JIMMA UNIVERSITY

COLLEGE OF NATURAL SCIENCES

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF BIOLOGY

Comparative Study of Rodents and Insectivores in Natural and Coffee Forest Habitats of Afalo Area, Gera District, Southwestern Ethiopia

By:

Demelash Sime

A Thesis Submitted to the Department of Biology, College of Natural Science, and School of Graduate Studies of Jimma University, In Partial Fulfillment of the Requirements for the Degree of Master of Science in Biology (Ecological and Systematic Zoology Stream)

Jimma, Ethiopia

October, 2015

Jimma University

College of Natural Sciences

School of Graduate Studies

Department of Biology

Comparative Study of Rodents and Insectivores in Natural and Coffee Forest Habitats of Afalo Area, Gera District, Southwestern Ethiopia

By:

Demelash Sime

A Thesis Submitted to the Department of Biology, College of Natural Science, and School of Graduate Studies of Jimma University, In Partial Fulfillment of the Requirements for the Degree of Master of Science in Biology

(Ecological and Systematic Zoology Stream)

Advisors: Tadesse Habtamu (PhD)

Tsegaye Gadisa (PhD)

Jimma, Ethiopia

October, 2015

Declaration of the author

I, hereby, declare that this thesis is my original work and has not been presented for degree in any other University, and that all sources of materials used for the thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for Msc. Degree at Jimma University and is deposited at the University library to be made available to borrowers under rules of the library. I declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma. Brief quotations from this thesis are allowable without special permission provided that accurate acknowledgement of the source is made.

Name: Demelash Sime

Signature------------------

Date----------------------

Acknowledgement

First and for most I would like to thank the Almighty GOD who strengthened me and gave me capacity throughout my career to reach this stage.

Secondly, I would like to express my truthful gratitude to my advisors, Dr. Tadesse Habtamu and Dr. Tsegaye Gadisa for their wholehearted effort in advising, invaluable guidance, critical, useful comment and providing technical support to conduct the study. Their continuous follow up and constructive comments from the beginning of proposal development to the final write-up of this thesis have been enormous help to productively finish this research. I gratefully thank and appreciate both my advisors for their material and moral support too.

I am also happy to extend my deepest gratitude to my family for their moral and financial support, encouragement throughout my study and who made a baseline to reach this stage. Special thanks to my brother, Abayneh Sime, for his indispensable moral support.

I extend my appreciation to Mr. Mulugeta Wakjira, and Tokuma Negisho, for all support, advice and kindness that they gave me.

Also, I would like to thank Gera district for their permission, Aba Sharo and Sabit for showing through the forest and people of Afalo area.

I would like to thank all my friends specially, Gadisa Natea, Tsegab Temesgen and Ayele Demise, for their encouragement to finish this work on time.

Last but not least I thank all the people who are directly and indirectly involved in my work, but I could not mention their names due to the scarcity of space.

Table of Content Page

List of Tables **Page**

List of Figures **Page**

List of Appendix

Abbreviation and Acronyms

GPS - Global Positioning System

NLFC - Newhall Land and Farming Company

ZNHM - Zoological Natural History Museum, Addis Ababa University

CSA - Central Statistical Authority.
SPSS – Statistical Program of Software System

NF - Natural Forest

CF - Coffee Forest

ZNHM - Zoological Natural History of Museum.

A.S.L. - Above Sea Level

WARDO- Woreda Agricultural and Rular Development Office

ABSTRACT

A comparative study of the diversity, distribution and abundance of small mammals (rodents and insectivores) in natural and coffee forest habitats of Afalo area of Gera district was conducted from August, 2014 to March, 2015. Two sites, one with coffee forest and the other natural forest, were selected for the study. Grids were established and randomly selected in each of the habitats, and representative sample sites were taken from each habitat type. Mammals were sampled by setting traps on randomly selected grids. Sherman traps and snap traps were used to trap small mammals and animals were identified to the species level in the field. Skin and skull of some representative specimens were mounted and used for identification of animals that were difficult to identify in the field. A total of 110 individuals were trapped during the present study. Seven species of rodents and three species of shrews were identified and recorded from Afalo area. Of the total trapped species, Lophuromys flavopunctatus had the highest relative abundance 35(49.3%), followed by Grammomys dolichuros, and Lophuromys chrysopus with 23(47.5) % and 16(29.7) % respectively. Rattus rattus, Mus musculus, Crocidura flavescens, Crocidura fumosa and Crocidura bicolor had 22.2%, 20.7%, 13.3%, 10.7% and 1.4% respectively. Hystrix cristata and Paraxerus ochraceus had the lowest relative abundance (1.4%) each. Hystrix cristata and *Paraxerus ochraceus were recorded only from NF habitat*. *The abundance of species varied among habitats and between seasons. There was significance variation in the rodent and insectivore abundance among the seasons (x^2= 2.11, df =1, P<0.05). Diversity and abundance of small mammals affected by increased habitat heterogeneity, open habitat, habitat disturbance, vegetation structure and composition and seasonal availability of food and water. The highest and insectivore species diversity was recorded in NF habitat (H' =1.634). Vegetation cover, rainfall and human interference were the major factors affecting the diversity, abundance and distribution of small mammals in the study area. To gain detailed account of the forest fauna of the area and to evaluate the impacts of forest management on the diversity and abundance of small mammals several sites from each habitat has to be assessed.*

Key words: *Distribution, Diversity, Abundance, Small mammals, Gera, Coffee, Ethiopia*.

1. INTRODUCTION

1.1. Background of the study

Recent studies define small mammals as those less than 200gm body weight, but the threshold is still debatable (Juokaitis and Baranauskas, 2001; Hashim and Mahgoub, 2007).

Small mammals comprise the highest proportion and the most successful among the mammal species all over the world (Vaughan *et al*., 2000; Gadisa and Bekele, 2006; Gebresilassie *et al.*, 2006; Takele *et al.*, 2011). They are the most diverse groups and account for nearly half of the total mammal fauna in any given area (Kingdon, 1997). Diverse types of interactions with other organisms, adaptability to diverse habitats and variation in the food habit of small mammals have been responsible for their success in such wide distribution pattern, globally. In Africa, small mammals are probably the most ubiquitous and numerous (Skinner and Chimimba, 2005).

The diversity, abundance and distribution of small mammals can be affected by several biological and physical factors, including predator avoidance, competition within or with other species, and resource levels, especially the availability of food and water (Willig *et al.*, 2003; Kelt *et al.,* 2004). The population dynamics of small mammals follow seasonality in relation to variations in rainfall and reach peaks towards the end of the rainy season when resources are plenty (Feliciano *et al*., 2002; Mssawe *et al.,* 2006). In community dynamics of small mammals habitat selection is considered as an important factor because of their high potential for reproduction and ability of their invasion (Shanker, 2001). Generally, habitats with increased structural heterogeneity positively influence small mammal abundance and richness (Tews *et al*., 2004).

Small mammals play an important role in natural communities including as a source of energy for predators and raptors (Davies, 2002; Schmidt *et al.*, 2002). They are good indicators of habitat disturbance (Solari *et al.,* 2002). Also, small mammals have been particularly useful in the study of elevational gradients, mainly because they form well-defined assemblages (in contrast to medium-sized and large mammals) along such gradients (Lomolino, 2001; Mena and Vazquez Dominguez, 2005).

Small mammals are good bio-indicators of environmental condition due to their rapid turnover rate (Happold, 1979), high biotic potential, ability to invade reclaimed areas and sensitivity to environmental disturbance (Malcom and Ray, 2000).

They may potentially influence vegetation composition via selective foraging (Brown & Heske, 1990). Small mammals diversity tends to be lower in open habitats, where cover providing food and resources (Silva *et al*., 2005) is reduced, leading to lower fecundity (Grant *et al.*, 1982) as well as increased predation risk (Kotler, 1997; Andreassen & Ims, 1998).

A number of studies have been carried out on several aspects of small mammal communities in some parts of the country. There are 58 forested areas in Ethiopia that have been given priority conservation status (Kidane, *et al.*, 2010, but rodents and insectivore have been assessed in only some of these (Senbeta and Teketay, 2003). Most of the assessments have been confined to those forests in the central and southern highland areas (Bekele, *et al*., 1996; Datiko, *et al.*, 2007). None of these, assessed the small mammalian diversity of the tropical forest and rare for the coffee forest habitats (Habtamu and Bekele, 2012). Gera forest is one of the forest under protection of Belete-Gera National Priority Forest in the Oromia region of southwestern Ethiopia, are less studied.

Coffee plantation has led to a loss of natural habitats and affected both the composition and diversity of small mammal communities living in natural habitats (Peter, 2012). Coffee plantations and extensive resettlement activities has leading to the destruction of natural habitats (Fitzgibbon, 1997; Mekuria, 2005). Small mammal communities would be expected to be less diverse and more homogeneous in agricultural lands than in conservation land-uses because of the homogeneous vegetative structure.

Small mammal species richness was reported to be higher in structurally complex forests (Sullivan and Sullivan, 2001), and species composition and abundance is positively influenced by forest management and increased habitat heterogeneity (Tews *et al*., 2004). In addition, activity of changing natural forest had negative effects on small mammal abundance due to decrease herbaceous understory on recently cut sites. Bayessa (2010) indicated that modified habitats including plantation forest and cultivation influenced rodent distribution due to availability and quality of food, shelter and rainfall. Therefore, this study aimed to assess the areas for their faunal diversity may contribute to the enrichment of the faunal list of the country. And this study also report faunal potential of the region has and the potential economic and social risks particularly associated with small mammals. In addition, to fulfill the gap on information on the small mammal fauna of the tropical forest, attempts to collect data on the diversity, distribution and relative abundance of small mammals between natural and managed tropical coffee forest habitat of the study area.

