ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
DEPARTMENT OF ZOOLOGICAL SCIENCES

Diversity, Distribution and Conservation Status of Small Mammals of Chilalo-Galama Mountains Range, Southeastern Ethiopia

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March 2018
Addis Ababa, Ethiopia

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A Thesis Submitted to
The Department of Zoological Sciences

Presented in Fulfilment of the Requirement for the Degree of
Doctor of Philosophy (Ecological and Systematic Zoology)

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Approved by Examining Board:

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4. Dr. Demeke Datiko	(Examiner)
5. Prof. Abebe Getahun	(Chairman)

ABSTRACT

A study on diversity, distribution and conservation of small mammals was conducted in Chilalo-Galama Mountains Range from August 2013 to December 2016. The main objective of this research was to make ecological assessment on diversity, distribution, relative abundance, habitat association of small mammals and on their prevailing conservation challenges. Data on diversity, distribution, abundance, habitat association, pest status, possible conservation challenges of small mammals and their habitat were collected. A total of 40 grids from eight representative habitats were selected. A 5x5 Sherman Live trapping grid with 15 m spacing was employed for three consecutive days per each intensive grid. Overall, 230 mist net net-nights were employed during 60 nights. For chromosomal and molecular analysis tissue samples from each representative species were collected. For survey of local communities perception on small mammals conservation and pest status 370 households were selected. Sherman live traps, mist nets and mole rat traps were used to capture small mammals. Overall 36 species of small mammals were recorded of which at least 20 species or 55.56% were endemic to Ethiopia. Trap success ranged from 27% to 85.71% with overall trap success of 44.6%. Out of the 4302 captured individuals 4074 were rodents and 228 were shrews. In addition, 219 bats were captured of which 197 (89.95 were new captures, 16 (7.31%) were recaptures and the 6 (2.74%) were unidentified. The overall netting success and capture rate were 0.95 bats/net-night and 0.83 bats/net-h, respectively. The highest relative abundance was recorded for L. brevicaudus (21.36%) followed by S. griseicauda (17.50%) and S. albipes (16.44%). The least relative abundance was recorded for D. nikolausi and M. imberbis each having 0.03%. Capture per trap night was highest (55) for moorland habitat and least (16) in plantation habitat. Stenocephalemys griseicauda and L. brevicaudus were the most widely distributed species whereas C. fumosa, C. lucina, C. olivieri and M. imberbis were recorded from limited sites. More individuals of small mammals were captured during the wet season. The overall mean of reproductively active individuals was 38.17% and 20.02% and 18.15% during wet and dry seasons, respectively. The capture per trap night showed variations among the age of burnt Erica. Small mammals showed variation in distribution and abundance along altitudinal zonation. Results on chromosomal and molecular analysis of the representative species show similality with its previously described from different parts of the country and showed close affinity with the Bale Mountains. A total of 1993 individuals of ectoparasites that belonged to 24 taxa from examined 204 individuals of small mammals with the overall prevalence rate of 73.53% were recorded. All respondents perceived rodents as principal pests that cause great damage to their agricultural and household items. Overpopulation, uncontrolled hunting, poaching and deforestation, habitats destruction and degradation by agricultural expansion and settlement were perceived as major threats for the conservation of the area. Community based conservation strategies were supported by nearly all of respondents. As Chilalo-Galama Mountains Range had high diversity of fauna and flora, proper conservation measures have to be implemented.

Keywords: Abundance, bats, Chilalo-Galama Mountains Range, conservation, distribution, diversity, ectoparasite, *Erica* burn, karyotype and molecular, small mammals

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DEDICATION

I dedicate this work to:

- My wife Sofia Dina
- My son Nafiyad Mohammed
- My daughter Muna Mohammed and for the rest of my families and relatives

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ACRONOMY

AMNP	Arsi Mountains National Park
EWCA	Ethiopian Wildlife Conservation Authority
NHM	Natural History Museum, Addis Ababa University
JERBE	Joint Ethio-Russian Biological Expedition

1. INTRODUCTION

Although there is no generally accepted definition for the term “small mammal”, it is usually intended to include rodents, insectivores and bats (Rodgers *et al.*, 2008). Most of the time such grouping of mammals depends on body mass eventhough general agreement is lacking. For instance, Tattersall *et al.* (2000) refer small mammals with maximum mass of 50 g; Rodgers *et al.* (2008) mammals with less than 200 g; Mena and Medell (2010) mammals less than 250 g; Barnett and Dutton (1995) mammals weighing less than 1 kg; Bennett (1990) mammal less than 2 kg weight; Zakaria *et al.* (2001) consider mammals which weigh less than 5 kg and Geiser and Kortner (2010) even considered mammals less than 10 kg. However, in the present study, small mammal refers only to all members of Order Rodentia, Order Chiroptera and Order Eulipotyphla. Larger rodents Meson-mammals are loosely defined as mammals larger than rodents (though sometimes including the largest rodents) up to roughly fox-sized mammals like porcupines (Parker *et al.*, 2012).

Mammals are among the best recognizable groups of animals and they are more readily studied (Istvan and Derbowka, 2011). Small mammals are the most numerous wild vertebrates in a number of natural biotopes (Kanchev *et al.*, 2012). However, studies of small mammals are among the least favoured subject amongst zoologists or wildlife ecologists in the world (Louis *et al.*, 1988). Furthermore, the local people’s knowledge on small mammals is also limited. Many mammal species are not studied in detail because of their rarity and small geographic ranges (Happold, 2013).

Among the vertebrates, small mammals have a number of attributes that provide valuable results in ecological and paleontological studies (Manthi, 2007). Their study is needed due to their high abundance, comparatively easy to study, well known general principles of their ecology, good ecological indicators, exhibition of habitat or dietary specificity and specimens that are easily prepared and transported (Barnett and Dutton, 1995). For instance, unlike the highly mobile macro-fauna, most small mammals usually have very specific habitat requirements. As a result, many specialists like palaeontologist use them as sensitive indicators of environment (Manthi, 2007). They have higher metabolic rates and shorter life span than larger ones (Nowak, 1999). Their fast metabolism and short life span and high reproductive rates enable them to respond quickly to environmental changes (Barnett and

Dutton, 1995; Bagne and Finch, 2010). Their demographic plasticity, high turnover rate and adaptability make them interesting in the study of demography and population dynamics (Barrett and Peles, 1999). They have crucial relationships with ecosystem components like plant community composition, seed dispersal, mycorrhizal fungi dispersal and predator population dynamics (Bagne and Finch, 2010). These characteristics make small mammal populations as good subjects for assessing ecosystem health and effects of landscape alterations (Bagne and Finch, 2010). They exhibit different adaptations to the environment and play a greatrole in determining the patterns of biodiversity and ecosystem functioning. Hence, they use as good indicators for the health of ecosystems (Barragan *et al.*, 2010).

Small mammals show variability in their ecology, morphology, physiology, behaviour and life history strategies (Demeke Datiko and Afework Bekele, 2014). They exploit a wide range of habitats and environments throughout the world (Vaughan *et al.*, 2000). They also show remarkable seasonal population dynamics (Mohammed Kasso *et al.*, 2010). However, the seasonal population dynamics seems to be relatively moderate for species that live in more stable climatic conditions than unstable ones (Happold, 2013). The distribution and relative abundance of small mammals is strongly influenced by microhabitat factors in different habitat types (Afework Bekele and Leirs, 1997). The seasonal availability of food and water, vegetation structure and cover mostly determine their distribution and abundance (Demeke Datiko and Afework Bekele, 2014).

Small mammals are useful in the study of environmental gradients (altitudinal and latitudinal) due to their noticeable assemblages modification with altitude (Mena and Vazquez-Dominguez, 2005). Different studies hypothesized that habitat complexity and heterogeneity at the different altitudes influence diversity and distribution of small mammals (Mohammed Kasso *et al.*, 2010; Getachew Bantihun and Afework Bekele, 2015). The variation of species richness with elevation gradient frequently shows the hump-shaped pattern peak for nonvolant small mammals at intermediate between the base and peak of a mountain (Brown, 2001; Heaney, 2001; McCain, 2005; Novillo and Ojeda, 2012). However, conversely most species of bats occur at the lower end of the gradient, with progressively fewer species at higher elevations. This is due to the high-energy expense during flight and thermoregulation for the compensation of lost energy by naked wings in cool nights on higher elevations (Presley *et al.*, 2012).

In addition to abundance, most high attitude areas are endowed with high levels of endemicty (Yalden, 1983; Yalden *et al.*, 1996; Lavrenchenko *et al.*, 1998a; Corti *et al.*, 1999; Afework Bekele and Yalden, 2013). This is due to high speciation rates encouraged by a particular set of environmental conditions like complex topography, narrow homothermal elevation zones, separated habitat distribution (Novillo and Ojeda, 2012) and isolation mechanisms (Vetaas and Grytnes, 2002). The proportion of endemic species increases gradually as elevation increases. At the same time, the peak in endemism might match to swift decrease in species richness (Vetaas and Grytnes, 2002). Elevation gradients have qualities that make them useful for studying the responses of species to variation along environmental gradients (Presley *et al.*, 2012). The local conditions of mean annual temperature and precipitation determine the altitudinal zonation of each habitat type (Heaney, 2001). Elevation changes can predict changes in abiotic characteristics and associated vegetation (Presley *et al.*, 2012). Abiotic characteristics in turn change gradually with elevation. For example, there is a 6.5 °C decrease in temperature above freezing for every 1 km increase in elevation although there is slight variation along latitudinal gradient (Presley *et al.*, 2012). This makes the distribution of small mammals to vary along altitudinal zonation based on ecological factors like climate, productivity, habitat heterogeneity and dispersal and historical factors like extinction and speciation (Mena and Vazquez-Dominguez, 2005). Hence, altitudinal zonation or gradient is considered as a primary environmental factor that determines the pattern of species distribution of small mammals (Presley *et al.*, 2012).

Small mammals are highly dependent on vegetation and habitat. Hence habitat loss, fragmentation, overexploitation of natural resources, pollution and the spread of invasive alien species have been recognized as the five foremost threats to them and other global biodiversity (Lopoukhine *et al.*, 2012). Habitat loss and fragmentation affect the well-being and survival of individual populations, entire species and in the end, it may affect the functioning of the entire ecosystems (NRMMC, 2010). Parasites and diseases lead to the decline of the small mammal population (Letnic *et al.*, 2013).

Fire is a common disturbance in many ecosystems (Langlands *et al.*, 2012). It is a key component in fire-prone systems by influencing the ecological and evolutionary processes (Bagne and Finch, 2010). It is the most important ecological regulator of plant and animal populations in tropical savannas and grasslands worldwide (Radford, 2012). Like other groups, small mammals can be strongly influenced by fire-induced vegetation changes (Radford, 2012). In particular, fire causes the abundance of small mammal to decline by limiting resources (food and shelter) and exposing them to predation and disease (Letnic *et al.*, 2013).

Meinig and Boye (2009) identified forest management, agriculture and habitat fragmentation to have strong negative impact on small mammals. Although, small mammals have a lower level of threat than large mammals like primates, almost half of the extinct species belong to this group (IUCN, 2015). Many of the small mammal species are considered as Data Deficient (Happold and Happold, 2013; Happold, 2013; IUCN, 2015). Climate change can reduce populations of mammals, in particular species living at higher altitudes (Meinig and Boye, 2009).

Out of the 27 orders and 5,488 living and recently extinct species of mammals, Order Rodentia (2,255), Order Chiroptera (1,150) and Order Eulipotyphla (450) constitute the most diverse groups accounting to nearly 70% of all mammal species (Vie *et al.*, 2009; IUCN, 2015). These orders contain small-bodied mammal species such as rodents, bats, shrews, solenodons, moles, hedgehogs, and nesophontes (IUCN, 2015). The seven orders that are considered as small mammals present in Africa (Order Rodentia (395), order Lagomorpha (13), order Afrosoricida (24), order Macroscelidea (15), order Erinaceomorpha (6), order Soricomorpha which contains members of order Eulipotyphla (150) and order Chiroptera (224) collectively comprise 74.1% (827 of 1,116) of all African mammalian species (Happold and Happold, 2013; Happold, 2013). Kingdon (1997) reported about 1,150 species of mammals from the entire Africa continent including also species from oceanic islands like Madagascar, Comoros, Seychelles, Mauritius, Canary, Madeira and Cape Verde which are excluded by Happold and Happold (2013) and Happold (2013). As the result, the numbers reportedwere reduced to 1,116.

The Afrotropical region possesses the most diverse fauna accounting for more than 23% of all described species with the highest proportion of endemic genera and species (Cole *et al*., 1994; IUCN, 2012). Ethiopia alone acquired much diversity of species and endemics (more than 320 species of mammals) (Yalden and Largen, 1992; Malcolm and Sillero-Zubiri, 1997; Lavrenchenko *et al.*, 1998b; Afework Bekele and Yalden, 2013; Kalpi *et al.*, 2015;

Kruskop *et al.*, 2016). From about 315 species of mammals listed by Afework Bekele and Yalden (2013), about 18 species occur exclusively in Eritrea.

Among the mammals, Order Rodentia constitutes the most diverse and abundant group, currently accounting for over 25% of the families, 35% of the genera, and about 50% of the species of living mammals (Macdonald, 1984). Wilson and Reeder (2005) and Happold (2013) stated that Order Rodentia is the largest order of mammals, encompassing 2,277 out of the 5,422 living mammal species or approximately 42% of worldwide mammalian biodiversity. Out of 2,277 rodent species, 395 species (in 15 families and 98 genera) occur in Africa. The order contains more species (395) than anyof the other 16 recognized orders of African mammals and comprises about 36% of the species of African mammals (Happold, 2013).

Africa and its islands afforded ideal geographic settings for radiations of endemic major clades of Rodentia due to geologic history of periodic isolation that resulted in 14 of the 33 recognized rodent families to be indigenous except family Myocastoridae that was introduced into Africa (Wilson and Reeder, 2005). Out of the 15 families of rodents present in Africa, seven are endemic at the generic and species levels that indicate the contribution of African landscapes to the phylogenetic diversification of these rodent families (Happold, 2013). Most of the non-endemic genera and species occur in North Africa where they are shared with nearby Arabian Peninsula and Middle East. However, endemism is nearly 100% within sub-Saharan zones, where taxa tend to be more narrowly restricted in distribution and limited to distinct sub-regions (Happold, 2013). In particular, East Africa is a home to various rodent species and some are endemic to the region. They account nearly 28% in East Africa and 30% in Ethiopia (Kingdon, 1974; Yalden and Largen, 1992). Among 320 species of mammals that occur in Ethiopia, about 90 species are rodents (Afework Bekele and Yalden, 2013). Out of these, more than 24 (27%) are endemic, constituting more than 50% of the Ethiopian endemic mammalian fauna (Yalden and Largen, 1992; Yalden *et al*., 1996; Afework Bekele and Leirs, 1997; Lavrenchenko *et al.*, 1998a, 2007, 2012; Corti *et al.*, 1999; Afework Bekele and Yalden, 2013). There are five genera namely *Megadendromus* (1), *Desmomys* (2), *Muriculus* (1), *Nilopegamys* (1), *Stenocephalemys* (4) from rodents and *Theropithecus* (1) from Primates that exclusively occur in Ethiopia (Afework Bekele and Yalden, 2013). Recently however, based on the phylogenetic analysis of mitochondrial (cytochrome *b*) and nuclear (inter photoreceptor binding protein) gene sequences, it was strongly suggested that *Muriculus* and *Megadendromus* do not belong to a distinct monotypic genera, but to the genus *Mus* (Meheretu Yonas *et al.*, 2015), and to the genus *Dendromus* (Lavrenchenko *et al.*, 2017) in respective order hence updating the endemic genera to be only three.

The number of rodent species within Africa remains probably underestimated and controversial. The estimation of valid number of species ranges from 300 to 600 (Happold, 2013). However, the new field discoveries of museum-based revision and the improved methodologies on morphological, chromosomal, or molecular methods have led to an increase of the species number over the last 10–15 years. It is likely to stabilize their number to be around 500 species (Happold, 2013).

Among small mammals, rodents range widely in size from 5 g of small African pigmy mouse (*Mus minutoides*) to 50 kg, capybara (Vaughan *et al.*, 2000). African rodents vary greatly in size; the majority weigh 20–80 g, but the smallest weighs only 3 g (*Mus haussa*), and the largest weigh about 3.25 kg (*Pedetes* spp.) and about 20 kg (*Hystrix critata)* (Happold, 2013). Rodents are remarkable for their morphological diversity related to their ecological, behavioural, trophic and locomotory adaptation (Happold, 2013). Most African rodents are typically ‘mouse-like’ or ‘rat-like’. However, some have extremely long hind limbs and jump like kangaroos (jerboas *Allactaga*, *Jaculus* and springhares *Pedetes* and some have large wing like membranes used to glide from tree to tree (anomalures *Anomalurus*, *Idiurus*) and some have blunt muzzles, cylindrical bodies, large short forelimbs and rudimentary eyes (mole-rats *Bathyergus*, *Georhychus*, *Heliophobius*) (Happold, 2013). The existing huge variation in the biological characteristics of rodents is the reflection the evolutionary diversity, adaption to different environments and large number of species (Kingdon, 1997; Nowak, 1999; Happold, 2013).

Rodents are widely distributed in every continent except Antarctica (Happold, 2013). They have capability to exploit a wide range of habitats and environments throughout the world (Vaughan *et al.*, 2000). Certain commensal species have expanded their ranges by human introduction (Happold, 2013). At a local scale, their distribution and abundance is influenced by habitat condition such as vegetation, species composition and structure and its level of disturbance (Demeke Datiko and Afework Bekele, 2014). Habitat complexity and heterogeneity resulting from altitudinal zonation also influence the diversity and distribution of small mammals (Mohammed Kasso *et al.*, 2010). Over all, their occurrence in particular habitat is linked with their diversity in morphology, ecology, physiology and behaviour is remarkable (Happold, 2013). Hence, they show incredible variation in their ecology, morphology, physiology, behaviour and life history strategies (Happold, 2013; Demeke Datiko and Afework Bekele, 2014). Some of them are fossorial, terrestrial, arboreal, or semi-aquatic (Happold, 2013). They are accordingly adapted to move by leaping, running, climbing, gliding and swimming (Delany and Happold, 1979; Oguge, 1995).

Most species are terrestrial; many of them rest in burrows or under rocks when inactive. Some of them are scansorial because they climb low vegetation close to the ground. The arboreal species such as some genera of squirrels, *Graphiurus, Grammomys, Thallomys* spend all (or most) of their time in large shrubs and trees, and rarely descend to the ground. Some small species are adapted for climbing on tall grasses (*Dendromus*, *Dendroprionomys*, and *Prionomys*) and have opposable fingers and prehensile tails for holding on to slender grass stems. A number of genera (*Bathyergus*, *Georhychus*, *Heliophobius*, and *Heterocephalus*) are subterranean and live permanently underground. Few species also live in wet swampy habitats and are capable of swimming. Most species are habitat-specific and are found in only one or two types of habitats. In contrast, a few species such as *Mastomys natalensis*, *Cricetomys gambianus*, *Thryonomys swinderianus*, *Hystrix* spp. are widespread and habitat generalists (Happold, 2013).

Rodents, despite their great species diversity, show less overall variation in morphology and share many common features compared to other mammalian orders (Macdonald, 1984; Happold, 2013). The major feature is their dentition (paired incisors) specialized for gnawing. From this dentition, the name “rodent” derived from the Latin term “rodere” which means to gnaw (Macdonald, 1984; Kingdon, 1997; Nowak, 1999). The upper and lower jaws have a single pair of enlarged and ever-growing chisel like incisors whose enamel is mainly limited to the anterior surface. Deliberate honing motions of the lower incisors upon the upper incisors (Happold, 2013) achieve the keen sharpness and chisel shape of the incisors. Although the adaptive role of the incisor is for gnawing, it also used for biting, cutting, piercing, stabbing, holding, tearing, slicing, and scraping, digging, chipping, interdental sharpening and for gathering and carrying of foodstuffs, nesting material and young. It also plays a great role in communication, behaviour, ecology and reproduction (Happold, 2013). The masticator muscles are complexly subdivided and its orientation used for suborder level classification of its species into Sciuromorpha, Myomorpha and Hystricomorph (Happold, 2013). However, the recent classification groups them into two suborders (Sciurognathi and Hystricognathi) (Macdonald, 1984; Nowak, 1999; Vaughan *et al*., 2000; Kingdon, 2004; Happold, 2013).

The majority of species of African rodents are herbivores. Others are omnivores, feeding on plants and animals (usually arthropods) and few of them are insectivores and even carnivorous. Many are opportunistic in their diet based on the availability of food and seasons of the year (Happold, 2013). Subterranean species (species of Bathyergidae and Spalacidae) feed on a variety of underground corms, bulbs, tubers, fibrous roots and rhizomes (Happold, 2013).

Rodents show a wide range of reproductive strategies that is determined partly by their phylogeny, environment and location (Wilson and Reeder, 2005). They show a great variation in their fecundity (Happold, 2013). Their fecundity is further enhanced by physiological aspects. For instance, their high reproductive potential and a short period of maturation lead to rapid population growth (Getachew Bantihun and Afework Bekele, 2015). They have rapid population growth especially during favourable conditions (Getachew Bantihun and Afework Bekele, 2015). Litter size of most rodents ranges from one to eight offspring even if it can vary based on environmental conditions (Afework Bekele and Leirs, 1997). However, squirrels, anomalurids and *Pedetes* have only 1–2 young per litter whereas *Mastomys natalensis* and *Heterocephalus glaber* have 10-20 young per litter (Happold, 2013) and mole rats can produce as many as 28 offspring in a single litter (Getachew Bantihun and Afework Bekele, 2015).

Rodents are essential components of the ecosystem playing a major role in seed dispersal, pollination, predator-prey relationships and in habitat modification (Johnson *et al.*, 2001; Dickman, 2003). As they are chief elements of forest ecosystems, they affect the structure, composition and dynamics of forest communities through activities such as, seed dispersal, pollination and control of insect pest populations (Getachew Bantihun and Afework Bekele, 2015). They are also important food sources for predatory mammals and birds. They are important prey for many small and medium-sized carnivores such as mongooses, genets, civets, small canids, small felids, owls, hawks and snakes (Happold, 2013). Among the predatory mammals in Ethiopia, the Ethiopian wolf (*Canes simensis*, Rappel, 1838) is a specialist rodent feeder, adapted to prey upon the diurnal rodents that occur in Afroalpine grasslands (Sillero-Zubiri *et al.*, 1995; Mohammed Kasso and Abebe Getahun, 2013). Even though small mammals provide major benefits to an ecosystem some rodent species (less than 5%) are pests and cause significant losses to agricultural crops (Getachew Bantihun and Afework Bekele, 2015). They also play an important role in public health (MohdZain *et al.*, 2015). Some are reservoirs of pathogens for human and domestic animals diseases including plague, Lassa fever, rickettsiosis, leptospirosis, toxoplasmosis, leishmaniasis and trichinosis (Meheretu Yonas *et al.*, 2011). Some zoonotic diseases are transmitted directly by rodents through bites, urine and faeces. Leptospirosis affects 7-10 million people per year globally (MohdZain *et al.*, 2015). Some other diseases are also indirectly transmitted through rat-borne ectoparasites (MohdZain *et al.*, 2015).

