ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES
FACULTY OF SCIENCE
DEPARTMENT OF BIOLOGY

Certain Aspects of Ecology of Rodents in Pawe Area, northwest of Ethiopia

By
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A Thesis Submitted to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Biology
(Dryland Biodiversity stream)

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June, 2009

ACKNOWLEDGEMENTS

I am extremely grateful to my advisor, Professor M. Balakrishnan for his initiation, encouragement, advice, assistance and unreserved help in all aspects of this research. His valuable suggestions and comments, and friendly approach throughout the period of this research and critical reading of the draft are greatly acknowledged. His willingness to provide reference materials and to share his knowledge and experiences is also greatly appreciated.

I would also like to express my special appreciation to Professor Afework Bekele for allowing free access to all field and reference materials, introducing me to the techniques of trapping and identification of small mammals and for sharing ideas after each field sessions.

I greatly acknowledge the Department of Biology, Addis Ababa University for the facilities and financial support received during my research work. I thank Ato Ketema Amberbir for his interest and willingness to be with me in all my work in the Zoological Natural History Museum of the Addis Ababa University. My thanks are also due to Pawe Agricultural Research Centre and the Woreda Agriculture and Rural Development staff members, for their help during the field work.

I extend my thanks to Mark and Genanaw Menichel for their assistance in the field work and material provision and to Gilgel Beles College of Teacher Education for sponsoring my graduate studies.

June 5, 2009

Tilahun Chekol

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ABSTRACT

An ecological study dealing with species composition, distribution, relative abundance population density, biomass and habitat association of rodents was carried out in Pawe area around Almu in Ethiopia during August, 2008 − March, 2009 in natural forest, plantation, bushland, grassland and maize farm habitats. In each of the habitat types, grids were randomly selected for live-trapping and snap-trapping. Live-traps and snap-traps were set for three days twice during the wet and dry seasons. A total of 643 individuals comprising 10 species of rodents and two species of insectivores were captured. The rodents trapped were *Mastomys natalensis* (37.9%), *Arvicanthis dembeensis* (28.8%), *Stenocephalemys albipes* (9.2%), *Mastomys erythroleucus* (7.5%), *Arvicanthis niloticus* (4.5%), *Acomys cahirinus* (3.6%), *Tatera robusta* (2.6%), *Lemniscomys striatus* (1.7%), *Mus musculus* (0.9%) and *Rattus rattus* (0.3%). The two species of insectivores trapped were *Crocidura flavescens* (2.2%) and *Crocidura fumosa* (0.8%). In addition to this, *Tachyorctes spledens, Hystrix cristata, Heliosciurus gambianus* and *Euxerus erythropus* were observed in the study area. The population density ranged from 50/ha in the plantation to 311/ha in the bushland. *M. natalensis* was the most abundant and widely distributed species and *R. rattus* the least with limited in distribution in the present study area. The majority of the rodents and insectivores were associated with the bushland habitat. More number of rodents was trapped during the wet season than during the dry season. There was also significant variation in trap success among different habitat types. High cumulative average trap success of 26.2% was recorded in the bushland, whereas the lowest trap success of 4.2% was recorded in the plantation. Individuals of all age categories were present during the present study in all trapping sessions. Abundance of rodents was reduced during the dry season as a result of fire. The level of maize crop damage by rodents was 14.2 %. *M. natalensis, A. dembeensis, M. erythroleucus* and *T. robusta* were recorded as pests of maize crop in the study area.

Key words/ phrases: Abundance, distribution, habitat association, Pawe, population density, rodents, species composition.

1. INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Ethiopia is one of the most physically and biologically diverse countries in the world (Tesfaye Hundessa, 1997; Leykun to the Abunie, 2000). The variation in altitude ranges from 110 m below sea level at Kobar sink in the Afar depression to the highest peak at Ras Dejen (4,620 m asl) (Shibru Tedla, 1995; Afework Bekele and Corti, 1997; Gete Zeleke, 2003). Such wide variation in altitudinal ranges, geographical position and rainfall patterns result in the presence of diverse biological resources in this country. These variations resulted in diverse sets of ecosystems with a variety of wildlife habitats ranging from alpine moorlands to savannah and arid lands to extensive wetlands (Tesfaye Hundessa, 1997). Other associated factors also result in a wide range of climate that affects the distribution of flora and fauna, human population, agricultural practices, evapotranspiration potential and temperature zones in Ethiopia (Yalden and Largen, 1992).

The flora of Ethiopia is very heterogeneous and diverse with an estimated number between 6,500 and 7000 species of higher plants of which about 12 % is endemic (Tewoldebirhan G/Egziabhere, 1988). The country is also rich in its faunal diversity. Over 284 species of mammals, 860 species of birds, 200 species of reptiles, 145 species of fish and 63 species of amphibians are known from Ethiopia (Yalden and Largen, 1992; Malcolm and Sillero–Zubiri, 1997). Among these, 31 species of mammals, 26 species of birds, 24 species of amphibians and 150 species of higher plants are endemic to Ethiopia (Yalden and Largen, 1992; Malcom and Sillero Zubiri, 1977).

Mammals are diverse groups of vertebrates with an estimated number of 5000 species, globally. Among them, rodents are the most numerous (Kingdon, 1997; Vaughan *et al*., 2000; Afework Bekele, *et al*., 2003). Rodents comprise more than 2000 species, which accounts for nearly 40% of the entire mammalian species in the world (Meehan, 1984; Wilson and Reeder, 1993). Out of the 284 species of mammals that occur in Ethiopia, 84 species are rodents. Among them, 15 (12%) are endemic to Ethiopia (Yalden and Largen, 1992; Hillman, 1993; Afework Bekele, 1996a; Afework Bekele and Leirs, 1997). This shows the diversity and success of rodents in the country is as a consequence of diverse factors such as altitude, variation in rainfall and climatic patterns, soil variability, vegetation and habitats.

Majority of the Ethiopian highlands have large number of endemic species of mammals; even though the species diversity is less than many lowlands (Yalden and Largen, 1992). Many of the endemic mammals are associated with high altitude moorland and grassland habitats (Yalden, 1983). On the other hand, in the relatively western lowlands, the vegetation is typically of savanna type, characterized by tall grasses or deciduous broad leaved plants (Yalden and Largen, 1992), which support a range of species. The western lowlands of Ethiopia, laying to the west of the northern mountain and the southwestern highlands extend from Tigrai in the north to Illubabor in the southwest. This area forms the Ethio-Sudanese border, which includes the lowlands of Benshangul Gumuz Regional State.

A number of investigations was carried out to study various aspects of small mammals in the southwestern forests, south and southeastern highlands, the Rift Valley, the Smien massifs and few isolated blocks of central Ethiopia by Yalden and Largen (1992), Afework Bakele (1996 a, b), Afework Bekele and Courti (1997), Tsegaye Gadisa and Afework Bekele (2006), Workneh G/Selassie *et al*. (2004), Manyingerew Shenkut *et al.* (2006) and Demeke Datiko *et al*., (2007), but different areas of the country including the western lowlands are under-explored as a result of inaccessibility, remoteness and inhospitability of the area. Lack of scientific information about the fauna of the area and accelerated human interference in search of arable land and resettlements, adversely affect the natural habitats of this area. Therefore, the aim of the present investigation was to gather data on the species composition, distribution, population density, relative abundance, biomass and habitat association of rodents in Pawe area in Benshangul Gumuz Regional State in the north western lowland of Ethiopia, near the Ethio-Sudanese border.

1.2 Literature Review

Small mammals in general represent a heterogeneous group from a taxonomic point of view (Torre, 2004). They share biological and ecological features related to their small size. Small sized species have high metabolic rate and shorter life span than larger ones. Fast metabolism and short life span are also linked to high reproductive rates related to r–strategies of growth and development (Stearns, 1992). Because of these characters and relatively small home ranges, small mammals are considered as ideal taxonomic forms to be used as models, addressing questions at different spatial scales (Manning and Edge, 2004). Species diversity of small mammals can be influenced by many factors. The habitat heterogeneity hypothesis states an increase in habitat heterogeneity leads to increase in species diversity (Cramer and Willig, 2002). Habitat heterogeneity could enhance diversity when habitats are large enough to support distinct populations. In addition to this, the presence of dominant species (both numerically and competitively) can also have strong influence on community structure and diversity (Anderson, 1992; Heske *et al.*, 1994). Disturbance is also another important factor affecting species diversity in natural ecosystems (Sousal, 1984). These effects are more prevalent on those species that share niche requirements with the dominant species, whereas species with little niche overlap are unaffected (Heske *et al.*, 1994).

Diversity of a community can be measured either by number of species present (species richness) or with indices that incorporate richness and distribution of individuals among the species present (evenness or equitability) (Krebs, 1989). Both richness and evenness can be affected by interactions among species leading to changes in diversity (Brady and Slade, 2001). Interactions among species, lead to changes in species richness (Brady and Slade, 2001).

Small mammals form the highest proportion of mammals all over the world (Tsegaye Gadisa and Afework Bekele, 2006; Workneh G/Selassie *et al.*, 2006). Among them, the Order Rodentia contains the largest group of the species (Macdonald, 1984; Buckle and

Smith, 1994; Kingdon, 1997; Nowak, 1999; Vaughan *et al.,* 2000; Magige and Senzota, 2006; Tsegaye Gadissa and Afework Bekele, 2006; Feldhamer *et al*., 2007). Rodents account for more than 40% of the mammalian species in the world with 21 living families, 443 genera and more than 2000 species (Wilson and Reeder, 1993; Danell and Aeve-Olsson, 2000). Among the rodent species, 66% belongs to the Muridae family with 281 genera and 1325 species. It is the largest mammalian family with nearly worldwide distribution (Vaughan *et al.,* 2000; Demeke Datiko *et al*., 2007). Diverse types of interactions with other organisms, adaptability to diverse habitats and the food habit of rodents have been responsible for their success in such wide distribution pattern globally.

Rodents date 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). They occur in every habitat and show great diversity in their morphology, ecology, physiology and behaviour. A number of rodents are fossorial (e.g. mole rat), some are terrestrial (e.g. ground squirrel), arboreal (e.g. tree squirrels) or semi-aquatic (e.g. beavers and water voles) (Vaughan *et al*., 2000; Feldhamer *et al*., 2007) and move by leaping, climbing, gliding and swimming (Delaney and Happold, 1979). They also show considerable diversity in their diet (Leirs, 2003).

Diverse varieties of food are consumed by rodents. These include items like grains, cereals, fruits, seeds, nuts, buds, seedlings, barks, leaves, flowers, roots and invertebrates (Macdonald, 1984; Vaughan *et al*., 2000). Most rodents are opportunistic feeders, capable of changing their feeding habit depending on the availability of food from season to season. Their behavioural traits make them the most distructive pest of cultivated plants (Leirs *et al*., 1994; Workneh G/Selassie *et al*., 2004).

Rodents also range in size from about 5 g to 50 kg (Vaughan *et al*., 2000). The harvest mouse (Micromys) is the smallest, which weighs 5- 8 g and some rodents such as squirrels, beavers and porcupines reach medium size. On the other hand, Capybara is the largest of all rodents, which is about the size of a sheep. The African rodents also range in size from the small pygmy mouse (*Mus muscloid*), which weighs 7 g to the crested porcupines (*Hystrix cristata*), which weighs 12–27 kg (Delany and Happold, 1979; Kingdon, 2004). However, rodents show less overall variation in body plan compared to other mammals.

Although, rodents are diverse and most numerous groups of mammals, all of them share a uniquely derived characteristic, *i.e*. their dentition specialized for gnawing (Macdonald, 1984; Wilson and Reeder, 1993; Vaughan *et al*., 2000). All rodents have one pair of incisors enlarged sharply, bevelled and evergrowing. Enamel of the incisors is restricted to the outside surface only and during gnawing. The softer posterior dentine is wearing away as the incisors grind each other. Broad diastema is always present between incisors and premolars of both upper and lower jaws resulting from the absence of canines and some cheek teeth. Most rodents never have more than 22 teeth except silver mole rat, which has 28 (Macdonald, 1984; Nowak, 1999).

Population dynamics addresses the causes of the variations in population density including limiting and regulating factors that account for these variations (Krebs, 1999). From the tropics to the polar regions, rodent populations experience seasonal, inter-annual and multi-annual fluctuations in numbers (Stenseth and Ims, 1993; Meserve *et al*., 1996; Leirs *et al.*, 1996; Lima and Jaksic, 1999). Such fluctuations can be regular or not. These fluctuations are the results of the basic demographic processes such as reproduction, survival, mortality, emigration and immigration (Lima *et al*., 2001). The survival, reproduction and population dynamics of rodents are in turn limited by the habitat structure and food supply (Boutin, 1990). Reproduction is the most vital source or recruitment that influences population density of rodents (Leirs, 1995).

Seasonal pattern of reproduction has been observed in rodents in relation to variations in rainfall; reaching its peak during the rainy season and declining during the dry season (Taylor and Green, 1976; Delany and Monro, 1986; Afework Bekele and Leirs, 1997). Rainfall increases availability of food and hence is a key factor in determining the reproductive season of rodents in the area (Toylor and Green, 1976). Availability of sufficient food is a major factor, which influences the initiation of reproduction, litter size, body condition and growth rate of rodent communities (Boutin, 1990). Hence, the availability of food is considered to have demographic consequences. On these bases, rodents have been used as models to study the role of food availability on population dynamics using both experimental and natural approaches (Duquette and Millor, 1995; Meserve *et al.,* 2001; Diaz and Alonso, 2003).

