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Species composition, distribution, relative abundance and habitat association of rodents in Bir Farm Development (Birsheleko) and nearby natural habitat area, Ethiopia

By
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ABSTRACT: *A comparative study on species composition, distribution, relative abundance and habitat association of rodents and insectivores were carried out in Bir Farm Development (Birsheleko) and nearby bushland area from August, 2007 to February, 2008. Live-trapping (each 70 × 70 m) and snap trapping (each 80 × 80 m) in the forest, bushland, grassland and agricultural fields revealed the presence of Arvicanthis dembeensis (34.2%), Lophuromys flavopunctatus (19.4%), Mus mahomet (15.7%), Stenocephalemys albipes (13.6%), Tatera robusta (10.6%), Pelomys harringtoni (2.7%) and Crocidura flavescens (3.8%). In addition to this, Hystrix cristata and Tachyoryctes splendens were observed in the study area. A. dembeensis was the dominant species in the study area. The distribution of species varied from habitat to habitat and season to season. L. flavopunctatus has a wide range of distribution than other small mammals trapped. Population density, biomass and diversity of rodents and insectivores were higher in maize farms from local farmed areas than other farms in the study area. The population density by Capture-Mark-Recapture method ranged from 44/ha in maize and soybean farms from the farm development to 165/ha in maize farm from local farmed areas. The population density was also varied from season to season; highest was observed during the dry season and less during the wet season. Diet analysis indicated that consumption of animal matter was more during the wet season, and monocot seeds, dicot seeds and plant roots were more during the dry season. More number of pregnant females was also found during the wet season. The level of damage by rodents was 13.2% for wheat, 12.9% for soybean and 9.6% for maize farms from the farm development. Comparatively, high rate of damage (29.2%) was observed in the maize farm from the locally farmed areas.*

Key words/phrases: Agricultural fields, biomass, Bir Farm Development, diversity, habitat association, pest, population density, rodent.

1. INTRODUCTION

Ethiopia is one of the most physically and biologically diverse countries in the world (Glass, 1965; Yalden and Largen, 1992; Corti *et al*., 1999; Leykun Abunie, 2000; Birru Yitaferu, 2003; Mersha Engida, 2003: Shifferaw Dessie, 2003). It is also distinct in its high rate of endemism (Fadda and Corti, 2000). The country is characterized by physiographic, climatic and edaphic diversity resulting in variable vegetation and fauna (Gebre Markos Wolde Selassie, 1998). The topographical variation ranges from 135 m below sea level in the Dallol depression to a peak of 4620 m asl at Ras Dejen in the Simien Mountains (Tewoldebirhan Gebreegziabher, 1988; Shibru Tedla, 1995; Tesfaye Hundessa, 1996; Afework Bekele and Corti, 1997; Gete Zeleke, 2003; Teshale Adgo, 2003). Geographically, the country is located in the horn of Africa between latitude 3^0-15^0 N and longitude 33^0-48^0 E (Tesfaye Hundessa, 1996; Gebre Markos Wolde Selassie, 1998).

Mammals are the most biologically successful group with the possible exception of insects (Hickman *et al*., 1988). Globally, small mammals form a major proportion of the mammalian fauna and are also a common feature of agricultural landscapes (Jacob *et al*., 2003; Workneh Gebresilassie *et al.*, 2005). The small mammals of East Africa include a diverse group of rodents, insectivores and bats, and they represent a heterogeneous group (Corominas, 2004; Keesing, 2000). Of the mammalian orders, rodents contain the largest number of species (Kingdon, 1997; Vaughan *et al*., 2000; Tsegaye Gadisa and Afework Bekele, 2006) and they account nearly 44% of the mammal species (Wolff, 2007).

Among the mammals of Africa, rodents are the most ubiquitous and numerous (Macdonald, 1984; Delany, 1986; Afework Bekele, 1996). They show considerable diversity in their diet (Leirs, 2003). Diets are extremely significant for determining evolution, life history strategies and ecological role of animals as food is one of the most important dimensions of the niche. The food habits of small rodents are poorly known, mainly because the finely masticated food components are hard to identify (Hansson,

1970). The diet of rodents is usually evaluated by analyzing stomach contents, although it demands sacrificing the animals (Kronfeld and Dayan, 1998). They are opportunistic feeders, capable of changing their feeding habits depending on the availability of food from season to season (Workneh Gebresilassie *et al.,* 2004).

Rodents comprise 29 living families, 443 genera, and more than 2000 species (Cole *et al*., 1994, Vaughan *et al*., 2000; Danell and Aave-Olsson, 2002; Amori and Gippoliti, 2003). Although rodents show considerable diversity in morphology, habitat utilization, behaviour, life history strategies and distribution (Sewnet Mengistu and Afework Bekele, 2003), they show less overall variation in body plan than do other mammalian orders (Macdonald, 1984). Vaughan *et al.* (2000) revealed that rodents range in size from about 5 g to 50 kg.

In Africa, 381 species of rodents occur of which 77 are pests (Singleton *et al*., 2007). Out of these pests, between 12 to 20 are significant pest species in cropping systems (Table 1).

Table 1. Pest rodents in different regions of the world.

Continent or country	No. of species	Pest rodents	Major pests	Conservation status	
				At risk	Little known
Africa	381	77	12-20	60	11
Australia	67	7	4	14	1
Europe	61	16	5	4	-
India	128	18	12	1	1
Indonesia	164	≥ 25	13	≥ 11	≥ 28

(Source: Singleton *et al*., 2007).

Of the 284 mammalian species of Ethiopia, 84 species are rodents and 11% of them are major agricultural pests (Afework Bekele and Leirs, 1997; Manyingerew Shenkut *et al*.,

2006) and 21% are endemic (Afework Bekele, 1996) constituting 50% of the Ethiopian endemic mammals (Afework Bekele and Corti, 1997). For instance, *Tachoryctes macrocephalus* is an endemic rodent to Ethiopia and is restricted to high altitude grassland and moorland habitats (Yalden, 1985; 1988). *Arvicanthis dembeensis* and *Stenocephalemys albipes* are also endemic rodents to Ethiopia (Rabiu and Fisher, 1989; Afework Bekele, 1995; Corti *et al*., 2005). There are nine families of rodents in Ethiopia. The family Muridae alone comprises 57 species (84% of the total number of species) and 93% of the total endemic rodents of Ethiopia (Afework Bekele and Corti, 1997). *Lophuromys flavopunctatus* is also the most common rodent in the moist eastern part of East Africa, inhabiting a wide range of habitats (Delany, 1964; Yalden and Largen, 1992; Clausnitzer and Kityo, 2001).

Small mammals select and utilize some habitats more than others (Happold and Happold, 1989, 1991; Fitzherbert *et al*., 2006) and the habitat selection of different species of small mammals is mainly dependent upon the vegetation type and ground cover (Iyawe, 1988). Their distribution and abundance are influenced by environmental factors, mainly upon the nature and density of vegetation, food and shelter (Clout and Russell, 2004; Workneh Gebresilassie *et al.*, 2004), climatic conditions, disease, predation and habitat manipulation by man (Nandwa, 1973; Hubert, 1978; Odhiambo and Oguge, 2003). Abundance of small mammals is significantly affected by loss of food and cover. The disturbance of the forest floor as an ecologically disturbed ecosystem is often associated with decrease in small mammal diversity (Waters and Zabel, 1998; Cramer and Willig, 2005; Hoffmann and Zeller, 2005). Abundance of food increases rodent density in agricultural areas, grassland and forest habitats (Halvorson, 1982; Lentic and Dickman, 2005). The loss of ground vegetation cover also leads to reduced food supply and may result in predation risk (Hoffmann and Zeller, 2005).

Reproductive patterns and population dynamics of rodents follow seasonality in relation to variations in rainfall and reach peaks towards the end of the rainy season when resources are plenty (Feliciano *et al*., 2002; Mssawe *et al*., 2006; Workneh Gebresilassie

et al., 2006). Breeding decreases during the dry months (Tilaye Wube, 2005) and rainfall is the ultimate source of variation in rodent density (Caro, 2002; Brevig, 2003). The type of diet affects the reproductive status of rodents as seen in *Mastomys natalensis*, where 6% of the diet is protein for full reproductive success (Jackson and Aarde, 2004). Temperature and humidity have also a significant factor in determining the rodent activity (Cheeseman, 1977; Ghobrial and Hodieb, 1982; Windberg, 1998).

Change in land-use pattern because of human activities has a striking effect on composition of small mammal communities. The best known examples are agriculture, the replacement of natural forests by other plantations, habitat fragmentation and deforestation (Happold and Happold, 1987; Massawe *et al*., 2005). This may alter habitats and drive the rodent population into new habitats (Happold, 1975; Taylor and Green, 1976; Happold and Happold, 1987; Leirs *et al*., 1993; Medellin and Equihua, 1998; Giuggioli *et al*., 2005).

Crop fields provide habitat for a variety of wildlife species, which often result in crop damage (Witmer *et al*., 2007). Agricultural fields are also homogenous landscapes because the vegetation is dominated by one or few crop species. Different practices were used by farmers to increase productivity such as application of fertilizers and weeding that enhance soil fertility and water availability for agricultural pests. As a result, plentiful amount of energy-rich food becomes available in the field not only for humans but also for pests (Leirs, 2003; Manyingerew Shenkut *et al*., 2006).

Among mammals, particularly the giant mole rat are the single most important food item that contributes significantly to the survival of one of the most endangered canids in the world, *Canis simensis* (Zelalem Tefera *et al*., 2005; Sillero-Zubiri and Gottelli, 1995; Magige and Senzota, 2006). Rodents are also important preys for different carnivores such as mongooses (Ray, 1998; Kisingo *et al.*, 2005). In addition, rodents are important food sources for humans and also a source of income (Assogbadjo *et al*., 2005). Rodents are menace in public health due to their role as vectors and reservoirs of bacterial diseases such as leptpspirosis, murine typhus, salmonellosis and plague (Rao, 2003).

They are also the principal hosts of the parasite *Capillaria hepatica*, which is essentially limited to commensal rats (*Rattus rattus*) (Farhang-Azad and Schlitter, 1978).

Rodents are historically mankind's oldest competitors in acquiring and storing food (Engeman and Whisson, 2006). They represent major pest problems worldwide both in the countryside and in the cities. They cause serious damage to crops both before and after harvest (Delany, 1972; Smythe, 1986; Makundi *et al*., 1999; Singleton *et al*., 1999a; 1999b; 2004; Pech *et al.*, 2003; Skonhoft *et al.*, 2006; Fayenuwo *et al*., 2007; Palis *et al*., 2007). They are also responsible for infrastructural damage (Meerburg *et al.*, 2004).

The most common rodent pests in sub-Saharan Africa are multimammate rats, belonging to the murid genus *Mastomys* (Meester *et al*., 1979; Christensen, 1996; Leirs *et al*., 1996; Venturi *et al*., 2004) and *Arvicanthis* (Afework Bekele and Leirs, 1997; Stenseth *et al*., 2001) that destroy as much as 80-100% of crops throughout their ranges in sub-Saharan Africa (Green *et al*., 1980; Keesing, 2000). In Ethiopia, maize, enset and potatoes are the crops most affected by rodents (Tristiani *et al*., 2000; Makundi *et al*., 2005a). Destruction of crops and stores by rodents has resulted in heavy loss of food and human economy (Singleton *et al*., 1999a; 1999b; Keesing, 2000; Makundi *et al*., 2005b). Brown and Khamphoukeo (2007) estimated that the severity of damage ranged from 5-10% in non-outbreak years to crop losses of 30-100% during outbreak years leading to localized or widespread famine. Afework Bekele *et al*. (2003) also estimated that rodent damage in maize fields at Ziway, Ethiopia, which was up to the 26.4%.

The damage in underdeveloped countries caused by rodents and the subsequent yield losses at harvest is economically significant, where farmers are small landholders with limited alternative income (Makundi *et al*., 2005a). Hence, reducing crop losses by rodents occurring at different stages of harvesting to meet the rapid growth of the world's population is of a great concern (Tatlidial *et al*., 2005). However, rodents also consume insects, weed seeds, and a variety of other items, which are important to man's agriculture and health. Control by using acute poisons and providing rodent-proof storage

containers are complicating factors in developing countries (Brown, 1970). In developing countries where high level of illiteracy and low nutritional levels are common (Cuong *et al*., 2003; Leirs *et al*., 2003; Makundi *et al*., 2005b), the problems caused by rodents are more serious, widespread and difficult to solve especially at the most susceptible stage of crop growth. The tested and approved methods of reducing rodent populations are:

1. manipulate by burning or herbicide spraying the non-crop habitat (which may serve as rodent refugia)
2. applying rodenticides to the surrounding non-crop habitats or to apply zinc phosphide (Witmer *et al*., 2007).

