	-	61	-	549
2	71	28	-	77	-	-	-	-	12	-	188
3	57	261	-	250	-	-	-	-	22	-	590
4	-	107	-	26	30	-	-	-	-	14	177
5	14	32	22	20	-	12	4	8	-	-	112
Total	233	610	146	464	30	12	4	8	95	14	1616

Grid 1= open grassland, Grid 2= moorland, Grid 3=*Lobelia* with *Hypericum revolutum,* Grid 4= montane forest, Grid 5= farmland

5.2.2 Snap trapping

A total of 78 individual small mammals was captured in 1500 trap nights, with a trap success of 5.2%. The recorded species from the snap trapping were *S. griseicauda L. flavopunctatus*, *A. dembeensis*, *O. typus*, *S. albipes*, *P. harringtoni*, *D. lovati*, *C. flavescens* and *C. fumosa*. *Otomys typus* was the most abundant species. It contributed 26.9% of the total 78 small mammals recorded. While *A. dembeensis* was the second abundant species which comprised 23.1%. *Pelomys harringtoni* and *D. lovati* were the least captured species accounting for 1.3% of the total. *M. mahomet* was not captured in the snap trap (Table 11).

Table 11. Species composition, distribution and relative abundance of snap trapped small mammals.

Species	Habitat Types					Total catch in (%)
	OGL	ML	LH	MF	FL	
O. typus	5	6	9	1	-	21(26.9)
A. dembeensis	14	-	-	-	4	18 (23.1)
L. flavopunctatus	3	2	6	-	2	13(16.7)
S. griseicauda	4	1	7	-	-	12 (15.4)
S. albipes	-	-	-	3	-	3 (3.8)
P. harringtoni	-	-	-	-	1	1 (1.3)
D. lovati	-	-	-	-	1	1 (1.3)
C. flavescens	3	-	2	-	-	5 (6.4)
C. fumosa	-	-	-	4	-	4 (5.1)
Total	29	9	24	8	8	78 (100)

OGL = open grassland, ML = moorland, LH = *Lobelia* with *Hypericum*, MF = montane forest, FL = farmland.

5.2.2.1 Body measurements

Body measurements of 9 species of small mammals snap trapped are given in Table 12. Based on the data collected from different trapping sessions, the body weight showed variation in most species for instance, *L. flavopunctatus,O. typus,* and shrews.It is statistically significant (χ^2_1=1.4, p< 0.05, χ^2_1= 2.3, p< 0.05, χ^2_1=0.4, p< 0.05, χ^2_1=2.1, p<0.05, χ^2_1= 0.7, p<0.05, χ^2_1= 3.9, p<0.05) for species, *S. griseicauda*, *L. flavopunctatus*, *A. dembeensis*, *O. typus*, *S. albipes* and *C. flavescens,* respectively, between seasons within species. Whereas, external body measurements did not show significant difference (P> 0.05) within species between seasons (Table 12)

Table 12. Body weight (g) and measurements (mm) (mean ± SD) of small mammals snap-trapped during wet and dry seasons.

Species	Season	Indiv. no.	Body Measurements				
			BW	HB	TL	HF	ER
S.g	Wet	7	88.7± 3.3	123.0 ± 1.0	124.0 ± 0.8	25.7 ± 0.5	21.3 ± 0.9
	Dry	5	73.4 ± 0.9				
L.f	Wet	8	69.4 ±1.6	109.1 ± 0.8	60.1 ±1.1	20.3 ± 0.5	12.4 ±0.5
	Dry	5	52.0 ± 2.7				
A.d	Wet	6	93.5 ±1.6	140.8 ±1.8	94.8 ± 0.8	24.3 ± 0.5	12.5 ± 0.6
	Dry	12	84.7 ±1.6				
O.t	Wet	13	123.0 ±15.9	132.7 ± 0.6	74.1 ± 0.6	23.9 ± 0.4	21.7 ± 0.5
	Dry	8	101.6 ± 4.0				
S.a	Wet	2	48.5 ± 0.7	89.5 ± 0.7	152.5 ± 3.5	25.5 ± 0.7	23.5 ± 0.7
	Dry	1	40.0				
P.h	Wet	-	-	-	-	-	-
	Dry	1	58.0				
D.1	Wet	-	-	-	-	-	-
	Dry	1	25.0				
C. fl	Wet	4	20.8 ± 7.9	58.8± 0.9	41.3 ± 0.5	14.0 ± 0.5	5.3 ± 0.5
	Dry	1	10.0				
C. f	Wet	4	22.0 ± 3.6	64.3 ± 0.5	42.50± 0.6	14.8 ± 0.5	5.3 ± 0.5
	Dry	-	-	-	-	-	-