Rodents show preferences for habitats with high amount of vegetation cover (Kotler and Brown, 1988), which is closely related with predation risk (Bowers, 1988; Diaz, 1992; Lagos *et al*., 1995). The selection of thick vegetation is considered to be an antipredatory strategy against both aerial (Longland and Price, 1991) and terrestrial (Jedrzejewski and Jedrzejewska, 1990) predators. Various means of cover removal have resulted in depletion of rodent populations (Taylor and Green, 1976). The composition and abundance of rodents a given habitat can maintain will depend on microhabitat features, which provide food and shelter against predators (Lin and Batzli, 2001).

Rodents are important components of the earth's terrestrial ecosystems. Some are important herbivores that aerate the soil by burrowing activities and assist plant propagation by consuming and disseminating seeds (Wada and Uemura, 1994). Others form the most important food base for many mammals and birds. They are also sources of human food in many regions of the world (Feldhamer *et al*., 2007). Rodents are the most important groups of mammals in terms of the problems they create in agriculture, horticulture, forestry and public health, globally.

Rodents are the most noxious among vertebrates as pests (Makundi *et al*., 1999). They are responsible for substantial damage to food and cash crops, structures and industrial and domestic properties. Many species of rodents have been recorded as pests in agriculture, causing a wide range of damage and losses in cereals, legumes, vegetables and tuber crops (Makundi *et al*., 1999; Pech *et al*., 2003; Palis *et al*., 2007). For example, in Africa, out of the 381 species of rodents, 77 are pests (Singleton *et al*., 2007) of which the genus *Mastomys* and the genus *Arvicanthis* are major known pests (Taylor and Green, 1976; Leirs, 1999). In Australia, out of the 67 species of rodents four, in Europe, out of

61 species five, in India, out of 128 species 12 and in Indonesia, out of 164 species 13 are major pests (Singleton *et al*., 2007). In Ethiopia, out of the 84 species, 11 are pests (Afework Bekele and Leirs 1997).

Globally the average annual yield loss by rodents is very high, which could otherwise form food for millions of people. Rodents are known to damage and destroy 30% of the crops in both pre-harvest and post-harvest conditions (Singleton, 2001). Rodents consume an average of agricultural food crops worth of $ 30 billion, globally (Feldhamer *et al*., 2007). In East Africa, rodents cause considerable economic losses to staple crops, particularly tubers and cereals. For example, in Tanzania, the loss of cereals by rodents reaches approximately 15% (Makundi *et al*., 1999) and the damage of maize at sowing and seedling stage is around 40–80% (Mwanjabe and Leirs, 1997). In western Kenya, Taylor (1968) reported a 20%, 34-100% and 34% loss of maize, wheat and barley, respectively, following an outbreak. Afework Bekele *et al*. (2003) reported that in Ethiopia, the loss of cereal crops is from 20-26%, annually.

A survey made in Pakistan showed a 2-9% pre-harvest damage of wheat and a 3-8% of damage of rice (Hopf *et al*., 1976). A study in Bangladish showed an estimated 12.1% loss of mature wheat, which indicated an approximate damage of 77,000 tons in the field before harvest by the lesser bandicoot (*Bandicota bengalensis*) (Bruggers, 1983). In Australia, almost 200,000 tonnes of wheat, oats, maize and sorghum were destroyed by house mice during 1969-1970. During the same period, in one of the main irrigation areas, the average damage to all standing crops was estimated to be more than 15% (Hopf *et al*., 1976). According to Buckle and Smith (1994), damage to stored grain and animal feed was estimated to be US $ 17-34 million per year in Hampshire, England.

In addition to this, rodents are major pests of sugarcane plantation causing direct damage at sugar formation stage and indirectly by increasing the risk of infection by bacteria and fungi (Serekebirhan Takele *et al*., 2008). For instance, in the 1999 harvest season, rodents in Australian cane fields destroyed sugarcane valued at US $ 50 million (Rao, 2003). In Hawaiian sugar cane plantations, they caused losses that have been estimated at 4.5

million US$ annually (Leung, 1998). Serekebirhan Takele *et al*. (2008) reported about 4% loss of sugarcane by rodents in Wonji sugarcane plantation in Central Ethiopia.

Most of the rodent damages in agricultural fields occur during the sensitive young seedling stage and just before harvest (Fiedler, 1994; Stenseth *et al*., 2001). However, farming practice, change in climatic factors and the intrinsic characteristics of the pest species are among the factors that possibly influence the occurrence and severity of rodent attacks on crops (Makundi *et al*., 1999).

Pest rodents range from the medium sized multimammate rat (*Mastomys natalensis*) to the giant rat (*Cricetomys gambianus*) and the crested porcupine (*Hystrix cristata*). They are causing a wide range of damage and losses in cereals, legumes, vegetables and root crops. Some pest species are found specifically in certain geographical and environmental conditions, while others are widely distributed. For example, *Rattus norvegicus* is restricted to coastal sea-ports and is not found in the interiors of the continents (Mwanjabe, 1987; Fiedler, 1994). The house mouse (*Mus musculus*) is found mostly in urban areas and in some village dwellings (Delany, 1972; Fiedler, 1994). *Rhabdomys pumilio* is commonly found in grasslands lying at high elevations (Hubbard, 1972). However, the roof rat (*Rattus rattus*), the multimammate rat (*Mastomys natalensis*) and the Nile rat (*Arvicathis niloticus*) are widely distributed over East Africa (Kingdon, 1974), thus occupy diversity of habitats including cultivated fields.

In addition to direct consumption, rodents cause severe damage indirectly by contaminating stored crops by their droppings, urine, hairs, oily skin gland secretions and microorganisms (Macdonald, 1984; Nowak, 1999). They also gnaw and perforate irrigation pipes, peel off plastic covers of communication and electric cables causing short circuit and fire hazards (Heth, 1991). Rodents that burrow into banks, sewers and under roads and buildings also cause flooding, soil erosion and collapse of human built structures (Macdonald, 1984).

Other than being instrumental in crop damage, they are also reservoirs and carriers of zoonotic diseases that can infect both humans and livestocks. Rodents act as vectors for diseases such as Leptospirosis, Murine typhus, Salmonellosis and Plague (Rao, 2003). Unhygienic surroundings infested with rodents are ideal for transmission of zoonotic diseases to man and domestic animals (Makundi *et al*., 1999).

Knowledge on population dynamics and characteristics of pest rodents will allow prediction of rodent population fluctuation probabilities, which would help to formulate appropriate pest management strategies (Tsegaye Gadisa and Afework Bekele, 2006). The seasonality of breeding and abundance of rodent pest species are known for different countries (Taylor and Green, 1976; Delany and Monro, 1986; Neal, 1986). These are not similar for all nations and for different regions such information is important to apply pest management and control measures from time to time. Hence, each nation and region should have sufficient scientific information on rodent pests of the respective nation and region.

Rodent management and control should be targeted in bringing down the rate of reproduction to reduce their population. Rodent control programme would be more effective if applied during the pre-breeding season, which also coincides with the reproductive phase of the vegetation around (Workkneh G/Selassie *et al*., 2004). Further, as rodents get shelters in the area of natural vegetation around farmlands throughout the seasons, it is advised to follow clean farming practices by clearing shrubs and rocky outcrops in areas around farmlands, as ecological means of rodent control (Manyingerew Shenkut *et al*., 2006). By considering their economic importance, controlling rodent populations using appropriate pest management measures is important to reduce crop damage (Gratz, 1997; Stenseth *et al*., 2001).

1.3 Objectives of the present study

1.3.1 General objective

- The general objective of the present study is to assess the current status of rodents in Pawe area, northwest of Ethiopia.

1.3.2 Specific objectives

The specific objectives of the present investigation were:

- to identify the species composition of rodents in Pawe area.
- to study the distribution and relative abundance of rodents in the area.
- to study the population density and biomass of rodents in the area.
- to describe the habitat association of rodents in the area.
- to identify pest rodents in agricultural fields, and
- to suggest possible measures to control the effect of rodents as pests in the study area.

2. THE STUDY AREA AND METHODS

2.1 The study area

Pawe is a resettlement area in Benshangul Gumuz Regional State, northwest Ethiopia, located around 570 km from Addis Ababa near to the Ethio-Sudanese border. This area lies within the centre of the western lowland bordering Sudan on the west. It lies between 36°15`E-36°34`E longitude and 11°10`N-11°23`N latitude (Fig. 1). The task of clearing the Pawe area and surveying the location for the resettlement villages were initiated in mid–November 1984. The actual work of building huts for the new arrivals started in 1985. The University students and Professors were sent to build huts and other facilities for the people relocated during the summer of 1985, before the end of the academic year (Dessalegn Rahmato, 1988). Before the arrival of the state-sponsored resettlers in the 1980s, the area was inhabited by Gumuz people, who as a result of the arrival of resttleres were dispersed and pushed to the periphery (Woldeselassie Abute, 2002). The natural forest of the area was too dense to cross from one place to the other, which was the habitat for a variety of wild animals. At present, the area is occupied by the state-sponsored settlers. Most of the closed forest is being disappearing as a result of human resettlement activities. Wild animals have migrated to the neighbouring areas. These state-sponsored settlers inhabit a lowland area at an altitude range of 1000-1200 m asl, which is now called Pawe.

Topography

The topography of the area is more or less plain and is characterized as slightly undulating from hilltops towards rivers. The altitude of Pawe ranges from 1000 to 1200 m asl, thus belonging to the general classification of lowlands of less than 1500 m asl. The area is relatively gentle and flat with an average 5% slope (Woldeselassie Abute, 2002).

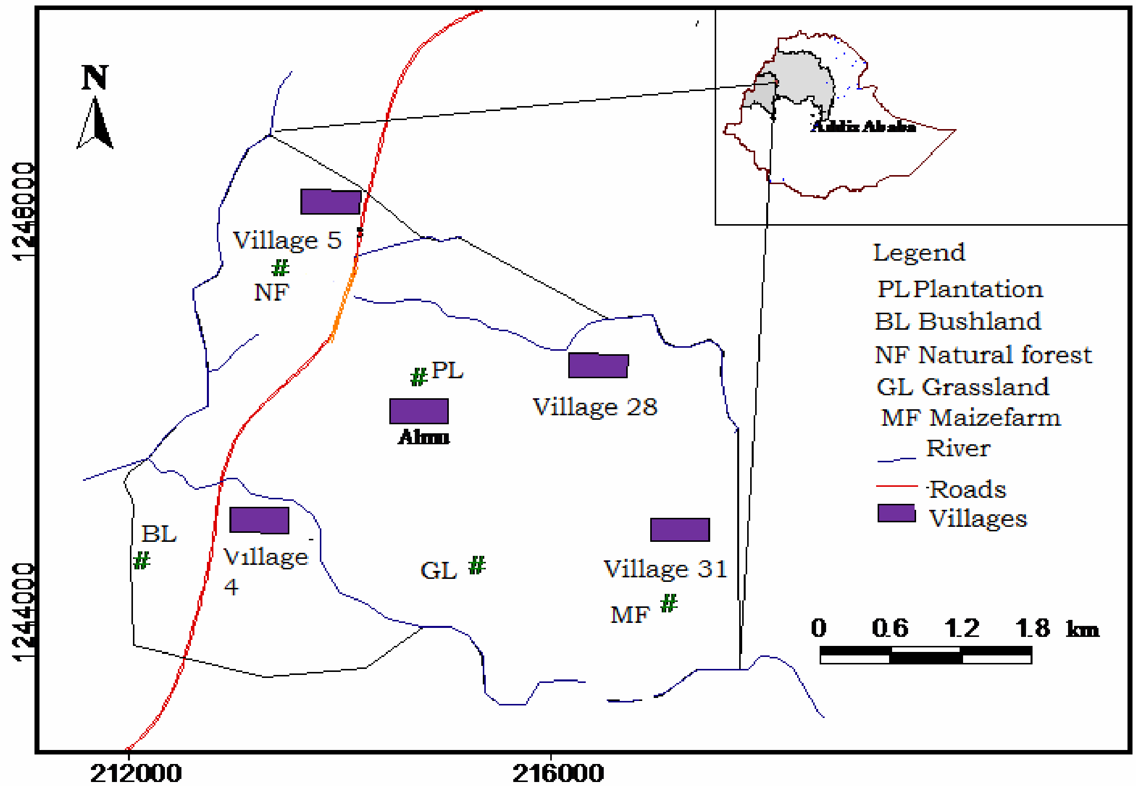

Figure 1. Location map of the study area with the map of Ethiopia in inset.

(# = grids)

Geology and Soil

The geology of Pawe area consists of metaconglomerate and quartzite of the Precambrian basement complex. The geological formation of the area is characterized by Tulu Dimtu groups with tolalite, metabasalt, greenschist, marble and precious metals like gold. The soils of Pawe are broadly categorized as vertisols (black clay soils), which accounts for 40-50% of the area, nitisols (red or reddish-brown laterite soils), which accounts for 25-30% and intermediate soils of blackish brown colour, which accounts for 25-30% (Franco, 1992). The area has 60% black soil and 40% red soil. The soil in general is clay in texture. The pH of the soil ranges from 5.5 to 6.9 and the subsurface soils have higher pH value than surface soil (Franco, 1992).