A correct assessment of biological communities depends primarily upon an effective sampling procedure or design (Astua *et al*., 2006). Most studies of small mammal communities rely on sampling methods involving trapping with space ranging from 5 to 20 m, which is a typical range for small mammals (Corominas, 2004; Nicolas and Colyn, 2006). Both Sherman live and snap traps are efficient to capture rodents (Greenwood, 1996; Nicolas and Colyn, 2006). The effectiveness of the traps is affected by different factors such as body mass of the animal and bait (Lee, 1997). Sherman live and snap traps are the common trap types used in ecological studies (Hansson and Hoffmeyer, 1973).

Despite being the most numerous, widespread and diverse group of mammals on earth, the importance and the biology of rodents remain poorly understood and unappreciated by the general public. In addition, pest status of rodents are aslo poorly known for many regions of Ethiopia (Demeke Datiko *et al*., 2007). Although few ecological studies on rodents have been carried out in different parts of Ethiopia, population ecology, habitat association, distribution and relative abundance of rodents in many regions are also poorly known. Therefore, an ecological survey was in Bir Farm Development and nearby bushland area to determine the species composition, distribution, relative abundance and habitat association of rodents in the region. The study also provides important information on the population status and their impacts on agricultural productivity.

2. OBJECTIVES

2.1. General objective:

The general objective of the present study is to assess the current status of rodents in Bir Farm Development and nearby bushland area.

2.2. Specific objectives:

The specific objectives of the study are the following:

- To determine the species richness, diversity and composition of rodents in the area.
- To estimate the density and biomass of rodents in different habitat types and seasons.
- To make a survey of species distribution and abundance of rodents.
- To describe the habitat association of rodents in the study area.
- To assess the extent of damage caused by rodents in the farmland.

3. STUDY AREA

3.1. Location and area

The present investigation was carried out in Bir Farm Development and nearby bushland area. The farm is located approximately 400 km northwest of Addis Ababa in the Amhara National Regional State, Western Gojjam Zone, Jabi Tenhan Woreda. The farm area was established in 1978 as 'Birsheleko State Farm'. The farm was purchased from the Ethiopian Privatization Agency, in March 2001 by Ethio Agri-CEFT. It is situated between 10^{o} 27'-10^{o}42' N latitude and 37^{o}6' -37^{o}13' E longitude at an altitude ranging from 1400-2000 m (Fig. 1). The farm has an area of 8854 ha; of which the utilized one is less around 7500 ha. The rest of the area is covered with forest, grass, artificial plantation and bushlands. The major crops currently cultivated at the farm include maize, soybean and wheat. But, to make the farm more productive and cost effective, Ethio Agri-CEFT has also started trials of herbs, medicinal plants and spices.

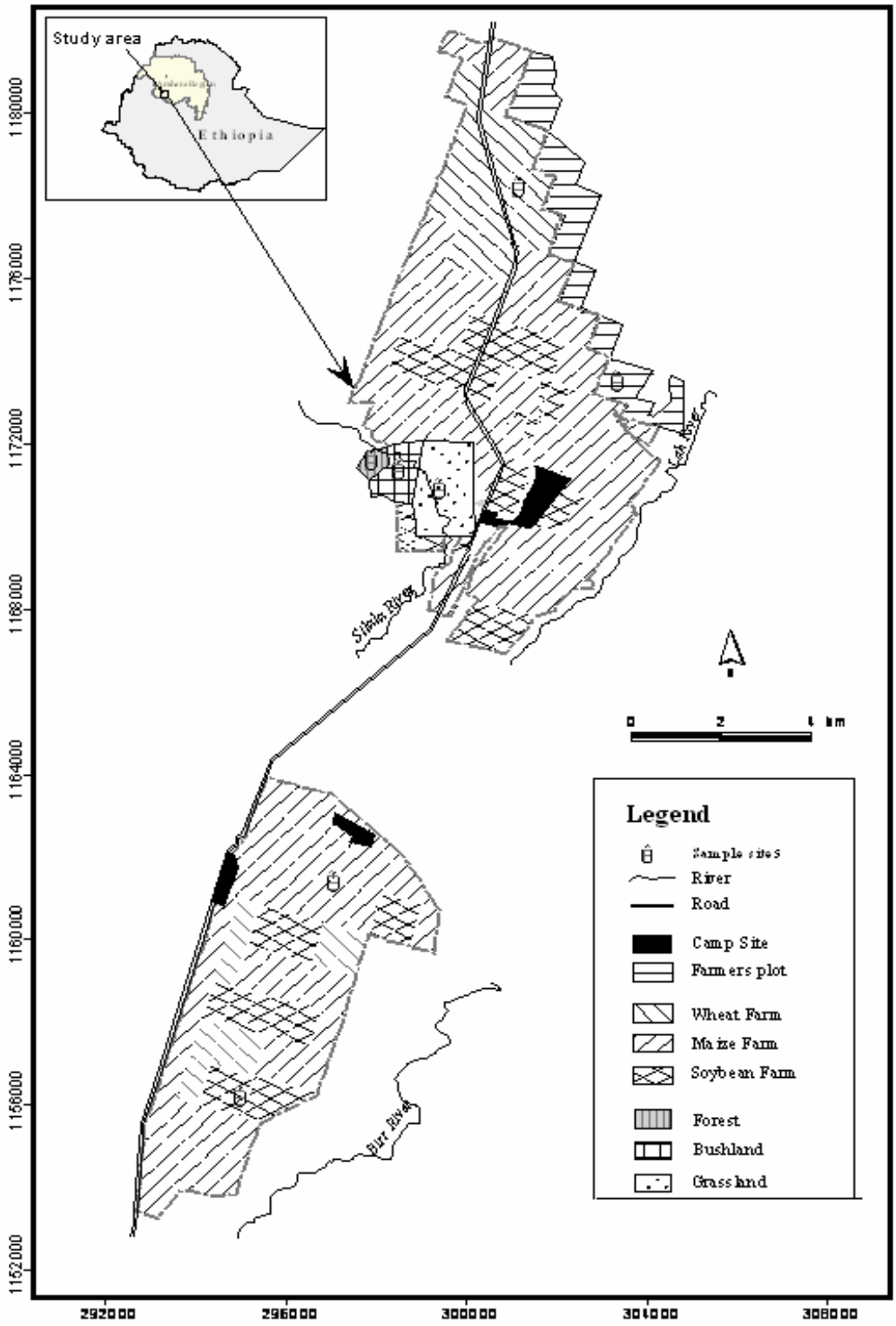

Figure 1. Map of the study area with habitat types.

3.2. Climate and soil

The climate of Birsheleko area is tropical with wet and dry seasons. The annual rainfall follows unimodal regime that includes the main rain season from June to September (Fig. 2). The annual rainfall is around 1100 mm. Most of the area falls into 'Weina Dega' agro-climatic zone with the temperature range of 12-33.8^{o}C. The minimum temperature is 8.2^{o}C (July) and the maximum is 33.8^{o}C (March). The hottest month of the year are March and April and the coldest is July. The soil type is reddish brown clay and black vertisol. The topography of the farm is flat and undulating, thus making it suitable for both mechanized farming and irrigation. Suitable climate, soil, and the presence of rivers (Bir River and Lah River) for irrigation, give the farm great potential to be one of the large-scale viable commercial enterprises of the country.

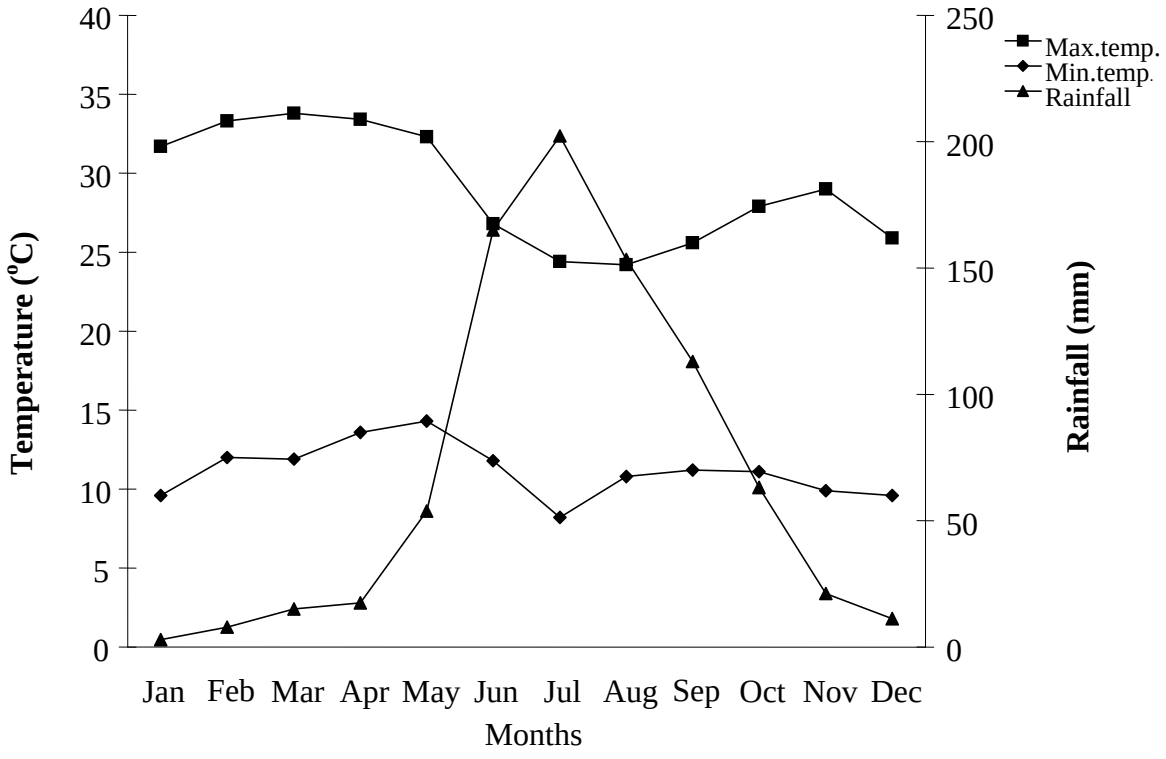

Figure 2. Monthly average maximum and minimum temperature and rainfall from 2001 to 2007 (Source: Bir Farm Development Head Office).

3.3. Vegetation and habitat classification

The following habitats are present in the area: forest, bushland, grassland and the agricultural field.

3.3.1. Forest

The forest area that covers is dominated by species of plants such as *Carissa edulis*, *Buddleja polystachya*, *Vernonia amygdalina*, *Phytolacca dodecandra*, *Rubus* spp., *Myrsine africana*, *Rosa abyssinica*, *Clematis* sp., *Capparis micrantha* and *Embelia schimperi* (Plate 1).

Plate 1. View of the forest habitat type in the study area (Photo: Ejigu Alemayehu, 2007).

3.3.2. Bushland

This habitat is dominated by plant species grown at the base with many branches. The main plant species found in the bushland habitat include: very short *Acacia sieberiana*, *Stereospermum kunthianum* and *Ipomoea tenuirostris* (Plate 2).

Plate 2. View of the bushland habitat type in the study area (Photo: Ejigu Alemayehu, 2007).

3.3.3. Grassland

This area is dominated by herbaceous species in which grass species accounted for 15-60% species composition. The main grass species that inhabited the area was *Pennisetum ramosum*. *Agrostis semiverticillata* was also occur abundantly in the area (Plate 3).

Plate 3. View of the grassland habitat type in the study area (Photo: Ejigu Alemayehu, 2007).

3.3.4. Farm Development (Agricultural field)

The crop species cultivated in the Farm Development includes maize (*Zea mays*), soybean (*Glycine max*), wheat (*Triticum sativum*) and other cereal crops. The maize, wheat and soybean farm covers around 4294 ha, 741 ha and 1355 ha, respectively. The nearby farmer's plot also cultivate maize of the same verities with the Farm Development Agronomic practices such as fertilizer application and weeding were carried out equally in all areas of crop types except the one from the local farmed areas (Plate 4,5 and 6). The wheat farm was planted using broadcast sowing whereas the maize and soybean farm was using rows.