1.2. Statement of the problem

Small mammals play a fundamental role in ecosystem functioning as they constitute the prey base for many predators (Schmidt *et al.*, 2002) and may potentially influence vegetation composition via selective foraging (Brown & Heske, 1990). Small mammals have been used elsewhere as ecological indicators of the effects of forest management practices (Pearce and Venire, 2005; Kaminski *et al*., 2007). Small mammals are also good bio-indicators of environmental condition, and habitats due to their rapid turnover rate, high biotic potential, ability to invade reclaimed areas and sensitivity to environmental disturbance (Happold, 1979; Malcom and Ray, 2000).

They also affect the structure, composition, and dynamics of ecosystems through natural processes such as pollination, seed dispersal and depredation, mycorrhizal dispersal, insectivore, and as food for predators (Mangan and Adler, 2002; Naranjo *et al*., 2003 and Napolitano *et al.*, 2008).

So far, no comparative study of small mammal's composition, distribution, and abundance in the natural and tropical coffee forests habitats was conducted. This study therefore, attempted to assess the diversity of small mammals in two different habitats and identify the habitat that is less diverse on the composition of small mammals. With the result of the research the faunal potential of the region mentioned and factors affecting the composition, distribution and diversity of small mammals identified and recommended to be solved by concerned body.

1.3. Objectives

1.3.1. General Objective

The general objective of this study aims to compare the diversity, distribution and abundance of small mammals (rodents and insectivores) in natural and coffee forest habitats in Afalo area, Gera district, Southwestern Ethiopia.

1.3.2. Specific Objectives

- ✓ To determine the diversity, distribution and abundance of rodents and insectivores in natural forest habitat of Afalo area.
- ✓ To determine the diversity, distribution and abundance of rodents and insectivores in managed coffee forest habitat of Afalo area.
- ✓ To compare the diversity and abundance of rodents and insectivores in the natural and coffee forest habitat of Afalo area.
- ✓ To determine the impacts of managed coffee forest habitat of Afalo area on the diversity, distribution and abundance of rodents and insectivores.

1.4. Significance of Study

Small mammal species play key ecological roles in tropical forests. Small mammals are good bio-indicators of environmental condition due to their rapid turnover rate, high biotic potential, and sensitivity to environmental disturbance. They also provide food for predators. Therefore, study is essential to determine the diversity, distribution and abundance of small mammals among non-coffee bearing natural tropical forest and in tropical forest with coffee plantation and then to compare the diversity and abundance of small mammals in both habitat types and the study also enrich faunal list of the country and fills the gap of faunal potential of the study area have. Hence, this study is planned to give stand line information on small mammals in the study area for future study and provide information on the broad knowledge of these important mammals. And also forward the recommendation on the action to be taken for the problem these small mammals faced.

2. LITERATURE REVIEW

2.1. Global distribution of Small mammals

Small mammals form the highest proportion of mammals all over the world (Gadisa and Bekele, 2006; Gebresilassie *et al.,* 2006; Takele *et al.,* 2011). Wilson and Reeder (2005) reported that a total of 5416 mammalian species are recorded globally, of which more than 2277 species are rodents and insectivores. They account for about 42% of small mammal species grouped under, 481 Genera and 33 Families (Wolff and Sherman, 2007). Insectivore fauna are also diverse, having 429 species worldwide, of which 312 are shrews, and 140 species found in East Africa (Kingdon, 1997). Small mammals occur in every habitat, from the high Arctic Tundra, where they live and breed under the snow, to the hottest and driest deserts (Kingdon, 1997). They are able to exploit a wide range of habitats throughout the world (Vaughan *et al.,* 2000; Lange *et al*., 2004).

2.2. Distribution of Small mammals in Africa

Rodents and shrews are important contributors to biodiversity of ecosystems in sub-Saharan Africa (Linzey and Kesner, 1997). Small mammals are probably the most ubiquitous and numerous in Africa (Skinner and Chimimba, 2005). Over 1150 species of mammals are currently listed for Africa, but still more mammalian species, especially rodents, insectivores and bats, await discovery (Kingdon, 1997). In Africa, 381 species of rodents occur (Wilson and Reeder, 1993). In east Africa, mountain landscape, such as the Kilimanjaro, Elgon, Meru, Usambra and Uluguru contain a number of endemic species with high disjunctive distribution (Clausnitzer and Kityo, 2001; Stanley *et al.,* 2005).

Many studies were carried out in the continent on rodents and insectivores diversity and distribution. These include, Skinner and Chimimba (2005) in Southern African sub region, Avenant and Cavallini (2008) and Avenant (2011) in South Africa, Linzey and Kesner (1997) in Zimbabwe, Oguge (1995) in Kenya, and Leirs *et al*. (1994) in Tanzania. For instance, one study on the community structure of small mammals (Rodentia and Soricomorpha) from the Gulf of Guinea region of West Africa found 45 species of Soricomorphs and 101 of rodents (Amori and Luiselli, 2011). However, ecological studies for small mammals in Africa focused mostly on the western region, with minimal attention on the eastern part of the continent (Habtamu and Bekele, 2008).

2.3. Distribution of Small mammals in Ethiopia

As a result of geology, topography, climate and altitude, Ethiopia possesses a very diverse set of ecosystems ranging from humid forest and extensive wetland to the desert (Shibru, 1995). As a consequence, the country acquired much diversity of species and endemics (Yalden and Largen, 1992). Over 284 mammalian species have been recorded from Ethiopia (Yalden and Largen, 1992). Out of these, 31 mammal species are currently believed to be endemic (Yalden and Largen, 1992). Many of the endemic mammals of Ethiopia are associated with high altitude moorland and grassland habitats (Yalden, 1983).

Of all the mammalian orders, the rodents contain the largest number of species which are widely diversified and distributed (Nowak, 1991; Kingdon, 1997). Some studies were carried out on several aspects of small mammal communities in some parts of the country including Chebera-Churchura National Park (Datiko and Bekele, 2012), Alatish National Park (Habtamu and Bekele, 2008), Jiren Mountain, (Habtamu and Bekele, 2012), Nechisar National Park (Datiko *et al.,* 2007), Bale Mountains National Park (Yalden, 1988; Lavrenchenko *et al.,* 1997) and Simen Mountains National Park (Yalden *et al.,* 1996) and in Central Ethiopia (Bekele and Leirs, 1997).

The abundance and diversity of small mammals in forest ecosystems depend mainly on the nature and density of vegetation for food and shelter (Gebresilassie *et al.,* 2004). Coffee plantations had significant reductions in species richness and heterogeneity and showed an increase in community similarity, suggesting a more homogenized small mammal community (Peter, 2012). Small mammals are well suited for examination of population responses to habitat fragmentation as they have modest spatial requirements and short generation times. Small mammals appear to be altered by high-intensity agriculture (Monadjem and Perrin, 2003); but information on their community composition across agriculture and conservation land-uses are limited (Caro, 2001). In previous time, a particular impact of expanding monoculture habitat (coffee plantation) on small mammalian faunal diversity was not studied. However, it has been shown that reducing the heterogeneity of habitats favours few more generalist pest species

(Peter, 2012). Therefore, this study attempted to explain the impacts of managed coffee plantation on the diversity of small mammals and their abundance.

2.4. Factors affecting diversity, distribution and abundance of small mammals

According to Willig *et al.* (2003); Kelt *et al.* (2004) the diversity, abundance and distribution of small mammals can be affected by several biological and physical factors, including predator avoidance, competition within or with other species, and resource levels (especially the availability of food and water).

Species composition and abundance is positively influenced by forest management and increased habitat heterogeneity (Tews *et al*., 2004). Small mammals' distributions are likely affected by any kind of structural and temporal disturbance in their habitat, mainly caused by anthropogenic influence. Therefore, changes in land use are very likely to have effects on small mammals (Fitzgibbon, 1997) and their associated functions in the ecosystem. At a local scale, their distribution and abundance is influenced by vegetation structure and composition, which reflect the habitat condition (Gebresilassie *et al.*, 2004; Kannan & James, 2009; Nowak, 1999), increases with reduction in body size of the species. In addition, vegetation structure and cover affect the micro-climate and necessary cover for small mammals against predators (Hansson, 1999). However, the reactions of small mammals to structural changes in habitat attributes and different management are not completely understood.

The abundance and diversity of small mammals in forest ecosystems depend mainly on the nature and density of vegetation for food and shelter (Gebresilassie *et al.*, 2004). Habitat complexity, association and disturbance are other important factors affecting species diversity and distribution in natural ecosystems (Obsom & Parker, 2003; Datiko *et al*., 2007; Habtamu & Bekele, 2008; Kilgore *et al*., 2010). Disturbance is an important ecological factor affecting species diversity in natural environments (Sousa, 1984). These events can remove biomass, creating free substratum, and competition. Small mammal diversity tends to be lower in open habitats, where cover providing food and resources (Silva *et al.*, 2005) is reduced, leading to lower fecundity (Grant *et al.*, 1982) as well as increased predation risk (Kotler, 1997; Andreassen and Ims, 1998).

2.5. Roles of small mammals in Forest Ecosystems

Small mammals are important components of biological diversity (Hashim and Mahgoub, 2007). Small mammal species play key ecological roles in tropical forests. Small mammals are known to have economical, ecological, social and cultural values (Bekele and Leirs, 1997; Martin, 2003; Avenant, 2011). Non-flying, small mammals play crucial roles in many ecosystems because they are abundant and constitute important members of food webs.