Climate

The climatic condition of the area is characterized by tropical hot humid state with an annual rainfall of 600-1450 mm, concentrating in one season, during the months of May-October. Rainfall reaches its peak during July-September. Annual temperature of the area ranges from 18°C to 40°C with mean maximum and minimum temperature of 38°C and 16°C, respectively. The coolest period is July-August (12ºC) and the hottest period is March-April (40°C). The mean annual monthly rainfall and mean maximum and minimum temperature record for the study area for 10 years (1998-2007) is shown in Figure 2.

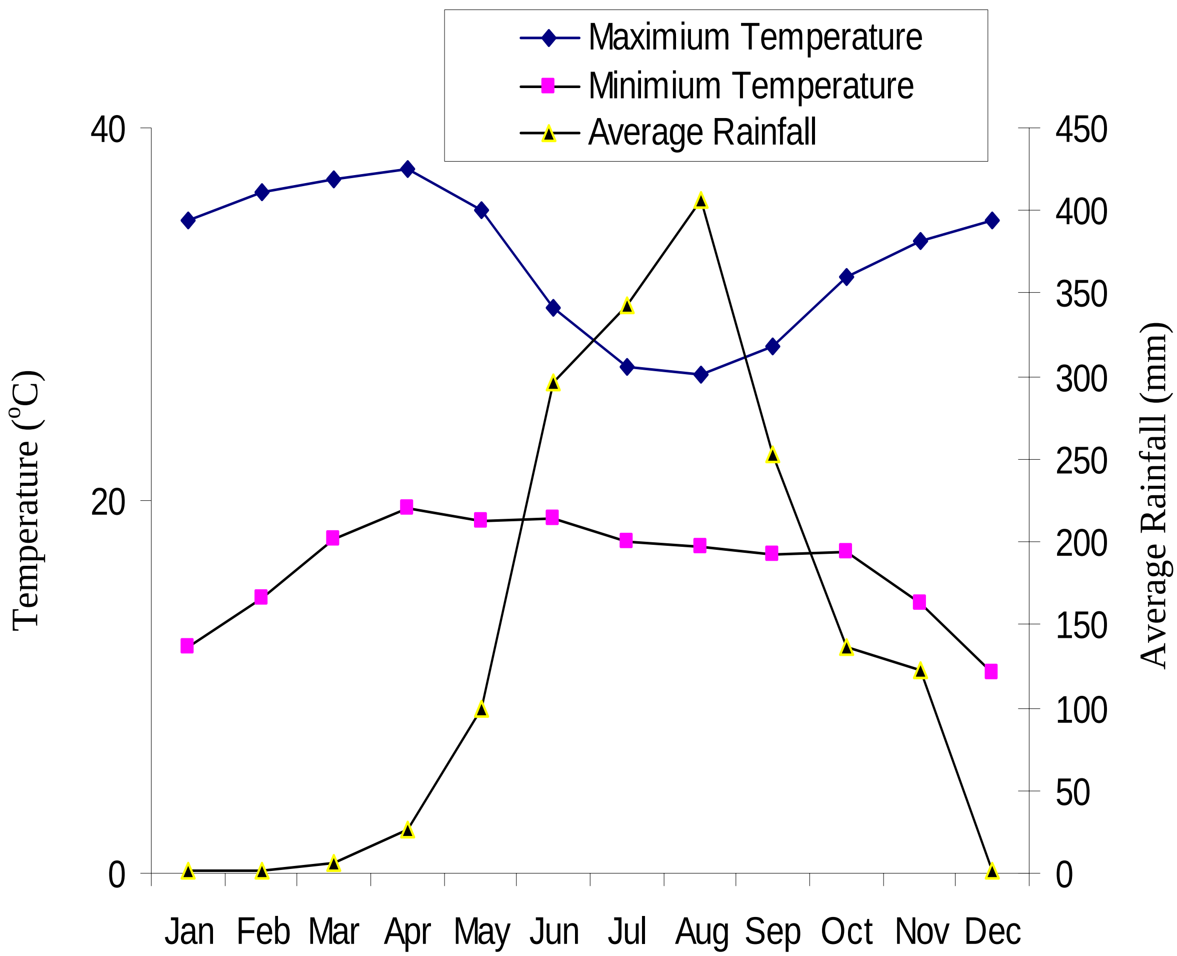

Figure 2. Monthly mean rainfall and mean maximum and minimum temperature of Pawe area from 1998-2008.

Vegetation

Benshangul Gumuz region lies in the Abay and Baro drainage basin, and is one of the few areas in Ethiopia that is still holding significant part of its landmass covered by natural vegetation. This area is covered by bamboo, broad leaved deciduous trees, *Acacia* woodlands and riverine forests. The bamboo thicket covers large extent of the area and the main bamboo species in the region is *Oxytenanthra abyssinica.* The boswellia woodland and bushland extends to the western part of the region, mainly Guba and Pawe, bordering Sudan. Broad leaved deciduous plants such as *Cumbertum molle*, *Terminalia browni, Syzgeium guineense* and *Ficus* spp. are the dominant ones in the area. Large extent of grassland, which is used as pasture, is also found in the area.

Pawe is part of Benshangul Gumuz region on the northwestern border in the upper part of Beles Valley. *Acacia*, lowland bamboo and *Hyperenia* spp. of grass were the dominant species of the area. However, the forest cover has been cleared since the beginning of the resettlement scheme in 1985 for farmlands, villages settlements, construction and fuel wood. As a result, the forest cover has been swiftly diminishing. The natural habitat of this area consists of natural forest, bushland and grassland

Natural forest

The natural forest habitat selected as the study site is around Almu near village five. The area is situated on the plain surface adjacent to Dangur hillside. The altitude of this site is 1060 m asl. It covers an area of around 9.4 ha. Other plant species in the area include *Cordia africa*, *A. caffra*, *A. albida*, *Adannsonia digitata*, *C. allidora*, *Combretum molle, Milletia ferruginia, Celtis africana*, *Balanite aegyptica, Ximania americana, A. polycantha, Albizia schimperiana, Terminalia browni, Prunes africanus, Ficus* spp. and other broad leaved deciduous plants. This forest habitat was protected by Comitato International per to Sviluppo dei Popoli (a non-governmental organization) and is developed as a Millennium Park as recognized by the Woreda Agriculture and Rural Development Office (Fig. 3).

Figure 3. View of the natural forest in the area (Photo: Author).

Plantation

The plantation is predominantly covered by different plant species planted by Tana Beles project at the side of the main residence camp and senior consultants' offices. At present this area is handed over to Benshngul Gumuz Regional Government Education Bureau and functions as Pawe Female Boarding School. Plant species in this area are *Spathodia* *nilotica*, *Melia azadarches, Mangifera indica, Delonix regia, Grevillea robusta* and *Acacia* sp. At present this habitat is well protected and fenced (Fig. 4).

Figure 4. View of the plantation habitat in the study area (Photo: Author).

Bush and scrubland

This is a habitat of various herbaceous plants, scattered woody trees and grass. It covers a large area of Pawe. The study site consists of bushy plants with weak stems emerging from a single underground base and herbaceous plants such as *Acacia senegal*, *Grewia ferruginea, Tacazzea venosa, Carisa edulis, Maytenus gracilipus,* grass and scattered woody *Acacia* trees.

Grassland

This habitat is dominated by grass species which is used as pasture in both wet and dry seasons. This area is sloppy, bordered by flood canals, rocky plain and gorge on one side and with *Acacia* woodland on the other side. The upper slope is grazed during the wet season and the lower slope during the dry season. *Pennisetum romosum*, *Agrostis* *semiverticillata* and *Syndon dactilon* are the dominant species of grass in this habitat (Fig. 5).

Figure 5. A view of the grassland habitat in the study area (Photo:Author).

Farmland

The three most common crop species cultivated in the study area are maize (*Zea mays*), sesame (*Sesamum indicum*) and groundnut (*Arachis hypogaea*). Maize is the main staple food crop, whereas sesame and groundnut are cultivated as cash crops in the area. Maize farm is taken as sample site in this study. Figure 6 shows standing maize plant during the wet season.

Figure 6. A view of maize cultivation in the area (Photo: Author).

2.2 Materials and Methods

2.2.1 Materials

Materials used during the present study were Sherman-live traps, snap-traps, bait (peanut butter), GPS, spring balance, polythene bags, gloves, dissecting kits, ruler, pen, pencil, field guides and data sheets. In addition to this, 70% ethyl alcohol as preservative and compound microscope were also used.

2.2.2 Preliminary study

A preliminary survey was conducted in Pawe area during August 1-5, 2008. During this survey, all the available and relevant information about the area (climatic condition, topography, size of the area, vegetation and habitat type) were gathered. Representative habitat sites were identified and grids were selected randomly based on representation of the main vegetation types in the area.

2.2.3 Sampling design

Based on the vegetation type, five sample sites were identified in the central part of Pawe area around Almu. These were natural forest (NF), plantation (PL), bushland (BL), grassland (GL) and farmland (maize farm) (Mf). Permanent grids were marked in each habitat type and numbered as 1, 2, 3, 4 and 5, respectively. These sampling grids were used during both the wet and dry seasons. A total of 49 Sharman live-traps and 25 snap-traps were used per grid and survey, respectively.

2.2.4 Live-trapping

Permanent live-trapping grids, each of 4900 m^2 in extent were established one in each habitat type. In each grid, 49 Sherman live-traps, measuring 7.5 × 7.5 × 23.5 cm were set at 10 m interval between trap stations (Fig. 8). The traps were baited with peanut butter and checked twice a day, late in the afternoon (17:00 - 18:00 h) and in the morning (07:00- 08:00 h). Traps were set for three consecutive nights, giving standard trapping effort of 147 trap nights per grid.

A scotch tape was placed near each trap and labelled with consecutive numbers. Trapped animals were removed from traps and placed in a pre-weighed polythene bag and weighed to the nearest gram. They were marked by toe-clipping and released at the point of capture after recording the location of capture, weight, species, sex and approximate age (juvenile, sub-adult, adult) based on the visibility of nipples (visible or not), vaginal condition (perforated or non-perforated) and testes (abdominal or scrotal). Population density of live-trapped small mammals was estimated for both the wet and dry seasons by estimating the number of individuals of each species per hectare. Biomass of different species captured was estimated as the total weight of the population of each species per hectare in each season.

2.2.5 Snap trapping

Snap-traps were set at around 200 m away from the live-trapping grids and 20 m apart from each other. Snap-traps were also set during the wet and dry seasons. Grids in the study area contained 25 snap traps in a 5x5 alignment (Fig. 9). Snap-traps were also baited with peanut butter and checked twice a day, late in the afternoon and in the next morning, immediately after checking live traps. A scotch tape was placed near each trap and labelled with consecutive numbers. Trapping was done for three consecutive nights for a total of 75 trap nights per grid. Records on date, location, habitat and species type were noted for each individual trapped. In addition, sex, weight, head and body length, hind foot length, ear length and tail length were also recorded for each individual. The stomach of each of the snap-trapped individuals was removed and preserved in 70% alcohol for diet analysis. Skins of the sample specimen of each species were prepared and were compared and identified at species level by referring to the specimens in the Zoological Natural History Museum, Biology Department, Addis Ababa University, Ethiopia.

A_1	B_1	C_1	D_1	E_1	F_1	G_1
A_2	B_2	C_2	D_2	E_2	F_2	G_2
A_3	B_3	C_3	D_3	E_3	F_3	G_3
A_4	B_4	C_4	D_4	E_4	F_4	G_4
A_5	B_5	C_5	D_5	E_5	F_5	G_5
A_6	B_6	C_6	D_6	E_6	F_6	G_6

A_7	B_7	C_7	D_7	E_7	F_7	G_7

Figure 7. Diagrammatic representation of live-trapping grid with trap location.

2.2.6 Stomach content analysis

The stomach contents preserved were brought to the Zoology laboratory of the Department of Biology, Addis Ababa University, dried to a constant weight, washed with warm water to remove gastric juice and fully digested items, and mixed thoroughly. A small quantity from each sample was collected on a microscope slide and observed under a light microscope to identify the type as well as the proportion of the stomach contents.

2.2.7 Assessment of maize crop damage

Estimation of maize crop damage was carried out in October in two different maize farms. The first maize farm (Mf_1) was surrounded by natural vegetation (grass, bushes and scrubs, *Acacia* woodland and other tree species). It was a newly cultivated plot prepared by clearing natural vegetation. The second maize farmland (Mf_2) was surrounded by sesame and groundnut farms around it. Grids were set on the two farmlands at least 50 m away from the edge of the maize crop. Each grid had 49 cells of 100 m^2 area. Out of the 49 cells in a grid, 12 cells (24.5%) were randomly selected from each maize farm. Individual maize cobs that were damaged by rodents in these cells were counted to calculate the extent of damage by rodents. The distance between rows was about 80 cm and the distance between maize plants within the same row was 40 cm. On an average 312 maize plants were found in an area of 100 m^2. Estimate of damage of maize crop by rodents was calculated by:

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

Where a = number of damaged individual cobs in the sample and

b = total number of maize cops in sample.