Plate 4. View of the maize farm during the wet season (Photo: Ejigu Alemayehu, 2007).

Plate 5. View of the soybean farm during the wet season (Photo: Ejigu Alemayehu, 2007).

Plate 6. View of the wheat farm during the wet season (Photo: Ejigu Alemayehu, 2007).

4. MATERIALS AND METHODS

4.1. Materials

Materials used during the study period are: global positioning system (GPS), meter, digital camera, Pesola spring balance (300 g), polythene bag, dissecting kits, protective gloves, snap traps, Sherman live-traps, stove, bait (peanut butter) and slides. 70% ethyl alcohol as preservative and compound microscope were also used for stomach content identification.

4.2. Preliminary survey

A preliminary survey was conducted in Bir Farm Development and nearby bushland area from August 5 to 12, 2007. During this survey, all the available and relevant information about the area (establishment of the area, climatic condition, crop types cultivated in the area, approximate size of the different vegetation types and crop coverage) was gathered.

4.3. Sampling design and grids

Based on the habitat type, the total area was identified as forest (F), bushland (BL), grassland (GL), wheat farm (Wf), maize farm (Mf) and soybean farm (Sf). The number of sampling grids chosen for different vegetation zones was based on the total size of the area that the vegetation type covers. Representative sample grids were set in the different habitat types.

4.4. Data collection

Based on the data collected during the preliminary survey, an ecological survey of small mammals was conducted during wet (August 2007 to October 2007) and dry seasons (December 2007 to February 2008). During the study period, both Sherman traps and snap traps were used. The capture-mark-recapture (CMR) technique was used in sampling small mammal populations, to estimate the population size and structure of the

populations and communities. The duration between two successive trap sessions was 30 days.

4.5. Trapping

Both Sherman live and snap traps were provided with bait to catch and sustain trapped individuals. Traps were covered with grass to reduce mortality from heat and cold, and checked twice a day Caught animals were removed from traps, handled without anesthesia, weighed to the nearest gram. Trapping was done on six permanent grids in different habitats on the Farm Development and nearby bushland area, forest and grassland. One additional trap site from the nearby farmer's plot was also taken. Trapping was made in four sessions covering different seasons. Trapping session one (August, 2007) coincided with the main rainy season when the cultivation was approaching fruiting condition. The second trapping session was during mid-September to mid-October (2007), which coincided with the flowering and fruiting phase of cereal crops. The third trapping session (December, 2007) coincided with maturity before farmer's intended date of harvest (two weeks before harvest). The fourth session (February, 2007) was the post-harvest period. In all these trapping sessions, trapping were also done from the forest, bushland areas and grassland.

4.5.1. Data collection by live-traps

A permanent 4900 m^2 live trapping grid was established in all the seven different habitat types. Seven rows by seven columns were set at 10 m intervals between trap stations (Fig. 3). Live-traps were baited with peanut butter checked twice a day, late afternoon (between 05:00 and 06:00 p.m.) and early the next morning (between 07:00 and 08:00 a.m.). Traps were set for three consecutive nights, giving a standard trapping effort of 147 trap nights per grid. A scotch tape was placed near each trap and labeled with a different number. Trapped animals were removed from traps, and placed in a polythene bag weighed to the nearest gram. The trapped animals were marked by toe-clipping (Linder

and Fuelling, 2002; Mahlaba and Perrin, 2003) and released at the point of capture after recording the location of capture, weight, species type, sex and reproductive condition.

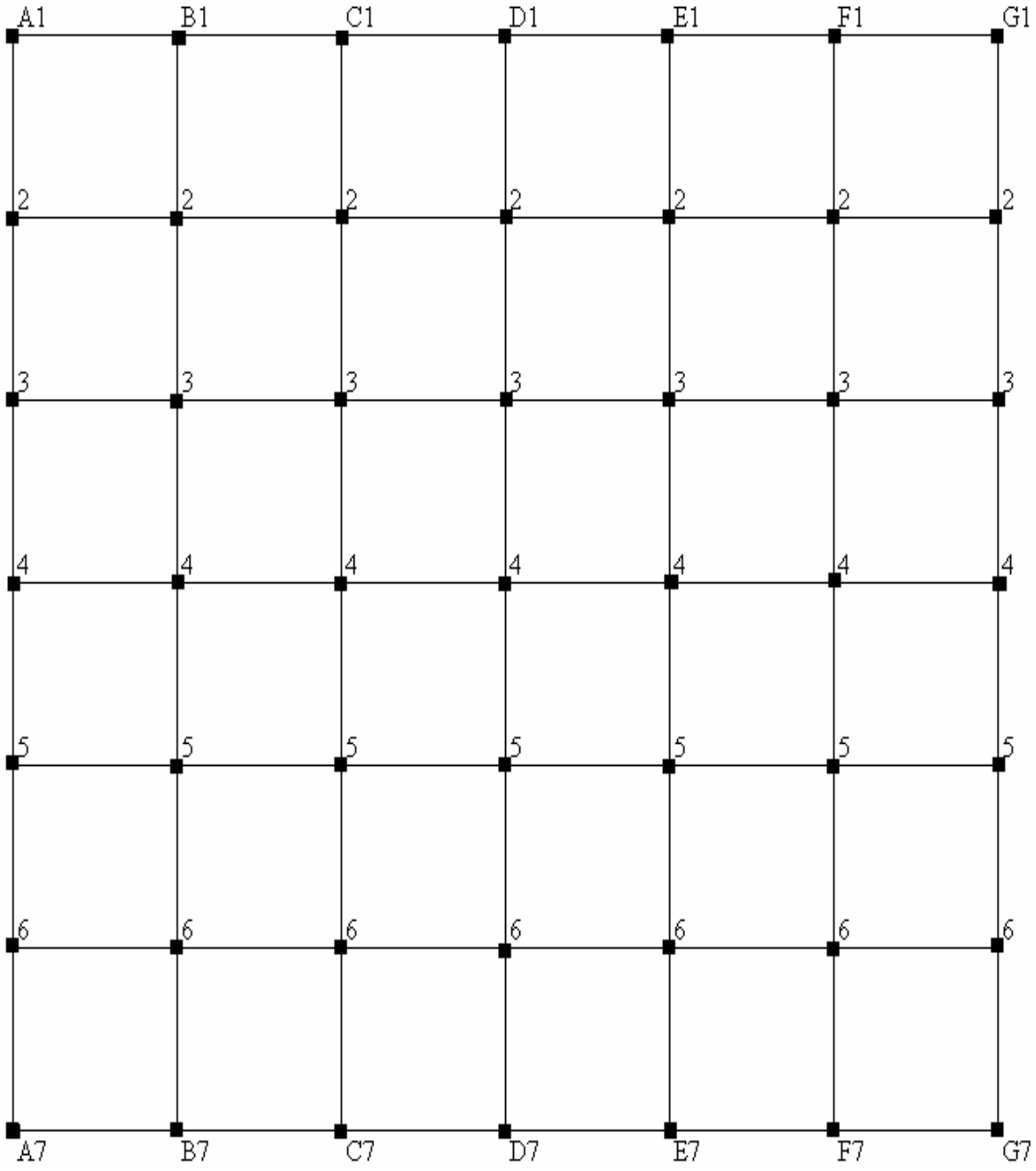

Figure 3. Diagrammatic representation of live-trapping grid with trap locations.

Weight was recorded by a Pesola spring balance. Each species captured was assessed as:

- Juvenile: females with non-perforated vagina and invisible nipple or males with inguinal, non-developed testes.
- Sub-adult: females with small visible nipples but a non-perforated vagina or males with non-scrotal testes (internally developed but not externally visible).
- Adult: females with large nipples and/or a perforated vagina or males with scrotal, externally visible testes (Afework Bekele, 1996; Amundala *et al.*, 2005; Okia, 1973).

Population density of live-trapped small mammals was estimated for both wet and dry seasons by dividing the number of rodents alive per area of the hectare. The biomass of the different species captured was estimated as the total weight of the population per area for each grid in each of the different trapping sessions.

4.5.2. Data collection by snap-traps

Snap-traps were used to collect data each for three consecutive nights during wet and dry seasons. Each season, seven snap-trap grids were placed in fields of each major crop (maize, wheat and soybean) and in permanent grass cover, forest and bushland vegetation. All snap-traps were 20 m away from any other snap-traps and 200 m away from Sherman live-traps. Generally, grids in the study area contained 25 snap-traps in a 5×5 arrangement (Fig. 4).

Snap traps were baited with peanut butter checked twice a day, late afternoon and early the next morning. A scotch tape was placed near each trap and labeled with different number. Trap grids were operated for three consecutive nights for 75 trapping nights per grid. For each capture in each grid, date, location, crop or cover type, and species type were recorded. Weight, head and body length, hind foot length, ear length and tail length were also recorded for each species. During both seasons, the stomach was removed from each species (38 individuals) and preserved in 70% alcohol for further diet analysis (Afework Bekele, 1996; Iyawe, 1988; Monadjem, 1997). The trapped animals were

dissected and the number of embryos in each uterine horn was counted for pregnant females.

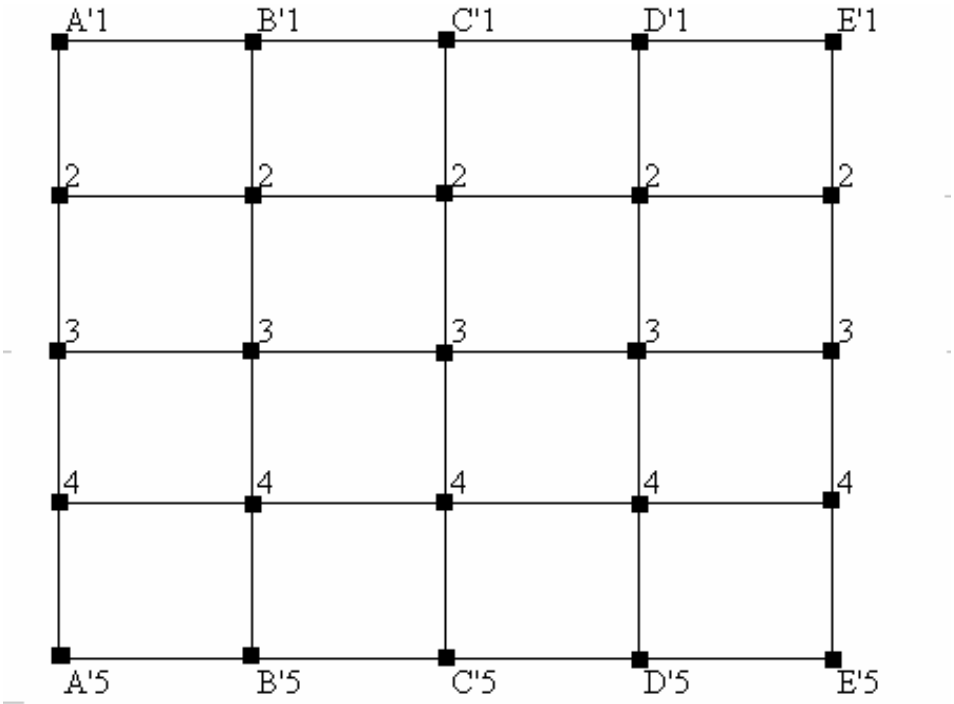

Figure 4. Diagrammatic representation of snap trapping grid with trap locations.

4.6. Diet analysis

Stomach contents of the different species were washed with warm water to remove gastric juices and fully digested items. In the process, stomach contents were dried, homogenized and then mixed with a small amount of water. A small quantity was placed on a microscopic slide and then examined under a microscope.