BW= body weight, HB=head and body length, TL = tail length, HF= hind foot length, ER=ear length; *S.* g = *S. griseicauda*, L. f = *L. flavopunctatus*, A. d = *A. dembeensis,* O. t = *O. typus*, S. a= *S. albipes,* P.h = *P. harringtoni*, D. l = *D. lovati*, C. fl = *C. flavescens*, C. f = *C. fumosa*

5.2.2.2 Reproductive condition

Large number of pregnant females were trapped mainly during the wet season. However, the number of pregnant females decreased during the dry season. The litter size of different species of rodents and insectivores varied within the species between seasons during the study period. In addition, the number of embryos varied from species to species. This also varied among individuals of the same species as well as between right and left horns. However, it did not show statistically difference ($p > 0.05$). The number of embryos obtained from snap trapped five species of rodents and one species of insectivore is given in (Table 13).

Table 13. Number of embryos recorded from snap trapped rodents and insectivores.

Species	Season	No. of pregnant	No. of embryos
S. griseicauda	Wet	5	4-6
	Dry	2	3
L. flavopunctatus	Wet	4	1-3
	Dry	1	2
O. typus	Wet	8	2-3
	Dry	3	1
A. dembeensis	Wet	2	5
	Dry	6	4-6
P. harringtoni	Wet	-	-
	Dry	1	4
C. flavescens	Wet	2	4-7
	Dry	-	-

5.2.2.3 Diet analysis and composition

During the wet season, the stomach contents of *S. griseicauda, O. typus*, *A. dembeensis,* and *S. albipes* had higher percentage of plant leaves than plant seeds and invertebrates. The diet of *L. flavopunctatus,* and *C. flavescens* was dominantly invertebrates. During the dry season, the dominant food fragments in the stomach samples of most species were also plant leaves and seeds except *L. flavopunctatus* and *C. flavescens*. However, small proportions of roots were observed in *S. griseicauda*, *O. typus*, *L. flavopunctatus* and *A. dembeensis*. In addition, in the stomach sample of *O. typus* mosses and lichens were observed. Some food items that were not recognized were grouped under undifferentiated food fragments (Table 15).

Table 14. Mean percentage of the diet of snap trapped rodents and insectivores during the period.

Species	Season	Percentage of food fragments							
		1	2	3	4	5	6	7	8
S. griseicauda	Wet	65.6	22.4	4.0	-	3.2	-	-	4.8
	Dry	62.8	19.6	5.7	-	4.1	-	1.7	6.1
L. flavopunctatus	Wet	18.5	14.4	-	-	1.6	-	62.1	3.4
	Dry	22.7	16.3	4.7	-	3.1	-	49.3	3.9
O. typus	Wet	57.2	21.4	-	-	8.6	2.1	-	10.7
	Dry	55.5	24.3	3.5	1.4	5.5	-	-	9.8
A. dembeensis	Wet	57.0	15.2	11.4	3.5	3.8	-	-	9.1
	Dry	55.7	20.3	13.5	6.5	1.4	-	-	2.7
S. albipes	Wet	57.4	29.4	2.9	-	-	-	-	10.3
	Dry	60.2	22.4	3.0	6.1	-	-	3.1	5.2
C. flavescens	Wet	15.0	6.1	-	-	-	-	52.6	26.3
	Dry	-	-	-	-	-	-	-	-

1, monocot leaves; 2, dicot leaves; 3, monocot seeds; 4, dicot seeds; 5, roots; 6, mosses and lichens; 7, Invertebrates; 8, undifferentiated food fragments