2.2.8 Data analysis

For species identification, taxonomic characteristics listed in Yalden *et al.* (1976) and Kingdon (1997, 2004) were used. Further, the specimens in the Zoological Natural History Museum of Addis Ababa University were used for confirmation. Population density of rodents was estimated for each habitat by dividing the number of rodents per hectare. Population size and biomass in each of the different habitat types of the different species was estimated during the wet and dry seasons grouped separately. Total biomass of rodents and insectivores in the study area was obtained after finding the area from which animals were supposed to be trapped. The species richness, diversity and similarity were computed by using different formulae to estimate diversity and similarity between different habitats. The Shannon-Weaver Diversity Index (Shannon and Weaver, 1949) was used to estimate the diversity for the small mammals trapped in the study area, following the formula

$H' = \sum (Pi) \ln (pi)$.

Where, H'= species diversity

S= the number of species

Pi=the proportion of individuals of the total sample belonging to i^{th} species.

ln = the natural logarism

The Simpson-Index of diversity (D) was calculated as

$D = 1 - \sum (Pi)^2$

Where, Pi = is the proportion of individuals of the total sample belonging to the i^{th} species.

The Simpson’s Similarity Index was estimated using the following formula:

SI= 5C/I+II+III+IV+V

Where, SI= Similarity Index

C= number of common species recorded in all the five habitat types

I = number of species recorded in habitat type one

II = number of species recorded in habitat type two

III = number of species recorded in habitat type three

IV = number of species recorded in habitat type four

V = number of specie recorded in habitat type five

3. RESULTS

Data gathered during the present investigation are presented in four sections. The first section deals with the species composition and relative abundance of small mammals as revealed from the data from live-trapped and snap-trapped small mammals. In addition to this, small mammals observed in the area, but not trapped are also listed. The second section, describes the species composition, distribution, relative abundance and habitat association of live-trapped rodents and insectivores. In this section, species richness, diversity, species similarity between different habitat types, seasonal variation, sex ratio, trap success, age class distribution, population density and biomass in relation to wet and dry seasons are also presented. In the third section, results dealing with species composition, relative abundance, body measurement, embryo size and stomach contents of the snap trapped rodents are described. The fourth section deals with the effect of rodent pests on maize crop in the study area.

3.1 Species composition and relative abundance of small mammals

A total of 643 small mammals belonging to the order Rodentia (Family: Muridae and Cricetidae) and the order Insectivora (Family: Soricidae) was trapped using both live and snap-trapping techniques during both the wet and dry seasons. These constituted 10 species of rodents and two species of shrews (Table 1). Out of the total trapped individuals, 97% (n= 624) were rodents and 3 % (n = 19) were shrews. The 10 species of rodents captured were *Mastomys natalensis* (37.7%), *Arvicanthis dembeensis* (28.8%), *Stenocephalemys albipes* (9.2%), *M. erythroleucus* (7.5%), *A. niloticus* (4.5%), *Acomys* *cahirinus* (3.6%), *Lemniscomys striatus* (1.7%), *Tatera robusta* (2.6%), *Mus musculus* (0.9%) and *Rattus rattus* (0.3%). The two species of insectivores trapped were *Crocidura flavescens* (2.2%) and *C. fumosa* (0.8%). In addition to this, the presence of the following four species of rodents was recorded by observation: *Tachyorctes splendens*, *Hystrix cristata*, *Heliosciurus gambianus* and *Euxerus erythropus* (Table 1).

Family	**Species**	**No. of individuals**	**Relative abundance (%)**
Muridae	*Mastomys natalensis* A. Smith 1834	244	37.9
	Arvicanthis dembeensis Rüppell 1842	185	28.8
	Stenocephalemys albipes Rüppell 1842	59	9.2
	Mastomys erythroleucus Temminck 1853	48	7.5
	Acomys cahirinus Desmarest 1822	23	3.6
	Arvicanthis niloticus Desmarest 1822	29	4.5
	Lemniscomys striatus Linnaeus 1758	11	1.7
	Mus musculus Linnaeus 1758	6	0.9
	Rattus rattus Linnaeus 1758	2	0.3
Cricetidae	*Tatera robusta* Cretschmar 1826	17	2.6
Soricidae	*Crocidura flavescens* I. Geoffroy 1827	14	2.2
	Crocidura fumosa Thomas 1904	5	0.8
Rhizomyidae	*Tachyorctes splendens* Rüppell 1836	*	*
Hystricidae	*Hystrix cristata* Linnaeus 1758	*	*
Sciuridae	*Heliosciurus gambianus* Ogilby 1835	*	*
	Euxerus erythropus E. Geoffroy 1803	*	*
Total		643	100%

Table 1. Species composition, abundance and relative abundance (%) of small mammals in the study area (* = observed species, but not trapped).

3.2 Sherman Live-trapping

3.2.1 Species composition and relative abundance of rodents and insectivores

A total of 606 captures of rodents and shrews were made using live-traps. Among them, 519 were new captures and 87 were recaptures. There were 500 individuals of 10 species of rodents, and 19 individuals of two species of shrews. Among the 10 species of rodents, 197 (38.0%) were *M. natalensis*, 147 (48.3%) *A. dembeensis*, 45 (8.7%) *S. albipes*, 38 (7.3%) *M. erythroleucus*, 24 (4.8%) *A. nilotocus*, 20 (3.9%) *A. cahirinus*, 14 (2.7%) *T. robusta*, 7 (1.3%) *L. striatus*, 6 (1.2%) *M. musculus*, and 2 (0.4%) were *R. rattus*. Among the two species of shrews trapped, 14 (2.7%) were *C. flavescens* and 5 (0.9%) were *C. fumosa*. *M. natalensis* was the dominant (38.0%) species trapped, followed by *A. dembeensis* (28%). *R. rattus* was the least in abundance (0.4%) among the live-trapped small mammals (Table 2).

Species	Total capture	Relative abundance (%)
M. natalensis	197	38.0
A. dembeensis	147	28.3
S. albipes	45	8.7
M. erythroleucus	38	7.3
A. niloticus	24	4.6
A. cahirinus	20	3.9
T. robusta	14	2.7
L. striatus	7	1.3
M. musculus	6	1.2
R. rattus	2	0.4
C. flavescens	14	2.7
C. fumosa	5	0.9
Total	519	100%

Table 2. Species composition and relative abundance of live-trapped rodents and insectivores in the study area.

3.2.2 Distribution of species and their habitat association

Table 3 shows the data of live-trapped small mammals in different habitat types during the present investigation. The distribution of rodents and insectivores was not uniform in all habitat types. Variations in species composition and their abundance was observed from habitat to habitat. *M. natalensis* was the most widely distributed species in the study area. It occurred in all habitat types studied. Moreover, the population of this species was high in the study area (n=197). The other widely distributed species was *M. erythroleucus*. This species was trapped from all habitats except grasslands. However, its abundance was relatively less in the area. Five species of rodents, *viz*., *A. dembeensis, S. albipes, A. niloticus, A. cahirinus* and *T. robusta* were recorded from three different habitats in different proportions. Among these, *A. dembeensis* was the second most abundant species (147) next to *M. natalensis* in the study area.

Table 3. Distribution of live-trapped rodent and insectivore species in different habitat types (- indicates no capture).

Species	**Habitat types and abundance**					
	NF	**PL**	**BL**	**GL**	**Mf**	**Total**
M. natalensis	39	16	54	43	45	197
A. dembeensis	-	-	45	67	35	147
S. albipes	37	4	4	-	-	45
M. erythroleucus	1	2	16	-	19	38
A. niloticus	-	-	10	13	1	24

A. cahirinus	-	-	3	15	2	20
T. robusta	-	-	7	6	1	14
L. striatus	-	-	7	-	-	7
M. musculus	-	-	2	4	-	6
R. rattus	-	-	-	-	2	2
C. flavescens	9	3	2	-	-	14
C. fumosa	1	-	4	-	-	5
Total	87	25	154	148	105	s519

(NF= natural forest, PL= plantation, BL= bushland, GL= grassland, Mf= maize farm).

The least distributed species of rodents were *L. striatus* and *R. rattus*, which were restricted only to bushland and maize farm, respectively. Insectivores were trapped from three habitats. *C. flavescens* was trapped from natural forest, plantation and bushland, whereas *C. fumosa* was trapped only from natural forest and bushland. The number of habitats in which each species was trapped is shown in Figure 8. Among the 12 species of small mammals trapped, bushland had the highest diversity with 11 species, whereas the plantation had the least diversity with only four species (Figure 9). *R. rattus* was the only rodent not recorded from bushland in this study area. There was a significant difference in the number of species recorded from different habitat types ($\chi^2 = 4.4$, df = 4, $P < 0.05$).

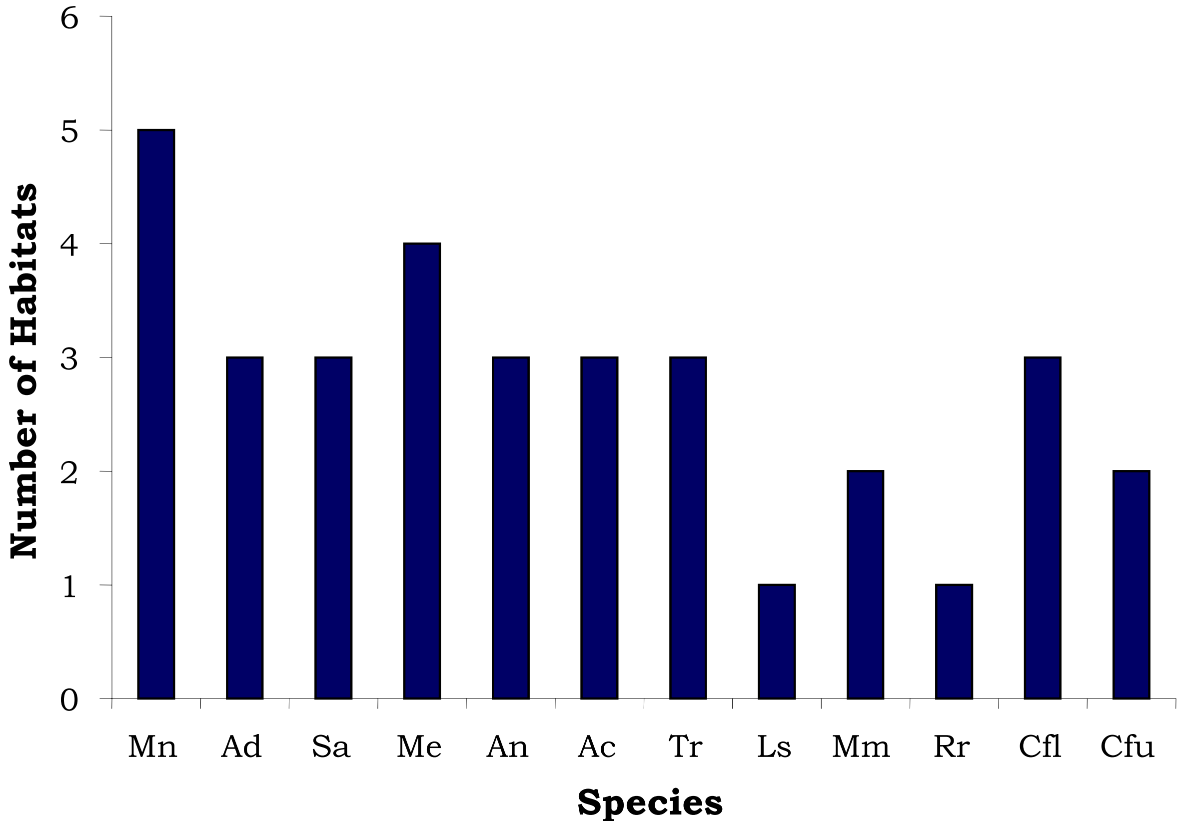

Figure 8. Number of habitats in which each of the species of small mammals was trapped. (Mn = *Mastomys natalensis*, Ad = *Arvicanthis dembeensis*, Sa = *Stenocephlemys albipes*, Me = *Mastomys erythroleucus*, An = *Arvicanthis niloticus*, Ac = *Acomys cahirinus*, Tr = *Tatera robusta*, Lm = *Lemniscomys striatus*, Mm = *Mus musculus*, Rr = *Rattus rattus*, Cfl = *Crocidura flavescens,* Cfu = *Crocidura fumosa).*

Relative abundance in different habitat types

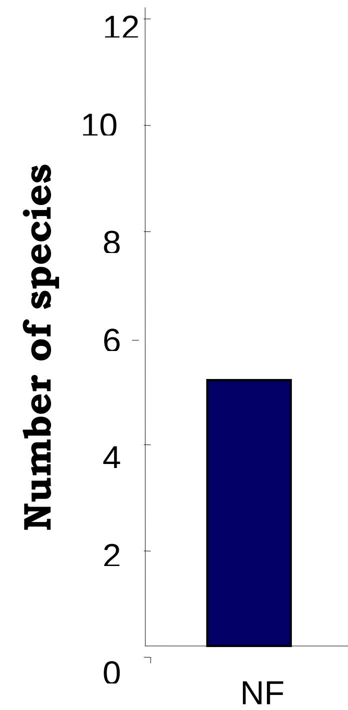

Figure 9. Number of small mammal species recorded from different habitat types. (NF= natural forest, PL= plantation, BL= bushland, GL= grassland, Mf= maize farm).