4.7. Assessment of crop damage at pre-harvest season

Crop damage assessment was performed at maturity before the farmer's intended date of harvest (two week before harvest). Grids were set on the wheat, maize and soybean farm; at least 50 m from edge of the crop (roads, fencelines, and block sides) from the farm development. Each grid has 49 cells of 100 m^2 area in the live-trapping and 25 cells of

400 m^2 area in the snap trapping grid. Out of the 49 cells in a live-trapping grid, 12 cells (24.5%) were randomly selected. Also, out of 25 cells of 400 m^2 area (100 cells of 100 m^2 area) in snap-trapping grid, 25 cells of 100 m^2 area were randomly selected. The actual damage was measured by walking along rows and recording the number of maize cobs and soybean pods damaged as maize and soybean were planted in rows. Wheat tillers damaged was also counted in the sampled area and it was planted by means of broadcast. The number of undamaged and damaged cobs/pods/tillers was recorded per plant as well as the number of plants damaged per sampling point. The distance between rows was about 85 cm in maize fields and 60 cm in soybean fields. The distance within the same row was 40 cm for maize plants and 9 cm for soybean plantation. Hence, for each 10 m × 10 m maize and soybean farms, approximately 275 maize and 1776 soybean plants were visited. Estimation of damage (Mulungu *et al*., 2007) of maize, soybean and wheat crops by rodents was calculated by: % maize crop damage = $100\ (\frac{a}{b})$

Where: a = number of damaged individual cobs/pods/tillers in sample, and
b = total number of individual cobs/pods/tillers in a sample.

4.8. Data analysis

For species identification, taxonomic characteristics listed in Yalden *et al*. (1976) and Kingdon (1997) were used. Further, the specimens in the National Zoological Museum were used for confirmation.

The Shannon-Weaver diversity indexes (Shannon and Weaver, 1949) for the small mammals in all the seven habitats sampled were calculated as H' = $\sum_{i=1}^{S}(\boldsymbol{Pi})\ln(\boldsymbol{pi})$

Where S= the number of species and

Pi = the proportion of individuals of the total sample belonging to ith species. The Simpson index of diversity (D) was calculated as D = 1-$\sum_{i=1}^{S}(Pi)^2$ where, Pi is the proportion of individuals of the total sample belonging to ith species (Kisingo *et al.*,

2005). With reference to the composition of species, Simpson's Similarity Index (SI) was used to assess the similarity of species between different habitats using the formula:

SI = 2C/A+B where,

A = Number of species occur in habitat type A

B = Number of species occur in habitat type B

C = Number of common species occur in habitat type A and B

To evaluate the richness of species in the study area $(RI) = \frac{S-1}{\ln(N)}$ was used,

Where: RI= Richness index,

S= the number of species of the taxonomic group observed and

N= total number of individuals observed.

Evenness (E_1) was calculated as $E_1 = H' / \ln S$, where $\ln S$ is the natural logarithm of the number of species (Gubista, 1999; Hengeveld, 1996; Kasangaki *et al*., 2003; Li *et al*., 2003; Webala *et al*., 2006; Mahlaba and Perrin, 2003).

Degree of dominance (I) $= \frac{Ni}{N}$

where: Ni = is the number of animals per species and

N = the numbers of animals (Zhang *et al*., 2007) were also calculated.

Trapping success was calculated as T= $\left(\frac{Nm}{Ntn}\right) \times 100$

where: Nm = is the set of individuals trapped

Ntn = the number of trap night.

The data were analyzed using Chi-square test and ANOVA (SPSS Version 13.0).

5. RESULTS

The result of this study is presented in four separate sections. The first section deals with the general small mammal survey of the area and their relative abundance. The second section deals with the results of Sherman live-trapping method. This deals with species composition, distribution, relative abundance and habitat association of rodents and insectivores. In this section, species richness, species diversity, species similarity between the different habitat types, seasonal variation, sex ratio, trap success, age class distribution, population density and biomass in relation to both wet and dry seasons are given. The third section presents the results of snap-trapping including species composition, distribution, relative abundance, habitat association, body measurement, embryo size and diet analysis. The fourth section deals with major rodent pests and their effect on maize, wheat and soybean crops in the Farm Development and local farmed areas.

5.1. Species composition and relative abundance of small mammals

A total of 479 small mammals were captured belonging to the orders Rodentia (family Muridae and Cricetidae) and Insectivora that includes all live-trapped without recaptures and snap-trapped rodents and insectivores. These were six species of rodents belonging to two families and one species of shrew trapped by both Sherman live-trap and snap-traps during both wet and dry seasons. The rodents were *Arvicanthis dembeensis* (Rüpell, 1842), *Lophuromys flavopunctatus* (Thomas, 1904), *Mus mahomet* (Linnaeus, 1758), *Stenocephalemys albipes* (Rüpell, 1842), *Pelomys harringtoni* (Thomas, 1903), *Tatera robusta* (Cretzschmar, 1830) and *Crocidura flavescens* (Geoffroy, 1827). The relative abundance of each of these species are presented in Table 2. In addition to this, common mole-rat (*Tachyoryctes splendens*), *Hystrix cristata*, common duiker (*Sylvicapra grimmia*), *Redunca redunca* and Grivet monkey (*Cercopithecus aethiops aethiops*) were also observed in the study area, particularly in the forest and bushlands.

Table 2. Species composition, number of individuals and relative abundance of small mammals (* = observed species).

Family	Species	Number of individuals	Relative abundance (%)
Muridae	*A. dembeensis*	164	34.2
	L. flavopunctatus	93	19.4
	M. mahomet	75	15.7
	S. albipes	65	13.6
	P. harringtoni	13	2.7
Cricetidae	*T. robusta*	51	10.6
Soricidae	*C. flavescens*	18	3.8
Rhizomyidae	*T. splendens*	*	*
Hystricidae	*H. cristata*	*	*
	Total 9	479	100

5.2. Sherman live-trapping

5.2.1. Species composition and relative abundance of rodents and insectivore

In all the four trapping sessions, a total of 459 captures were made in 4116 trap nights with a capture rate of 11.2% using live-traps. Among these, 316 small mammals were recorded as new captures and 143 individuals were recaptures. Of these, 298 were rodents and 18 were one species of shrew. The six species of rodents and one species of insectivore identified and recorded were *A. dembeensis, L. flavopunctatus, M. mahomet, S. albipes, T.* robusta, *P. harringtoni* and *C. flavescens*. The relative abundance of live-trapped species was: *A. dembeensis* (31.6%), *L. flavopunctatus* (20.6%), *M. mahomet* (15.8%), *S. albipes* (13.6%), *T. robusta* (10.8%), *P. harringtoni* (1.9%) and *C. flavescens* (5.7%) (Table 3). *A. dembeensis* comprised the largest percentage, followed by *L. flavopunctatus* (20.6%) and *M. mahomet* (15.8%).

Table 3. Species composition, total catch and relative abundance of live-trapped rodents and insectivore from different habitats (Figures in parentheses are recaptures).

Species	Total capture	Recapture	New individuals	Relative abundance of new individuals (%)
A. dembeensis	151	51	100	31.6
L. flavopunctatus	89	24	65	20.6
M. mahomet	66	16	50	15.8
S. albipes	69	26	43	13.6
T. robusta	43	9	34	10.8
P. harringtoni	9	3	6	1.9
C. flavescens	32	14	18	5.7
Total 7	459	143	316	100

5.2.2. Distribution of species and their habitat association

The distribution of species varied from species to species in the study area. The distribution of each species in seven randomly selected grids is shown in Figure 5. Comparison of species number within the seven habitat types was not statistically significant ($\chi^2 = 1.69$, df = 6, $p > 0.05$).

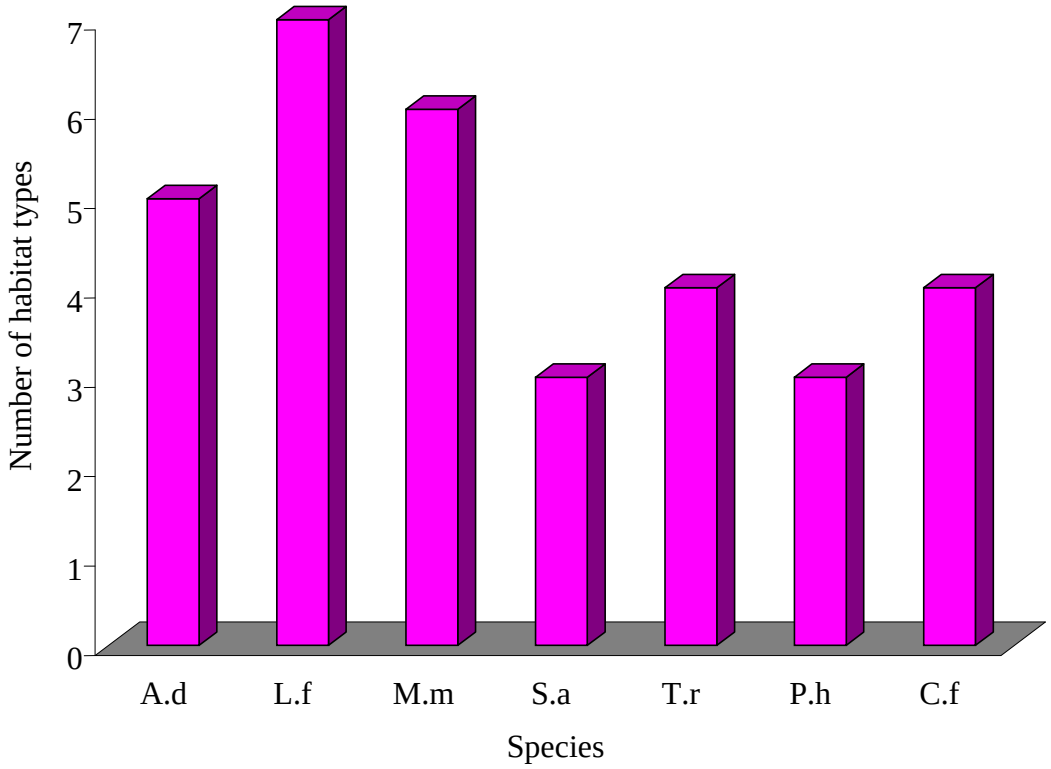

Figure 5. Species distribution of live-trapped rodents and insectivore from the seven different habitat types (*A. d = A. dembeensis, L. f = L. flavopunctatus, M. m = M. mahomet, S. a = S. albipes, T. r = T. robusta, C. f = C. flavescens, P. h = P. harringtoni).*

A. dembeensis comprised the largest total capture in farmlands and grasslands. *L. flavopunctatus* was found in all the sampled habitats areas. *M. mahomet* also occurred in all the sampled areas except the forest habitat. Among the rodents and insectivores trapped, *S. albipes* and *P. harringtoni* had less distribution in the area. *P. harringtoni* was restricted in the forest and bushland vegetation. Two individuals of this species were captured in maize farm from the local farmed areas. *S. albipes* was captured only from the natural vegetation. *C. flavescens* was restricted to bushland, forest and grassland vegetation though one individual was captured from the wheat farm (Table 4).

Table 4. Distribution of live-trapped rodent and insectivore species in different habitat types (Dash indicates the absence of capture).

Species	Habitat types							Total
	F	BL	GL	Mfd	Mf	Wf	Sf	catch
A. dembeensis	-	-	14	16	44	16	10	100
L. flavopunctatus	19	31	2	1	10	1	1	65
M. mahomet	-	2	2	5	19	12	10	50
S. albipes	23	18	2	-	-	-	-	43
T. robusta	-	15	12	-	6	-	1	34
P. harringtoni	3	1	-	-	2	-	-	6
C. flavescens	5	9	3	-	-	1	-	18
Total	50	76	35	22	81	30	22	316

(F = forest, BL = bushland vegetation, GL = grassland, Mfd = maize farm from the farm development, Mf = maize farm from the local farmed area, Wf = wheat farm, Sf = soybean farm).

L. flavopunctatus population did not show any statistically significant variation between maize plantation from the farm development, grassland, wheat and soybean farms (Tukey HSD test: $p > 0.05$). However, it showed statistically significant variations between bushland areas and forest, and other habitat types [$F(6, 7 = 6.83, p < 0.01)$].

S. albipes showed statistically significant variation between farmlands and the natural vegetation [$F(6, 7 = 16.87, p < 0.01)$]. However, there was no statistically significant variation in its distribution between forest and bushland areas ($p > 0.05$). However, statistically significant variation was observed between the grassland habitat, and the other habitat types. *P .harringtoni* population did not show any significant mean variation between forest, bushland and maize farm from the locally farmed areas the different habitat types ($p > 0.05$).