The order Chiroptera is the second most diverse order of mammals that exhibits great physiological and ecological diversity (Stevens and Willig, 2002; Wilson and Reeder, 2005) and originated before 52 million years ago (Happold and Happold, 2013). They are the only mammals that have an active flight (although there are gliding mammals in other orders). Worldwide, there are 1,150 species, placed in 18 families and 202 genera, of which 42% are monotypic and 16% have only two species (Happold and Happold, 2013; IUCN, 2015). However, the number of bat species seems to be unstable, some scholars indicated more than 1,232 extant species (ACR, 2016). About 225 species of bats (approximately 20% of the mammals) are found in Africa although their taxonomy is still not resolved (Happold and Happold, 2013). However, according to the report of ACR (2016), there are currently 16 families (3 extinct), 72 genera (16 extinct) and 357 species (36 extinct) recorded in Africa that cover the geographic area of the African continent and Madagascar, and other surrounding islands in the Indian and Atlantic oceans. Out of the extant bats 11 (85%) families, 35(63%) genera and at least 96 (30%) of species occur in Ethiopia (Lavrenchenko *et al.*, 2004; Lavrenchenko *et al.*, 2010, Kruskop and Lavrenchenko, 2006, Kalpi *et al.*, 2015; Kruskop *et al.*, 2016).

The bat fauna of Ethiopia is the dominant fauna comprising greater than 30% of the total mammals recorded from the country (Kingdon, 1997; Wilson and Reeder, 2005; ACR, 2016). More than 96 species of bats are recorded from Ethiopia, with the microchiropterans being better represented than the megachiropterans (Kruskop and Lavrenchenko, 2000;

Lavrenchenko *et al.*, 2010; Kruskop and Lavrenchenko, 2006; Kalpi *et al.*, 2015; Kruskop *et al.*, 2016). Among the Microchiroptera, large number of species are from the family Vespertilionidae, followed by the families Rhinolophidae, Hipposideridae, Emballonuridae, Molossidae, Rhinopomatidae and Megadermatidae. Of this diversity, five species, namely, *Stenonycteris petra* (Pteropodidae), *Myotis scotti* (Vespertilionidae), *Plecotus balensis* (Vespertilionidae) and *Kerivoula eriphora* (Vespertilionidae) *Scotophilus ejetai* (Vespertilionidae) are endemic to the country. The Nabu Research Group or Kalpi *et al.* (2015) mentioned *Lasioncteris petra* as endemic even though Nesi *et al*. (2012) revised it as subspecies (ACR, 2015). As most part of the country is not yet surveyed, their future diversity increase is expected (Hutson *et al*., 2001; IUCN, 2012).

Traditionally, Order Chiroptera is divided into suborder Megachiroptera and suborder Microchiroptera (Happold and Happold, 2013). Evidence from recent phylogenetic studies supports the monophyly of the Megachiroptera, even though the Microchiroptera are not considered as monophyletic taxon (Happold and Happold, 2013). All megabats belong to one family, the Pteropodidae (Old World Fruit Bats) while the rest 17 families to microbats, of which eight are represented in Africa (Happold and Happold, 2013). The chiropteran monophyly or diphyly has been put down by recent molecular studies that reject any close relationship among bats, flying lemurs and tree shrews and instead support a sister taxon relationship between Chiroptera and Eulipotyphla. However, based on neural findings still others suggest a diphyletic origin of Chiroptera with Megachiropterans being a sister group of the primates (ACR, 2015). Recent studies using molecular techniques to investigate higher-level relationships within Chiroptera have challenged their monophyly. The analyses of nuclear and mtDNA gene sequences strongly support an alliance of megachiropterans and rhinolophoids (excluding Nycteridae) in one suborder (Yinpterochiroptera), and all other microbats and nycteriids in the other suborder (Yangochiroptera) (ACR, 2015).

Usually the number of species is larger than the number of genera, but there is one exception: in the Megadermatidae, three genera and two species mentioned. The reason for this is that only extant taxa are included, and although *Megaderma gigas* is an extinct species for Africa, the genus itself still has representatives in Asia. Vespertilionidae contain the largest number of both genera and species, followed by the Molossidae and Pteropodidae in number of species, and the Pteropodidae in number of genera (ACR, 2015).

Bats form one of the largest non-human aggregations and the most abundant groups of mammals when measured in numbers of individuals (Mohammed Kasso and Balakrishnan, 2013). They are small, with adult masses ranging from 2-1,500 g; although most living bats weigh less than 50 g as adults (Mohammed Kasso and Balakrishnan, 2013).

The forelimb of a bat is modified into a wing with elongated finger bones joined together by a thin and large (85% of the total body surface area) membrane with rich blood flow. Their wing is an unusual structure in mammals enabling for active powered flight. Skin covering the wings of bats not only constitutes a load-bearing area that enables flying but also performs multiple functions like providing a protective barrier against microbes and parasites, gas exchange, thermoregulation, water control, trapping of insects, food manipulation and for swimming (Mohammed Kasso and Balakrishnan, 2013). The powerful flight of bats plays the most important role for their widespread distribution and diversity. This helps in the distribution of bats across all continents except Antarctica, some Polar Regions and some isolated oceanic islands (Jones *et al.*, 2009).

The assessment of their distribution and species composition is challenging (Jaberg and Guisan, 2001) due to their nocturnal behaviour, large home ranges, seasonal migration patterns and the problems associated with species identification in flight (Walsh and Harris, 1996) making accurate surveys difficult (Jaberg and Guisan, 2001).

Roosts are one of the essential elements for the survival of bats because they need a place to rest and seek protection from predators (Law and Anderson, 2000; Neuweiler, 1989). Roost preference of bat is determined by randomly available roosting site, age, sex and reproductive condition (Fenton and Rautenbach, 1986; Barclay *et al*., 1988; Campbell *et al*., 1996; Vonhof and Barclay, 1996). A wide variety of sites on tree is used by bat for roosting (holes, barks, logs, leaves and branches) (Campbell *et al*., 1996; Hutson *et al*., 2001). Caves and mines, rock crevices and artificial structures including a wide range of buildings and bridge bottom are also used as roosting sites.

About 75% of microchiropterans feed on insects, although food sources may include other invertebrates, fish, amphibians, small mammals, blood, fruit, and flowers (Hutson *et al*., 2001). Some of the larger Microchiroptera are carnivorous, feeding on fish, amphibians, birds, and small mammals, including other bats (Navarro and Wilson, 1982; Hutson *et al*., 2001).

Bats are among the most overlooked economically and ecologically important groups. They provide a tremendous value to ecosystems as primary, secondary and tertiary consumers by supporting and sustaining both natural and human dominated ecosystems (Kunz *et al.*, 2011). Bat populations are affected by climate change, deterioration of water quality, agricultural intensification, loss and fragmentation of forests, fatalities at wind turbines, disease, pesticide use and overhunting (Obrist and Syme, 1992; Jones *et al*., 2009). Particularly, pesticides used on crops like organochlorines such as DDT, organophosphate and carbamate insecticides pose serious threats to bats and other small mammals like rodents and shrews. Insect-eating bats are more at risk to pesticides and environmental contaminants. Bats and other small mammals may be affected by eating contaminated insects, drinking contaminated water, or absorbing the chemicals while feeding in treated habitats (Merlin *et al*., 2005) and are used as excellent ecological health indicators (Estrada *et al*., 1993; Fenton *et al*., 2000; Wickramasinghe *et al*., 2003; Kunz *et al.*, 2007).

Bats are increasingly viewed as a threat to human health, despite their important roles in ecosystems such as pollination, seed dispersal and predation on insects. They are also excellent bioindicators of environmental changes (Kunz *et al*., 2007). They are sensitive to a wide range of anthropogenic disturbances such as urbanization, agricultural intensification, habitat loss and fragmentation. To improve the management of bats and their habitats, understanding the ecology of the potential reservoirs of zoonotic pathogens is needed (Gay *et al.*, 2014).

Order Eulipotyphla is the third most diverse group of mammalian order comprising about 450 species (IUCN, 2015). For a long time, its members have been viewed as closely related to ancestral mammalian stock due to their retention of numerous primitive characteristics (Douady *et al.*, 2002). Due to complexity in diversity of the members, their placement in order, changes from time to time (Kingdon, 1997; Wilson and Reeder, 2005; Afework Bekele and Yalden, 2013; Happold and Happold, 2013). For a long time, insectivores are viewed as closely related to ancestral mammalian stock due to their retention of numerous primitive characteristics (Douady *et al.*, 2002). However, based on morphological and molecular studies, flying lemurs, tree shrews, and elephant shrews are excluded from Order Insectivora and placed in their own respective orders Dermoptera, Scandentia, and Macroscelidea, respectively (Douady *et al.*, 2002; IUCN, 2015). While, the remaining former members of insectivores were named order Lipotyphla, which is monophyletic based on morphology, even though molecular data suggest, as lipotyphlans are polyphyletic. The golden moles and tenrecs are placed in order Afrosoricida and the rest are placed under order Eulipotyphla (Douady *et al.*, 2002; IUCN, 2015). Hence, currently shrews, hedgehogs, moles and solenodons as major groups (IUCN, 2015) representing Order Eulipotyphla. The Order is highly radiated to fill the terrestrial insectivore niche in most habitats in both temperate and tropical regions. Hence, it has the widest distribution compared to all the family of insectivorous mammals (Happold and Happold, 2013). It consists of five families namely: Family Erinaceidae (hedgehogs, moonrats and gymnures), Soricidae (white-toothed shrews, red-toothed shrews, and African white-toothed shrews), Talpidae (desmans, moles, shrew-like moles), Solenodontidae (solenodons) and the Nesophontidae (extinct West Indian shrews) (IUCN, 2015). All members of these groups share similar morphological characters like simple hindgut caecum, typically long narrow snout and reduced to absent eyes (Douady and Douzery, 2009). The family Soricidae (the shrews) contain 23 recent genera and about 374 species. Shrews are by far the most numerous (nine genera and 150 species) and widespread of the terrestrial insectivorous mammals found in Africa even though their exact number of species is uncertain and under constant review (Happold and Happold, 2013). The most widespread genus is *Crocidura*, with approximately 104 species recognized (Happold and Happold, 2013; Kingdon, 2013). Their taxonomy is complex due to their morphological similarity but molecular approaches are capable of differentiating them into species and providing insight into their phylogenetic relationships (Happold and Happold, 2013).

In Ethiopia, shrews of the family Soricidae are represented by 28 species of which 10 (36%) of these species are endemic (Lavrenchenko *et al.*, 2017). Although Ethiopian highlands are considered as important centres of diversity and adaptive radiation, the cytogenetic and molecular data show monophyly for most Ethiopian endemic species of *Crocidura* (Lavrenchenko *et al.*, 2017). In the check-lists of Ethiopian endemic mammal, they take highest share next to rodents (Yalden and Largen, 1992; Afework Bekele and Yalden, 2013) of which some species are also threatened. In particular, the Ethiopian plateau is an important centre of diversity and adaptive radiation of the genus. For instance, out of the six *Crocidura* species known from the Bale Massif, four are endemic to the southeastern highlands (Lavrenchenko *et al.*, 2017).

African shrews range in size from the tiny *Suncus etruscus* and *S. infinitesimus* of about 2 g to the large, rat-sized *Crocidura olivieri*, *C. goliath* and *Scutisorex somereni*, which have mean weights of about 60 g in Africa (Happold and Happold, 2013) and up to 100 g (*Suncus murinus*) in the world (Afework Bekele and Yalden, 2013). Among the genus *Crocidura*, size ranges from the smallest (*C. bottegoides*; HB: ca. 50 mm, HF: 10 mm, WT: 3 g) to large (*C. olivieri*; HB: up to 140 mm, HF: ca. 23 mm, WT: 65 g) (Kingdon, 2016). They are typically small, fast-running, terrestrial or semifossorial insectivores with long pointed snouts, minute eyes, small ears, short limbs, long tails and short dense fur. The eyes are small, and most species have poor eyesight and prey is located largely by smell, touch and by random searching (Happold and Happold, 2013). They have long and flexible snout with wide array of touch-sensitive vibrissae and whiskers that are well supplied with nerve endings useful in orientation and location of prey (Afework Bekele and Yalden, 2013).

Shrews are widely distributed in most terrestrial habitats like forest, scrub and grassland, arid and at a wide range of altitudes (Afework Bekele and Yalden, 2013; Happold and Happold, 2013). Shrews are most abundant in moist, well-vegetated habitats but a few are well adapted for life in xeric habitats. Several species such as *Crocidura russula*, *C. olivieri* and *Suncus murinus* are commensals with humans (Afework Bekele and Yalden, 2013; Happold and Happold, 2013).

Shrews feed on different invertebrates mainly on arthropods, molluscs and earthworms. Few of them are highly opportunistic and larger species will prey upon fish, amphibians and small reptiles (Happold and Happold, 2013). Shrews have voracious appetite and little resistance to starvation, needing to feed frequently day and night in order to survive. They have significantly higher daily energy expenditures and basal metabolic rates than those of rodents of similar size (Happold and Happold, 2013). They need more food due to the high water and indigestible chitin content of prey and high metabolic rate. In addition, their high metabolic rates, small body size and inability to store large quantities of fat as a food reserve make shrews to be incapable of hibernating or entering extended torpor during critical unfavourable condition (Happold and Happold, 2013). The small size of shrews permits them to exploit a variety of habitats and penetrate narrow spaces, cracks and crevices in search of food and suitable nest sites (Happold and Happold, 2013).

Many shrews are capable of breeding whenever conditions are favourable, but most African species breed mostly during warm, wet months and reproduction declines during the dry season. They normally produce 2–3 litters during a breeding season (Happold and Happold, 2013).

Many of the small mammal species have similar external body structures except bats. For this reason, the classification and phylogenetic studies of small mammals have become complicated for many years. However, many cryptic or sibling species can be easily distinguishable based on their chromosome sets and the new molecular sequencing technologies (ACR, 2016).

Karyological analysis can provide important information for the evaluation of the systematic and phylogenetic diversification of small mammals (Zima, 2000). Chilalo-Galama Mountains range possesses remnant Afroalpine mammals with high species diversity and endemism (Mohammed Kasso *et al.*, 2010). The potential for the presence of new cryptic and sibling species unknown to science is considerable. Therefore, molecular and chromosomal data of some small mammal species of Chilalo-Galama Mountains Range are used to provide precise species identification of the local small mammals. Furthermore, the analyses performed with the use of advanced methods of contemporary systematic allow reconstruction of the phylogeny of some groups of small mammals in connection with the history of Ethiopian montane ecosystems.

Despite high species diversity of small mammals in Ethiopia, only few studies carried out on their population biology and ecology (Yalden *et al.*, 1976; Afework Bekele *et al.*, 1993; Afework Bekele, 1996; Afework Bekele and Corti, 1997; Lavrenchenko *et al.*, 1997; Lavrenchenko *et al.*, 2009; Lavrenchenko *et al.*, 2017). In Ethiopia, limited areas have been extensively surveyed for small mammals (Yalden and Largen, 1992). Furthermore, few studies (Demeke Datiko *et al.*, 2007; Mohammed Kasso *et al.*, 2010; Mohammed Kasso and Afework Bekele, 2011) have been carried out to record data on the various aspects of small mammals (rodents, shrews, overlooking or excluding bats) in Ethiopia. However, studies on diversity, distribution, habitat selection, habitat use and population dynamics of the small mammal (rodents, shrews and bats) community are poorly known for many regions of Ethiopia. Particularly information on the species composition, distribution and conservation of highland bats is lacking from most parts of Ethiopia including Chilalo-Galama Mountains Range. This area is understudied and its small mammal fauna is poorly known relative to the other Afroalpine habitats in Ethiopia (Mohammed Kasso *et al.*, 2010) with the exception of limited surveys by Mohammed Kasso *et al.* (2010) and Zerihun Girma *et al.* (2012) and short expedition by the JERBE team and others. Despite this, it possesses a relic afro-alpine fauna representing pronounced centre of species diversity and endemism. The area comprises the type locality of several endemic high-altitude rodent species like *Stenocephalemys albocaudata*, *Arvicanthis blicki* and *Otomys helleri*. Therefore, the potential for the presence of new cryptic and sibling species unknown to science is considerable. Furthermore, the analysis performed with the use of advanced methods of contemporary systematic will allow reconstruction of the phylogeny of some groups of small mammals in connection with the history of Ethiopian montane ecosystems.

In most ecological studies of small mammals, bats are neglected. However, in the present study, in order to fill the existing gap an ecological study on bats was also conducted in alongside other small mammals like rodents and shrews. Therefore, the aim of the present study was to investigate the species composition, distribution and taxonomy of small mammals (Order Rodentia, Chiroptera and Eulipotyphla) and major conservation challenges in Chilalo-Galama Mountains Range. The study also aimed at suggesting possible management plan for the conservation of the area and for protection of Arsi Mountains National Park (AMNP).

2. LITERATURE REVIEW

2.1. Distribution and habitat selection of small mammals

Rodents have cosmopolitan distribution. They are distributed nearly worldwide by covering all habitats except the sea and Antarctica (Happold and Happold, 2013). The occurrence of rodents in every habitat has resulted in large number of species that shows highly diversified and varied characters in habitat utilization, morphology, ecology, physiology, behaviour, life history strategies and distribution (Wilson and Reeder, 2005). Some species are aquatic, some are terrestrial, and some are subterranean. Some are arboreal, and semi aerial, gliding from one tree to another (Vaughan *et al*., 2000). The success of small mammals particularly rodents is due to their ability to produce large litters in a short period of gestation, ability to adapt quickly to environmental changes and they are relatively small animals, which help them to easily hide themselves from predators (Vaughan *et al*., 2000).

Bats form one of the largest non-human aggregations and the most abundant groups of mammals when measured in numbers of individuals. They have evolved into an incredibly rich diversity of roosting and feeding habits. They roost on foliages, caves, rock crevices, hollows of trees, crevices beneath exfoliating bark and different fabricated structures. Flying ability of bats plays the most important role for their widespread distribution and diversity. It has also contributed a lot for their extraordinary feeding and roosting habits, reproductive strategies and social behaviour (Mohammed Kasso and Balakrishnan, 2013).

Habitat selection is the process by which individuals choose among available habitat patches (Mohammadi, 2010). The patterns of habitat use by mammals are important for understanding determinant of their distribution and abundance (Mohammadi, 2010). The small mammal habitat use, distribution and abundance are often influenced by macro and microhabitat characteristics. Among these, the nature and densities of vegetation play a significant role (Afework Bekele and Leirs, 1997) because it provides food, shelter, breeding site and protection against predators (Mohammed Kasso and Afework Bekele, 2014). Furthermore, it also creates favourable conditions for the prey of small mammals such as invertebrates, fungi and herbs (Mohammadi, 2010). The other microhabitat features like food availability, predation risk, temperature, status of moonlight are also important in determining the diversity and abundance of small mammals (Mohammadi, 2010). Seasonal distribution and quantity of rainfall are considered as the major climatic variables in determining population dynamics of small mammals (Mohammed Kasso and Afework Bekele, 2011). The density of various small mammals remains low during most of the time, but at the end of the breeding season they proliferate (Afework Bekele and Leirs, 1997). Particularly due to their high metabolic rates and high moisture requirements for homeostasis, shrews have specific habitat requirements such as high amount of leaf litter and stem densities. Although these species are often sympatric with other small mammal species, they are more restricted in their movements and abilities to exploit a variety of habitats. In general, microhabitat characteristics play a major role in small mammal abundance, distribution and habitat selection (Mohammadi, 2010).

Habitat use in small mammals is also correlated with species life-history traits. For example, some rodents like the African root-rats (*Tachyoryctes*, Rüppell, 1835) are solitary subterranean rodents, living underground in semi-permanent burrow-systems and exclusively herbivores feeding on a wide range of vegetation (Lavrenchenko *et al.*, 2014). Some bats have a worldwide distribution and in the temperate regions many of them the ability to hibernate and migrate during unfavourable environmental conditions.

Body size is also often related to dispersal distance and home range size, which in turn reflect the abilities of a species to exploit complex landscapes and habitats. Flying species like bats are able to exploit a variety of habitats across a landscape whereas other non-volant small mammals or less-mobile species are restricted to certain habitat patches (Happold and Happold, 2013).

Diet is extremely improtant in determing the community structure, species diversity, relative abundance, and resource partitioning among small mammal species (Mohammed Kasso and Afework Bekele *et al.*, 2011). Rodents exploit a broad spectrum of food items. Some of them consume diverse plant materials (seeds, stem, leaves, flowers, root, tubers, fruits and berries) and small invertebrates such as insects (grasshoppers, ants, flies and termites), spiders, and worms but a few of them are strictly specialized on specific type of food (Yalden and Largen, 1992; Happold, 2013). Diet is a key factor in determining reproduction and population. The quality and quantity determine breeding often attributed to gonadotropic factors present in plants at certain times, which stimulate reproduction (Mohammed Kasso and Afework Bekele, 2011). The diet of bats is as diversified as their habitats and species. Invertebrates (insects) are the major diet of microchiropterans although they are also known to feed on vertebrates (mice, other bats, lizards, amphibians and fish), and blood of mammals or birds (Kingdon, 1997).

Many small mammals are adapted to living in different habitats with different characteristics. For example, Afroalpine habitats (altitudinal range above 3,400 m asl) are characterized by short, sparse vegetation, heavy frosts, low rainfall and low temperature. The ericaceous belt that encircles the Afroalpine belt above the tree line at altitude ranging from 3,400-3,800 m asl is characterized with a uniform *Erica* scrub (Sillero-Zubiri *et al.*, 1995). Temperature extremes could result in several limitations in all species of mammals even though some like *Stenocephalemys albocaudata* and *S. griseicauda*, *Arvicanthis blicki* and *Crocidura* species employ some adaptive mechanisms (Sillero-Zubiri *et al.*, 1995). Some rodent species occur in varieties of habitats with the generalized ecological requirements, while others have restricted and limited ecological requirements. The multimammate mouse (*Mastomys natalensis*) is one of the commonest and most widespread species in sub-Saharan Africa (Stenseth *et al.*, 2001).

Humans are greatly modifying the landscape patterns (Mohammed Kasso and Afework Bekele, 2013). Species with limited mobility, large area requirements, and strong dependence on a certain type of habitat will be more affected and consequently their abundance and richness will be modified (Mohammed Kasso and Afework Bekele, 2013).

2.2. Altitudinal gradient on the distribution of small mammals

The term ‘gradient’ refers to a region that possesses directional environmental change (Carpenter, 2005). Sometimes gradients and domains are irregularly used. Even though, both are delimited by physical or climatic boundaries, domains do not hold the assumptions about internal environmental change (Carpenter, 2005). Patterns of abundance, distribution and diversity of organisms is one of most general features of life on earth reflected in environmental gradients (latitude, elevation, sea depth and intertidal) (Brown, 2001). The earth is a complex place, without uniform substrate and regular gradients of climate and other abiotic variables. No two geographically isolated places or mountains, offer identical environmental conditions (Brown, 2001).

Some environmental variables are closely correlated with elevation on all, or nearly all, mountains. These include temperature, precipitation, atmospheric pressure and partial pressures (oxygen and carbon dioxide), land cover, human population density and human land-use patterns (Carpenter, 2005). These environmental variables tend to decrease relatively uniformly with increasing elevation, although they may be affected by local topography and weather conditions (Brown, 2001). Biologically meaningful explanations involve dispersal barriers at the gradient edge and control by climatic or non-climatic environmental variability along the elevation gradient (Carpenter, 2005). It might influence species richness across a geographical domain by dispersal barriers and environmental variability by permitting fewer species near the edge (Carpenter, 2005).

In regions with diverse landscapes that range from sea level to high mountains, the land area in different elevation bands varies greatly. Commonly, land area decreases as elevation increases (Bachman *et al.*, 2004; Novillo and Ojeda, 2012). Because most mountains erode to produce gradually sloped, roughly conical landforms, land surface area also decreases relatively continuously with increasing elevation (Brown, 2001). A further consequence of uplifting and erosion processes is that tops of mountains tend to be more isolated than sites at lower elevations (Brown, 2001). If species richness is estimated for latitude or elevation bands that differ in total area, biases due to a species–area effect can occur (Bachman *et al.*, 2004; Carpenter, 2005). Several studies show that the area controlled by species richness peaks at mid-elevations, although unimodal peaks have been found without accounting for the area (Bachman *et al.*, 2004). Hence, currently the mid-elevation peak is recognised as a common pattern in becoming the recent revival of interest in studies of species richness along elevation gradients (Brown, 2001; Bachman *et al.*, 2004; Carpenter, 2005). Species richness and endemic richness vary along elevation gradients, but not necessarily in the same way (Vetaas and Grytnes, 2002; Bhattarai and Vetaas, 2003).