Small mammals also play an important role in natural communities and provide the main supply of live-food for many of the predatory mammals, birds and reptiles (Granjon *et al.*, 2002; Davies, 2002). They make up a significant percentage of the diet of a variety of carnivores (Jorge, 2008). They play a fundamental role in ecosystem functioning as they constitute the prey base for many predators (Schmidt *et al.*, 2002).

Small mammals are considered to be good bio-indicators of habitats because of their short lifespan, rapid population dynamics and low level of pressure on their populations as a result of hunting in comparison with large mammals (shrews are never hunted because of the strong, unpleasant smell of their flank glands) (Barriere *et al*., 2006). They are also good bio-indicators because of the diversity, in tropical Africa, in terms of species and habitat preference (Barriere *et al*., 2006). Small mammals are good bio- indicators of environmental condition due to their rapid turnover rate (Happold, 1979), high biotic potential, ability to invade reclaimed areas and sensitivity to environmental disturbance (Malcom and Ray, 2000). Small mammals have been used elsewhere as ecological indicators of the effects of forest management practices (Pearce and Venier, 2005; Kaminski *et al.*, 2007).

Likewise, small mammals have been particularly useful in the study of altitudinal gradients, mainly because they form well-defined assemblages (in contrast to medium-sized and large mammals) along such gradients (Lomolino, 2001; Mena and Vazquez Dominguez, 2005)**.**

They affect the structure, composition, and dynamics of ecosystems through natural processes such as pollination, seed dispersal and depredation, mycorrhizal dispersal, insectivore, and as food for predators (Mangan and Adler, 2002; Naranjo *et al*., 2003; Vieira and de Moraes, 2006; Napolitano et al., 2008).

3. STUDY AREA

3.1. Description of Study area

3.1.1. Geographic location

This study was conducted in Afalo area, Gera district. It is located west of Jimma town, southwestern Ethiopia between 7°38’12.5’’- 7°46’13’’N and 36°17’04.6’’- 36°21’ 0.5’’E. The altitudinal ranges of Afalo area was 7°38’ N, 36°13' E (De Beenhouwer, 2011). Gera district is 70 km west of Jimma and 435 km from Addis Ababa (Figure 1). Gera is located in the Eastern Afromontane biodiversity hotspot1, one of 34 hotspots in the world (Schmitt *et al*., 2010). The areal extent of the district is 1,330 km^2 (Hylander *et al.*, 2013).

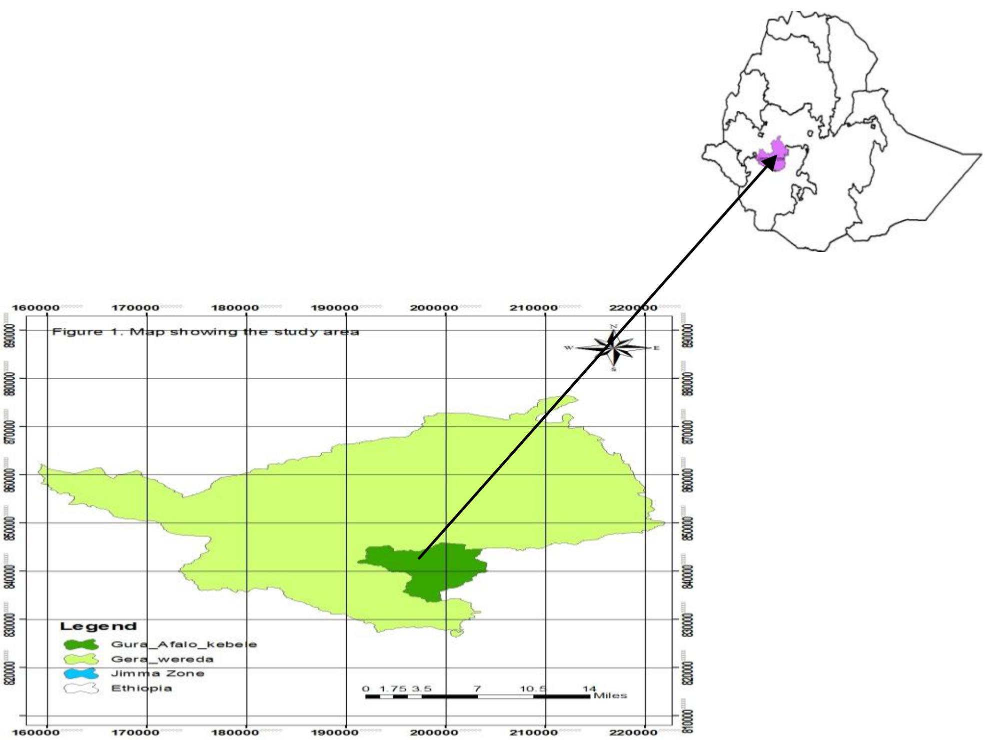

Figure 1: Map of the study area

3.1.2. Climate

The climate data for temperature and rainfall over the five years (2010-2014) for the study area was obtained from Jimma meteorology station.

3.1.2.1. Temperature

Differences in temperature throughout the year are small. According to the temperature data obtained from the Ethiopia Metrological Agency at Jimma station the mean maximum and minimum annual temperature of area ranged between 24.5°C and 11.0°C, respectively (Figure 2).

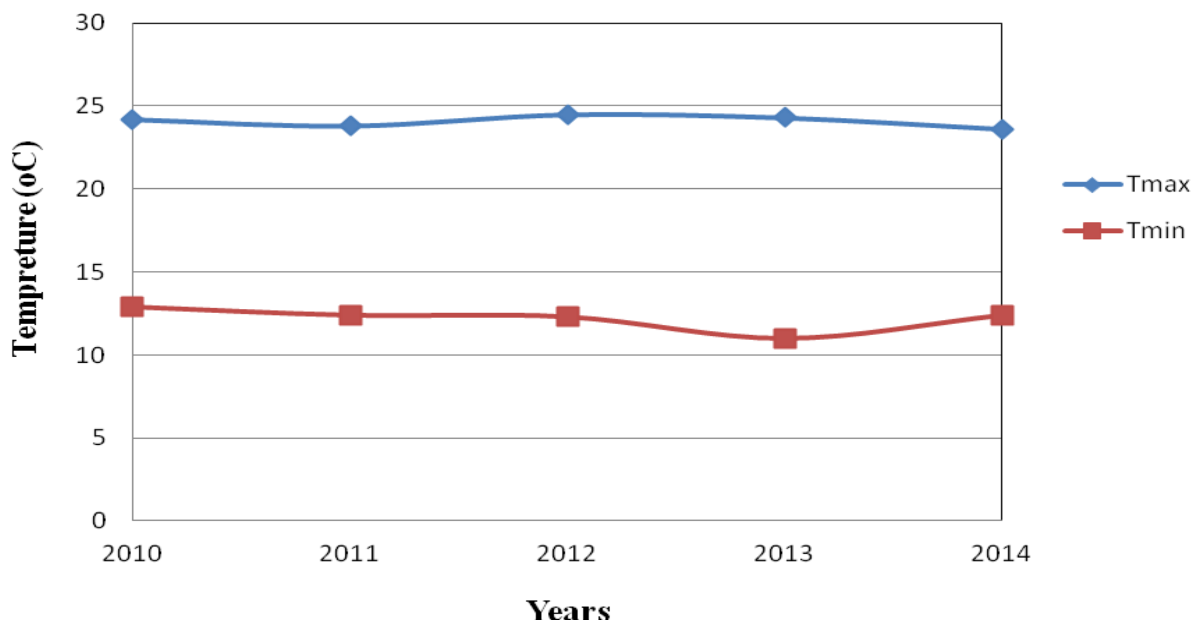

Figure 2. The mean annual minimum (Min) and maximum(Max) temperature of Gera Woreda (Afalo area) from 2010-2014 (National Meteorological Agency, Jimma Branch, 2015).

3.1.2.2. Rainfall

The area experiences frequent rainfall, and hence moisture stress is not a problem for their agricultural production. The rainfall distribution pattern of this area is bimodal, the highest rainfall between June and September and with low rainfall during March and April the (National Meteorology Agency, Jimma Branch, 2015). The total amount of annual rain fall in the study area varies between 1200mm and 1800mm (Figure 3) and the mean annual rainfall of the area is 1900mm.

