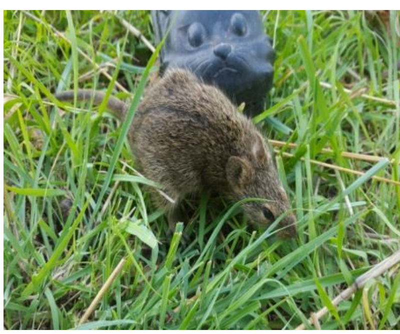
ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COPUTATIONAL SCIENCES

DEPARTMENT OF ZOOLOGICAL SCIENCES

COMMUNITY ECOLOGY, ABUNDANCE AND PEST IMPLICATIONS OF SMALL MAMMALS IN AND AROUND YEGOF MOUNTAIN PRIORITY FOREST AREA, SOUTH WOLLO, ETHIOPIA



By

Gezahegn Getachew

A Dissertation Submitted to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Zoology (Ecological and Systematic Zoology Stream)

Advisor: Professor Afework Bekele

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This is to certify that the thesis prepared by Gezahegn Getachew entitled: **COMMUNITY ECOLOGY, ABUNDANCE AND PEST IMPLICATIONS OF SMALL MAMMALS IN AND AROUND YEGOF MOUNTAIN PRIORITY FOREST AREA, SOUTH WOLLO, ETHIOPIA** and submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Zoological Sciences (Ecology and Systematic Zoology Stream) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Gezahegn Getachew,

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ABSTRACT

An investigation on species composition, abundance, habitat association and human-small mammal conflict in and around Yegof Mountain Forest, South Wollo, Ethiopia was carried out from 2016–2019. The study area was classified into six habitats and three altitudinal zones. Both Sherman and snap traps were used to collect small mammals. Thirteen (13) species of small mammals were recorded. Out of these, ten species were trapped and three species were observed. The trapped species were *Mastomys natalensis* (24.81%), *Stenocephalemys albipes* (19.53%), *Stenocephalemys griseicauda* (13.21%), *Arvicanthis abyssinicus* (11.98%), *Lophuromys flavopunctatus* (11.79%), *Otomys typus* (7.36%), *Rattus rattus* (5.28%), *Myomyscus brockmani* (5.19%), SpA (0.66 %) and *Crocidura flavescens* (0.19%) by using both traps. The highest number of species and abundance were recorded in a bushland habitat and in the altitudinal range between 2201–2600 m asl. There was statistically significant variation in the abundance of small mammals between habitats and altitudinal ranges ($p<0.05$). Species diversity was highest in the bushland habitat (H'=1.75) and lowest in the wooded grassland habitat (H'= 0.37). Highest species diversity was recorded in the altitudinal range between 2201-2600 m asl (H'= 1.79) and the lowest between 2601-2927 m asl (H'=0.39). Abundance of small mammals was higher during the wet season (54.64%) than the dry season (45.36%). The age structure of small mammals showed statistically significant variation ($p <0.05$). *M. natalensis, S. griseicauda, L. flavopunctatus, A. abyssinicus, O. typus, R. rattus, T. splendens* and *H. cristata* were categorized as the main pest rodent species. The majority of the respondents of the study area had negative attitude towards rodents and their conservation status. To reduce the damage caused by pest rodents, farmers use various techniques. Vegetation diversity, cover, rainfall, altitudinal zonations and human interference were the major factors affecting the abundance, distribution and diversity in the study area. Although, the study area is home for different species of small mammals including the endemic mammals of Ethiopia but it is highly disturbed by human encroachment and domestic animal activities through grazing and browsing. Hence, there is a need for urgent conservation measures to save the species.

Keywords: Pest rodent, small mammals, species diversity, Yegof Mountain Forest

LIST OF ABBREVIATIONS

CSA=Central Statistical Authority

ETB= Ethiopian Birr

EWNHS= Ethiopian Wildlife and Natural History Society

ha= hectare

IBA= Important Bird Area

IPM = Integrated Pest Management

t =Tone

1. INTRODUCTION AND LITERATURE REVIEW

1.1. Introduction

Small mammals represent more than 43% of all the total mammal species of the world (Happold, 2013; Wilson and Reeder, 2005; Chris and Stuart, 2016). In Africa, the diversity and abundance of mammal species are higher than other continents. Out of the total mammal species of the world, 1160 species of mammals are found in Africa, which are categorized in 296 genera, 57 families and 16 orders (Happold, 2013; Kingdon, 2015). The Order Rodentia covers 34% of the total mammal species of the continent (Delany, 1986; Happold, 2013; Chris and Stuart, 2016). Due to the presence of varied topographical and climatic conditions, Africa is rich in species diversity and comprises more endemic species compared to other continents of the world (Kingdon, 2015).

Afework Bekele and Yalden (2013) stated that more than 315 species of mammals occur in Ethiopia. Among these, 84 species are rodents, which constitute 27% of the total mammal species and 50% of the total endemic mammal species of the country. Principally, the highland ecosystem of the country hosts several endemic species. Yalden and Largen (1992) stated that the majority of endemic mammals of Ethiopia were found in the highland ecosystem in the country (Lavrenchenko and Afework Bekele, 2017). The altitudinal variation within the country produces varied climate conditions that affect diversity as well as the distribution of mammals (Yalden and Largen, 1992). As a result, the diversity of mammals was high in the highlands of Ethiopia. Mammals are found in various habitats of the earth (Rose, 2006; Feldhamer *et al.*, 2007; Kingdon, 2015; Vaughan *et al.*, 2015). The distribution of mammals is worldwide due to the capability of adaptation to various environments (Kingdon, 2015). Mammals are diverse in morphological structures (Feldhamer *et al*., 2007; Smith and Xie, 2013; Vaughan *et al*., 2015). The body weight of mammals ranges from the smallest bumblebee bat *Craseo nycteris* (2 g body weight) to the largest mammals, the blue whale *Balaenoptera* (more than 100,000 kg body weight) (Rose, 2006). Mammals are also well known over other groups of vertebrates due to the presence of hair on their body and mammary glands in the female to nourish the young (Turner, 2004; Rose, 2006).

In developing countries, humans and wild mammals would compete for limited common resources, which lead to conflict. Human wildlife conflict is more intense in an area where human population lives in close proximity to the natural habitats of animals (Homewood and Brockington, 1999; Muruthi, 2005). The competition and share of natural resources between humans and animals cause to food insecurity in humans affecting their livelihood (Seoraj-Pillai and Pillay, 2017).

In Ethiopia, many mammal species are under continuous threat, due to their habitat disturbance and illegal hunting in and out of the protected areas. As a result, several species of mammals were destroyed (Melaku Tefera, 2011; Lavrenchenko and Afework Bekele, 2017).

1.2. Literature review

The taxonomy of Order Rodentia is debatable and complex due to their obscure relationship by convergence, divergence and parallel evolution (Livingstone and Kingdon, 2013; Vaughan *et al*., 2015). However, African rodents are categorized into four major groups. These are gundi and porcupine forms (Hystricomorphs), squirrel forms (Sciuromorphs), anomalures (Anomaluromorphs) and rat forms (Myomorphs). All these groups have distinctly different arrangements of the chewing muscles, orbits, and teeth (Happold, 2013; Kingdon, 2015; Vaughan *et al.*, 2015). The Order Rodentia comprises 33 families, 481 genera and 2277 species all over the world (Wilson and Reeder, 2005; Hoath, 2009; Kingdon, 2015).

The present study on small mammals does not include bats. These mammals are more diverse and abundant species among other groups. Among the groups of mammals, Order Rodentia is the most diverse and abundant, followed by Order Chiroptera (Turner, 2004; Hoath, 2009; Rose, 2006; Happold, 2013; Kingdon, 2015). The family Muridae consists of more than half of all rodent species (Rose, 2006; Honeycutt, 2007; Hoath, 2009; Kingdon, 2015). Although, Muridae are believed to be latecomers to the African continent, they are very widespread, dominant and diverse groups replacing other groups of rodents (McDade, 2005; Happold, 2013; Kingdon, 2015).

In Africa, there are about 395 rodent species grouped in 98 genera and 15 families (Happold, 2013). Among 98 genera and 395 species of rodents, Muridae consist of 50 genera and 250 species (Happold, 2013). Out of the total African rodent species, Eastern Africa harbours 101 species of rodents that are grouped in 14 families and 62 genera (Fiedler, 1994).

The diversity of small mammals was closely associated with vegetation cover and availability of resources in their habitats (Vaughan *et al.*, 2015). Habitat complexity and vegetation heterogeneity are the main factors to determine the diversity and abundance of small mammal species. Habitat heterogeneity increases species richness through protection from predators and as a source of food item for small mammals (Williams *et al.*, 2002). Habitat disturbance of small mammals is the leading factor that reduces species diversity and abundance (Vera and Rocha, 2006). Altitudinal range and environmental variables such as rainfall, soil type and food are the main factors to the diversity of small mammal species (Michel *et al.*, 2007).

Small mammals are the most abundant and diversified groups due to adaptability of different environmental conditions, habitats (Burgess, 2009; Hoath, 2009; Kingdon, 2015) and small body size (McDade, 2005; Burgess, 2009; Happold, 2013; Kingdon, 2015).

Biogeographically, distribution of small mammals is worldwide except Antarctica and oceanic islands (Meserve, 2007; Happold, 2013; Vaughan *et al*., 2015; Francis, 2016). Small mammals are adapted from the coldest area (Tundra) to the hottest ecosystem (Morgan, 2003; Wood and Singleton, 2015). The house mouse and the black rat have mainly lived in close association with humans and they are widespread species worldwide. The squirrels from family Sciuridae, also have a worldwide distribution except in desert areas (Morgan, 2003; Kingdon, 2015; Vaughan *et al*., 2015). However, some species of small mammals are restricted to a specific area or country. For instance, the mountain beaver is restricted to the northwest of the United States, Pocket gophers are found in North and Central America and members of the family Heteromyidae (kangaroo rats and pocket gophers) occur in North and Central America. Scaly-tailed squirrels (*Anomalurus*), African mole rats (family Bathyergidae) and spring hares (*Pedetes capensis*) also occur in parts of sub-Saharan Africa. The family Dipodidae is found in the Middle East and northern Africa, whereas Zapodidae occur in North America and some parts of Europe and Asia. Some species of rodents and insectivores are also found only in Ethiopia (Afework Bekele and Yalden, 2013) and some are restricted in lowland and highland areas within particular regions.

Abiotic factors such as altitude, rainfall, temperature, and soil types influence the distribution of small mammals (Yalden, 1988; Monadjem, 1999). Similarly, the biological factors such as predators, diseases, vegetation type and structure can affect the distribution of small mammals (Afework Bekele, 1996; Kelt, 1996; Marino *et al*., 2003). The climatic condition and vegetation characteristics of different areas are often correlated with altitude (Monadjem, 1999). Vegetation structure is the main factor for the determination of rodent diversity and abundance within the ecosystem (Hoath, 2009; Kingdon, 2015; Vaughan *et al*., 2015).

The preference of habitats by small mammals is based on the availability of resources such as food, breeding sites, water, and shelter. The distribution of small mammals is mainly associated with habitat complexity and heterogeneity (Fitzgibbon *et al*., 1995; Massawe *et al*., 2005; Coppeto *et al*., 2006), plant species structure and availability of precipitation (Monadjem, 1999; Sans-Fuentes and Ventura, 2000; Andrews and Obrien, 2000; Kaminski *et al*., 2007; Mohammed Kasso *et al*., 2010) and habitat type and landscape (Tadesse Habtamu and Afework Bekele, 2008; Scott *et al*., 2008). Mulungu *et al*. (2008) and Hoath (2009) stated that mixed habitat types and lowland areas supported higher species diversity of rodents than homogeneous habitats and highland areas, respectively. High-quality habitats have a high reproductive advantage over low-quality habitats. This leads to small mammal species being more abundant in some habitats than others (Contreernras *et al*., 1997; Cramer and Willig, 2002).

Soil texture also influences the distribution of burrowing small mammals. For instance, loam textured soil is preferred by *M. Natalensis* and other species because it contains a higher percentage of sand than clay soil. As a result, loam soil is suitable for burrowing and nesting, particularly during the rainy season in relation to high aeration and water logging during the wet season than clay soil. Non-cultivated areas are also important for burrowing rather than farmed areas because plowing disrupts burrow systems. In addition, plant residue build-up on the surface of non-cultivated areas; provide cover and insulation for small mammals (Witmer *et al*., 2007).

Small mammal species composition and abundance vary across altitudinal ranges of the terrestrial ecosystems. This is associated with habitat cover, climatic condition, and soil type. Mohammed Kasso *et al*. (2010) described that the altitudinal zone ranging from 3101 to 3400 m asl contained the highest number of rodent species compared to the altitudinal ranges from 2800–3100 m asl. Some small mammals are widely distributed across different altitudinal ranges such as *S. girsiecauda* (Yalden *et al*., 1976; Yalden and Largen, 1992). However, some species are restricted to a limited altitudinal distribution.

The altitudinal distribution of small mammals varies from species to species. Yalden *et al*. (1976) described that rodents are dispersed along with different altitudinal ranges in Ethiopia. However, some species are more widespread. For instance, *Lophuromys flavopunctatus* is the most abundant and widely distributed rodent in all types of altitudinal ranges (Mohammed Kasso *et al*., 2010).

Highland ecosystems have a higher number of endemic small mammal species. Yalden and Largen (1992) and Lavrenchenko and Afework Bekele (2017) stated that several endemic species of small mammals were recorded from the highland ecosystems of Ethiopia. Even though, Afro–alpine ecosystems lack many larger ungulates, they contain several small mammals such as mole rats and grass rats in high abundance (Sillero-Zubiri *et al*., 1995; Vial *et al*., 2011).

Small mammals are characterized by diverse morphology. The body size and weight of small mammals range from the smallest bumblebee bat, *Craseonycteris thonglongyai*, which ranges about 3 cm and weighs 2 g, to the largest capybara, *Hydrochaeris hydrochaeris*, which is 100 cm long and can weigh more than 50 kg (Morgan, 2003; Rose, 2006; Hoath, 2009; Macdonald *et al*., 2015). The majority of rodent species weigh from 20 to 100 g. Insectivores also have smaller body weight that ranges from 3 to 100 g. However, most shrew species weigh from 10 to 15 g and have a head-body length of about 50 mm (Feldhamer *et al*., 2007; Vaughan *et al*., 2015).

All species of rodents have shared features associated with a single set of large, ever-growing, chisel like upper and lower incisor teeth (Nowak, 1999; Morgan, 2003; Chris and Stuart, 2016). Their teeth grow continuously throughout their lives and are worn down as rodents feed hard materials. The rootless incisors are used for gnawing and enable them to gain access to a wide range of food items (Hoath, 2009). Canines are absent, leaving a long gap or diastema between the incisors and the cheek teeth (Smith and Xie, 2013). Herbivorous rodents have high-crowned cheek teeth, whereas omnivorous species have low-crowned cheek teeth and well-defined arrangements of cusps (Mcdade, 2005; Kingdon, 2015; Vaughan *et al*., 2015).

Small mammals are social animals and live in groups (Bays *et al.*, 2006). Among the total species of rodents, about 70 species of murids live in groups (group living, alloparental care and for reproductive purposes) (Lacey and Sherman, 2007). Males also show a hierarchical system of dominance and in some groups of species, female offsprings remain in the colony while male young ones disperse (Lahvis, 2017). Several rodent species are social animals, living in large groups and interacting with one another frequently and their social systems vary from species to species (Macdonald *et al.*, 2015). Limited numbers of small mammals are solitary (Poole, 1985). These are porcupines, pocket gophers, pocket mice, and several desert species. They are burrowing animals and live in isolation. However, during the mating season, they make a social system (Jarvis and Bennett, 1991; Nevo, 2007; Macdonald *et al*., 2015; Lahvis, 2017).

Scent marking is a very essential feature for the social organization of rodent communication through the physiological impact (Poole, 1985). Urine of small mammals gives information about the species, sex and individual identity (Roberts, 2007). For instance, house mice use urine to mark their home range, recognize family members and find a mate. Males produce more scent than female rodents (Beatty *et al*., 2008). However, some species of small mammal lack scent-marking glands for their social communication such as mice and rats, but they can mark their territory by rubbing their faces and whiskers on their environment (Poole, 1985; Bays *et al.,* 2006).

Small mammals have a wide range of feeding habits such as leaves, fruit, grass, herbs, seeds and small invertebrates (Kays and Wilson, 2009; Kingdon, 2015; Francis, 2016). Some species also gnaw the bark of plants during the dry season (McDade, 2005; Happold *et al*., 2013; Kingdon, 2015). The mode of feeding in small mammals varies from species to species.

Reproduction of small mammals was facilitated by a rainy season and quality of diet (Makundi *et al.*, 2006; Massawe *et al*., 2007, Workneh Gebresilassie *et al*., 2006). On the other hand, breeding decreases during the dry season (Tilaye Wube, 2005). Most of the females trapped during the wet season were sexually active (either in estrous, pregnant, or lactating). During the dry season, there was no or only less evidence of reproductive activities among rodents. Temperature, humidity and predation also have significant roles in determining small mammal reproduction (Wolff, 2006). The mating strategies of small mammals also vary from species to species. Some species of rodents are monogamous, in which male-female pairs last for multiple mating seasons. Some species have a harem-based mating system, one male with several females during the mating season (Waterman, 2007). However, several rodents are promiscuous (McDade, 2005). Schulte-Hostedde (2007) also stated that sexual dimorphism occurs in several species of rodents.

Environmental factors influence the reproductive status of small mammals. For instance, hibernating species in the squirrels and jumping mice produce one progeny per year, whereas non-hibernating species can produce more than one offspring. Chemical communication also affects the breeding activity of small mammals; in the absence of pheromones, the male is not active or ready for mating (Mcdade, 2005). The breeding of small mammals is facilitated by a rainy season and quality of diet (Jackson and Van Aarde, 2004; Shanas and Haim, 2004; Makundi *et al.*, 2006; Massawe *et al.*, 2007, Workneh Gebresilassie *et al.*, 2006) and breeding decreases during the dry season (Tilaye Wube, 2005). The majority of females captured during the wet season are sexually active (either pregnant or lactating). Temperature, humidity, and predation also have significant roles in determining small mammal reproduction (Wolff, 2006).

Threats of small mammals are accelerated by increment of the human population from time to time because of agricultural expansion and overgrazing nearby habitats of small mammals (Monadjem *et al.*, 2015; Francis, 2016). Small mammals require good habitat cover for hiding themselves from predators. The usage of agro-chemicals in the farmland also causes small mammal habitat destruction (Gomez *et al*., 2017). As a result, humans are threats for several small mammal species by destroying their living habitats and introducing exotic species that prey on them (McDade, 2005).

Degradation of small mammal habitat leads to changes in small mammal diversity and abundance (Tam *et al*., 2003). The decline of small mammal density and local extinctions are due to the depletion of resource availability in their habitats (Lima *et al*., 2006; Milstead *et al.*, 2007). The pattern of habitat use and density of predators are the main factors to determine the diversity and abundance of rodent species (Workneh Gebresilassie *et al*., 2004; Meserve, 2007; Mohammadi, 2010; Zerihun Girma *et al*., 2012). During habitat disturbance some species disappear, while opportunistic species such as Mastomys *natalensis* and *Arvicanthis nairobae* find a suitable condition and migrate to the newly cultivated land. Clearing and fragmentation of the natural forest vegetation have great impacts on small mammal fauna (Mugatha, 2002). Grazing also has a great effect by changing the vegetation structure on small mammal abundance and species richness (Avenant and Cavallini, 2007; Torrea *et al.*, 2007). For example, *Tachyoryctes macrocephalus*, *Arvicanthis blicki* and *Lophuromys melanonyx* are the leading herbivorous of rodents in the Bale Mountains and they are affected by grazing and the presence of high densities of domestic livestock in their habitats (Vial *et al*., 2011). Roads and highways also affect small mammal diversity and abundance by habitat fragmentation (Marnell *et al*., 2009). This blocks small mammal movements, re-colonization of empty habitats, and immigration (Sauvajot, 1998; Rico *et al*., 2007; McGregor *et al*., 2008).

Out of the 395 rodent species in Africa, more than 77 are identified as pests (Fiedler, 1988; Happold, 2013). These species are identified based on their frequent involvement in damaging several crops and their broad distribution. The most common rodent pests in sub-Saharan Africa are the multi-mammate rats, which destroy about 80% of the crops throughout their ranges. However, they also consume insects, weed seeds, and a variety of other items (Brown *et al*., 2007).

Pest rodents damage crops throughout the growing season from germination to harvesting periods. Yield loss is observed during all cropping stages during both wet and dry seasons (Jain and Tripathi, 1988; Conover, 2002; Lagwen, 2016). Pest rodents damage field crops and post-harvest products (Prout *et al*., 2006). *R. rattus* and *M. natalensis* are the main pest species of field crops with partially overlapping habitats and resource usage (Dehghani *et al*., 2012). *Mastomys natalensis* is the most important pest rodent of rice in most developing countries. The decrease of agricultural yield has significant economic impacts on the local community (Shwiff *et al*., 2008). Cereal crops, mainly sorghum and maize were most susceptible at the seedling, vegetative, matured and storage stage (Ejigu Alemayehu and Afework Bekele (2013). More than half of the cereal crops are damaged in storage, maturity, seedling and vegetative stage (Mohammed Kasso, 2013) and sugarcane (Redwan Mohammed *et al*., 2017). Maize, enset and potatoes are the most affected crops in Ethiopia, whereas maize is highly damaged in Tanzania (Makundi *et al*., 2005). Fruits and cash crops are also affected at a different stage of growth. The major damage to fruits occurs at maturation and vegetative stages (Mohammed Kasso, 2013).

Mole rats have a great impact on vegetable. They are fossorial and consume the root parts of the vegetable and other crops. The main crops damaged by mole rats are sweet potato, tuber, and other roots of vegetables (Lund, 2015). Large plants are also damaged by mole rats by cutting off the root leading to drying of plants. Porcupines are also ranked as primary pest rodents for sweet potatoes and other crops in Ethiopia (Mohammed Kasso, 2013).

Pest rodents cause a loss of billions of dollars every year worldwide. They also devastate a wide range of properties such as domestic households, commercial and business establishments and farmlands. Overall, they are responsible for the mortality of young trees and shrubs (Varnham *et al.,* 2011).

Afework Bekele *et al.* (2003) reported that *Arvicanthis dembeensis* and *Mastomys erythroleucus* were the major pest species, whereas *Mus mahomet* and *Tatera robusta* were minor pest species in central Ethiopia. Crop damage by pest species is a big worry in the local community of Ethiopia because 85 % of the population depends on crop growth.

Tropical diseases are more abundant in Africa and rodents are responsible for several diseases affecting human and livestock (Fiedler, 1988). Rodents, particularly those that live in close proximity to humans cause threat to human and livestock health as vectors of viral, rickettsia, parasitic and bacterial diseases (Fiedler, 1988; Begon, 2003; Makundi *et al.,* 2003; Singleton *et al.,* 2003; Agbo and Terlumun, 2010;). They serve as reservoirs or hosts for various human diseases (Conover, 2002). More than 60 types of diseases are transmitted to humans by rodents. In addition, they eat and contaminate feed and their gnawing destroys buildings (Mcdade, 2005). Rats carried the fleas that caused the plague of Europe (Black Death) that destroyed about a quarter of the medieval population (Battersby, 2015).

Andersen *et al*. (2016) and Baumans (2016) stated that rodents are widely used as model organisms for laboratory testing, teaching and research work. Small mammals, principally rodents are essential components of the ecosystem and they serve as pollinators, seed dispersal and making a ground hole for soil aeration (Douglas *et al*., 2004; Kingdon, 2015). They are also essential for nutrient recycling and habitat modification (Yunger *et al*., 2002; Avenant, 2003; Davies and Howell, 2004; Kelt *et al*., 2004; Bagchia *et al*., 2006; Avenant and Cavallini, 2007; Fricke *et al*., 2009; Ferreira and Delibes-Mateos, 2012). Rodents have an important role in the ecosystem modification by pruning or eliminating vegetation types (Kingdon, 2015; Vaughan *et al*., 2015). Small mammals change the environment in which they live a process known as 'ecological engineering' by burrowing the soil profile. By altering and rushing, the new soil to the surface, this provides increased soil nutrients to promote plant growth and crop productivity (Kingdon, 2015).

Rodents are important as sources of food for many people in a different part of the world and other animals. For instance, cane rat or grasscutter rat is a source of protein in Nigeria, especially in Western and Central Africa. In Benin, 500 tonnes of meat is produced from cane rat by hunting annually (Fayenuwo and Akande, 2002). In South America, Africa, and Asia, people trap or breed grasscutter rats and edible dormice for food (Monadjem *et al*., 2015). Tadesse Habtamu and Afework Bekele (2008) also reported that in Ethiopia, the Gumuz indigenous people depend on rodents as a source of food. Rats are also captured in the field and sold as meat after killing or as live rats for human consumption in Vietnam (Khiem *et al*., 2003). The endangered and endemic Ethiopian wolf (*Canis simensis*) also depends on rodents as a source of food. The abundance and distribution of endemic Ethiopian wolf are positively correlated with the abundance and distribution of rodents (Sillero-Zubiri and Marino, 2004).

1.2.1. Justification of the study

In Ethiopia, several investigations have been carried out on small mammal composition, abundance, distribution and habitat association in selected regions. Usually, the mountainous area of the country contains several endemic species of small mammals (Yalden and Largen, 1992). However, the increment of farmland in the highlands of the country leads to the instrument of pest status of rodents. Therefore, grazers and human activities affect the diversity of small mammal species in and out of the protected highland ecosystems (Vial *et al*., 2011). Study on small mammal species is important to acquire information about the status of small mammals within the ecosystem.

Several investigations were carried out on the diversity, habitat association, and pest status of rodents worldwide. As a result, several new species of rodents have been identified in recent times from different parts of Africa. In Ethiopia, several studies have been carried out on small mammal composition, distribution, abundance, habitat association and their pest status. Afework Bekele and Yalden (2013) stated that the number of small mammal species is continuously increasing in Ethiopia, due to the exploration of new areas. However, there is a scarcity of vital information on small mammal species diversity, abundance, distribution and economic importance in many unexplored areas. Similarly, investigation of community ecology, abundance and pest implications of small mammals in and around Yegof Mountain Priority Forest area was not carried out. Hence, the present investigation was carried out in and around the Yegof National Priority Forest Area, South Wollo, Ethiopia. The current investigation may open the gate for other researchers who would like to conduct further investigation on the biodiversity of the area.

1.3. Objectives of the study

1.3.1. General objective

The general objective of the study is to investigate the community ecology, abundance and pest implications of small mammals in and around Yegof Mountain Priority Forest Area, South Wollo, Ethiopia.

1.3. 2. Specific objectives

- To identify the species composition of small mammals in the study area.
- To describe the habitat association and abundance of small mammals in the study area.
- To describe the altitudinal association of small mammals in the study area.
- To study the seasonal variation of small mammals in the study area.
- To estimate the trap success of small mammals in different habitats during the wet and dry season in the study area.
- To describe the level of crop damage by rodents in the study area.

1.4. Research hypothesis

- What kinds of small mammals are there in Yegof Mountain?
- Which types of small mammals are endemic in the study area?
- What is the association of small mammals with habitat and altitudinal zonation in the study area?
- Which species of rodents are frequently damaged the crops?