Elevation range size and position along the gradient influence the environmental conditions for species survival and reproduction (Brown, 2001). Species with small geographic ranges (endemics) tend to show more variable different pattern in richness than the more widespread species. Endemics are affected by topographic heterogeneity while wide-range species are affected by productivity of the habitat (Bhattarai and Vetaas, 2003; Novillo and Ojeda, 2012). Mountains with a larger breadth of elevation have more habitats and higher species richness than mountains with smaller elevations (Heaney, 2001; Bhattarai and Vetaas, 2003; Mena and Vazquez-Dominguez, 2005).

Several factors change predictably with increasing elevation, the most obvious of which is the generally linear decrease in temperature (Halbritter *et al.*, 2013). Temperature decreases by an average of approximately 0.68°C for each 100 m increase in elevation (Brown, 2001). The moist adiabatic lapse rate varies depending on the latitude, size, shape and prevailing weather patterns from 0.48°C to 0.78°C for each 100 m increase in elevation (McCain and John-Arvid, 2010). For instance, tropical mountains, due to higher temperatures at low latitudes, have warmer temperatures at the base and therefore need to be very tall to reach the extreme cold temperatures seen on temperate mountains (McCain and John-Arvid, 2010).

Elevation gradients create variation in suitable environment and habitat for biodiversity. Precipitation and other environmental factors along elevation gradient increase species persistence because individuals are able to exploit resources in a variety of ways along a continuum (Banko *et al.*, 2002). Low temperature is the main factor controlling the distribution of species (Brown, 2001; Halbritter *et al.*, 2013). Elevation gradient has close correlation between the temperature limits (Halbritter *et al.*, 2013).

The variation in abiotic factors such as day length, ultraviolet (UV) radiation, light intensity and day and night temperature variation along elevation gradient result in differences in distributional patterns along these gradients. In addition, other factors that are not necessarily correlated along these gradients might also affect distribution, such as habitat type, substrate type or precipitation patterns (Halbritter *et al.*, 2013).

Gradients of elevation and other environmental factors provide insights into patterns of animal community structure, richness, diversity, distribution, density, phonology and habitat use (Banko *et al.*, 2002; Bachman *et al.*, 2004). Most animal communities change in response to elevation, climate, vegetation, and other biotic factors, including alien species (Banko *et al.*, 2002). Some species may be exterminated at mid-elevation due to alien disease vectors, predators, and many other alien species that reduce food resources and degrade habitats (Banko *et al.*, 2002). Vegetation associations often have distinctive boundaries along elevation gradients forming different habitat type, which determine the distributions of animals (Presley *et al.*, 2012).

Three major classes of interrelated historical processes have influenced the relationship between mammal species richness and patterns of diversity along elevation gradient (Brown, 2001; McCain, 2009). The first one is dispersal and colonization particularly relevant for Pleistocene shifts in climate, sea level and vegetation. These have periodically altered the habitat barriers and allowed interchange of non-volant mammals among islands and other isolated mountains (Brown, 2001). The second relevant historical process is extinction. Dispersal facilitates the accumulation of diversity when barriers are temporarily reduced or absent while extinction tends to reduce diversity. The third important historical process is differentiation and speciation. Long isolation of populations on different mountains or different habitats has often led to evolutionary differentiation, sometimes culminating in the formation of highly restricted endemic species. Thus, these three processes (dispersal, extinction and speciation) have played major roles in shaping the elevation variation in species diversity of mountain systems (Brown, 2001; McCain, 2009).

The drivers of small mammals diversity along elevation gradient can be grouped into four main categories namely the current climate, topographic feature, evolutionary history and biotic processes (McCain, 2009). Climatic hypotheses are based on current abiotic conditions, such as temperature, rainfall, productivity, humidity and cloud cover. Spatial hypotheses include the classic species–area relationship. Evolutionary history is based on speciation rates, extinction rates, clade age and phylogenetic niche and biological processes are based on competition, source–sink dynamics and ecotone effects, habitat heterogeneity and habitat complexity (McCain, 2009).

Elevation gradient is nothing to organisms but its environmental variables of the past and present, abiotic and biotic factor generate and maintain its patterns of abundance, distribution and diversity (Brown, 2001). Lomolino (2001) pointed out that many components of climate and local environment (e.g. temperature, precipitation, seasonality and disturbance regime) vary along the elevation gradients and ultimately create the variation in species richness (Bhattarai and Vetaas, 2003; Halbritter *et al.*, 2013). Afework Bekele and Corti (1997) concluded that, as elevation alone seems not to impose severe limits on distribution on small mammals unless it is related with other biotic and abiotic factors.

Much progress was made on the assessment of species distributions along elevation gradients (Bhattarai and Vetaas, 2003; Halbritter *et al.*, 2013). Two general hypotheses have been proposed for how species richness is related to altitude either species richness decreases with increasing elevation or species richness peaks at midpoints (McCain, 2005). Some of the proposed processes accounting for richness patterns along gradients are species–area relationships, species–energy relationship and mid-domain effect (Novillo and Ojeda, 2012). It has been generally recognised that species richness declines with elevation (Bachman *et al.*, 2004). However, monotonic declines in richness are less typical than unimodal peaks or patterns where species richness plateaus before decreasing (Bachman *et al.*, 2004). Climatic variables that affect net primary productivity tend to be good predictors of species richness on gradients (Carpenter, 2005).

Most studies of elevation trends in nonvolant small mammals, including rodents, insectivores, and sometimes marsupials, demonstrate mid-elevation peaks in species richness (McCain, 2004). Numerous hypotheses exist to explain elevation pattern of species richness although many of them are mutually neither exclusive, nor independent and consistently supported with empirical evidence (Brown, 2001; Heaney, 2001; McCain, 2004). Most diversity hypotheses are attempted to explain entire gradients based on biological factors such as productivity, habitat complexity, habitat diversity, environmental stress, disturbance, resource diversity or competition (Heaney, 2001).

High diversity of non-volant mammals and many other organisms frequently occur at intermediate elevations due to at least two ecological phenomena. One when elevation gradient spans a wide range of elevations from sea level to permanently ice-bound peaks. This constructs few species able to tolerate the entire spectrum of environments and range throughout the gradient. Instead, species with elevationally limited ranges replace each other with some overlap along the mountainside. Secondly, if precipitation and consequently primary productivity also peak at an intermediate elevation, sites that are more productive can support more coexisting species (Brown, 2001).

Species turnover along elevation has been demonstrated by the composition of species changes at different intervals along elevation gradients (Mena and Vazquez-Dominguez, 2005). Species turnover in ecological communities can reflect adaptations of species to differences in climate and local ecological dynamics (Mena and Vazquez-Dominguez, 2005). From small mammals, bats exhibit significantly less turnover than rodents (Presley *et al.*, 2012). Rodent and shrew inability to quickly and safely move between habitats constrains like seasonal variation in resource abundance via habitat switching and obliges them to conduct critical biological activities (forage, nest, mate, reproduce) within a local area. This fosters rodents and shrews to be more specialized to particular habitat types along elevation gradients than bats and birds (Presley *et al.*, 2012).

The bat fauna has clumped range boundaries, with many in proximity to ecotones, indicating shared responses by many bat species to changes in habitat type. There is a difference between the nested structure for bats and the Clementsian structure for rodents and shrews. There is no sorting limit for species distributions of bats at the high-elevation end of the gradient like both ends of the gradient for rodents and shrews (Presley *et al.*, 2012). The upper distribution of bat species is determined by environmental tolerance, whereas the lower distributional limit for most bats extends to the low-elevation end of the gradient. Some of this pattern is attributed to the distribution of food resources for bats, with all food types (e.g. fruit, nectar, arboreal insects, aerial insects) present and abundant at lower elevations and declining in diversity and abundance with increasing elevation (Presley *et al.*, 2012). In addition to resource availability, bat distributions may be limited by thermoregulatory constraints that do not apply to passerines or rodents along elevation gradients (Presley *et al.*, 2012).

The regions with largest area will have more species than smaller ones (Novillo and Ojeda, 2012). Along elevation gradients, area influences richness patterns in diverse manners (Novillo and Ojeda, 2012). Using equal-area bands in regions where the amount of available area declines steadily with elevation, equal-area bands increase in elevation breadth as elevation increases. This might mean that species richness for equal-area bands will increase with elevation simply because as the elevation breadth of each band increases, each band will include a greater number of species and also because beta diversity (species turnover) tends to increase with elevation (Bachman *et al.*, 2004). It has been demonstrated recently that a mid-elevation peak in species richness may result from hard boundaries. Hard boundaries are defined in relation to the degree of resistance to dispersal and survival. This theory predicts that total species richness will have a peak close to the mid-elevation. The hard boundary theory also predicts that wide-ranging taxa are more likely to show a mid-elevation peak than narrow-ranging taxa, as the latter are more influenced by environmental and historical factors (Vetaas and Grytnes, 2002). Because many endemic species have narrow ranges, one might expect that they have higher numbers in the tropical lowlands coherent with maximum richness (Vetaas and Grytnes, 2002).

2.3. Impact of fire on small mammals

Fire is a major disturbance force in many biomes across the world including forests, grasslands, savannas, Mediterranean systems sub-Afroalpine and Afroalpine habitats (Parr and Chown, 2003). Fire is partly a natural process that shapes the structure and function of ecosystems (Haslem *et al.*, 2011; Kelly *et al.*, 2012). It is also widely used to manage habitats to achieve conservation goals (Kelly *et al.*, 2012). However, Haslem *et al.* (2011) argued that fire management might not be compatible with conservation objectives. It is an integral process in the structure and maintenance of a variety of ecosystems throughout the world (Roberts *et al.*, 2008; Kelly *et al.*, 2012; Radford, 2012). It is part of a complex and dynamic process influencing the structure and composition of vegetation, which in turn shapes faunal composition (Roberts *et al.*, 2008). It promotes the existence of grass and other vegetation in different types of fire regimes that cause more subtle changes in vegetation community structure (Radford, 2012). Aside from edaphic and climatic influences, fire management is perhaps the most important ecological regulator of plant and animal populations in tropical savannas and grasslands worldwide (Sutherland and Dickman, 1999; Radford, 2012). The variations in fire management can also cause changes in vegetation community structure, leading to multiple cascading effects in animal communities (Sutherland *et al.*, 2009).

The effects of fire on biodiversity is poorly known and there is an ongoing debate about its effects on fauna (Parr and Chown, 2003). For instance, Letnic *et al.* (2013) indicated fire had relatively little effect on the small mammal assemblage in desert habitat. However, Andersen *et al.* (2012), showed with strong evidence that increased fire frequency, incidence and intensity contributed to the broad-scale decline and extinction of savannah small mammals fauna.

Fire severity depends on the magnitude effect on environment and on all components of ecosystems (Roberts *et al.*, 2008). It can also threaten human life and assets in fire-prone regions (Haslem *et al.*, 2011). Ignition methods may play a role in affecting fauna because line-ignited fires are likely to cover a wider area and be more intense than point-ignited fires, and thus it could be expected that they would have a great impact on fauna (Parr and Chown, 2003). The most important effects on fauna are typically indirect, through changes in habitat, resource availability and predation risk, rather than through direct mortality (Andersen *et al.*, 2012). Small mammals are strongly influenced by fire-induced vegetation changes (Weltzin *et al*., 1997). Fire-related vegetation structural changes can cause change in predator–prey interactions, habitat use and food preference (Radford, 2012). Recent analyses suggest that fire-induced declines may relate to increased impacts by predators due to frequent fire removal of ground-layer vegetation (Radford, 2012). Inadequate understanding of biotic responses to fire and strong public pressure to minimize fire hazards (Haslem *et al.*, 2011) increases the potential for prescribed fire to negatively affect biodiversity. Woody debris created during thinning may provide greater protective cover for small mammals, but eventual removal of these materials may result in reduction of small mammal populations (Bagne and Finch, 2010).

If predatory regulation is more important for mammals, increase in predator numbers and shifts in prey intake after fire will correspond with changes in mammal abundance. Conversely, if mammal populations are primarily driven by their food resources (e.g. prey groups, seed availability), they are likely to show strong post-fire changes associated with changes in abundance (Radford, 2012). The primary productivity can produce an abundance of vegetative growth, which can cause irruptions of rodents and their predators (Letnic *et al.*, 2013). The availability of food resources and predation pressure are the more important factors influencing the abundance and assemblage composition of small mammals than vegetation structure or time since last fire (Letnic *et al.*, 2013). Fires may also directly affect the abundance of seeds, stems and leaves of grasses and forbs and shelter sites (hollow logs, tree hollows and dense tussocks of grass) and other critical resources for small mammals (Andersen *et al.*, 2012).

Fire history is significantly correlated with the abundance, diversity and composition of mammal assemblages, typically with fewer mammals at sites with a recent history of more frequent or intense fires (Andersen *et al.*, 2012). A primary mechanism for this is linked with the properties of fire mosaics that determine the amount of suitable habitat in a landscape (Kelly *et al.*, 2012). Changes in the spatial extent of different fire histories will modify the total amount of these resources available in the landscape and thereby influence the abundance and distribution of species (Kelly *et al.*, 2012). Intense fires with short recurrence times severely limit the opportunities for recovery by fire-sensitive fauna (Andersen *et al.*, 2012). Severely burnt areas act as small mammals population sinks, requiring repopulation from unburnt source areas (Andersen *et al.*, 2012). Unburnt patches in the landscape can provide refugia for animals. Following fire, the patches can provide a source for recolonization into disturbed areas (Kelly *et al.*, 2012). The shape, size and patchiness of fire are also important in determining the abundance and distribution of small mammals. It affects animal movements during, after fire, and for the potential survival on unburnt area as re-colonization possibilities (Parr and Chown, 2003).

Small mammals can influence vegetation structure through feedback mechanisms leading to altered fire regimes (Weltzin *et al*., 1997). However, it is also important to focus on the longer-term effects of fire particularly on responses to fire regimes rather than to individual fire events. The observation that some fires or fire regimes lead to highly negative impacts on mammals while others lead to more subtle or no impacts, suggests that fire effects on mammals are not uniform. Rather, they may depend on fire-specific properties (e.g. season, intensity, area burnt) and site-specific environmental context (e.g. rocky *vs.* non-rocky habitat) (Andersen *et al.*, 2012). In the absence of a clear understanding of fire-related impacts on small mammals, it is difficult to prescribe management programmes (Radford, 2012).

2.4. Karyotypes and chromosomal variability

Geographical and climatic diversity in Ethiopia produce different ecosystems that accommodate diverse cultural and biological diversities and endemism (Mohammed Kasso *et al.*, 2010). Historical, geographical, and climatic reasons and the long period of relative isolation resulted in the mammalian fauna of Ethiopia to be unique, with more than 28% (57 of 320 species) endemic to the country (Yalden *et al.*, 1996; Afework Bekele and Yalden, 2013). The level of endemicty is not only limited to the species but it also uplifted to the genus level in *Nilopegamys* and *Stenocephalemys* (Yalden *et al.*, 1996; Afework Bekele and Yalden, 2013; Hapold, 2013; Meheretu Yonas *et al.*, 2015). Most of the endemic fauna and flora of the country occur in the two Biodiversity Hotspots (Horn of Africa Biodiversity Hotspot and eastern Afro-montane Biodiversity Hotspot) of which the majority of endemic small mammals inhabit highland habitats (Yalden and Largen, 1992). This high level of endemism and existence of threat on its habitats made Ethiopian highlands to be categorized as one of the 34 biodiversity hotspots of the world (Mohammed Kasso *et al.*, 2015). Environmental changes due to large-scale deforestation leads to desertification, which ultimately result in loss of the endemicity and other biodiversity. Some of the Ethiopian small mammals particularly endemics are enigmatic taxa (Lavrenchenko *et al.*, 2007; Meheretu Yonas *et al.*, 2015). The existing number of species is not clearly known.

The taxonomy of many Ethiopian small mammals (*Arvicanthis, Stenocephalemys, Lophuromys*, *Tachyoryctes* and *Crocidura*) has an unstable history. Some of their members are clamped together once were described into distinct species level based on their variation in pelage coloration and external and cranial measurements (Lavrenchenko *et al.*, 2014). For instance out of the 18 distinct species, seven belonged to Ethiopia for *Tachyoryctes*. However, latter all taxa of Ethiopian *Tachyoryctes* were lumped under *T. splendens* with the exception of the distinct *T. macrocephalus* based on the results of geometric morphometric analyses of cranial morphology (Afework Bekele and Yalden, 2013). However, currently cytogenetic and molecular analyses of mitochondrial DNA (mtDNA) are indicating that at least four different distinct groups exist among *T. splendens* s.l. from Ethiopia (Lavrenchenko *et al.*, 2014). The attempts to reveal the taxonomic position of small mammals of Ethiopia based only on morphological data without considering karyological or genetic data have resulted in different conclusions (Meheretu Yonas *et al.*, 2015).

For many species, the cytogenetic methods, represent the most economical and efficient means of initially recognizing inter-population genetic variation (Zima, 2000). Such study provides valuable insights into taxonomic relationships and furnishes distinctive evidence on the phylogeny of extant taxa and revea biological diversity of small mammals. In the process, many cryptic or sibling species of small mammals that possess unique karyotypes were discovered (Zima, 2000). Hence, karyological analysis can provide additional and important information for the evaluation of their systematic and phylogenetic diversification. Karyotypic studies on mammals of Ethiopia play an important role in species identification and in the interpretation of phylogenies of taxonomic groups even though the karyotype description for most taxa is not yet complete (Lavrenchenko *et al.*, 2011). Except for the limited reports, no cytogenetic data on small mammals of Chilalo-Galama Mountains have been available. This is also true for small mammals of Chilalo Galama Mountains Range. Therefore, the aim of this study was to provide chromosomal sets for some species of Chilalo Galama Mountains range in order to provide information about their diversity conservation status.

2.5. Phylogeography and genetic variability

Ethiopia has rich mammalian species diversity particularly in small mammals (Afework Bekele and Yalden, 2013). However, little is known about the evolutionary relationships, geographical distribution and population biology of most of the species. The lack of such knowledge and high rate of mortality on local populations, there are concerns that locally adapted genetic diversity might be lost through extinctions. The aim of this study was to sequence a mitochondrial DNA gene (cytochrome *b*) for the investigation of the phylogenetic relationships of some species of small mammals to test the biogeographic hypothesis radiations in the region and to investigate their systematic position. Therefore, the aim was to determine the phylogeophraphy and genetic variation among selected small mammal species of Chilalo-Galama Mountains Range and to compare them with the small mammals of Bale Mountains. The study was also used as a first attempt to construct the phylogenetic relationship and assess the level of genetic divergence of some selected small mammal species of Chilalo-Galama Mountains Range.

2.6. Ectoparasite prevalence and species composition

Parasitism is the most common species interaction (Harris and Dunn, 2010; Harris *et al.*, 2013). Parasites exert strong selection pressures on their hosts and can vary in their diversity independent of the number of available hosts (Harris *et al.*, 2013). Unlike most free-living species, the geographic range of parasites consists of a set of more or less uniformly inhabited ''islands'' or patches. The distribution of a parasite population across a host population is characterized by their aggregation, or over dispersion (Krasnov *et al.*, 2002). Variation among populations is most prominent in parasite assemblage (Pedersen and Fenton, 2015). Parasites may also be absent from or limited in host populations because of competitive interactions and parasite-induced immune responses in the host that exclude certain parasite species from co-occurring (Harris *et al.*, 2013). Extrinsic conditions such as the composition of alternative hosts or climate may cause the parasite assemblages of a host to exhibit marked differences across populations (Harris *et al.*, 2013).

Parasites can regulate their host populations depending on the characteristics of the host-parasite relationship (Harris and Dunn, 2010). They can reduce the fitness of their hosts, either in terms of survival or reproductive success (Hofstede and Fenton, 2005; Saraiva *et al.*, 2012; Pedersen and Fenton, 2015). They may have indirect effects on host populations through increasing susceptibility to predation (Harris *et al.*, 2013). They also negatively affect host fitness due to their pathological impact, reducing growth and reproduction. Particularly the potential impacts of parasites become apparent when a newly emerging disease causes devastating losses on the population of conservation concern or high economic importance (Pedersen and Fenton, 2015). Understanding the richness of ectoparasite species provides valuable insights into the ecological roles they play in the regulation of their host populations and communities (Wei *et al.*, 2010; Saraiva *et al.*, 2012).

Ectoparasites are diverse and highly adapted group of animals that infest the external body surface of vertebrates (small mammals) (Madinah *et al.*, 2011). The majority of ectoparasites of small mammals belong to Arthropoda (Happold and Happold, 2013; Happold, 2013). Arthropoda compose the most numerous group of organisms on earth of which some of them are external (ecto) parasites on farm animals, pets, wildlife and bird (Meheretu Yonas *et al.*, 2011; Kanchev *et al.*, 2012). Some ectoparasite species are host-specific, whereas others exploit wider spectrum of hosts (Meheretu Yonas *et al.*, 2011). The most common arthropod ectoparasites that infest small mammals belong mainly to the group of arachnids namely Ixodida (Ixodidae and Argasidae), Gamasida (Laelapidae and Macronyssidae), Mesostigmata and some groups of insects (order Siphonaptera (Rhopalopsyllidae) and Phthiraptera (Amblycera, Ischnocera and Hoplopleuridae) (Kanchev *et al.*, 2012; Saraiva *et al.*, 2012). Numerous haematophagous obligate ectoparasites also live on the skin surface and in the fur of bats, such as bat fleas (Ischnopsyllidae), bat flies (Nycteribidae and Streblidae) (Changbunjong *et al.*, 2010), bat mites (Spinturnicidae) and bugs (Cimicidae) (Mohammed Kasso and Balakrishinan, 2013), Hemiptera (Dahal and Thapa, 2010). Saraiva *et al.* (2012) identified Arthropoda ectoparasites (classes Aracnida and Insecta) representing five orders: Ixodida, Gamasida, Phthiraptera, Siphonaptera and Diptera from rodents and marsupials. Some parasites live in the burrows of hosts (Kanchev *et al.*, 2012).

Ectoparasites are an important component of the ecosystem and biodiversity (Saraiva *et al.*, 2012). Parasitic arthropods are the agents or hosts of a number pathogens for humans or other animals (Chuluun *et al.*, 2005; Kanchev *et al.*, 2012). Many ectoparasites are vectors of bacteria, viruses, cestodes, nematodes and other disease agents (Wei *et al.*, 2010). They are considered as the main vector and hosts of zoonotic diseases and play an important role in the transmission of a wide variety of diseases (Madinah *et al.*, 2011; Saraiva *et al.*, 2012). For instance, ticks are notorious vectors of numerous pathogenic organisms, such as protozoa, rickettsiae, bacteria and viruses. They cause serious and life-threatening illnesses in humans and animals (Madinah *et al.*, 2011). Ticks and fleas are among the most important vectors of pathogens that cause diseases in human and other animals (Saraiva *et al.*, 2012). They play important roles in distribution of arboviruses, streptococcal infections, choriomeningitis, plague, tularemia, leptospirosis and spirochetosis (Madinah *et al.*, 2011). Macronyssidae mites are suspected to be involved in the circulation of the bacteria in the natural environment (Saraiva *et al.*, 2012). Fleas are hematophagous parasites of birds and mammals. There are currently about 2,120 flea species; approximately 80% of these are associated with mammalian hosts, with 74% parasitizing rodents. This high percentage of

Siphonaptera-rodent associations is observed in all regions of the world (Sanchez and Lareschi, 2014). They infest humans and may lead to the development of dermatitis during blood sucking. They are also known to transmit zoonotic pathogens such as those that cause epidemic typhus and tularaemia and bubonic plague to humans (Wei *et al.*, 2010). Lice are also vectors of louse-borne epidemic typhus, relapsing fever and trench fever with occurrence of outbreaks among homeless people or in refugee camps, schools and other crowded conditions that result from war and natural disasters (Zuo and Guo, 2011). However, unlike predator–prey relationships quantifying the impact of parasites on their host individuals is difficult (Pedersen and Fenton, 2015).