A. dembeensis showed variation between maize farm from the local farmed areas and other habitat types [(F6, 7 = 6.4, p < 0.01)]. *M. mahomet* also showed a significant variation between the natural vegetation and the farmlands (p < 0.05). The captured population from the maize farm in the local farmed areas showed highly significant variation from the maize farm in the farm development (p < 0.05). However, there was no statistical significant variation between wheat and soybean farms in its distribution (P > 0.05). A statistically significant mean variation of *T. robusta* was also observed between the bushland habitat and other habitat types in the study area [(F6, 7 = 9.37, p < 0.01)]. The shrew, *C. flavescens*, showed no statistically significant variation in its distribution between forest, bushland and grassland except the wheat farm [(F6, 7 = 2.259, P > 0.05)].

High percentage of habitat association of *A. dembeensis* and *M. mahomet* to farmlands, S. *albipes* and *P. harringtoni* to forest, *L. flavopunctatus, T. robusta* and *C. flavescens* to bushland habitat was observed (Table 5).

Table 5. Percentage of habitat association of each species with different habitat types (Dash shows the absence of trapped individuals).

Species	Habitat types						
	F	BL	GL	Mfd	Mf	Wf	Sf
A. dembeensis	-	-	14.0	16.0	44.0	16.0	10.0
L. flavopunctatus	29.2	47.7	3.1	1.5	15.5	1.5	1.5
M. mahomet	-	4.0	4.0	10.0	38.0	24.0	20.0
S. albipes	53.5	41.9	4.6	-	-	-	-
T. robusta	-	44.1	35.3	-	17.6	-	3.0
P. harringtoni	50.0	16.7	-	-	33.3	-	-
C. flavescens	27.8	50.0	16.7	-	-	5.5	-

(F = forest, BL = bushland vegetation, GL = grassland, Mfd = maize farm from the farm development, Mf = maize farm from the local farmed areas, Wf = wheat farm, Sf = soybean farm).

The species composition and abundance in the maize farm from the local farmed areas were *A. dembeensis* (44.0%), *M. mahomet* (38%), *P. harringtoni* (33.3%), *T. robusta* (17.6%) and *L. flavopunctatus* (15.5%). *C. flavescens* (50.0%), *L. flavopunctatus* (44.7%), *T. robusta* (44.1%), *S. albipes* (41.9%), *P. harringtoni* (16.7%) and *M. mahomet* (4.0%) constituted in the bushland areas. *A. dembensis* constituted the largest percentage followed by *M. mahomet* in both maize fields.

5.2.3. Species richness, diversity and similarity between habitats

Bushland and grassland habitats have the highest Shannon-Wiener diversity index, whereas the grid on maize farm from the Farm Development shows the lowest value (Table 6).

Table 6. Species richness and diversity of rodents and insectivores during both wet and dry seasons.

Grid	F	BL	GL	Mfd	Mf	Wf	Sf
Rodent individuals	45	67	32	22	81	29	22
Shrew individuals	5	9	3	-	-	1	-
Species richness	4	6	6	3	5	4	4
H'	1.11	1.44	1.42	0.70	1.22	0.91	0.97
H_{max}	1.39	1.79	1.79	1.10	1.61	1.39	1.39
E	0.80	0.80	0.79	0.64	0.75	0.65	0.69
D	0.63	0.72	0.71	0.41	0.63	0.56	0.56

(F = forest, BL = bushland vegetation, GL = grassland, Mfd = maize plantation from the farm development, Mf = maize farm from the nearby farmer's plot, WP = wheat farm, SP = soybean farm, H' = Shannon-Wiener diversity index, $H_{max} = \ln S = \ln$ (total number of species), E= evenness, D = Simpson's index of diversity).

Simpson's (D') index shows a highest value of 0.72 in the bushland area and a lowest value of 0.41 in maize farm from the Farm Development. The highest species diversity index was obtained in the bushland vegetation and grassland, followed by forest from the natural vegetation. The lowest species diversity was obtained from the agricultural field at the maize farm from the Farm Development. The highest species evenness was equally found in the forest and bushland and lowest species evenness was found in the maize farm from the Farm Development. Species richness was highest at the bushland vegetation and grassland, followed by forest habitat. Lowest species richness was recorded in the maize farm from the Farm Development. There was no statistically significant difference between the number of species present in natural vegetation (mean = 5.7, cumulative total = 17) and farmlands (mean = 4.0, cumulative total = 16) (χ^2 = 0.03, df = 1, $p > 0.05$).

P. harringtoni had the highest species richness index and *A. dembeensis*, lowest species richness index. On the other hand, *A. dembeensis* has the highest value of degree of dominance and *P. harringtoni* has the lowest (Table 7).

Table 7. Richness index and degree of dominance of the different species.

Parameter	Species						
	A.d	*L.f*	*M.m*	*S.a*	*T.r*	*P.h*	*C.f*
Richness index (RI)	1.30	1.44	1.53	1.60	1.70	3.35	2.08
Degree of dominance (DI)	0.32	0.21	0.16	0.14	0.11	0.02	0.06

The species similarity between the different habitats type is given in Table 8. Highest similarity was observed between forest and bushalnd areas. Similarity was also high between maize farm from the Farm Development, wheat and soybean farms. There was less overall similarity of rodent and insectivore species among the habitat types (0.22).

Table 8. Species similarity among the habitat types during both wet and dry seasons.

Habitats	F	BL	GL	Mfd	Mf	Wf	Sf
F	-	0.80	0.60	0.29	0.44	0.50	0.25
BL	-	-	0.83	0.44	0.73	0.60	0.60
GL	-	-	-	0.67	0.73	0.60	0.80
Mfd	-	-	-	-	0.75	0.86	0.86
Mf	-	-	-	-	-	0.75	0.75
Wf	-	-	-	-	-	-	0.50
Sf	-	-	-	-	-	-	-

(F = forest, BL = bushland vegetation, GL = grassland, Mfd = maize farm from the farm development, Mf = maize farm from the local farmed areas, Wf = wheat farm, Sf = soybean farm).

5.2.4. Seasonal variation and sex ratio

A total of six rodent and one insectivore species was trapped in both wet and dry seasons. The species composition between the two seasons was similar (Table 9). The overall number of individuals captured between the different months of the wet season was not statistically significant (χ^2 = 0.41, df = 1, p > 0.05). However, this was statistically significant between the different months of the dry season (χ^2 = 7.02, df = 1, p < 0.05). The overall number of captured individuals between the two seasons (wet and dry) was statistically significant (χ^2 = 17.33, df = 1, p < 0.01). The rodent abundance between wet and dry seasons was 33.5% and 66.5%, respectively. The seasonal abundance of *L. flavopunctatus, P. harringtoni, P. albipes, C. flavescens* was not statistically different (χ^2 = 1.86, df = 1, p > 0.05, χ^2 = 0.67, df = 1, p > 0.05, χ^2 = 0.03, df = 1, p > 0.05, χ^2 = 0.00, df = 1, p > 0.05, respectively). However, the abundance of *M. Mahomet, A. dembeensis* and *T. robusta* showed statistically significant difference between seasons (χ^2 = 11.5, df = 1, p < 0.05, χ^2 = 7.84, df = 1, p < 0.05, χ^2 = 5.77, df = 1, p < 0.05, respectively). The

ratio of live-trapped males: females did not differ significantly from 1: 1 ratio (χ^2 = 0.013, df = 1, p > 0.05) in the trapping sessions.

Table 9. Seasonal variation and sex distribution of live-trapped rodents and insectivores (M = male, F = female).

Species	Wet season		Dry season		Total	
	M	F	M	F	M	F
A. dembeensis	18	18	31	33	49	51
L. flavopunctatus	12	15	19	19	31	34
M. mahomet	6	8	17	19	23	27
S. albipes	12	9	12	10	24	19
T. robusta	4	6	14	10	18	16
P. harringtoni	3	1	1	1	4	2
C. flavescens	5	4	5	4	10	8
Total	60	61	99	96	160	156

5.2.5. Trap success and distribution of catches

Trap success was 8.5% in the forest, 12.9% in the bushland areas, 5.9% in the grassland, 3.7% in maize farm from the Farm Development, 13.8% in maize farm from the farmer's plot, 5.1% in the wheat farm and 3.7% in the soybean farm (Fig. 6). Trap success in the maize farm from the farmer's plot also showed the highest percentage compared to the farmland samples and natural vegetation. From the natural vegetation, highest trap success was in the bushland areas followed by forest and grassland areas in the natural vegetation. The lowest trap success was observed in the maize farm from the Farm Development and soybean farm.

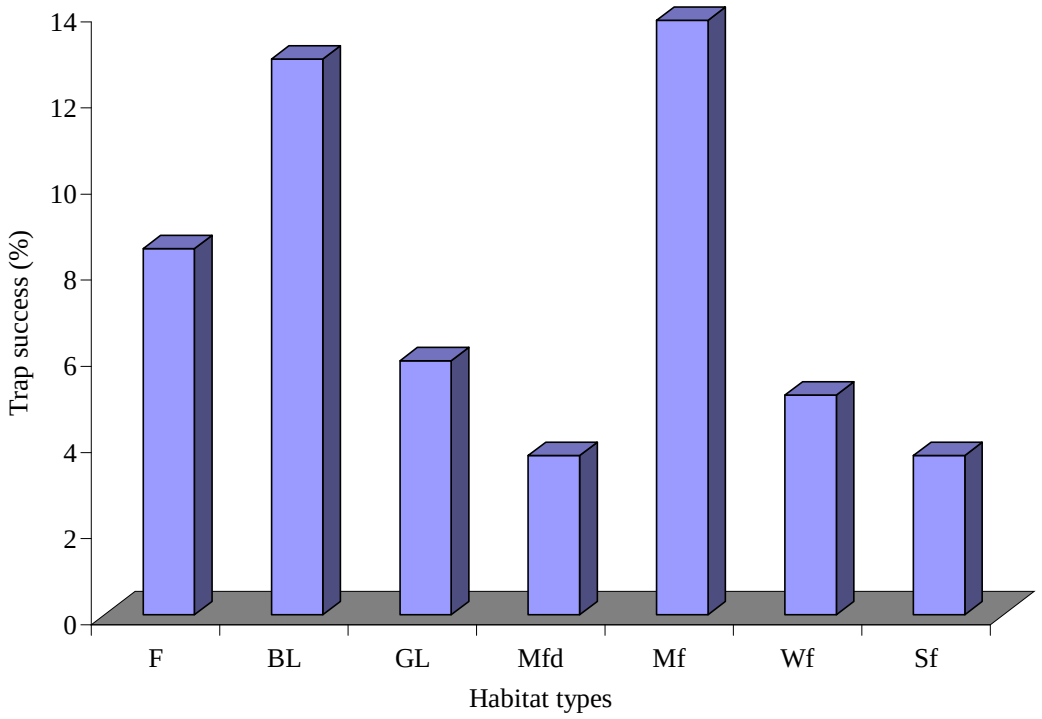

Figure 6. Trap success in the different habitat types during both wet and dry seasons (F = forest, BL = bushland vegetation, GL = grassland, Mfd = maize farm from the farm development, Mf = maize farm from the nearby farmer's plot, Wf = wheat farm, Sf = soybean farm).

Trap success ranged from 1.4% in soybean and maize farm from the Farm Development to a maximum of 20.4% in maize farm from the farmer's plot, two weeks before harvest (Table 10). The number of individuals captured in each of the habitat types was statistically significant (χ^2 = 81.18, df = 6, $p < 0.01$). The number of individuals from maize, wheat and soybean farms from the Farm Development before two-weeks of harvest and after harvest showed statistically significant variations (χ^2 = 5.40, df = 1, $p < 0.05$, χ^2 = 9.78, df = 1, $p < 0.01$, χ^2 = 10.89, df = 1, $p < 0.01$, respectively). However, maize farm from the local farmed areas did not show statistically significant variation between pre- and post-harvest periods (χ^2 = 2.47, df = 1, $p > 0.05$). Statistically significant higher population in the post-harvest session of the agricultural field in grassland habitat was also observed (χ^2 = 4.0, df = 1, $p < 0.05$).

Table 10. Number of rodents and insectivores in different habitat types, trap nights and trap success during the wet and dry seasons.