2. THE STUDY AREA AND METHODS

2.1. Description of the study area

Yegof National Priority Forest is found in South Wollo, Amhara Regional State, Ethiopia. It is located in the northern highland of Ethiopia, which lies between 11° 01' to 11° 03' North latitude and 39° 40' to 39° 44' East longitude with an elevation between 1800 and 2927 m asl. It is 375 km away north of Addis Ababa, 26 km southeast and 8 km west of Dessie and Kombolcha towns, respectively. It is bounded by Kallu, Kombolcha, Albko and Dessie Zuria Woredas. Yegof Mountain is situated on a steep slope overlooking Kombolcha town. From all parts of the study area, there are sharp elevation ranges, which drop from 2927 m asl to 1800 m asl. The forest is one of the most important state forests in South Wollo. It is mainly composed of natural highland vegetation and plantations. Formerly, the area is estimated to be around 18,000 ha (EWNHS, 1996). However, the forest cover is now diminished to 1527 ha due to several threats such as deforestation, grazing, and expansion of agricultural land (Fig. 1). The forest has received legal protection since 1973 with 63 forest guards to minimize deforestation and human encroachment. However, several households still live in and around the perimeter of the forest, extracting wood for fuel and house construction. Grazing is not allowed in the reserved forest, but cattle are usually seen inside.

The forest hosts several endemic species of birds and mammals. Based on Important Bird Area (IBA) criteria the forest fulfills category A3 criteria and considered as an important bird area category (Ethiopian Wildlife and Natural History Society, 1996) and at the national level, the forest is considered as “National Forest Priority Area”.

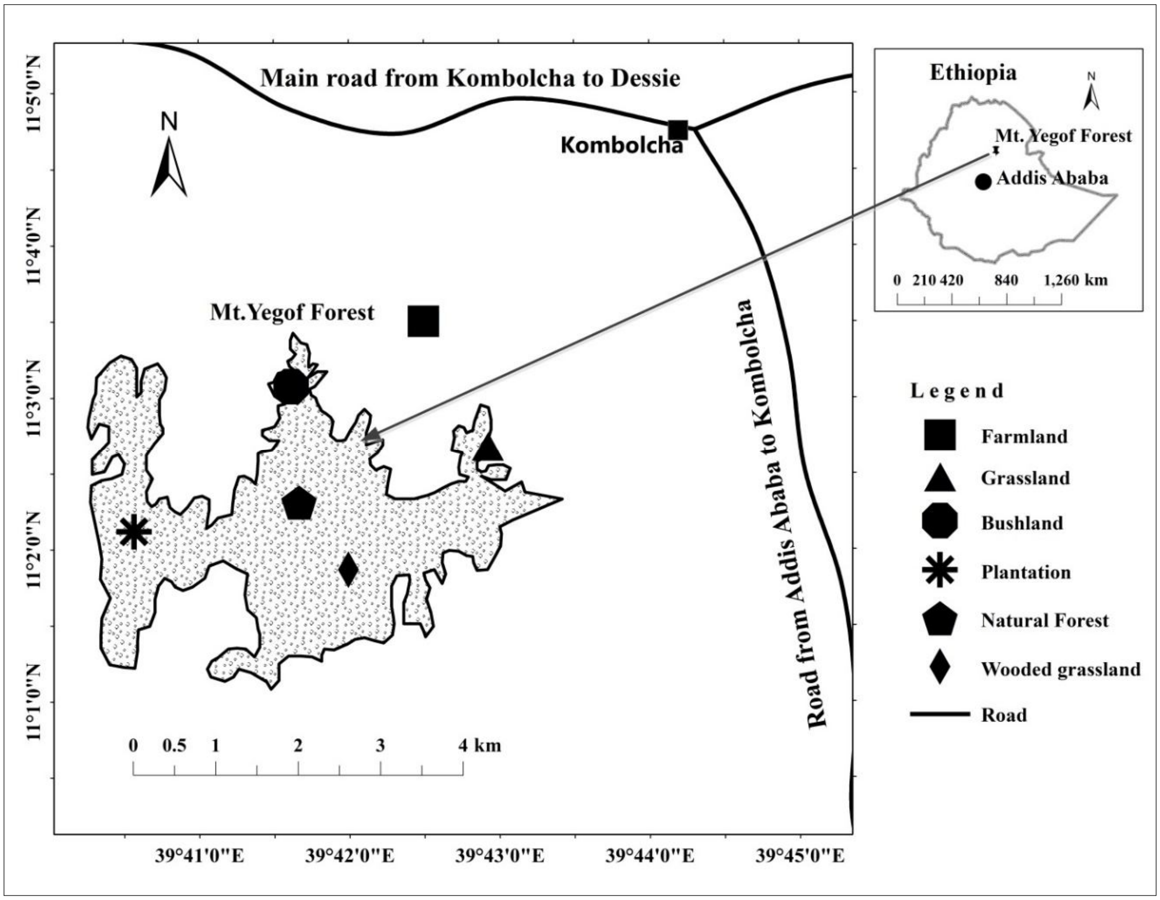

Figure 1: Map of the study area.

The climate of the Yegof National Forest Priority Area is characterized by distinct wet and dry seasons. The climatic condition of the study area can be classified as 'Dega' and 'Woina-Dega' agro-climatic zone. The data for temperature and rainfall were collected from Kombolcha Meteorological Station, which is the nearest meteorological station in the study area (around 8 km). The wet season of the area is characterized by a 'bimodal' rainfall patterns having one main rainy season (Kiremt or meher) during July – September and the minor rainy season (Belg) during March – May. The area receives the highest rainfall during the main wet season (300.5 mm) and the lowest rainfall during the dry season from November – February, 18.3 mm and 13.2 mm, respectively (Fig. 2). The annual rainfall of the study area is around 1026.7 mm. However, most farmers depend on the main rainy season for cultivation. Although, the rainfall pattern of the study area is influenced by two rain-bearing wind systems: conveying the westerly winds from the South Atlantic and the easterly winds from the Indian Ocean and the Arabian Sea (Sebsebe Demissew, 1998).

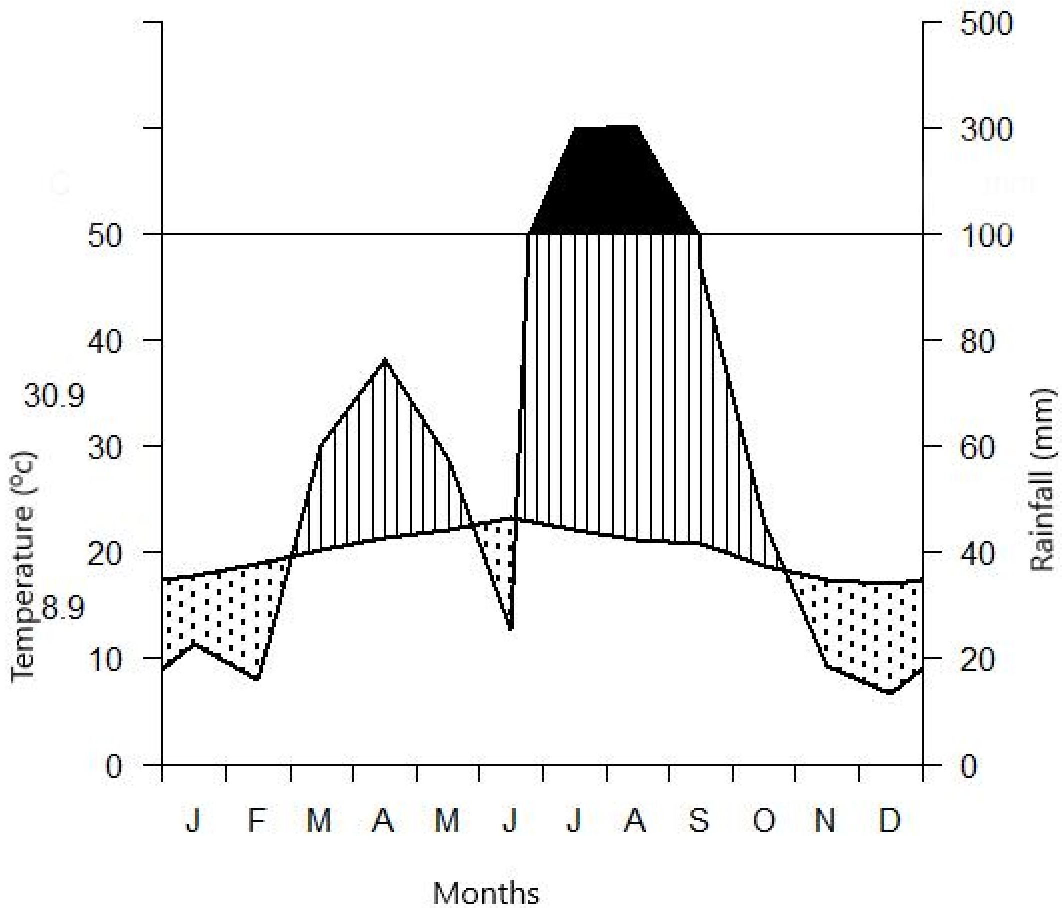

Figure 2: Monthly rainfall, maximum and minimum temperatures of the study (1999 – 2018) (Source: Ethiopian National Meteorological Agency, 2019).

Based on the data source from Kombolcha Meteorological Station, the temperature of the study area is characterized by relatively hot during April up to June, which ranges from

27.8 ^{o}C up to 30.9 ^{o}C. The annual average temperature of the area was 27.2 ^{o}C (Fig. 2). The minimum temperature is registered in December (8.9 ^{o}C) and the maximum temperature in June (30.9 ^{o}C).

Annual average humidity of 20 years data shows that the highest humidity was registered during the wet season and the lowest during the dry season (Fig. 3). The overall annual average humidity of the study area is 53%.

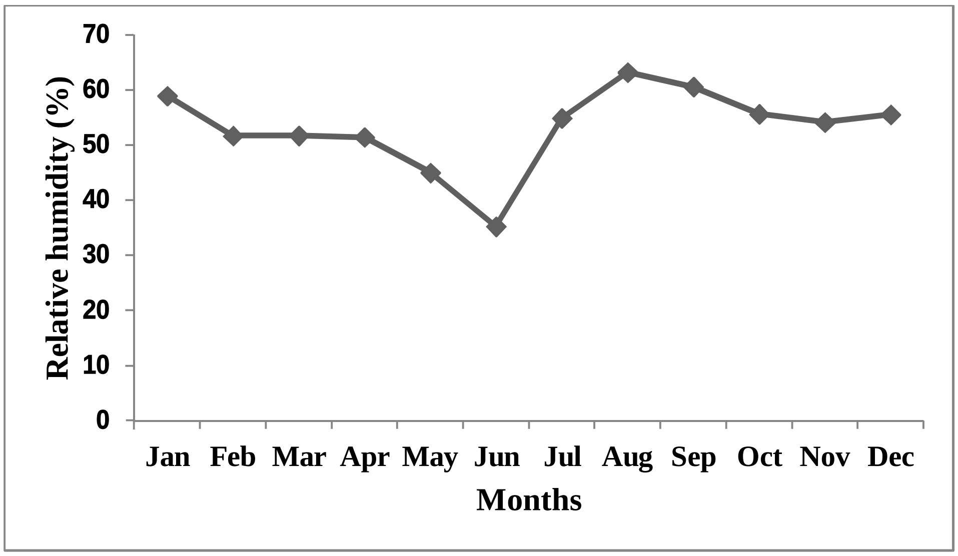

Figure 3: Relative humidity of the study area (1999−2018) (Source: Source: Ethiopian National Meteorological Agency, 2019).

The landscape of the study area is characterized by varying topography. It consists of mountains, plateaus, valleys, and lowland plains. The altitude of the study area ranges from 1800 up to 2927 m asl. This landscape variation of the area results in the formation of diverse climatic conditions (temperature, rainfall and humidity), soil, and vegetation types. The lower part of the study area is a flat area suited for farming activities. Yegof National Forest Priority Area is mountainous and surrounded by agricultural land. It also serves as a source of water for bottom residents as well as for the people of Kombolcha town.

On the rugged landscape cultivation is regular in the present study area. The majority farmland of the study area is found at the highest altitude. The main crops grown in the highlands are wheat and barley (Getachew Tadesse *et al*., 2008). However, sorghum, teff, and maize are the major cultivated crops in the middle and lower altitudes of the study area.

Based on Friis *et al*. (2011) current classification of Ethiopian vegetation types, the vegetation of Yegof Mountain forest is categorized as dry evergreen montane forest and moist evergreen montane forest. The Yegof Mountain forest is mainly represented by a dry evergreen montane forest.

The floristic composition of Yegof Mountain consists of about 199 species, representing 109 genera and 63 families (Sultan Mohammed and Berhanu Abraha, 2013, Tsegaye Gobeze, 2017).

The Yegof forest consists of a wide variety of habitats such as forest, bushland and grassland with varied topography. The forest consists of several endemic and non-endemic species of vertebrates**.** Ethiopian Wildlife and Natural History Society (1996) reported that 62 bird species were recorded from the Yegof Mountain forest. However, Amhara Regional State Government Office (2011) reported that more than 82 bird species were found in the Yegof Mountain forest.

The Yegof Mountain forest is also home to more than 22 mammal species (Appendix I). Among these, gelada baboon and Menelik's bushbuck are the endemic species that are found in the study area.

The study area is broadly classified into six habitats. These were:

Farmland habitat

The farmland habitat of the study area was covered by maize, wheat, teff and other types of crops and vegetables (Plate 1). It is found at the bottom of the mountain at an altitude of 1800 m asl. Previously, this habitat was covered by natural forest. However, due to the expansion of agricultural land, the natural forest was converted into farmland. The most cultivated crops in the lower parts of the Mountain were sorghum and maize.

Plate 1: Farmland habitat of the study area (Photo: Gezahegn Getachew, 2018).

Grassland

The grassland habitat is covered by grass and herbaceous species. *Hyparrhenia* and *Pennisetum* are the main grass species of the study area (Sebsebe Demissew, 1998) (Plate 2). This habitat is dominated by tall and short grass species, used for grazing and roof construction.

Plate 2: Grassland habitat of the study area (Photo: Gezahegn Getachew, 2018).

Bushland habitat

The bushland habitat is located at an altitude of 2200 m asl. It is a disturbed habitat by local community for farmland. It was dominated by tree species of *Calpurnea aurea*, *Carissa edulis, Dodonaea angustiolia*, *Euclea schimperi* and *Euphorbia candelabrum* (Plate 3).

Plate 3: Bushland habitat of the study area (Photo: Gezahegn Getachew, September, 2018).

Plantation habitat

The plantation habitat covers with man-made plant species. The plantation of exotic species started in 1973 (Ethiopian Wildlife and Natural History Society, 1996). The introduced plant species in the forest were *Acacia mearnsii, A. saligna, Cupressus lusitanicus, Eucalyptus camaldulensis, E. globulus, Pinus radiata* and *P. patula* (Sebsebe Demissew, 1998). This habitat is located at an altitudinal range between of 2300-2800 m asl (Plate 4).

Plate 4: Plantation habitat of the study area (Photo: Gezahegn Getachew, February, 2018).

Natural forest habitat

This site is covers by large trees. The forest habitat is found within the altitudinal range between 2530‒2750 m asl. The most dominant tree species in the forest were *Croton macrostachyus, Kebergia capensis, Juniperus procera, Olea europaea subsp. cuspidate, Olinia rochetiana* (Sebsebe Demissew, 1998; Sultan Mohammed and Berhanu Abraha, 2013) (Plate 5).

Plate 5: Natural forest habitat of the study area (Photo: Gezahegn Getachew, September, 2018).

Wooded grassland

This area covers by large trees and grass species. The grass species grow under the foot of the largest and oldest plants of the forest. This site is located at an altitudinal range of 2927 m asl. It is the tip site of the Yegof Mountain Forest (Plate 6).

Plate 6: Wooded grassland habitat of the study area (Photo: Gezahegn Getachew, September, 2018).

2.2. Methods

The following field and laboratory equipment were used during the present investigation. These are Sherman live-traps, snap-traps, peanut butter, coloured plastic tag, Pesola spring balance, gloves, polythene bag, Geographical Positioning System (GPS), data sheets, field guides, dissecting kit, ruler, metre, 70% ethyl alcohol, compound microscope, digital camera, petridish, distilled water, dissecting kits, slides and slide cover.

A preliminary survey was conducted before the actual data collection within the study area. Relevant information on the physical (climatic condition and topography), biological (fauna and flora) features, socioeconomic activities of the local people, altitudinal range, habitat type and other information of the study area were gathered. Traps were randomly set in different habitats.

A pilot survey was carried out in the selected villages from during July, 2018. During this pilot survey, 20 households were randomly selected and interviewed. Based on the outcome of the pilot survey, the questionnaire was revised and developed.

Based on the topography and vegetation types, the study area was classified into Farmland (FL), Grassland (GL), Bushland (BL), Plantation (PL), Natural forest (NF) and wooded grassland (WGL) habitats. Representative grids were prepared in these habitats for both Sharman live traps and snap traps. Then, a code number was given for each grid in all habitats and traps were placed. Both live and snap traps were used for data collection of small mammals.

Interviews, observation and focus group discussions were conducted in different villages and adjacent to the Yegof Mountain Forest to assess the attitude of farmers towards pest rodents. Eight villages were selected through purposive sampling technique and then, from each village respondents were determined through simple random sampling techniques.

Investigation on small mammals was carried out from December 2016 to October, 2018 in and around Yegof Mountain National Priority Forest Area. Data were collected during both the wet season (July to September) and the dry season (December to May). This was conducted twice during the wet season and the dry season each per year with a minimum of 30 days interval. Sherman live traps and snap (break back) traps were used to study small mammals successfully during the present investigation.

A total of 7056 Sherman live-traps were used for 144 days during both seasons and in each habitat one permanent 70 x 70 m or 4900 m^2 live trapping grid was set to collect the species diversity, habitat association and abundance data. Traps were placed at 10 m intervals (Fig. 4).

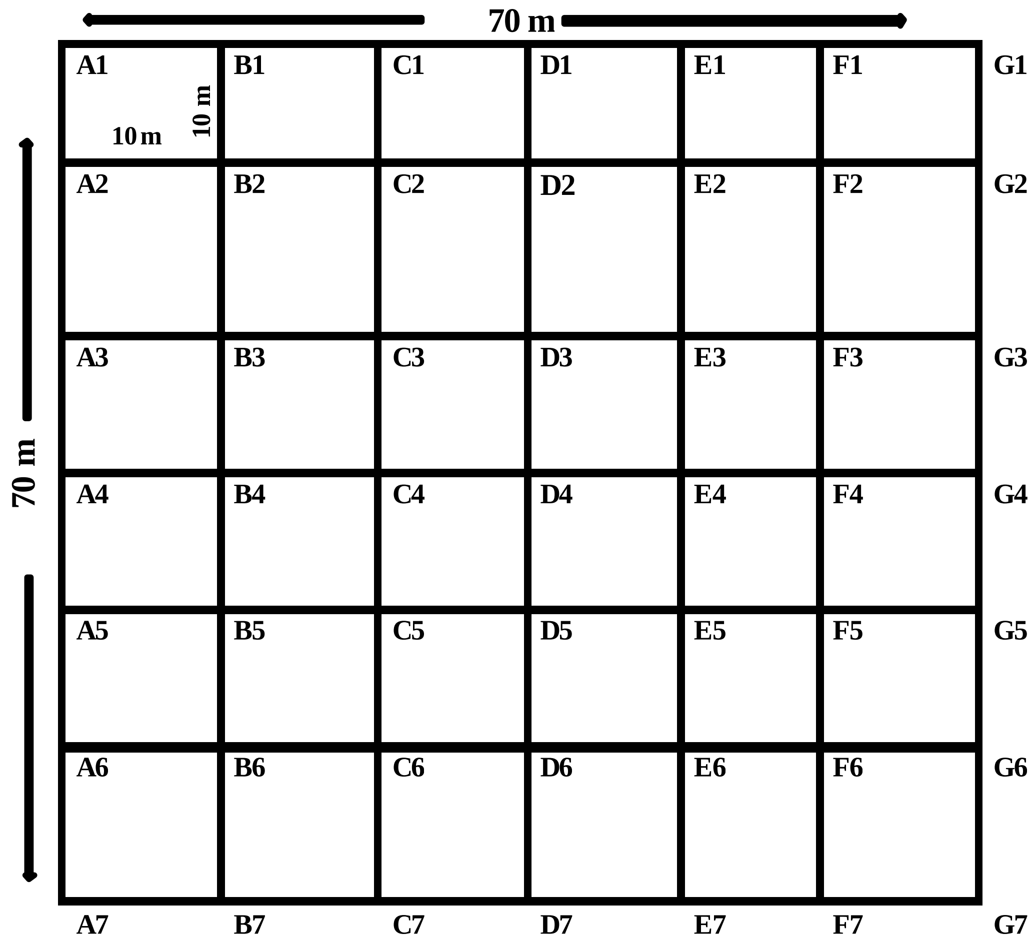

Figure 4: A schematic representation of Sherman live-trapping grid with trap location.

During the present investigation, an equal distance grid was used to collect species diversity and abundance data in each habitat and altitudinal zonation. Trapping of small mammals by using Sherman live traps was conducted during both the wet season and the dry season. To locate the traps easily during the inspection time, each trap location was provided a number, marked with GPS or a yellow coloured plastic tag. Traps were covered with leaves and grasses to protect against excessive heat, cold and to camouflage. Live traps were baited with peanut butter and replenished during a check-up period. Trapping was carried out for a minimum of three consecutive days during each trapping session. Traps were checked in the morning (06:30-08:00 h) and in the afternoon (17:00-18:30 h) twice a day.

Recording of trapped individuals were carried out on the species type, sex and reproductive condition (perforated vagina, closed vagina, pregnant and lactating for females) and the position of the testicles (scrotal or abdominal for males), body weight and finally released in their trapped site after toe clipping (Afework Bekele, 1996). The code was given for unknown species until further identification carried out.

A total of 3600 snap traps were set at 20 m intervals for 144 days at a distance of more than 200 m away from Sharman live-traps due to far apart from the home range of live trapped small mammals during both the wet and dry seasons. These traps were baited with peanut butter. Traps were checked in the morning (08:00 – 08:30 h) and in the afternoon (18:30–19:00 h). Trapped individuals were removed from the traps and body measurements were taken. Records were made on body weight, sex, age, GPS location, body length, tail length, hind foot length, and ear length. They were also dissected for embryo count and stomach content analysis. The stomach contents from the dissected animals were removed and preserved in 70% alcohol. The skin of the representative specimen was prepared and deposited as voucher specimens in the Zoological National History Museum, Addis Ababa University for further identification of unknown species.

Questionnaire survey

Pest status of rodents was collected from eight bordering villages of Yegof Mountain Forest during household interviews, observation and focal group discussions after a brief orientation about the aim of the study. The pest status data of rodents were collected from respondents using the semi structured interview. Purposive random sampling technique was used to select the villages and simple random sampling was used to selected respondents from each village during this study. The respondents of the study area were selected based on the inclusion and exclusion criteria (Table 1).

Table 1: Inclusion and exclusion criteria for respondent selection.

Inclusion criteria	Exclusion criteria
✓ The person who owns farmland adjacent to the forest.	✓ The person who was a guest or visitor to the protected area/forest.
✓ The person who faced pest rodents in the study area.	✓ The person whose age is less than or equal to 18 years old.
✓ The person who was voluntary and agreed to respond to prepared questions.	✓ The person who was not voluntary and did not agree to provide the informed consent form.

The interview contained both open and close-ended questions to get information about the level of crop impacts by small mammals in the study area (Appendix III). The pest status data of rodents were collected from the sampled households habituated in or adjacent to forest areas. Target populations were established on the bases of the distance of their village from the forest boundary.

During this study, purposive sampling technique was used to sample representative villages based on the proximity to the forest boundary. For this survey, 300 households were used. The sample size was determined by using the formula's of Yamane (1967).

$$n = \frac{N}{1 + N(e^2)}$$

Where "n" is sampled households, "N" is a total target household (1133), *e* is a level of precision. Based on Yemane (1967) population correction factors, 300 sample households were selected using random sampling techniques from 1133 total households in eight villages of the study area. The number of households from each village was also allotted using proportionate allocation procedures. The allocations of the number of sampled households in each village with the proportion to the number of household heads living in each village was carried out as shown in Table 2.

$$n = \frac{HS}{N\ total}$$

Where n =number of required samples

H= number of households in one village

S=total households to be treated;

Ntotal=the number of households in all villages.

Table 2: Total household and sample size in each selected village in the study area.

Villages	Number of Households	Sample Size
Sidenager	160	42
Mentera	205	54
Dagna	208	55
Albati	138	36
Tabeta	35	9
Bokimos	102	27
Abalemne	195	51
Beleager	90	26
Total (8)	1133	300

During the present investigation, the data on pest status of rodents were gathered through focus group discussion (FGD), interview and observation in and around the Yegof Mountain Forest.

Diagonal cluster sampling techniques was used to collect a percentage of crop loss by rodents. Cluster sampling is widely used to group a set of observations on crop damage (Rennison and Buckle, 1988). A total of five plots (one meter by one meter), four at the diagonal and one at the center were used to collect the level of crop damaged during the present investigation. The diagonal plots were one meter far apart from the grid margin to avoid bias. Each plot was observed four days within five days interval and the damaged and un-damaged crops by pest rodents were recorded (Fig 5). The sample grid was covered with one grid of maize and one grid of wheat farmland in each village during the production season. It was conducted during the time of seedling and maturation time.

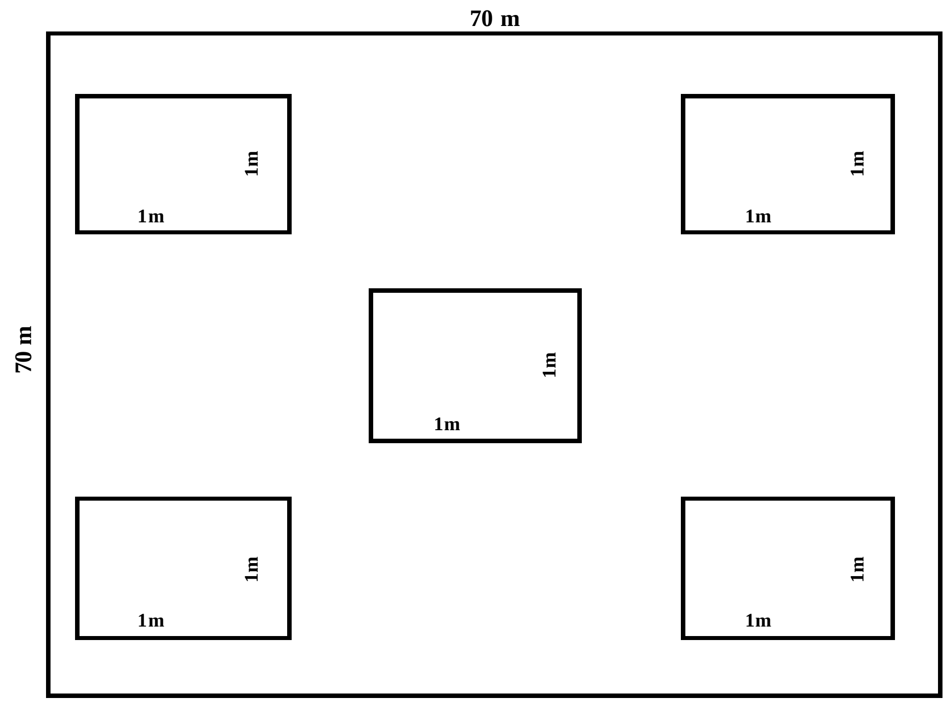

Figure 5: A schematic representation of direct observation plots.