Avoidance and removal of parasites are behavioural strategies animals use to reduce the costs. For instance, hosts can avoid ectoparasites by living in habitats that are unsuitable for the parasite. Habitat selection can occur over very short time periods, involving individual animals moving from locations with high to low ectoparasite abundance (Hofstede and Fenton, 2005). Unlike endoparasites, ectoparasites are influenced not only by characters of the host, but also by characters of their off-host environment, because their contact with the host is usually irregular (Krasnov *et al.*, 2002; MohdZain *et al.*, 2015). The range of off-host and on-host ratio of different ectoparasite taxa shows great variations. It varies from almost constant occurrence like lice (Anoplura) to sporadically attacking ticks (Ixodidae) and sand flies (Phlebotomidae) (Krasnov *et al.*, 2002). They also show variation in altitudinal distribution. For instance, according to MohdZain *et al.* (2015), ticks are found in reasonable numbers at the higher altitudes than chiggers. However, the actual effect of altitude on the distribution of rat-borne ectoparasites is not readily apparent (MohdZain *et al.*, 2015). Environmental disturbances like fire, which can alter the patterns of microhabitat use and species composition of small mammals, also may facilitate the exchange of ectoparasitic arthropods among host species (Lareschi *et al.*, 2006).

Very limited reports are available regarding the relationship of small mammals and their arthropod ectoparasites (Meheretu Yonas *et al.*, 2011) and in the transmission of zoonotic infectious agents in Ethiopia. The taxonomic knowledge of small mammals and their ectoparasites is also very much limited. Most of the available studies mainly target the associations between ectoparasites and domestic animals. Information regarding ectoparasites on small mammals is scant (Meheretu Yonas *et al.*, 2011). Very limited studies of ectoparasites on wild small mammals in Ethiopia have been conducted with the exception of study by Meheretu Yonas *et al.* (2011) in Northern Ethiopia. However, there were some ectoparasitic studies conducted on domestic animals in different parts of the country including the vicinity of the current study area. Some ectoparasites of small mammals are known to be of public health importance. However, there is little quantitative information available regarding ectoparasites on small mammals, as hosts of zoonotic pathogens or their vectors (Madinah *et al.*, 2011). No ectoparasite surveys of small mammals have been conducted in Chilalo-Galama Mountains Range of Arsi Mountains National Park (AMNP). The lack of up-to-date studies on the species of composition and prevalence of ectoparasitic of small mammals in Ethiopia in particular on Chilalo-Galama Mountains Ranges, was the main reason for investigating the species composition and prevalence of the ectoparasites in small mammals in Chilalo-Galama Mountains Range. Thus, the aim of this study was to determine the species composition of the ectoparasites, their prevalence, distribution and small mammal host interaction in Chilalo-Galama Mountains Range.

2.7. Pest damage to agricultural crops and household items

Numerous species of birds and mammals contribute to crop losses (Witmer *et al.*, 2007). Among mammals, rodents, mongoose, baboon, monkey, hyaena, bats and fox were mostly considered as pest animals (Mohammed Kasso, 2014). Agricultural pests like birds and rodents cause significant damage to crops, particularly if an agricultural sector plays a major role in the economy (Stenseth *et al.*, 2001). This may also pose multiplier effects of damage since it typically provides inputs to all other sectors in the economy (Witmer *et al.*, 2007). The damage to crops by vertebrates is also increases, as agriculture becomes more intensified.

Among mammals, rodents have been identified as the most important agricultural pests at the global level (Stenseth *et al.*, 2001; Fayenuwo *et al.*, 2007; Witmer *et al.*, 2007). They are the most serious and important vertebrate pests of various crops (Sheikher and Jain, 1997; Witmer *et al.*, 2007). In some countries although rodents were not treated as most important pre-harvest pest to farmers, they were perceived as pests they had least control over (Singleton *et al.*, 2003) and still rank them as number one important pests (Mohammed Kasso, 2013). They are important pests of crops causing major yield and livelihood loss of smallholder farmers (Stuart *et al.*, 2011). However not all rodents are pest (Afework Bekele *et al.*, 2003; Mohammed Kasso, 2013). More than 20 species of rodents were considered as minor and major pest in Ethiopia (Afework Bekele *et al.*, 2003; Abdurahman Abdulahi *et al.*, 2009; Ejigu Alemayehu and Afework Bekele, 2013; Mohammed Kasso, 2013; Meheretu Yonas *et al.*, 2014). See Appendix 1.

Although most bats are not grouped as pest animals in many parts of the world, a few of them are considered as pests since they cause damage on humans, livestock, agricultural crops, airplane strike, buildings and infrastructure infestation and rarely become aggressive or bite humans during self-defence (Mohammed Kasso and Balakrishnan, 2013). Mostly frugivorous bats and vampire bats cause economical loss to fruits and livestock, respectively. Similar to birds, bats also cause airplane strikes which results in the loss of human lives and damage to materials (Brown *et al.*, 2001; Mohammed Kasso and Balakrishnan, 2013). In addition to these, different buildings and houses can be infested by bats, which in turn cause a serious public health problem, cause discomfort to human, spoil food and make ceilings, walls and floors to be dirty with the accumulation of guano and urine (Mohammed Kasso and Balakrishnan, 2013).

Losses in agricultural production in which pests are involved may also be superimpose by environmental factors (Ezealor and Giles, 1997). Rodents cause damage from sowing to harvesting, storage, distribution and consumption (Sheikher and Jain, 1997). Mostly the damage is caused by their gnawing activity on crops direct feeding, spoilage in storage or structural damage to plants (Brown and Singleton, 2002; Brown *et al.* 2008; Eisen *et al.*, 2013). The pre- and post-harvest crop losses due to rodent pests reduce food security in the world (Sheikher and Jain, 1997).

In livestock production, rodents contaminate their feed and also cause physical injury by gnawing them which leads to reduced rates of production and increased risk of disease (Brown and Singleton, 2002; Mohammed Kasso, 2013). They also cause transmission of rodent-borne human pathogens through direct contact between humans and infected rodents, or indirectly through contaminated food or water by their urine and faeces. They are sources of exposure to rodent associate ectoparasites (Eisen *et al.*, 2013).

Ground cover increases the risk of attack by pest animal as it provides shelter, foraging opportunities and a hiding place from predators (Puan *et al.*, 2011). Traditional housing surrounded by agriculture crop fields and storage, often attracts pest rodents (Eisen *et al.*, 2013). Monoculture crop productions also increases some pest rodent species to be common (Puan *et al.*, 2011). In addition, many pest problems can also arise under no-till conditions (Witmer *et al.*, 2007). Some of the local methods used to combat soil erosion and fertility loss like stone bunds promote rodent pests (Meheretu Yonas et *al.*, 2014). Abundant food also increases the size of rodent pest density in agricultural fields (Ejigu Alemayehu and Afework Bekele, 2013).

Rodents pose a significant threat to economy and public health, particularly in developing countries where concerns about food security and rodent-associated zoonoses are often closely linked (Jakel *et al.*, 2006; Fayenuwo *et al.*, 2007; Eisen *et al.*, 2013). Their damage is a serious obstacle for agricultural production (Fayenuwo *et al.*, 2007). Pest rodents make farmers to suffer due to pre- and post-harvest loss (Brooks *et al.* 1999). The extent of the problems range from eruptive to chronic populations that cause losses/damage annually (Singleton *et al.*, 2003).

The effect of pest rodents on agriculture is complex as almost all crops are attacked by them (Fayenuwo *et al.*, 2007). Reliable quantitative estimates of pre- and post-harvest crop losses caused by rodents are lacking for East Africa (Makundi *et al.*, 1999). The extent of such losses are also geographically and temporally variable (Eisen *et al.*, 2013). However, some have estimated losses in East Africa to be greater than 15% (Makundi *et al.*, 1999; Eisen *et al.*, 2013). For instance, the economic losses to maize by rodent pest in Kenya are 20–30% and can reach 34 - 100% during their outbreaks (Fayenuwo *et al.*, 2007). In Tanzania, rodents pest cause about 15% loss to maize crop annually (Fayenuwo *et al.*, 2007). In Ethiopia, losses due to pests annually indicate 15-40% pre-harvest loss in field cereal crops, 13-29% loss in horticultural crops, 9-48% loss in coffee and 21-60% loss in cotton (Meheretu Yonas *et al.*, 2014). The pre- and post-harvest losses to insects, diseases, weeds and other vertebrate pests add up to 30-40% (Meheretu Yonas et *al.*, 2014). Ejigu Alemayehu and Afework Bekele (2013) estimated loss of 29.2% in the locally farmed areas of maize. Afework Bekele *et al.* (2003) estimated damage on cereal crops by rodents to be 20-26% annually. Estimates by Stuart *et al.* (2011) shows, the preharvest losses to crops, particularly to rice, by rodent pests to ranges from 5% to 50% based on the region and types of crops. Such losses can no longer be tolerated due to increase in human population (Singleton *et al.*, 2003).

Pest rodents are perceived as clever, which counteract control measures used by farmers (Mohammed Kasso, 2013). As a result, farmers show the tolerance to depredations caused by them (Singleton *et al.*, 2003). Some traditional and other methods such asdestroying or flooding of burrows, trapping, using of cat and modern rodenticides are practiced to control them (Stuart *et al.*, 2011). The commonly used rodenticides cause acute poisoning or have anticoagulant property (Stuart *et al.*, 2011). However, recent studies have shown that synthetic chemicals negatively affect non-target beneficial species and cause excessive adverse effect on the environment (Stenseth *et al.*, 2001; Stuart *et al.*, 2011). Consequently, lethal control is becoming increasingly unpopular (Ezealor and Giles, 1997). Traditional methods such as killing by trapping, hunting, flooding and gassing that have been applied in many places also show less effect on the population (Stenseth *et al.*, 2001). On the other hand, there have been some new development in strategies for the effective rodent management using eclological methods (Singleton *et al.*, 2003).

Reduction of ground vegetation by weeding aids in rodent control by decreasing in rodent pest abundance (Puan *et al.*, 2011). Thus, modifying habitats by reducing structural complexity may reduce the potential of habitats to support small mammal populations (Puan *et al.*, 2011).

The choice of pest management techniques depends on many factors such as type of pest species, population composition and size, farm size, the value of crop being damaged, phenological stage at which the damage is occurring, weather and climatic factors, resource for the control operation and attitudes of people towards the use of chosen methods (Ezealor and Giles, 1997). In general, appropriate methods of rodent control are used to improve food storage practices by increasing the quantity and quality of food available to humans, and reducing the risk of rodent-associated diseases (Eisen *et al.*, 2013).

In Ethiopia, food production is seasonal (Abraham Tadesse *et al.*, 2008). Hence, its supply and food security are mainly dependent on the status of its storage. It is estimated that about 60 to 90% of the produce is retained by the farm household and stored for 6 to 12 months. However, it is subject to post-harvest losses and deterioration due to biotic and abiotic factors mainly by pests (insects, rodents and fungi) (Abraham Tadesse *et al.*, 2008; Mohammed Kasso, 2013).

Globally, most surveys on pest damage focus on recording insect pests and fungi associated with stored grain rather than small mammal pests (Abraham Tadesse *et al.*, 2008). Research on rodent pests and birds conducted in research centres in the country is also scant (Abdurahman Abdulahi *et al.*, 2009). However, based on the scarce information obtained from different parts of the country, rodents were accounted the principal pests among small mammals (Ezealor and Giles, 1997; Afework Bekele *et al.*, 2003; Fayenuwo *et al.*, 2007; Eisen *et al.*, 2013; Mohammed Kasso, 2013; Ejigu Alemayehu and Afework Bekele, 2013; Meheretu Yonas *et al.*, 2014).

Studies on rodents as post-harvest pests in Ethiopia are scarce, despite their importance in most surveyed localities (Afework Bekele *et al.*, 2003; Abraham Tadesse *et al.*, 2008; Abdurahman Abdulahi *et al.*, 2009; Ejigu Alemayehu and Afework Bekele, 2013; Meheretu Yonas *et al.*, 2014; Mohammed Kasso, 2013). The impact of rodent pests on the rural communities of Mount Chilalo and its surrounding is unknown. In addition, as the area is biologically rich with high endemic rodent fauna, the management practices taken by the local community to control rodent pest may have a negative impact on them and environment. The identification gaps in of farmers' knowledge to enhance their pest identification and management skills and identifying farm-level constraints for the adoption of alternative integrated pest management strategies require immediate attention. Therefore, the objective of this study was to investigate the farmers' knowledge and perceptions about pest problems around Mount Chilalo in order to promote the development of ecologically based integrated pest management.

2.8. Local communities attitude towards conservation of small mammals and their habitat

Biodiversity conservation is the protection, maintenance and/or restoration of living natural resources to ensure their survival over the long term based on the different values, objectives and worldviews (Roe *et al.*, 2011). In developing countries, 75% of their populations live in rural areas where they directly depend on biodiversity and ecosystem services for their livelihoods and immediate survival. The dependence on biodiversity is because of their physical location and the nature of their livelihood activities like small-scale farming, hunting, collecting and trading of forest products. Biodiversity is often freely available for them and serves as an emergency lifeline during starvation and as a social safety net by providing food, medicines and clean water, climate change mitigation; and as stepping stone out of poverty serving as a source of income generation and jobs through trade, tourism and food production (Roe *et al.*, 2011). Hence, the conservation of biodiversity ensures continuity of services for livelihoods, but, if it is not carefully designed, the conservation intervention may make poor people worse off (Roe *et al.*, 2011; Jalilova and Vacik, 2012). For instance, strict enforcement of protected areas and prohibition of resource use increase poverty due to loss of access of resources (Roe *et al.*, 2011). Communities that conserve wildlife should be allowed to use sustainably the surpluses and to receive the revenue earned as an economic incentive for its conservation (Tisdell *et al.*, 2007).

Small mammals and their habitats are challenged by natural and anthropological activities and other different threatening factors. The natural threatening factors (biotic and abiotic) are predators, prey, parasite, disease, inbreeding and genetic deterioration, food, shelter and climate change (Olifiers *et al.*, 2005). Additionally anthropogenic activities are also frequently cited as threatening factor in many ways like forest fragmentation and alteration of natural communities (Olifiers *et al.*, 2005; Jalilova and Vacik, 2012). Habitat loss and modification are considered among the leading threats to all species globally (Istvan and Derbowka, 2011).

Cattle grazing has strong effects on the structure and dynamics of grassland plant communities. Effects of grazing on plants and soil could also affect the animal communities inhabiting grasslands, as they depend on vegetation for food and rely on cover and soil for foraging safely and/or for building temporary or permanent burrow systems (Torre *et al.*, 2007). Small mammals are especially affected in grasslands habitat because of their top–down effects on plant and arthropod communities and in turn effect on their predators (Torre *et al.*, 2007).

3. JUSTIFICATION, HYPOTHESIS, RESEARCH QUESTIONS AND OBJECTIVES

3.1. Justification

Ethiopia has a very diverse set of ecosystems ranging from humid forest and extensive wetland to desert as the result of extensive altitudinal variation (Shibru Tedla, 1995). Almost 50% of the African highlands above 2000 m and 80% of the land above 3000 m asl occur in Ethiopia (Yalden, 1983). The mountains of Ethiopia comprise the largest Afroalpine habitat with high level of endemism (Yalden and Largen, 1992), which can be considered as biological ‘sky islands’. It is dissected into two by the Ethiopian Rift Valley from northwest to southeast (Tesfaye Hundessa, 1997). This makes some of the endemic species distributed on either the eastern or the western side of the Ethiopian Rift Valley. The eastern or southeastern highlands encompass Arsi Mountains that constitute diverse sets of endemic species of small mammals (Corti *et al.*, 1999; Mohammed Kasso *et al.*, 2010).

Even though, the majority of Ethiopian highlands have fewer species diversity than many lowland parts in tropical African regions, they have a large number of endemics, particularly birds, mammals, and amphibians (Yalden and Largen, 1992). This high level of endemicity is a consequence of high altitudinal variation (Yalden, 1983; Lavrenchenko *et al.*, 1998a; Corti *et al.*, 1999). Additionally, temperature, rainfall, vegetation and historical determinants also play a major role in determination of the diversity of flora and fauna (Yalden and Largen, 1992). The array of organisms that colonized Ethiopia during glacial times is now isolated at high elevations resulting in the formation of new species. Many of these endemic animals are specifically associated with the high altitude moorland and grassland habitats (Yalden, 1983). For instance, the previous study conducted by Mohammed Kasso *et al.* (2010) on Chilalo-Galama Mountains Range indicated 60% endemic species record. Chilalo-Galama Mountains Range also endowed with varieties of vegetations (Appendix 2) and large and medium sized mammals (Appendix 3). It has the second largest population of the Ethiopian wolf next to the Bale Mountains with suitable habitat of 572 km^2 (Malcolm and Sillero-Zubiri, 1997). However, like other parts of the highland areas of the country, these areas are occupied by dense concentration of human population because of good agricultural production favoured by sufficient rainfall and temperature, low level of disease and flat land configuration that attracts settlements

(APEDO and ABRDP, 2004). The increase in human population in the area is causing encroachment to the higher altitude despite its unfavourable climatic conditions resulting in biodiversity loss and habitat fragmentation and degradation.

The effects of habitat loss and fragmentation on wildlife become clear if attention is given to species composition, abundance, distribution, and the processes threatening them. They may be affected by interacting with exogenous and endogenous threats like habitat loss, degradation and isolation, changes in the biology, behaviour and interactions of species and stochastic threats (Fischer and Lindenmaye, 2007). The impact of habitat fragmentation and degradation varies in different organisms due to their differences in life history strategies (Ewers and Didham, 2006). Large numbers of empirical studies document changes in species richness with decreasing habitat area. However, no relationships were regularly reported (Ewers and Didham, 2006; Fischer and Lindenmaye, 2007). For example, the changes in biotic and abiotic parameters at edges make ecological processes to be more variable than in habitat interiors. Individuals are more likely to encounter habitat edges in fragments leading to increased turnover and variability in population size (Ewers and Didham, 2006).

Biodiversity, both wild and domesticated, provides a range of livelihood support to local communities. However, it is facing serious threats from different human activities. Some of the major threats are mining in biodiversity rich areas, large development projects, poaching; human-wildlife conflicts, habitat loss and habitat fragmentation due to a variety of human actions, diversion of grazing lands and other common pool resources to other uses, growing demand for fuel and fodder resources and loss of crop and livestock diversity with the promotion of commercial agriculture and animal husbandry (IBC, 2005).

Humans greatly alter the landscape patterns that are frequently correlated with species assemblages that include the amount and structure of native vegetation, the prevalence of anthropogenic edges, the degree of landscape connectivity, and the structure and heterogeneity of modified areas (Fischer and Lindenmaye, 2007). Since the consequence of habitat fragmentation to animals is complex, species respond differently to the loss and isolation of habitats. Many habitats of mammals are undergoing degradation due to high human encroachment for agriculture, pastureland, collection of firewood and medicinal plant, settlement and for other human activity (Kingdon, 1974; Singleton *et al.,* 2003). Most of Ethiopian habitats and landscapes including Chilalo-Galama Mountains Range face similar problems despite the possession of high diversity of mammalian fauna (Afework Bekele *et al*, 1993). Therefore, there is a need for further surveys, as most of the habitats are being affected by human activities and climate change. Thus, in the present study, the current ecological information on the diversity, distribution and conservation of small mammals (Order Rodentia, Order Chiroptera and Order Eulipotyphla) with their prevailing threatening factors were revealed. Based on the results of the study, possible solutions for conservation of the small mammals and their habitats were suggested or recommended.

In general, the outputs of this study were as follow:

- The current information on diversity and distribution of small mammals was assessed. Information on the conservation challenges and threatening factors for the small mammals and the conservation of other biodiversity and the habitats were also gathered. Above all, the study updated information on bats in the area since little is known about the bats of Ethiopia, in particular Chilalo-Galama Mountains Range. The major challenge in bat conservation is lack of knowledge about the species composition and distribution. This makes the strategic development plan for bat habitats management and conservation difficult. Hence, the present bat survey and other small mammal diversity and distribution determination will help us to fill the gap in biodiversity assessment and some ecological information of the country in particular the Chilalo-Galama Mountains Range and to facilitate the development of the conservation action plan.
- As bats and other small mammals use a variety of habitats both for roosting, nesting and feeding (Crampton and Barclay, 1998; Hutson *et al*., 2001), effective conservation strategies that focus on the protection of their nesting, roosting and feeding habitats are feasible if accurate information is gathred and direct threats by human activities are correctly identified. This facilitates the future protective action as it needs relatively low resource investment, and raises few socioeconomic disputes (Fenton, 1997; Law and Anderson, 2000; Almenar *et al*., 2009). Thus, the results of the present study on bats and other small mammal distribution and habitat preference were used to determine the conservation status and their ecological requirements. As bats feed on different food items like insects, fruits, seed, nectar, blood and other vertebrates the challenges they face vary. For example, bats that feed on insects may be challenged by the application of pesticides. In the same way, due to their feeding habits, they may be treated by local

community as pest animals and could be considered as threatened animals. Since bats are active only at night and are usually difficult to observe, they are often misunderstood and not known by many local communities. They are unknowingly killed and their habitats disturbed despite their ecological services. Thus, this study on bats will identify the knowledge gap and attitude of the local community towards bats for appropriate conservation measures.

- Less attention has been given in recent years to variation in species richness along elevation gradients, even though highland ecosystems usually support the highest local concentrations of species in the tropics (Heaney, 2001). In this study, the distribution and abundance of small mammals along altitudinal zonation of Chilalo-Galama Mountains Range was assessed to create base line information for conservation and management of the small mammals and their habitats.
- The effects of *Erica* burn and landuse and plantation on small mammals and other biodiversity are poorly studied. However, several studies indicate fire intensity, interval, landuse and plantation significantly affect the abundance, distribution and diversity of small mammals. The current study on the impact of *Erica* burn, landuse and artificial/exotic plantation, on small mammal species composition had a significant contribution on small mammal conservation, control and habitat management
- Mammals are among the better-studied animal groups and their taxonomy is relatively well documented (Wilson and Reeder, 2005). However, field determinations for many small mammal species are difficult due to their sibling and cryptic nature. Molecular approaches are the best method for identification of taxonomic groups and for facilitating fast and accurate species identifications (Borisenko *et al.*, 2008). It also serves as genetic vouchers to validate field identifications made by researchers with limited taxonomic background and to make it as a valuable tool for ecological surveys (Borisenko *et al.*, 2008). Hence, in the present study karyological and molecular techniques were used to provide valuable insights into the taxonomic relationships and the phylogeny of extant taxa. In different parts of the world, these techniques have revealed biological diversity of small mammals. In the process, many cryptic species of small mammals were discovered. Except for the limited reports, yet no cytogenetic and molecular data on small mammals of Chilalo-Galama Mountains Range have been carried out. Therefore, this study provided karyological and molecular data of some small mammal species of Chilalo-Galama Mountains Range, additionally providing

useful information about the extent of genetic diversity and phylogenetic relationships useful for conservation compared with the nearby Bale Mountains.