The total number of individuals trapped from bushland (154) was higher than those trapped from other habitat types. The number of individuals trapped from grassland, maize farm, natural forest and plantation was 148, 105, 87 and 25, respectively. The overall abundance of rodent and insectivores trapped from different habitats was significantly different (χ^2 = 106.8, df = 4, P< 0.01). *L. striatus* (100%), *C. fumosa* (80%) and *T. robusta* (50%) showed close association with bushland. *A. dembeensis* (45%), *A. niloticus* (54%) and *A. cahirinus* (75%) were more associated with grassland. *M. erythroleucus* (50%), *M. natalensis* (22%) and *R. rattus* (100%) were more in maize farm. On the other hand *S. albipes* (82.2) and *C. flavescens* (64.3%) showed their association with natural forest (Table 4).

Table 4. Habitat association of small mammal species.

Species	NF	PL	BL	GL	Mf
M. natalensis	19.8	8.1	27.4	21.8	22.9
A. dembeensis	-	-	30.6	45.6	23.8
S. albipes	82.2	8.9	8.9	-	-
M. erythroleucus	2.6	5.2	42.1	-	5
A. niloticus	-	-	41.7	54.2	4.1
A. cahirinus	-	-	15.0	75.0	10.0
T. robusta	-	-	50.0	42.9	7.1
L. striatus	-	-	100.0	-	-
M. musculus	-	-	33.3	66.7	-
R. rattus	-	-	-	-	100
C. flavescens	64.3	21.4	14.3	-	-
C. fumosa	20.0	-	80.0	-	-

(NF= natural forest, PL= plantation, BL= bushland, GL= grassland, Mf= maiz farm).

3.2.3 Seasonal variation in the abundance and distribution of small mammals

Among the 519 individuals trapped, 331 (63.8%) were trapped during the wet season and 188 (36.2%) were trapped during the dry season (Table 5). The number of individuals trapped during the wet season was significantly higher than those trapped during the dry season ($\chi^2 = 39.4$, df =1, $P < 0.01$). There was also significant difference in the number of individuals trapped during different trapping sessions of the wet season ($\chi^2 = 27.2$, df =1, $P < 0.01$) and different trapping sessions of the dry season ($\chi^2 = 13.2$, df = 1, $P < 0.01$). The seasonal abundance of *M. natalensis, A. dembeensis* and *S. albipes* was statistically significant ($\chi^2 = 21.4$, df = 1, P < 0.01; $\chi^2 = 20.5$, df = 1, P < 0.01 and $\chi^2 = 9.8$, df =1, P < 0.01). However, seasonal abundance of *L. striatus*, *A. niloticus*, *T. robusta* and *C. fumosa* was not statistically different ($\chi^2 = 0.28$ df =1, P > 0.01; $\chi^2 = 0.16$, df = 1, P > 0.01; $\chi^2 = 0.24$, df = 1, P > 0.01 and $\chi^2 = 0.20$, df = 1, P > 0.01). During the wet season, 10 species of small mammals were trapped, whereas, 12 species were trapped during the dry season. The overall difference in the number of species trapped between the two seasons was not statistically significant ($\chi^2 = 0.18$, df = 1, P > 0.05).

Table 5. Species abundance of small mammals trapped during different seasons.

	Abundance					
		Wet			**Dry**	
Species	**I**	**II**	**III**	**I**	**II**	**III**
M. natalensis	47	84	131	42	24	66
A. dembeensis	38	63	101	32	14	46
S. albipes	11	22	33	5	7	15
M. erythroleucus	8	14	22	9	7	16
A. niloticus	4	9	13	8	3	11
A. cahirinus	6	1	7	8	5	13
T. robusta	0	8	8	4	2	6
L. striatus	0	3	3	2	2	4
R. rattus	0	0	0	2	0	2
C. flavescens	4	6	10	3	1	4
C. fumosa	0	3	3	1	1	2
Total/Session	118	213	-	119	69	-
Total/Season		331			188	

(I=session 1, II= session 2, III= Total for session I and II)

During the wet season, more individuals (92) were trapped from the grassland, followed by bushland (91), maize farm (77) and natural forest (56). However, during the dry season, more individuals were trapped from bushland (63), followed by grassland habitat (56), natural forest (31) and maize farm (28). The lowest number of individuals trapped was from plantation (Table 6). There were seasonal variations in the number of individuals trapped from natural forest, bushland, grassland and maize farm (χ^2= 7.2, df = 1, P < 0.05; χ^2 = 5.09, df= 1, P < 0.05; χ^2 =8.7, df = 1, P < 0.05 andχ^2=22.6, df=1, P < 0.05, respectively) but the variation was insignificant in the case of plantation (χ^2= 1, df = 1, P < 0.05). Further, the highest number of species was recorded from bushland (10 and 9) during the wet and the dry seasons, respectively. The lowest number of species was recorded from plantation (3) during both wet and dry seasons.

3.2.4 Trap success

Trap success for different habitats and for the wet and dry seasons are given in Table 7. There were differences in trap success in different habitats and during different seasons. The cumulative average trap success for both seasons was 14.8% in natural forest, 4.2% in plantation, 26.2% in bushland, 25.1% in grassland and 17.8% in the maize farm. In the present study area, the highest trap success was in the bushland, followed by grassland and the lowest trap success was in the plantation.

Table 6. Seasonal abundance of live-trapped rodents and insectivores from different habitats (- denotes absence).

(NF=natural forest, PL= plantation. BL= bushland, GL= grassland, Mf= maize farm, Mn=*Mastomys natalensis*, Ad=*Arvicanthis dembeensis*, Sa= *Stenocephalemys albipes*,

	Abundance in different habitats and seasons									
	NF		**PL**		**BL**		**GL**		**Mf**	
Species	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Mn	24	15	9	7	34	20	30	13	34	11
Ad	-	-	-	-	28	17	48	19	25	10
Sa	25	12	4	-	4	-	-	-	-	-
Me		1	-	2	8	8			14	5
An	-	-	-	-	5	5	7	6	1	-
Ac	-	-	-	-	1	2	4	11	2	-
Tr	-	-	-	-	4	3	3	3	1	-
Ls	-	-	-	-	3	4	-	-	-	-
Mm	-	-	-	-	-	2	-	4	-	-
Rr	-	-	-	-	-	-	-	-	-	2
Cfl	6	3	2	1	2	-	-	-	-	-
Cfu	1	-	-	-	2	2	-	-	-	-
Total	56	31	15	10	91	63	92	56	77	28
No. of species	4	4	3	3	10	9	5	6	6	4

Me=*Mastomys erythroleucus*, An=*Arvicanthis niloticus*, Ac=*Acomys cahirinus*, Tr=*Tatera robusta*, Lm=*Lemniscomys striatus*, Mm=*Mus masculus*, Rr=*Rattus rattus*, Cfl= *Crocidura flavescens*, Cfu=*Crocidura fumosa).*

Variation in trap success between different habitats was statistically significant (χ^2= 18.8, df = 4, P < 0.01). Trap success ranged from 1.3% during the first session of the dry season from the plantation to a maximum of 41.4 % during the second session of the wet season in the bushland. The average trap success during the wet season was 22.5% and during the dry season, it was 12.7%. During the wet season, trap success was highest for grassland (31.2%), followed by bushland (31.0%), maize farm (26.1%), natural forest (19.0%) and plantation (5.1%). During the dry season, trap success was 21.4% for bushland, 19.0% for grassland, 10.5% for natural forest, 9.5% for maize farm and 3.4% for plantation. Overall, average trap success in the study area was 17.7%. Trap success between these habitats during the wet season was statistically significant $\chi^2 = 21.2$, df= 4, $P < 0.01$). The trap success for wet season was high in grassland and bushland area. Trap success between the habitats during the dry season also showed statistically significant variation ($\chi^2 = 18.8$, df=4, $P < 0.01$). During this season, high trap success was recorded from bushland.

3.2.5 Species richness, diversity and similarity between habitats

The high diversity indices for small mammals estimated by both Shannon-Weaver Index (H'= 1.44) and Simpson's diversity Index (D= 0.772) were found in the bushland, followed by grassland. The lowest species diversity was obtained from plantation area. The highest species evenness was estimated in the grassland habitat, followed by plantation. The lowest species evenness was estimated for the bushland (Table 8). The highest number of species was recorded from bushland followed by grassland, whereas plantation had the lowest species richness.

Table 7. Trap success during wet and dry seasons in different habitat types. (Trap nights were 147 for each session, total 2940 trap nights).

Grids	**Habitat types**	**Seasons**	**Months**	**Total catch**	**%Trap Success**
1	Natural forest	Wet	August/2008	22	14.9
		Wet	October/2008	34	23.1
		Dry	December/2009	17	11.5
		Dry	March/2009	14	9.5
2	Plantation	Wet	August/2008	4	2.7
		Wet	October/2008	11	7.4
		Dry	December/2009	2	1.3
		Dry	March/2009	8	5.4
3	Bushland	Wet	August/2008	30	20.4
		Wet	October/2008	61	41.4
		Dry	December/2009	38	25.8
		Dry	March/2009	25	17.0
4	Grassland	Wet	August/2008	35	23.8
		Wet	October/2008	57	38.7
		Dry	December/2009	43	29.2
		Dry	March/2009	13	8.8
5	Maize farm	Wet	August/2008	27	18.3
		Wet	October/2008	50	34.0
		Dry	December/2009	19	12.9
		Dry	March/2009	9	6.1

The data on species similarity among different habitat types showed that the highest similarity was observed between natural forest and plantation, followed by between grassland and maize farm, grassland and bushland, maize farm and bushland and natural forest and bushland (Table 9). On the other hand, the lowest similarity was observed between natural forest and grassland. The overall similarity between the five habitat types in the study area based on the presence of rodents and insectivore species was less (0.06).

Table 8. Number of species and diversity of rodents and insectivores estimated for the study area (cumulative for wet and dry seasons).

Habitat types	**Number of Species**	**Individuals trapped**	**H'**	**D**	**E**
Natural forest	5	87	1.05	0.602	0.652
Plantation	4	25	1.03	0.541	0.742
Bushland	11	154	1.44	0.772	0.601
Grassland	6	148	1.40	0 .692	0.781
Maize farm	7	105	1.30	0.676	0.668

(H'= Shannon-Weaver diversity index, D = Simpson's diversity index, E= evenness).

R. rattus had the highest species richness index, whereas *M. natalensis* had the lowest species richness index in the study area. *M. natalensis* had the highest value of degree of dominance followed by *A. dembeensis,* whereas *R. rattus* had the lowest value of degree of dominance (Table 10).

Table 9. Species similarity among the habitat types of the study area (cumulative for wet and dry seasons).

Habitats	NF	PL	BL	GL	Mf
NF	-	0.888	0.625	0.181	0.333
PL	-	-	0.533	0.200	0.363
BL	-	-	-	0.705	0.666
GL	-	-	-	-	0.769
Mf	-	-	-	-	-

(NF= natural forest, PL= plantation, BL= bushland, GL= grassland, Mf= maize farm).

Table 10. Richness index and degree of dominance of the different species of rodents and insectivores in the study area.

Parameter	Species											
	Mn	Ad	Sa	Me	An	Ac	Tr	Ls	Cfl	Mm	Cfu	Rr
RI	2.1	2.2	2.9	3.1	3.5	3.6	4.2	5.6	4.2	6.1	6.8	8.1
DI	0.4	0.3	0.01	0.01	0.05	0.04	0.03	0.01	0.01	0.01	0.001	0.001

(Mn=*Mastomys natalensis*, Ad=*Arvicanthis dembeensis*, Sa= *Stenocephalemys albipes*, Me=*Mastomys erythroleucus*, An=*Arvicanthis niloticus*, Ac=*Acomys cahirinus*, Tr=*Tatera robusta*, Lm=*Lemniscomys striatus*, Mm=*Mus musculus*, Rr=*Rattus rattus*, Cfl= *Crocidura flavescens*, Cfu=*Crocidura fumosa).*

3.2.6 Age structure and sex ratio

Out of the 519 individual small mammals live-trapped, there were 274 (52.8%) adults 112 (21.6%) sub-adults and 133 (25.6%) juveniles (Table 11). The number of adults, sub-adults and juveniles was 161, 61 and 109, respectively, during the wet season, while it was 113, 51 and 24, respectively, during the dry season. More juveniles were trapped during the wet season than during the dry season (χ^2 = 54, df =1, P < 0.01). The number of juveniles was more than the sub-adults during the wet season and the number of sub-adults was more than the juveniles during the dry season. The overall age distribution between adults, sub-adults and juveniles was also statistically significant (χ^2= 87.8, df = 2, P < 0.01).

Table 11. Age distribution of live-trapped rodents and insectivore

Month/ Season	**Number of individuals trapped**			**Total**
	Adult	**Sub-adult**	**Juvenile**	
August/ 2008 (Wet season)	70	16	32	118
October/ 2008 (Wet season)	91	45	77	213
December/2008 (Dry season)	71	31	17	119
March/ 2009 (Dry season)	42	20	7	69
Total	274	112	133	519

Out of the total individuals live-trapped, males comprised 267 (51.4 %) and females 252 (48.6%) individuals. The overall sex ratio was not significantly different (χ^2 = 0.43, df=1, P > 0.05). The number of males trapped during the wet season was 170 and during the dry season, it was 97; whereas the number of females trapped during the wet and dry seasons was 161 and 91, respectively (Table 12). Thus, the difference between the number of trapped males (χ^2 = 19.9, df=1, P < 0.01) and females (χ^2 =19.4, df =1, P < 0.01) with respect to wet and dry seasons was statistically significant.