In Focus Group Discussion (FGD), the respondents were invited to tell about the events in the study area based on their views and attitudes about the impacts of pest rodents on various crops. The group size in each village discussion varied from 4 to 16 individuals. Data were collected on the knowledge and attitude of local communities on pest status and control methods of pest rodents. During FGD, the investigator was a facilitator and the respondents provided information. FGDs were conducted together with forest keepers and local people.

Stomach content analysis was performed following the method used by MacKay and Russell (2005). The stomach content was removed from dissected animals and preserved in a glass container with 70% ethyl alcohol, until the further microscopic examination. In the laboratory, the samples were washed with distilled water to remove gastric juice and fully digested items. Then, weighed using digital balance after drying the moisture content for 24 h. Four slides were prepared for each sample and observed under a compound microscope to identify the type as well as the number of fragments of the types of diet.

2. 3. Data analysis

As a field guide for species identification and taxonomic characteristics of small mammals, Afework Bekele and Yalden (2013); Happold (2013); Kingdom (2015) and other several field guides of mammals were used. The prepared skins of unknown species were compared with the specimens deposited in the Zoological Natural History Museum of Addis Ababa University.

Small mammal species diversity of each habitat and across the varied landscape of the study area was analyzed by using the formula of Shannon diversity index (H') (Shannon and Wiener, 1949):

$$H' = \Sigma (Pi) \ln (pi)$$

Where, H′= species diversity

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

ln = the natural logarism

The Simpson-Index of diversity was calculated as

$$D = 1 - \Sigma (Pi)2$$

Where, D= Simpson-Index of diversity was calculated as $D= 1-\Sigma (Pi)^2$

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

The evenness index of small mammals of the study area was calculated using the following equation (Shannon and Wiener, 1949):

$$E = \frac{H'}{H'\,max}$$

Where E = Shannon equitability or evenness index

H' = Shannon-Wiener diversity index,

H' max = the maximum level of diversity possible within a given population

The values of the evenness index range between 0 and 1. The higher the value of the evenness index, all species are equally abundant in the study area.

$$H'max = LnS$$

Where, H' max = the maximum level of diversity possible within a given population

Ln = the natural logarithm.

S = the number of species

Sorensen similarity index was used to assess the degree of small mammal species similarity between different habitats and altitudes. The following equation was used to calculate Sorensen similarity Index or Sorensen binary:

$$Ss = \frac{2a}{2a + b + c}$$

Where Ss = Sorensen similarity coefficient

a = the number of species common to both sites

b = the number of species present in the first habitat only

c = the number of species present in the second habitat only.

The species composition dissimilarity between habitats in the study area was also analyzed using the beta (β) diversity. Beta diversity measures the change in the diversity of species among a set of habitats. It calculates the number of species that are not the same in two different habitats.

There are different ways to calculate beta diversity where all methods determine species turnover (replace one another) between different habitats or along environmental gradients (Whittaker, 1972). During the present investigation, the pairwise comparison of beta diversity between habitat types and environmental gradients was computed using the following formula:

$$\beta = \frac{b + c}{2a + b + c}$$

Where β=beta diversity

a = the number of shared species in two sites

b= the numbers of species unique to site one

c = the numbers of species unique site two

A higher value of beta diversity index indicates that a low level of similarity, while a lower value of the beta diversity index shows a high level of similarity.

Small mammal abundance was also measured by trap success rate (Mohammed Kasso *et al.*, 2010). In each grid, trap success was expressed in terms of capture per trap night called Trap Success Index and is calculated based on the following formula:

$$TS = \frac{\text{Number of individuals}}{\text{Number of traps} \times \text{nights}} * 100$$

Where, TS= Trap Success

The Relative Abundance of species was also calculated as the total abundance of species per abundance of all species times one hundred: $RA = \frac{Tn}{TN} * 100$

Where, RA= Relative abundance

Tn=Total abundance of a single species

TN= Total abundance of all species

The Species Richness index of various habitats in the study area was calculated by using the following formula (Krebs, 1999): $SR = \frac{S-1}{\ln N}$

Where; SRI = Species Richness Index

S= The number of species of that taxonomic group observed

N=Total individuals of the observed

Ln=Natural logarism

The species richness would be estimated from quadrat sampled based on the following formula (Krebs, 1999):

$$SRE = s + \frac{k(n-1)}{n}$$

Where, SRE = Species richness estimator

s = Total number of species captured

k = Unique species in the site or only found in one quadrat

n = Number of quadrats

The density of small mammal species was calculated by using the following formula;

$$\text{Density} = \frac{\text{Number of individuals}}{\text{area of the grid}}$$

The diet of rodents was calculated as the mean percentage of the relative abundance of a food item obtained from the stomach content analysis procedure.

Percentage of crop damage that occurred during the seedling and maturation stages was calculated as the number of damaged plants (crops) divided by the total crop population planted in the plots times one hundred using the calculation of Rennison and Buckle (1988):

$$\%\ \text{cut tillers} = 100 * \frac{a}{\text{b}}$$

Where, a = number of cut tillers in the sample

b = total number of tillers in sample

Statistical Package for Social Sciences (SPSS) Software version 25.0, Excel, R software, Ecological software version 7.3 was used to analyze the data. Statistical analyse of frequency, chi-square test, descriptive statistics and percentage were used to tabulate the data.

3. RESULTS

The results of this investigation are presented in three separate sections. The first section deals with species composition, habitat association, similarity between different habitats and altitudinal zone, seasonal variation, sex ratio, trap success, age class distribution and population density of the live-trapped small mammals. The second section deals with the result obtained by snap-trap surveys. This section deals with species composition, abundance, body measurements, reproduction, embryo count and diet analysis of rodents recorded during the wet and the dry seasons. The third section deals with the result obtained by questionnaire survey about human-rodent conflict. This section deals with the species composition, abundance and economic importance of pest rodents.

3.1. Sherman live-trapped small mammals

Thirteen species of small mammals were recorded from the Yegof Mountain forest (Table 3). Among these, ten species were captured by traps, whereas *Hystrix cristata* (Linnaeus, 1758), *Tachyorcytes splendens* (Rüppell, 1836) and *Procavia carpensis* (Pallas, 1766) were recorded from the study area through direct or indirect evidences. Evidence of burrow soil of *T. splenden* and quills for *H. cristata* was observed in addition to direct observation of the species in the study area, in the farmland and grassland habitat. *Procavia capensis* was observed in the farmland and natural habitats.

Out of the total captured small mammals, 895 new and 182 recaptured individuals were trapped by using Sherman live-traps in 7,056 trap nights during the wet and dry seasons. The trapped species were: *Mastomys natalensis* (Smith, 1834), *Stenocephalemys albipes*

(Rüppell, 1842), *Stenocephalemys griseicauda* (Petter, 1972), *Lophuromys flavopunctatus* (Thomas 1888), *Arvicanthis abyssinicus* (Rüppell, 1842), *Otomys typus* (Heuglin, 1877), *Rattus rattus* (Linnaeus, 1758), *Myomyscus brockmani* (Thomas, 1908), SpA and *Crocidura flavescens* (Geoffroy, 1827).

Out of thirteen species recorded during live trapping, nine species were rodents and one species of insectivorous. Out of the total live-trapped small mammal individuals, 893 (99.78%) individuals were rodents and 2 (0.22%) individuals were insectivores. These are *M. natalensis*, *S. albipes*, *L. flavopunctatus*, *S. griseicauda*, *M. brockmani*, *O. typus*, *R.rattus*, SpA and *C. flavescens. M. natalensis* was the most abundant (226, 25.25%) followed by *S. albipes* (181, 20.22%) (Table 3). The total live-trapped individuals of different species in the study area showed statistically significant variations ($\chi^2 = 519.76$, df =9, $p < 0.05$).

The distribution and abundance of live-trapped small mammals varied across habitats. The highest individuals were trapped from bushland habitat (212, 23.69 %) followed by forest (188, 21.01%). The abundance of small mammals in various habitats of the study area showed statistically significant variation (χ^2=81.28, df=5, $p < 0.05$). *M. natalensis* was the most widely distributed species and trapped from all habitats of the study area followed by *S. albipes,* which was recorded from four habitats (bushland, plantation, natural forest and wooded grassland) (Table 3).

Table 3: Species composition, distribution and abundance of small mammals in various habitats of the study area (F: Farmland; GL: Grassland; BL: Bushland; PL: Plantation; F: Forest; WGL: Wooded grassland; R.A= Relative abundance; * = observed species).

Species	Small mammal habitats						Total
	FL	GL	BL	PL	F	WGL	
M. natalensis	39	32	64	21	39	31	226
S. albipes	0	0	16	34	52	79	181
S. griseicauda	27	14	39	0	32	0	112
L. flavopunctatus	20	8	47	0	33	0	108
A. abysinicuss	31	66	0	0	0	0	97
O. typus	14	0	30	0	21	0	65
R. rattus	38	14	0	0	0	0	52
M. brockmani	0	0	9	27	11	0	47
SpA	0	0	5	0	0	0	5
C. flavescens	0	0	2	0	0	0	2
T. splendens	*	*	*	*	*	*	*
H. cristata	*	*	*	*	*	*	*
P. carpensis	*	*	*	*	*	*	*
Total	169	134	212	82	188	110	895
R. A	18.88	14.97	23.69	9.16	21.01	12.29	100
Trap night	1176	1176	1176	1176	1176	1176	7056
Trap success	14.37	11.39	18.03	6.97	15.99	9.35	12.68

Habitat choices of small mammals showed significant variation across habitats in the study area (Table 3). Several species of small mammals preferred the bushland habitat and the lowest number of small mammal species preferred the wooded grassland and plantation habitats, which were covered with scattered, few kinds of grass, herbs and old trees. Therefore, the highest trap success rate was recorded in the bushland (18.03%) (Table 3).

Species diversity showed variation in various habitats of the study area as shown in Table 4. The highest number of species (eight) was trapped from bushland habitat. This was covered with shrubs and tree-like vegetation of the montane zone and scrub followed by six species in the human-modified farmland and natural forest habitats.

During the present investigation, the highest diversity of small mammals was recorded in the bushland habitat (H'=1.75) followed by farmland (H'=1.74). Simpson's diversity index was also highest in farmland (D=0.82) followed by natural forest (D=0.80). The highest species evenness was recorded in the plantation habitat (E=0.98) followed by farmland (E=0.97) (Table 4).

Table 4: Species diversity index values of various habitats of Yegof Mountain Forest (F: Farmland; GL: Grassland; BL: Bushland; PL: Plantation; NF: Natural forest; WGL: Wooded grassland, H' = Shannon-Weaver diversity index, D = Simpson's diversity index (1-D), H_{max}= Natural logarithm of the total number of species, E= Evenness).

Habitats	Species composition	Total trapped individual	H'	D	H_{max}	E	SRI
FL	6	169	1.74	0.82	1.79	0.97	0.97
GL	5	134	1.33	0.73	1.61	0.83	0.82
BL	8	212	1.75	0.79	2.08	0.84	1.31
PL	3	82	1.08	0.65	1.10	0.98	0.45
NF	6	188	1.70	0.80	1.79	0.95	0.95
WGL	2	110	0.39	0.40	0.69	0.57	0.21

Species richness index of the study area varied from habitat to habitat as shown in Table 4. During the present investigation, the bushland habitat had the highest species richness index (SRI=1.31) followed by farmland (SRI=0.97).

Similarity index value also varied between paired habitats of the study area from the highest 0.91 similarity index value up to the lowest similarity index value (0.22) as shown in Table 5. The highest species similarity index value was observed between grassland and farmland (0.91) followed by natural forest and bushland (0.86). The lowest similarity index value was observed between plantation and farmland (0.22).

Table 5: Species similarity index between various habitats in the study area (F: Farmland; GL: Grassland; BL: Bushland; PL: Plantation; NF: Natural forest; WGL: Wooded grassland).

Habitat	FL	GL	BL	PL	NF	WGL
FL	1.00	0.91	0.57	0.22	0.67	0.25
GL	-	1.00	0.46	0.25	0.55	0.29
BL	-	-	1.00	0.55	0.86	0.40
PL	-	-		1.00	0.67	0.80
NF	-	-			1.00	0.50
WGL	-	-	-	-	-	1.00

The beta diversity value between habitats of the study area showed significant variation. The dissimilarity value of small mammal species between various habitats varied between 0.11 and 0.77 (Table 6). The highest beta diversity value (0.77) showed the highest variation in species composition between paired habitats and the lowest beta diversity value (0.11) indicated that paired habitats had more similar species. The highest beta diversity value was observed between plantation and farmland (0.77) followed by plantation and grassland (0.75) habitats.

Table 6: Beta diversity value in various habitats of the Yegof Mountain Forest (F: Farmland; GL: Grassland; BL: Bushland; PL: Plantation; NF: Natural forest; WGL: Wooded grassland).

Habitats	FL	GL	BL	PL	NF	WGL
FL	0.00	0.10	0.57	0.77	0.50	0.75
GL	-	0.00	0.54	0.75	0.45	0.71
BL	-	-	0.00	0.45	0.14	0.60
PL	-	-		0.00	0.33	0.20
NF	-	-	-	-	0.00	0.50
WGL	-	-	-	-	-	0.00

Small mammals were trapped from various altitudinal ranges of Yegof Mountain Forest. However, there was variation in abundance across various slopes of the study area. The abundance of small mammals showed statistically significant variation across varied altitudinal ranges of the study area (χ^2= 232.03, df= 2, p <0.05). *M. natalensis* is a widely distributed species from lowland to the highland altitudinal range between 1800-2927 m asl. However, more individuals were trapped from a lowland altitudinal range between 1800 - 2600 m asl. *S. albipes* was also the second most abundant species and mainly recorded from the middle and highland altitudinal range between 2201- 2927 m asl. However, *S.albipes* was not trapped from a lowland area in the altitudinal range between 1800 - 2200 m asl (Table 7). The highest trap success rate (13.66%) was recorded from the altitudinal range between 2201-2601 m asl followed by the altitudinal range between 1800- 2200 m asl (12.88%). The lowest trap success rate (9.35%) recorded from the altitudinal range between 2601-2927 m asl.

Table 7: Abundance of small mammals across altitudinal ranges of the study area.

Species	Altitudinal zonation (m asl)		
	1800-2200	2201-2600	2601-2927
M. natalensis	71	124	31
S. albipes	0	102	79
S. griseicauda	41	71	0
L. flavopunctatus	28	80	0
A. abysinicuss	97	0	0
O. typus	14	51	0
R. rattus	52	0	0
M. brockmani	0	47	0
SpA	0	5	0
C. flavescens	0	2	0
Total	303	482	110
Trap night	2352	3528	1176
Trap success (%)	12.88	13.66	9.35

Diversity index values varied in various altitudinal ranges of the Yegof Mountain Forest (Table 8). The highest number of species (eight species) was trapped from altitudinal ranges between 2201-2600 m asl, which was covered by shrubs and tree like vegetation of the montane zone and scrub followed by altitudinal ranges between 1800-2200 m asl. At this site six species were trapped and which was covered by various crops, grasses and other human-made vegetation. The lowest species (two species) were recorded from an altitudinal range between 2601-2927 m asl, which was also covered by grass and old and large trees. Species composition across altitudinal ranges of the study area was statistically insignificant (χ^2=3.50, df =2, p > 0.05). Shannon-Weaver diversity index was highest in the altitudinal range between 2201-2600 m asl (H'=1.79) followed by the altitudinal range between 1800-2200 m asl (H'=1.64). The lowest was found between altitudinal ranges 2601-2927 m asl (H' = 0.39). Simpson's diversity index was also highest from the altitudinal range between 2201-2600 m asl (D=0.82) followed by the altitudinal range between 1800-2200 m asl (D= 0.78). The lowest Simpson's diversity index of small mammals was found in the altitudinal ranges between 2601-2927 m asl (D=0.40) in the Yegof Mountain Forest. However, the highest species evenness was observed at the lower altitudinal ranges between 1800-2200 m asl (E=0.91) followed by the altitudinal range between 2201-2600 m asl (E=0.86). The lowest evenness value was observed in the altitudinal range between 2601-2927 m asl (E= 0.57).

Table 8: Species diversity index values across altitudinal ranges of the Yegof Mountain Forest (H' = Shannon-Weaver diversity index, H_{max}= Natural logarithm of the total number of species, D = Simpson's diversity index (1-D), E= Evenness, RI= Species richness index).

	Altitudinal range (m asl)		
Species	1800-2200	2201-2600	2601-2927
Number of species	6	8	2
Individual trapped	303	482	110
H'	1.64	1.79	0.39
H_{max}	1.79	2.08	0.69
D	0.78	0.82	0.40
Evenness	0.91	0.86	0.57

Species similarity index value varied across altitudinal ranges from the highest (0.57) to the lowest (0.25) as shown in Table 9. The highest species similarity index value was observed in the altitudinal range between 2201-2600 m asl and 1800-2200 m asl (0.57) followed by 2601-2927 m asl and 2201-2600 m asl (0.40). The lowest similarity index value was observed between 2601-2927 m asl and 1800-2200 m asl (0.25) altitudinal zone.

Table 9: Species similarity between various altitudinal zones of the study area.

Altitudinal zonation (m asl)	Similarity index		
	1800−2200	2201−2600	2601−2927
1800–2200	1.00	0.57	0.25
2201–2600	0	1.00	0.40
2601–2927	0	0	1.00

The beta diversity value of small mammals across altitudinal ranges varied from 0.43 to 0.75 (Table 10). The highest beta diversity value was observed between 2601-2927 m asl and 1800-2200 m asl altitudinal range. This indicated that there is a high species variation between the bottom and the top part of the Yegof Mountain Forest. The lowest value of beta diversity was observed between 2201-2600 m asl and 1800-2200 m asl altitudinal ranges.

Table 10: Beta diversity value across altitudinal ranges of Yegof Mountain Forest.

Altitudinal zonation (m asl)	Dissimilarity index		
	1800−2200	2201−2600	2601−2927
1800–2200	0.00	0.43	0.75
2201–2600	0	0.00	0.60
2601–2927	0	0	0.00

Out of the total trapped individuals, 489 individuals were trapped during the wet season and 406 individuals were recorded during the dry season. The highest individuls of *M. natalensis, S. griseicauda, L. flavopunctatus, A. abysinicuss, O.typus, M. brockmani,* SpA and *C. flavescens* were trapped during the wet season than the dry season. However, the highest individuals of *S. albipes* and *R. rattus* were recorded during the dry season. The abundance of small mammals between seasons did show statistically significant variation (χ^2= 7.70, df=1, p < 0.05). SpA and *C. flavescens* were trapped only during the wet season while S. *griseicauda, A. abysinicuss, L. flavopunctatu, M. natalensis, S. albipes, R. rattus, O.typus* and *M. brockmani* were trapped during both the wet and dry seasons. A total of ten species were captured during the wet season and eight species during the dry season. Species composition between seasons did not show statistically significant variation (χ^2= 0.22, df= 1, p > 0.05). There abundance of *M.natalensis, L. flavopunctatus, A. abysinicuss, M. brockmani* and *C. flavescens* did not show statistically significant variation between seasons (χ^2= 2.14, df =1, P > 0.05; χ^2= 0.14, df =1, P > 0.05; χ^2= 0.51, df =1, P > 0.05; χ^2= 0.19, df =1, P > 0.05; χ^2= 2, df =1, P > 0.05, respectively). However, the abundance of *S. albipes*, *R.rattus*, *S.griseicauda*, *O.typus* and SpA was show statistically significant variation between the wet and dry seasons (χ^2 = 11.19, df=1, p < 0.05; χ^2 = 9.31, df=1, p < 0.05, χ^2 = 48.89, df=1, p < 0.05; χ^2 = 16.75, df=1, p < 0.05; χ^2 = 5, df=1, p < 0.05, respectively) (Table 11).

Table 11: Abundance of small mammals during the wet and dry seasons in different habitats of the study area (F: Farmland; GL: Grassland; BL: Bushland; PL: Plantation; NF: Natural forest; WGL: Wooded grassland; W: Wet; D: Dry).

Species	The abundance of small mammals in various habitats												
	FL		GL		BL		PL		NF		WGL		Total
	W	D	W	D	W	D	W	D	W	D	W	D	
M. natalensis	29	10	23	9	33	31	8	13	7	32	24	7	226
S. albipes	0	0	0	0	0	16	11	23	20	32	37	42	181
S. griseicauda	27	0	14	0	28	11	0	0	24	8	0	0	112
L. flavopunctatus	20	0	0	8	36	11	0	0	0	33	0	0	108
A. abysinicuss	11	20	41	25	0	0	0	0	0	0	0	0	97
O.typus	14	0	0	0	14	16	0	0	21	0	0	0	65
R. rattus	15	23	0	14	0	0	0	0	0	0	0	0	52
M. brockmani	0	0	0	0	0	9	14	13	11	0	0	0	47
SpA	0	0	0	0	5	0	0	0	0	0	0	0	5
C. flavescens	0	0	0	0	2	0	0	0	0	0	0	0	2
Total	116	53	78	56	118	94	33	49	83	105	61	49	895

Small mammal abundance varied with seasons in various habitats. During the wet season, the highest individuals of small mammals were trapped from the bushland habitat (118) followed by farmland (116). However, during the dry season, more individuals were trapped from the natural forest habitat (105) followed by bushland (94) (Table 11). In over all, more individuals were captured during the dry season than the wet season in natural forest and plantation habitats. During the present investigation, the abundance of small mammals only in farmland habitat showed statistically significant variation between seasons (χ^2= 23.49, df=1, $p < 0.05$).

The species composition of the study area varied from season to season. Out of the total species recorded during the present investigation, six species were trapped in the farmland and bushland habitats each followed by five species in the natural forest habitats during the wet season (Fig. 6). During the dry season, six species were recorded from bushland, followed by four species from the grassland and natural forest. The overall species composition among the six habitats did not show statistically significant variation (χ^2= 4.80, df=5, $p > 0.01$).

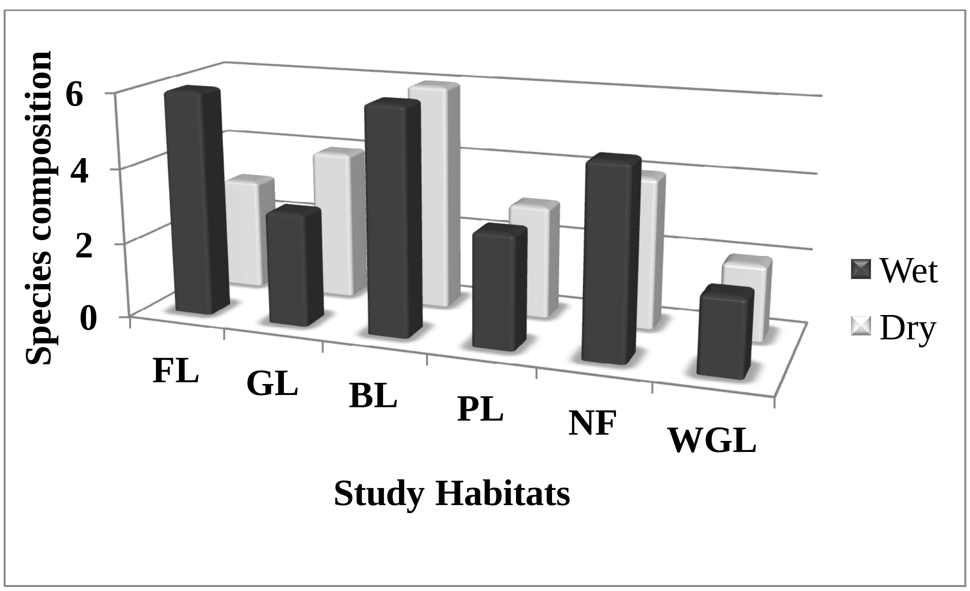

Figure 6: Species composition of small mammals in various habitats at different seasons (F=Farmland; GL= Grassland; BL=Bushland; PL=Plantation; NF= Natural forest; WGL=Wooded grassland).

Out of the total captured individuals, males comprised 497 (55.53%) individuals and females comprised 398 (44.47 %) individuals (Table 12). The abundance of males and female individuals did show statistically significant variation (χ^2= 10.95, df=1, $p < 0.01$). Higher number of males was caught during the wet season (267, 53.72%) than the dry season (230, 46.28%). Similarly, higher number of females was trapped during the wet season (222, 55.78%) than the dry season (176, 44.22 %). The abundance of males did not show statistically significant variation during the wet and dry seasons (χ^2= 1.37, df=1, $p > 0.05$). However, the abundance of females between seasons showed statistically significant variation (χ^2= 5.32, df=1, $p < 0.05$). The ratio of females to males was 1:1.25.

Table 12: Sex variation and distribution of small mammals at different seasons in the study area.

Species	Seasonal differences between sexes				Total
	Wet season		Dry season		
	Male	Female	Male	Female	
M. natalensis	66	58	62	40	226
S. albipes	39	29	63	50	181
S. griseicauda	52	41	11	8	112
L. flavopunctatus	28	28	29	23	108
A. abysinicuss	27	25	26	19	97
O.typus	26	23	9	7	65
R. rattus	11	4	17	20	52
M. brockmani	16	9	13	9	47
SpA	2	3	0	0	5
C. flavescens	0	2	0	0	2
Total (10)	267	222	230	176	895

Age structure of small mammals between seasons in the present investigation area is shown in Table 13. Out of the total small mammal individuals trapped during the present investigation, adults comprised (612, 68.38%), sub-adult (180, 20.11 %) and young (103, 11.51 %). During the wet season, adults comprised (332, 37.09 %), sub-adults (95, 10.61 %) and young (62, 6.93 %), whereas during the dry season, adults contained (280, 31.28%), sub-adults (85, 9.50 %) and young (41, 4.58 %). Adult individuals comprised the highest proportion during both the wet and dry seasons. The trapped individuals of adult (χ^2= 4.42, df=1, $p < 0.05$) and young (χ^2= 4.28, df=1, $p < 0.05$) showed statistically significant variation between seasons. However, the occurrence of sub-adult individuals did not show statistically significant variation between seasons (χ^2= 0.56, df=1, $p > 0.05$).

Table 13: Age class distribution of small mammals between seasons.

Seasons	Age groups			
	Adult	Sub-adult	Young	Total
Wet	332	95	62	489
Dry	280	85	41	406
Total	612 (68.38 %)	180 (20.11 %)	103 (11.51%)	895 (100 %)

Trap success of small mammals in various habitats during the wet and dry seasons is shown in Table 14. Highest trap success was observed in the bushland habitat (20.07%) and the lowest was in the plantation habitat (5.61%). During the wet season, trap success was highest in the bushland (20.07%) followed by farmland (19.73%). During the dry season, trap success was highest in the natural forest habitat (17.86 %) followed by bushland habitat (15.99 %). Trap success in the farmland habitat showed statistically significant variation between the wet and dry seasons (χ^2=4.00, df=1, $p < 0.01$). However, trap success in grassland, bushland, plantation, natural forest and wooded grassland habitats did not show statistically significant variations between seasons (χ^2=0.61, df=1, $p > 0.05$, χ^2=0.46, df=1, $p > 0.05$, χ^2=0.53, df=1, $p < 0.01$, χ^2=0.44, df=1, $p > 0.05$, χ^2= 0.22, df=1, $p > 0.05$, respectively). The overall trap success from all habitats in the study area did not show statistically significant variation (χ^2= 6.92, df=5 p > 0.05). Similarly, the overall trap success between the season in the study area did not show statistically significant variation (χ^2= 1.31, df=1 p >0.05). The overall trap success of small mammals between habitats of the Yegof Mountain forest was 12.68%. Trap success was higher during the wet season (13.86%) than the dry season (11.51%). However, trap success did not show statistically significant variations between seasons (χ^2=0.22, df=1, p > 0.05).