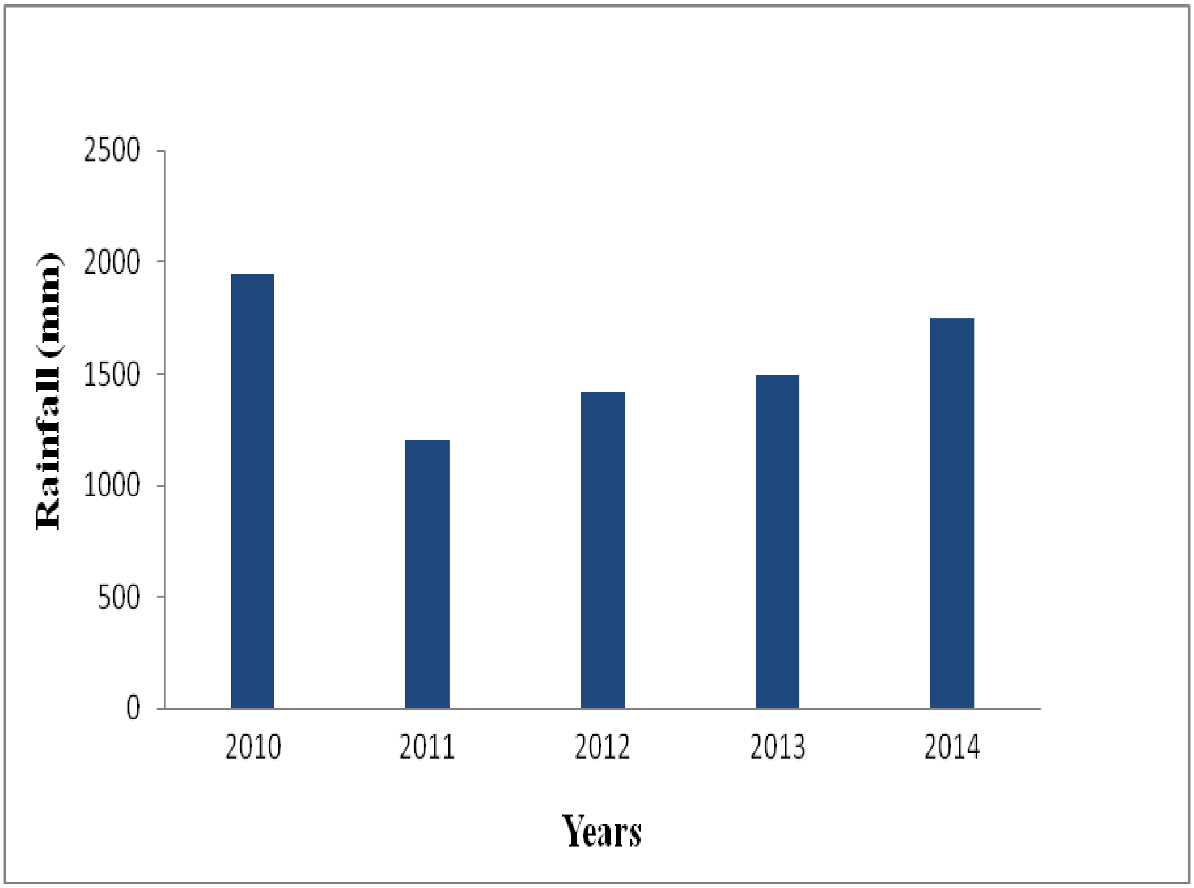

Figure 3. Mean annual rainfall of Gera District area from 2010-2014 (National Meteorology Agency, Jimma Branch, 2015).

3.1.3. Topography and Soil

The area has different topographical features ranging from low land to highland. The elevations in the district ranges between 1,500 m and 3000 m (Gera Woreda Profile, 2012, Gemechu *et al.*, 2014) and the area classified into lowland <1,500 m, mid-highland 1,500-2,000 m, and highland >2,000 m. According to CSA, (2008), and Hylander *et al. (*2013) 50% of the land is covered by natural forest. Dense forests cover most of the southern parts of Gera, where the altitude is below 2000 m. Belete-Gera National Forest Priority Area is found there in Gera district. Concerning the type of the soil, it is dominated by red-dish clay and forest soil in the gentle slopes and grey-vertic soil type in the lowlands (CSA, 2008).

3.1.4. Demography

The area has an estimated total population of 115,307 inhabitants, of which 95.9% live in rural areas subsisting on mixed agriculture (CSA, 2008; Gera Woreda Profile, 2012).

3.1.5. Land use patterns and Human settlement

Land-use patterns of the area include: farming, cattle rearing, harvesting coffee, wild honey collection and honey production. The northern part of district experience extended crop-production, where the altitude reaches above 2000 m.

3.1.6. Vegetation

One of the habitats identified for the study was natural forest, locally named as Gera Forest, which is found under the protection of Belete-Gera National Forest Priority. Natural forests are the dominant vegetation covers of the district (CSA, 2008). Due to this favorable climate, Gera has 113,514 ha of forest (Cheng *et al*., 1998). Slightly more than half of the district is covered by forest and the extent of forest cover has been reduced over the past few decades (Hylander *et al.*, 2013). Most of this forest belongs to a state-owned enterprise, the Oromia Forest and Wildlife Enterprise. Private companies and farmers, however, own a significant proportion of the forest. This forest is categorized under Afromontane rainforest type (Friis, 1992).

The forest generally forms a good canopy cover with a number of undergrowth plant species. Based on the vegetation type, the study area was classified in to two major habitat types as follows: Natural forest and Coffee forest (Figure 4 and Figure 5) respectively. Dominant tree species of the study area are trees such as*: Albizia gummifera, Bersema abyssinica, Cordia africana, Croton macrostachyus, Urtica simensis, Domboya torrid, Ekebegia capensis, Ficus sycomorus, Coffee arabica, Ficus vasta, Podocarpus falcatus, Ficus thoningi, Lippia adoensis, Maytenus arbutiolia, Juniperus procera, Phoenix reclinata, Pouteria adolfi-friederici, Syzygium guineense, Apodytes dimidiata and Maytenus arbutiolia (*Hundera, 2007*).*

Figure 4.Vegetation of NF habitat in the study area. (Photo: Demelash S., Aug., 2014)

Figure 5. Vegetation of CF habitat in the study area (Photo: Demelash S., August, 2014).

4. MATERIALS AND METHODS

4.1. Materials

Materials used during the present study were Sherman live-traps (16x6.5x5.5 cm), bait (Peanut butter, Corn flour), Dissecting kit, Camera, Face masks, Spring balance (Pesola), Zip lock plastic bag, GPS unit, Clipboard, Data forms, Pencils, Gloves, Calipers, Scale, Ruler, Head torches, the Kingdon field guide book.

4.2. Methods

4. 2.1 Preliminary Survey

Preliminary survey was conducted in early August, 2014. The survey was conducted in natural forest and managed coffee forest in around Afalo area to determine the different habitat types that suite for the purpose. Based on the presence or absence of coffee plantations, study area was classified into natural forest (NF) and coffee forest (CF). During the survey, information on the different vegetation types, their area extent and distance between them as a buffer area were also assessed. Geographic position of the study area, the altitude ranges, temperature and rainfall data were also secured.

4.2.2 Grid Design and Sampling

Trapping was conducted from August, 2014 to March, 2015 in Afalo area. In the selected habitats, eight permanent trapping grids, each of 30 m x 30 m (900m^2) four from each habitat types) were established to gather information on live-trapped specimens, the grids comprised of 3 parallel lines 10 m apart, with a trapping station in each line, resulting in 16 trapping stations. Three rows placed by 10m were established on each grid, for the trapping purpose. On each trapping stations one Sherman live trap was used. The grids were used during both the wet and dry seasons. Peanut butter mixed with corn flour was used as bait. The traps were covered by hay and plant leaves during the dry season to minimize temperature changes and to avoid from sight of baboons. This also provided protection for the trapped animals against the strong heat. Traps were set between 06:00 and 07:30 am, in the morning and checked for diurnal catch between (16:30-18:00 hr), the same day. Traps were checked for nocturnal catches and removed between

(06:30 - 09:00 hr), for 4 consecutive days. Traps were baited the first day and as necessary re-baited the following day. Each grid was trapped for 4 consecutive days per seasons for the wet (between August through October, 2014) and dry (December and February, 2015) seasons. Each grid was trapped for 4 consecutive days. Each habitat was sampled for about 256 trap nights for season.

After collecting the necessary data, all live trapped animals were released at spot they were trapped. Eight Snap traps were used and placed 200 m away from permanent grids for voucher specimen preparation purpose. Specimens from the snap traps were mounted and used as voucher specimens for confirmation of species identification. The standard procedure (Alpine et al., 2003) was used to mount voucher specimens.

Sexual conditions of males were assessed via examination of scrotal and abdominal testes (Ghobrial and Hodieb, 1982), while for female's conditions including perforate or imperforate vagina, pregnancy and lactating (Bekele, 1996; Alpine *et al*., 2003). Age of the trapped specimen was categorized adults, sub-adults and young on the basis of size, body weight, pelage colour (which is usually grey in young) (Bekele, 1996; Habtamu and Bekele, 2008).

Species identification was carried out based on the taxonomic characteristics listed in Yalden *et al*. (1976), Yalden and Largen, (1992), Bekele, (1996), Kingdon, (1997), Nowak, (1999) and Alpine *et al.*, (2003). Additionally, when species identification was difficult in the field; the mounted skins and skulls were compared with the specimens available in the Zoological Natural History Museum of Addis Ababa University.

4.2.3. Data Analysis

Species diversity of trapped small mammals were calculated using the Shannon-Weaver index of diversity, **H'= - ∑PilnPi** where Pi is the proportion of the i^{th} species in the habitat and *ln* is the natural logarithm (Shannon and Weaver, 1949). H' is influenced both by number of species as well as by the evenness with which mammals are distributed with those species.

Trap Success was calculated to expressed the total number of animal trapped per total trap-nights (a trap-night = 1 trap set for 1 night) according to Ofori *et al.* (2013). Thus,

Ts= Nc x 100/Tn, Where: *Ts* = trap-success, *Nc* = total number of captures, *Tn* = total number of trap-nights.

Abundance was used estimated as the total number of individuals captured per total capture according to Brown (1984). Thus,

Abundance **= Total number of individuals captured**

Total number of captured

Simpson similarity index (SI) was computed to assess the similarity between two habitats with reference to the composition of species. **SI= 2C/I+II**. Where:

SI= Simpson's similarity index, C= the number of common species to both habitats, I= the number of species in habitat one, II= the number of species in both habitats (Magurran, 2004).

For the statistical computations, SPSS version 16.0 computer software program was used and Chi-square test was used to compute significance of variation for each parameter used. Level of significance was determined using Chi square test at 5% level of significance.