- A survey conducted on ectoparasites of small mammals is used to create baseline information on the principal ectoparasite species composition, prevalence and their host preference. This study also is used to determine whether small mammal associated ectoparasites have a potential threat to public and livestock health within the vicinity of the protected area and in turn influence the conservation activities of the area. Although the ectoparasites associated with small mammals have ecological, economic and public health importance, their study in Ethiopia is scanty. Hence, this study was used to fill some of the existing gap.

- Small mammals cause a significant loss to resources and public health in many developing countries like Ethiopia. However, such type of research is almost non-existent in Ethiopia in particular at Chilalo-Galama Mountains Range. Hence, the current survey focused on perception of the local community around Mount Chilalo on the level of pest damage and weather control measures were effective small mammal pest management and conservation.
- Biodiversity conservation process requires the integration of the experience of local people and existing local knowledge about the social and economic constraints of potential management practices. The experiences and knowledge of the local people and their perceptions towards their surrounding environment are critical in designing meaningful conservation strategies. The assessment of public attitudes towards small mammals and conservationof their habitat is used to determine whether there is political support for their sustainable use and conservation. The assessed attitudes and beliefs of local communities can serve as a baseline for development of effective management options that wildlife managers or wildlife experts may prefer. It also can be used for designing management actions that have public support. Therefore, the local community perceptions on the conservation of small mammals and their habitat had tremendous contribution for the effective and efficient conservation and management action of the AMNP.
- In general, the present study provideds information on the species composition, relative abundance and major threats to the conservation of small mammals and their habitats. Although the study area is protected as one block of AMNP, there were few studies

carried out on the biodiversity of the fauna and flora. Therefore, the present study is to fill the existing gap. The recommendations for possible solutions to the existing problems will enhance sustainable use of natural resources in the area. It can also be used to device an effective policy and strategies for further development and conservation of the area.

3.2. Hypothesis

- Chilalo-Galama Mountains Range possesses significant diversity of small mammals distributed differently based on habitat type and altitudinal zonation.
- Small mammals in the study area are associated with different ectoparasites such as lice, flea, ticks, mite and bat flies. Some of the ectoparasites of the small mammals have potential health importance on human and domestic animals.
- *Erica* burn and plantation had significant negative impact on small mammal diversity and abundance. Based on previous studies conducted in nearby Mount Kaka and Honkolo and conceptual frameworks for the dynamics of small mammal assemblages, it is hypothesised that small mammal species composition and relative abundance would be low in relatively recently burnt areas than old burnt *Erica*.
- The chromosomal analysis and the phylogenetic tree reconstructions for the entire sequences of the *cyt-b* gene indicated that the small mammals of Chilalo-Galama Mountains Ranges show close relations with the nearby Bale Mountains National Park small mammals than others.

- Among the small mammals (rodents, bats and shrews), rodents are perceived as the principal pests that cause serious losses to agricultural crops, household items and human health.
- Local communities awareness and interest in the conservation of small mammals is low when compared with other large mammals and their habitat

3.3. Research questions

- What are the current species composition, relative abundance and habitat association of small mammals in Chilalo-Galama Mountains Range?
- Is there variation of diversity and relative abundance of small mammal along altitudinal gradient?
- Do artificial plantations, *Erica* burn and landuse have impact on small mammal distribution? Which small mammals are sensitive to habitat modification in the area?
- Is there close relationships of small mammals of Chilalo-Galama Mountains Ranges with the nearby Bale Mountains National Park in chromosomal analysis and phylogenetic tree reconstructions?
- What are the taxa composition of parasitic arthropods associated with small mammals of Chilalo-Galama Mountains Range and their prevalence?
- Which group of small mammals is perceived as serious pests by the local community? What is their pest status and means of control?
- Which threats prevail in the area? What are the challenges for the conservation of small mammals and their habitats?
- How the local communities perceive the conservation of small mammals and their habitat?
- What are the possible solutions for the existing problems affecting the survival of small mammals and other biodiversity in the area?
- What are the possible suggestions for better conservation of small mammals and mitigation for the major threats and challenges?
- What are the major recommendations for protection and conservation strategies for the AMNP?

3.4. Objective

3.4.1. General objective

The main objective of this study is to carry out a survey and overall ecological assessment on the diversity, spatial and temporal distribution, relative abundance, habitat association, possible threats of small mammals (Order Rodentia, Chiroptera and Eulipotyphla) and the prevailing conservation challenges for the protection of small mammals along the Chilalo-Galama Mountains Range.

3.4.2. Specific objectives

Specific objectives of the study are to:

- determine the species composition of small mammals
- compare the small mammal diversity and density in different habitats
- identify the distribution, relative abundance and habitat association of small mammals along altitudinal gradients and different land use
- to document species richness, diversity, reproductive conditions and sex ratios of bats
- identify the impacts of *Erica* burn on small mammals
- describe chromosomal sets for small mammal species of Chilalo-Galama Mountains Range
- sequence a mitochondrial DNA gene (*cyt-b*) for the investigatation of the phylogenetic relationships for some species of small mammals
- construct the phylogenetic relationship and level of genetic divergence of some selected representative small mammal species of Chilalo-Galama Mountains Range
- determine the diversity of ectoparasite species, rate of prevalence, distribution and small mammal host interaction
- identify the local communities perceptions on pest status of small mammals
- explore the anthropogenic impacts on small mammals and their habitat
- upgrade and fill a gap in the biodiversity assessment
- suggest possible conservation plan and solutions to mitigate the major threats and challenges for the conservation of small mammals and thier habitats

4. DESCRIPTION OF THE STUDY AREA

4.1. Location and area

The investigation was carried out with Chilalo-Galama Mountains Range, as one block of AMNP occurring between 7°30′ to 8°05′ N latitude and 39°10′ to 39°35′E longitude in the central part of the Arsi Administrative Zone, Oromia Regional State (Mohammed Kasso *et al.*, 2010) (Figure 1). It is bordered by nine Administrative Districts namely Tiyo, Hetosa, Lode-Hetosa, Diksis, Robe, Tana, Shirka, Lemmu-Bilbilo and Digalu-Tijo. Currently the block comprises 45 Peasant Associations (PAs) or administrative counts (Table 1). It occurs at about 60 km east of the Ethiopian Rift Valley lakes (Lake Ziway and Lake Langano) and about 200 km southeast of Addis Ababa (Mohammed Kasso *et al.*, 2010).

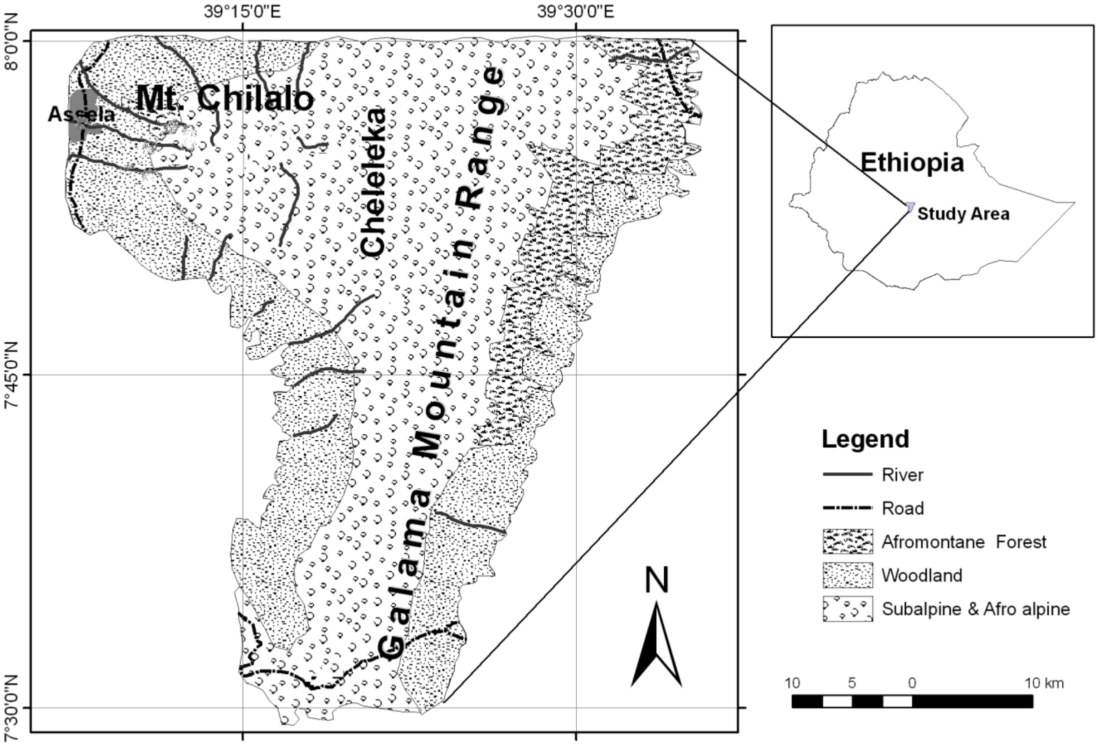


Figure 1. Map of the study area
(Source: Mohammed Kasso *et al.*, 2010**)**

Chilalo-Galama Mountains Range is the largest block covering 85.07% of the total area of AMNP. It dominates the Arsi Mountains by extending from north to south for 55 km and extends in the northeast to Mount Kaka (Mohammed Kasso *et al.*, 2010). The Chilalo-Galama Mountains Range also makes up the largest portion of the Arsi massif, covering an area of 1,200 km^2 (Evangelista *et al.*, 2007). Out of this area, 792 km^2 was demarcated and protected as one block among the four blocks of AMNP.

AMNP was established in October 31, 2011 and consist of four separate blocks namely Dhera-Dilfekar (13 km^2), Chilalo-Galama (792 km^2), Kaka (104 km^2) and Honkolo (22 km^2) and possess different ecosystems, with a total area of 931 km^2. The Park is one of those nearest to Addis Ababa at about 125 km to the Dhera-Dilfekar provisional headquarter. The Park is located in Arsi and Western Arsi zones and is surrounded by 14 districts (Table 1).

Table 1. Blocks, districts and peasant associations that border AMNP

Block	District	Peasant Association and Urban Counts
Chilalo-Galama Mountains Range	Tiyo	Ode Dewata, Denkaka Kunicha, Burke Chilalo, Haro Bilalo, Shela Chebeti and Bore Chilalo
	Digelu-Tijo	Kogo Ashebeka, Jemmo, Digelu Bora, Kubsa Bora, Digelu Arabi, Titte Waji, Burka Jalle, Sheldo Jegessa and Ansha Lekicha
	Lemmu-Bilbilo	Lemmu Burkitu, Bokoji Negesso, Cibba Mika'el, Ululle Hasa and Lemmu Mirti
	Shirka	Lemmu Gedemsa, Ari'a Gogota, Lemmu Tijo, Tijo Lebu, Hela Tijo Sero, Hela Waji, Sole Digelau Guna and Sole Negelle
	Tena	Sole Cheffa, Sole Waliyi, Sole Oda, Akkiya Misa, Jitu Tena, Koropta and Wedago Misa
	Robe	Jawi Sire
	Diksis	Tena Bemmo, Aleko Kara and Kara Lencha
	Lode-Hetosa	Aleko and Gabbe
	Hetosa	Sibu Abadir, Jawi Chilalo and Dabaya Adare
Kaka	Lemu Bilbilo	Gesse Bilbilo, Koma Ketara, Koma Kerra, Koma Hangarra, Koma Wolkite, Koji Ketara and Koji Kaka
	Munessa	Shune Wachu, Shune Goro and Wajii Ganage
	Kore	Webo Kaka
	Gedeb Hasasa	Hulukko Itittu, Chofira Shashe and Fuchu Kaka
Honkolo-Wabe	Lemu Bilbilo	Honkolo Gerjeda, Walalti Burka and Honkolo Farachu
	Honkolo Wabe	Siltena, Taji Walkitte and Lemmu Kara
Dhera-Delfiker	Dodota	Dire Kiltu, Awash Bishola, Delfiker, Dera 01 and Dera 02

Those districts are Dodota, Hetosa, Lode-Hetosa, Diksis, Robe, Tena, Shirka, Lemu Bilbilo, Digelu Tijo, Tiyo, Honkolo Wabe, Gedeb Asasa, Kore and Munessa that include 70 PAs (Table 1).

4.2. Topography and drainage pattern

Based on the landscape or land features and altitude, Arsi zone is divided into three major physiographic divisions, namely the highland, lowland and Ethiopian Rift Valley. The highland part includes Chilalo-Galama Mountains Range and peaks of Kaka (4,245 m asl), Honkolo (3,850 m asl), Gugu (3,625 m asl) and undulating high and low plateau of the central part of the zone (Yazachew Etefa and Kasahun Dibaba, 2011).

Chilalo-Galama Mountains Range has a great diversity of landscape like high and rugged mountainous ridges, flat topped plateau, wide caldera, slightly raised slopes, gently rolling steep hills, and frequently intersected gorges created by streams and rivers. It forms triangular shaped highland massifs that have peaks more than 4,200 m asl on the northwest called Chilalo Mountains Peak, and the northern part of Galama Ranges, Sango, Gara Kori, Gara Bada, Bora Luku Mountain peaks and on different parts of the central Galama Mountain Ranges. Its altitudes range from 2,000 to more than 4,000 m asl (Mohammed Kasso *et al.*, 2010). Chilalo-Galama Mountains Range has three prominent peaks: Mount Chilalo (4,089 m asl) in the northwest, Mount Badda (4,200 m asl) in the north, and the Boraluku (3,560 m asl) located in the north-central region. Although Mount Badda and Mount Albeso are well known from old literature there is doubt in locating specific site as the term ‘baddaa’ refers in local Afan Oromo to designate any highland with cool or cold traditional agro-climatic condition. At the same time Albeso refers the western part of Mount Chilalo including its plateaus and plains. The mountain escarpment that stretches along Boraluko peak south toward the town of Bekoji is called the Galama Ridge. The ridge was historically connected with Mount Kaka and Honkolo Afroalpine forests in the southwest and southeast, respectively. However, at present, all the three mountains are fragmented and separated by agriculture and human settlement (Evangelista *et al.*, 2007). The Galama Mountains Range is also separated from Mount Chilalo by a saddle-like terrain called Cheleleka at latitude of 7°55′ N and Longitude of 39°17′ E (Mohammed Kasso *et al.*, 2010). Unlike other mountains, the Cheleleka swamp and moorland habitat connects the two mountains. However, currently Mount Chilalo and Galama Mountains Range are under threats of fragmentation due to illegal expansion and encroachment of agriculture and human settlement around Cheleleka.

Arsi Zone is naturally endowed with many permanent river and stream networks. In particular Chilalo-Galama Mountain Range is a major water source for many permanent rivers (Yazachew Etefa and Kasahun Dibaba, 2011). Many rivers and streams emanate from it flow different directions forming three different drain basins (APEDO and ABRDP, 2004). These massifs also have Afroalpine lakes and swamps on the top of the plateau (Mohammed Kasso *et al.*, 2010).

The triangular shaped topographic feature of Chilalo-Galama Mountains Range controls the drainage system to be three. The first drainage basin is Wabe-Shebele, which drains about 54.8% of the area of Arsi Zone (Mohammed Kasso *et al.*, 2010; Mohammed Kasso and Afework Bekele, 2011). It includes all rivers that flow eastwards to Wabe-Shebele River. The major permanent rivers and at least their tributaries that emanate from Chilalo-Galama Mountains Range are Wabe, Robe, Elele, Megna, Gololcha, Ejersa and Shenen rivers (Yazachew Etefa and Kasahun Dibaba, 2011). The second one is a lake drainage basin. It covers 21.9 % of the total area of Arsi Zone. Katar and its tributary streams and rivers like Walkessa, Kunicha, Anku, Dosha, Kombolcha, Gonde, Gusha, Ashebeka and Kulumsa originate from these massifs and drain Lake Batu or Lake Ziway (Mohammed Kasso *et al.*, 2010; Yazachew Etefa and Kasahun Dibaba, 2011; Mohammed Kasso and Afework Bekele, 2011). Awash drainage basin is the third drainage basin that covers about 23.3% of the total drainage basins of the zone that falls in Awash Drainage Basin or catchment’s area. Rivers like Keleta, Hulule, Arba and Awash (Hawas) occur in this basin rivers, at least their tributary streams originate from Chilalo-Galama Mountains (APEDO and ABRDP, 2004; Mohammed Kasso and Afework Bekele, 2011).

Most of the rivers have a potential for irrigation and hydroelectric power generation even though the level of utilization is low. Chilalo-Galama Mountains Range also becomes a source of tap water or drinking water for more than 12 districts of urban and rural populations. These massifs also have Afroalpine lakes and many swamps on the top of the plateau (for example Lake Cheleleka and Marare swamp). Historically many rivers emanate from the upper watershed to different directions even though at present they are reduced in number due to deforestation and land degradation by human activity and probably due to global climate change. One of the main reasons for the establishment of the Park was to maintain water source in Chilalo and Galama catchment. As the area is a water source for the international and inter regional rivers like Wabe Shebelle River and Awash River, the consequences will be tremendous if the area is not conserved well.

4.3. Soil

Chilalo-Galama Mountains Range possesses different types of soils at different altitudes. Pellic Vertisols (lower altitude), Orthic Luvisols (medium altitude), Chromic Luvisols (higher altitude) and Eutric Nitosols (on the moorland) dominate Chilalo-Galama Mountains Range (Mohammed Kasso and Afework Bekele, 2011). Chromic and Pellic Vertisols have characteristics of water holding and heaviness for ploughing during rainy seasons due to their high clay content. Luvisols is good for agriculture with base saturation and weatherable minerals. Cambisols dominantly occur on the steep slopes and are often shallow or have many rock outcrops. Those developed on gentler slopes, however, have good base saturation and fertility and can highly be used for agriculture (Yazachew Etefa and Kasahun Dibaba, 2011). The soil colour along the western part of Mount Chilalo changes from darker to reddish brown between 2,500–3,000 m asl and becomes dark above 3,000 m asl. It has acidic pH value ranging from 5 to 6. The lower altitude area is frequently cultivated (Mohammed Kasso and Afework Bekele, 2011). The area possesses different types of soils and vegetation zones at different altitudes (Alemayehu Mengistu, 1975).

4.4. Wildlife and vegetation

The Ethiopian vegetation is classified into eight types such as: desert and semi-desert scrub, dry evergreen montane forest, moist montane forest, lowland semi evergreen forest, *Acacia-Commiphora* woodland, *Combretum Terminalia* woodland, Afroalpine and Sub-Afroalpine vegetation and wetland and riparian vegetation (Friis 1992; IBC, 2005). Three ecosystems namely Afroalpine and Sub-Afroalpine, Dry Evergreen Montane Forest and *Acacia-Commiphora* Woodland are found in AMNP. Out of these Chilalo-Galama Mountains Range alone encompasses dry evergreen montane or Afromontane forest and Afroalpine and sub-Afroalpine vegetation types based on its attitudinal zonation (IBC, 2005). For further information on species see Appendix 2.

Ethiopia has the largest area of sub-Afroalpine and Afroalpine habitats in Africa. The sub-Afroalpine areas occur between 3,200 and 3,500 m asl, while the Afroalpine areas occur between 3,500 m and 4,620 m asl (IBC, 2005; Evangelista *et al.*, 2007). The highlands of Ethiopia which were widely covered with Afroalpine moorlands and grasslands are currently threatened. Different factors such as rapid human population growth, poverty, forest clearing for cultivation, over-grazing, over-exploitation for fuel wood and construction materials are reducing forest cover in Ethiopia at an alarming rate (IBC, 2005). This makes the original sub-Afroalpine and Afroalpine to be restricted to scattered and easily inaccessible areas surrounded and isolated by agricultural areas (IBC, 2005; Evangelista *et al.*, 2007).

Most parts of Arsi zone used to be covered by dense and intact natural forest even though at present deforested and degraded due to anthropogenic activity. However, currently a very limited natural forest coverage remained only in some pockets of Munesa-Shashamene, Arbagugu and Chilalo-Galama Mountains range and the eastern peripheral lowlands of Amigna, Seru and Gololcha and the lowland of Ziway Dugda (Yazachew Etefa and Kasahun Dibaba, 2011). The natural vegetation is determined mainly by altitude, temperature, amount of rainfall and parent material from which the soil is derived and type of human interference (Yazachew Etefa and Kasahun Dibaba, 2011).

Chilalo-Galama Mountains Range comprises the second highest Afroalpine habitat in Ethiopia (Mohammed Kasso *et al.*, 2010). Relatively it has more or less intact sub-Afroalpine and Afroalpine although, historically the dry evergreen montane forest and grassland complex that existed before has already vanished from most parts except in the western part of Mount Chilalo and southeastern part around Ticho of Galama Mountain Range. There is also some stock of artificial plantation in other parts. The major artificial plantations are found in Western part of Chilalo (Checho and Gafrsa) and southern tip of Galama Mountains Range which is protected by Oromia Forest and Wildlife Enterprise. The dry evergreen montane forest and grassland ecosystem represent a complex system of successions involving extensive grasslands rich in legumes, shrubs and small to large-sized trees to closed forest with a canopy of several strata occurring between 1,900-3,300 m asl (IBC, 2005). The dry evergreen montane forest and grassland have been inhabited by people for centuries. This resulted in forests to be diminished and replaced by bushlands in most areas (IBC, 2005). This is also true for Chilalo-Galama Mountains Range.

Based on altitude and types of vegetation, the Chilalo-Galama Mountains Range historically is characterized by three vegetation zones (mixed montane and coniferous forest, ericaceous forest and Afroalpine vegetation) (Mohammed Kasso *et al.*, 2010). The mixed Montane and coniferous forest occurs at altitudes ranging between 2,000 – 3,100 m asl. It is dominated by *Hagenia abyssinica, Gnidia glauca, Schefflera abyssinica* and *Hypercum revolatum* at its very humid parts, whereas *Podocarpus falcatus* forest is found at lower altitude and *Juniperus procera* at higher relatively drier parts (APEDO and ABRDP, 2004). The ericaceous forest zones (3,100 – 3,900 m asl) is characterized and dominated by *Erica arborea* and *Erica trimera* and also other dwarf *Erica* species named *Erica tenuipilosa*. In this zone, the low temperature inhibits tree growth, and is dominated by low bushes, tuft grasses and lichens. The Afroalpine vegetation (3,300 – 4,200 m asl) largely comprises *Alchemilla helichrysum, Artimesia trimera,* and *Lobelia rhynchopetalum* and different grass species (Mohammed Kasso and Afework Bekele, 2011). More than 90% of the area of Chilalo-Galama Mountains range is covered by Ericaceous and Afroalpine vegetation zones (Malcolm and Sillero-Zubiri, 1997). In addition to the natural vegetation, there are also some patches of plantations of non-native tree species like *Cupressus lusitanica*, *Eucalyptus globulus*, *Eucalyptus amygdalina*, *Pinus patula*, *Pinus radiata* and *Pinus carribean* (Evangelista *et al.*, 2007; Mohammed Kasso and Afework Bekele, 2011). For further information about the lists of vegetation that occur in the area see Appendix 2.

The diverse climate and topographic features have provided a wide range of fauna and flora in Arsi Zone in general and Chilalo-Galama Mountains range in particular. Chilalo-Galama Mountains Range is endowed with varieties of Afromontane and sub-Afroalpine and Afroalpine animals with high proportion of endemic species. However, due to uncontrolled hunting and destruction of their natural habitat, there is a rapid decrease of wild life in abundance, species and distribution (Yazachew Etefa and Kasahun Dibaba, 2011). For more information see Appendix 3 and Appendix 4.