Table 14: Trap success of small mammals in various habitats.

Habitats	Seasons	Total caught	Trap night	Trap success
Farmland	Wet	116	588	19.73
	Dry	53	588	9.01
Grassland	Wet	78	588	13.27
	Dry	56	588	9.52
Bushland	Wet	118	588	20.07
	Dry	94	588	15.99
Plantation	Wet	33	588	5.61
	Dry	49	588	8.33
Natural forest	Wet	83	588	14.12
	Dry	105	588	17.86
Wooded grassland	Wet	61	588	10.37
	Dry	49	588	8.33
Total/Average		895	7056	12.68

Trap success as well as the occurrence of small mammals were influenced by seasons during the present investigation. As a result, more individuals were recorded during the wet season. However, only two species *S. albipes* and *R.rattus* had higher trap success during the dry season than the wet season as shown in Table 15. The trap success of small mammals ranged from 0.34% to 21.09%. *M. natalensis* had the highest trap success

(21.09 %) during the wet season and the lowest trap success was recorded for SpA (0.85%) and *C. flavescens* (0.34%) during the present investigation.

Table 15: Trap success of small mammals during the wet and dry seasons (F= Farmland, GL= Grassland, BL= Bushland, PL= Plantation, NF= Natural forest, WGL= Wooded grassland).

Species	Habitats	Season	Total caught	Trap Night	Trap success
M. natalensis	FL, GL, BL, PL, NF, WGL	Wet	124	588	21.09
		Dry	102	588	17.35
S. albipes	BL, PL, NF and WGL	Wet	68	588	11.56
		Dry	113	588	19.22
S. griseicauda	FL, GL, BL and NF	Wet	93	588	15.82
		Dry	19	588	3.23
L. flavopunctatus	FL, GL, BL and NF	Wet	56	588	9.52
		Dry	52	588	8.84
A. abysinicuss	FL and GL	Wet	52	588	8.84
		Dry	45	588	7.65
O. typus	FL, BL and NF	Wet	49	588	8.33
		Dry	16	588	2.72
R. rattus	FL and GL	Wet	15	588	2.55
		Dry	37	588	6.29
M. brockmani	BL, PL and NF	Wet	25	588	4.25
		Dry	22	588	3.74
SpA	BL	Wet	5	588	0.85
		Dry	0	588	0.00
C. flavescens	BL	Wet	2	588	0.34
		Dry	0	588	0.00
Total/Average			895	7056	12.68

Trap success of small mammals varied in altitudinal ranges. During the current investigation, the highest trap success of small mammals was registered in the altitudinal range between 2201-2600 m asl (13.66%) followed by the altitudinal range between 1800-2200 m asl (12.88%). The lowest trap success was recorded in the altitudinal range between 2601-2927 m asl (9.35%) as shown in Table 16.

Table 16: Trap success of small mammals across altitudinal ranges.

Species	Altitudinal zonation		
	1800-2200 m asl	2201-2600 m asl	2601-2927 m asl
M. natalensis	3.02	3.51	2.64
S. albipes	0.00	2.89	6.72
S. griseicauda	1.74	2.01	0
L. flavopunctatus	1.19	2.27	0
A. abysinicuss	4.12	0.00	0
O. typus	0.60	1.45	0
R. rattus	2.21	0.00	0
M. brockmani	0.00	1.33	0
SpA	0.00	0.14	0
C. flavescens	0.00	0.06	0
Total	303	482	110
Trap night	2352	3528	1176
Trap success	12.88	13.66	9.35

Based on Jackknife species richness estimation from grid count, 12 species were estimated at 95% confidence interval. Among these, two species were unique as the species were recorded only in one habitat. The population size of live trapped small mammal species varied between the wet and the dry seasons. The highest population of small mammals was recorded during the second wet season and the lowest during the second dry season. The population size of small mammals between seasons showed statistically significant variation (χ^2= 17.29, df= 3, P < 0.05).

The population density of small mammals varied in different habitats during the current investigation as shown in Table 17. *M. natalensis* had the highest density in the bushland habitat (130.61/ha) followed by farmland (79.59/ha). *S. albipes* had a density in the wooded grassland habitat (161.22/ha) followed by the natural forest habitat (106.12 /ha). *S. albipes* was not recorded in the farmland and grassland habitats of the study area. The density of *S. griseicauda* was 79.59/ha in the bushland habitat. *S. griseicauda* and *L. flavopunctatus* were not trapped from plantation and wooded grassland habitats. The density of *A. abysinicuss* was 134.69/ha in the grassland habitat. *A. abysinicuss* and *R. rattus* were not recorded from bushland, plantation, natural forest and wooded grassland habitats. In over all, *M. natalensis* had the highest mean density (76.87/ha) followed by *S. albipes* (61.57/ha) and the lowest density recorded for *C. flavescens* (0.68/ha) in the present study area.

Table 17: Density (ha^{-1}) of small mammals in various habitats (F= Farmland, GL= Grassland, BL= Bushland, PL= Plantation, NF= Natural forest, WGL= Wooded grassland).

Species	Habitats						
	FL	GL	BL	PL	F	WGL	Mean
M. natalensis	79.59	65.31	130.61	42.86	79.59	63.27	76.87
S. albipes	0	0	32.65	69.39	106.12	161.22	61.57
S. griseicauda	55.10	28.57	79.59	0	65.31	0	38.10
L. flavopunctatus	40.82	16.33	95.92	0	67.35	0	36.74
A. abysinicuss	63.27	134.69	0	0	0	0	32.99
O.typus	28.57	0	61.22	0	42.85	0	22.11
R. rattus	77.55	28.57	0	0	0	0	17.69
M. brockmani	0	0	18.37	55.10	22.45	0	15.99
SpA	0	0	10.20	0	0	0	1.70
C. flavescens	0	0	4.08	0	0	0	0.68
Mean	34.90	27.35	43.27	16.74	38.37	22.45	30.44

On the other hand, bushland habitat comprised the highest mean density of small mammals (43.27/ha) followed by 38.37 /ha in the natural forest (Table 17). The density of small mammal species across altitudinal ranges of the study area is given in Table 18. *M. natalensis* and *S. albipes* had the highest mean density (153.74/ha and 123.13/ha, respectively) in the altitudinal range between 2201-2927 m asl. Similarly, the altitudinal range between 2201-2600 m asl comprised the higher density of small mammals (98.37 individuals/ha) followed by 61.84/ha in the altitudes between 1800-2200 m asl.

Table 18: Density (ha^{-1}) of small mammals across altitudinal ranges.

Species	Altitudinal zonation (m asl)			Mean
	1800-2200	2201-2600	2601-2927	
M. natalensis	144.9	253.06	63.27	153.74
S. albipes	0	208.16	161.22	123.13
S. griseicauda	83.67	144.9	0	76.19
L. flavopunctatus	57.14	163.27	0	73.47
A. abysinicuss	197.96	0	0	65.99
O. typus	28.57	104.08	0	44.22
R. rattus	106.12	0	0	35.37
M. brockmani	0	95.92	0	31.97
SpA	0	10.2	0	3.40
C. flavescens	0	4.08	0	1.36
Mean	61.84	98.37	22.45	60.88

3.2. Snap-trapping

A total of nine species of rodents were captured by using snap traps in the present study area. However, the insectivore *C. flavescens* was not trapped by snap-traps during the present investigation. A total of 165 individuals were trapped from these nine species within 3, 600 trap nights. The distribution and habitat association of rodents were varied in the Yegof Mountain Forest. *M. natalensis* was widely distributed and found in all habitats. However, *R. rattus* and *A. abysinicuss* preferred and trapped from farmland and grassland habitats or the lower part of the study area. *S. albipes* was also mainly trapped from bushland, natural forest and Juniper plantation habitats of the study area. However, SpA was restricted in the bushland habitat.

Out the total trapped rodents by snap trapping, *M. natalensis* was the most abundant (37, 22.42%) followed by *A. abysinicuss* (30, 18.18%) (Table 19). The lowest recorded species was SpA (2, 1.21%). The abundance of snap trapped rodents varied from habitat to habitats. Highest individuals of rodents were trapped from farmland habitat (43, 26.06%) followed by grassland habitat (32, 19.39%). The overall trap success of the snap trapped individuals was 4.58 in and around the Yegof Mountain Forest.

Table 19: Distribution and abundance of snap-trapped small mammals in various habitats of the study area (F= Farmland, GL= Grassland, BL= Bushland, PL= Plantation, NF= Natural forest, WGL= Wooded grassland).

Species	Habitats of small mammals					
	FL	GL	BL	PL	NF	WGL	Total
M. natalensis	10	3	8	5	6	8	37
S. albipes	0	0	2	5	7	12	26
S. griseicauda	7	6	9	0	6	0	28
L. flavopunctatus	7	2	2	0	6	0	17
A. abysinicuss	10	20	0	0	0	0	30
O. typus	6	0	3	0	4	0	13
R. rattus	3	1	0	0	0	0	4
M. brockmani	0	0	3	4	1	0	8
SpA	0	0	2	0	0	0	2
Total	43	32	29	14	30	17	165

Body measurements of snap trapped rodents are shown in Table 20. Body weight ranged from 39.50 g in *M. brockmani* to 95.50 g in *R. rattus* during the present investigation. Similarly, there was variation in body length and tail length between different species. *M. natalensis, S. griseicauda, L. flavopunctatus, A. abysinicuss* and *O. typus* had relatively shorter tail than their body length. However, *S. albipe, R. rattus, M. brockmani* and SpA had a longer tail than their body length.

Table 20: Mean body measurements for snap trapped rodents in the study area (BW= Body weight, HB= Head body length, TL= Tail length, HL= hind foot length, EL= Ear length).

Species	Body measurements (Mean±SE)				
	BW	HB	TL	HL	EL
M. natalensis	56.47±2.41	13.08±0.31	11.88±0.27	3.19±0.12	1.62±0.04
S. albipes	53.31±2.36	12.10±0.25	14.99±0.26	4.47±0.68	1.64±0.04
S. griseicauda	79.93±5.79	13.36±0.46	11.85±0.47	3.43±0.13	1.67±0.08
L. flavopunctatus	59.77±2.29	11.79±0.27	7.58±0.19	2.60±13	1.58±0.05
A. abysinicuss	76.77±6.23	13.27±0.30	10.57±0.21	2.96±0.08	1.56±0.02
O. typus	73.39±8.28	13.08±0.51	8.23±0.69	2.70±0.16	1.49±0.01
R. rattus	95.50±20.41	12.75±1.01	13.00±0.94	3.25±0.43	1.63±0.16
M. brockmani	39.50±3.55	10.50±0.52	12.88±0.79	3.50±0.13	1.39±0.04
SpA	44.00±6.00	10.75±0.75	13.00±1.00	3.50±0.00	1.50±0.00

Embryos were counted for snap trapped pregnant females of eight rodent species as shown in Table 21. During the present investigation, more number of pregnant females were recorded during the wet season. The number of embryos also varied from species to species. The highest number of embryos recorded for *M. natalensis* and the lowest for *L. flavopunctatus* during the present investigation.

Table 21: Number of embryos for each species at different seasons.

Species	Number of pregnancies with seasons		Number of embryos
	Wet	Dry	
M. natalensis	7	2	3–7
S. albipes	6	-	2–5
L. flavopunctatus	7	2	2–4
S. griseicauda	5	4	3–5
A. abysinicuss	5	-	4–7
O. typus	5	3	2–3
M. brockmani	2	-	2–3
R. rattus	3	-	3–5
Total	39	12	

Diet composition varied from species to species during the wet and dry seasons as shown in Table 22. Animal matters (hairs, insects) and plant shoots were more abundant during the wet season in the stomach of rodents. During the dry season, plant roots, seeds and stem were abundant.

Table 22: Percentage of diet composition of rodents at seasons (DL = dicot leaf, DS = dicot seed, ML = monocot leaf, MS = monocot seed, PR = plant root, AM = nimal matter, UM = undifferentiated materials).

Species	Season	No.	Types of diet (percentage)						
			ML	DL	MS	DS	PR	AM	UM
M. natalensis	Wet	5	40.24	13.05	20.52	-	-	19.11	7.08
	Dry	5	19.69	-	16.75	18.38	34.62	-	10.56
S. albipes	Wet	5	14.56	12.82	21.63	13.42	11.67	17.18	8.72
	Dry	5	-	-	36.32	23.75	26.43	5.3	8.2
S. griseicauda	Wet	5	26.67	-	-	16.32	-	20.34	12.98
	Dry	5	13.56	7.87	27.8	9.46	39.78	13.78	15.57
L. flavopunctatus	Wet	5	31.18	-	28.67	-	3.64	33.06	3.48
	Dry	5	15.78	-	31.11	12.47	19.59	21.06	-
A. abysinicuss	Wet	5	52.64	8.14	13.44	-	-	13.82	11.99
	Dry	4	12.33	4.34	20.89	17.76	27.32	6.28	11.08
O. typus	Wet	2	34.87	4.68	24.34	17.11	3.82	6.05	12.96
	Dry	2	15.55	6.33	41.53	-	21.90	-	14.72
M. brockmani	Wet	2	42.22	24.8	-	11.77	6.37	-	14.84
	Dry	2	36.88	21.29	12.19	9.55	8.23	7.65	4.21
R. Rattus	Wet	4	32.57	14.66	13.89	8.67	5.65	18.29	6.27
	Dry	2	19.87	11.43	19.54	17.87	23.36	4.76	3.17
SpA	Wet	2	-	37.88	23.14	29.11	-	-	17.68

3.3. Pest implications of small mammals

Eight pest rodent species were recorded through field observation, trapping, and stomach content analysis. Among these, six pest species of rodents were trapped by using Sherman and snap traps. However, *Hystrix cristata* and *T. splendens* were recorded through direct and indirect evidences as a pest species in the farmland habitat of the study area. Out of the total trapped pest rodent species, *M. natalensis* was the most abundant in the cropland. Shrews and rock hyraxes were not registered as pests by the local community.

A total of 300 respondents were randomly selected from eight villages of the study area for an interview. Among these, 232 individuals were males and 68 individuals were females as shown in Table 23. The number of selected respondents from various villages of the study area showed statistically significant variation ($\chi^2 = 49.01$, df= 7, $p < 0.05$). Similarly, the sex ratio of the respondents also showed statistically significant variation ($\chi^2 = 89.65$, df= 1, $p < 0.05$).

Table 23: Percentage of male and female respondents at different villages (N=300).

Villages	Sex of respondents		Total
	Males	Females	
Sidenager	13.30	0.70	14.00
Mentera	14.00	4.00	18.00
Dagna	16.30	2.00	18.30
Albati	5.30	6.70	12.00
Tabeta	2.70	0.30	3.00
Bokimos	6.30	2.70	9.00
Abalemine	14.30	2.70	17.00
Beleager	5.00	3.70	8.70
Total	77.30	22.70	100.00

A sex difference was not important to shift the attitude of local farmers towards small mammal conservation during the present investigation in and around Yegof Mountain Forest as shown in Table 24. However, males had a better understanding of the essential of small mammal conservation than females. The attitude of the local respondents showed statistically significant variation in the conservation of small mammals between sex differences (χ^2=136.01, df=1, $p < 0.05$).

Table 24: Respondents attitude based on sex differences towards rodent species and their conservation (N=300).

Sex	Attitude of respondents		
	Positive	Negative	Total
Males	14.00	63.30	77.30
Females	2.30	20.30	22.70
Total	16.30	83.70	100.00

From all age categories, the majority of respondents had a negative attitude towards rodents and their conservation. However, young respondents had more positive attitude towards rodents and their conservation than older respondents (Table 25). Attitude of the local respondents showed statistically significant variation in the conservation of small mammals under various age categories ($p < 0.05$).

Table 25: Respondents attitude towards rodents under various age categories (N=300).

Age category (years)	Attitude of respondents (%)		
	Positive	Negative	Total
21-30	1.00	2.00	3.00
31-40	4.70	14.70	19.30
41-50	6.70	24.30	31.00
51-60	2.30	22.70	25.00
> 60	1.70	20.00	21.70
Total	16.30	83.70	100.00

Attitude of local farmers based on their educational status is given in Table 26. Out of the total respondents, the majority were informal 155 (51.70 %) followed by illiterate 89 (29.70%). As a result, the majority of the respondents in the current study area had a negative attitude (223, 83.70 %) towards rodents and 77 (16.30 %) had a positive attitude towards small mammals. The educational status of the local community did not influence their negative attitude towards rodent conservation. However, the respondents who had better educational status (primary and secondary) had a relatively more positive attitude than the others.

Table 26: Attitude of respondents towards rodent species at various educational levels (N=300).

Educational status	Attitude of respondents (%)		
	Positive	Negative	Total
Illiterate	0.70	29.00	29.70
Informal	7.70	44.00	51.70
Primary	6.30	7.70	14.00
≥ Secondary	1.70	3.00	4.70
Total	16.30	83.70	100.00

Out of the total respondents, 137 (45.70) had their farmland less than 1 km from forest boundary followed by 1-3 km (99, 33.00) (Table 27). Some households living far away > 6 km (41, 13.70 %) from the forest boundary. The distance of respondents to the study area showed statistically significant variation between villages (χ^2= 110.40, df= 3, $p < 0.05$).

Living

Table 27: Approximate distance of farmland from forest boundary in various villages.

Villages	Percentage of respondents with various distances				
	< 1 km	1-3 km	3.1-6 km	> 6 km	Total
Sidenager	5.00	5.70	1.30	2.00	14.00
Mentera	3.70	10.70	1.70	2.00	18.00
Dagna	13.00	4.00	0.30	1.00	18.30
Albati	2.30	4.70	2.00	3.00	12.00
Tabeta	0.70	2.00	0.00	0.30	3.00
Bokimos	4.70	1.00	0.70	2.70	9.00
Abalemine	11.30	3.70	0.70	1.30	17.00
Beleager	5.00	1.30	1.00	1.30	8.70
Total (8)	45.70	33.00	7.70	13.70	100.00

The main source of income for local farmers of the study area was from agriculture (284, 94.70 %). However, few farmers have mixed crop cultivation (14, 4.70%) and livestock husbandry (2, 0.70%) as a source of income. The source of income of local respondents showed statistically significant variation between villages ($p < 0.05$).

During the present investigation, various kinds of crops were grown in the farmland such as wheat, barley, teff, maize, sorghum, pea, beans, chickpea, lentil and various types of vegetables. However, barley, teff, wheat and maize were the most grown crops by farmers (Fig. 7). As a result, local farmers claim that rodents have a serious impact on their crop production. Out of the total respondents, 188 (62.70%) respondents grow barley, teff and wheat followed by maize and sorghum (44, 14.70%). Types of crop grown by the respondents in their farmland showed statistically significant variation (χ^2= 349.70, df= 4, $p < 0.05$).

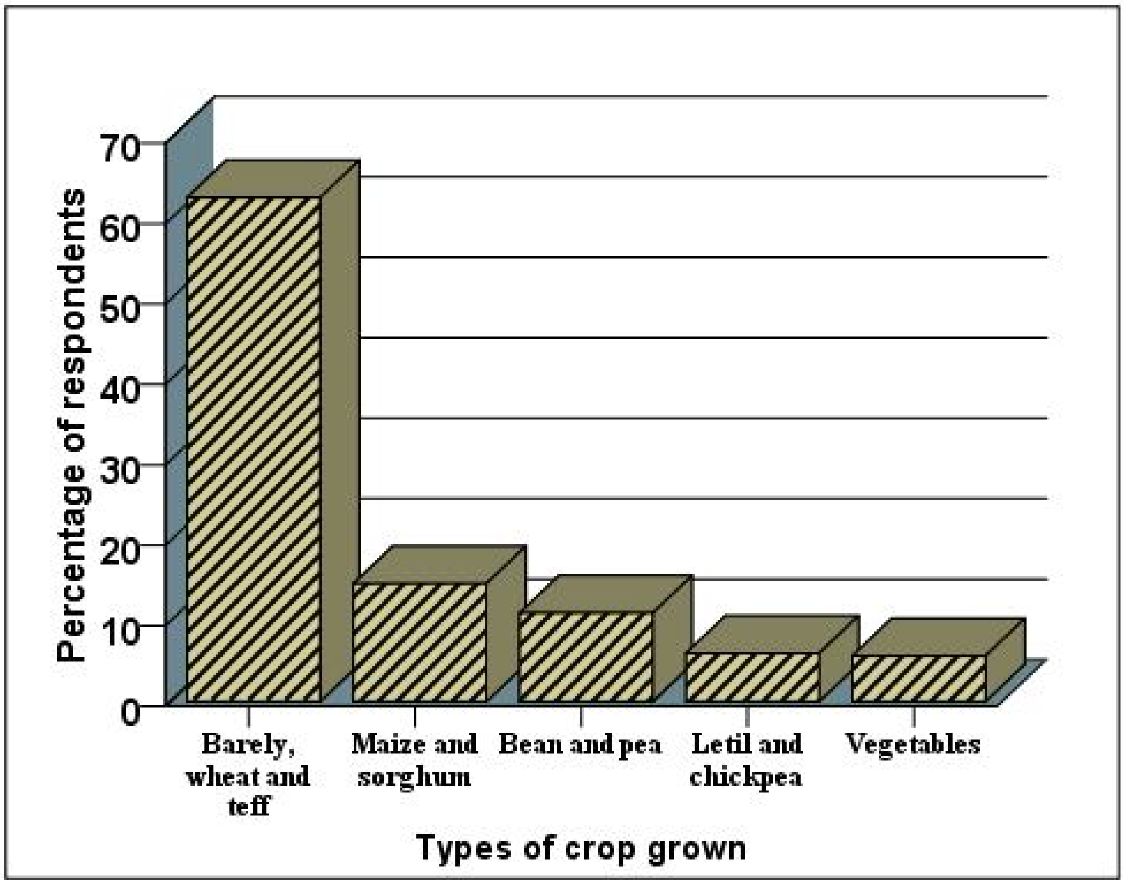

Figure 7: Type of crops grown in the study area.

The majority of respondents of the study area responded that all types of crops were vulnerable to rodent damage at various stages of growth. Out of the total respondents, 164 (54.70%) responded that crops were susceptible to rodent damage at the maturity stage followed by booting (98, 32.70%). The vulnerable growth stage of crops by rodent damage in the current study area showed statistically significant variation (χ^2= 349.70, df= 4, $p < 0.05$) (Fig. 8).

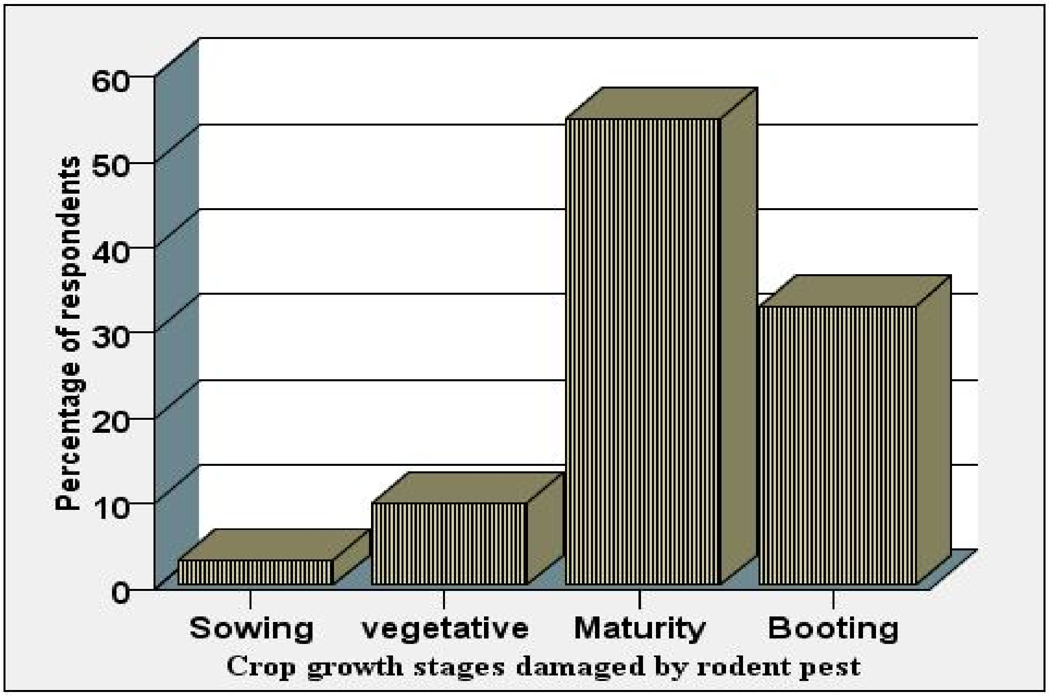

Figure 8: Response of local farmers to vulnerable stages of crop growth by pest rodents.

The level of crop damage varied from species to species. Porcupines and rats damaged different types of crops. Porcupines greatly damage maize and sorghum (179, 59.70 %) followed by lentil and chickpea (46, 15.30 %) and rarely barley, wheat and teff. However, barely, wheat and teff (230, 76.7 %) were enormously damaged by rats followed by bean and pea (29, 9.70 %) (Table 28).

Table 28: Percentage of local farmers' responses to crop damage by rodents (N=300).

Crops	Porcupines		Rats	
	Respondents	Percentage	Respondents	Percentage
Barely, wheat & teff	7	2.30	230	76.70
Beans & peas	35	11.70	29	9.70
Lentil & chickpea	46	15.30	14	4.70
Maize & Sorghum	179	59.70	11	3.70
Vegetables	33	11.00	16	5.30
Total	300	100.00	300	100.00

Time of crop damaged by pest rodents is shown in figure 9. The occurrence of pest rodents in the cropland varied with time. The majority of respondents of the study area claim that rodents damage the crops during both the day and night time (275, 91.70%) followed by night time (19, 6.30%) and day time only (6, 2.00%). Pest rodent occurrence between time showed statistically significant variation (χ^2= 460.22, df= 2, $p < 0.05$).

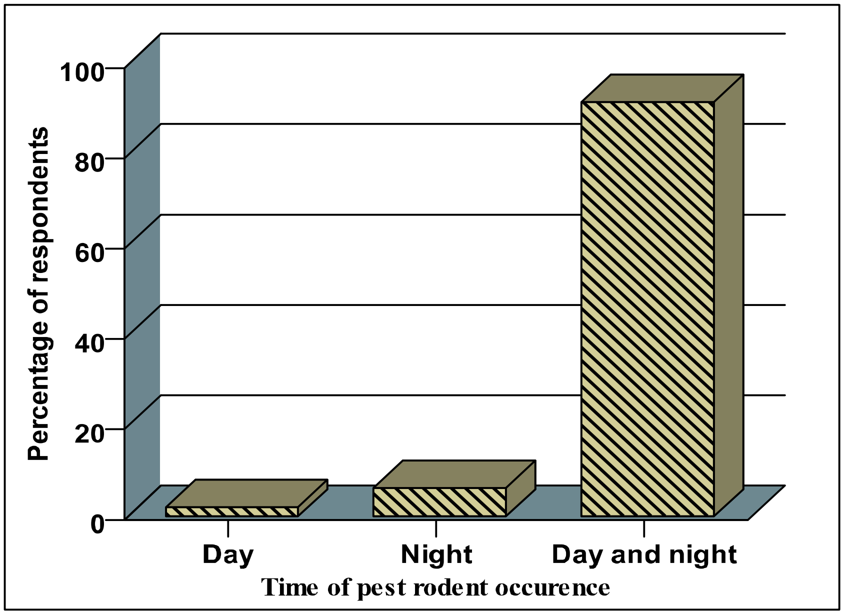

Figure 9: Rodent occurrence in the study area.