5. RESULTS

5.1. Species composition

During this study, a total of 110 individuals of small mammals were trapped in 512 trap nights. Ten species of small mammals (rodents and insectivores) belonging to two orders (Rodentia and Insectivora) and four families (Muridae, Hystricidae, Sciuridae and Soricidae), were identified both at dry and wet seasons. The captured rodents and insectivores are in the table. Out of the total trapped small mammals, 96(87.3%) individuals represented seven species of rodents and 14(12.7%) individuals represented three species of shrews (Table 1).

Table 1. Small mammals species identified in study area.

Order	**Family**	**Common Name**	**Scientific Name**
Rodentia	Muridae	Yellow spotted brush-furred rat	*Lophuromys flavopunctatus*
	Muridae	Woodland thicket rat	*Grammomys dolichuros*
	Muridae	Ethiop. Forest Brush-furred rat	*Lophuromys chrysopus*
	Muridae	Common rat	*Rattus rattus*
	Muridae	Common mouse	*Mus musculus*
	Hystricidae	Crested porcupine	**Hystrix cristata*
	Sciuridae	Striped squirrel	**Paraxerus ochraceus*
Insectivora	Soricidae	Greater musk shrew	*Crocidura flavescens*
	>	Smoky white-toothed shrew	*Crocidura fumosa*
	>		*Crocidura bicolor*

(*) The visual species (= not trapped)

5.2. Relative abundance of small mammal species

Lophuromys flavopunctatus was high in number with (n= 35) individuals 49.2% of the total. This was followed by *Grammomys dolichuros*, and *Lophuromys chrysopus* with 23(49.5%) and 13(29.7%) respectively. *Rattus rattus*, *Mus musculus*, *Crocidura flavescens* and *Crocidura fumosa* had 22.2%, 20.7%, 13.3%, and 10.7% respectively. The least abundant species was *Crocidura bicolor* with 1.4%. Rodents such as *Hystrix cristata* and *Paraxerus ochraceus* were observed in the study area (Table 2). *Grammomys dolichuros*, *Lophuromys chrysopus*, *Rattus rattus*, *Mus musculus*, *Crocidura flavescens and Crocidura fumosa* were widely dispersed species and recorded from both habitat types. However, *L. flavopunctatus*, *Crocidura bicolor*, *Hystrix cristata* and *Paraxerus ochraceus* were present only in one habitat (Table 2). *L. flavopunctatus* species had high numbers as compared to other species in natural forest habitats.

Table 2. Species composition, number of individuals and the relative abundance of each species captured in both habitats during dry and wet seasons.

Number of individuals trapped during the wet and dry seasons in both habitats					
Species	NF		CF		
	WET	DRY	WET	DRY	Relative abundance
L. flavopunctatus	20(28.16)	15(21.12)	_	_	35(49.3%)
Grammomys dolichuros	4(5.6)	4(5.6)	9(23.0)	6(15.3)	23(49.5%)
Lophuromys chrysopus	7(9.85)	5(7.04)	3(7.69)	2(5.12)	17(29.7%)
Rattus rattus	3(4.22)	_	3(7.69)	4(10.25)	10(22.2%)
Mus musculus	1(1.40)	1(1.40)	4(10.25)	3(7.69)	9(20.7%)

Crocidura flavescens	3(4.22)	1(1.40)	2(5.12)	1(2.56)	7(13.3%)
Crocidura fumosa	3(4.22)	1(1.40)	2(5.12)	_	6(10.7%)
Crocidura bicolor	1(1.40)	_	_	_	1(1.4%)
**Hystrix cristata*	1(1.40)	_	_	_	1(1.4%)
**Paraxerus ochraceus*	1(1.40)	_	_	_	1(1.4%)
Total	44(39.9%)	27(24.5%)	23(20.9%)	16(14.5%)	110

Keys: **(-)** = indicates the absence, (*) =Visualized species, **NF**= natural forest, **CF**= coffee forest.

In the present study a total of 71(64.6%) individuals were trapped from natural forest habitat. *L. flavopunctatus* (49.29%) was the most abundant rodent species in the NF habitat followed by *Grammomys dolichuros* (11.2%). For the coffee forest habitat, the most abundant was *Grammomys dolichuros* (38.4%).

Between the habitats, the relative abundance of the trapped species was significant for *L. flavopunctatus* (χ^2 =49.16, df =1, P<0.05), *G. dolichuros* (χ^2 =17.06, df =1, P<0.05), *L. chrysopus* (χ^2 =11.73, df=1, P<0.05) and *R. rattus* (χ^2 =9.00, df=1, p<0.05). The overall difference in abundance of small mammals among the two habitats of the study area was significant at (χ^2 =84.06, df =1, P<0.05) (Table 3).

Lophuromys flavopunctatus species vary between habitat and season, show significance difference at (χ^2 =28.8, df=1, P<0.05) (Table 3). The abundance of *Grammomys dolichuros* species vary between season in a CF, which statistically also shows significance difference at (χ^2=10.37, df=1, P<0.05). However, its abundance didn't vary in NF habitat during wet and dry season (χ^2 =8.0, df=1, P>0.05) (Table 3). This is true for *species Mus musculus.*

More species and individuals were trapped from the natural forest, and hence the highest diversity index (H'= 1.634) than the coffee forest and the difference was significant (χ^2 =2.11, df=1, P<0.05) (Table 3).

Table 3. Number of Species (N), Abundance, Evenness (J) and Diversity indices (H') for small mammal species in different habitats types.

Habitat types	No of Species	Abundance	J	H'
NF	10	71	0.512	1.634
CF	6	39	0.823	1.597

The calculated similarity index (SI) for the similarity of species between the two habitats was 0.75 indicating that about 75% of the species were common for both habitats.

5.3. Trap success

The average trap success in the study area in 512 trap nights was 21.48% but vary between habitats and seasons. For the natural forest, the success was 27.7% but 15.2% for the coffee forest. The trap success of small mammals was highest during the wet season than the dry. The success was highest for NF (17.2%) during the wet and least for CF during the dry season (6.6%). Success variation between seasons were significant (χ^2 = 8.96, df =1, P<0.05) (Table 4).

Table 4. Trap success of rodents and insectivores species at different seasons in both habitat types (each 256 trap nights per season).

Habitat types	**Season**	**Captures**	**Trap nights**	**Trap success (%)**	**Mean %**
Natural forest	Wet	44	256	17.2	27.7%
	Dry	27	256	10.5	
Coffee forest	Wet	23	256	8.6	15.2%
	Dry	16	256	6.6	

5.4. Sex ratio distribution

More male individuals were trapped than females during the present study. More male of species *L. flavopunctatus,* and *L. chrysopus* were trapped during the wet season than the dry. Single female individual of species *C. bicolor* was trapped from NF during wet season (Table 5).

Table 5. Seasonal variation and sex distribution of small mammals during wet and dry seasons.

Species	**Sex distribution along seasons**							
	Coffee Forest				**Natural Forest**			
	Wet		**Dry**		**Wet**		**Dry**	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**
L. flavopunctatus	_	_	_	_	15	5	3	12
G. dolichuros	5	4	4	2	3	1	2	2
L. chrysopus	2	1	1	1	4	3	3	2
Rattus rattus	2	1	3	1	2	1	-	-
Mus musculus	3	1	1	2	1	-	1	-
C. flavescens	-	1	1	1	2	1	-	1
C. fumosa	1	1	_	_	1	2	1	-
C. bicolor	_	_	_	_	_	1	_	_
**Hystrix cristata*		_		_		1	-	
**Paraxerus ochraceus*		_		_		1	-	
Total	13	9	10	7	28	16	10	17

5.5. Age distribution

Animals from all age groups were trapped during this study. However, adult animals accounted most (43.6%), followed by sub-adult (34.5%) and less young (20.9%).

Table 6. Age groups distribution of captured small mammals during study.

Species	Total Catch	**Age groups**					
		Dry season			**Wet season**		
		A	Sa	Y	A	Sa	Y
L. flavopunctatus	35	5	7	4	8	5	6
G. dolichuros	23	4	2	1	7	6	3
L. chrysopus	16	4	3	1	3	4	1
Rattus rattus	10	2	1	1	3	-	3
Mus musculus	9	1	1	1	2	3	1
C. flavescens	7	2	1	1	1	2	_
C. fumosa	6	2	-	-	2	2	-
C. bicolor	1	_	-	-	-	1	-
Total	110	20	15	9	28	23	14

Keys: A-adult, Sa- sub-adult, and Y-young.

Majority of small mammals for instance *G. dolichuros*, *R. rattus*, *Mus musculus*, *Crocidura flavescens*, *Crocidura fumosa* and *Crocidura bicolor* were trapped nocturnally. Also, *Lophuromys chrysopus* were trapped diurnal. *L. flavopunctatus* was trapped both at night and day time.

6. DISCUSSION

Several studies in Ethiopia documented small mammal's characteristic to the major ecology and specific habitats. Comparative studies on the diversity and habitat preference of small mammals among habitats were limited (e.g. Datiko and Bekele, 2012; Habtamu and Bekele, 2012). However, comparative studies on the diversity of small mammals between intact tropical forest and the adjacent coffee forest habitat were rare. This was essential to document the characteristic fauna for each and those shared between the habitats. The generated data also serves to reveal the impact of forest management on the faunal diversity and abundance.

The present study revealed the presence of 10 species of small mammals in Afalo area. The recorded species were not unique and are common to reported fauna from related habitats in the country. The recorded diversity, however, was relatively less as compared to most other areas elsewhere in the country (e.g. Kassa and Bekele, 2008, Habtamu and Bekele, 2008; Datiko and Bekele, 2012; Habtamu and Bekele, 2012). The present survey involves small areas sampled to represent the two habitats, however, the sampled rodents and insectivores provide good insight for the resident fauna of the area.