Table 12. Seasonal variations in sex distribution of each species of rodents and

insectivores live-trapped (M= male, F=female).

Species	Aug/2008		Oct/2008		Dec/2009		Mar/2009		Total	
	Number of individuals trapped									
	Wet season				**Dry season**					
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Mn	35	12	32	52	27	15	12	12	106	91
An	20	18	27	36	14	18	8	6	69	78
Sa	5	6	9	13	3	2	5	2	22	23
Me	4	4	9	5	3	6	2	5	18	20
An	3	1	6	3	3	5	1	2	13	11
Ac	6	_	_	1	3	5	2	3	11	9
Tr	_	_	5	3	2	2	2	0	9	5
Ls	_	_	1	2	1	1	1	1	3	4
Mm	_	_	_	_	1	2	1	2	2	4
Rr	_	_	_	_	2	_	_	_	2	_
Cfl	3	1	4	2	2	1	1	_	10	4
Cfu	_	_	1	2	1	0	_	1	2	3
Total	76	42	94	119	62	57	35	34	267	252

(Mn= *Mastomys natalensis*, Ad= *Arvicanthis dembeensis*, Sa= *Stenocephalemys albipes*, Me=*Mastomys erythroleucus*, An= *Arvicanthis niloticus*, Ac=*Acomys cahirinus*, Tr= *Tatera robusta*, Lm=*Lemniscomys striatus*, Mm=*Mus musculus*, Rr=*Rattus rattus*, Cfl= *Crocidura flavescens*, Cfu=*Crocidura fumosa).*

3.2.7 Density in different habitats

Population density estimated for each species of rodent and insectivores in different habitats in the study area during different seasons are given in Table 13. The density of *M. natalensis* ranged from 32/ha in plantation habitat to 110/ha in bushland. The lowest density of *A. dembeensis* was recorded in the maize farm (71/ha), whereas the highest density of the species was recorded in the grassland (135/ha). There were no record of this species in natural forest and plantation. The density of *S. albipes* ranged from 8/ha in the bushland and plantation to 75/ha in the natural forest with no records in other habitats. *M. erythroleucus* had a density of 38/ha in maize farm, 32/ha in the bushland, 4/ha in plantation, 2/ha in natural forest and with no record in the grassland. The density of *C. flavescens* was 18/ha in the natural forest, followed by 6/ha in plantation and 4/ha in the bushland. There was no record of this species in grassland and maize farm. Highest density of *A. niloticus, A. cahirinus* and *M. musculus* was observed in the grassland and the highest density of *T. robusta, L. striatus* and *C. fumosa* was observed in the bushland. High cumulative density of rodents and insectivores for the wet and dry seasons was recorded in the bushland (311/ha) followed by grassland (298/ha), natural forest (176/ha) and maize farm (212/ha). The lowest density was recorded in the plantation area (50/ha) during the entire study period.

3.2.8 Population Size and Biomass

The data on population size and biomass of rodent and insectivore species in different habitat types during different seasons is given in Table 14. Population size and biomass of each species declined during the dry season. The maize farm had maximum biomass (20658 g), followed by grassland (13047 g), bushland (11558 g), natural forest (5664 g) and plantation (1631g) during the wet season. During the dry season, the highest biomass was estimated in the bushland (6511 g), followed by grassland (5647 g), maize farm (3215 g), natural forest (2768 g) and plantation (948 g).

Table 13. Estimation of population density of rodents and insectivores in different habitats in the present study area (individual/ha).

Season	Species	Density					
		NF	PL	BL	GL	Mf	Total
Wet	*M. natalensis*	49	18	69	61	69	266
	A. dembeensis	0	0	57	97	51	205
	S. albipes	51	8	8	0	0	67
	M. erythroleucus	0	0	16	0	28	44
	A. niloticus	0	0	10	14	2	26
	A. cahirinus	0	0	2	8	4	14
	T. robusta	0	0	8	6	2	16
	L. striatus	0	0	6	0	0	6
	M. musculus	0	0	0	0	0	0
	R. rattus	0	0	0	0	0	0
	C. fluvescence	12	4	4	0	0	20
	C. fumosa	2	0	4	0	0	6
Sub-total		114	30	184	186	156	670
Dry	*M. natalensis*	30	14	41	26	22	133
	A. dembeensis	0	0	34	38	20	92
	S. albipes	24	0	0	0	0	24
	M. erythroleucus	2	4	16	0	10	32
	A. niloticus	0	0	10	12	0	22
	A. cahirinus	0	0	4	22	0	26
	T. robusta	0	0	6	6	0	12
	L. striatus	0	0	8	0	0	8
	M. musculus	0	0	4	8	0	12
	R. rattus	0	0	0	0	4	4
	C. fluvescence	6	2	0	0	0	8
	C. fumosa	0	0	4	0	0	4
Sub-total		62	20	127	112	56	377
Grand Total		176	50	311	298	212	1047

(NF=Natural forest, PL= Plantation, BL= Bushland, GL= Grassland, Mf= Maize farm).

Table 14. Number and biomass of rodents and insectivores (g/ha) during the wet and dry seasons in different habitat types.

(NF= natural forest, PL= plantation, BL= bushland, GL= Grassland, Mf= maize farm).

Season	**Species/ weight (g)**	Number of individuals and biomass (g) in different habitats				
		NF	**PL**	**BL**	**GL**	**Mf**
Wet	Mn (64.1)	49(3140)	18(1153)	69(4422)	61(3910)	69(4422)
	Ad (77.1)	0	0	57(4394)	97(7478)	51(3932)
	Sa (50.3)	51(2565)	8(402)	8(402)	0	0
	Me (52.8)	0	0	16(844)	0	28(12034)
	An (61.2)	0	0	10(612)	14(856)	2(122)
	Ac (36.1)	0	0	2(72.2)	8(489)	4(144)
	Tr (52.0)	0	0	8(416)	6(312)	2(104)
	Ls (41.6)	0	0	6(249)	0	0
	Cfl (18.6)	12(223)	4(74)	4(74)	0	0
	Cfu (17.4)	2(34)	0	4(69)	0	0
Sub-total		5964	1630	11488	13047	20656
Dry	Mn (52.3)	30(1569)	14(732)	41(2144)	26(1359)	22(1150)
	Ad (65.2)	0	0	34(2216)	38(2477)	20(1304)
	Sa (46.7)	24(1120)	0	0	0	0
	Me (47.3)	2(94)	4(189)	16(758)	0	10(473)
	An (57.8)	0	0	10(578)	12(693)	0
	Ac (34.3)	0	0	4(137)	22(754)	0
	Tr (49.7)	0	0	6(298)	6(298)	0
	Ls (37.5)	0	0	8(300)	0	0
	Mm (27.9)	0	0	4(111)	8(223)	0
	Rr (71.9)	0	0	0	0	4(287)
	Cfl (13.1)	6(78)	2(26)	0	0	0
	Cfu (11.6)	0	0	4(46)	0	0
Sub-total		2768	947	6590	5806	3215

The total biomass of rodents in different habitats of the study area is given in Table 15. Bushland had the highest biomass of rodents and shrews whereas the plantation had the lowest.

Table 15. Biomass of rodents and shrews estimated for the total study area.

Habitats	Estimate area of each habitat (ha)	Biomass (kg)/ha	Biomass(kg)/habitat
NF	100	8.7	870
PL	50	2.6	130
BL	2100	18.0	37800
GL	1400	18.7	26180
Mf	500	23.9	11950
Total	**4150**	**71.9**	**76930**

3.3 Data from snap-trapped rodents

3.3.1 Species composition and abundance

A total of 124 individuals of eight species of rodents was snap-trapped in 1,500 trap nights with a trap success of 8.2%. The species of snap-trapped rodents were *M. natalensis, A. dembeensis, S. albipes, M. erythroleucus, A. niloticus, A. cahirinus, L. striatus* and *T. robusta*. Relative abundance of snap-trapped species is given in Table 16.

Table 16. Species composition, number and distribution of snap trapped rodents in different habitats.

Species	Abundance of snap-trapped individuals							
	NF	**PL**	**BL**	**GL**	**Mf**	**Total Catch**	**Relative abundance (%)**	**Species wise trap success (%)**
Mn	9	2	13	12	11	47	37.9	3.13
Ad	-	-	8	18	12	38	30.7	2.51
Sa	12	1	1	-	-	14	11.3	0.92
Me	1	-	5	-	4	10	8.1	0.63
An	-	-	2	3	-	5	4.0	0.31
Ac	-	-	1	2	-	3	2.4	0.20
Ls	-	-	4	-	-	4	3.2	0.26
Tr	-	-	2	1	-	3	2.4	0.20
Total	22	3	36	36	27	124	100	
Habitat wise trap success (%)	7.3	1.0	12.0	12.0	9.0	8.2		

(Mn= *Mastomys natalensis*, Ad= *Arvicanthis dembeensis*, Sa= *Stenocephalemys albipes*, Me= *Mastomys erythroleucus*, An= *Arvicanthis niloticus*, Ac= *Acomys cahirinus*, Tr= *Tatera robusta*, Lm=*Lemniscomys striatus*).

3.3.2 Body measurements

Data on body measurements of the eight species of rodents snap-trapped during both the wet and dry seasons are given in Table 17. Variations in the mean body weight showed statistically significant difference between seasons within most of the species ($\chi^2 = 2.1$, df=1, P< 0.05 for *A. niloticus*, $\chi^2 = 1.7$, df=1, P< 0.05 for *M. natalensis*,, $\chi^2 = 0.6$, df=1, P< 0.05 for *L. striatus* and $\chi^2 = 0.8$, df=1, P< 0.05) *for M. erythroleucus*. No other external body measurements showed statistically significant variation between seasons.

Table 17. Body weight (g) and body measurements (mm) of snap-trapped rodents (Mean± SD) during wet and dry seasons. *= There was no significant change in their parameter seasonally.

Species	Season	BW	HB*	TL*	HF*	EL*
M. natalensis	Wet	64.1± 4.2	126± 7.5	124.2±6.1	26±1.1	17±0.2
	Dry	50.3± 3.9				
A. dembensis	Wet	78.2± 4.8	132± 1.4	120±2.1	25.4±1.4	16±0.4
	Dry	67.7± 3.5				
S. albipes	Wet	52.9± 3.1	115± 2.3	137±1.4	27±1.7	22±1.2
	Dry	48.4 ±2.2				
M. erythroleucus	Wet	53.1± 3.2	109.1± 2.1	8.4±2.2	22±1.1	5±0.1
	Dry	44.2± 2.7				
A. niloticus	Wet	77.3± 2.3	127± 1.5	119±1.0	23±2.1	13±0.1
	Dry	60.0± 2.1				
A. cahirinus	Wet	38.0	97.0	84.0	16.0	11.0
	Dry	34.1±1.6				
L. straitus	Wet	50.2±2.1	111± 2.7	104±2.7	21±1.5	14±1.3
	Dry	41.0				
T. robusta	Wet	58.2±2.4	122.0±1.7	139±3.1	24.0±2.6	16.0

(BW= body weight, HB= head and body length, TL= tail length, HF= hind foot length, EL=ear length).

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3.3.3 Reproductive condition

There were pregnant females collected only for six species of snap-trapped rodents (Table 18). More pregnant females were trapped during the wet season. The seasonal variation in the number of pregnant females was statistically significant ($\chi^2 = 6.1$, df=1, $P < 0.01$). The number of embryos of pregnant females varied within species and between seasons in the same species. More number of embryos was recorded in *M. natalensis* during the wet season.

Table 18. Number of pregnant females and embryos recorded in snap-trapped rodents during the wet and dry seasons.

Species	Seasons	No. of pregnant females	No. of embryos
M. natalensis	Wet	10	6-12
	Dry	3	5-7
A. dembeensis	Wet	6	5-6
	Dry	3	3-5
S. albipes	Wet	3	4-6
	Dry	1	3
M. erythroleucus	Wet	3	4-6
	Dry	-	-
A. niloticus	Wet	-	-
	Dry	2	3-4
L. striatus	Wet	1	3
	Dry	-	-

3.3.4 Stomach contents

The food items identified from the stomach contents of snap-trapped rodents were broadly categorized as monocoat leaf, dicoat leaf, monocoat seed, dicoat seeds, plant root, animal matter and unidentified items (Table 19). Most of the items were recorded in the stomach contents of all species, with no significant difference. Among the items recorded plant matters were the more common in the stomach contents of most of the rodents. The proportion of plant leaves in the stomach contents was higher during the wet season than during the dry season. The proportion of animal matter was also higher during the wet season. The proportion of seeds in the stomach contents was higher during the dry season than during the wet season. The proportion of different food items varied significantly between different species and between seasons within the same species.