In addition, the intensity of crop damage varied with seasons. During the current investigation, rodents greatly damage crops more during the wet season (259, 86.30%) than the dry season (8, 2.70 %) (Fig. 10). The occurrence of rodents in the cropland of farmers showed statistically significant variation between seasons (χ^2= 382.34, df= 2, $p < 0.05$).

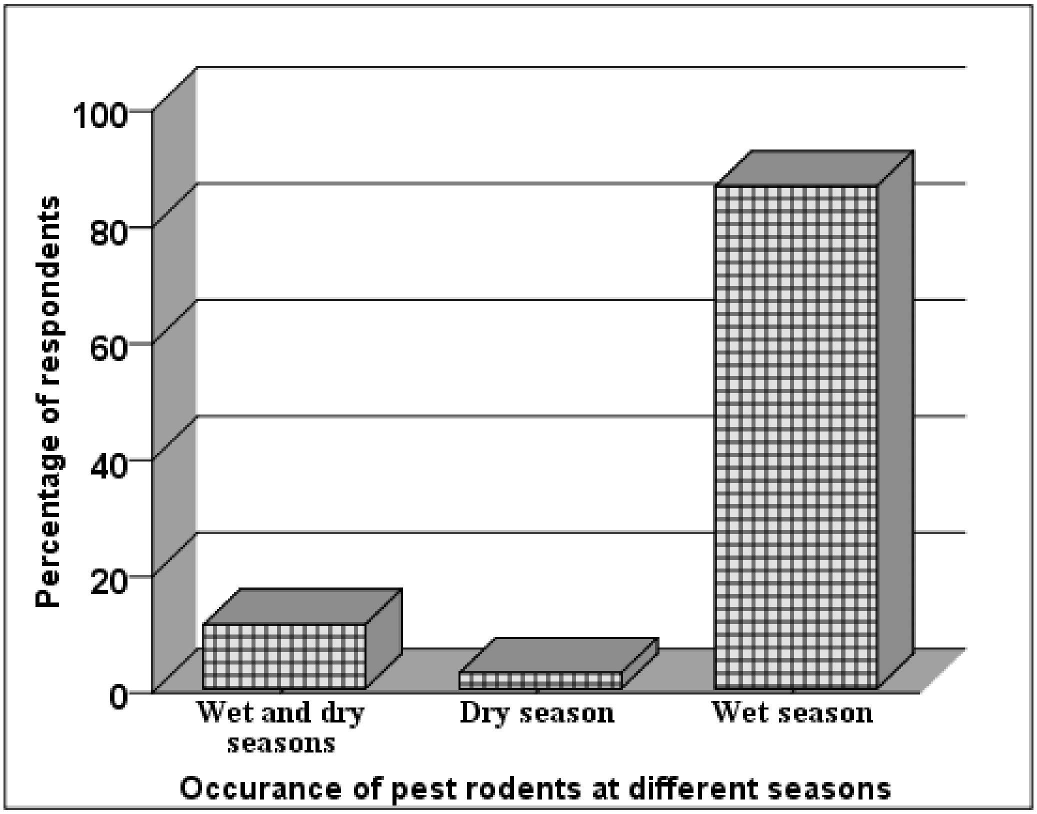

Figure 10: Farmer response to the seasonal occurrence of rodents in the study area.

The local farmers responded that the population status of pest rodents varied with seasons as shown in Table 29. During the present investigation, the majority of respondents noted that the population status of rodents increased during the wet season (253, 86.30 %) than the dry season (5, 2.70 %).

Table 29: Population status of rodents during the wet and dry seasons as responded by farmers in the study area.

Seasons	Population status of rodents (%)			Total
	Increased	Decreased	The same	
Dry season	1.70	0.00	1.00	2.70
Wet season	84.30	1.30	0.70	86.30
Wet and dry seasons	10.00	0.00	1.00	11.00
Total	96.00	1.30	2.70	100.00

During the present investigation, the majority of respondents responded that rodents occur regularly (207, 69.00%) every crop grown season followed by occasional (80, 26.70%) (Table 30). The outbreak of pest rodents in the cropland of the study area did not show variation between farmland distances from the forest boundary.

Table 30: Percentage of respondents to the outbreak of pest rodents in the cropland at various distances from the forest boundary (N= 300).

Farmland distance	Occurrence of pest rodents on crop damage			Total
	Regular	Occasional	Rare	
< 1 km	15.30	29.00	1.30	45.70
1-3 km	8.30	22.30	2.30	33.00
3.1-6 km	0.30	6.70	0.70	7.70
> 6 km	2.70	11.00	0.00	13.70
Total	26.70	69.00	4.30	100.00

Pest rodent damage was widely distributed in all parts of the farmland. However, the abundance and diversity of rodents varied from area to area due to the presence of several factors such as predators, resource availability and habitat coverage. During the present investigation the majority farmers responded that rodent damage was random in their cropland (Fig. 11). The variation between the distribution of rodent damage in the farmland showed statistically significant variation (χ^2= 257.28, df= 2, $p < 0.05$).

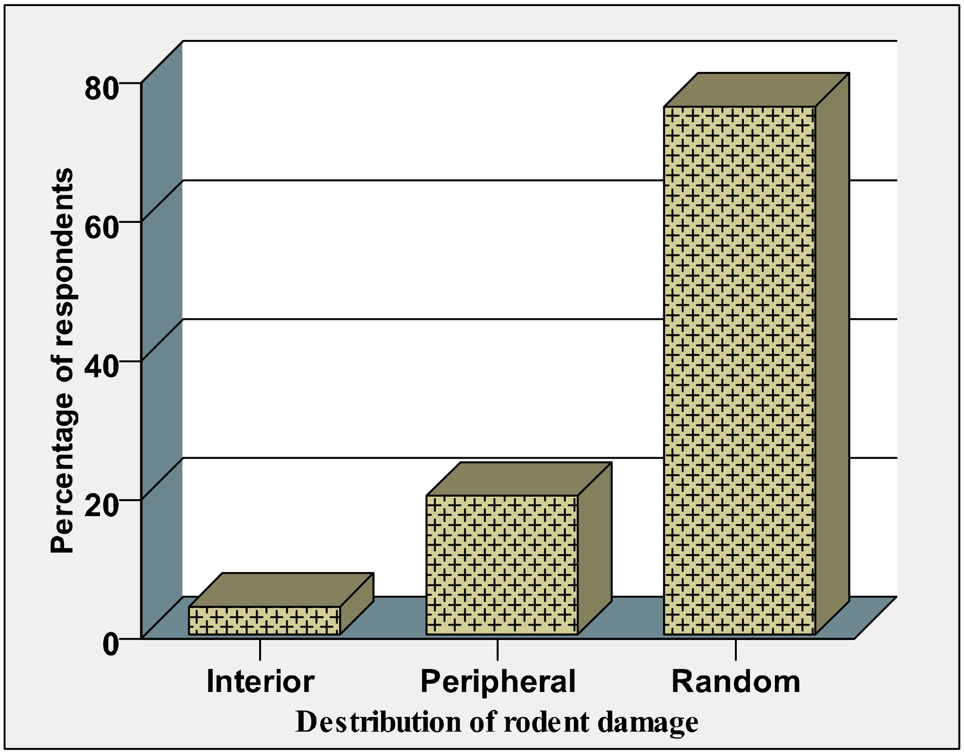

Figure 11: Distribution of rodent damage in the farmland of the study area (N=300).

The tendency of rodent damage responded by the local farmers showed statistically significant variation (χ^2= 292.05, df= 1, $p < 0.05$). Based on the data obtained from the local respondents, rodent damage did not depend on the distance from the margin of the protected area. Distance from the forest and trends of crop damage were shown in Table 31.

Table 31: Tendency of crop damage by a rodent in the study area (N=300).

Farmland distance	The tendency of crop damage		
	Increased	Decreased	Total
< 1 km	45.00	0.70	45.70
1–3 km	33.00	0.00	33.00
3.1–6 km	7.70	0.00	7.70
> 6 km	13.70	0.00	13.70
Total	99.30	0.70	100.00

The level of crops damaged by pest rodent species ranged from high to low. The majority of the respondents responded that different levels of crop damage occur in the present study area (Fig. 12).

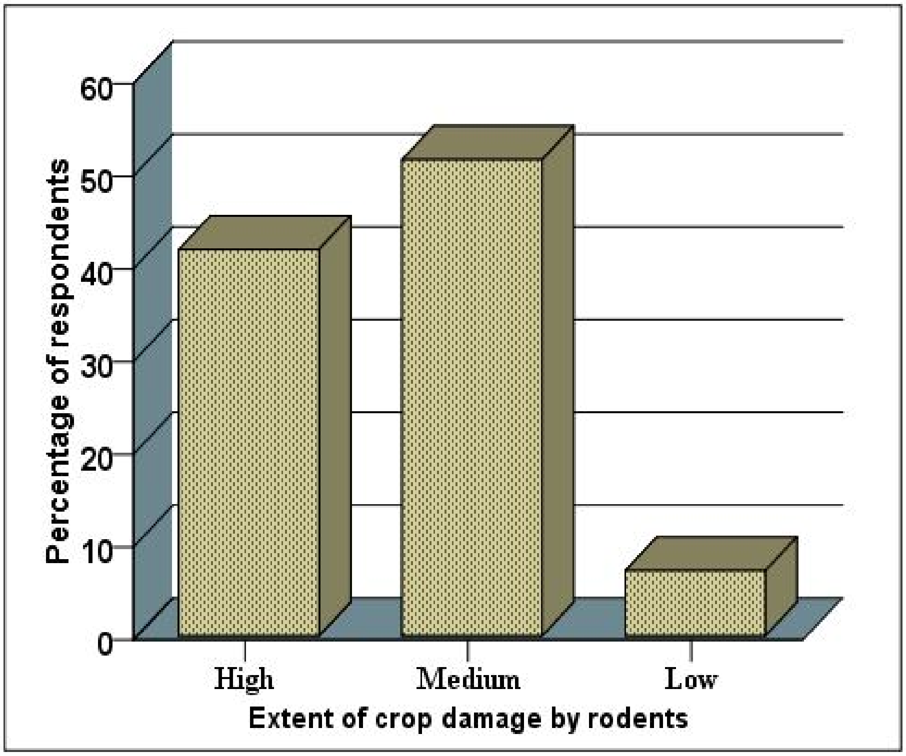

Figure 12: Extent of crop damaged by pest rodents (N=300).

Different types of control techniques were practiced by local communities before and after planting the crops in the study area as shown in Table 32. The farmers use rodenticides, field sanitation, biological techniques and trapping techniques to control pest rats in the study area. Out of the total respondents, 162 (54.00 %) used the combination of traps, chemicals and predator control techniques, traps and chemicals (91, 30.30 %), traps and predators (34, 11.30 %) and traps and field sanitation (13, 4.30 %) to control pest rats in their cropland. However, the majority of the respondents preferred biological and rodenticide control techniques as effective. The variation in the practice of control techniques showed statistically significant variation (χ^2= 178.00, df= 3, $p < 0.05$). The majority of farmers used a pest control technique after planting (270, 90.00 %), before and after planting (28, 9.33%) and before planting (2, 0.67%). The time of usage of the control techniques to minimize crop damage in the present study area showed statistically significant variation (χ^2= 436.88, df= 2, $p < 0.05$).

Table 32: Rat control techniques practiced by local farmers in the study area (N=300).

Time of control	Control techniques of rat damage				
	Traps and field sanitation	Traps and chemical	Traps and predators	Traps, chemicals and predators	Total
Before planting	0.00	0.30	0.00	0.30	0.67
After planting	3.70	27.30	10.00	49.00	90.00
Both	0.70	2.70	1.30	4.70	9.33
Total	4.30	30.30	11.30	54.00	100.00

Most respondents of the study area were used field sanitation, chasing, fences, guarding and trapping techniques to control porcupine damage in the study area (Table 33). Out of the total respondents, 259 (86.30 %) used the combination of traps and guarding control techniques. The majority of respondents preferred traps and guarding control techniques to minimize crop damage. Several farmers use the control techniques more after planting (270, 90.00%) than before and after planting (28, 9.33%) and before planting (2, 0.67%).

Table 33: Porcupine control techniques practiced and time of control by respondents in the study area (N=300).

Time of control	Control techniques of porcupine damage				
	Traps and fence	Chasing	Hole and field sanitation	Traps and guarding	Total
Before planting	0.30	0.00	0.00	0.30	0.70
After planting	4.00	0.70	6.30	79.00	90.00
After and before planting	1.30	0.00	1.00	7.00	9.30
Total	5.70	0.70	7.30	86.30	100.00

In the present study area, the size of farmland varied from household to household. Out of the total respondents, 144 (48.00%) respondents had 1–5 ha of farmland. The loss of crop production is directly related to the size of farmland. The increment of farmland area results in a high loss of crop production by pest rodents (Fig. 13). There was a statistically significant variation between farmland size and loss of crop production ($F=65.253$, $p < 0.0001$).

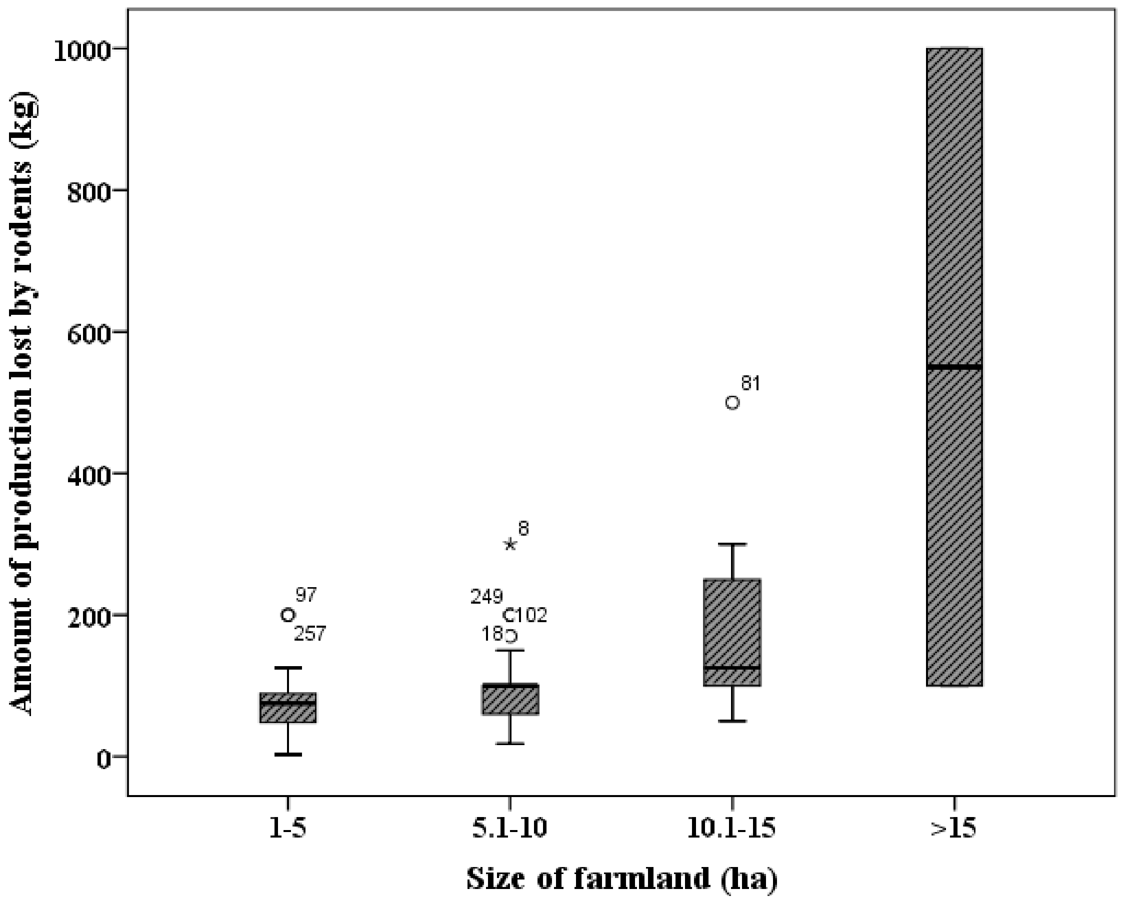

Figure 13: Amount of yield lost by rodents per hectare.

Farmers who had the lowest size of farmland in hectare (1–5 ha) had low amount of production (10.45 quintals) followed by from 5.1–10 ha that produced 14.54 quintals (Fig. 14). Farmland size and amount of production showed statistically significant variation ($F=59.412$, $p < 0.0001$).

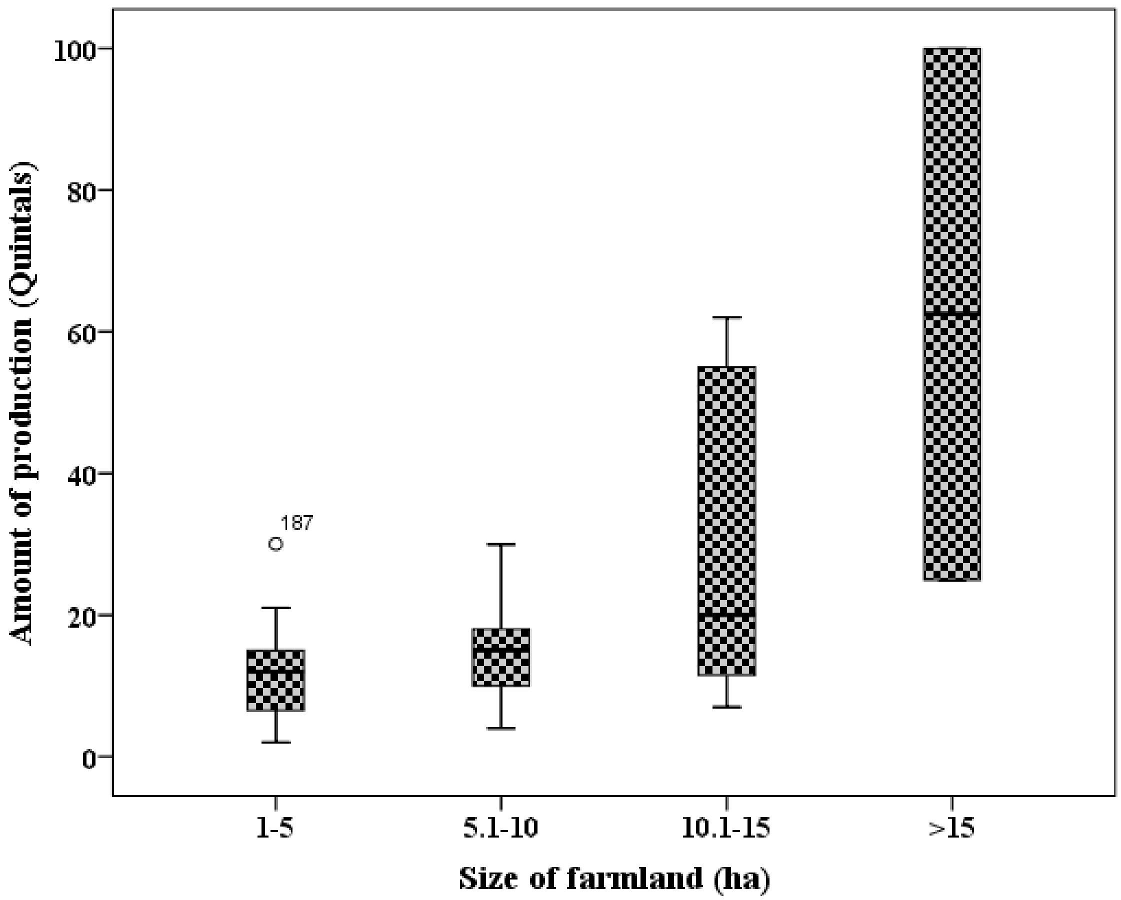

Figure 14: Size of farmland versus amount of yield per household in the study area.

Out of the 300 respondents in the present study area, 251 (83.30%) had a negative attitude towards rodents, while 49 (16.30%) respondents had a positive attitude (Table 38). There was a significant variation in the attitude of the local farmers towards rodents (χ^2= 136, df= 1, $p < 0.05$).

During the present investigation, the majority (221, 73.70%) of respondents responded that conserving of rodents is not important while 79 (26.30%) responded that it is important to environmental engineering and educational purposes (Fig. 15). The responses of local farmers to the importance of conserving small mammals showed a significant variation during the present investigation (χ^2= 71.05, df= 1, $p < 0.05$).

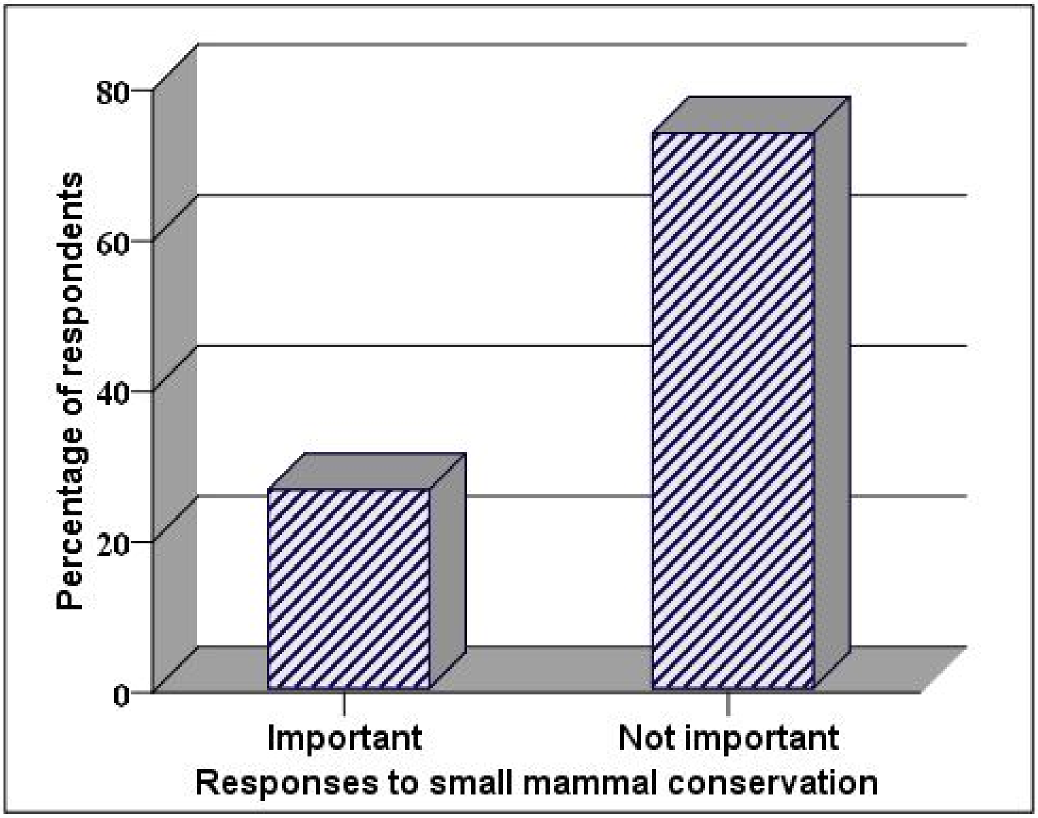

Figure 15: Responses of farmers to small mammal conservation (N=300).

The area of crop damage varied from village to village. A total of 16026.00 m^2 farmland was damaged during the present investigation. Among these, 2970.55m^2 was damaged in Dagna village followed by Abalemne 2619.36m^2 (Table 34).

Table 34: Damaged area (m^2) of cropland in each village.

Villages	Respondent number	Mean area of crop damage (m^2)/individual	Mean area of crop damage (m^2)/village
Sidenager	42	53.88	2262.96
Mentera	54	45.73	2469.42
Dagna	55	54.01	2970.55
Albati	36	50.00	1800.00
Tabeta	9	72.67	654.03
Bokimos	27	51.39	1387.53
Abalemne	51	51.36	2619.36
Beleager	26	48.29	1255.54
Average/total	300	53.42	15,419.39

The highest loss of yield was on wheat, barley and teff 15226.12 kg (380, 653.00 ETB) followed by bean and pea 3570.93 kg (124, 982.55 ETB) (Table 35). Overall, 24, 952.60 kg crop yield was lost per season and estimated as **680, 911.99** ETB in monetary value (about 24,000 USD) based on average market price.

Table 35: Amount of yield and monetary loss of crops by pest rodents in the study area.

Type of crops damaged	Mean yield loss (kg)	Mean market value (Birr/kg)	Mean monetary loss (ETB)
Wheat, barley & teff	15226.12	25	380, 653.00
Maize & sorghum	3600.52	22	79, 211.44
Bean & pea	3570.93	35	124, 982.55
Lentil & chickpea	1287.54	50	64, 377.00
Vegetable	1267.52	25	31, 688.00
Total	24, 952.60	-	680, 911.99

Maturation stage of the crops was relatively more damaged by pest rodents as shown in Table 36. The percentage of damaged tillers of wheat farm at seedling and maturation stages did not significant variation ($\chi = 0.10$, $p > 0.05$).

Table 36: Percentage of wheat damage by pest rodents in the study area.

	Number of sample plots	Number of cut tillers in the samples	Total number of tillers in the sample	Percentage
Seedling	20	2261	22805	9.91
Maturation	20	2406	21194	11.35

Maize crop was highly damaged by pest rodents, particularly by porcupines during the maturation stage (Table 37). The percentage of cut tillers of maize at seedling and maturation stages did not show significantly variation ($\chi^2 = 2.23$, $p > 0.05$).

Table 37: Percentage of maize damage by pest rodents in the study area.

Stages	Number of sample plots	Number of cut tillers in the samples	Total number of tillers in the sample	Percentage
Seedling	20	312	1940	16.08
Maturation	20	482	1873	25.73

4. DISCUSSION

4.1. Species composition and abundance

Species composition of small mammals in the present study area was higher compared to other studies in different parts of Ethiopia. For instance, Ashetu Debelo (2016) recorded five rodent species and one shrew species from Chato Protected Area (CPA), Ethiopia. Ayenew Gezie (2009) noted eight species of rodents and two species of insectivores from Meklite Forest and associated areas, Ethiopia. Daniel Bayessa (2010) recorded eleven small mammal species from the forest and farmland habitats around Tepi, Southwest Ethiopia. A total of eight rodents and two insectivore species were recorded from Wonji-Shoa sugarcane plantation and nearby natural habitats (Serekebirhan Takele *et al*., 2011). Moges Dubale and Dessalegn Ejigu (2015) also recorded ten species of small mammals from Aquatimo Forest patches and adjacent farmland, East Gojjam, Ethiopia. Dawit Kassa and Afework Bekele (2008) recorded nine species of small mammals from Wondo Genet, Ethiopia. Seven species of small mammals were recorded from the Web Valley of the Bale Mountains National Park (Addishiwot Fekadu *et al*., 2015). However, lower number of species was recorded during the present investigation compared to the studies of Sintayehu Workineh *et al*. (2011) recorded a total of twenty species of rodents and four species of insectivores from Nechisar National Park, Ethiopia. Tadesse Habitamu and Afework Bekele (2008) recorded twenty-nine species of rodents and insectivores from the Alatish National Park, northwestern Ethiopia. Mohammed Kasso *et al.* (2010) recorded seventeen species of small mammals from Mount Chilalo and Galama Mountains. Tilahun Dinaw *et al.* (2017) recorded eighteen species of small mammals in the Chebera Churchura National Park. The decrease in small mammal species in the present study area might be associated with less availability of resources and habitat disturbance. Barrett and Peles (1999) noted that the diversity and abundance of small mammals were determined by the quality of food, the number of predators and habitat quality.