4.5. Climate

Arsi Zone agro-climatical zone is known for its variation in altitude. It has four major physiographic divisions such as cool agro-climatic zone (above 3,500 m asl), which covers the highest altitude areas of the zone and constitutes about 2.74% of the total area. The second one is the cool temperate agro-climatic zone that includes the mountain ranges, massifs and high plateaus (2,500 - 3,500 m asl) covering about 22.74% of the total area of the zone. The third is the warm temperate agro-climatic zone (1,500 -2,500 m asl), which comprises low plateaus of the zone and covers about 49.60%. The fourth is lowland zone (less than 1,500 m asl) that constitutes about 24.92% of the total area (Yazachew Etefa and Kasahun Dibaba, 2011). Two of the four thermal Zones, temperate cool and cool/cold types are found on the highland areas. In particular, cool/cold climate is confined to the top of major mountains like Chilalo-Galama Mountains Range, Kaka, Honkolo and Gugu mountains. This climate category accounts for 6% of the total areas of the zone. It is found at an altitude of more than 3,300 m asl with a temperature of less than 10^{o}C (Yazachew Etefa and Kasahun Dibaba, 2011). Despite these agro-climatic zones, Chilalo-Galama Mountains Range is described by three traditional agro-climatic classification such as moderately cool "Weina daga" (<2,350 m asl), cool "Dega"- (2,350-3,350 m asl) and cold "Wirch" (>3,300 m asl) based on its altitudinal ranges (Mohammed Kasso *et al.*, 2010; Mohammed Kasso and Afework Bekele, 2011).

The Arsi Mountains play a vital role in climate control in the region by attracting large amounts of orographic rainfall. Chilalo-Galama Mountains range of AMNP has two rainy seasons, namely the small rainy season and the heavy rainy season. The small rain falls between March and June with its peak in April. The heavy rainy season is between July and October, with the highest peak in August. In the lower altitudes the amount of annual rainfall reaches 600 to 1000 mm while the higher altitudes get rainfall of 1000 up to 1400 mm annually (Miehe and Miehe, 1994).

The mean annual temperature and rainfall vary depending on the altitude. Areas above 3,300 m asl have annual mean temperature less than 10^{o}C and areas <3,300 m asl have annual mean temperature of 10-15^{o}C (Mohammed Kasso *et al.*, 2010). However, there is a slight variation of temperature based on months and seasons (Yazachew Etefa and Kasahun Dibaba, 2011). During the dry season, day temperature is high and night temperature is low (Mohammed Kasso *et al.*, 2010).

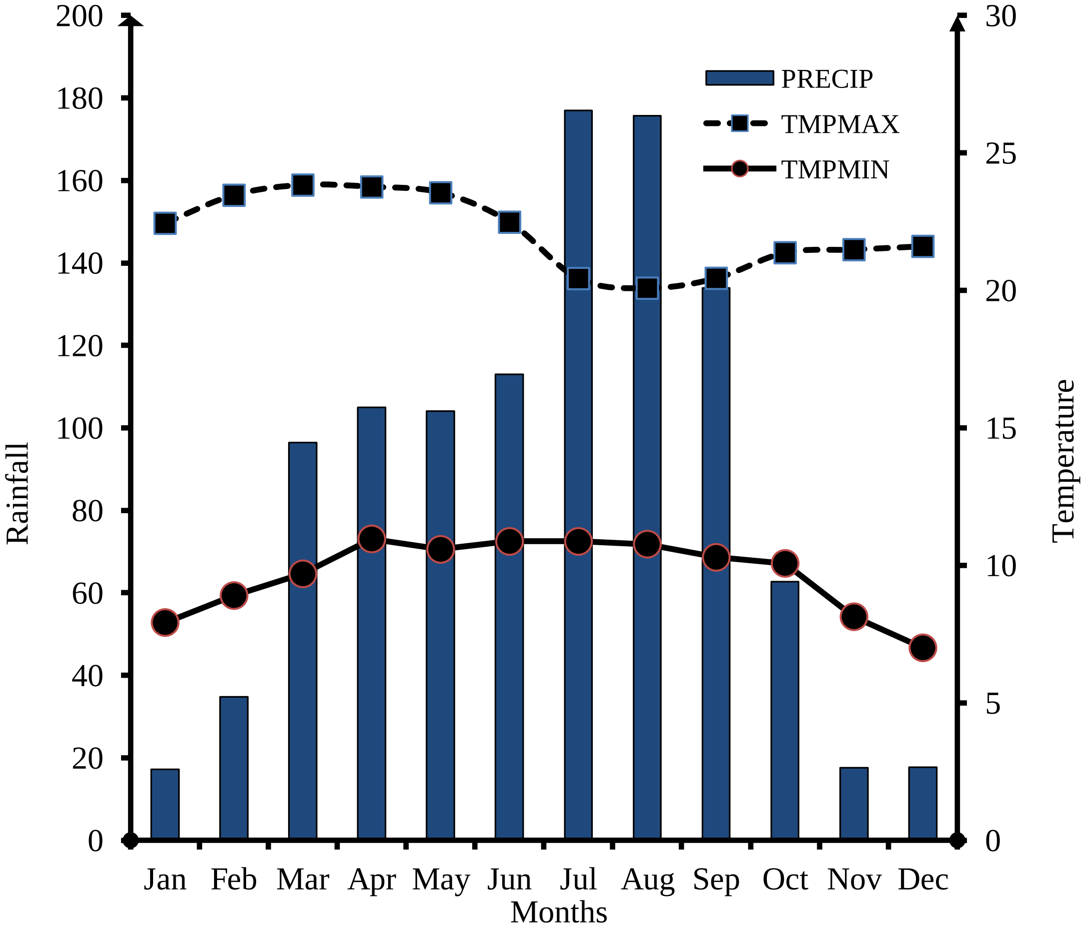


Figure 2. Monthly average maximum and minimum temperature and precipitation (rainfall) of Asella area (1990-2015)
Source: Ethiopian Metrological Service Agency

Chilalo-Galama Mountains Range experiences eight months of rainfall commencing from March and extending until November with the highest rainfall concentration from June to August. The elevation from 2,000 to 4,200 m receives annual rainfall averaging over 1,000 mm (Evangelista *et al.*, 2007). The annual rainfall ranges from 800-2,000 mm (APEDO and ABRDP, 2004).

4.6. Socio-economic status

Arsi Zone is a densely populated zone in Oromia Regional State. From the total 2,637,657 people in Arsi Zone, 1,174,080 (44.51%) occur in the districts including Asella town that encloses in Chilalo-Galama Mountains Range (CSA, 2008). Arsi Zone, especially the peasant association around Chilalo-Galama Mountains Range, has high potential for livestock rearing even though more emphasis is given to quantity rather than quality of the animals (Yazachew Etefa and Kasahun Dibaba, 2011).

Almost all of the land of Chilalo-Galama Mountains Range that is demarcated as AMNP seems intact with the exception of high but illegal encroachment by the local community for the expansion of agricultural land and settlement. Areas above 3,300 m asl are the limit to human cultivation and predominantly occupied by heathlands (Mohammed Kasso *et al.*, 2010). There are few pastoralists residing above the crop cultivation zone in temporary nomadic huts and under different caves up to the summit of the peaks. Agriculture is the mainstay and land is an important economic base for the local communities that reside around Chilalo-Galama Mountains Range.

The area is considered as one of the Afrotropical hotspots for biodiversity. It is also one of the areas that is affected by habitat fragmentation due to climate change and anthropogenic factors like deforestation. In addition to the burning of *Erica*, there is deforestation of remnant forests for settlement, agriculture and construction (Mohammed Kasso and Afework Bekele, 2011).

Before the establishment of Chilalo-Galama Mountains range as part or one block of AMNP, it was previously attempted to protect it as Boraluku Control Hunting Area and priority forest conservation area. In 1995, the Galama Mountains became one of 39 FPAs in Ethiopia to be managed for the production, protection and conservation of its forests by the Ministry of Agriculture. This has been only minimally facilitated the creation of a few small-scale plantations in the southern regions below the Galama Ridge and western parts of Mount Chilalo (Evangelista *et al.*, 2007). In 2002, management of the Chilalo Galama Forest Priority Area was transferred from the Federal Government to the Oromia Regional State (Evangelista *et al.*, 2007). The area is enclosed under Oromia Forest and Wildlife Enterprise of the Arsi Branch (Mohammed Kasso *et al.*, 2010) from which its protection level was upgraded to Park status. At present, it is conserved as part of the Regional Park named as AMNP which encompasses four blocks (Chilalo-Galama Mountains Range, Kaka, Honkolo and Dhera-Delfikar). However, the management of Chilalo-Galama Mountains Range seems to be difficult since it encompasses portions of nine different Districts of the Arsi Zone representing nearly 1,174,080 people (CSA, 2008), with unclear boundaries of the district that meet at the higher elevations and extensive exploitation of natural resources without regulation (Evangelista *et al.*, 2007).

4.7. Tourism attractions

AMNP has attractive climatic conditions and beautiful natural landscape scenery, cultural and traditional heritage. Particularly, Chilalo-Galama Mountain Range has very beautiful natural landscapes which have similarity with the prominent Bale Mountains National Park. It also possesses several endemic fauna and flora. It is also nearest to road facilities although it is under-developed. In many situations, the Chilalo-Galama Mountains Range and other blocks of AMNP have high potential for the development of tourism industry.

From the four blocks of the AMNP, Dhera-Delfiker is more frequently visited by foreign and domestic visitors. But sometimes Chilalo-Galama Mountains Range’s traditional and religious places for traditional pilgrimage or ‘Muda’ in Mount Chilalo is more likely to be visited as it is closer to Asella town. The other tourist attractions of the AMNP are different peaks and caves of Arsi Mountains, hot and cold water springs, water falls (Katar and Indetu), cultural and traditional pilgrimage (Muda, Frankasa, Gate, Delfiker and Ayo Momina), Tulu Gudo Church, historical battle field of Anole Sallan (Plate 1), manmade lakes (Koka and Melka Wakena) and natural lakes (Batu, Abijata, Shala and Langano) (Yazachew Etefa and Kasahun Dibaba, 2011).

Koka and Melka Wekena lakes have been used for generating hydroelectric power and for fish production. Lake Batu (Ziway) and Langano are home for different. Therefore, it has a high potential for fishery and recreation purposes (Yazachew Etefa and Kasahun Dibaba, 2011). However, most of the potential tourist attraction sites are not ready for the visitors due to lack of study of its existing potential resources, lack of significant conservation actions, lack of promotion and limited tourist amenities like standard hotels and other social infrastructures.

Plate 1. Aannolee Oromo Martyrs’ Memorial Monument and Aannolee Cultural/Historical Museum and Ethiopia Wolf

4.8. Habitat description

A total of eight habaits were identified from Chilalo-Galama Mountains Range. The grid code, GPS information, local site name, number of traps, habitat type and descrption is given in Table 2.

Table 2. Grids and their habitat description

Grid Code	Latitude	Longitude	Altitude	Site Name	Habitat	No of Traps	Habitat and Vegitations Description
CH-01* (1)	7°56′12″	39°11′52″	3100	Gafarsa	Montane forest	25	It is a degraded montane forest with slight regeneration and highly overgrazed. During the dry season, the herbs and grass cover will dry leaving bare ground except with bushy tufts and scrubs of afromontane vegetations of *Hagenia abyssinica*, *Gnidia glauca*, *Schefflera abyssinica* and *Hypercum revolatum*.
CH-02* (1)	7°56′12″	39°11′59″	3200	Gafarsa plantation	Plantation	25	Plantation habitat with *Cupressus lusitanica* and *Pinus patula* with slight herbs understory during wet season but bare ground during dry season. It has closed canopy at approximately around six meters with the branches of the plantation which is not trimmed except at 2 meters above the ground. It has relatively young plantation around fragmented and degraded natural forest of *Hagenia abyssinica*, *Gnidia glauca*, *Schefflera abyssinica* and *Hypercum revoaltum*. There is a sever over exploration of *Hagenia abyssinica* leading to its local extinction.
CH-03* (1)	7° 56′00″	39° 12′25″	3400	Gafarsa *Erica*	*Erica* forest	25	Relatively thick regenerating *Erica* forest after the *Erica* fire 6 years ago. The *Erica* forest canopy is at maximum of 2 m and at an average of 1.5 m height. The open space between the *Erica*

							bundles and understory has also herbaceous cover in particular during wet seasons although it relatively looks like open during dry season.
CHE-01# (1)	7°56′11″	39°12′06″	3268	Gafarsa	Montane forest	10	Mixed montane forest with *Erica arborea* and *Erica trimera* species near the border of tree line zone.
CHE-024# (1)	7°56′ 06″	39°12′18″	3300	Tulu Gafarsa	*Erica* scrub	15	The habitat shows similarity with Grid CH-03 except the altitude and relatively few herbaceous cover and few signs of the existence of small mammals during preliminary survey where a juvenile *Otomys* was captured by hand from the site. The grid was selected for the extensive study of the diversity of small mammals at altitude of 3,300 m asl in *Erica* forest
CH-04* (1)	7° 55′ 41″	39°13′04″	3700	Tulu Chilalo	*Erica* forest	25	Very thick *Erica* forest with understory of lichens, ferns and other herbs. The site is closer to the rock escarpments and stream of water at peak elevation. The habitat has a lot of signs like scat, run ways and burrows indicating the existence of small mammals. However, in 2015 it was burnt and the IV session was used for the study of the impact of *Erica* fire on small mammals.
CH-05* (1)	7° 55′38″	39°13′ 47″	3758	Intil Moorland	Moorland	25	It possesses moorland vegetations dominated by *Alchemilla*, *Helichrysum*, *Artimesia* and *Lobelia* species. It also possess many signs like burrows, runways and whistling sounds or alarming calls indicating the existence of small mammals.
CH-Ag* (1)	7° 56′16″	39° 11′32″	3000	Gafarsa	Agricultural land	25	Intensive study for the diversity and abundance of small mammals in modified habitat. The farmland is sown with barely and other crops like beans in different years at intervals. The habitat is also deliberately selected for identification of species that are considered as pest and able to leave in human modified habitat.
CH-06* (2)	7°56′53″	39°11′53″	3188	Dankaka	Bushland	25	It is a disturbed bushland that is dominated by mixed *Erica* and *Hypericum revolatum* scrub and other bushy tufts of rebus. The grid was very close to human settlement and highly disturbed by overgrazing, burning and deforestation activity for fuel wood, charcoal and for agricultural land expansion. It is one of the highly

							disturbed habitats even though the *Erica* and *Hypericum revolatum* scrubs seem to resist the disturbance probably due to good soil conditions and high rainfall.
CH-07* (2)	7°56′57″	39°12′12″	3200	Dankaka	*Erica* scrub	25	The grid was selected for the study of impact of *Erica* burn on the diversity and abundance of small mammals. The *Erica* forest was burnt approximately six month before and started to regenerate and sprout with good shoot. As the habitat seems open with few and sparse ground cover during the preliminary survey of the habitat, it seems devoid of small mammals even though in some places fresh burrows and excavated mounds were observed.
CH-08* (2)	7°56′49″	39°12′33″	3300	Dankaka	*Erica* scrub	25	The gird was selected for the intensive study of the diversity and distribution of small mammals along altitudinal zonation. The habitat is dominated by *Erica* forest of four years old since burning. It looks good habitat for small mammals as it has good shelter and relatively better herbaceous vegetation that can be used for food and shelter for small mammals.
CH-09* (2)	7°56′24″	39°13′ 06″	3600	Muda area	*Erica* Forest	25	Intensive gird for the study of diversity and abundance of small mammals along altitudinal zonation and impacts of *Erica* fire on small mammals. The habitat is close to ‘Muda’ area and has very thick *Erica* forest more than 6 years old since time of fire. It is surrounded by rocky cliffs from north, south and east direction. Except with relatively lower altitude its vegetation composition and structure is similar to Grid CH-05
CH-Bat# (2)	7°57′20″	39°11′14″	2910	Kunicha	Montane forest	10	Fragmented mixed montane forest dominated by *Juniperus procera* close to human settlement and agricultural land
CHE-03# (3)	7°55′55″	39°13′20″	3700	Intil Moorland	Moorland	10	The habitat looks like marshland or swamp land but with relatively short *Erica* and other vegetation dominated by short *Festuca* grass

CHE-04# (3)	7° 56′04″	39°13′59″	3717	Intil Valley	Grassland		The habitat for this grid is characterized by complex and heterogeneous vegitations. It has a marshy tuft of *Carex monostachya*, *Alchemilla ellenbecki* and other moorland vegetations that is surrounded by very attractive regenerating *Erica* forest burns that occurred 6 years before and rock escarpment surrounded by thick *Erica* forest in the valley of the Mount Chilalo. The area seems as naturally fragmented by the large steep cliff and mountain ridge with many streams emanating from it. The cliffy and rocky parts have short and sparse *Erica* vegetation.
CH-10* (4)	7°55′21″	39°10′58″	3100	Checho	Plantation	25	Intensive for the study of diversity and abundance of small mammals in Checho Plantation. The habitat has different types of plantations (*Cupressus lusitanica*, *Eucalyptus globulus*, *Eucalyptus amygdalina*, *Pinus patula*, *Pinus radiate* and *Pinus carribean*). The trapping line of the grid was designed in order to sample the different microhabitat of the plantation. Some traps were placed in matured with bare ground cover and closed canopy, others were placed with relatively young plantation with small and weak understory and rest were placed in sparsely planted *Eucalyptus* plantation with a mixed *Erica* and other vegetation scrubs.
CH-11* (4)	7°55′01″	39°12′05″	3400	Checho	*Erica* scrub	25	Intensive study for the diversity and abundance of small mammals along altitudinal zonation and Impacts of *Erica* burn. The habitat is more or less similar with other habitats on the similar altitudinal zonation but it has *Erica* forest which is older and matured and looks like it reached climax condition of its growth. However, during the last session (IV session) the site was burnt by the large scale *Erica* fire and the trapping results after two weeks of the *Erica* fire is used for study of the impact of *Erica* fire on small mammals.
CHE-05#	7 °55′26″	39°11′13″	3100	Checho	Bushland	10	Extensive study for the diversity of small mammals. The habitat has thick mixed montane forest with a lot of lines herbs, big trees

(4)							and shrubby thickets.
CH-12* (5)	7°53′20″	39°12′19″	3313	Shela Chebet	*Erica* scrub	25	Intensive study for diversity and abundance of small mammals' at altitudinal zonation and study of impact of *Erica* burn. The habitat has sparse *Erica*, two years old since time of fire. The area was historically cleared and farmed more than 40 years ago during the Hailesilassie regime.
CH-13* (5)	7°53′20″	39°12′19″	3311	Shela Chebet	*Erica* forest	25	Intensive study for diversity and abundance of small mammals and for the impact of *Erica* burn on small mammals. The habitat has thick *Erica* along stream. It looks like more than 10 years old with good understory and ground cover.
CH-14* (6)	7°53′48″	39°16′38″	3520	Bore Chilalo	*Erica* forest	25	Intensive study for diversity and abundance of small mammals along altitudinal zonation and different nature of *Erica* forest and scrub. The first 10 traps were placed inside *Erica* forest with sparse vegetation and bare land due to overgrazing and impacts of fire before three years ago. The other ten traps were placed near spring water grassland surrounded by *Erica* scrub and the rest traps were placed along rocky cliffs with short *Erica* scrub.
CH-15* (7)	7°54′48″	39°19′16″	3400	Cheleleka	Grassland	25	Intensive study for diversity and abundance of small mammals along altitudinal zonation. The habitat is grassland dominated by *Erica* scrub at the edge. More or less the habitat is overgrazed and highly disturbed. The two trapping lines (10 traps) were placed along the edge whereas the rest 3 trap lines (15 traps) were placed in grass land.
CH-16* (8)	7°54′25″	39°20′57″	3494	Cheleleka near Galama	*Erica* scrub	25	Intensive study for diversity and distribution of small mammals along altitudinal zonation and impacts of *Erica*. The habitat is dominated by *Erica* scrub more or less disturbed as it is found near the nomadic settlement. The open area is covered with grasses and *Alchemilla* and *Helichrysum* scrub. The *Erica* was regenerated after five years *Erica* fire.
CH-17* (8)	7°54′26″	39°22′12″	3885	Sango	*Erica* scrub	25	Intensive study for the diversity and abundance of small mammals along altitudinal zonation and study of impacts of *Erica* burn. The habitat has short and sparse *Erica* scrub near the rock escarpment

							approximately three years since time of *Erica* fire.
CH-18* (8)	7°54′08″	39°22′45″	4104	Sango	Moorland	25	Intensive study for diversity of small mammals along altitudinal zonation. The habitat is moorland dominated by *Alchemilla* and *Helichrysum* scrubs
CH-19* (9)	7°57′18″	39°14′26″	3431	Jawi Chilalo	*Erica* scrub	25	Intensive study for the diversity and abundance study of small mammals along altitudinal zonation and impacts of *Erica* burn. The *Erica* forest was burnt 3 years before and regenerated in good condition despite high disturbance by overgrazing as it is closer to human settlements
CH-20* (9)	7°56′39″	39°16′46″	3431	Jawi Chilalo	*Erica* scrub	25	Intensive study for diversity and abundance of small mammals along altitudinal zonation and impacts of *Erica* burn. The regenerated burnt *Erica* scrub of about 1 year old is near thick *Erica* forest in good condition. The one trapping line was designed in order to sample the edge of the mossic habitat which was not burnt.
CH-21* (10)	7°55′39	39°15′57″	4020	Sibu Abadir	Moorland	25	Intensive study for diversity and abundance of small mammals along altitudinal zonation. The habitat is a moorland habitat dominated by Alchemilla and Helichrysum sp.
CH-22* (10)	7°55'00″	39°16'20″	3,800	Abnas	Moorland	25	Swampy area, surrounded by *Erica* thicket
CH-23* (10)	7°55'13″	39°17'21″	3,500	Walich	*Erica* forest	25	Scattered *Erica* thicket and rocky grasslands and at periphery of the stream dominated by herbaceous vegetation of *Alchemilla* and *Helichrysum*. It contains matured *Erica* older estimated to than 10 years
CH-24* (10)	7°54′59″	39°15′45″	4090	Chilalo peak	Moorland	25	Intensive for the study of diversity and abundance of small mammals along altitudinal zonation. The habitat is close to Muda area and has very thick *Erica* forest more than 6 years old. It is surrounded by rocky cliffs from north, south and east direction. Except with of relatively lower altitude its vegetation composition and structure is similar to Grid CH-05
CH-	7°56′19″	39°08′24″	2455	Wolekessa	Bushland	10	Bush land along none accessible Wolkessa River gorges. The

Wal* (11)							habitat is dominated by Eucalyptus plantation with herbaceous and bushy thickets.
CH-AS1* (12)				Campus	Montane forest	25	The grid is selected for the study to compare the impact of plantation on the diversity and abundance of small mammals. Even though it is also modified and degraded more or less it contains the regenerating natural forest
CH-AS3* (12)				Campus	Plantation	25	The habitat selected for altitudinal zonation and impacts of plantation on small mammals. The habitats more or less has different type exotic and indigenous trees in particular *Juniperus procera* and *Hagenia abyssinica* and the exotic species like *Cupressus lusitanica*, *Eucalyptus camaldulensis* and *E. globules* which has understory of natural shrubs and bushes in the recently planted plantations
CH-AS4* (12)				Campus	Grassland	25	The habitat is dominated by grasses with few scattered shrubs
CH-AS2* (13)	7°56′16″	39°08′17″	2500	Child Care	Montane forest	25	Montane dry forest dominated by Podo tress and secondry growth of typical dry Afromontane ever green forest remnant
Gal-01# (14)	7°49′13″	39°25′53″	3600	Ticho water plant	*Erica* scrub	10	Extensive study of small mammal’s diversity in short *Erica* which was probably burnt before three year ago. The habitat seems to have no many signs for the existence of rodents.
Gal -02# (14)	7°49′25″	39°25′07″	3721	Galama Plateau	Grassland	15	Extensive study for the survey of the diversity of small mammals in marsh or swamp area with relatively dry month due to dry season.
Gal-03# (14)	7°49′42″	39°24′31″	3780	Galama Plateau	Moorland	5	Extensive study for the diversity of small mammals in moorland habitat dominated by Alchemilla and Helichrysum sp.
Gal-04# (14)	7°51′04″	39°23′47″	4000	Galama highland	Moorland	10	Extensive study for the diversity of small mammals in highland moorland. The habitat is dominated by Alchemilla and *Erica* scrubs closer to rocky cliffs

Number in bracket shows transect code, * - refers intensive study grids, # - shows extensive study grids

5. MATERIALS AND METHODS

5.1. Materials

Materials which were used for the study include: traps (mist net, Sherman live-traps, hand held traps and mole rat traps), bait (peanut butter and roasted barley floor), bag (polythene and special cloth), binoculars, balance (Pesola spring balance), GPS, field guides, data sheet, dissecting kit, ruler, meter, string, plastic tag with different colour, digital camera, spade, measuring cylinder, vials, microscopes (dissecting and compound), slide, petri-dish, preservative chemical (ethyl alcohol, formalin and chloroform), pins, adhesive and carton, calliper, glove (dissecting, leather and clothes), torch (powerful red light filter, small hand held and over head), batteries and accessories, pen and pencil, note book, field shoes, field jacket, rain coat, tent, sleeping bag, centrifuge tubes, first aid kit, fur dye and rat cage, centrifuge, thermometer, incubator and water bath.