5.2.3 Pest status of rodents

Three species of rodents, *A. dembeensis*, *M. mahomet* and *H. cristata* were recognized as pests of crops on the farmlands of Denkoro forest (Table 16). The first two species of rodents were captured from cultivated areas and open grassland, whereas *H. cristata* was not trapped but observed during the study period. In the first trapping session, *A. dembeensis* accounted 4(80%) in the open grassland and 1(20%) in the farmland. While in the second trapping session *A. dembeensis* reached peak 30(87.7 %) towards the end of wet season and the beginning of dry season in the grassland habitat. *M. mahomet* was not recorded during the first and second trapping sessions. During the dry season, the population of *A. dembeensis* in the open grassland and farmland relatively decreased from the second trapping session. While *M. mahomet* contributed 4(25%) during the third trapping session (December) in the farmland and it was not recorded during the fourth trapping session (February). Porcupine (*Hystrix cristata*) was rarely observed near villages, around the farmland. It usually feeds upon vegetables and maize kobs, whereas, *A. dembeensis* and *M. mahomet* were trapped in the wheat farm. Hence, in order to assure whether they are pests or not stomach samples were taken mainly from *A. dembeensis*. However, *M. mahomet* was not snap trapped.

Table 15. Species composition, distribution and percentage of snap trapped pest rodents

Species	Habitat types	Trapping sessions				Total catch in (%)
		1	2	3	4	
A. dembeensis	Open grassland	4	30	10	17	61 (83.6)
	Farmland	1	5	2	-	8 (10.9)
M. mahomet	Farmland	-	-	4	-	4 (5.5)
H. cristata	Moorland and Farmland	*	*	*	*	*
Total		5	35	16	17	73 (100)

- = absence, * = observed species

5.2.3.1 Damage assessment of wheat crop at seedling and near harvest

The percentage of damaged tillers of wheat farm at seedlings and near harvest stages was significantly different (χ^2 = 198.1, P<0.0001). Wheat loss was highest mainly near to harvest (8.6%).

Table 16. Estimation of rodent damage on wheat farm.

Stages	Total plots taken	No. of damaged tillers	No. of undamaged tillers	Percentage loss
Seedling stage	12	32	3332	0.95%
Near harvest	12	281	2987	8.6 %

6. DISCUSSION

In the present study at Denkoro Forest Priority Area, ten species of small mammals were captured and two more were observed. Similar numbers of rodent and insectivore species were recorded in different parts of the country. For example, around Arbaminch forest area eight species of rodents and two shrews were recorded (Duckworth *et al*. 1993) In addition, Bekele Tsegaye (1999) has recorded nine species of rodents from Entoto area, Afework Bekele (1996b) recorded twelve species of rodents from Menagesh State Forest and Yalden (1988) recorded seven species of rodents from the Bale Mountains National Park.

Distribution of small mammals over an area is not uniform and species are more abundant in some habitats than others (Morris, 1987). In the present study area, distribution of rodents and insectivores were unevenly distributed; some species were restricted only to a particular habitat type; for instance, *C. fumosa* and *S. albipes* were trapped from forest habitat type. While *P. harringtoni, M. mahomet, D. lovati* were recorded only from farmland. But *S. griseicauda*, *O. typus*, *A. deembensis*, *C. flavescens* and *L. flavopunctatus* were relatively distributed in different habitat types (Table 3).

Yalden and Largen (1992) reported the distribution of *Stenocephalemys griseicauda* in Ethiopia on both western and eastern plateax, associated with scrubby and open habitats between 3,000 to 4,000 m asl. During the present study, this species was recorded at similar altitudinal ranges.

Clausnitzer and Kityo (2001) stated that species of the genus *Lophuromys* are very successful and ubiquitous rodents in tropical Africa. Also Clausnitzer *et al*. (2003) reported, *Lophuromys flavorpunctatus* is one of the most numerous rodents in the moist area of East Africa, inhabiting a wide range of different habitats and without any ecological and geographical restriction. Yalden (1988), and Happold and Happold (1989) state the distribution of *L. flavopunctatus* along the high plateau of Ethiopia. It was also the most widely distributed and abundant species of rodent in the present study area, from the altitudes ranging from 2,848 to 3,490 m asl. This species occurred in all habitat types such as open grassland (OGL), moorland (ML), *Lobelia* with *Hypericum* (LH), montane forest (MF) and farmlands (FL) (Table 3).