Among the total captured small mammal species in the present study area, *M. natalensis* was the most abundant and widespread species. It was also the second-largest number of species in Tendaho Sugarcane Plantation, Afar Region, Ethiopia (Redwan Mohammed *et al*., 2017). It was also recorded as the most abundant and a major agricultural pest species in East Africa (Fiedler, 1994). Sintayehu Workeneh *et al*. (2011) and Tadesse Habtamu and Afework Bekele (2008) recorded this species from all habitats of their study area. It is known as a multi-mammate rat and usually found in savannas, woodlands, forest, houses and farmland habitats throughout Africa (Happold, 2013; Kingdon, 2015). Tilahun Chekol *et al*. (2012) described that *M. natalensis* was the most abundant and widely distributed species in Pawe area, northwestern Ethiopia. This species was recorded from Wonji-Shoa sugarcane cultivation and nearby areas, Ethiopia (Serkebirehan Takele *et al.*, 2011). Getachew Bantihun and Afework Bekele (2015) reported that this species was recorded only from natural habitats from Aridtsy forest, Awi Zone, Ethiopia. It was also captured from fallow and bushy habitats in Gachoka Division of Mbeere District, Kenya (Mugatha, 2002). However, Ayenew Gezie (2009) and Moges Dubale and Dessalegn Ejigu (2015) reported that this species was trapped only from farmland and grassland habitats. In central Ethiopia, the species was recorded only from the farmland habitat (Gezahegn Getachew *et al.*, 2016). This might be associated with the adaptation of various habitats and opportunistic feeding habits of the species.

S. albipes was the second most abundant species in the present study area. This species was more abundant in the plantation habitat and at higher altitudes during the present investigation. Dawit Kassa and Afework Bekele (2008); Sintayehu Workeneh *et al.* (2011) and Getachew Bantihun and Afowrek Bekele (2015) reported that *S. albipes* was widely distributed and recorded from all habitats of their study sites. *S. albipes* is distinguished from the moorland species (*S. griseicauda*) by its longer tail and shorter body size (Monadjem *et al.*, 2015). Yalden (1988); Yalden and Largen (1992) and Afework Bekele (1996) noted that it is an endemic species to Ethiopia and the most numerous species.

L. flavopunctatus was captured from four habitats of the Yegof Mountain Forest. This species is the most widely dispersed in all parts of Ethiopia (Happold, 2013). Mainly, it is found in moist vegetation and altitudes from lowland rainforest to montane grassland habitats. *L. flavopunctatus* is the most numerous species of rodents in some localities (Happold, 2013; Kingdon, 2015). Mesele Yihunie and Afework Bekele (2012) recorded this species from all habitats of their study site, except *lobelia* stand in Simien Mountains National Park. It was the most widely distributed and dominant species in Kaka and Hunkolo, southeast Ethiopia (Zerihun Girma *et al*., 2012). Mohammed Kasso *et al*. (2010) described that *L. flavopunctatus* was the most widespread species occurring in all habitats of Chilalo and Galama Mountains. However, Tilahun Dinaw *et al*. (2017) reported that this species was the least abundant species and occurring in grassland, wooded grassland and bushland habitats in the Chebera Churchura National Park. The variation of species abundance and distribution might be associated with the availability of food, habitat cover, the density of predators and habitat disturbance.

S. griseicauda was also trapped from four habitats of the Yegof Mountain Forest. This species is endemic and found in the highland area of Ethiopian. The species mainly prefers to occur in the scrub growing area at slightly lower altitudes of the highlands (Afework Bekele and Yalden, 2013; Happold, 2013; Kingdon, 2015). The habitat preference of the species might be associated with the suitability of the area for breeding. *S. griseicauda* was the most abundant and trapped in all habitats of Simien Mountain National Park (Mesele Yihunie and Afework Bekele, 2012).

M. brockmani was trapped from natural and plantation habitats of the study area. The species is smaller than other species of Ethiopian rodents, but possesses a very long tail. It is known as 'Panya Jiwe' or 'Stone Rat' due to the presence of a strong preference in the rocky broken ground. It is also found in stony terrain under extreme heat and cold conditions (Happold, 2013; Kingdon, 2015). Afework Bekele and Yalden (2013) stated that this species was recorded in different parts of Ethiopia. It is a dry area species and frequently found in association with gerbils (Yalden *et al*., 1976). Sintayehu Workeneh *et al*. (2011) recorded the species from grassland, bushland and riverine forest habitats from the Nechisar National Park, Ethiopia. In Yetere Forest, this species was trapped only from natural habitats (Gezahegn Getachew *et al*., 2016).

O. typus usually prefers grassland, dense forest, open savannah and farmland habitats at higher altitudes (Happold, 2013; Kingdon, 2015). It was recorded from farmland and natural habitats of the present study area. The distribution of this species is discontinuous, mainly found in eastern highland and southern temperate areas of Africa (Kingdon, 2015). This might be associated with resource distribution and climatic factors of the area. Mesele Yihunie and Afework Bekele (2012) recorded this species from *Festuca lobelia* and *Festuca-carex* grassland habitats with a limited number in the Simien Mountains National Park. It was also recorded from *Erica* scrub and agricultural farmland from Kaka habitats (Zerihun Girma *et al*., 2012). Mohammed Kasso *et al*. (2010) captured this species from Chilalo and Galama Mountains.

R. rattus is the well-known major pest species all over the world. It was recorded from farmland and grassland habitats in the present study area. Afework Bekele and Leirs (1997) also recorded this species from grassland and maize farmland from Central Ethiopia. Tilahun Chekol *et al*. (2012) and Moges Dubale and Dessalegn Ejigu (2015) captured the species from maize farmland as the least abundant. It is found in the human settlement area and wild habitats (Afework Bekele and Yalden, 2013; Kingdon, 2015). Prakash and Singh (2001) stated that *R.rattus* was the most abundant species in scrubland and crop field habitats of southeastern Rajasthan. Serekebirhan Takele *et al*. (2011) trapped this species from sugarcane plantation and natural habitat. Mohammed Kasso (2013) also reported that *R. rattus* was the most abundant and widely distributed species in all habitats of the study area from eastern Ethiopia. This might be due to the adaptability of the human settlement habitat and the availability of diet. Serkebirehan Takele *et al*. (2011) explained that sugarcane cultivation and bushland habitats were the preferred places for the species in Wonji-Shoa sugarcane plantation and nearby areas, Ethiopia. It was also reported from farmland and natural habitats of Wondo Genet forest, Ethiopia (Dawit Kassa and Afework Bekele, 2008).

A. abyssinicus is an endemic species to Ethiopia and it inhabits montane grassland habitat (Afework Bekele and Yalden, 2013). It was also trapped from grassland and farmland habitats in the Yegof Mountain Forest during the present investigation. However, Getachew Simeneh (2016) reported that *A. abyssinicus* was the most widely distributed rodent in Choke Mountains, East Gojjam, Ethiopia. This species occurs in grassland and moorland habitats of northern Ethiopia (Happold, 2013). Dawit Kassa and Afework Bekele (2008) recorded the species from bushland, farmland and grassland habitats of Wondo Genet, Ethiopia. This might be the distribution of the species was influenced by vegetation structure, predator density and habitat disturbance by humans and livestock activities.

This study added SpA as the newly recorded species of rodents in the Yegof Mountain Forest. It was recorded from bushland habitat of the study area. It is known as a striped species and easily recognized by its distinct one black stripe along the back. The body measurements of the species were 44g mean body weight, 10.75 cm mean body length and 13 cm tail length.

C. flavescens was the only insectivore and the lowest abundant species in the Yegof Mountain Forest and recorded from bushland habitat. Similarly, Getachew Bantihun and Afowrek Bekele (2015) recorded the species in the bushland habitat of Aridtsy Forest, Awi Zone, Ethiopia. However, it was widely distributed and recorded from natural forest, plantation and bushland habitats of Pawe area, northwestern Ethiopia (Tilahun Chekol *et al.*, 2012). Ayenew Gezie (2009) and Serkebirehan Takele *et al.* (2011) also recorded the species in sugarcane cultivation and bushland habitats of their study sites. Tadesse Habtamu and Afework Bekele (2008) reported that the species damages household materials and notorious chicken raiders in the study area of the Alatish National Park, northwestern Ethiopia.

4.2. Habitat association

Small mammals are mobile and their distribution is influenced by vegetation types and human disturbance (Jing-yuan *et al*., 2008). During the present investigation, the highest number of small mammal species and abundance were recorded in bushland and forest habitats. Demeke Datiko *et al*. (2007) and Gezahegn Getachew *et al*. (2016) also reported a higher number of small mammal species from the natural habitats than farmland habitats. This indicated that the natural habitats are suitable for the existence of endemic and non-endemic species and protect the species from predators. The diverse natural habitats might be more suitable for breeding and a relatively better source of food obtained during the dry season. However, Ayenew Gezie (2009) and Moges Dubale and Dessalegn Ejigu (2015) reported that a higher number of rodent species from the farmland habitat than the natural habitats. This might be due to the presence of sufficient resources related to fruiting of crops in the farmland habitat during the wet season or during the dry season. Daniel Bayessa (2010) described that vegetation cover; rainfall and human interference were the major factors affecting the abundance and distribution of rodent species in various habitats. As a result, habitat complexity and resource availability determine the species diversity and abundance in the present study area. Barrett and Peles (1999) explained that the habitat preference of small mammals is interrelated with the pattern of heterogeneity. Habitat usage of rodents is also associated with environmental variables, species requirements and biological interactions (Gomez-Villafane *et al*., 2012).

Plantation habitat had the lowest species diversity and abundance during the present investigation. This might be associated with less habitat heterogeneity and dominated by homogenous tall and old trees with less habitat cover and availability of resources. This result agrees with the finding of Tilahun Chekol *et al*. (2012) who recorded the lowest species and individuals in plantation habitat. However, Njaka *et al*. (2014) reported the highest number of species of small mammals in the plantation habitat than shrubs and forest habitats.

Natural forest comprised of the second most abundant individuals and species during the present study area. Delciellos *et al*. (2016) stated that habitat structure was one of the main determining factors for small mammal diversity and abundance. Similarly, Pupila and Bergmanis (2006) stated that small mammal diversity and abundance were highest in the forest habitat than human-modified habitats. This might be associated with the availability of protection and availability of food.

Wooded grassland contained very few species of small mammals in the present study area. However, in the Chebera Churchura National Park, all species were found and recorded in wooded grassland habitats (Tilahun Dinaw *et al.*, 2017). Tadesse Habtamu and Afework Bekele (2008) stated that most insectivore and rodent species were trapped from the wooded grassland habitat.

4.3. Altitudinal association

Ten species of small mammals were captured in the altitudinal range between 1800 m to 2927 m asl in the Yegof Mountain Forest. Small mammal species diversity and distribution were determined by altitudinal ranges. Some species were widely distributed across altitudinal ranges while others are restricted during the present study. Fiedler

(1988) described that small mammal species occur from the lowest to the highest altitude in Africa. This might be due to adaptation to extremely cold and hot environmental conditions. For instance, *M. natalensis* was found an altitudinal range between 1800–2927 m asl during the present investigation. It had a wider distribution in Ethiopian highlands, ranging from 500–2900 m asl (Yalden *et al*. 1976). Afework Bekele and Yalden, (2013) reported this species occurs in altitudinal ranges between 430–4400m in the southern of Ethiopia. This might be that the species is adapted to varied environmental conditions. The endemic *S. albipes* also found in the altitudinal range between 2201–2927 m asl in Yegof Mountain Forest. However, more individuals have recorded an altitudinal range between 2201–2600 m asl. Afework and Corti (1997) confirmed that *S. albipes* occurred in the altitudinal range between 1500–3300 m asl. Mohammed Kasso *et al*. (2010) also recorded this species at an altitudinal range between 2500–3400 m asl from Chilalo–Galama Mountains.

S. griseicauda is also an endemic rodent species found in the highlands of Ethiopia. It is inhabited in the Afro–alpine habitat of Ethiopia from 2,400–4,050 m asl. The species, mainly preferred to occur in the scrub area at slightly lower altitudes of the highlands of Ethiopia (Afework Bekele and Yalden, 2013; Happold, 2013; Kingdon, 2015). During the present investigation, this species was recorded from an altitudinal range between 1800–2600 m asl. However, Getachew Simeneh (2016) recorded *S. griseicauda* above 3600 m asl. *O. typus* was recorded in the altitudinal range between 1800–2600 m asl in the Yegof Mountain Forest. Afework Bekele and Yalden (2013) described that *O. typus* is widely distributed in different parts of Ethiopia an altitudinal range between 1800–4050 m. In the Yegof Mountain Forest

M. brockmani is also found in the southeast of Ethiopia and has been recorded from an altitude of 600–1700 m (Afework Bekele and Yalden, 2013). Fadda and Corti (2000) stated that this species is occurs in different habitats in the Afro-Alpine moorlands above 4000 m asl and it is widely distributed across African countries (Fadda and Corti, 2000). During the present investigation, *M. brockmani* was recorded in the altitudinal range between 2201–2600 m asl. Yalden (1988) reported that *L. flavanctatus* was the most abundant and found from the 1500 m up to the upper zone of the Bale Mountain Park. In the Yegof Mountain Forest, *L. flavanctatus* was recorded in the altitudinal range between 1800–2600 m asl. *A. abyssinicus* was recorded in the highlands of Ethiopia ranging between 1300-3400 m asl (Yalden *et al*., 1976; Kingdon, 2015). During the current study, *A. abyssinicus* was recorded in the altitudinal range between 1800–2200 m asl in the Yegof Mountain Forest.

Yalden *et al.,* (1996) stated that most endemic mammals of Ethiopia were exclusively confined to the highlands of the country at an altitudinal range greater than 1800 m asl. This might be associated with the adaptation and the suitability of the area. Njaka *et al*. (2014) described that the species richness of small mammals is influenced by elevation or landscape. Njaka *et al*. (2014) reported that trap success increased with increase in altitude in the West Usambara Mountains, Tanzania. Similarly, Jing-yuan *et al*., (2008) stated that an area increased with altitude results increased small mammal species diversity. Similarly, the composition of small mammal species varied in different parts of Ethiopia due to the presence of landscape and climatic variation as shown in Appendix II.

4.4. Species richness

Species richness also varied from habitat to habitat with the seasons. The highest species richness was observed in the bushland habitat followed by natural and farmland habitats during the present investigation. Out of the total trapped small mammal species, *R. rattus* and *A. abyssinicus* were not found in the bushland habitat. Sintayehu Workeneh *et al*. (2011) reported that the highest number of species and individuals were trapped from grassland and bushland habitats. Torrea *et al*. (2007) stated that the species richness of small mammals is usually affected by grazing and other human activities due to depletion of the natural resources such as food, shelter, breeding sites, suitable soil for burrowing species and increased predation risk in a grazed area as well as deforested habitats. The difference of species richness in various habitats between seasons might be associated with the availability of heterogeneity habitat, natural resources, and climatic conditions. Barrett and Peles (1999) described that the diversity and abundance of small mammals were related to the availability of food, predator density, habitat cover and rainfall. Small mammals preferred moist soil and moderate temperature during the dry season (Tilahun Chekol *et al*., 2012). Barnett *et al.* (2000) described that small mammal diversity and abundance were positively associated with the percentage of vegetation cover and availability of resources. The presence of habitat cover might provide refugia for small mammals to escape from their predators. During the present investigation, species richness was less in plantation and wooded grassland habitats. This might be due to the absence of suitable food sources and habitat cover. Pearson *et al*. (2001) stated that habitat selection of small mammal depends upon the availabilities of resources in the habitats and the presence of habitat cover. In farmland habitats usually, more pest species occur during the cropping wet season. However, the preference of natural habitats might be more due to the presence of food resources and protective cover than farmland during the dry season. Fitzherbert *et al*. (2006) stated that the presence of habitat complexity in bushland and forest habitats results in the occurrence of more species. King and Moller (1997) also described that small mammal abundance increased during the presence of food sources and protection from predators. Overall, the preference of bushland and forest habitats than farmland and plantation habitats during the present investigation might be associated with heterogeneity (bushland and forest) and homogeneity (farmland and plantation) vegetation. Even within the farmland habitat, less mammal population is influenced by strip-crop and monoculture systems (Peles *et al.*, 1997). Habitat heterogeneity leads to increased species diversity than habitat homogeneity (Cramer and Willig, 2002).

On the other hand, the farmland habitat was preferred by most pest rodents during the wet season due to the presence of ground cover and plenty of food. Previtali *et al.* (2009) described that precipitation plays an important role in the dynamics of small mammal species in arid and semiarid environments. Population fluctuations of small mammals are driven by a combination of multiple factors such as precipitation, resource availability and population of predators. This might be at fruiting and maturation time that the farmland habitat provides protection and food for small mammals during the wet season (Workneh Gebresilassie *et al*., 2004).

4.5. Seasonal variation

During the present investigation, there was variation in the abundance and diversity of small mammal species between seasons. The highest number of species and individuals of small mammals was trapped during the wet season. Similarly, Tilahun Chekol *et al*. (2012) and Zerihun Girma *et al*. (2012) reported the highest number of small mammals during the wet season than the dry season from their study sites. This might be associated with the availability of food, high reproduction rate and the presence of rainfall. Jing-yuan *et al*. (2008) stated that small mammal density was higher during the winter time than that of spring. However, Demeke Datiko *et al*. (2007); Tadesse Habtamu and Afework Bekele (2008); Mesele Yihune and Afework Bekele (2012) and Tilahun Dinaw *et al*. (2017) recorded a larger number of small mammals during the dry season than the wet season. This might be associated with the bait (peanut butter, maize and barely flour) that attracted more number of small mammal individuals due to the absence of quality and available food in the environment during the dry season.

Seasons showed variation in the habitat cover and food availability. As a result, some species found in one season might not occur in the other season. For instance, SpA and *C. flavescens* were not trapped during the dry season. This might be associated with a low population density of the species and the presence of high predator risk in the study area. Kingdon (2015) described that lowering of the food source, high predator density and low habitat cover result in the population decline of the species. Felicciano *et al*. (2002) also described that rainfall is the main factor to determine the number of rodents indirectly through the effect of resource availability.

The abundance of small mammals of each species showed seasonal variations during the present investigation. For instance, the abundance of *M. natalensis, L. flavopunctatus, S. griseicauda*, *M. brockmani*, *O. typus*, SpA and *C. flavescens* was high during the wet season, whereas the abundance of *S. albipes* and *R. rattus* increased during the dry season. This seasonal fluctuation might be associated with vegetation cover, availability of resources and abundance of predators. Food shortage and reduced ground cover might be the main reasons for the decline of rodent population during the dry season.

Moreover, farmland, grassland, bushland and wooded grassland habitats had high abundance of small mammals during the wet season. These habitats might have a suitable cover and plentiful food for the species due to the growth and development of crops, leaf, grass and herbs in the study area during the wet season. Telleria *et al*. (1991) and Sassi *et al*. (2011) stated that the availability of resources and habitat cover are the main requirements for species occurrence and abundance. However, forest and plantation habitats had more abundance of small mammals during the dry season. This might be an association with the migration of small mammals into the farmland habitat during the wet season and returning back to the forest and plantation habitats during the dry season.

4.6. Sex variation

The sex of small mammal species showed variation during the present investigation. The number of males is higher than females. This might be related to the high rate of mobility in males and limited home range in females to lowering the trap success of female individuals. Similarly, Mesele Yihune and Afework Bekele (2012) reported highest number of males was recorded from Simien Mountains National Park. Zerihun Girma *et al*. (2012) recorded a higher number of male individuals than females. Barrett and Peles (1999) also described that in most species, females remain near their natal site. The less dispersal of female species might have resulted in fewer trapped individuals. However, Teklu Damtie (2008); Adugnaw Admas and Mesele Yihune (2016) and Tilahun Dinaw *et al*. (2017) recorded a higher number of females than males during their study periods.

This might be due to lower number of males than females in the area or females might be more attracted by trap bait than males.

4.7. Age distribution

The age distribution of small mammals varied from season to season during the present investigation. All age groups (adult, sub-adult and young) were recorded during both seasons. This indicated that the species reproduce throughout the year if resources are available. During the wet season, more number of young was recorded than the dry season. This might be related to the seasonal reproduction of small mammals and the availability of diet during the rainfall season. Afework Bekele and Leirs (1997) described that the reproduction of rodents in Africa is highly correlated with the availability of rainfall and diet. From the overall results of this study, larger numbers of adults were captured than sub– adults and young. This might be associated with adult individuals which were more attracted by traps bait and more active than sub– adults and young. However, Teklu Damtie (2008) recorded highest number of young during the dry season than the wet season, but a higher number of adults and sub-adults during the wet season. The higher number of sub– adults was also trapped than adults and young from Yekoche Forest, East Gojjam, Ethiopia (Adugnaw Admas and Mesele Yihune, 2016). Feliciano *et al*. (2002) stated that highest juveniles were recorded during the mid-dry season and the late wet season.

4.8. Trap success

During the present investigation, highest trap success was recorded in the bushland habitat during the wet season. This might be due to the presence of habitat heterogeneity; sufficient habitat covers and availability of food. However, lowest trap success was recorded from plantation habitat during the wet season (5.61%). This might be related to the homogeneity of habitat, scattered plant growth, low density of vegetation, less availability of food and increased number of predators. Higher trap success during the wet season in the present study area supported by Azied Osman (2007) and Akililu Ayiza and Afework Bekele (2017), they were recorded the highest trap success during the wet season than the dry season.

The presence of higher trap success in bushland and forest habitats is due to more capture of *M. natalensis* and *S. albipes* during the wet and dry seasons. The mean trap success during the present investigation was 12.68%. This trap success was low compared to several previous studies in different parts of Ethiopia. For instance, Tadesse Habtamu and Afework Bekele (2008) recorded 36.80% trap success in Alatish National Park, northwestern Ethiopia; Daniel Bayessa (2010) recorded a trap success of 13.30% from forest and farmlands around Tepi, southwest Ethiopia; Sintayehu Workeneh *et al.* (2011) recorded 25.80% trap success from Nechisar National Park, Ethiopia; Tilahun Chekol *et al*. (2012) recorded 17.70 % trap success from Pawe area, northwestern Ethiopia. The low trap success during the present investigation might be due to the presence of habitat disturbance, shortage of resources and low population density of rodents and insectivores in the study area. Sanchez-Cordero *et al*. (2005) described that habitat disturbance is the major factor to reduce the quality of small mammal habitats leading to reduction in population. Overall, trap success was more during the wet season than the dry season. This might be due to seasonal variation in food availability.

4.9. Population size and density

The population size of small mammals was highest during the second wet season during the present investigation. This might be associated with high breeding rates, low predator density, the presence of food and shelter for small mammals. However, fewer small mammals were trapped during the second dry season.

The density of small mammal showed variation from habitat to habitat during the present investigation. The highest density of small mammals was recorded from bushland habitat (432.65/ha), whereas the lowest density was estimated from plantation habitat (167.35/ha). This might be due to the presence of good vegetation cover, food availability and heterogeneous habitat in the bushland habitat and in the plantation, habitat might be also associated with homogenous vegetation cover, the low population of small mammals and high predator density. This result agrees with the result of Tilahun Chekol *et al*. (2012) who recorded the highest and the lowest density of small mammals in the bushland and plantation habitats, respectively.

The highest density of *M. natalensis* (130.61/ha) was recorded in the bushland habitat during the present investigation. This might be due to the presence of available diet and low predation risk. *S. albipes* and *A. abysinicuss* had high density in the wooded grassland habitat (161.22/ha) and grassland habitat (134.69/ha). This shows that these species prefer grassland habitats than others.

4.10. Snap trapping

The recorded species of small mammals during the present investigation showed a significant variation in body weight during the wet and dry seasons. During the wet season, the body weight of small mammal was high, but low during the dry season. This might be due to the availability of food and pregnancy for females during the wet season. This seasonal reduction in weight might be correlated with the shortage of food, which was limited in quantity and quality during the dry season. Tilahun Chekol *et al*. (2012) described that the weight of small mammals decreased during the dry season. The availability of food and quality is important in maintaining body weight and in determining the reproductive rate of small mammals. Henschel *et al*. (1982) also stated that body weight and external body measurements have been used to determine the age of individuals

The diet of rodents consists of varied animal and plant materials. However, the proportion of plant matter is higher than animal matter during the present investigation. Similarly, the types of plant matter and proportion also varied with the seasons. Sassi *et al*. (2011) noted that feeding behaviour of small mammal varied with season. More new outgrowth components where recorded during the wet season whereas seeds and root components of animal diet cover a higher percentage during the dry season. This result supported by Azied Osman (2007) and Yonas Terefe and Fikresilasie Samuel (2015). Leirs *et al*. (1994) described that more insects were recorded in the stomach of rat species during the rainfall season. The stomach content analysis serves to reveal the diet of small mammals. Diet consists of varied animal and plant matters. The proportions of food items vary from species to species and season to season. The presence of both plant and animal matters in the diet of rodent species show that they are opportunistic feeders. During the wet season, there was more plant leaves, animal matters like hairs and insects in their stomach analysis. Barnett *et al.* (2000) described that most species of rodents feed on mix of insects, earthworm and plant matters during the wet season. This might be due to the availability of insects and other invertebrates during the wet season. Invertebrates were more abundant in the stomach continents of small mammals during the wet season (Miller and Miller, 1995). During the dry season, there were more plant roots, stems and seeds. This might be associated with the scarcity of alternative food sources. This is also show that small mammals are opportunistic feeders. They can adjust their feeding habits based on the environmental conditions and availability of food sources. The wide range of feeding habits helped them to occupy a wide range of habitats in all continents as opportunistic feeders, capable of changing their feeding habit based on the availability of diet with season (Workneh Gebresilassie *et al*., 2004).

The present investigation showed that high number of females was pregnant during the wet season. Teklu Damtie (2008) reported that the higher number of pregnant females was recorded during the wet season. The increment of the rodent population in an area is related to high reproduction during the wet season (Afework Bekele and Leirs, 1994). Leirs *et al*. (1994) stated that there were significant positive correlations between reproduction and rainfall leading to high breeding rate.

4.11. Pest implications of small mammals

Increase in human population leads to agricultural land expansion. As a result, farmers and wild animals come into conflict for the use of limited resources in the area. Based on the responses of respondents from eight villages, crested porcupine, rats and mole rats damage different types of crops. *M. natalensis* and *R. rattus* were recorded as major pest species during the present investigation. The impact of these pest rodents is universal since they occupy a wide range of environmental conditions and habitats from desert to rainforest ecosystems (Monadjem *et al*., 2015).

The majority of respondents mentioned that maturity stages of crops were highly susceptible to rodent damage. This might be due to the maturity stage of crops is tasty and preferred edible stage for pest rodents. Similarly, Mohammed Kasso (2013) described that the major damage on cereal crops occurred during the maturity stage. More than half of the cereal crops were damaged at various stages of its development from the sowing up to harvesting stage. For instance, squirrels highly damage the seed of crops before and after germination in Eastern Ethiopia (Mohammed Kasso (2013).