Grid	Habitat types	Seasons	Month	Total catch	Trap night	Trap success (%)
G_1	Forest	Wet	Aug/2007	12	147	8.2
		Wet	Sep-Oct/2007	6	147	4.1
		Dry	Dec/2007	14	147	9.5
		Dry	Feb/2008	18	147	12.2
G_2	Bushland	Wet	Aug/2007	17	147	11.6
		Wet	Sep-Oct/2007	17	147	11.6
		Dry	Dec/2007	21	147	14.3
		Dry	Feb/2008	21	147	14.3
G_3	Grassland	Wet	Aug/2007	9	147	6.1
		Wet	Sep-Oct/2007	10	147	6.8
		Dry	Dec/2007	4	147	2.7
		Dry	Feb/2008	12	147	8.2
G_4	Maize farm	Wet	Aug/2007	2	147	1.4
	(farm development)	Wet	Sep-Oct/2007	5	147	3.4
		Dry	Dec/2007	12	147	8.2
		Dry	Feb/2007	3	147	2.0
G_5	Maize farm	Wet	Aug/2008	11	147	7.5
	(farmer's plot)	Wet	Sep-Oct/2007	21	147	14.3
		Dry	Dec/2007	30	147	20.4
		Dry	Feb/2008	19	147	12.9
G_6	Wheat farm	Wet	Aug/2007	4	147	2.7
		Wet	Sep-Oct/2007	3	147	2.0
		Dry	Dec/2007	19	147	12.9
		Dry	Feb/2008	4	147	2.7
G_7	Soybean farm	Wet	Aug/2007	2	147	1.4
		Wet	Sep-Oct/2007	2	147	1.4
		Dry	Dec/2007	16	147	10.9
		Dry	Feb/2008	2	147	1.4

5.2.6. Age-class distribution

The age class distribution of rodents and insectivores during wet and dry seasons is given in Table 11. Out of the 316 individuals live-trapped, 17.4% were juveniles, 25.3% sub-adults and 57.3% adults. There was a statistically significant variation among the age classes (χ^2= 84.5, df = 2, $p < 0.01$). Out of the 60 individuals of juvenile rodents and insectivores, 39 (65.0%) were trapped during the wet season and 21 (35.0%) trapped during the dry season. Sub-adults comprised 31 (50.0%) each during the wet and dry seasons. Among adults, 51 (26.3%) were live-trapped during the wet season and 143 (73.7%) during the dry season. Age variation for juveniles and adults during the wet and dry seasons was statistically significant (χ^2= 5.4, df = 1, $p < 0.05$, χ^2= 111.7, df = 1, $p < 0.01$, respectively).

Table 11. Age distribution of live-trapped rodents and insectivores (figures in parentheses shows number of insectivores).

Season	Age groups			Total
	Juvenile	Sub-adult	Adult	
Aug/2007 (Wet season)	24	10 (1)	23 (2)	57 (3)
Sep-Oct/2007 (Wet season)	15 (3)	21	28 (2)	64 (5)
Dec/2007 Dry season	16	22 (2)	78 (4)	116 (6)
Feb/2008 Dry season	5	9 (1)	65 (3)	79 (4)
Total	60 (3)	62 (4)	194 (11)	316 (18)

5.2.7. Population density

The densities of each species were different in different habitats and during different seasons (Table 12).

Table 12. Population density (Per ha) of rodents and insectivores.

Season	Grid	Species							Total
		A d	*L.f*	*M.m*	*S. a*	*T.r*	*P.h*	*C.f*	
Wet season	F	0	8	0	18	0	4	6	36
	BL	0	35	0	23	8	0	4	70
	Gl	17	4	2	2	8	0	6	39
	Mfd	10	0	4	0	0	0	0	14
	Mf	35	8	14	0	4	4	0	65
	Wf	8	0	4	0	0	0	2	14
	Sf	4	0	4	0	0	0	0	8
Sub-total		74	55	28	43	20	8	18	246
Dry season	F	0	31	0	29	0	2	4	66
	BL	0	28	4	14	23	2	14	85
	Gl	12	0	2	2	17	0	0	33
	Mfd	22	2	6	0	0	0	0	30
	Mf	55	12	25	0	8	0	0	100
	Wf	25	2	21	0	0	0	0	48
	Sf	16	2	16	0	2	0	0	36
Sub-total		130	77	74	45	50	4	18	398
Total		204	132	102	88	70	12	36	644

(F = forest, BL = bushland vegetation, GL = grassland, Mfd = maize farm from the farm development, Mf = maize farm from the farmer's plot, Wf = wheat farm, Sf = soybean farm, *A. d = A. dembeensis, L.f = L. flavopunctatus, M. m = M. mahomet, S. a = S. albipes, T.r = T. robusta, C.f = C. flavescens, P. h = P. harringtoni*).

The density for *A. dembeensis* ranged from 20/ha in soybean farms to 90/ha in the maize farm from local farmed areas with no record from forests and bushland areas. The density of *L.flavopunctatus* ranged from 2/ha in the maize farm from the farm development, wheat and soybean farms to 63/ha in the bushland areas. The density for *M. mahomet* ranged from 4/ha in the bushland and grassland to 39/ha in maize farm from the local farmed areas. *S. albipes* had a density of 47/ha in forest habitats to 4/ha in the grassland, with no record from the farmlands. Highest density of *T. robusta* and *C. flavescens* was observed in bushland habitats followed by the grassland and forest respectively. *P. harringtoni* had a density of 2/ha in the bushland areas to 6/ha in the forest. Rodent and insectivore density was high in the maize farm of the farmer's plot followed by bushland areas. The forest habitat also supported a relatively higher population of rodent and insectivore followed by grassland habitat than wheat, soybean and maize framings of the Farm Development. Higher number of rodent density was observed during the dry season than the wet season (χ^2= 35.87, df = 1, $p < 0.01$). Statistically significant variation was observed between the wet and dry season captures of *A. dembeensis, M. mahomet* and *T. robusta* (χ^2= 15.37, df = 1, $p < 0.01$, χ^2= 20.75, df = 1, $p < 0.01$, χ^2= 12.86, df = 1, $p < 0.01$, respectively). However, there was no statistically significant variation in the density of *L.flavopunctatus, S. albipes, C. flavescens,* and *P. harringtoni* (χ^2= 3.67, df = 1, $p > 0.05$, χ^2= 0.05, df = 1, $p > 0.05$, χ^2= 0.01, df = 1, $p > 0.05$, χ^2= 1.33, df = 1, $p > 0.05$, respectively).

5.2.8. Population estimation and biomass

The total population size per hectare and biomass in each of the different habitat type of the different species was estimated during wet and dry seasons grouped separately (Table 13). During the wet season, a maximum biomass was revealed in maize farm from locally farmed areas followed by, bushland area, grassland, forest, maize, wheat and soybean farm from the farm development. On the other hand, maize farm from the farmer's plot supported maximum biomass followed by bushland areas, forest, wheat, grassland, maize and soybean farm from the farm development during the dry season.

S. albipes in the forest, *L. flavopunctatus* in the bushland areas and *A. dembeensis* in the grassland and farms comprised the largest proportion of biomass during both wet and dry seasons. *C. flavescens* had the least biomass in the study period. Though *P. harringtoni* was the least abundant species in the study area, it constituted greater biomass than *C. flavescens*. Generally, *A. dembeensis* constituted the largest biomass, followed by *L. flavopunctatus, S. albipes, T. robusta, M. mahomet, P. harringtoni* and *C. flavescens* during both wet and dry seasons. Maximum biomass was obtained during dry season than the wet season.

Table 13. Total number of population estimated and biomass of rodents and insectivores (Per ha) live-trapped from different habitat types and season

Season	Grid		Species							Total
			A.d	*L.f*	*M.m*	*S.a*	*T.r*	*P.h*	*C.f*	
Wet Season		Mbw	79.2	49.4	12.1	51.2	53.3	56.3	18.2	
		N	74	55	28	43	20	8	18	
	F		0	8 (395)	0	18 (922)	0	4 (225)	6 (109)	36 (1651)
	BL		0	35 (1729)	0	23 (1178)	8 (426)	0	4 (73)	70 (3406)
	GL		17 (1346)	4 (198)	2 (24)	2 (102)	8(426)	0	6 (109)	39 (2205)
	Mfd		10 (792)	0	4 (48)	0	0	0	0	14 (840)
	Mf		35 (2772)	8 (395)	14 (169)	0	4 (213)	4 (225)	0	65 (3774)
	Wf		8 (634)	0	4 (48)	0	0	0	2(36)	14 (718)
	Sf		4 (317)	0	4 (48)	0	0	0	0	8 (362)
	Sub-total		74 (5861)	55 (2717)	28 (337)	43 (2202)	20 (1065)	8 (450)	18 (327)	83039 (3778943)
Dry Season		Mbw	63.4	42.1	9.4	47.4	49.8	50.1	11.6	
		N	130	77	74	45	50	4	18	
	F		0	31 (1305)	0	29 (1375)	0	2 (100)	4 (46)	66 (2826)
	BL		0	28 (1179)	4 (38)	14 (664)	23 (1145)	2 (100)	14 (162)	85 (3288)
	GL		12 (761)	0	2 (19)	2 (95)	17 (847)	0	0	33 (1722)
	Mfd		22 (1395)	2 (84)	6 (56)	0	0	0	0	30 (1535)
	Mf		55 (3487)	12 (505)	25 (235)	0	8 (398)	0	0	100 (4625)
	Wf		25 (1585)	2 (84)	21 (197)	0	0	0	0	48 (1866)
	Sf		16 (1014)	2 (84)	16 (150)	0	2 (100)	0	0	36 (1348)
	Sub-total		130 (8242)	77 (3241)	74 (695)	45 (2034)	50 (2490)	4 (200)	18 (208)	398 (17210)
	Total		204 (14103)	132 (5958)	102 (1032)	88 (4336)	70 (3555)	12 (650)	36 (535)	644 (30166)

(Mbw = mean body weight, N = total number of individuals captured, *A. d = A. dembeensis, L.f = L. flavopunctatus, M. m = M. mahomet, S. a = S. albipes, T.r = T.robusta, C.f = C. flavescens, P. h = P. harringtoni*

5.3. Snap-trapping

A total 163 individual rodents were captured in 2100 trap nights using snap-traps. The relative abundance of each of the species was: *A. dembeensis* (39.3%), *L. flavopunctatus* (17.2%), *M. Mahomet* (15.3%), *S. albipes* (13.5%), and *T. robusta* (10.4%) and *P. harringtoni* (4.3%).

Table 14. Species composition, number of rodents captured by snap trapping surveys and their distribution in different habitats.

Habitat types	Species						Total catch	Relative abundance	Trap success
	A.d	*L.f*	*M.m*	*S.a*	*T.r*	*P.h*			
F	-	11	-	8	-	3	22	13.5	7.3
BL	-	9	2	10	7	4	32	19.6	11.3
GL	8	2	2	4	4	-	20	12.3	6.0
Mfd	13	-	2	-	-	-	15	9.2	5.0
Mf	24	2	9	-	6	-	41	25.2	12.3
Wf	10	2	6	-	-	-	18	11.0	7.0
Sf	9	2	4	-	-	-	15	9.2	5.0
Total	64	28	25	22	17	7	163		
Relative abundance (%)	39.3	17.2	15.3	13.5	10.4	4.3		100	

(*A. d = A. dembeensis, L. f = L. flavopunctatus, M. m = M. Mahomet, S. a = S. albipes, T.r =T. robusta, P. h = P. harringtoni).*

A. dembeensis constituted high percentage followed by *L. flavopunctatus* and *M. mahomet*. The least trapped rodent was *P. harringtoni*. Trap sucesss was highest in the maize farm from farmer's plot followed by bushland areas. Less trap success was recorded from maize and soybean farm from the Farm Development. Snap-trap success was low compared to the live-trapped ones.

5.3.1. Body measurement

Body weight and body measurement of six species of snap-trapped rodents are given in Table 15. There was a statistically significant variation in mean body weight of the same species between seasons ($P < 0.05$). However, in other external body measurements, there were no statistically significant variations within the same species between seasons ($P > 0.05$).

Table 15. Body weight (g) and measurements (mm) (mean ± standard deviation) of rodents snap-trapped during wet and dry seasons.