Arvicanthis dembeensis has been described as endemic species to Ethiopia (Fadda and Corti, 2001; Corti *et al*., 2005). The species has a wide distribution in many parts of Ethiopia (Afework Bekele *et al*., 1993). Some records about the species indicated that it occurred in different parts of the country including Menagesha State Forest usually at 2,200 m asl (Afework Bekele, 1996b). Workneh Gebresilassie *et al*. *(*2004) also recorded *A. dembeensis* from Maynugus irrigation field, northern Ethiopia. Besides, the presence of this species was also confirmed at higher elevation near to Kutaber (north Shewoa) at 2,650 m asl (Yalden *et al*., 1976). Furthermore, Tsegaye Gadisa and Afework Bekele (2006) recorded the species, around Bilalo village, Arsi, at an altitude of 2,643 m asl this is almost similar to Yalden *et al*. (1976). However, the species was not recorded at higher altitude above 2,650 m asl in Ethiopia, and it was considered as a lowland species occurring from sea level to 2,000 m. In contrary, it was recorded in the present study area, at altitudes ranging from 2,848 to 3,293 m asl in the farmland and open grassland, respectively. The probable reason might be due to ecological degradation, change of climate and competition enabled the species to extend its altitudinal distribution to the highlands.

During the present study, it was a commonly trapped rodent from open grassland (OGL) and farmland (FL). However, the species was not recorded in moorland (ML), *Lobelia* with *Hypericum* habitat (LH) and montane forest (MF). The species was more abundant relatively in open grassland than farmland. This may be an indication of its grass loving nature.

Otomys typus usually occurring above 2,300 m and had been recorded from various mountains in Kenya, Uganda, Sudan, Zambia and Tanzania, in addition to Ethiopia (Delany and Happold ,1979). In Ethiopia, the species has been recorded in the south-eastern highlands, central highlands (Shewa) and Simien Mountains (Yalden *et al*., 1976; Sillero-Zubiri, 1995b; Carleton and Byrne, 2006). Similarly, it was also a commonly distributed rodent species in the present study area, and the species was trapped in all habitat types. In addition, it was the second abundant species that accounted (28.5%) next to *L. flavopunctatus* (35.7%). During the present study, it was the dominant species in the *Lobelia* with *Hypericum* habitat (56.8%) than other habitats of the study area, but it was less abundant in the farmland (3.1%).

Among the rodents of Ethiopia, *S. albipes* is the most widely spread endemic species in both forests and bush vegetation although the species is ubiquitous in its distribution within Ethiopia at altitudes ranging from 800 to 3,300 m asl (Yalden *et al*., 1976; Yalden, 1988; Afework Bekele, 1995, 1996a; Afework Bekele and Corti, 1997; Fadda and Corti, 2000; Corti *et al*., 2005). Similarly, it was also a widely distributed rodent species in the central highlands of Ethiopia. However, in the present study the species was recorded only at altitudes of 3,114 m asl in the forest habitat type.

Pelomys harringtoni is widespread on the Ethiopian plateau, on both side of the Rift Valley, at altitudes from 1,800 to 2,800 m asl (Yalden and Largen, 1992). In the present study, it was the least distributed species and was confined to agricultural area (farmland) at 2,848 m asl. It was not recorded in other habitats of the study area.

Dendromus lovati is an endemic species which is distributed on the highlands of Ethiopia. Yalden *et al*. (1976) confirmed that the species occurs in the Menagesha State Forest, Bale Mountains (Dinshu), Arussie plateau, and around Dessie areas. The species was recorded at altitudes ranging from 2,500 to 3,550 m asl. It frequents grassland and nests beneath the ground. In the present study area, it was recorded at altitudes of 2,848 m asl and it was the least distributed and less abundant species that occurred only in the farmland (wheat farm).