5.2. Methods

The study was carried out from September 2013 to December 2016 and the laboratory analysis was carried out until December 2016. During data collection from the field, information on the diversity, spatial and temporal distribution, relative abundance, habitat association, possible threats of small mammals, their pest status and the prevailing conservation challenges for the protection of small mammals were assessed.

5.2.1. Preliminary study

During the preliminary survey, all the available and relevant information such as vegetation types, topography, altitudinal zonations, size of the area, level of human encroachment and habitat fragmentation, duration of fire burn of *Erica*, nature of vegetation and habitat types were gathered. A detailed area survey was conducted in each of the nine districts that encompass Chilalo-Galama Mountains Range. Based on the different vegetation and habitat types, the topography and altitudinal zonation and duration of *Erica* burn, different representative habitats types from each representative grid were identified. Information on the number of households in each peasant associations bordering Mount Chilalo-Galama Mountains Range was also collected for the selection of the number of respondents for local community perception on the conservation of the area and perception on the pest status in small mammals of the study area.

5.2.2. Sampling design

The study area was classified into nine clusters (Tiyo, Hetosa, Lode-Hetosa, Diksis, Robe, Tana, Shirka, Lemmu-Bilbilo and Digalu-Tijo) following the boundary line of each District that encloses Chilalo-Galama Mountains Range. Based on the results of preliminary survey, the study area included at least seven geographical clusters. The selected study area covered all sides of Mount Chilalo and south-western and central part of Galama Mountains Ridge. As Smith *et al.* (1975) stated the spatial arrangement of traps was determined by shape and amount of habitats available and intensity of effort and number of traps and other logistics. The trap configuration is based on transect and grids. Based on the topography, altitudinal zonation, nature of vegetation, size of the area and homogeneity or heterogeneity of habitat, 40 representative grids (30 intensive and 10 extensive study grids) that were positioned on 14 transects were selected. The intensive study grids were permanently used throughout the study period whereas the extensive study grids were used temporally. Extensive study grids were aimed for the survey on the diversity of small mammals in order to complement intensive study grids by covering relatively wide area and some unique habitats.

The number of sampling grids selected from each transect was based on the size of the area, altitudinal zonation, nature and type of habitats and vegetation, duration fire of *Erica* and ease of accessibility and representativeness of habitats. Near to each transect, as necessary, several extensive study grids were also selected. Trapping was carried out for three consecutive days in the intensive study grids whereas for one to three days in the extensive study grid depending on the nature of habitat and vegetation, weather condition and trap success. The extensive study grids were laid at least 500 m away from the intensive live trapping grids. The intensive study transects run from the possible base of non-degraded habitat of Mount Chilalo and south western part of Galama Ridge to the summit or peak for altitudinal zonation study. Three transects were selected around Asella town in Welkessa River, Child Care Centre and compound of the College of Agriculture and Environmental

Sciences of Arsi University. Each transect was named by the respective PA or local area name as Dankaka, Gafarsa, Checho, Shalla, Boree , Cheleleka, Bada, Sibu, Jawi, Dabaya, Arsi University, Child Care Centre, Wolkessa and Bora Luku. In addition to the intensive study transects, four extensive study transects were selected namely Gafrsa, Checho, Dabaya and Bora Luku. Except for the Bora Luku Transect all others have intensive study girds in close proximity. In the present study, based on nature of vegetation and topography features of the area, a total of eight habitats namely Agricultural land, Bushland, *Erica* forest, *Erica* scrub, Grassland, Montane forest, Moorland and Plantation were selected (Plate 2).

Bat capturing followed a different design. The most direct and accepted method for surveying bats is mist netting (Flaquer *et al.*, 2007). Mist net surveys were commonly used to assess bat diversity and to provide sex, age, and reproductive condition of captured bats. Most mist netting surveys focussed on areas where capture success is traditionally highest (Flaquer *et al.*, 2007). Rather than using grids, a transect trapping was conducted close to river, forest clearing, flight path, ponds, cliffs and caves, waterfall and near human settlement.

5.2.3. Data collection

The traps used were Sherman live traps, mist nets and mole rat traps. As stated by Barnett and Dutton (1995), other methods that complement trapping were also used. Some of them were owl pellet, carnivore scat, dental impression, footprint, runways, rub marks, digging and burrow, sound and call, nest and roosting site. Species specific methods like scent stations, arboreal den count, associated species and food catches or remains were also used. Data on local community perception on the conservation and damage by the small mammals were collected by questionnaire and focus group discussion.

Plate 2. Representative habitats selected from the study area

For the capture, handling and care of the small mammals, the guidelines of the American Society of Mammalogists (Gannon *et al.*, 2007) and the Research proposal approved by Ethiopian Wildlife Conservation Authority were followed.

5.2.3.1. Live trapping

Trapping of small mammals (rodents and shrews) was carried out by using collapsible Aluminium Sherman Live Trap of 7.5 x 9 x 22 cm. Arboreal, fossorial and semi fossorial small mammals may not be sufficiently sampled unless the traps are placed in their appropriate place (Smith *et al.*, 1975). Hence, for mole rats, O-sized gopher foot traps were used. For porcupine, indirect observation methods like burrow scat and quill, remains of food were in the selected grid and its close vicinity.

The number and arrangement of the traps depends on the species and the location (Lettink and Armstrong, 2003). During small mammal trapping adequate number of traps is used while also considering the inter-trap distance to catch a high fraction of the animals present and to prevent trap competition (Krebs *et al.*, 2011). The traps were set at equal spacing as a way of standardising the trapping effort per unit distance or area (Aplin *et al.*, 2003). The traps distribution should not affect the probability of capture of individuals due to their placement (Lettink and Armstrong, 2003). Trapping grid is usually placed at the centre of a homogeneous habitat and should be large enough to easily include the average distance moved by relatively large sized small mammals under the study (Smith *et al.*, 1975). Actual grid area should be designed to be approximately, 16 times the average home range of the species being studied (Pearson and Ruggiero, 2003). Trap spacing is important for density estimation and must be based on the ability of animals to detect the trap. It should also reflect the expected size and abundance of the target species. Under most conditions, with expected rodent densities of tens to hundreds of animals per hectare, placing of traps at interval of 10–20 m is recommend by Aplin *et al.* (2003). A trapping space of 15 m may be good compromise for most of species throughout the world (Smith *et al.*, 1975). The spacing should be derived by considering the home range of the target species as a general guideline a spacing of approximately 15 m between capture stations will effective and used to provide adequate coverage (TETF, 1998). In the same way Krebs *et al.* (2011) used 100 stations spaced with 15 m; Pacheco *et al.* (2013) used 25 stations spaced at 20 m; Pearson and Ruggiero (2003) 25 stations spaced with 10 m; Ylonen *et al.* (2003) used 120 stations at 15 m spacing and Belant and Windels (2007) used 25 stations at 17.5 spacing. Martins-

Hatano *et al.* (2002) also used a 3.24-ha grid, with 10 lines of 20-m intervals and each line with 10 live traps spaced by 20-m. Here we used 25 trapping stations spaced at 15 m based on the available resources like traps, time and budget.

In each intensive and extensive trapping grid, five parallel transect lines with a length of 75 m that form square gird of 5,625 m^2 (75 m x 75 m) were established at different habitats and altitudinal ranges. Each live trapping line had 5 trapping stations spaced at 15 m interval. Except for extensive study grid, the same grid and trapping station were used for all trapping sessions. Five Sherman live traps were set on each of the five parallel line of trapping grid with a total of 25 Sherman live traps per grid. Each trap was marked by water proof marker as A_1, …, A_5; $B_{1,\ldots,}$ B_5; $C_{1,\ldots,}$ C_5; D_1,…, D_5; E_1,…, $E_{5.}$ The letters A, B, C, D and E represent the lines of the trapping grid and the subscript numbers represent trapping stations on the line (Appendix 6 and Appendix 10). Some traps were also placed on the branches of tree and thick bushes at height of 1-2 m above the ground whenever suitable habitat was encountered in the trapping station in order to trap arboreal small mammals. Each trap station was marked by coloured plastic tags on tall branches of the tree or on deliberately erected poles prepared from any branch or stem of suitable tree to easily locate the traps during checking and collection. For each line, the first and last trapping stations were marked uniquely to identify the position of the traps during checking and collection. Strings were put down along each line in dense and tall *Erica* thicket to mark and locate the trap stations easily. Traps were covered by available material like hay, leaves, branches, ferns and lichen and grasses in order to avoid the trapped animals from harsh environmental condition and to minimize its observation to foreign intruders. Traps were mostly baited with peanut butter and during favourable climatic conditions, it was also baited with peanut butter mixed with roasted barley flour. The bait was replenished each day or at any time if it was eaten by trapped animal or other animals (insects), got wet, grew mould, or dried up. Traps were checked twice a day early in the morning (6:30 to 8:30 a.m.) and in the late afternoon from (4:30 to 6:30 p.m.).

Information on weight, sex, approximate age (young, sub-adult, adult) and reproductive conditions from all trapped small mammals were gathered (Appendix 6). Marking was used for population size estimation, demographic variables calculation and recognition of behaviour of the individuals. Hence, all live trapped animals were marked and released an the site of capture with the exception of the selected representatives that were sacrificed.

For all live trapped individuals, a uniform design and part of the body fur clipping and dyeing was used for marking.

From the sacrificed individuals data on species (weight, sex, approximate age, reproductive condition, and standard body measurements) and ectoprasites were taken. They were dissected for tissue sample collection and for embryo count in pregnant females. Skin and skull of each representative specimen were prepared as voucher specimen for further species identification. Tissue samples from liver, heart, kidney and muscle were collected for molecular genetic analysis.

5.2.3.2. Mist netting

There are several methods (such as mist nets, hoop nets, hand capture, insect net traps, harp traps, net flicking, throwing objects and shotguns) used to capture bats. However, mist nets have been the most direct, accepted and commonly used live capture devices for several decades and are also the most cost effective (Flaquer *et al.*, 2007; Larsen *et al.*, 2007). Mist net surveys were conducted during late-March to early-December, 2014 to March 2016 focusing on areas where capture success is traditionally highest (Flaquer *et al.*, 2007). Bats were captured using mist nets set at locations where capture success for all bat species was expected to be high (for example, wetlands, streams, trails, and forest edges in mature forests). Sixteen sites in Chilalo-Galama Mountains Range and its surrounding area were sampled. The sites were selected based on distance to water source and size of surrounding contiguous forest and its accessibility. The majority of the nets were placed over the nearest water source, nearly all of which were intermittent or perennial streams or small rivers, bridge and in edge and interior of the available forest. In the Afroalpine and moorland habitats, the mist nets were placed in suitable habitats close to cliff and bats possible fly path.

For 2.5 m and 2.6 m height mist nets, poles made of 2.8 lengths of aluminium tubing are used to support the nets. In addition, 1.5 m high 4 different sized (12 mm x 12 mm, 16 mm x 16 mm, 20 mm x 20 mm and 25 mm x 25 mm) with thickness of 01 mm of light weight furniture square hole tube which fit inside one another were assembled to height at its extended level reaching more than six meters. This innovative manufactured pole for this project was designed to ease its transportation and to be easily used for different size as it can be adjusted to appropriate height by fastening it with bolt. Most netting was carried out during nights with good weather and infrequently (2% of nights) netted in nights with intermittent light rain during wet season, full moon and windy weather conditions. Most days with full moon were deliberately ignored as it affects bats activity. The altitude of trap sites ranged from 2,300 to 4,000 m asl.

Bat sampling was carried out in each of 16 selected representative sites. Not all sites were netted each year. High rainfall, inaccessibility and lack of any sign for the presence of bats in some sites makes all sites not to be sampled in more than one trapping session. However, some more productive trapping sites were sampled in more than two trapping session. A total of 230 net-nights were employed for the period of 60 nights with mean of 14.375± 2.368 net-night (Table 3). Generally, one to eight mist nets with different sizes (length and height) ranging in size from 2.5 to 6 m height with 6 to 18 m lengths were used at a particular site. The type of mist nets used were: 8 x 2.5 m, 9 x 2.5 m, 12 x 6 m, 12 x 2.6 m and 18 x 2.6 m (Table 3). Nets were opened at sunset (approximately 6:45 p.m.) and monitored for 2:00-3:45 hours with an average of 2.5±0.5 h per night. Nets were closed early if severe weather occurred or if capture rates and bat activity detection by ANABAT were extremely low. The total trapping hours per site ranged from 10.5 to 90.5 with total of 576.5 h (Table 3). A total of 8770.7 m^2 mist nets were used ranging from 138.6 to 1087 m^2 per sample site. Trapping effort varied from one trapping station to an other based on the number and type of net, netting night and the time in which the nets were open. The highest trapping effort (39.39 TMNA/TH) was carried out along Kombolcha Stream and the lowest (9.67 TMNA/TH) was in Dankaka *Juniperus* forest with sum up of 263.01 TMNA/TH (Table 3). On six (10%) of 60 net night sessions, a single episode trapping was conducted whereas in the rest at least two night mist-netting were implemented. Nets were checked every 10 to 15 minutes during high bat activity and 15-25 minutes when bat activity decreased. A portable hand and overhead torch were used to check the captured bats. After capture bats were carefully removed from the net, they were placed in individual cloth bags with air ventilation (Webala *et al.*, 2004). Then, after information on species, weight, sex, approximate age (sub-adult, adult), and reproductive conditions was gathered and also their ectoparasites were recovered, they were released by marking with dye, indelible ink or by non-lethal wing biopsy on the site.

Table 3. Sampling sites, number and type of mist net, net-night, mist net area and trapping effort for each sampling site

Site name	No of night	No of each type of mist-net and night					Net-night (NN)	Trapping hours (TH)	Total mist net area (TMA)	Trapping effort (TMNA/TH)
		(8*2.5)*night	(12 *6)*night	(9*2.5)*night	(12*2.6)*night	(18*2.6)*night				
Anku River Bridge	2	2*2	2*2	0	0	0	8	16.5	368	22.30
Asella 07	6	2*2	3*2	2*1	0	3*2	18	45.25	837.8	18.51
Bora Luku	1	3*1	0		4*1	2*1	9	23.35	278.4	11.92
Checho Plantation	1	0	0	2*1	3*1	0	5	10.25	138.6	13.52
Chilalo-Muda	1	2*1	1*1	0	3*1	2*1	8	16.45	299.2	18.19
Child Care	10	4*3	2*3	3*2	0	3*2	30	77.35	1087.8	14.06
Dankaka *Juniperus* forest	8	8*1	0	4*2	2*1	3*1	21	56.15	542.8	9.67
Gefersa Forest	5	4*2	3*2	4*1	0	4*2	26	69.8	1056.4	15.13
Wolkessa stream	2	4*2	4*2	0	2*2	1*1	21	47.75	907.6	19.01
Jawi *Juniperus* forest	1	3*1	0	3*1	2*1	1*1	9	22.15	236.7	10.69
Jitu Tena	1	4*1	0	3*1	2*1	1*1	10	24.25	256.7	10.59
Kombolcha Stream	5	3*4	2*2	1*2	0	2*2	7	19.3	760.2	39.39
Kombolcha River Bridge	2	2*2	2*2	0	0	0	8	20.25	368	18.17
Koropta	1	3*1	1*1	0	0	2*1	6	15.15	225.6	14.89
Wolkessa River and Bridge	12	6*2	2*2	3*3	1*2	2*3	35	90.5	1073.7	11.86
Chilalo-Summit	2	2*2	2*1	0	2*1	1*1	9	22.05	333.2	15.11
Total	60						230	576.5	8770.7	263.01

All pregnant female bats in late pregnancy stages were relapsed with care. However for the sacrificed females at their early stage of pregnancy development and from the accidently dead pregnant females, embryo count was conducted.

Reproductive condition of adult females was characterized as pregnant (PR) (estimated by palpation of the abdomen) and mammae inspection (for lactating (LA) swollen pink nipples, presence or absence of milk and for non-pregnant/impregnate (IM) unswollen, furred nipples whereas for male reproductive condition was determined by checking of positions and size of testes as scrotal (S) and non-scrotal/inguinal (I) (Perry *et al.*, 2010). The age classes adult (A) or sub-adult (SA) was based on the degree of ossification of metacarpal-phalanx joints and fur colour and texture (Perry *et al.*, 2010).

Nights with rain and full moon were not sampled. At all trapping sites, fine thread mist-nets were placed across presumed bat flyways: forest paths, small streams, roosting sites and cave entrances (Lavrenchenko *et al.*, 2004). From each species, a representative individual was scarified for molecular analysis and for further species identification. Visual observations were conducted at dusk and at night with the aid of hand and overhead torches and using night vision microscope. In addition to mist netting, acoustic survey was also conducted for over 75 nights to determine the bats activity, select the best productive trapping sites and to determine the bats diversity and distribution in the area. Acoustic monitoring was conducted by using Anabat II bat detector systems (Titley Electronics, Ballina, NSW, Australia). Bat calls were recorded using digital recordings of Anabat SD1 bat detector (Titley Electronics, Ballina, NSW, Australia). For active sampling, detectors were manually operated at each sample location and oriented at approximately 45° angles, scanning in front of the detector for bats activity. Day time roosting site inspections were also conducted. The representative specimen tissue samples for molecular studies were collected and preserved in 96% alcohol in 1.5 ml vial. Faecal samples from bags were also collected for each captured bat whenever available for diet analysis. Direct observations on their nesting site, diet and microhabitat choice were also recorded.

The following external measurements were taken by callipers or ruler to the nearest 0.1 mm from all representative captured and sacrificed representative specimens: EL - ear length (from the lower border of the external auditory canal to the tip of the pinna, with hair/excluding hairs), FA - forearm length (from the wings folded, from the outer end of the elbow to the outer end of the wrist joint or carpus), HB - head body length (taken dorsally, from the tip of the snout to the base of the tail), HF - hindfoot length (from the outer end of the heel at the base of the calcar to the outer end of the longest digit with hair and excluding hairs or claws), TL - tail length (from the base of the tail near the anal opening to tip of the tail).

5.2.3.3. Erica fire

The impacts of burning were quantified in terms of both faunal species composition, relative and absolute abundance and species richness (Parr and Chown, 2003). Hence the relative abundance and richness were used to quantify the impacts of *Erica* burn on small mammals. Thus, the impact of fire severity and related spatial and temporal parameters on species of small mammals were assessed following the method described by Roberts *et al.* (2008) and Gutema Jira *et al.* (2013).

5.2.3.4. Altitudinal zonation

Nine transects from all sides of Mount Chilalo and additional one transect on south-western part of Galama Mountains Range was established for elevational gradient study. Each transect was run from the base of undisturbed forest to the summit of the mountain. In addition, four short transects were selected in central Galama Mountains Range, Walkessa River and the two fragmented remnant forests around Asella Town for small mammals at relatively lower elevation with the exception of Central Galama Mountains Range transect for extensive study. With the exception of transects around Galama Mountains Range, Asella and Welkessa River, all elevational gradient was divided by 250-m bands starting from the base of natural habitats available along the elevational gradient to the summit.

5.2.3.5. Karyotypes and chromosomal variability

Animal collection

Representative small mammals were collected from each habitat and season following the procedure developed for the study. The captured representative animals selected for chromosomal study were kept alive for latter bone marrow suspension in temporary field laboratory. The collected and analyzed small mammals were seven species of rodents *Dendromus* sp.1, *Lophuromys brevicaudus*, *L. melanonyx*, *Stenocephalemys albocaudata*, *S. griseicauda*, *Tachyoryctes splendens* and *Otomys helleri*. Karyological and molecular analysis were conducted in the laboratory of A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences from May 10 to June 10, 2015 and from April 20 to May 20, 2016. In addition, the specimens from the study area collected during the Joint Ethiopian-Russian Biological Expedition (JERBE) from 2012-2016 were used. All voucher specimens are housed in the Natural History Museum of the Addis Ababa University, Ethiopia, and the Zoological Museum of the Moscow State University (ZMMU), Russia. The guidelines of the American Society of Mammalogists were followed for the capture, handling and care of mammals.

Tissue sample collection

The tissue samples from liver, kidney, heart and muscle were collected from sacrificed animals for genetic or molecular analysis. As necessary, toe clip and non-lethal wing biopsy of 3-5 mm from non sacrificed small mammals were collected from each representative species recorded at different habitats and altitudinal range of the study area following the procedure of Lavrenchenko *et al.* (2014) and protocol developed by Bulatova *et al.* (2009).

After the selected captured animal was sacrificed by cervical dislocation, information on sex, age, reproductive condition, weight, standard body measurement were recorded and ectoparasites were collected. Then it was dissected for tissue sample collection. Other non-sacrificed individuals were released after important information and non-lethal tissue samples were taken. All equipment for dissection and tissue sampling were cleaned and sterilized by flaming it with 95% euthanized alcohol after the treatment of each individual in order to avoid genetic material contaminations.

The samples from different organs of the same individual were stored in separate labelled and coded 1.5 ml Eppendrof tubes. Each code used for specimen label was linked with date, GPS ID, weather, habitat, trapping session, transect code, grid code, species, sex, age, reproductive condition, mass and standard body measurements.

Bone marrow suspension collection

The techniques for chromosome preparation are based on sources of dividing cells of bone marrow to produce high quality metaphase spreads with good chromosome definition by the use of some chemicals like colchicines, hypotonic and fixative solutions (Bickmore, 2001). For chromosome suspension preparation from the bone marrow of the karyotyped small mammals, the procedures of Tolliver and Robbins (1991), Bulatova *et al.* (2009) and Lavrenchenko *et al.* (2014) were followed.

The selected small mammals were injected intraperitoneally with colchicine in proportion to their body size (0.1 - 0.5% of 0.1 ml/10 g); then the animals were kept in a cage for about an hour, to let the chemical arrest mitotic chromosomes at metaphase stage. Then the animal was sacrificed by cervical dislocation. After standard body measurement and other information was recorded, it was dissected to remove hind leg bones (femur for rodents and shrews and humerus for bats) by cutting through the bones at the ankle and as near the pelvis or arm pits as possible. Then after the extra muscles and fats were trimmed, the bones were cut at epiphysis to create opening into bone marrow cavity at both ends. The bone marrow was washed with slight pressure by 0.075 M KCl filled in 3-cc syringe into centrifuge tube. The bone marrow solution was gently aspirated until more or less homogenous cellular suspension was formed. Then the cell suspension was incubated for 15-30 minutes at about 37°C, in an incubator in the laboratory or water bath adjusted at 37°C at the field. Then the incubated suspension was centrifuged for 2 minutes at 1500 rpm. The supernatant was discarded without disturbing the cell button (pellet). The pellet was fixed in fixative solution consisting of methanol and glacial acetic acid in 3:1 v/v. Centrifugation and fixation processes were repeated 3 times and finally the pellet was suspended in fixative solution and preserved for further chromosomal study in the laboratory.