The diversity, abundance and habitat preference of small mammals are largely determined by the availability of resource and vegetation cover. The diversity of small mammal was relatively higher in natural forest than in the coffee forest. Bayessa (2010) reported similar finding for similar habitat in Tepi, Ethiopia. The abundance and diversity of small mammals in forest habitat depend mainly on the nature, habitat heterogeneity, and density of vegetation, for food and shelter (Gebresilassie *et al*., 2004).

In the present study, most species were common to both habitats, but few were specific. For instance, *G. dolichuros, L. chrysopus, Rattus rattus, Mus musculus, C. flavescens* and *C. fumosa* species were common for both habitats. On the other hand *L. flavopunctatus* and *Crocidura bicolor* were recorded only from NF. Also, two rodent species were observed in NF only. This is in agreement with the finding of Morris (1987), distribution of small mammals over an area is not uniform and species are more abundant in some habitats than others. Avenant and Cavallini

(2008) stated that habitat complexity, food and cover availability are key factors influencing the overall distribution of small mammals.

In the present study, the lowest composition and abundance of small mammals was recorded in coffee forest. This might be due to homogeneous vegetation that is dominated by few species of trees and the underground habitat is open or has less cover resulting in shortage of cover, food. Happold & Happold (1987) shown that the change from natural forest to plantation caused decline in both total number of individuals and species composition. Clearance of ground cover during the wet season and the intensive human activity to harvest coffee beans in the early dry season seem affected the diversity and abundance of some species. Similar finding was reported by Habtamu and Bekele (2012) for small mammalian fauna in coffee forests around Jimma area. Bayessa (2010) was also recorded the lowest abundance of species from coffee plantation habitat. According to Iyawe (1988), habitat selection of different species of small mammals is mainly dependent on the vegetation of the habitat.

During the present study, it was observed that, some species were more abundant than others in both habitats. For instance, *L. flavopunctatus, G. dolichurus* and *L. chrysopus* were more numerous in natural forest than in coffee forests. *L. flavopunctatus* (49.2%) was the most widely distributed species as compared with others and followed by *G. dolichurus*. *L. flavopunctatus* is one of the most widespread and numerous rodents in the moister areas of East Africa, inhabiting a range of different habitats with a preference for montane habitats (Clausnitzer *et al*., 2003). Misonne (1969) stated that this species occurred from lowland forests at about 500m asl to afro-alpine, reaching well above 4200m and extending into ericaceous habitats and montane moorlands. Similarly, it was also the most abundant rodent species in the present study area, but only from natural forest habitat.

The soft-furred rat, *L. flavopunctatus*, was one of the most common rodents in the moister areas of East Africa, inhabiting a wide range of montane and highland habitats (Clausnitzer & Kityo, 2001). In Ethiopia, it is essentially a species of the plateau with distribution records between 1500-4000 m (Yalden & Largen, 1992). In the present study, two species of the genus were recorded, *L. flavopunctatus* from the natural forest and *L. chrysopus* from the coffee forest and in both areas, they were the most trapped rodents. The species showed extremely high local variation (Clausnitzer & Kityo, 2001). Such behavior of the animal was also reported elsewhere (Habtamu and Bekele, 2012), where several related assemblage was sympatrically recorded from small extent of area. During the present study, however, only single species was recorded from a habitat. This finding may reveal the other behavior of the species, i. e. competitive exclusion.

Mus musculus has a wide distribution in Ethiopia. Yalden (1988) described the occurrence habitat between 1510 and 3000 m asl. In the present study, it occurred at an altitudinal range between 1200 and 1300 m asl. It was recorded mainly from CF as a major pest with few only from NF.

C. flavescens is a very large shrew with flat brain case and likely to be confused with *Suncus murinus*. It is, however, a very variable species in both size and color, and there are some suggestions that both characters are influenced by altitude. This shrew is one of the most common and widespread in Ethiopia, where it ranges from approximately 1000-3000m asl. It was thought to be a typical forest species (Yalden *et al*., 1976). It was recorded in different parts of Ethiopia including Addis Ababa, Chilalo Mountains, Debre Markos and west shore of Lake Tana. Yalden (1988) also observed the species in Bale Mountains National Park, below the tree line, and in association with clearings and within the forest. Similarly, in the present study it was trapped in the natural forest and coffee forest and accounted for only 6.4% from the total catches.

C. fumosa is essentially a montane shrew with thick fur usually showing little contrast between the grey brown dorsum and silvery grey ventral. It has been recorded in Ethiopia at an altitude of 1750- 3900m (Yalden *et al*., 1976). At the present study, few specimens were captured from both habitats. This is within the reported altitudinal range of the species. The species was comprised 5.5% abundant of the total number. *Crocidura bicolor* were trapped only from NF habitat only in single season. *Hystrix cristata* and *Paraxerus ochraceus* were highly expected from both habitats but not observed in CF during the present survey.

During the present study, there was variation in abundance of small mammals between seasons. Seasonality might cause the dynamic changes which occur in the habitats such as cover and food availability as noted by Oguge (1995). More individuals were recorded during the wet season than during the dry season. The abundance of small mammals in the wet and dry seasons was 64 and 46, respectively. Unlike the present record, most studies on small mammals reported the abundance of individuals during the dry season (e.g. Habtamu and Bekele, 2008; Datiko and Bekele, 2012). This is comparable with finding of Chekol *et al.* (2012) who has recorded more individual during wet season. However, this is not in agreement with the findings of Happold & Happold (1991), Datiko *et al*. (2007) and Habtamu & Bekele (2008) who recorded more individuals during the dry season in their respective study areas. Trap success during the wet season was relatively high, and more from the natural habitat. This is in agreement with finding of Chekol *et al.* (2012); Bantihun and Bekele (2015) have recorded similar results from different habitats. However, from the characteristics of managed coffee farm, farmers clear the floor of coffee forest that may remove food and covers, the resource very critical for small mammals.

The variation in trap success among different habitat types was significant in the present study area. The overall trap success in the present study was 21.48%. The highest trap success (27.7%) was recorded during the wet season in the NF habitat. The least trap success (15.2%) was recorded in coffee plantation during the dry season. The present trap success was low as compared to the study by Habtamu and Bekele, (2008) who recorded with trap success of 36.8% from Alatish National Park and Kasso *et al.* (2010) who recorded 44.1% from Chilalo Galama Mountain range. The difference in trap success might be due to the effects of habitat factors as the habitats vary in vegetation composition and cover. However, the present trap success was highest as compared to the study by Bantihun and Bekele (2015), who obtained 15.8% from Arditsy Forest, Datiko et al. (2007), who obtained 17.6% from Arbaminch Forest and Farmlands.

Sexual conditions of males were assessed via examination of scrotal and abdominal testes (Ghobrial and Hodieb, 1982), while for female's conditions like perforate or imperforate vagina, pregnancy and lactating (Alpine *et al*., 2003).

According to the present results, ages class of captured individuals varied from species to species and among seasons as given in (Table 6). Adult rodents accounted for the highest proportion. The capture rate of young was more during wet season than the dry season. This could possibly be associated with the effect of rainfall. Young are non-violent individuals, less weight, grayer than adult. Sub-adult are violent and fully grown where as adult show mature size, large pelage in male (scrotal or abdominal) and females may lactating, suckling nipples, or imperforate vagina according to Bekele, (1996); Alpine *et al.* (2003).

Out of the 110 individuals of rodents and insectivores captured, male comprised 61 (55.5%) and females 49 (44.5%). This is in agreement with the findings of Smith *et al.* (1975) and Chekol *et al.* (2012) who have recorded higher number of males.

7. CONCLUSION AND RECOMMENDATIONS

7.1. Conclusion

The present study identified and documented 10 small mammalian species from Afalo area. Some of the species are common to both habitats and few were unique for forest habitat. As the sampled areas were limited in size, in relation to the large extent of tropical forest, the documented diversity could be underestimated. However, the study gives bird's eye view about the characteristic small mammalian fauna of the area. The study revealed that, more species with relatively large number were recorded from natural forest. This brief survey also showed the impact of forest management on the diversity and abundance of small mammals. Most of the species documented from the area were not unique but largely reported for many areas in the country and most are reputed to have large ecological ranges across the country.

7.2. Recommendations

Based on the results of the study;

- Detailed small mammals faunal assessment involving several sites from each habitat is recommended to gain detailed account of the tropical forest fauna of the area and to evaluate the impacts of different level forest management on the diversity and abundance of small mammals.
- I recommend including shade trees, maintaining high amounts of canopy cover, and retaining lower strata vegetation within the coffee farms.
- I also recommend preserving or reestablishing forested areas surrounded within the coffee landscape to enhance small mammal diversity.

REFERENCES

Alpine, K. P., Brown, P. R., Jacob, J., Krebs, C. J. and Singleton, G. R. (2003). Field Methods for Rodent Studies in Asia and the Indo Pacific. BPA Printing group. Malborne.

Amori, G. and Luiselli, L. (2011). Small mammal community structure in West Africa: A meta-analysis using null models. *Afr. J. Ecol*. **49**: 418-430.

Andreassen, H. P. and Ims, R. A. (1998). The effects of experimental habitat destruction and patch isolation on space use and fitness parameters in female root vole, *Microtus oeconomus*. *J. Anim. Ecol.* **67**: 941-952.

Avenant, N. (2011). The potential utility of rodents and other small mammals as indicators of ecosystem 'integrity' of South African grasslands. *Wildl. Res*. **38**: 626-639.

Avenant, N. and Cavallini, P. (2008). Correlating rodent community structure with ecological integrity, Tussen-die-Riviere Nature Reserve, Free State Province. *South Africa. Integr*. *Zool*. **2**: 212-219.