Mus mahomet is a widespread species in Ethiopia (Yalden, 1988). Yalden and Largen (1992) have also reported that the species is often associated with secondary scrub around agricultural areas, and it was recorded at altitudes ranging from 1,500 to 3,200 m asl. Furthermore, Workneh Gebresilassie *et al*. (2004) revealed that the species mostly occurs in vegetable and cultivated monocot microhabitats. Apart from these, it was also recorded as pest of crops in Ethiopia (Afework Bekele *et al*., 2003). It had a restricted distribution in the farmland (wheat farm) during the present study.

Crocidura flavescens is one of the most common and widespread shrew in Ethiopia, where it ranges from approximately 1,000 to 3,000 m asl (Yalden *et al*., 1976). The species is also distributed at lower altitudes which are a characteristics of riverine and lake side habitats

(Monadjem, 1997). Yalden (1988) observed the occurrence of *C. flavescens* in Bale Mountains National Park, below the treeline, and in association with clearings and within the forest. It was also recorded in the present study area, at altitudes ranging from 3,293 to 3, 490 m asl in the habitats of open grassland (OGL), moorland (ML) and *Lobelia* with *Hypericum* (LH) types. But it was not observed in the montane forest (MF) and farmland. Studies on the ecology and breeding of small mammals in Uganda by Delay (1964) stated *C. flavescens* to be a widely distributed species including the forest.

Crocidura fumosa was confirmed to occur in Ethiopia at altitudes of 1,750 to 3,900 m asl and it is also known from the mountains of Kenya, Uganda, and Malawi (Yalden *et al*., 1976). In the present study area, the species was recorded at altitudes of 3,114 m asl similar to the elevation stated by earlier studies. However, its distribution was restricted only in the montane forest habitat type.

During the present study, the number as well as species composition of rodents and insectivores varied from season to season within and between habitats. Happold and Happold (1987) have stated that within a community of small mammals, one or more response may occur to the changing conditions, and species which can fully utilize the new condition will survive and perhaps even flourish whereas, others which can only partially utilize the new conditions will decline in numbers; resulting in changes in species composition and total number. Hence, some species that occur in one season might not show up in the next. For instance, *P. harringtoni*, *D. lovati* and *M. mahomet* were not recorded during the wet season, but they were trapped during the dry season in the farmland (wheat farm) at the time of harvest. Furthermore, the number of species increased during harvest stage of wheat farm. This was probably due to the availability of food resource even though the population number of each species decreased. To the contrary, Demeke Datiko *et al*. (2007) stated that farmlands were less preferred by most rodent species, except few which are pest. *C. fumosa* was not recorded during the dry season in the forest habitat. Similarly, *L. flavopunctatus* was not trapped during the dry season in the moorland habitat (ML). This might be related to the population change during the dry season, due to scarcity of food. This showed that rodents and insectivores are opportunistic feeders, capable of changing their feeding habits depending on the seasonal availability of food.

The age distribution in a population of most species of rodents and insectivores is directly related to seasonality in reproduction (Yalden, 1988) When reproduction of a species is seasonal, all age groups are expected to occur in the population within that specific season. In the present study, during the wet season, a large number of juveniles was recorded next to adults,whereas, sub-adults were less in number compared to the juveniles. However, during the dry season, the number of both sub-adult and adult individuals decreased, the same was true for juvenile. Even for the most abundant species *L. flavopunctatus* and *O. typus*, juveniles were rarely recorded during the dry season eventhough there are a number of contradictory accounts of breeding activity in *L. flavopunctatus*. Delany (1964) observed a continuous breeding through out the year in tropical Africa.

In the present study, the sex ratio of rodents and insectivores did not show significant variation based on seasonal changes (Table 4). However, in some cases, the number of females increased as the number of captured rodents and insectivores increased. This was probably due to that populations size might follow the pattern of increase in number of fertile females.