Species	Season	BW	HB	TL	HF	EL
A.d	Wet	78.3 ± 7.1	131.5 ± 13.1	150.0 ± 11.4	24.5 ± 2.5	17.0 ± 1.4
	Dry	66.7 ± 5.2				
L.f	Wet	51.5 ± 7.2	120.0 ± 8.4	60.0 ± 6.5	20.5 ± 1.1	17.8 ± 1.5
	Dry	47.6 ± 5.2				
M.m	Wet	11.2 ± 3.2	71.0 ± 8.2	49.0 ± 17.3	13.0 ± 1.5	13.0 ± 9.4
	Dry	9.7 ± 1.2				
S.a	Wet	53.2 ± 7	118.0 ± 12.3	136.0 ± 11.4	26.5 ± 1.7	19.0 ± 1.3
	Dry	46.1 ± 5.2				
T.r	Wet	57.5 ± 7.9	124.5 ± 13.2	139.0 ± 9.5	30.5 ± 3.1	17.5 ± 1.6
	Dry	51.3 ± 8.2				
P.h	Wet	61.5 ± 7.3	120.0 ± 5.1	129.0 ± 6.5	23.5 ± 4.1	17.8 ± 1.5
	Dry	52.7 ± 4.2				

(BW = body weight, HB = head and body length, TL = tail length, HF = hind foot length, EL = ear length, *A. d = A. dembeensis, L.f = L. flavopunctatus, M. m = M. mahomet, S. a = S. albipes, T. r = T. robusta* and *P. h = P. harringtoni*).

5.3.2. Embryo size

Embryo numbers of snap-trapped rodents for the five species is given in table 16. Highest numbers of pregnant females were observed during September-October, 2007. The duration was the end of rainy season and the beginning of dry season. This is also the time when crops in fruiting reproductive phase. More pregnant females were captured during the wet season than the dry season ($\chi^2 = 16.03$, df = 1, $p < 0.05$).

Table 16. Number of pregnant females and embryos recorded from pregnant females of rodents during wet and dry seasons.

Species	Seasons	No. of pregnant females	No. of embryo
A. dembeensis	Wet	8	5-7
	Dry	3	3-5
L. flavopunctatus	Wet	7	1-4
	Dry	-	-
M. mahomet	Wet	9	2-4
	Dry	1	2
S. albipes	Wet	9	3-4
	Dry	2	3
T. robusta	Wet	2	3-4
	Dry	-	-
P. harringtoni	Wet	2	3-4
	Dry	-	-

5.3.3. Diet

The proportion of different food items varied significantly between different species and within the same species in different seasons ($p < 0.05$) (Table 17). Monocot seeds, dicot seeds, monocot leaf, dicot leaf, plant root and animal matter were observed in the

stomach contents of *A. dembeensis, L. flavopunctatus, M. Mahomet, T. robusta* and *P. harringtoni*. However a major proportion of animal matter was observed in the stomachs of *L. flavopunctatus*. The diet analysis also indicates that there was no significant seasonal variation in types of food items. Consumption of animal matter was more during the wet season whereas monocot seeds, dicot seeds and plant roots were more during the dry season.

Table 17. Percentage of the diet of snap-trapped rodents during wet and dry seasons (MS = monocot seed, DS = dicot seed, ML = monocot leaf, DL = dicot leaf, PR = plant root, AM = animal matter, UN = undifferentiated material).

Species	Season	Samplings	Food items						
			MS	DS	ML	DL	PR	AM	UN
A. dembeensis	Wet	5	5.6	4.6	29.8	20.3	7.5	16.2	16.0
	Dry	5	32.2	28.4	9.2	8.6	8.2	7.4	6.0
L. flavopunctatus	Wet	4	18.3	15.3	15.3	2.1	2.6	39.6	6.8
	Dry	4	31.0	21.6	2.7	1.6	6.8	29.4	6.9
M. mahomet	Wet	2	6.0	10.4	16.3	10.4	16.2	23.9	16.8
	Dry	2	29.3	28.9	6.2	7.4	17.0	5.4	5.8
S. albipes	Wet	4	2.9	2.0	19.2	23.4	17.5	15.0	20.0
	Dry	4	5.9	4.3	19.4	26.2	20.2	12.1	11.9
T. robusta	Wet	2	19.3	23.5	11.4	10.2	10.2	13.5	11.9
	Dry	2	28.2	27.4	10.2	8.7	12.6	7.6	5.3
P. harringtoni	Wet	2	15.5	6.0	37.2	3.0	2.9	11.2	24.2
	Dry	2	21.0	3.8	41.2	4.0	4.0	9.4	16.6

5.4. Pest status

The level of damage to crops before two weeks of harvest was generally low in areas from the Farm Development (13.2% for wheat, 12.9% for soybean and 9.6% for maize

crops) (Table 18). On the other hand, damage in the maize farm of the farmer's plot was relatively high (29.2%). Statistically significant variation existed in maize damage between the Farm Development and farmer's plot ($\chi^2 = 732.5$, df = 1, $p < 0.05$). The rate of damage between wheat and maize farms from the Farm Development also had statistically significant variation ($\chi^2 = 5740.8$, df = 1, $p < 0.05$). However, no statistically significant variation was observed between wheat and soybean farms ($\chi^2 = 1.4$, df = 1, $p > 0.05$).

Table 18. Damage to maize, wheat and soybean crops two weeks prior to harvest

Crop type	Number of damage to tillers/pods/cobs	
	Mean ± SE	Range
Maize farm (from the farm development)	26.4 ± 3.2	21.0-34.0
Maize farm (from the farmer's plot)	80.2 ± 4.9	72.0-89.0
Wheat farm	233.7 ± 12.1	220.0-239.0
Soybean farm	228.9 ± 5.0	220-239

6. DISCUSSION

A total of six rodent and one insectivore species were captured during the present investigation. *A. dembeensis* was the most dominant and abundant species in farmlands and nearby grassland areas. The species is also common and trapped from Maynugus irrigation field (Workneh Gebresilassie *et al*., 2005), Bilalo area, Arsi (Tsegaye Gadisa and Afework Bekele, 2006) and Arbaminch forests and farmlands (Demeke Datiko *et al*., 2007). The decreased species abundance after harvest in agricultural fields might be due to the diurnal activity of the species, making them susceptible to predators as cover was absent. At the same time, migration to other areas is a possibility because of limited resources. *A. dembeensis* is a lowland species with most record between sea level and 2000 m (Yalden *et al*., 1976).

L. flavopunctatus was captured in all the farmlands and natural vegetation though it was more abundant in the natural vegetation than in crop fields. This goes in line with Tilaye Wube (2005) in Entoto Mountain that the species is more abundant in bushland areas compared to crop fields. However, the species also inhabits cultivated areas (Makundi *et al.*, 2006). The species was more recorded in bushland areas (47.7% of the total capture) because it prefers places with better ground cover, abundant and diversified grasses and herbs. The species is also unable to live in exposed areas (Southern and Hook, 1963; Delany, 1964, Happold, 1975; Happold and Happold, 1987). Yalden *et al*. (1976) also revealed that it is a species of the Ethiopian plateaux with distribution along altitudes between 1500 and 4000 m asl. Clausnitzer and Kityo (2001) described the species with ecologically and geographically wide distribution in East Africa. This wide distribution and success might be associated with insectivorous feeding habit of the species (Clausnitzer *et al*., 2003).

The pigmy mouse of the Ethiopian plateaux, *M. mahomet*, was the third most abundant species in the study area. The species is also most abundant in Bilalo area, Arsi (Tsegaye Gadisa and Afework Bekele, 2006). Workneh Gebresilassie *et al*. (2005) also found as

the third most abundant species in Maynugus irrigation field. In the present study area, the species is mostly dominant or found in the grids from farmlands and better covered areas of bushland and grassland. The species was also categorized as an agricultural pest by Afework Bekele *et al*. (2003) in Ziway, Tsegaye Gadisa and Afework Bekele (2006) in Bilalo area, Demeke Datiko *et al*. (2007) in Arbaminch forests and farmlands and Manyingerw Shenkut *et al*. (2006) in Alleltu Woreda, Ethiopia.

S. albipes, common and widespread endemic species of the Ethiopian plateaux of altitudes from 1500 to 3300 m, was also captured only from the natural vegetation (i.e. forests, bushland and grassland). Yalden *et al.* (1976) described the species associated with more of natural vegetation. Afework Bekele (1995) and (1996) also explained the species as widespread in forests (Menagesha State Forest) and bushy vegetation. Tilaye Wube (2005) also described the species as more abundant in bushland areas than in crop fields.

Another rodent species, *T. robusta*, was the fifth abundant species in the study area. The species was widely distributed in the bushland, grassland and also in farmlands. Afework Bekele *et al*. (2003) also described the species as minor pest in agricultural areas. This species has been captured from maize fields and grasslands from central Ethiopia (Afework Bekele and Leirs, 1997) and from Arbaminch forests and farmlands (Demeke Datiko *et al*. (2007).

P. harringtoni is the least captured (1.9%) rodent species in the study area. Afework Bekele (1996) also trapped the rodent in Menagesha State Forest, although the trap success was less. The species is a species of Ethiopian plateaux between altitudes 1800 and 2800 m with semi-arboreal habits (Yalden *et al*., 1976). As the species has semi-arboreal habits, it may be underestimated as the traps were set on the ground.

C. flavescens was the only insectivore captured during the present study. It is one of the common and widespread shrews in Ethiopia in altitude ranges of 1000-3000 m (Yalden *et al*., 1976). Delany (1964) described this as a typical forest species. However, in the

present study, this species also occurred in the bushland and grassland habitat types. Probably these habitat types provided enough cover for them.

Among the rodents and insectivore species captured, *L. flavopunctatus* had a wide range of distribution. This might be associated with their diverse feeding habits as discussed by Hanney (1964). The present study showed that rodents are not uniformly distributed in the agricultural fields. More number of individuals were observed at the margins (near roads and canals) in the agricultural fields of the farm development. Makundi *et al*. (2005b) described that human activity, change in vegetation type and clearing of natural forests for agricultural development affect the distribution of small mammals. Local distribution of small mammals is also influenced by food availability and land preparation methods as more number of individuals were restricted to the margins of mechanized farms (tractor ploughing) than in areas of traditional farming practices. Marginal areas such as canals and roads act as refugia for small mammals (Aplin and Singleton, 2003). Yeboah and Akyeampong (2001) also described that mechanized farms destroy the burrow of rodents or even kill some individuals resulting in the destruction of their food sources. As a result, the population may be restricted to the margins of the mechanized farms. This also goes in line with Massawe *et al*. (2003) that abundance of rodents are influenced by land preparation methods.

The bushland and grassland habitat types had the highest species richness and diversity. This is consistent with Kotler's (1984) observation that these areas provide enough food and predation risk is low thereby increasing the richness and diversity. The forest habitat was the third richest and diversified habitat in which evenness of individuals was relatively high in terms of rodents and the insectivore. This indicates that the natural vegetation (i.e. bushland area, grassland and forest) supports comparatively more number of species than the crop fields. The higher number of species in the natural vegetation resulted from complex vegetation structure and micro-habitats (Makundi *et al.*, 2005b; Avenant and Cavallini, 2007). Iyawe (1988) also stressed that natural vegetation type is highly selected by small mammals.

The highest species diversity in the bushland and grassland areas might be associated with better cover that these particular habitat types support. This increases availability of suitable sites for breeding, foraging and refugia (Conde and Rocha, 2006; Jacob, 2008). The dense forest has relatively less ground cover compared to the bushland and grassland areas. Ground vegetation cover in the bushland and grassland habitats results in increased food supply and avoids predation risk. Hoffmann and Zeller (2005) stress the loss of ground vegetation cover leading to reduced food supply and enhanced predation risk.

Species richness and diversity in the maize farm from the Farm Development relatively supports less number of species than both the natural vegetation and other farmland sites. The wheat and soybean farm also had comparatively less species diversity. Extensive application of different insecticides, herbicides, rodenticides and fungicides might kill or prevent the ground cover weeds and herbs from growing. This may result in less species diversity and number of rodents to such area. Barrett and Darnell (1967) also described that application of such chemicals would lead to reduced level of rodents as a result of food shortage. This might be associated also with shortage of cover as discussed by Jacob and Brown (2000) and Hoffmann and Zeller (2005) that ground vegetation cover increases food supply and avoids predation risk thereby increasing species number and diversity.