Bantihun, G. and Bekele, A. (2015). Population structure of small mammals with different seasons and habitats in Arditsy Forest, Awi Zone, Ethiopia. *Intern. J. Biodiv and Cons.* **7**(**8**):378-387.

Barriere, P., Hutterer, R., Nicolas, V., Querouil, S., and Colyn, M. (2006). Investigating the role of natural gallery forests outside the Congolese rain forest as a refuge for African forest shrews. *Belg. J. Zool*. **135**:27-35.

Bayessa, D. (2010). Species composition, distribution, abundance and habitat association of rodents in forest and farmlands around Tepi, southwest Ethiopia. MSc Thesis, Addis Ababa University, Ethiopia. Pp. 79

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

Bekele, A. and Leirs, H. (1997). Population ecology of rodents of maize fields and grass lands in central, Ethiopia. *Belg. J. Zool.***127**:39–48.

Brown, J. (1984). On the relationship between abundance and distribution of species. *Am. Nat*. **124**:255-279.

Brown, J. H. and Heske, E. J. (1990). Control of a desert grassland transition by a keystone rodent guild. *Science*, **250**:1705-1707.

Caro T.M. (2001). Species richness and abundance of small mammals inside and outside an African national park*. Biological Conservation* **98**: 251–257.

Chekol, T. Bekele, A. & Balakrishnan, M. (2012). Population density, biomass and habitat association of rodents and insectivores in Pawe area, northwestern Ethiopia. *Inter. Soc. Trop. Ecol.* **53**(1): 15-24.

Cheng, S., Hiwatashi, Y., Imai, H., Naito, M. and Numata, T. (1998). Deforestation and degradation of natural resources in Ethiopia: Forest management implications from a case study in the Belete-Gera Forest. *J For Res*. **3:**199-204.

Clausnitzer, V. and Kityo, R. (2001). Altitudinal distribution of rodents (Muridae and Gliridae) on Mtn. Elgon, Uganda, *Trop. Zool.* **14**:95-118.

Clausnitzer, V., Chrchfield, S. and Hutterer, R. (2003). Habitat occurrence and feeding ecology of *Crocidura montis* and *L. flavopunctatus* on Mt. Elgon, Uganda. *Afr. J. Ecol.* **41**:1-8.

CSA, (2008). Summary and Statistical Report of the 2007, Population and Housing Results – Population Size by Age and Sex. FDRE Population Census Commission. UNFPA, Addis Ababa. Pp. 56-78.

Datiko, D. and Bekele, A. (2012). Species composition and abundance of small mammals in Chebera-Churchura National Park, Ethiopia. *Afr. J. Ecol*. **5** (6): 95-102.

Datiko, D., Bekele, A. and Belay, G. (2007). Species composition, distribution and habitat association of rodents from Arbaminch forest and farmlands, Ethiopia. *Afr. J. Ecol*. **45**: 651-657.

Davies, G. (2002). African Forest Biodiversity: A field Survey Manual for Vertebrates. Cambridge: *Earth watch*, pp. 120-126.

De Beenhouwer, M. (2011). Effects of habitat fragmentation and coffee cultivation on the epiphytic orchids in Ethiopian Afromontane forests. Dissertations presented in fulfillment of the requirements for the degree of master in biology. *Systematic and Ecology Section*. Pp. 34-69.

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

Fitzgibbon, C.D. (1997). Small mammals in farm woodlands: the effects of habitat, isolation, and surrounding land-use patterns. *J. App. Ecol*. **34:** 530- 539.

Friis, I. (1992). Forests and forest trees of northeast tropical Africa. Kew Bulletin Additional Series. HMSO, London. Pp.15.

Gadisa, T. and Bekele, A. (2006). Population dynamics of pest rodents of Bilalo area, Arsi, Ethiopia. *Ethio J Biol Sci.,* **5**:63-74.

Gebresilassie, W., Bekele, A., Gurja, B. and Balakrishnan, M. (2004). Microhabitat choice and diet of rodents in Maynugus Irrigation Field, Northern Ethiopia. *Afr J. Ecol.* **42**: 315-321.

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

Gemechu, T. Borjeson, L. Senbeta, F. and Hylander, K. (2014). Balancing ecosystem services and disservices: smallholder farmers' use and management of forest and trees in an agricultural landscape in southwestern Ethiopia. *Ecology and Society* **19**(1): 30.

Ghobrial, I. L, and Hodieb, K. S. (1982). Seasonal variations in the breeding of the Nile rat. *J. Mammal*. **46:** 319-333.

Granjon, L., Bruderer, C., Cosson, F., Dia T, and Colas, F. (2002). The small mammal community of a coastal site of southwest, Mauritania. *Afr. J. Ecol*. **40**:10-17.

Grant, W. E., Birney, E. C., French, N. R. and Swift, D. M. (1982). Structure and productivity of grassland small mammal communities related to grazing-induced changes in vegetation cover. *J. Mammal.* **63**:248-260.

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

Habtamu, T., and Bekele, A. (2012). Species composition, relative abundance and habitat association of small mammals along the altitudinal gradient of Jiren Mountain, Jimma, Ethiopia. *Afr J. Ecol.* **51**: 37-46.

Hansson, L. (1999). Intraspecific variation in dynamics: small rodents between food and predation in changing landscapes. *Oikos*. **85**:159–169.

Happold, D. & Happold, M. (1987). Reproduction, growth and development of a West African Forest Mouse, *Praomys tullbergi* (Thomas). *Mammalia*, **42**(1):74-95.

Happold, D. & Happold, M. (1991). An ecological study of small rodents in the thicket-clump savanna of Lengwe National Park, Malawi. *Journal of Zoology* **223**: 527-542.

Happold, D. (1979). Age structure of a population of Pryomys tullbergi (Muridae, Rodentia) in Nigerian Rainforest. *Review Ecology* **33**: 253-274.

Hashim, M. and Mahgoub, S. (2007). Abundance, habitat preference and distribution of small mammals in Dinder National Park, Sudan. *Afr. J. Ecol.* **46:** 452–455.

Hundera, K. (2007). Traditional forest management practices in Jimma zone, Ethiopia. *Ethiopian J. Sci and Educ.* 2**(2):** 1-11.

Hylander, K., Nemomissa, S., Delrue, J. and Enkosa, W. (2013). Effects of coffee management on deforestation rates and forest integrity. *Conservation Biology* **27**(5):1031-1040.

Iyawe, J.G. (1988). Distribution of small rodents and shrews in a lowland rain forest zone of Nigeria, with observations on their reproductive biology. *Afr. J. Ecol*. **26**: 189-195.

Jorge, P. (2008). Effects of forest fragmentation on two sister genera of Amazonian rodents (*Myoproctaacouchy* and *Dasyprocta leporina*). Biol. Conserv. **141**:617-623.

Juokaitis, R. and Baranauskas, K. (2001). Diversity of small mammals in the northwestern Lithuania. *Acta Zool. Litua.* **11:** 343-348.

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

Kannan, R. and James, D. (2009). Effects of climate change on global biodiversity: a review of key literature. *Trop. Ecol*. **50**:31-39.

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

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

Kelt, A., Meserve, L., Nabors, K., Forister, L. & Gutie, R.R. (2004) Foraging ecology of small mammals in semiarid Chile: the interplay of biotic and abiotic effects. *Ecology* **85**: 383–397.

Kidane, L., Bekele, T. and Nemomissa, S. (2010). Vegetation composition in Hugumbirda-Gratkhassu National Forest Priority Areas, south Tigray. *Ethiopian J. Sci.* **2**:27-48.

Kilgore, A., Lambert, T. and Adler, G. (2010). Lianas influence fruit and seed use by rodents in a tropical forest. *Trop Ecol.* **51**:265-271.

Kingdon, J. (1997). The Kingdon Field Guide to African Mammals. Harcourt Brace and Company, London.

Kotler, B. (1997). Patch use by gerbils in a risky environment: manipulating food and safety to test four models. *Oikos*, **78**:274.282.

Lange, S., Stalleicken, J. and Burda, H. (2004). Functional morphology of the ear in fossorial rodents, *Microtus arvalis* and *Arvicola terrestris. J Morpho* **262**:770-779.

Lavrenchenko, L.A., Milisnikov, A.N., Aniskin, V.M., Warhavsky, A.A. and Gebrekidan, S. (1997). The genetic diversity of small mammals of the Bale Mountains. SINET: *Ethiop J Sci.* **20**:213-233.

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

Linzey, A.V. & Kesner, M. H. (1997). Small mammals of a woodland savannah ecosystem in Zimbabwe. I. Density and habitat occupancy patterns. *J. Zool.* London. **243**:137-152.

Lomolino, M.V. (2001). Elevational gradients of species-density: historical and prospective views. *Glob. Ecol. Biogeogr. Lett.* ***10**: 3–13.*

Magurran, A.E. (2004). Measuring biological diversity. Blackwell Publishing; Oxford, United Kingdom. p. 256.

Malcom, J.R. and Ray, J.C. (2000). The influence of timber extraction routes on central African small-mammal communities, Forest Structure and Tree Diversity. *Conser Biol*. **14**:1623-1638.

Mangan, S. and Adler, G. (2002). Seasonal dispersal of arbuscular mycorrhizal fungi by spiny rats in a Neotropical forest. *Oecologia* **131**:587-597.

Martin, G. (2003). The role of small ground foraging mammals in topsoil health and biodiversity: implications to management and restoration. *Ecol. Manage. Restor*.**4:** 114-119.

Mekuria, K. (2005). Forest conversion – soil degradation – farmers' perception nexus: Implications for sustainable land use in the southwest of Ethiopia. Ecology and Development Series No. 26.