Table 19. Percentage of the food items of snap-trapped rodents during the wet and dry seasons
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Species	**Seasons**	**Food items (%)**						
		ML	DL	MS	DS	Ro	AM	UN
M. natalensis	Wet	24.6	29.4	11.2	14.5	3.4	14.5	8
	Dry	10.4	14.2	19.5	20.2	4.1	7.6	7.6
A. dembeensis	Wet	21.7	27.2	14.4	12.1	5.3	9.1	5.8
	Dry	15.3	13.5	25.1	22.9	8.7	4.5	9.1
S. albipes	Wet	28.9	30.1	3.4	2.5	10.3	20	5.3
	Dry	29.6	31.4	5.2	4.8	15.2	16.3	8.9
M. erythroleucus	Wet	11.7	13.9	12.2	13.1	-	-	11.3
	Dry	9.8	5.1	16.3	18.7	2	-	12
A. niloticus	Wet	19.3	23.5	6.6	7.4	1.4	7.6	11.9
	Dry	16.3	18.6	15.5	14.3	5.4	-	9
A. cahirinus	Wet	22.3	19.7	17.3	10	-	8.7	7.7
	Dry	15.3	13.4	23.4	13.8	-	5.9	8.2
T. robusta	Wet	9.9	8.5	20.1	27.1	11.5	8.9	11.4
	Dry	7	7.8	27	28.4	10.1	7.3	4.7
L. striatus	Wet	14.3	9.6	21.5	23.7	-	3.0	3.5
	Dry	8.2	5.1	16.6	18.4	-	1.0	2.1

(ML= Monocot leaf, DL= Dicot leaf, MS= Monocot seed, DS= Dicot seed, RO= Root, AM= Animal matter, UN= Unidentified items).

3.4 Pest status

The crop damages estimated from the two maize farms were statistically significant (χ^2 = 3.6, df=1, $P< 0.05$) (Table 20). High loss (19.23%) was recorded in the farm surrounded by natural vegetation (Mf_1). The loss in the maize farm surrounded by sesame and groundnut farms (Mf_2) was relatively less (8.97%). The average damage estimate from the two maize farms is 14.2% per ha. This is relatively high in terms of economic loss, which is estimated about 1680.00 Ethiopian Birr.

Table 20. Rodent damage estimates from the two maize farms in the study area.

Farm identity	**Total maize plants**		**Damaged plant**		**Loss, %**
	Per grid	Per hectare	Per grid	Per hectare	
Mf_1	15288	31200	2940	6000	19.23
Mf_2	15288	31200	2940	2800	8.97

(Mf_1= Maize farm one, Mf_2= Maize farm two).

4. DISCUSSION

Small mammal species diversity is rich in many areas compared to the large mammal species diversity. Rodent species are particularly abundant, not only in natural habitats, but also in man-made habitats, in habitats with human interactions and in human dwellings (Laverncheko *et al*., 1998). Many species of rodents have been recorded as pests in agriculture. During the present study, 12 species of small mammals were trapped and four additional species of small mammals were observed. Among these, fourteen species were rodents and 2 were insectivores. Almost similar representation of rodents and insectivores were recorded earlier in different parts of Ethiopia. For instance, Yalden (1988b) recorded 14 species of rodents and five species of insectivores in the Bale Mountains National Park, Afework Bekele (1996b) recorded 12 species of rodents in the Menagesha State Forest, Agerie Addisu (2007) recorded 11 species of rodents in the area of the Alage Agricultural Technical Vocational Education and Training College, Demeke Datiko *et al*. (2007) recorded 12 species of rodents and two species of insectivores in Arbaminch forest and farmland and Mohammed Kassu (2008) recorded 14 species of rodents and three species of insectivores in Mount Chilalo and Galema Mountain range. High level of human encroachment (resettlement), extensive fire during the dry season and excessive grazing by livestock might have influence on the abundance of species of rodents and insectivores in the present study area. However, Tadesse Habtamu and Afework Bekele (2008) recorded the presence of 29 species of rodents and insectivores in Alatish Proposed National Park, northwestern Ethiopia.

M. natalensis was the most common rodent pest in sub-Saharan African countries (Fiedler, 1994). It occurs all over the continent in grasslands, cultivated areas and in human habitats (Laverncheko *et al*., 1998). This species is also a major rodent pest in East Africa (Afework Bekele and Leirs, 1997; Makundi *et al*., 1999). It has wider distribution in different parts of Ethiopia in altitudinal ranges of 500-2900m asl (Yalden *et al*., 1976). In the present study area, *M. natalensis* was the most abundant and widely distributed species of rodents. This species was trapped from all the five habitats (natural forest, plantation, bushland, grassland and maize farm) in the present study area. Its abundance was very high in farmlands and bushlands. Demeke Datiko *et al*. (2007) also stated that *M. natalensis* was the most abundant rodent species in farmlands and bushlands in Arbaminch area of southern Ethiopia. The abundance and wide distribution of this species in different areas also show the heterogeneous nature of the habitats, climatic and geographic ranges of *Mastomys* (Taylor and Green, 1976). There are several reports on the occurrence and abundance of this species in most habitats in Ethiopia (Bulatova *et al*., 2002; Manyingerew Shenkut *et al*., 2006; Demeke Datiko *et al*., 2007; Tadesse Habtamu and Afework Bekele, 2008). According to Afework Bekele and Leirs (1997) and Magige and Senzota (2006), this is the most abundant and widely distributed rodent species in areas with high human influence. Human influence in the present study area during and after resettlement might have been a major factor responsible for its high abundance in the present study area.

The unstriped grass rat, *A. dembeensis* is a lowland species commonly seen in areas of altitudinal ranges between sea level and 2200 m asl (Capanna *et al*., 1996). It is the most common species of rodent in the African savannah habitat (Ducroz *et al*., 1997). This species was commonly trapped from Gambela (Bulatova *et al*., 2002), Maynugus irrigation field (Workneh G/Selassie *et al*., 2005), Bilalo area, Arsi (Tsegaye Gadissa and Afework Bekele, 2006), Alatish Proposed National Park (Tadesse Habtamu and Afework Bekele, 2008) and from Bir Farm Development and nearby habitat (Ejigu Alemayehu, 2008). This species is distributed in diverse habitat types in these study areas. In the present study area, it was also recorded as the second most abundant species. It occurred in the grasslands, bushlands and in maize farms. It was also one of the major rodent pests of maize crops in the area. Its presence was recorded by Afework Bekele and Leirs (1997), Workneh G/Selassie *et al*. (2005) and Demeke Datiko *et al*. (2007) in Zeway maize farm, Maynugus Irrigation Field and Arbamich maize plantation, respectively, and reported as one of the major rodent pests of agriculture.

S. albipes, the third most abundant species in the present study area is the most widely distributed species in forest habitats in altitudinal ranges between 800-4000 m asl (Yalden and Largen, 1992; Fadda and Corti, 2000). Afework Bekele (1996a) also reported that *S. albipes* prefers dense forests that are progressively shrinking. If so, this species can serve as an indicator species to reveal the status of forest block reduction. This species was the most abundant in the natural forest habitat in the present study area. However, the extent of natural forest in the present study area is highly reduced by human encroachment. It is also recorded in bushland and plantation areas with no record in the grassland and maize farm.

M. erythroleucus is an important murid pest of maize crops in east Africa including Kenya (Odhiambo *et al*., 2005). It is recorded as the fourth most abundant species in the present study area. In Ethiopia, it is one of those agricultural pests (Afework Bekele and Leirs, 1997). This species was recorded by Bulatova *et al*. (2002) from Gambela, Workeneh G/Selassie *et al*. (2005) from Maynugus irrigation farm and Tadesse Habtamu and Afework Bekele (2008) from Alatish Proposed National Park. In the present study area, this species was trapped from all habitat types except grassland. The highest abundance was recorded in the maize farm. As it is abundant in the maize farm, it can be inferred that this species would act as a major pest of maize crop.

A. niloticus was recorded from grassland, bushland and maize farm in the present study area. Its abundance was very high in the grassland habitat. Its distribution is strongly influenced by the ground cover. It was reported that they prefer shrub grasslands for shelter and food (Magige and Senzota, 2006). It is common in the savannahs and grasslands of sub-Saharan Africa (Musser and Carleton, 1993). This species was recorded from Gambela and lower Omo Valley (Bulatova *et al*., 2002) and from Wonji sugarcane plantation (Serekebirhan Takele *et al*., 2008) in Ethiopia. The overall abundance of this species was very low in the present study area. This might be due to the reduced extent of habitat in the context of competition with other species due to the resettlement issue in the study area.

A. cahirinus was common in arid lowland regions, often found in *Acacia* scrubs. In Ethiopia, this species was reported as common in areas from sea level to 1500 m altitudinal range (Yalden *et al*., 1976; Sokolov *et al*., 1993). Kingdon (1997) noted that *A. cahirinus* is a savannah species. In the present study area, this species was common in grassland and trapped only rarely from bushland and maize farm. It was not recorded from plantation and forest habitats. Tadesse Habtamu and Afework Bekele (2008) also recorded this spiny rat mainly from wooded grassland habitat.

T. robusta was commonly distributed in bushland, grassland and maize farm areas. Bates (1988) observed the distribution of this species in some parts of Kenya and Sudan. It is a characteristic species of arid habitats at lower altitudes. It was recorded in Ethiopia from altitudinal ranges of approximately 200-1700 m asl (Yalden *et al*., 1976). This species was captured from maize field and grasslands from central Ethiopia (Afework Bekele and Leirs, 1997). Demeke Datiko *et al*. (2007) also recorded this species in deciduous bushland in Arbaminch forest and farmlands at altitudinal ranges of 1100 and 1160 m asl. In the present study, it was recorded in bushland, grassland and maize farm area at an altitudinal range of 1000-1200 m asl.

As per the present findings, *L. striatus* is restricted only to the bushland habitat at an altitude of 1170 m asl. Yalden *et al*. (1976) also stated that this species is confined to open woodland and grasslands in the western lowlands of Ethiopia at altitudinal range of 500-2000 m asl. Tadesse Habtamu and Afework Bekele (2008) also recorded this species from Alatish Proposed National Park, northwestern border of Ethiopia.

M. musculus is known to occur in open habitats between altitudinal ranges of 1500-3000 m asl (Yalden, 1988a). Bates (1988) stated that this species is exclusively urban and village dweller. However, during the present study, it occurred in bushland and grassland in altitudinal ranges of 1000-1200m asl. It was trapped only during the dry season when the ground cover was relatively less.

The least abundant species of a rodent in the present study area was the black rat, *R. rattus*. This species is known to be abundant in cities, villages, cultivated fields and in some natural forests (Nowak, 1999). This species is a commensal in Ethiopia. During the present study, this species was trapped from the maize farm with lower trap success.

C. flavescens is a common shrew in the present study area trapped from natural forest, plantation and bushland habitats. This species is one of the most common and widely distributed among insectivores in Ethiopia within altitudinal ranges of 1000-3000 m asl (Yalden *et al*., 1976). Delany (1964) stated that this species is typically a forest species. However, bushland and plantation habitats were also sites of its occurrence in the present study area.

Yalden *et al*. (1976) reported that *C. fumosa* was confined to altitudinal ranges of 1750-3900 m asl in Ethiopia. It was considered as a moorland species (Yalden, 1988b). In the present study area, it was trapped mainly from bushland area at altitude of 1170 m asl, which is beyond its earlier reported altitudinal range. Tadesse Habtamu and Afework Bekele (2008) recorded few individuals of this species from Alatish Proposed National Park in areas of altitude < 700 m asl.

Most rodent species in the present study area were found to prefer the bushland habitat. The bushland habitat had the highest number of individuals and species of rodents. Out of the 12 trapped small mammal species, all except *R.rattus* were present in this habitat. This might be due to the heterogeneous nature of the vegetation composition comfortable for food and shelter. Further, the moisture content of the soil and moderate temperature in the habitat might also favour small mammals to prefer such habitat. Kotler (1984) also noted that such habitats with enough ground cover provide sufficient food and reduce predation risk, which in turn would enhance the richness and diversity of habitats. Further, habitat heterogeneity created from resource patches has a profound influence on the density of rodents. Martin and Dickinson (1985) also reported that areas providing more microhabitat types or those with more habitat diversity are likely to accommodate more species of rodents. A more complex habitat will contain more niches, which will be exploited by diverse species including rodents (Rozenzwig and Winakur, 1969).

It was revealed that, the plantation habitat had the lowest species composition and abundance. Only four species and 25 individuals were trapped from this habitat type during the present investigation. The homogenous vegetation dominated by few species of tall trees in the plantation has resulted in less microhabitat diversity and absence or loss of under growth at the ground level leading to shortage of cover and food. This is consistent with the conclusion of Hoppold and Happold (1987) that the change from natural forest to plantation caused decline in both total number of individuals and species composition. The natural forest had relatively higher species composition and abundance of small mammals in the present study area. The dense patches of heterogeneous vegetation in the forest habitat offers shelter and act as refugia during the hottest period of the year. Iyawe (1988) also noted that natural vegetation is highly selected by small mammals. *S. albipes* and *C. flavescens* were the most dominant species in the natural forest habitat. Yalden *et al.* (1976) and Afework Bekele (1996b) have stated that these species are typically forest dwellers in Ethiopia. The findings of the present study also confirm that they are forest habitat dwellers.

Next to bushland, the grassland had relatively high abundance of rodents. Kasangaki *et al.* (2003) reported that grassland has low species abundance and diversity compared to bushland. It is clear that grassland has less habitat heterogeneity and vegetation cover unlike that of the bushland. Further, most of the grassland areas are dry and therefore the species composition is comparatively low during the dry season.