The maize farm from the local farmer's areas compared to the grids from the Farm Development showed more species diversity. As the local farmers do not apply r chemicals in their area except fertilizers, rodents may take the nearby area as refugia from the Farm Development during the high disturbances, mechanized farming, and application of insecticides, herbicides, rodenticides and fungicides. Avenant and Cavallini (2007) and Fox and Fox (2000) also described that area with high disturbances shows lowest species diversity. Further, the base of the farmer's maize farm was relatively covered with weeds and herbs, which may be preferred by rodents for shelter. Utrera *et al.* (2000) also explained that subsistence agricultural plots are more variable

and showed more species richness and diversity, whereas mechanized farms have less species diversity. At the same time, human activities in different areas result in disturbances leading to the shift in habitat types (Happold, 1975; Taylor and Green, 1976; Happold and Happold, 1987; Leirs *et al*., 1993; Medellin and Equihua, 1998; Giuggioli *et al*., 2005).

During the present study, *A. dembeensis* was the commonest and dominant species. The high number of individuals of *A. dembeensis* in maize, wheat and soybean farms and grassland reflect its habitat preference. Workneh Gebresilassie *et al*. (2004) also confirmed that this species is abundant in areas of monocots and grasses. On the other hand, *P. harringtoni* was the least rich and least dominant species.

The effect of season on the population of rodents is evident in the present investigation. Population size on maize farms at Ziway (Afework Bekele *et al*., 2003) and Odhiambo *et al*. (2005) revealed seasonal fluctuation. The maximum population size in agricultural fields recorded was at a time when crops matured and were ready for harvest. Rodents in the surrounding area would move to the agricultural fields during the attractive stage of the crop when food resources are available in plenty. This is consistent with the observations of Taylor and Green (1976) that matured cereal crops are highly favoured habitats of rodents as they provides cover and food source. As a result, the area attracts several species of rodents and their population size increases (Tsegaye Gadisa and Afework Bekele, 2006). Abundant food also increases rodent density in agricultural areas (Halvorson, 1982; Lentic and Dickman, 2005).

The population size of rodents in the Farm Development decreased after harvest. This is because agricultural areas are unstable, being highly favourable in matured stage of the crop and become vacant during few days after harvest. This results in inadequate food and loss of cover, exposing rodents to their enemies and food shortage. This goes in line with the findings of Tsegaye Gadisa and Afework Bekele (2006) that inadequate food and cover expose rodents to their natural enemies and are forced to migrate to areas

where food and shelter are available. This may partly explain the higher population density in the grassland habitat during post-harvest season of the agricultural fields. MacKay and Russell (2005) also described that low population density resulted from food shortage in the post-harvest season.

More number of juveniles during the wet season and adults during the dry season were observed. Taylor and Green (1976) also observed that rainfall had a direct correlation with reproduction. The sex-ratio of the different species did not vary from season to season

On the other hand, the population size in natural vegetation was comparatively equal during both wet and dry seasons and relatively supported high number of individuals during the post-harvest session of the agricultural fields. This might be due the fact that the natural vegetation is relatively characterized by stability or little disturbance compared to the agricultural fields. This goes in line with Manyingerew Shenkut *et al.* (2006) that nearby agricultural fields relatively support higher number of rodents than agricultural fields during unfavourable periods. Generally, disturbances decreases density of small mammals as discussed by Wijesinghe and Brooke (2005). The high number of pregnant females during the wet season and decrease during the dry season was related with rainfall as discussed by Tilaye Wube (2005).

The overall trap success in Bir Farm Development and nearby bushland area was 11.2%. This is low compared to Demeke Datiko *et al*. (2007) who had 17.6% trap success in Arbaminch forests and farmlands and Tsegaye Gadisa and Afework Bekele (2006), who had 15.4% trap success in Bilalo areas, Arsi, Ethiopia. The low trap success of the present study in both the farmland and the natural vegetation might be associated with the low population density in the study area. Tsegaye Gadisa and Afework Bekele (2006) also reasoned out that population size affects trap success and for higher population size, trap success was also higher. On the other hand, this is higher than Afework Bekele (1996) and Manyingerew Shenkut *et al*. (2006) who have revealed only 3.5% and 8.42% trap success, respectively.

The trap success in February, 2008 (post-harvest session of agricultural fields) in the wheat, soybean, and maize farms from the Farm Development was less compared to that with natural vegetation. During the harvesting season, the area will be more disturbed as the vehicles (combiners and tractors) move in the process. This causes disturbance and disturbed habitats result in less small mammal diversity and population number (Waters and Zabel, 1998; Cramer and Willig, 2005; Hoffmann and Zeller, 2005). As a result, rodents will be forced out to move to less disturbed areas. Makundi *et al*. (2005b) also described that agricultural fields are variable and populations fluctuate greatly as resources change in quality and quantity. However, the maize farm from the local farmed areas, support relatively higher number of rodents even during the post-harvest season. This might be due to the degree of disturbance during the traditional method of harvest was low and some remnant seeds and fruits may lie on the ground to be available for rodents. On the other hand, the high disturbance in the Farm Development may affect would affect the populations.

There were differences in the population density in different habitat types studied. Maize farm from locally farmed areas had the highest rodents and insectivore density and maize and soybean farms from the Farm Development had the lowest. *A. dembeensis* was the most abundant rodent. The highest density of *A. dembeensis* (90/ha) was observed in maize farm from locally farmed areas. This may be attributed to the increased weed density in the traditional farming practices, providing cover or may be used as alternative source of food. The observations of Taylor and Green (1976) also indicated that rodents depend on weed seeds and leaves of dicotyledon plants when cereal crops in the fields are insufficient. High peak density (81/ha) was also observed in Maynugus irrigation field by Workneh Gebresilassie *et al*. (2005). This higher density of the species in agricultural areas than natural vegetation may indicate the pest status of the species.

The density of *M. mahomet* was also higher in the maize farm from the locally farmed areas. The wheat farm supported 25/ha rodents, comparatively lower than the wheat farm

in Alleltu Woreda (104/ha) (Manyingerew Shenkut *et al*., 2006). This wide variation may result from low population density in the area. The high population density in the wheat farm on the farm development might be associated with the broadcast method of seedling providing better ground cover.

Generally, the population density in the mechanized farms was relatively low compared to areas of the traditional farming practices (Table 12). Yeboah and Akyeampong (2001) described that traditional farming practices has a lesser effect on the density and distribution of rodents than in areas of mechanized farms. This may partly explain the higher density estimate of rodents and insectivores in the locally farmed areas compared to mechanized farms.

During the wet season, the highest rodent and insectivore biomass was recorded in the bushland area from the natural vegetation. This might be due to the fact that bushalnd areas had food resources and good ground cover in both trapping sessions. Habitats that possess sufficient food resources support highest rodent biomass as discussed by Workneh Gebresilassie *et al*. (2005). The mean monthly range of biomass recorded in the study area during the wet season in the present investigation ranged from 362 g in soybean farms to 4625 g in maize farm from local farmed areas. This shows comparatively extreme on both sides compared to Menagesha State Forest (454-1569 g/ha, Afework Bekele, 1996).

The present study also confirmed that maximum biomass was obtained during the dry season. The high population density due to high food availability and enough cover before two weeks harvest during the dry season may influence the rodent and insectivore density to be high during the dry season than the wet season (Makundi *et al*., 2005b).

The stomach content analysis confirmed that rodents feed on a variety of food sources, both plant and animal matters. The feeding ecology of small mammals throughout the world is highly diverse (Campos *et al*., 2001). The wide range of feeding habits helped them to occupy a wide range of habitats in all continents. The high percentage of animal

matter during the wet season, and monocot seeds, dicot seeds and plant root during the dry season showed that the feeding habit of rodents depended on the availability of food sources. The number of invertebrates increases with an increase in precipitation and their number declined during dry months (Frith and Frith, 1990). Workneh Gebresilassie *et al.* (2004) described rodents as opportunistic feeders, capable of changing their feeding habits depending on the availability of food from season to season. Martin and Dickinson (1985) also described the rainy season as a time of abundant invertebrate populations, which may be a source of food for small mammals. The high percentage of animal matter observed in *L. flavopunctatus* was an indication of its high insectivorous feeding habit (Clausnitzer *et al*., 2003).

In the present study, crop damage was assessed at the pre-harvest stage. Relatively high percentage of cereals was observed in the diet of *A. dembeensis*, *M. mahomet* and *T. robusta* than other snap-trapped rodents. This may indicate their higher pest status. Afework Bekele *et al*. (2003) recognized *A. dembeensis* as a major agricultural pest, and *M. mahomet* and *T. robusta* were considered as minor pests. Manyingerew Shenkut *et al*. (200); Tsegaye Gadisa and Afework Bekele (2006) and Demeke Datiko *et al*. (2007) also described *A. dembeensis* is an agricultural pest in maize farms.

The damage rate of maize from the Farm Development was 9.6%. When it was estimated in terms of economic loss, it was estimated as 2016 Birr (approximately 202 US dollars) per hectare. This was comparatively higher than (5.7%, Demeke Datiko *et al*., 2007) and by far less than the damage in Ziway (26.4%, Afework Bekele *et al*., 2003) and farms of Tanzania (17.2-82%, Mulungu *et al*., 2007). This comparatively low rate might be due to the extensive application of chemicals in the area that may result in low population density of rodents thereby decreasing the damage. This was also an area of less ground cover compared to other grids in the study area. The relatively higher rate of damage (29.2%) in the locally farmed areas of maize might be due to the high population density. When it was estimated in terms of economic loss, it was estimated as 3833 Birr (approximately 384 USA dollars) per hectare.

13.2% rate of damage was observed for wheat crop in the area. When it was estimated in terms of economic loss, it was estimated as 1716 Birr (approximately 172 US dollars) per hectare. This was comparatively higher than (2-9%, Mutze, 1993) and (12.1%, Poche *et al*., 1982) when treated with strychnine. 12.9% rate of damage was also observed for soybean farms. When it was estimated in terms of economic loss, it was estimated as 960 Birr (approximately 96 US dollars) per hectare This was also comparatively higher than (0.56-2.58%, Kay *et al*., 1994), (4-8.5%, Twigg *et al*., 1991) and (2.9-12.7%, Singleton *et al*., 1991) in Macquarie Valley after the application of different rodenticide types.

Brown *et al*. (1997, 2002) also described that crop yields were significantly high after the treatment of rodent control measures on the farms resulting in lower damage. They also described that population density of rodents and damage to pods or cobs were linearly related. Thus, the relatively higher damage of wheat crop might be associated with the high population density of rodents in the wheat farm than the soybean and maize farms of the Farm Development. On the other hand, the different cereal crops damage was comparatively higher than the estimates by Brown and Singleton (2002) (< 7% for wheat and < 4% for soybean) and the abundance was also low (17/ha).

7. CONCLUSION AND RECOMMENDATIONS

During the present study, eight rodent species (six trapped and two observed) and one species of insectivore were identified with limited overall trap success. Bushland and grassland habitats had the highest species diversity, and the maize farm from locally farmed areas provided high number of individuals. The present study also indicated that the distribution of species varies according to the habitat type and rate of damage between farms. This provides important information on the pest status of rodents in the Farm Development and nearby farmer's plot to take appropriate conservation action and control measures. In recent years, the increased human population growth has resulted in the reduction of the natural vegetation and an increased level of fragmentation of surviving forests. Clearing of forests for agricultural practices, human settlements and extensive applications of rodenticides in agricultural fields had impacts on rodent s and their habitats leading to change in species diversity and abundance. This was the actual situation in Bir Farm Development. In addition to this, mostly endemic species (for instance *Stenocepahlemys albipes*) show a habitat preference of the natural vegetation and are unable to utilize modified habitats resulted in deforestation. Hence, the low level of tolerance of endemic species to habitat changes might mean that they are the first to disappear when habitat modification occurs. Therefore, to maintain the rodent species and to reduce the pest status of rodents, the following suggestions are forwarded:

- Since endemic species add a particular fauna for a particular country, they should have to be conserved.

- Keeping the nearby vegetation short is one mechanism to reduce the abundance of pest rodents thereby increasing their susceptibility to predators.

- Detailed study on the ecology of each species is required to elucidate the species specific habitat requirements to take control measures.

- Ecologically based rodent management is an alternative approach to manage rodents in agricultural systems by combining a variety of control measures, rather than relying largely on rodenticides.

- Local people should be aware of the pest status of rodents to take control measures.

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