Mena, J. & Vazquez-Dominquez, E. (2005). Species turnover on elevational gradients in small rodents. *Glob Eco. Biogeo.* **14**:539–547.

Misonne, X. (1969). African and Indo Australian Muridae. Evolutionary trend. *Ann. Mus. Roy. Afr. Center.* **8**:1-219.

Monadjem, A. and Perrin, R. (2003). Population fluctuation and community structure of small mammals in a Swaziland grassland over a three-year period. *Afr Zool* **38**:127–137.

Morris, D.W. (1987). Ecological scale and habitat use. *J. Ecol.* **68**:362-369.

Mssawe, A.W., Rwamugira, W., Leirs, H., Makundi, R.H. and Mulungu, L.S. (2006). Do farming practices influence population dynamics of rodents? A case study of the multimammate field rats, *Mastomys natalensis,* in Tanzania. *Afr. J. Ecol.* **45**:293-301.

Napolitano, C., Bennett, M., Johnson, W.E., Brien, S.J., Marquet, P.A., Barría, I., Poulin, E. and A. Iriarte. (2008). Ecological and biogeographical inferences on two sympatric and enigmatic Andean cat species using genetic identification of faecal samples. *Molecular Ecology* **17**:678-690.

Naranjo, M.E., Rengifo, C. and Soriano, P.J. (2003). Effect of ingestion by bats and birds on seed germination of *Stenocereus griseus* and *Subpilocereus repandus* (Cactaceae). *J. Trop. Ecol.* **19**:19-25.

Nowak, R. M. (1991). Walker's Mammals of the World, 5th Edition, The Johns Hopkins University Press. Vol. II.

Nowak, R. M. (1999). Walker's: Mammals of the World, 6th edn. John Hopkins University Press, Baltimore and London. pp. 837-865.

Obsom, F.V. and Parker, G.E. (2003). Linking two elephant refuges with a corridor in the communal lands of Zimbabwe. *Afr. J. Ecol*.**41**:68–74.

Ofori, B., Attuquayefio, D. and Owusu, E. (2013). Aspects of the ecology of the Tullberg's Soft-Furred Mouse (*Praomys Tullbergi*: Thomas 1894) in mount, Afadjato, Ghana. *J. Exp. Biol. and Agri. Sci.* 1(**5**):2320-8694.

Oguge, N. (1995). Diet, seasonal abundance and microhabitats of *Praomys* (*Mastomys*) *natalensis* (Rodentia: Muridae) and other small rodents in Kenyan sub-humid grassland community. Afr. J. Ecol. **33**:211-225.

Pearce, J. and Venier, L. (2005). Small mammals as bio-indicators of sustainable boreal forest management. *Forest Ecology and Management*, **208**:153-175.

Peter, B. (2012). Experimental treatment control studies of ecologically based rodent management in Africa: balancing conservation and pest management. *S. Afr. J. Wildl. Res*. **39**: 51–61.

Schmidt, N.M., Hubertz, H. and Olsen, H. (2002). Diet of Kestrels *Falco tinnunculus* on grazed coastal meadows. *Dansk Ornitol. Foren. Tidsskr.* **96**:171-175.

Schmitt, C., Denich, M., Sebsebe, D., Friis, I. & Boehmer, H. (2010). Floristic diversity in fragmented Afromontane rainforests: Altitudinal variation and conservation importance. *Appl. Veg. Sci.*, **13**: 291-304.

Senbeta, F. and Teketay, D. (2003). Diversity, Community types and population structure of woody plants in Kimphee Forest, a virgin Nature Reserve in Southern Ethiopia. *Ethiopian J. Biol. Sci.* **2**:169-187.

Shanker, K. (2001). The role of competition and habitat in structuring small mammal communities in a tropical montane ecosystem in southern India. *J. Zool. Lond*. **253**: 15–24.

Shannon, G. E. and Weaver, W. (1949). The Mathematical Theory of Communication. University of Illinois Press, Chicago.

Shibru, T. (1995). "Protected areas management crisis in Ethiopia" *Walia*, **16**:17-30.

Silva, M., Hartling, L. and Opps, S.B. (2005). Small mammals in agricultural landscapes of Prince Edward Island (Canada): effects of habitat characteristics at three spatial scales. *Biol. Conser.* **126**:556-568.

Skinner, J. D. and Chimimba, C.T. (2005). The Mammals of the Southern African Sub region (3rd Ed). Cambridge: Cambridge University Press, pp 874.

Smith, M. H, Gardner, R.H, Gentry, J.B, Kaufman, D.W, and O'Farrell, M.J. (1975). Density estimations of small mammal populations. In: Small Mammals: Their Productivity and Population Dynamics (Golley, F. B., Petrusewicz, K. and Ryszkowski. L. eds). Cambridge University Press, Cambridge. pp. 25-53

Solari, S., Rodriguez, J., Vivar, E. and Velazco, M. (2002). A framework for assessment and monitoring of small mammals in a lowland tropical forest. *Environ. Monit. Assess.* **76:** 89–104.

Sousa, W.P. (1984). The role of disturbance in natural communities. *Annual Review in Ecology and Sistematics*, **15**: 353-391.

Stanley, W.T., Nikundiwe, A..M., Mturi, F.A., Kihaule, P.M., and Moehlman, P.D. *(*2005). Small mammals collected in the Udzungwa Mountains National Park, Tanzania. *J. East African Natural Hist.* **94**:203-212.

Sullivan, T.P. and Sullivan, D.S. (2001). Influence of variable retention harvests on forest ecosystems. II. Diversity and population dynamics of small mammals. *J Appl. Ecol.* **38**:1234-1252.

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

Tews, J., Brose, U., Grimm, V., Tielborger, K., Wichmann, M.C., Schwager, M. and Jeltsch, F. (2004). Animal species diversity driven by habitat heterogeneity/diversity: the importance of keystone structures. *J. Biogeography*. **31**:79-92.

Vaughan, J.A., Ryan, J.M. and Czaplewsiki, N.J. (2000). Mammalogy, 4th edn. Harcourt Inc., London.

Vieira, E.M., and de Moraes, D.A. (2006). Carnivory and insectivory in Neotropical marsupials.

Williams, S.E., H. Marsh and J. Winter. (2002). Spatial scale, species diversity, and habitat structure: small mammals in Australian tropical rain forest. *Ecology* **83**:1317-1329.

Willig, R., Kaufman, M. & Stevens, D. (2003). Latitudinal gradients of biodiversity: pattern, process, scale and synthesis. *Annu. Rev. Ecol. Evol. Syst.* ***34****: 273–309*.

Wilson, D.E. and Reeder, D.M. (2005). Mammal Species of the World: A Taxonomic and Geographic Reference. JHU Press, Baltimore, MD, USA. pp. 21-42.

Wilson, D.E. and Reeder, R. (1993). Mammal Species of the World: A Taxonomic and Geographic Reference. Smithsonian Institution Press, Washington, D.C.

Wolff, J.O. and Sherman, P.W. (2007). Rodent Societies: An Ecological and Evolutionary Perspective. Chicago: The University of Chicago Press.

Yalden, D.W. (1983). The extent of high ground in Ethiopia compared to the rest of Africa. SINET: Ethiop. *J. Sci.* **6(3):** 5–38.

Yalden, D.W. (1988) Small mammals in the Harenna Forest, Ethiopia: Bale Mountains National Park. SINET: *Ethiop*. *J. Sci*. **11**: 41–53.

Yalden, D.W. and Largen, M. J. (1992). “The endemic mammals of Ethiopia,” *Mammal Review* **22**(3): 115-150.

Yalden, D.W., Largen, M.J. and Hillman, J.C. (1996). Catalogue of the mammals of Ethiopia. *J Trop Ecol* **9(**1**):**73-164.

Yalden, D.W., Largen, M.J., and Kock, D. (1976). Catalogue of the mammals of Ethiopia. Insectivora and Rodentia. *Italian Journal of Zoology*, **8**(1): 1-118.

APPENDICES

Appendix I. List of recording elements of capture for small terrestrial mammals.

Recording capture data	**Habitat description**
Field number (consecutive)	**Description of trap location/station**
Date:	Trap height
Collector(s):	Canopy density
Check time / Control	Nearest tree
Trap ID:	Groundcover
Trap type:	**Inventory of environmental features**
Bait used:	-Elevation
GPS	-Rainfall
Species (Field ID)	-Temperature (min/max)
Sex: Male, Female,	-Humidity (min/max)
Age: Adult, Sub-adult, Juvenile	-Vegetation: ground cover, plant diversity, stage of maturity, canopy density
Reproductive Status: Male: Testes descended or non descended Female: Pregnant, Lactating, Vagina perforated or non-perforated or plugged	-Habitat structures (rocks, burrows, soil, logs) -Abundance of small mammals

Appendix II. List of field equipment for the record of small terrestrial mammals.

Trapping	**Treatment of small mammals**
-Traps: Sherman, Trip and Snap traps	-Gloves (hard to bites)
-Bait: Peanut butter, corn	-Disposable gloves
Specimen preservation dry/wet	-Plastic bags (3 litre size)
-Disposable gloves	-Measurement tools (ruler, calliper)
-Formalin	-Spring balances (10 g, 30 g, 100 g and 300 g)
-95% (75%) Ethanol for whole body preservation	-Field book
-Scissors, scalpel	-Identification keys
-Maize meal	
-Pins, wire rings, needle	
-Thread or twine for tags	
-Hand-held GPS unit	
-Binocular	
-Digital camera	
-Headlamps, additional flash lights	
-Forceps	

Appendix III. Different photos taken at study site during data collections.










08.10.2014



08.10.2014

Natural Forest habitat

Natural forest habitat