Data on rodent and insectivore biomass (Table 6) show the mean biomass from the recorded species together in all trapping occasions was 11,791.4 g/ha for *Lobelia* with *Hypericum* habitat type, followed by 8,002.9 g/ha for open grassland habitat. The lowest mean biomass estimated 1,567 g/ha for wheat farm. The highest and the lowest average biomass estimates were obtained during the second trapping session in the *Lobelia* with *Hypericum* habitat type and during the fourth trapping session (post-harvesting) at wheat farm, respectively. Manyingerew Shenkut et *al*. (2006) revealed that variation in the biomass recorded at different trapping sessions was associated with the fluctuation in population number. Similarly, in the present study, the biomass of small mammals varied from one grid to another in different trapping occasions.

In the present study, the trap success significantly varied between habitats and seasons. Afework Bekele (1996a) observed a difference in trap success between different habitat types. The mean trap success was 26.9%. Also similar studies in different parts of Ethiopia showed Variations. Afework Bekele (1996b) recorded a mean trap success of 9.1% in the Menagesha State Forest. Yalden (1988) obtained 18.7% mean trap success from Harenna Forest, Happold and Happold

(1991) recorded average trap success 33% from Lengwe National Park, Malawi and Bekele Tsegaye (1999) has recorded 62.8% average trap success from Entoto Natural Park. During the present study, the highest overall trap success was recorded from open grassland and *Lobelia* with *Hypericum* habitat (65.9%), whereas the lowest was from farmland (4.1%) in general, the present study showed trap success to be high during the wet season than the dry season. This was highly related to the population dynamics between seasons. During the wet season, the population increased probably due to increased availability of food. At the same time, during this period, the burrows were filled with water. As a result, the animals were forced to hide in grass. This increased the chance of accessibility to enter the snap traps enabling to increase trap success during the wet season. However, low trap success was recorded during the dry season. This could be due to low population density. Population in the dry season was affected by shortage of food supply in the habitat in addition to high number of avian predators. Furthermore, during the dry season due to excessive solar radiation, trap success were greatly affected. Since most small mammals preferred to hide in their burrows for a long period to passthrough the harsh conditions.

The density of small mammals in the present study varied from habitat to habitat. The overall, density of small mammals recorded at habitat level throughout the trapping sessions greatly varied. The lowest density was estimated from the wheat farm (112/ha). Whereas, the highest density was from *Lobelia* with *Hypericum* habitat type was 590/ha. The density of small mammals per hectare in the present study showed a range of 2-116/ha. This can be compared with densities in other localities in Africa. Happold and Happold (1989) estimated the density of small mammals in montane area of Malawi from 3-17/ha, Dieterlen (1967) found densities of 236 – 361/ha in the lowland forest of Congo, Happold (1974) estimated population densities in western Nigeria from 16–106/ha. In general, comparisons of population density are difficult. Afework Bekele (1996a) stated comparison of densities and biomasses are difficult due to the variation of habitats and weights in different species of small mammals, and underestimation of the available numbers.

Biomass of rodents and insectivores significantly decreased during the dry season. This was probably correlated with food, which was expected to be restricted during the dry season in both quantity and quality. Merritt *et al*. (2001), Taylor and Green (1976) have stated that weight of small mammals decreased more during the dry season than wet season. This was due to limited availability of food during the dry season. Besides, food quality as well as food availability might be important in determining the fertility rate of small mammals. Hence, the number of embryos from the recorded small mammals decreased during the dry season.

Small mammals are opportunistic feeders, capable of changing their feeding habits depending on the availability of food from season to season (Kingdon, 1997). In the present study, stomach samples of five rodent and one insectivore species were taken and the results show most of them were omnivores and granivores. *S. griseicauda* shows effective foraging activity on monocot leaves, and it contributed the highest percentage of its diet. In addition, the species feed on dicot leaves, small proportion of dicot seeds and roots. Similarly, Sillero-Zubiri *et al*. (1995b) revealed that *S. griseicauda* dominantly recorded in montane grassland and it observed frequently foraging on monocot plants or grass. Clausnitzer *et al*. (2003) have reported a relatively large number of *L. flavopunctatus* in the wet areas may reflect its dependency in soil dwelling prey. *L. flavorpunctatus* is thus an omnivore, feeding on both plant materials and invertebrates. The present study also supports this view. However, a great proportion of its diet was invertebrates.