Mukherjee *et al*. (2004) described that rodents are the main pest crops in developing countries. As a result, rat species prefer cereal crops as important source of diet. Similarly, Muluken Mekuyie (2014) stated that porcupines and mole rats mostly affect maize, tubers, banana, and sugarcane in Wondo Genet, southern Ethiopia. Ejigu Alemayehu and Afework Bekele (2013) reported that wheat, soybean and maize were highly damaged by rodents in Bir Farm Development, Ethiopia while maize was highly the preferred crop. This might be related to their choice, satisfaction, and accessibility of handling the crops during the feeding process.

Several species of rodents are responsible for the loss of agricultural products (Fiedler, 1988). In Ethiopia, maize, enset and potatoes were the most affected cereal crops and vegetables (Makundi *et al*., 2005). Mainly, maize was susceptible to rodent damage and most severe at planting and seedling stages. Tsegaye Gadisa and Asfawosen Birhane (2016) stated that among the crops grown in the southwest, Ethiopia, the majority of farmers responded that maize was the most susceptible crop to rodent damage followed by barley and sorghum.

In Ethiopia and Tanzania, maize is the most affected crops by rodents and more than 26.40 % of maize products lost by rodents (Makundi *et al*., 2005; Afework Bekele *et al*., 2003). It is also the main factor for the loss of agricultural products (Ngowo *et al*., 2003).

The impacts of pest rodents varied with seasons. Seasons are important factors for the outbreak of pest rodents in the farmland habitats. During the present investigation, pest rodents damage crops more during the wet season than the dry season. This result goes in line with the finding of Mohammed Kasso (2013) who reported that pest rodent damage was higher during the wet season. Demeke Datiko and Afework Bekele (2013) also described that wildlife damage was more during the wet season. Afework Bekele *et al*. (2003) reported that the population size of rodents fluctuates with seasons in maize farms of Ziway, Ethiopia. This might be associated with the presence of available resources such as shelter, food, breeding site and migration of pest rodents to the agricultural field from other areas during the wet season.

During the present investigation, crops damaged by pest rodents happened randomly in the farmland of the study area. This result agreed with the finding of Odhiambo and Oguge (2003) who reported that rodent pests were not uniformly distributed in maize fields. This might be associated with an uneven distribution of resources leading to the random distribution of pest species based on adaptation various environmental conditions.

In Ethiopia, trapping, hunting and rodenticides are the most practiced techniques for rodent control (Makundi *et al*. 2005). Similarly, rodenticide usage and sanitation are the most practiced control techniques to minimize the damage to crops (Tsegaye Gadisa and Asfawosen Birhane, 2016). Ojwang and Oguge (2003) reported that biological control technique could be important to control pest rodents in agricultural land, while the breeding of predators was recommended controlling pest rodent population in the farmland. Singleton *et al*. (2004) noted that ecologically based rodent management was efficient for pest rodent control, which leads to increasing crop yield production and decreasing the cost of pest control.

4.12. Damage assessment by direct observation

During the present investigation, seedling and maturation stages of wheat and maize crops were taken to identify the susceptible stages of the cereal crops. As a result, the damage of crops occurred in all growth stages of the crops, but more severe during maturation stages. This might be associated with tasty nature and preference by the pest rodents. Mohammed Kasso (2013) reported that sorghum and maize were the dominantly cultivated crops in eastern Ethiopia. These were susceptible at the seedling, vegetative, maturation and storage stage. Makundi *et al*. (2005) also stated that maize was the most damaged crop at planting and seedling stages. The average rate of crop damage in the current study area was 20.91 % for the maze and 10.63% for wheat. Thus, was estimated as 419.54 ETB ($14.57) per hectare. Ejigu Alemayehu and Afework Bekele (2013) reported that the damage rate of maize from the Bir Farm Development was 9.6%. In monetary, it was estimated as 2016 Birr (202$) per hectare. However, damage on the wheat farm was 13.20%. Thus, was also estimated as 1716 Birr (172$) per hectare. Afework Bekele *et al*. (2003) reported that from maize farms of Ziway, the yield loss at the harvesting stage of maize by pest rodents was 26.4%.

5. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study provided information on species diversity, abundance, habitat and altitudinal distribution of small mammals in the Yegof Mountain Forest. The study also assessed the economic loss by pest rodents on local farmers. During the present investigation, there was variation in trap success in various habitats of the study area. The composition and abundance of small mammals were related to habitat types and other key ecological factors. The existence of small mammals was closely associated with habitat quality. The natural habitats of the study area supported more species of small mammals and less fluctuation in abundance between seasons. They also respond to habitat disturbance. The bushland habitat had a relatively good ground cover and which serves as hosts for the highest number of species in the present study area. Reproduction of small mammals correlated with resource availability.

Three endemic species of rodents were recorded during the present investigation in the Yegof Mountain Forest. In addition, one new species (SpA) was recorded and *C. flaveness* was the only insectivorous species recorded from the Yegof Mountain Forest.

Yegof Mountain Forest is serves as a home for several endemic and non-endemic small mammal species and comprised the majority Ethiopian highland species. It has also similar ecological features with that of other main forests of Ethiopia such as Wof Washa forest, Harenna forest, Denkoro forest and southern west Ethiopia forest, which comprised the tallest and the biggest trees. However, human encroachment has occurred in the present study forest. Even if, the presence of guards, there is extraction of wood for construction and fuel. This also the major threat of small mammals as well as their habitats. Therefore, the forest needs urgent protection to save the golden species from their extinction.

Based on the respondents' response and researcher direct observation, wheat and maize were relatively more damaged during the fruiting or the maturation stage in the present study area.

5.2. Recommendations

Yegof Mountain Forest was covered by both natural and plantation forests that harbour several species of fauna. Among these, small mammals have a great economic and ecological importance. However, the forest cover was mostly cleared for farmland, fire wood and infrastructure activities. This also resulted in low abundance and diversity of small mammal species. Human activities have negative impacts on small mammal species diversity and abundance in the Yegof Mountain Forest.

Based on the finding of the present investigation, the following recommendations are suggested to reduce the threat of small mammal species, degradation of their habitats and crop damage in the Yegof Mountain forest:

- Small mammal habitats should be conserved by minimizing deforestation.
- The extent of the forest should be demarcated and the agricultural land should be far apart from the forest boundary.
- The study area was protected. However, there is an intense human disturbance in and around the Yegof Mountain Forest. As a result, disturbance by local communities should be restricted.

- The forest is managed by Amhara Regional Forest Enterprise Agency. But the agency is focused only on the plantation. Wild animals should also be given priority.
- Creating community awareness about the importance and conservation of the natural forest should be given.
- The ecosystem of the study area is very attractive and has a great potential to attract tourists. However, infrastructures like road, wildlife experts, lodges and other facilities are lacking. Therefore, the government as well as the local community should work together to obtain benefits.
- Community awareness about the use of pest control techniques especially rodenticides to avoid the impact of non-targeted species should be developed.
- The nearby bushes and weeds of crops should be removed to avoid the breeding and hiding sites of pest rodents.

6. REFERENCES

Addishiwot Fekdu, Afework Bekele and Demeke Datiko (2015). Comparative study of species composition, relative abundance and distribution of rodents between exclosure and control sites in the Web Valley of the Bale Mountains National Park, Ethiopia. *Punjab. Univ. J. Zool.* **30:** 57-64.

Adugnaw Admas and Mesele Yihune (2016). Species composition, relative abundance and habitat association of rodents in Yekoche Forest, East Gojjam, Ethiopia. *Int. J. Biodivers. Conserv.* **8:** 216-223.

Afework Bekele and Yalden, D.W. (2013). *The Mammals of Ethiopia and Eritrea*. Addis Ababa University Press, Addis Ababa.

Afework Bekele (1996). Population dynamics of the Ethiopian endemic rodent *Praomys albipes* in the Menagesha State Forest. *J. Zool.* **238:**1-12.

Afework Bekele and Corti, M. (1997). Forest blocks and altitude as indicators of *Myomys albipes* distribution in Ethiopia. *Tropical Zoology* **10:** 287-293.

Afework Bekele and Leirs, H. (1997). Population ecology of rodents of maize fields and grassland in Central Ethiopia**.** *Belg. J. Zool*. **127:** 39–48.

Afework Bekele, Leirs, H. and Verhagen, R. (2003). Composition of rodents and damage estimates on maize farms at Ziway, Ethiopia. **In:** *Rats, Mice and People: Rodent Biology and Management*, pp. 262-263, (Singleton, G.R., Hinds, L.A., Krebs, C.J. and Spratt, D.M., eds). Australian Centre for International Agricultural Research, Canberra.

Agbo, O.E. and Terlumun, A.T. (2010). A survey of rats trapped in residential apartments and their ectoparasites in Makurdi, Nigeria. *Res. J. Agr. Biol. Sci.* **6:** 144 –149.

Aklilu Ayiza and Afework Bekele (2017). Species composition, abundance and habitat association of small mammals from Damot Mountain Forest Priorities Protected Area, Wolayita Zone, Ethiopia. *Proc. Zool. Soc. India* **16:**1-12.

Amhara Regional State Government Office (2011). A survey of Yegof Mountain Forest to fulfillment of the criteria of IUCN for protective Capability. Amhara Regional State Cultural and Tourism Department, Bahir Dar.

Andersen, M.L., Costa, R.M. and Costa, M.F.O. (2016). Rats. **In:** *Rodent Model as Tools in Ethical Biomedical Research*, pp. 61-94, (Andersen, M.L. and Tufik, S. eds). Springer International Publishing, Gland.

Andrews, P. and Obrien, E. M. (2000). Climate, vegetation and predictable gradients in mammal species richness in southern Africa. *J. Zool. Lond.* **251:** 205–231.

Ashetu Debelo (2016). *Species Composition, Habitat Association and Distribution of Rodents and Shrews in Chato Protected Area (CPA), Ethiopia.* M.Sc. Thesis, Addis Ababa University, Addis Ababa.

Avenant, L. N. and Cavallini, P. (2007). Correlating rodent community structure with ecological integrity, Tussen-die-Riviere Nature Reserve, Free State Province, South Africa. *Integr. Zool.* **2:** 212 – 219.

Avenant, N. L. (2003). The use of small mammal community characteristics as an indicator of ecological disturbance in the Korannaberg Conservancy. **In:** *Rats,* *Mice and People: Rodent Biology and Management*, pp. 95–98, (Singleton, G.R., Hinds, L.A., Krebs, C.J. and Spratt, D.M. eds). Australian Centre for International Agricultural Research, Canberra.

Ayenew Gezie (2009). *Species Composition, Relative Abundance, Distribution and Habitat Association of Rodents in Meklite Forest and Associated Areas, Ethiopia.* M.Sc. Thesis, Addis Ababa University, Addis Ababa.

Azied Osman (2007). *Species Composition, Abundance and Diet of Rodents in Chilelo Irrigated Field, Legedaddi Area, Ethiopia*. M.Sc. Thesis, Addis Ababa University, Addis Ababa.

Bagchia, S., Namgail, T. and Ritchie, M.E. (2006). Small mammalian herbivores as mediators of plant community dynamics in the high-altitude arid rangelands of Trans-Himalaya. *Biol. Consrv*. **127:** 438 – 442.

Barnett, A. A., Read, N., Scurlock, J., Christopher, L., Norris, H. and Shapley, R. (2000). Ecology of rodent communities in agricultural habitats in eastern Sierra Leone: Coca groves as forest refugia. *Trop. Ecol.* **41:** 127–142.

Barrett G.J. and Peles J.D. (1999). *Landscape Ecology of Small Mammals*. Springer Science, Business Media, LLC, New York.

Battersby, S.A. (2015). Rodents as Carriers of Disease. **In:** *Rodent Pests and their Control*, pp.81-100, (Buckle, A.P. and Smith, R.H. eds). CAB International, London.

Baumans, V. (2016). The aspects of the use of rodents in experimental research. **In:** *Rodent Model as Tools in Ethical Biomedical Research*, pp. 7-12, (Andersen, M.L. and Tufik, S. eds). Springer International Publishing, Bern.

Bays, T.B., Lightfoot, T. and Mayer, J. (2006). *Exotic Pet Behavior: Birds, Reptiles and Small Mammals*. Saunders Elsevier Inc., New York.

Beatty, R., Beer, A., Green, J. and Taylor, B. (2008). *Exploring the World of Mammals.* The Brown Reference Group Plc., New York.

Begon. M. (2003). Disease: health effects on humans, population effects on rodents. **In:** *Rats, Mice and People: Rodent Biology and Management*, pp. 13–19, (Singleton, G.R. Hinds, L.A., Krebs, C.J. and Spratt, D. M. eds). Australian Centre for International Agricultural Research, Canberra.

Brown, P.R., Huth, N.I., Banks, P.B. and Singleton, G.R. (2007). Relationship between abundance of rodents and damage to agricultural crops. *Agri. Ecosy. Enviro.* **120:** 405–415.

Burgess, N.R.H. (2009). *Rodents.* Australian Centre for International Agricultural Research, Canberra.

Chris, T. and Stuart, T. (2016). *Mammals of North Africa and the Middle East*. Bloomsbury Publishing Plc., London.

Conover, M. (2002). *Resolving Human–Wildlife Conflicts*. Lewis Publishers, London.

Contreernras, H. T., Aranguiz, E. S., Marquet, P. L., Camus, P. A. and Jaksic, F. M. (1997). Spatiotemporal variability of rodent sub-populations at a semiarid neotropical locality. *J. Mammal.* **78:** 505 –513.

Coppeto, S.A., Kelt, D.A., Vuren, D.H., Wilson, J.A. and Bigelow, S. (2006). Habitat associations of small mammals at two spatial scales in The Northern Sierra Nevada. *J. Mammal.* **87:**402–413.

Cramer, M. J. and Willig, M. R. (2002). Habitat heterogeneity, habitat associations and rodent species diversity in a Sand–Shinnery-Oak Landscape. *J. Mammal.* **83**: 743–753.

Daniel Bayessa (2010). *Species Composition, Distribution, Abundance and Habitat Association of Rodents in Forest and Farmlands around Tepi, Southwest Ethiopia*. M.Sc. Thesis, Addis Ababa University, Addis Ababa.

Davies, G. and Howell, K. (2004). African forest biodiversity: A field survey manual for vertebrates. **In:** *Small Mammals: Bats Rodents and Insectivores*, pp. 45-65, (Davies, G. ed). Earth watch Institute, London.

Dawit Kassa and Afework Bekele (2008). Species composition, abundance, distribution and habitat association of rodents of Wondo Genet, Ethiopia. *SINET: Ethiop. J. Sci*. **31:** 141–146.

Dehghani, R., Vazirianzadeh, B., Asadi, M.A., Akbari, H. and Moravvej, S.A. (2012). Infestation of rodents (Rodentia: Muridae) among houses in Kashan, Central Iran. *Pakistan J. Zool.* **44:** 1721-1726.

Delany, M. (1986). Ecology of small rodents in Africa. *Mammal. Rev.* **16:**1-41.

Delciellos, A.C, Vieira, M.V., Grelle, C.V., Cobra, P. and CerqueirA, R. (2016). Habitat quality versus spatial variables as determinants of small mammal assemblages in Atlantic Forest fragments. *J. Mammal.* **97:** 253–265.

Demeke Datiko (2007). *Species Composition, Distribution, Relative Abundance and Habitat Association of Rodents in Arbaminch Forest and Farmlands, Ethiopia*. M.Sc Thesis, Addis Ababa University, Addis Ababa.

Demeke Datiko and Afework Bekele (2013). Conservation challenge: Human-carnivore conflict in Chebera Churchura National Park, Ethiopia. *Greener J. Biol. Sci*. **3:**108-115.

Douglas A. Kelt, D.A., Meserve, P.L. and Gutierrez, J.R. (2004). Seed removal by small mammals, birds and ants in semi-arid Chile, and comparison with other systems. *J. Biogeogr*. **31:** 931–942.

Ejigu Alemayehu and Afework Bekele (2013). Seasonal variation and pest status of rodents in Bir Farm Development, Ethiopia. *Res. J. Agric. Environ. Manage*. **2:**378-385.

Eshetu Moges (2008). *Species Composition, Distribution, Relative Abundance and Habitat Association of Small Mammals in Denkoro Forest, South Wollo, Ethiopia*. M.Sc. Thesis, Addis Ababa University, Addis Ababa.

Ethiopian National Meteorological Agency (2019). *Climate Data Records for the Study Area obtained from the National Meteorological Services Agency, Ethiopia*. South Wollo Station, Kombolcha

Ethiopian Wildlife and Natural History Society (1996). *Important Bird Areas of Ethiopia: A First Inventory*. Ethiopian Wildlife and Natural History Society, Addis Ababa.

Fadda, C. and Corti, M. (2000). Three-dimensional geometric morphometric complex (Murinae, Rodentta) studies of the Ethiopian *Myomys-Stenocephalemys. Hystrix* **10:** 1311–1343.

Fayenuwo, J.O. and Akande, M. (2002). *The Economic Importance and Control of Cane-Rat* (*Thryonomys swinderianus* Temminck). University of California, California.

Feldhamer, G. A., Drickamer, L. C., Vessey, S. H., Merritt, J. F. and Krajewski, C. (2007). *Mammalogy*: *Adaptation, Diversity and Ecology*. 3rd ed. The Johns Hopkins University Press, Baltimore.

Felicciano, B.R., Fernandez, F.A.S., Freitas, D.D. and Figueiredo, M.S.L (2002). Population dynamics of small rodents in grassland between fragments of Atlantic forest in south eastern Brazil. *Mamm. Biol*. **67:** 304-314.

Ferreira, C. and Delibes-Mateos, M. (2012). Conflictive management of small mammals considered as pests: A long way to evidence-based policy making. *Current Zool*. **58**: 353-357.

Fiedler, L. A. (1994). *Rodent Pest Management in East Africa.* Food and Agricultural Organization, Rome.

Fiedler, L.A. (1988). Rodent problems in Africa. **In:** *Rodent Pest Management*, pp. 35-66, (Prakash, I. ed.). CRC Press, Inc., Boca Raton.

Fitzgibbon, C.D., Leirs, H. and Verheyen, A. (1995). Distribution, population dynamics and habitat use of the lesser pouched rat, *Beamys Hindei. J. Zool., Lond.* **236:** 499–512.

Fitzherbert, E., Gardner, T., Caro, T. and Jenkins, P. (2006). Habitat preferences of small mammals in the Katavi ecosystem of western Tanzania. *Afr. J. Ecol.* **45:** 249–257.

Francis, C.M. (2016). *Mammals of South East Asia*. Bloomsbury Publishing Plc., London.

Fricke, K. A., Kempema, S. L. F. and Powell, L. A. (2009). Ecology of small mammals, vegetation and avian nest survival on private rangelands in Nebraska. *Great Plains Res.* **19:** 65–72.

Friis I., Sebsebe Demissew and Van Bruegel, P. (2011). *Atlas of the Potential Vegetation of Ethiopia.* Addis Ababa University Press, Addis Ababa.

Getachew Bantihun and Afework Bekele (2015). Diversity and habitat association of small mammals in Aridtsy forest, Awi Zone, Ethiopia. *Zool. Rese.* **36:** 88–94.

Getachew Simeneh (2016). *Species Composition, Distribution, Abundance and Economic Importance of Rodents in Choke Mountains, East Gojjam, Ethiopia.* PhD Dissertation, Addis Ababa University, Addis Ababa.

Getachew Tadesse, Tamrat Bekele and Sebsebe Demissew (2008). Dryland woody vegetation along an altitudinal gradient on the eastern escarpment of Wollo, Ethiopia. *SINET: Ethiop. J. Sci.* **31:**43-54.

Gezahegn Getachew, Balakrishnan, M. and Afework Bekele (2016). Species composition and habitat association of rodents in Yetere Forest, Central Ethiopia. *Int. J. Ecol. Environ. Sci*. **42:** 193 –200.

Gillespie, C. A. (2003). *Ethiopia*. Chelsea House Publishing, New York.

Gomez, M.D., Coda, J.A., Serafini, V.N., Steinmann, A.R. and Priotto, J.W. (2017). Small mammals in agro-ecosystems: responses to land use intensity and farming management. *Mastozool. Neotrop.* **24:**289-300.

Gomez-Villafane, I.E., Exposito, Y., Martin, A.S., Picca, P. and Busch, M. (2012). Rodent diversity and habitat use in a protected area of Buenos Aires province, Argentina. *Revista Mexi. Biodi.* **83:** 762-771.

Happold, D.C.D. (2013). *Mammals of Africa. Vol. III: Rodents, Hares and Rabbits*. Bloomsbury Publishing, London.

Henschel, J.R., David, J.H.M. and Jarvis, J.U.M. (1982). Age determination and age structure of a striped field mouse, *Rhabdomys pumilio*, population from the Cape Flats. *S. Afr. J. Zoot.* **17:** 136-142

Hoath, R. (2009). *A Field Guide to the Mammals of Egypt*. The American University in Cairo Press, Cairo.

Honeycutt, R.L., Frabotta, L.J. and Rowe, D.L. (2007). Rodent Evolution, Phylogenetics, and Biogeography. **In:** *Rodent Societies: An Ecological and Evolutionary Perspective*, pp.8-26, (Wolff, J.O. and Sherman, P.W. eds). The University of Chicago Press, Chicago.

Hubert, H. (1978). *Modern Rodent Fauna of the Lower Omo Valley, Ethiopia*. Trustees of Carnegie Institute, New York.

Jackson, T. P. and Van-Aarde, R.V. (2004). Diet quality differentially affects breeding effort of *Mastomys coucha* and *M. natalensis*: implications for rodent pests. *J. Exp. Zool*. **301:** 97–108.

Jain, A.P. and Tripathi, R.S. (1988). *Major Rodent Pests of Agriculture*. Central Arid Zone Research Institute, New Delhi.

Jarvis, J. U. M. and Bennett, N. C. (1991). Ecology and behavior of the family Bathyergidae. **In:** *The Biology of the Naked Mole-rat*, pp. 66-96, (Sherman, P.W., Jarvis, J. U.M. and Alexander, R. D. eds). Princeton University Press, Princeton.

Jing-yuan, L., Hong, D.U., Geng-bai, T., Pin-hong, Y., Shen-wen, W. and Hong, P. (2008). Community structure and diversity distributions of small mammals in different sample plots in the eastern part of Wuling Mountains. *Zool. Res.* **29:**637−645.

Kaminski, J. A., Davis, M. and Kelly, M. (2007). Disturbance effects on small mammal species in a managed Appalachian Forest. *Am. Midl. Nat*. **157:** 385–397.

Kays, R.W. and Wilson, D.E. (2009). *Mammals of North America*. 2nd ed. Princeton University Press, Princeton.

Kelt, D. A., Meserve, P. L. and Gutierrez, J. R. (2004). Seed removal by small mammals, birds and ants in semi-arid Chile and comparison with other systems. *J. Biogeogr*. **3:** 931–942.

Kelt, D.A. (1996). Ecology of small mammals across a strong environmental gradient in southern South America. *J. Mammal.* **77:** 205 –219.

Khiem, N. T., Cuong, L. Q. and Chien, H.V. (2003). Market study of meat from field rats in the Mekong Delta. **In**: *Rats, Mice and People: Rodent Biology and Management*, pp. 543–547, (Grant, R., Singleton, G. R. Hinds, L. A., Krebs,

C. J. and Spratt, D. M. eds). Australian Centre for International Agricultural Research, Canberra.

King, C. M. and Moller, H. (1997). Disribution and response of rats *Rattus rattus, R. exulans* to seed fall in New Zealand beech Forests. *Pacific Conserv. Biol.* **3:**143-155.

Kingdon, J. (2015). *The Kingdon Field Guide to African Mammals*. Academic Press. San Diego.

Krebs, C.J. (1999). *Ecological Methodology*. 3rd ed. Harpes Collins Publishers, New York.

Lacey, E.A. and Sherman, P.W. (2007). The Ecology of sociality in rodents. **In:** *Rodent Societies: An Ecological and Evolutionary Perspective,* pp. 243-254, *(*Wolff, J.O. and Sherman, P.W. eds*)*. University of Chicago Press, Chicago.

Lagwen, P. (2016). *Response of Rice Yield to Rat Damage in Irrigated Rice (Oryza Sativum L.) in Mvomero District, Morogoro, Tanzania*. PhD Dissertation, Sokoine University of Agriculture, Sokoine.

Lahvis, G.P. (2017). Social Reward and Empathy as Proximal Contributions to Altruism: The Camaraderie Effect. **In:** *Social Behavior from Rodents to Humans*, pp.126-157, (Wohr, M. and Krach, S. eds). Springer International Publishing, Gland.

Lavrenchenko, L.A. and Afework Bekele (2017). Diversity and conservation of Ethiopian mammals: What have we learned in 30 years? *Ethiop.J. Biol. Sci.* **16:**1–20.

Leirs, H., Verhagen, R. and Verheyen, W. (1994). The basis of reproductive seasonality in *Mastomys* rat (Rodentia: Muridae) in Tanzania. *J.Trop. Ecol.* **10:** 55–66.

Lima, M., Previtali, M. A. and Meserve, P. L. (2006). Climate and small rodent dynamics in semi-arid Chile: the role of lateral and vertical perturbations and intra-specific processes. *Clim. Res*. **30:** 125–132.

Livingstone, D. and Kingdon, J. (2013). The Evolution of a Continent: Geography and Geology. **In:** *Mammals of Africa.*Vol.I. pp.27-42, (Kingdon, J., Happold, D., Butynski, T., Hoffmann, M., Happold, M. and Kalina, J. eds). Bloomsbury Natural History, London.

Lund, M. (2015). Commensal rodents. **In:** *Rodent Pests and their Control*. pp. 18-32, (Buckle, A.P. and Smith, R.H. eds). CAB International, London.

Lyneborg, L. (1971). *Mammals in Colour*. Blandford Press Ltd., Norwich

Macdonald, D.W., Fenn, M.G.P. and Gelling, M. (2015). The natural history of rodents: preadaptation pestilence. **In:** *Rodent Pests and their Control*, pp. 1-18, (Buckle, A.P. and Smith, R.H. eds). CAB International, London.

MacKay, J.W. B. and Russell, J. C. (2005). Ship rat *Rattus rattus* eradication by trapping and poison-baiting on Goat Island, New Zealand. *Conserv. Eviden.* **2:** 142-144.

Makundi, R. H., Afework Bekele, Leirs, H., Massawe, A.W., Rwamugira, W. and Mulungu, L. S. (2005). Farmer's perceptions of rodents as crop pests: Knowledge, attitudes and practices in rodent pest management in Tanzania and Ethiopia. *Belg. J. Zool.* **135:** 153–157.

Makundi, R. H., Kilonzo, B. S. and Massawe, A. W. (2003). Interaction between rodent species in agro-forestry habitats in the western Usambara Mountains, north-eastern Tanzania, and its potential for plague transmission to humans. **In**: *Rats, Mice and People: Rodent Biology and Management*, pp. 20–24, (Singleton, G. R.

Hinds, L. A., Krebs, C. J. and Spratt, D. M. eds). Australian Centre for International Agricultural Research, Canberra.

Makundi, R. H., Massawe, A.W. and Mulungu, L. S. (2006). Breeding seasonality and population dynamics of three rodent species in the Magamba Forest Reserve, Western Usambara Mountains and north-east Tanzania. *Afr. J. Ecol.* **45:** 17–21.

Marino, J. (2003). Threatened Ethiopian wolves persist in small isolated Afroalpine enclaves. *Oryx* **37:** 62-71.

Marnell, F., Kingston, N. and Looney, D. (2009). *Terrestrial Mammals*. National Parks and Wildlife Service, Dublin.

Massawe, A. W., Mrosso, F. P., Makundi, R. H. and Mulungu, L. S. (2007). Breeding patterns of *Arvicanthis neumanni* in central Tanzania. *Afr. J. Ecol.* **46:** 320–324.