Maize farm is the other habitat in this study area, had relatively high abundance and species composition of rodents. This habitat is highly preferred by rodent pests, which are more dominant in the area. For instance *M. natalensis, A. dembeensis* and *M. erythroleucus* accounted for 95% of the abundance in this habitat. *M. natalensis* and *A. dembeensis* were also recorded as major pests of maize and other crops in different parts of Ethiopia (Afework Bekele and Liers, 1997; Afework Bekele *et al*., 2003; Workneh G/Selassie *et al*., 2004; Demeke Datiko *et al*., 2007). Odhiambo *et al*. (2005) recorded *M. erythroleucus* as an important murid pest of maize crop in the Kenyan rift valley.

There was significant fluctuation in the abundance and species composition of rodents and insectivores from season to season within and between habitats in the present study area. Vegetation cover, climate, abundance and quality of food and level of predation change seasonally and hence in relation to this, the small mammal population would also fluctuate. According to Taylor and Green (1976), the timing of rainfall and breeding of rodents are correlated. As rainfall is seasonal in the area, it facilitates ground cover and increases the abundance and quality of food during the wet season. This in turn, results in the increase of rodent population during the wet season in the area.

Among the different trapping sessions, more number of individuals were trapped during the second trapping session of the wet season. The least trapping was during the last session of the dry season. More individuals were recorded during the wet season than during the dry season. These were not in agreement with the findings of Happold and Happold (1991), Taddesse Habtamu and Afework Bekele (2008), Demeke Datiko *et al*. (2007) and Ejigu Alemayehu (2008), who have recorded more individuals during the dry season trapping. Various factors such as weather conditions, quality and abundance of food, fire and predation would influence and contribute for population fluctuations of small mammals, especially in areas with intensive human interactions. In the present study area, fire, deforestation and grazing were major factors for the reduction of rodent population during the dry season. These factors ultimately reduce the ground cover and abundance and quality of food for small mammals. Wijesinghe and Brooke (2005) also noted that the density of small mammals would decrease in disturbed habitats. Such environmental factors would be accompanied by intensified attack of predators in the absence of sufficient cover to act as a protective agent in the habitat. So, reduced rate of capture during the dry season was directly correlated with the seasonal habitat disturbances in the study area.

The effects of habitat changes are not uniform for all species. Such effects may have diverse influences in different habitats, in the case of different species of small mammals (Pahl *et al*., 1988). Happold and Happold (1987) have stated that within a community of small mammals, one or more responses may occur in relation to the changing conditions. Those species, which can fully adapt to the changing environmental factors, would survive better, whereas others, which can only partially adapt to the effects of changes, will decline in their population, resulting in changes in species composition and abundance. Hence, some species that occur in one season might not occur in the other season. For instance, during the present study, *M. musculus* and *R. rattus* were not trapped during the wet season. The disappearance of *M. musculus* in the study area during the wet season might be associated with the excessive flooding in the area and loss of more energy in the cold season. Appearance of *R. rattus* in the maize field during the dry season might be associated with the harvesting stage of the maize crop in the area.

Trap success would vary due to factors such as changes in the availability of food, cover, habitat type and activity of animals (George, 1984; Kotler, 1984; Sillero-Zubiri *et al*., 1995). During the present study, there was variation in trap success between habitats and between seasons (see Table 7). Among the five habitats, the highest trap success was obtained from bushland. This might be due to high abundance of rodents as a result of habitat heterogeneity, sufficient cover, food availability and quality. On the other hand, the lowest trap success was recorded from plantation. This might be due to less abundance of rodents because of lack of habitat heterogeneity and absence of ground cover and sufficient food in the area.

The higher trap success during the wet season might be associated with the influence of rainfall. During the wet season, rainfall facilitates the growth of ground cover and exerts influence on food availability, which in turn enhances breeding of rodents. At the same time, burrows were filled with water and rodents were hiding and moving freely on the ground devoid of water leading to increased trap success. George (1984) also noted that rainfall can significantly increase the capture rate of rodents.

The mean trap success of 17.7% obtained in the present study was low when compared to earlier studies in different parts of Ethiopia. For instance, Rupp (1980) recorded 35% trap success in the Bale Mountains National Park, Bekele Tsegaye (1999) has recorded 62.8% trap success in Entoto Natural Park, Tadesse Habtamu and Afework Bekele (2008) recorded overall trap success of 38.6% in the Alatish Proposed National Park and Mohammed Kassu (2008) recorded overall trap success of 44.1% in Mount Chilalo and Galema Mountain ranges. The comparatively low trap success record of the present study might be due to frequent habitat disturbances and drastic modification of habitat in connection with human resettlement and related factors.

Individuals of all age categories were present during the present study period in all trapping sessions. However, there were significant seasonal variations among and within the age groups. This might be due to the seasonality pattern in reproduction of the species concerned. Yalden (1988a) noted that age distribution in a population of rodents and insectivores is directly related to seasonality in reproduction. All age structures appeared in the population only during a specific season, when reproduction is seasonal. If all age groups are present in all seasons, it would mean that reproduction of that species is continuous. During the wet season, large number of juveniles was recorded. The number of juveniles was less than the number of sub-adults and adults during the dry season. It is evident that the young ones will benefit the presence of more nutritious food available during the wet season in comparison to the shortage of essential food items during the dry season. To make use of the seasonal abundance of food and shelter in the habitat, surface living rodents have to adapt to be seasonal breeders, coinciding the birth early in the wet season.

The density of small mammals per hectare in the present study area varied from habitat type to habitat type. The lowest density was estimated from the plantation habitat, whereas the highest density was recorded from the bushland. The density of small mammals per hectare observed in the present study was comparable to earlier results of Happold (1974), who estimated rodent population density in western Nigeria from 16-106/ha and Delany and Kansieriimubanga (1970) who recorded 160/ha. The density of small mammals in the present study area showed a range of 2-110/ha.

Most rodent species had a significant decrease in the body weight during the dry season. This seasonal reduction in biomass might be correlated with the shortage of food, which was limited in quantity and quality during the dry season. Taylor and Green (1976) have also stated that weight of small mammals decreased during the dry season. Food availability and quality are important for attaining weight and in determining fertility rate of small mammals.

Diets are extremely significant for determining the evolution, life history strategies and ecological role of animals in their habitat. Information on food preferences of rodents is important to predict control measures and management programmes for the concerned species. Diets of animals are studied by analyzing faeces or stomach contents. However, analysis of faeces may not be accurate in the case of rodents due to digestion (Kronfeld and Dayan, 1998) and hence it is better to study the stomach contents. The stomach content analysis confirmed that these rodents feed on a variety of food items, both plant and animal matters. As Campos *et al.* (2001) stated, the feeding ecology of small mammals throughout the world is highly diverse. It is this wide range of feeding habits and adaptability that helped rodents to distribute and occupy a wide range of habitats all over the world in addition to the nature of rodents as commensal of human beings. Rodents prefer different food items depending on its availability in different seasons. The present study also showed that high percentage of animal matter was consumed during the wet season, whereas monocot seeds, dicot seeds and plant roots were consumed more during the dry season. Most species of rodents appear to be opportunistic feeders, capable of changing their feeding habits depending on the availability of food from season to season (Johnson, 1961; Taylor and Green, 1976 and Workneh Gebreselassie *et al*., 2004).

In the present study, four species of rodents viz., *M. natalensis*, *A. dembeensis*, *M. erythroleucus* and *T. robusta* were recorded as pests, and they were trapped from maize farms. Relatively high percentage of cereals was observed in their diet from snap-trapped individuals. Among them, *M. natalensis* and *A. dembeensis* were highly abundant. These two species were also known as serious pests of maize in East Africa including Ethiopia (Afework Bekele *et al*., 2003) and *T. robusta* and *M. erythroleucus* were considered as minor pests in agricultural fields (Ejigu Alemayehu, 2008; Workneh G/selasie *et al*., 2004). According to Christensen (1996), pattern of cultivation (cultivated and fallow fields) is among the major factors known to affect the abundance and diversity of small mammals. As the fallow lands are not disturbed compared to cultivated areas, they provide suitable ground for shelter, food and refugia (Conde and Rocha, 2006). Shelter and food are the main factors affecting abundance of rodents in a given habitat.

Damage rate estimates from the two maize farms showed that the pests caused a damage rate of about 14.2% per hectare. This was comparatively higher than the earlier record of Demeke Datiko *et al*. (2007) (5.7%) and less than that of Afework Bekele *et al*. (2003) (26.4%). The economic loss is estimated to be 1680.00 Ethiopian Birr or 152.00 US dollar per hectare. However, the damage rate was high (19.2%) in Maize Farm 1, which was surrounded by natural vegetation and low (8.9%) in Maize Farm 2, which was surrounded by sesame and groundnut farms. This damage results confirmed that the presence of non-cropped refuge habitat has great impact on the damage rate of maize crop adjacent to it. Hence the high crop damage in Maize Farm 1 might be due to better diversity and cover of the natural vegetation around the farm, which increases the availability of cover and breeding sites for rodents. The surrounding natural vegetation is suitable for breeding and survival of the young to reproductive stage and cause damage on maize crop at maturity. This is consistent with the views of Taylor (1968) and Mwanjabe *et al*. (2002) that more serious damage of the crops occur when farmlands are interspersed with fallow land. Hence, adjacent non-crop habitats play an important role by providing shelter for rodents, which enhances crop damage in the neighbouring agricultural field.

The area adjacent to Maize Farm 2 was frequently disturbed by humans during weeding and other farming practices. Sesame and groundnut farms were weeded and cleared three times from the time of seedling to the stage of harvest. The weeding practice causes disturbance that result in the loss of cover and food for rodents leading to reduction in population density. Fox and Fox (2000) also noted that areas with high disturbances show lowest species diversity and population number. The low abundance and diversity of rodents in the neighbourhood were reflected in less crop damage in agricultural area. This feature highlights the significance of ecological pest control measures to be adapted as a better means of rodent control.

5. CONCLUSION AND RECOMMENDATIONS

The present study has revealed that the species composition and abundance of rodents varied in different habitats and seasons. Bushland had relatively better habitat heterogeneity and cover and hence this habitat supports the highest abundance of rodents both during the wet and the dry seasons, whereas the plantation had the lowest abundance of rodents. The abundance of rodents showed significant seasonal variations. Rainfall and fire had significant role for seasonal abundance of rodents in the area. Populations of rodents increased during the wet season and decreased during the dry season. More pregnant females were also observed during the wet season. This reveals that breeding of rodents is strongly correlated with rainfall. Wild fire has negative effect, which reduced vegetation cover and increased predation risk of rodents. This in turn resulted in a decrease in abundance of rodents during the dry season.

The mean body weight of rodents in this study was higher during the wet season than during the dry season. This seasonal variation in the weight of rodents was associated with the seasonal availability of food in the area.

Pawe area was covered with dense patches of natural vegetation that harbour many species of wild animals. However, the forest cover has been cleared since the commencement of the resettlement scheme for farmlands, construction, fuel wood and for infrastructural activities, resulting in the disappearance of flora and fauna. Annual wild fire with high speed flames, also burn forests, bushlands and grasslands, which are homes for small mammals. All these have serious effects on the species diversity and abundance of rodents that has great economic, ecological and cultural values. As a result of encroachment, important species of rodents and other fauna are already extinguished or displaced from the area. To maintain the diversity and abundance of rodents, the following recommendations are suggested:

- The forest habitat harbours vegetation with diverse economic and ecological values. In addition to this, it is the habitat of many small mammals. Therefore, it is essential to conserve the natural habitats available in the area.

- Fire could be an important tool as part of the ecosystem management when applied to a specific area with proper care and management. However, unmanageable spread of fire has adverse effects, especially on small mammals. Therefore, community participatory actions should be taken to control fire in the area during the dry season. Controlled fire can be a better option in the area.

- The demand for farmland, wood and thatched grasses have dramatically increased in the recent past. This results in the destruction of the remaining forest and other natural habitats. Therefore, there is a need for a campaign to make the local people aware of the consequences of habitat destruction and the need for conservation of natural habitats.

- The local people should be aware of the pest status of rodents and ecologically based rodent management practice as an alternative approach to manage rodents in agricultural systems by combining a variety of control measures rather than relaying largely on rodenticides. Essential information should be spread among the local people on ecologically based pest control measures.

- Detailed studies on the biology and ecology of each of the species of rodents in the area are required for designing appropriate measures to control major rodent pests in the area.

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Appendix-1. List of observed large mammal species in the study area

Common Name	Scientific Name
Hyaena	*Crocuta crocuta*
Common jackal	*Canis aureus*
Warthog	*Phacocherus aethiopicus*
Bohor Reedbuck	*Redunca redunca*
Civet	*Civeittictis civetta*
Stark's hair	*Lepus starki*
Serval cat	*Felis serval*
Mongoose	*Herpestes ichneumon*
Menelik's Bushbuck	*Tragelapphus scriptus meneliki*
vervet monkey	*Cercopithecus aethiops*
Bush duiker	*Sylvicapra grimmia*
Aardvark	*Orycteropus afer*
Abyssinian Genet	*Genetta abyssinica*
Ratel (Honey Badger)	*Mellivora capensis*
Klipspringer	*Oreotragus oreotragus*
Columbus Monkey	Colombus guereza
Salt's Dik-Dik	*Madoqua saltiana*

Anubis Baboon	*Papio anubis*

DECLARATION

I, the undersigned, declare that the information provided in this work is an original work, and that has not been presented in a degree in any Universities and all sources of material used for the thesis have been duly acknowledged.

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