Taylor and Green (1976) stated that the diet of *O. typus* consisted exclusively the vegetative parts of plants, mainly grass with a tendency for more dicotyledons plants during the dry months. Relatively small quantities of seeds, barks of shrubs and trees were occasionally eaten by *O. typus* during the dry season. In addition, the present study showed that the highest proportion of the diet of *O. typus* was monocot leaves mainly *Festuca abyssinca,* followed by dicot leaves. Furthermore, small proportions of seeds, roots and mosses along with the barks of shrubs were also obtained in their diet during the dry season.

A. dembeensis was abundant in the area where grass occurs. The highest percentage of the diet was monocot leaves and a relatively less percentage of dicot leaves were found in both seasons. Workneh Gebresilassie *et al*. (2004) also found higher percentage of grass and monocot seeds in the stomach of *A. dembeensis.*

S. albipes was observed to be highly dependant on monocot leaves and a considerable dicot leaves during both wet and dry seasons. Besides, few fragments of monocot and, dicot seed and invertebrates were also observed. In the stomach contents of *C. flavescens*, plant fibers of monocot and dicot leaves were obtained. However, the majority of the stomach contents of *C. flavescens* were animal matter with a considerable amount of undifferentiated food fragments.

Crop damage was assessed at different stages of wheat growth. Rodent damage follows crop phenology. Leirs (2003) reported that rodents cause more damage at some stages in the growth of crops than others. In the present study area, the common pest rodents of wheat crop were *A. dembeensis*, *M. mahomet* and *H. cristata*. The stomach content analysis showed that *A. dembeensis* consumed a small proportion of grains. Afework Bekele *et al*. (2003), Workneh Gebresilassie *et al*. (2004) and Manyingerew Shenkut *et al*. (2006) reported *M. mahomet* to be a crop pest in different localities of Ethiopia. Whereas, *A. dembeensis* is the most notorious pest in eastern Africa including Ethiopia (Leirs *et al*., 1996). In the present study to estimate the damage on wheat crop two stages of wheat growth were considered. In the first stage of wheat crop the damage was 0.95% whereas, near harvesting stage the damage increased to 8.6%. This was probably due to that pest rodents preferred near harvesting stage to the others to obtain seeds.

7. THREATS

Denkoro Forest Priority Area is the sole protected area to conserve the remaining afroalpine and evergreen afromotane forest with a distinct vegetation zone. It harbours different species of avian and mammalian fauna. However, this priority area is exposed to various environmental threats.

Stocking density around the forest is very high; hence, the high number of grazing cattle and other domestic animals show a devastating effect on the edge of protected area, mainly at the afroalpine grassland ecosystem. Because of overstocking, there has been deterioration in the quality of vegetation with an increase in unpalatable grasses like *Festuca abyssinica*. The construction of road that passthrough the forest between Debresina and Densa Woredas caused a lot of destruction by overgrazing and trampling of large numbers of Pack animals and humans. These cause the deterioration of plant species and disturbance of wildlife along the road sides. Additionally, the main road cuts the corridor of Gelada Baboon and Klipspringer that connect the eastern lower escarpment to the northern one with many ridges and peaks.

The most pervasive impact on the study area is people involved in the regular cutting of tussock grass for market, thatching house and other purposes. In addition, cutting of *Hygenia abyssinica* and *Erica arborea* also occurred for timber production and fuel consumptions mainly in the dry montane forest of Denkoro. Furthermore, undergrowth disturbance by domestic animals was high near the edge of the forest.

8. CONCLUSION AND RECOMMENDATIONS

Ecologically, small mammals have a significant impact on the environment as grazers, seed-eaters, insectivores, as prey for some carnivores and a source of human diet. Furthermore, they are important pest of agriculture in the field, and are vectors of disease.

In the present study, twelve species of small mammals were recorded from five randomly selected habitats. Distribution, habitat association and relative abundance of small mammals varied from season to season. Variation in the abundance of rodents and insectivores in different habitats show the key role of ground vegetation from season to season. Open grassland which had a relatively good ground cover showed the highest species abundance in the wet and dry seasons. Whereas, the wheat farm, after the post-harvesting period had the lowest species as well as population number due to less availability of ground cover.