Massawe, A.W., Rwamugira, W., Leirs, H., Makundi, R. H. and Mulungu, L. S. (2005). Influence of land preparation methods and vegetation cover on population abundance of *Mastomys natalensis* in Morogoro, Tanzania. *Belg. J. Zool.* **135:** 187–190.

McDade, M.C. (2005). *Grzimek's Student Animal Life Resource: Mammals*. The Thomson Corporation, New York.

Mcdade, M.C. (2005). *Mammals*. The Thomson Gale Corporation, New York.

McGregor, R. L., Bender, D.J. and Fahrig, L. (2008). Do small mammals avoid roads because of the traffic? *J. App. Ecol.* **45:** 117–123.

Meerburg, B.G., Singleton, G.G. and Kijlstra, A. (2009). Rodent-borne diseases and their risks for public health. *Crit. Rev. Microbiol.* **35:** 221–270.

Melaku Tefera (2011). Wildlife in Ethiopia: Endemic Large Mammals. *World J. Zool*. **6:** 108-116.

Mesele Yihune and Afework Bekele (2012). Diversity, Distribution and Abundance of Rodent Community in the Afro-alpine Habitats of the Simien Mountains National Park, Ethiopia. *Inter. J. Zool. Reser.* **8:** 137-149.

Meserve, P.L**.** (2007). Zoogeography of South America. **In**: *Physical Geography of South America*, pp. 112–132, (Orem, A. ed). Oxford University Press, Oxford.

Michel, N., Burel, F., Pierre Legendre, P. and Butet, A. (2007). Role of habitat and landscape in structuring small mammal assemblages in hedgerow networks of contrasted farming landscapes in Brittany, France. *Landscape Ecol*. **22:**1241–1253.

Milkias, P. (2011). *Africa in Focus: Ethiopia*. ABC-CLIO, LLC, Oxford.

Miller, C.J. and Miller, T.K. (1995). Population dynamics and diet of rodents in Rangitoto Island, New Zealand, including the effect of a 1080 poison operation. *J. Ecol.* **19:** 19–27.

Milstead, W. B., Meserve, P., Campanella, A., Previtali, M. A., Kelt, D. A. and Gutierrez, J. R. (2007). Spatial ecology of small mammals in North-Central Chile: role of precipitation and refuges. *J. Mamml*. **88:** 1532–1538.

Moges Dubale and Dessalegn Ejigu (2015). Diversity, relative abundance and habitat association of rodents in Aquatimo forest patches and adjacent farmland, East Gojjam, Ethiopia. *Ethiop. J. Biol. Sci*. **14:** 201–216.

Mohammadi, S. (2010). Microhabitat selection by small mammals. *Advan. Biol. Res*. **4:** 283–287.

Mohammed Kasso (2013). Pest rodent species composition, level of damage and mechanism of control in Eastern Ethiopia. *Inter.J. Inno. Appli. Stud.* **4:**502-511.

Mohammed Kasso, Afework Bekele and Graham Hemson (2010). Species composition, abundance and habitat association of rodents and insectivores from Chilalo–Galama Mountain range, Arsi, Ethiopia. *Afr. J. Ecol*. **48:** 1105–1114.

Monadjem, A. (1999). Geographic distribution patterns of small mammals in Swaziland in relation to abiotic factors and human land-use activity. *Biodiver. Conserv.* **8:**223- 237.

Monadjem, A., Taylor, P.J., Denys, C. and Cotterill, F.P.D. (2015). *Rodents of Sub-Saharan Africa*. Walter de Gruyter, Berlin.

Morgan, B. (2003). *Guide to Mammals*. The Gale Group, Inc., New York.

Mugatha, S.M. (2002). *Influence of Land Use Patterns of Diversity, Distribution and Abundance of Small mammals in Gachoka Division, Mbeere District, Kenya*. International Livestock Research Institute, Nairobi.

Mukherjee, S., Goyal, S. P., Johnsingh, A. J. T. and Pitman, M. R. P. L. (2004). The importance of rodents in the diet of jungle cat (*Felis chaus*), caracal (*Caracal caracal*) and golden jackal (*Canis aureus*) in Sariska Tiger Reserve, Rajasthan, India. *J. Zool., Lond.* **262:** 405–411.

Muluken Mekuyie (2014). Human-wildlife conflicts: Case study in Wondo Genet District, Southern Ethiopia. *Agri. Forest. Fisheri.* **3:** 352-362.

Mulungu, L. S., Makundi, R. H., Massawe, A.W., Machangu, R. S. and Mobije, N. E. (2008). Diversity and distribution of rodent and shrew species associated with variations in altitude on Kilimanjaro, Tanzania. *Mammalia* **72:** 178–185.

Muruthi, P. (2005). *Human Wildlife Conflict: Lessons Learned from AWF's African Heartlands*. African Wildlife Foundation, Nairobi.

Nevo, E. (2007). Evolution of Pacifism and Sociality in Blind Mole-Rats. **In:** *Rodent Societies: An Ecological and Evolutionary Perspective*, pp. 291-302, (Wolff, J.O. and Sherman, P.W. eds). University of Chicago *Press, Chicago.*

Ngowo, V., Lodal, J., Mulungu, L.S., Makundi, R.H., Massawe, R.H. and Leirs, H. (2003). Evaluation of thiram and cinnamamide as potential repellents against maize-seed depredation by the multimammate rat, *Mastomys natalensis*, in Tanzania. **In:** *Rats, Mice and People: Rodent Biology and Management*, pp. 260-261, (Singleton, G.R., Hinds, L.A., Krebs, C.J. and Spratt, D.M. eds). Australian Centre for International Agricultural Research, Canberra.

Njaka, A. R., Kimaro, D.N., Kihupi, N.I., Mulungu, L. S., Leirs, H., Msanya, B.M., Deckers, J.A. and Gulinck, H. (2014). Small mammal distribution and diversity in a plague endemic area in West Usambara Mountains,Tanzania. *Tanzania J. Heal. Resear.***16:**1-9.

Nowak, R.M**.** (1999). *Walker's Mammals of the World.* 6th ed. John Hopkins University Press, Baltimore.

Odhiambo, C.O. and Oguge, N.O. (2003). Patterns of rodent pest distribution in a maize cropping system in the Kenyan Rift Valley. **In**: *Rats, Mice and People: Rodent Biology and Management*, pp. 217–219, (Singleton, G. R., Hinds, L. A., Krebs, C.

J. and Spratt, D. M. eds). Australian Centre for International Agricultural Research, Canberra.

Ojwang, D.O. and Oguge, N.O. (2003). Testing a biological control program for rodent management in a maize cropping system in Kenya. In: *Rats, Mice and People: Rodent Biology and Management*, pp. 251–253, (Singleton, G. R. Hinds, L. A., Krebs, C. J. and Spratt, D. M. eds). Australian Centre for International Agricultural Research, Canberra.

Pearson, D. E., Ortega, Y. K., McKelveya, K. S. and Ruggiero, L. F. (2001). Small mammal communities and habitat selection in northern Rocky Mountain Bunchgrass: Implications for exotic plant invasions. *Northwest Sci.* **75:** 105–117.

Peles, J. D., Williams, C. K. and Barrett, G.W. (1997). Small mammal population dynamics in strip-cropped versus monoculture agro ecosystems. *J. Sust. Agr.* **9:** 51– 60.

Poole, T.B. (1985). *Social Behaviour in Mammals*. Blackie and Son Ltd, New York.

Prakash, I. and Singh, H. (2001). Composition and species diversity of small mammals in the hilly tracts of southeastern Rajasthan. *Trop. Ecol.* **42:** 25 –33.

Previtali, M.A., Lima, M., Meserve, P.L., Kelt, D.A. and Gutierrez, J.R. (2009). Population dynamics of two sympatric rodents in a variable environment: rainfall, resource availability, and predation. *Ecology* **90:**1996–2006.

Prout, D. M. and King, C.M. (2006). The effect of handling under an aesthetic on the recapture rate of wild ship rats (*Rattus rattus*). *Anim. Welf.* **15:** 63–66.

Pupila, A. and Bergmanis, U. (2006). Species diversity, abundance and dynamics of small mammals in the Eastern Latvia. *A. Uni. Latviensis* **710:** 93–101.

Redwan Mohammed, Afework Bekele and Balakrishnan, M. (2017). Species composition and pest status of rodents in Tendaho Sugarcane Plantation, Afar Region, Ethiopia. *Mammal. Stud.* **42:** 31–38.

Rennison, B.D. and Buckle, A.P. (1988). Methods for estimating the losses caused in rice and other crops by rodents. **In:** *Rodent Pest Management*, pp. 237-260, (Prakash, I. ed.). CRC Press, Inc., Boca Raton.

Rico, A., Kindlmann, P. and Sedlacek, F. (2007). Barrier effects of roads on movements of small mammals. *Folia Zool.* **56**: 1–12.

Roberts, S.C. (2007). Scent Marking. **In:** *Rodent Societies: An Ecological and Evolutionary Perspective.* pp. 255-316, *(*Wolff, J.O. and Sherman, P.W. eds). University of Chicago Press, Chicago.

Rose, K.D. (2006). *The Beginning of the Age of Mammals*. Johns Hopkins University Press, Baltimore.

Sanchez-Cordero, Illoldi-Rangel, P. and Linaje, M., Sarkar, S. and Townsend Peterson, T. (2005). Deforestation and extant distributions of Mexican endemic mammals. *Biol. Conserv.* **126:** 465–473.

Sans-Fuentes, M.A. and Ventura, J. (2000). Distribution patterns of the small mammals (Insectivora and Rodentia) in a transitional zone between the Eurosiberian and the Mediterranean regions. *J. Biogeogr.* **27:** 755–764.

Sassi, P.L., Borghi, C.E. and Dacar, M.A. (2011). Geographic and seasonal variability in feeding behaviour of a small herbivorous rodent. *Acta Theriol.* **56:** 35–43.

Sauvajot, R. M. (1998). Patterns of human disturbance and response by small mammals and birds in chaparral near urban development. *Urb. Ecosyst.* **2:** 279–297.

Schulte-Hostedde, A.I. (2007). Sexual size dimorphism in rodents. **In:** *Rodent Societies: An Ecological and Evolutionary Perspective,* pp. 115-128, (Wolff, J.O. and Sherman, P.W. eds*)*. University of Chicago Press, Chicago.

Scott, D. M., Joyce, C. B. and Burnside, N.B. (2008). The influence of habitat and landscape on small mammals in Estonian coastal wetlands. *Estonia J. Ecol.* **57:** 279–295.

Sebsebe Demissew (1998). A study of the vegetation and floristic composition of Southern Wollo, Ethiopia. *J. Ethiop. Stud.* **23:**159–191.

Seoraj-Pillai, N. and Pillay, N. (2017). A Meta-Analysis of human–wildlife conflict: south African and global perspectives. *Sustainability* **9:**1-21.

Serekebirhan Takele, Afework Bekele, Gurja Belay and Balakrishnan, M. (2011). A comparison of rodent and insectivore communities between sugarcane plantation and natural habitat in Ethiopia. *Trop. Ecol.* **52:** 61–68.

Shanas, U. and Haim, A. (2004). Diet salinity and vasopressin as reproduction modulators in the desert-dwelling golden spiny mouse (*Acomys russatus*). *Physiol. Behav.* **81:** 645– 650.

Shannon, C.L. and Weiner, W. (1949). The *Mathematical Theory of Communication.* Illinois Books, Urbana.

Shwiff, S.A., Kirkpatrick, K.N., Sterner, R.T. and Gebhardt, K. (2008). *The Economic Impacts of Bird and Rodent Damage to California Crops: A Methodology to*

Select Counties for Input-Output Modeling. University of California, California.

Sillero-Zubiri, C. and Marino, J. (2004). Ethiopian wolf *Canis simensis* Rüppell, 1835. **In**: *Canids: Foxes, Wolves, Jackals and Dogs*, pp. 167–183, (Sillero-Zubiri, C., Hoffmann, M. and Macdonald, D.W. eds). International Union for Conservation of Nature and Natural Resources, Gland.

Sillero-Zubiri, C., Tattersall, F.H. and Macdonald, D.W. (1995). Bale Mountains rodent communities and their relevance to the Ethiopian wolf (*Canis simensis*). *Afri. J. Ecol.* **33:**301-320.

Singleton, G. R., Smythe, L., Smith, G., Spratt, D. M., Aplin, K. and Smith, A. L. (2003). Rodent diseases in Southeast Asia and Australia: inventory of recent surveys. **In**: *Rats, Mice and People: Rodent Biology and Management*, pp. 25–30, (Singleton, G. R. Hinds, L. A., Krebs, C. J. and Spratt, D. M. eds). Australian Centre for International Agricultural Research, Canberra.

Singleton, G.R., Brown, P.R. and Jacobi, J. (2004). Ecologically-based rodent management: its effectiveness in cropping systems in South-East Asia. *N.J.A.S.* **52:** 163-171.

Sintayehu Workeneh, Afework Bekele and Balakrishnan, M. (2011). Species diversity and abundance of small mammals in Nechisar National Park, Ethiopia. *Afr. J. Ecol*. **50:** 102 –108.

Smith, A.T. and Xie, Y. (2013). *Mammals of China*. Princeton University Press, Princeton.

Sultan Mohammed and Berhanu Abraha (2013). Floristic Composition and Structure of Yegof Mountain Forest, South Wollo, Ethiopia. *Eth. J. Sci. Technol.* **1:**33-45.

Tadesse Habtamu and Afework Bekele (2008). Habitat association of insectivores and rodents of Alatish National Park, northwestern Ethiopia. *Trop. Ecol.* **49:** 1–11.

Tam, N.M., Tien, P.D. and Tuan, N. P. (2003). Conservation of rodents in tropical forests of Vietnam. **In**: *Rats, Mice and People: Rodent Biology and Management*. pp. 246–250, (Singleton, G. R. Hinds, L. A., Krebs, C. J. and Spratt, D. M. eds). Australian Centre for International Agricultural Research, Canberra.

Teklu Damtie (2008). An Ecological Study on Rodents and Their Significance to the Ethiopian Wolf (*Canis simensis*, Rüppel 1838) in the Afroalpine Belt of Abune Yoseph Mountain, Ethiopia. M.Sc Thesis, Addis Ababa University, Addis Ababa.

Telleria, J.L., Santosa, T. and Alcantara, N. (1991). Abundance and food-searching intensity of wood mice *(Apodemus sylvatzcus)* in fragmented forests. *J. Mamm*. **72:** 183–187.

Tilahun Chekol, Afework Bekele and Balakrishnan, M. (2012). Population density, biomass and habitat association of rodents and insectivores in Pawe area, northwestern Ethiopia. *Trop. Ecol.* **53:** 15–24.

Tilahun Dinaw, Berhanu Defar Berhanu and Habte Genzebe (2017). Species abundance, structure and seasonal variation of small mammals in the CCNP. *Afr. J. Ecol. Ecosyst.* **4:**234-241.

Tilaye Wube (2005). Reproductive rhythm of the grass rat *Arvicanthis abyssinicus* at the Entoto Mountain, Ethiopia. *Belg. J. Zool*. **135:** 53–56.

Torrea, I., Diazb, M., Martez-Padillac, J., Bonalb, R., Javier Vinuelae, D. and Juan, A. (2007). Fargall of cattle grazing, raptor abundance and small mammal communities in Mediterranean grasslands. *Bas. App. Ecol.* **8:** 565–575.

Tsegaye Gadisa and Asfawosen Birhane (2016). Farmers' perceptions of rodents as crop pests: Knowledge, attitude and practices of farmers about rodent pest management in Southwest Ethiopia. *J. Agric. Ext. Rural Dev*. **8:** 39 –46.

Tsegaye Gobeze (2018). *Dynamics, Spatial Configuration and Modelling of Yegof Forest Vegetation and Its Surrounding Patches, South Wollo, Ethiopia.* PhD Dissertation, Addis Ababa University, Addis Ababa.

Turner, J.R. (2004). *Mammals of Australia*: *An Introduction to their classification, Biology, and Distribution*. Pensoft Publishers, Bulgaria.

Varnham, K., Glass, T. and Stringer, C. (2011). *Involving the Community in Rodent Eradication on Tristan Cunha*. International Union for Conservation of Nature and Natural Resources, Gland.

Vaughan, T. A., Ryan, J. M. and Czaplewski, N. J. (2015). *Mammalogy.* 6thed. Jones and Bartlett Learning, Inc, New York.

Vera, C. F. and Rocha, C. F. D. (2006). Habitat disturbance and small mammal richness and diversity in an Atlantic rainforest area in southeastern Brazil. *Braz. J. Biol.* **66:** 983-990.

Vial, F., Macdonald, D.W. and Haydon, D.T. (2011). Response of endemic afroalpine rodents to the removal of livestock grazing pressure. *Current Zool.* **57:** 741−750.

Waterman, J. (2007). Male mating strategies in rodents. **In:** *Rodent Societies: An Ecological and Evolutionary Perspective*, pp. 27–41, (Wolff, J.O. and Sherman, P.W. eds). University of Chicago Press, Chicago.

Whittaker, R.H. (1972). Evolution and measurement of species diversity. *Taxon* **21:**213-251.

Williams, F.M. (2016). *Understanding of Ethiopia*. Springer International Publishing, Gland.

Williams, S.E., Marsh, H., and Winter, J. (2002). Spatial scale, species diversity and habitat structure: small mammals in Australian Tropical Rain Forest. *Ecology* **83:**1317–1329.

Wilson, D. E. and Reeder, D.M. (2005). *Mammal Species of the World: A Taxonomic and Geographic Reference*. 3rd ed. Johns Hopkins University Press, Baltimore.

Witmer, G., Sayler, R., Huggins, D. and Capelli, J. (2007). Ecology and management of rodents in no-till agriculture in Washington. *Integr. Zool.* **2:** 154–164.

Wolff, J. (2006). The social biology of rodents. *Intergr. Zool*. **2:**193–204.

Wood, B.J. and Singleton, G.R. (2015). Rodents in Agriculture and Forestry. **In:** *Rodent Pests and their Control*, pp.33-80, *(*Buckle, A.P. and Smith, R.H. eds*)*. CAB International, London.

Workneh Gebresilassie, Afework Bekele, Gurja Belay and Balakrishnan, M. (2006). Home range and reproduction of rodents in Maynugus irrigation field, northern Ethiopia. *SINET: Ethiop. J. Sci*. **29:** 57-62.

Workneh Gebresilassie, Afework Bekele, Gurja Belay and Balakrishnan, M. (2004). Microhabitat choice and diet of rodents in Maynugus irrigation field, northern Ethiopia. *Afr. J. Ecol.* **42:** 315–321.

Yalden, D. W. (1983). The extent of high ground in Ethiopia compared to the rest of Africa. *SINET: Ethiop. J. Sci.* **6:** 35-38.

Yalden, D. W. and Largen, M. J. (1992). The endemic mammals of Ethiopia. *Mammal. Rev.* **22:** 115–150.

Yalden, D. W., Largen, M. J., Kock, D. and Hillman, J. C. (1996). Catalogue of the mammals of Ethiopia and Eritrea. 7. Revised checklist, zoogeography and conservation. *Trop. Zool.* **9:**73-164.

Yalden, D.W. (1988). Small mammals of the Bale Mountain Ethiopia. *Afri. J. Ecol.* **26:** 281–294.

Yalden, D.W., Largen, M. J. and Kock, D. (1976). Catalogue of the mammals of Ethiopia, Insectivores and Rodentia. *Mon. Zool. Ital. Supplemento.* **8:** 1–118.

Yamane, T. (1967). *Statistics an Introductory Analysis*. 2^{nd} ed. Harper and Row, New York.

Yonas Terefe and Fikresilasie Samuel (2015). Seasonal Species Composition and Abundance of Rodents in Yerer Mountain Forest Area, Central Ethiopia. *Ameri. J. Bio. Sci.* **3:** 87–92.

Yunger, J. A., Meserve, P. L. and Gutierrez, J. R. (2002). Small mammal foraging behavior: mechanisms for coexistence and implication for population dynamics. *Ecol. Monogr.* **72:** 561–577.

Zelealem Tefera, Leader-Williams, N. and Coulson (2012). Consequences of human land use for an afro-alpine ecological community in Ethiopia. *Conserv. Soc.* **10:** 209-216.

Zerihun Girma, Afework Bekele and Hemson, G. (2012). Small mammals of Kaka and Hunkolo, southeast Ethiopia. *Trop. Ecol.* **53:** 33–41.

APPENDIX I: List of large mammal species of the study area.

Common name	Scientific name	Status
Menelik's bushbuck	*Tragelaphus seriptus*	Endemic
Common duiker	*Sylvicapra grimmia*	
Klipspringer	*Oreotragus oreotragus*	
Common hare	*Lepus timidus*	
Common warthog	*Phacochoerus aethiopicus*	
Wild pig	*Sus scrofa*	
Serval Cat	*Felis serval*	
African wildcat	*Felis silvestris*	
Caracal	*Caracal caracal*	
Leopard	*Panthera pardus*	
Spotted Hyena	*Crocuta crocuta*	
Common Jackal	*Canis aureus*	
Abyssinian genet	*Genetta abyssinica*	
African civet	*Civettictis civetta*	
Slender mangoose	*Herpestes sanguineus*	
Honey Badger	*Mellivora capensis*	
White tailed mangoose	*Ichneumia albicauda*	
Large gray/Egyptian	*Herpestes ichneumon*	
Aardvark	*Orycteropus afer*	
Gelada Baboon	*Theropithecus gelada*	Endemic
Anubis baboon	*Papio Anubis*	
Grivet monkey	*Cercopithecus aethiops*	
Common bushbuck	*Tragelaphus scriptus*	

APPENDIX II: Comparisons of species composition of small mammals from different highlands of Ethiopia.

Studied site	No. of spp.	No. of Species similarity with Yegof Mt.	Authors
Borena Sayint National Park	12	7	Eshetu Moges (2008)
Guassa Conservation Area	4	4	Zelealem Tefera *et al*. (2012)
Semien Mountain Park	8	4	Mesele Yihunie and Afework Bekele (2012)
Bale Mountain Forest	9	4	Yalden (1988).
Menagesha Supa Forest	13	7	Afework Bekele (1996)
Chilalo–Galama Mountains	17	9	Mohammed Kasso *et al*. (2010)
Abune Yoseph Mountain	10	6	Teklu Damtie (2008)

APPENDIX III. Questionnaire

ASSESSMENT THE PEST IMPLICATIONS OF SMALL MAMMALS AROUND YEGOF NATIONAL FOREST PRIORITY AREA

A. Introductory questions

1. Sex (Male/Female)

2. Age = A. < 20 B. 21-30 C. 31-40 D. 41-50 E. 51-60 F. >60

3. Marital status (Single, married, divorced, widowed) ________________

4. Educational status (illiterate, primary, Secondary, beyond secondary education) _____

5. Occupation= A. Agriculture B. Governmental employee C. No Job D. Trade

6. Family size = A. 1-3 B. 4-6 C. 6-9 D. > 9

7. Residence: Village___________ Kebele_________________________

B. Conflict and Damage questions

8. Approximate distance from the boarder of the study area

A. < 1 km B. 1- 3 km C. 3.1- 6 km D. > 6 km

9. Farmland holding per household.

A. < 1 ha. B. 1-4 ha C. 4.1- 8 ha D. 8.1-12 ha E. > 12ha

10. What is your main crop growing in your farmland?

A. Barely, wheat and teff B. Maize C. Peas and beans

D. Lentil and chickpeas E. Sorghum

11. Amount of production per season

A. 1-5 quintals B. 5- 10 quintals C. 10- 15 D.15-20 quintals E. > 20 quintals

12. Amount of production lost by pest rodents.

A. < 1quintals B. 1-3 quintals C. 3-6 quintals D. > 6quintals

13. What is your main source of income?

A. Agriculture B. Livestock husbandry D. Both

14. Which type of crop is more attacked by rats in your cropland?

A. Barley, wheat and teff B. Beans and peas C. Maize

D. Vegetable E. Lentil and chickpea

15. Which type of crop is most attacked by porcupines in your cropland?

A. Barley and wheat B. Beans and pens C. Maize D. Vegetable E. Lentil and chickpea

16. Which growth stage of crops susceptible to rodent damage?

A. Sowing B. Vegetative C. Booting D. Maturity E. others (mention) _______

17. Occurrence of small mammals impacts on crops: A. Regular B. Occasional C. Rare

18. Which portion of the crop land more damage by rodents?

A. Interior B. Peripheral C. Random E. Other (mention) ___________

19. At what time you control pest rodents?

A. Before planting B. After planting C. Both D. Others (mention)____

20. To what extent rodents are damage your crops?

A. High B. Medium C. Low

21. What is the major causes for the happening of crop damage in your area?

A. Expansion of agriculture around the forest edge B. Deforestation

C. Increment of small mammals population D. Other (mention)____

22. In which season small mammals are the most damage your crops?

A. Dry season B. Wet season C. Both wet and dry season

23. Population status of pest small mammals in your area.

A. Increasing B. Decreasing C. The same d. Unknown

24. Describe the types of pest rodents and their damage in the following table.

S. No.	Pest animal	Type of crop damaged	Stage of crop damage	Parts of crop damage	Time of the problem more sever (day or night)	Area of cropland damaged per year	Amount of crops damage per year

25. Your crops mainly damaged by? A. Rats B. Porcupines C. Mole Rats D. All

26. Do you think conserving of small mammals are important? (Yes/No) ___________

If your response is Yes how they are useful ___________________________________

If your response is No. Why? ____

28. What control measure has been used to safeguard you crops from pests?

A. Trapping B. Chemicals C. trapping and chemicals D. Field sanitation E. Others _

29. What is the tendency of crop damage by small mammals from time to time?

A. Increasing B. Decreasing C. Unknown

APPENDIX IV. Data collection Sheet for Sherman live trapped species.

Data Collector ______________________ **Habitat** ________________________ **Season** __________ **Date/Month**_______________________

Weather _____________________**Time: Morning** _______ **Afternoon** __________.

Tap No.	GPS Location			Sex category		Age				Weight	Reproductive Condition							Name of Species	Catch (New/ recaptured)	Remark
	x	y	Alt (m)								Male		Female							
											Testicles		Vagina		Breeding					
				M	F	A	SA	Y	JU		AB	SC	PF	CL	Preg	Lac	No. of Nipple			

Keys: 1. Sex: M= Male**, F=** Females

2. **Age**: **A**= Adult, **SA**= Sub-adult, **Y**=Young, **JU**= Juveniles

3. Reproductive condition: For male: **Ab**=Abdominal testicles, **Sc**= scrotal testicles; For females **PF**= perforate vagina, **CL**= Closed Vagina; Preg= Pregnant, **Lac**= lactating

APPENDIX V. Data collection sheet for snap trapped species

Data Collector ______________________ **Habitat** ________________________ **Season** __________ **Date/Month**_______________________
Weather ______________________Time: Morning _______ **Afternoon** _____________

Tap No.	GPS Location			Sex category		Age				Weight	Body Measurements				No. of Embryo	Name of Species	Remark
	x	Y	Alt (m)														
				A	F	A	SA	Y	JU		BL	TL	HL	EL			

Keys: 1. Sex: M= Male**, F=** Females
2. **Age**: **A**= Adult, **SA**= Sub-adult, **Y**=Young, **JU**= Juveniles
3. **Body Measurements**: **BL**= Body length, **TL**= Tail length, HL= Hind leg length, **FL**= Front Leg length, **EL**= Ear length