Density of small mammals per hectare varied within different habitats and seasons in the study, from 590 to 112/ha at habitat level whereas, seasonally showed that 22 to 204/ha. This was highly related to the variation in rainfall between seasons. Rainfall had significant effect on the seasonal abundance of small mammal species. Trap success was high during the wet season than dry season. Moreover, large number of juveniles and considerable pregnant females were recorded during the wet season. This ecological factor brought a significant difference on density of small mammals from season to season.

In the study, both the availability and quality of food resulted in differences in fertility and biomass of small mammals between seasons. These brought a variation in density of population during the entire period of the study. Hence, diet is the basic ecological parameter to the study small mammals. In general, data collected during the present study provide valuable information on species composition, distribution, habitat association and relative abundance of small mammals in Denkoro forest.

Based on the information obtained from the present study, the following recommendations are suggested**:**

- Livestock grazing, which is a common practice in the protected area should be reduced and develop alternative income generation to the people.
- Creating awareness on the various beneficial aspects of the forest resources.
- Timber cutting from the forest should be stopped, if possible, at least controlled.
- Apply alternative settlement programmes and promote agro-forestry practice.
- Avoid disturbance of small mammals by plant trampling and cutting. They are the main source of diet to the endemic Ethiopia wolf and other carnivores.
- Construct alternative roads out of the forest and the daily traders should be stopped so that trampling of *Festuca*, undergrowth and wildlife disturbance could be minimized.
- Denkoro forest can be considered as an island of valuable conservation area that harbours different endemic and endangered species, such as Ethiopian wolf, Gelada Baboon, Menelik's bushbuck, Stark's hare, Leopard, Colobus Gureza and avifauna. Hence, the government as well as the concerned bodies should give attention to conserve this remnant afro-alpine area.

9. LITERATURE CITED

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Appendix-1. List of large mammals of Denkoro Forest

Order/ Family	Common name	Amharic name
Carnivora/Canidae		
Canis aureus	Common jackal	Tera-kebro
Canis mesomelas	Black-backed jackal	Tikur-jerba kebro
Canis simenes	Ethiopian wolf	Key-kebro
Hyaenidae		
Crocuta crocuta	Spotted Hyena	Jebe
Felidea		
Files carcal	Caracal	Dalga- Anbesa
Files serval	Serval	Aner
Panthera pardus	Leopard	Neber
Herpestidae		
Ichneunia albicauda	White-tailed mongoose	Faro
Genetta abyssinica	Abyssinian Genet	Shelmtsematse
Mustelidae		
Mellivora capensis	Ratel (Honey badger)	Kefo-defi
Ictonyx striatus	Zorilla (Striped polecat)	Fadet
Artiodactyla/ Bovidae		
Tragelaphus scriptus Meniliki	Menelik's bushbuck	Menelik dekulla
Tragelaphus scriptus	Common bushbuck	Dekulla
Silvicapra grimmia	Bush duiker	Medakoa
Oreotragus oreotragus	Klipspringer	Ses
Madoqua saltiana	Salt's Dik- Dik	Inshu
Leporidae		
Lepus starckii	Starck's hare	Tinchel
Suidae		
Phacochocerus aethiopicus	Common warthog	Kerkero
Hyracoidae/Procaviidae		
Procavia capensis	Rock hyrax	Shekoko
Hetrohyrax brucei	Bush hyrax	Shekoko
Primate/ Cercopithecidae		
Theropithecus gelada	Gelada Baboon	Gelada zengero
Papio anubis	Anubis Baboon	Tera zengero
Papio hamadryas	Hamadryas Baboon	Nech zengero
Cercopethicus aethiops	Grivet Monkey	Tera-tota
Colobidae		
Colobus guereza	Colobus Monkey	Guereza

Declaration

I, the under signed, declare that this thesis is my original work; it has not been presented in other university, College or institutions, seeking for similar degree or other purposes. All sources of the materials used in the thesis have been dully acknowledged.

Eshetu Moges	Signature ______________________
Advisors	
Prof. Afework Bekele	Signature ______________________
	Date ______________________
Dr. Zelealem Tefera	Signature ______________________
	Date ______________________

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