Staining

Chromosome staining is a banding of chromosomes with a dye by different methods like G-(Giemsa), R-(reverse), C-(centromere) and Q-(quinacrine) banding (Bickmore, 2001). The G-banding (Giemsa-banding) and R-banding (Reverse-banding) techniques produce a characteristic pattern of contrasting dark and light transverse bands on the chromosomes to easily identify homologous chromosomes and construct chromosomal nomenclatures for many species (Bickmore, 2001; Graphodatsky *et al.*, 2011). This is also used to identify abnormalities of chromosome by translocations, deletions, inversions or amplifications of chromosome segments (Bickmore, 2001). After the fixed bone marrow suspension was thoroughly mixed by aspirating, few drops of the cell suspension were splashed on clean dry slide from a height of about half a metre. The slides were then allowed to air dry and stored away until needed for staining (Bulatova *et al.*, 2009; Lavrenchenko *et al.*, 2014). Then prepared slides were stained with 4% Giemsa in phosphate buffer with pH = 7.0 for 15-30 minutes then rinsed in distilled water, air-dried and mounted under a 22x50 mm cover slip in DEPEX mounting medium for routine karyotyping and C-staining for heterochromatin location following Lavrenchenko *et al.* (2014). The stained slides were observed under microscope. Photomicrographs of metaphase plates with good chromosome spreads were taken with x100 objective using a camera-fitted microscope (Lavrenchenko *et al.*, 2014).

5.2.3.6. Molecular and genetic variability

DNA extraction

About 10–30 mg tissue of kidney, liver, heart and muscle (mostly from liver) and toe clip and wing biopsy preserved in 96% alcohol were removed for lyses in proteinase K. The DNA was extracted using a standard phenol/chloroform/acetate alcohol protocol (Van Vuuren *et al.*, 2004; Lavrenchenko *et al.*, 2014).

For the amplification and polymerase chain reaction, Lavrenchenko *et al.* (2014) procedure was used (Plate 3). Complete cytochrome *b* (*cyt-b*) was amplified by PCR with the

Plate 3. Molecular work at the Laboratory of A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences

combination of the forward and backward appropriate primers for each species. The DNA extract was amplified by PCR in 20 µL reaction volume containing the following: 2 µl of 10x PCR reaction buffer, 0.8 µl of 50 mM $MgCl_2$, 2 µl of 2.5 mM dNTP, 0.3 µl of each primers, 0.2 µl of BioTaq DNA polymerase, 11 µl of H_2O and 2 µl template DNA. PCRs were performed under the following temperature profile: hot start at 95°C for 3 minutes, 35 cycles of denaturation at 94°C for 30 seconds, annealing at 50°C for 30 seconds, elongation at 72°C for 1 minute and a final elongation at 72°C for 10 minutes. To check the amount and quality of PCR product or the extracted DNA, Gel Agarose electrophoresis was performed.

Sequencing

All PCR products were purified by ethanol precipitation and sequenced directly by ABI PRISM 310 DNA automatic analyser (Applied Biosystems, Forster City, CA, USA) (Lavrenchenko *et al.*, 2014). Two or three overlapping PCR fragments were then assembled and checked for consistency to produce complete cyt *b* sequences (Stadelmann *et al.*, 2004).

The sequences were checked for quality and aligned by eye. Sequences were aligned using MEGA6 (Tamura *et al.*, 2013) and Chromas LITE (Technelysium Pty Ltd, 2012) and alignments were checked manually. To avoid erroneous inclusion of Numts (nuclear sequences of mitochondrial origin) in the data sets, the codons of the complete cytochrome *b* gene were translated into aminoacids to check for non-functional mutations. The sequences were submitted to the Gene Bank and the sequence data on relevant species of small mammals from Gene Bank were used (Lavrenchenko *et al.*, 2014). All sequences were also assembled, edited and aligned manually with the software BioEdit (Stadelmann *et al.*, 2004).

5.2.3.7. Ectoparasite collection

Rodents and shrews selected for further molecular and morphological studies were sacrificed whereas animals under protection by the EWCA were anaesthetized with chloroform or diethylether. To anaesthetize animals, a small piece of cotton was socked with diethylether or chloroform and placed inside the sealed cellophones bag for a few minutes. The anaesthetized individual was placed in special cloth bags before examining for ectoparasites. This is because many ectoparasites are host-specific and putting in a separate bag avoids contamination among hosts. Since collection of ectoparasite and handling of live bats is relatively easy, ectoparasites were collected from most bats before they were released after non-lethal wing biopsy with the exception of the selected sacrificed individuals. Bags were turned inside out, and their contents were shaken for collection of the ectoparasites and to reduce the chance of parasite-contamination between species.

Ectoparasites were collected from rodents and shrews by using slight modification of the procedures used by Lareschi *et al.* (2006), Oguge *et al.* (2009), Changbunjong *et al.* (2010) and Madinah *et al.* (2011). The sacrificed animals or anaesthetized animals were removed from the bag or trap. Then they were placed on a special white sheet paper with good contrasting background in the field and combed from the tail end forward with a fine tooth comb or brush. Particular attention was also given to ectoparasite collection from eye-lids, ear-lobes, ear fringes, chins, muzzles and other hidden parts of the body as necessary by using fine forceps besides the fine tooth comb and brush. The dislodged ectoparasites that fell from the host on paper were carefully examined and collected with a fine pointed forceps or by applicator stick wetted with alcohol. In addition, gentle continuous breath was also used to find ectoparasite inside fur from where they were hidden and firmly attached. They were immediately collected by the help of fine forceps with care. For a release animal, the collection of ectoparasites took place for the first capture only. Since the ectoparasites were directly collected from host animals, no attempt was made to collect ectoparasites off-host or its habitat (Changbunjong *et al.*, 2010). For the collection of the fast moving ectoparasites like fleas, a modified method by Kanchev *et al.* (2012) was used by spraying animal hair with alcohol or alcohol socked cotton rather than synthetic pyrethroid solution.

Procedures for collection of ectoparasites from bats followed the methods of Changbunjong *et al.* (2010) and Presley (2011). Special attention was also given to the wing membranes, eyelids, ear lobes and nose. The fur of bats was parted by forceps and by gentle breath to examine ectoparasites. While a bat was removed from the net and searched for parasites, a cloth bag was wrapped around the body as much as possible to reduce the number of ectoparasites that could escape. To prevent contamination of samples, bats were placed in separate cloth bags before processing. Fine forceps were used to remove all ectoparasites observed on the bats.

The collected ectoparasites from small mammals were placed in collection vials containing 70% ethanol. Separate labelled vials were used for each animal following the Madinah *et al.* (2011) technique for further processing. In the field, all ectoprasites collected from one individual were placed in one vial. The vials containing ectoparasites were labelled with a code linked with information on the date of collection, basic information host (species, sex, age, reproductive condition and standard body measurements), GPS coordinate, altitude, habitat type, season and weather condition (Appendix 5). The prepared Voucher specimens of ectoparasites were deposited at the Natural History Museum of Addis Ababa University.

5.2.3.8. Small mammal damage and local communities perception

Survey of the knowledge, attitudes and practices (KAP) of farmers was conducted on the identification of the major groups of pest small mammals, extent of damage and means of control during March 2014 to December 2015. Data were also collected from the nine peasant associations in Tiyo and Hetosa District that borders with Mount Chilalo (Figure 3). During data collection similar KAP surveys methods undertaken in Philippines by Stuart *et al.*, (2011), in Ethiopia by Meheretu Yonas *et al.* (2010) and Mohammed Kasso (2013), in Myanmar by Brown *et al.* (2008) and in Botswana by Obopile *et al.* (2008) was followed.

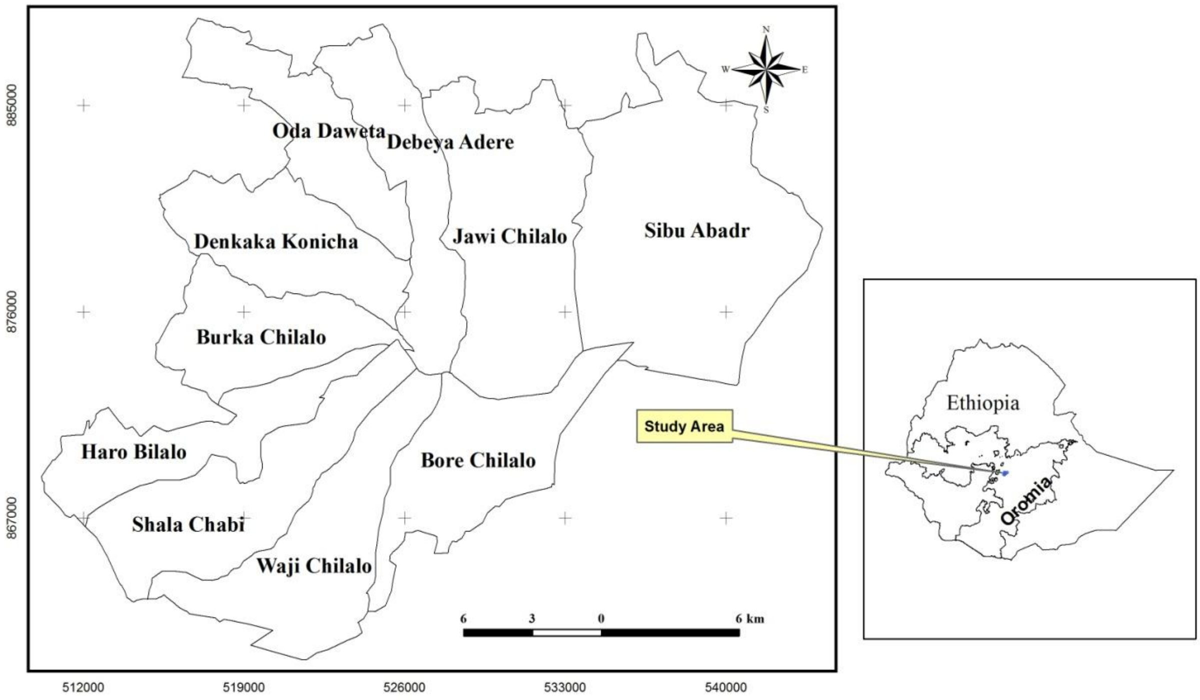


Figure 3. Map of the nine Peasant Associations surrounding Mount Chilalo

A total of 370 households from both sexes (252 males and 118 females) from 9 peasant associations or counties namely Bore Chilalo, Burka Chilalo, Dabaya Adarie, Denkaka Kunicha, Jawi Chilalo, Oda Dhawata, Shala Chebeti and Sibu Abadir were randomly selected based on the following formula.

$$n = \frac{[(z^2 * p * q) + ME^2]}{\left[ME^2 + \frac{z^2 * p * q}{N}\right]}$$

Where:

Z = 1.96, *ME* (Standard error) = 0.05, *N* (total number of households) = 9821, *p* (confidence interval) = 0.5 and *q* = 1-*p*

$$\frac{[(1.96^2 * 0.5 * 0.5) + 0.05^2]}{\left[0.05^2 + \frac{1.96^2 * 0.5 * 0.5}{9821}\right]} = 370$$

Then the total number of respondents selected from each peasant association was calculated based on the proportion of number of households in each PA (Table 4).

Table 4. Members of households in each PA of which households selected

Peasant Association	Male		Female		Grand total	
	Total	Selected	Total	Selected	Total	selected
Bore Chilalo	736	28	352	13	1088	41
Burka Chilalo	606	23	246	9	852	32
Dabaya Adarie	561	21	279	10	840	31
Dankaka Kunicha	709	27	311	12	1020	39
Haro Bilalo	780	29	360	14	1140	43
Jawi Chilalo	719	27	357	13	1076	40
Oda Dewata	793	30	407	15	1200	45
Shala Chebeti	628	24	242	9	870	33
Sibu Abadir	1160	44	575	22	1735	66
Total	6692	252	3129	118	9821	370

Source: Arsi Zone Landuse and Natural Resource Department

The number of male and female respondents selected is also based on the proportion of the number of male and female households in each PA (Table 4).

Each farmer was interviewed individually using a pre-tested and revised open and close ended questionnaire (Appendix 9). Most questions emphasized on the awareness of farmers on pests particularly on rodents, extent of damage and pest management methods with few questions the socio-economic background of the farmers. Each interview was conducted by translations to the local languages (Afan Oromo or Amharic) based on the respondents preference by principal researcher either at the farmer's home or in crop fields. On average, the interview took 45 minutes to one hour for each farmer. The questionnaire was divided into two sections. The first section deals with background information on socio-demographic characteristics of the farmer such as, address, age, sex, size of family, source of income, land size and on types of frequently cultivated agricultural crops. The second section deals with the farmers perception on the major pest mammals, extent of damage, types of damage and beliefs and practices on their management. To assess their attitude or perceptions on small mammal management, farmers were given a series of statements and asked to rate them on different point Likert scale based on the questions and possible answers.

5.2.3.9. Conservation of small mammals

The questionnaire was prepared in English and translated into the Afan Oromo language, as most of the respondents were Oromo (Appendix 8). In addition, Amharic language was also used whenever there was a need to clarify the questions and terms. All of the interviews were conducted by an experienced researcher who is native to the area and his mother tongue is Afan Oromo. Before each interview, the respondent was assured as his or her participation was completely voluntary and his options or suggestion is confidential and only used for the use of this study.

The total number of selected respondents from each peasant association is given in Table 4. Stratified random sampling was used to sample households based on the household settlement distance from the protected area such as residents inside the protected area, residents at the border or near the protected area and residents far away from the protected area were considered. Based on their interest and time availability out of 370 respondents interviewed for pest animal damage assessment, 270 were also interviewed for their perceptions on the conservation of small mammals and their habitat whereas the reremainig 100 were exclusively interviewed for conservation survey.

5.3. Data analysis

The collected data were tabulated and organized. Both qualitative and quantitative data were analysed with appropriate statistical method. IBM®SPSS® Statistics Version 24 computer program and PAST (Paleontological Statistics Software package for Education and Data Analysis) Version 3.14 Statistical computer programs were used (Hammer *et al.*, 2001). Appropriate statistical methods such as mean, standard deviation and standard error of the mean, percentage and Chi-square test were used. Different diversity indecies like species richness, dominance, Simpson similarity, Shannon-Wiener, evenness and Chao-1 diversity indices were computed by using PAST Version 3.14.

5.3.1. Species identification

All the observed (directly or indirectly) and trapped mammals were identified to species level by using the taxonomic characters listed in Kingdon (1974; 1997; 2004; 2013; 2016), Yalden and Largen (1992), Afework Bekele (1996), Nowak (1999), Wilson and Reeder (2005), Happold (2013) and Happold and Happold (2013). Whenever identification becomes difficult in the field, the skins and skull of voucher specimens prepared from the representative specimens were compared with collected museum specimens in the Zoological Natural History Museum, Addis Ababa University and Zoological Museum of Moscow State University. Some species were identified by using modern karyological and molecular methods. Karyological and molecular analyses from tissue samples were conducted with the appropriate equipment and software in the Laboratory of A.N. Severtsov Institute of Ecology and Evolution of Russian Academy of Sciences in Moscow. All captured bats were identified to species level by the help of field guides (Kingdon, 2004; 2013; 2016), Happold and Happold (2013) and comparing representative samples and alcohol preserved specimens with the vouchers in Natural History Museum of Addis Ababa University and Zoological Museum of Moscow State University and molecular analysis sequence was carried out. Information on morphometric measurements, sex, age and reproductive condition was obtained from all captures used in identification. In addition, the molecular sequence and analysis from the tissue and wing biopsy in the laboratory of

Estacion Biologica de Donana (Spain) were also used for the confirmation of species identified by classical morphometric methods.

5.3.2. Small mammal abundance and distribution

Mark recapture analysis can also be used to estimate other population parameters such as population size, density, abundance and relative abundance (Lettink and Armstrong, 2003). To evaluate abundance, the relative abundance of each trapped species was computed based on the percentage of trap success or the total number of individual captured per 100 trap nights from Sherman live traps. The key issues to consider when designing a closed population mark-recapture study are the number of capture sessions, their timing, and the number and arrangement of traps (Lettink and Armstrong, 2003). The relative abundance was computed based on capture-mark-recapture, total count, and number of population from indirect observations. Habitat preference of small mammals was computed based on the relative or mean abundance and the significance level of difference was tested by using Chi-square ($\chi 2$) test at 95% of level significance for critical probability.

The number of rodent burrows in a given area is a useful index of the relative abundance for many ground-dwelling species (Aplin *et al.*, 2003). Hence, for mole rats, fresh burrow counts were used for estimation of abundance (Aplin *et al.*, 2003). The quil, scat and burrow for porcupine observation was used as index for abundance and existence of porcupine in the area.

Trap success for each grid was calculated based on the record of trap status for each grid for all trapping session. Trap status was obtained by total capture (new capture and recapture) of rodents and shrews by total trap night.

$$TS = \frac{C}{TN} x 100\%$$

Where:

TS = refers percentage of trap success

C = total capture of small mammal (new capture and recapture)

TN = total trap night

Traps that have been triggered without making a capture (sometimes called ‘null traps’) should be subtracted from the total (Aplin *et al.*, 2003). Since trap failure due to different reasons, the effective trap success (ETS) was also computed using effective trap nights (ETN). Effective trap nights for each grid was obtained by excluding the trapnights with trap failure due to closing of Sherman live traps by wind or trigger failure or by trap damage, loss or removal from its station by predators of small mammals, children or thieves.

$$ETS = \frac{C}{ETN} x100\%$$

Where:
ETS = refers percentage of effective trap success
C = total capture of small mammal (new capture and recapture)
TN = total effective trap night

For the analysis of abundance, mean abundance, relative abundance, proportion, age, sex, reproductive condition, distribution, habitat preferences, altitudinal distribution and for impacts of *Erica* fire and plantation or habitat modification, only the new captures of small mammals were used. Since there were variations in the number of grids in each habitat to simiplfy the comparesion the mean and relative abundance were computed. The mean abundance for each habitat and altitudinal zonation gradient was calculated by dividing the number of new individuals recorded in the habitat or altitudinal zonation gradient by total number of grids in each habitat or altitudinal zonation.

Comparing captures among areas or time periods with mist netting surveys can be complicated because of differences in trapping effort (Perry *et al.,* 2010). These differences include mist net with different sizes or numbers of nets and differences in time where nets are open and number of netting night. Hence, to standardize the modified capture rate (CR) estimates, method applied by Perry *et al.* (2010) were used for the overall capture rate and trapping sites.

$$CR = \frac{C}{TNMH}$$

Where:
CR = Capture rate
C = new individuals bat captures

TNMH = total length (m) multiplied by height (m) divided by total net open hours.

Net-Night (NN) was computed by multiplying the number of each type of mist net by its number of netting night. That is one Net-Night is equivalent to one net open for one evening.

The capture rate of each bat species was calculated as total new individual capture of each species divided by overall capture effort. The relative abundance of each species of bats was computed by dividing new individual capture by total capture excluding recaptures. The overall sex ratios was estimated without including recaptures and individuals escaped and its ratios difference from 50:50 was tested using chi-square tests. All averages were presented as means ± standard error and all statistical tests were conducted at alpha = 0.05.

To check the quality of the survey and the extent of the inclusion of the species assemblage in the study area, the species accumulation curve was plotted by using PAST (Hammer *et. al.*, 2001). Species-accumulation curves were built by using the cumulative number of captured species against the total number of captured species. To compensate the bias related with mist netting and trap effort, the species accumulation curves were drawn using all captures and captures of the dominant and widely distributed species only. Accumulation curves for total captures and captures in each sampling sites were plotted separately. A Shannon-Wiener Diversity Index of bat captures was calculated for each habitats and total captures (Flaquer *et al.*, 2007).

For rodent and shrew population estimation, the Schnabel method was used. As Schnabel Methods allows for more than 2 capture-recapture encounters and can be applied to minimum of 3 trapping session's captures (Alcoy, 2013). In addition to this, it distinguishes two types of individuals which are caught in one or more prior samples and marked and which were never caught before and unmarked (Alcoy, 2013).

It was computed as follows:

$$\frac{\sum_{t=1}^{m} MiCi}{\sum_{t=1}^{m} Ri}$$

Where:

Mi = the total number of previously marked animals at time i,

Ci = the number caught at time i, and
Ri= the number of marked animals caught at time i.

To standardize the comparison among the habitats, mean population estimation was computed by dividing the total estimated population by the number of grids in particular categories (habitat). A standardized trap data for abundance was used in all analyses (captures/grid-night) (Letnic *et al.*, 2013). Trap effort was standardized for each grid for each trapping session by dividing the numbers of animals caught by the number of nights that grids were open.

Based on population estimation, the density of each species was determined as the total population number per hectare (10, 000 m^2). The effective trapping area of the grids was calculated by adding the border strip half the distance between the trap stations (7. 5 m) as suggested by Krebs (1999).

Biomass of rodents and shrews per hectare was estimated based on the total weight of new individuals of adults captured.

5.3.3. *Erica* Fire

Data were examined and Chi-square ($\chi 2$) used to test for differences among habitat types, sampling dates, sites and environmental attributes. Nested repeated measure analysis of variance was used to test for differences in small mammal species abundance between trap sites and post-fire interval by using the slight modification of Radford (2012) procedures.

Since there was variation in the number of trap night in the categories of time since *Erica* fire capture per 100 trap-nights was used for the comparative capture of rodents and shrews in the categories:

$$CTN = \frac{C}{TN} x100$$

Where:
CTN = capture per 100 trap night
C = total new captures in the specific category
TN = total trap night in particular category

In similar way, mean capture per 100 trap night and its mean relative abundance was used for each species in each categories of time since *Erica* fire. All the decimal numbers above zero were roundedup as there was at least one individual of that particular species captured.

5.3.4. Small mammals elevation gradients

Relative abundance of small mammals was estimated as the number of animals captured per 100 trap-nights. Species accumulation curve was used to determine the likelihood that all species had been sampled at given sites and transects (Heaney, 2001).

Species richness along gradients and number of incidence of each species along altitudinal gradient were quantified through the total number of species present at each band. The diversity indecies of rodents and shrews along altitudinal zonations were computed for comparison. The proportion of rodents and shrews along each altitudinal zonation was calculated dividing total abundance in particular altitudinal zonation band by total new individuals captures.

5.3.5. Chromosomal variability

Chromosomal analysis was performed from the somatic metaphases. Diploid number (2n) was determined from metaphase chromosome counts. The autosomal fundamental number (FNa) was determined as the total number of autosomal arms. Microphotographs were scanned into a computer and chromosome set was formed by arranging it based on size and shape. Chromosome length and centromeric position were used to arrange putative homologous chromosomes into pairs and used for characterization as metacentric, subtelecentric and acrocentric.

5.3.6. DNA variability and phylogenetics

The phylogenetic analysis from the sequence result followed the methods used by Stadelmann *et al.* (2004), Van Vuuren *et al.* (2004) Lavrenchenko *et al.* (2014) and Meheretu Yonas *et al.* (2015).

Phylogenetic reconstructions were performed for the entire sequences of the cyt- *b* gene using Neighbour Joining (NJ) method implemented in MEGA version 6 computer programs and topology was aslo compared with those, obtained by Maximum Likelihood (ML) method (Tamura *et al.*, 2013). To polarize characters, appropriate out-group taxon was denoted.

The NJ tree was reconstructed using the uncorrected *p* distance (Saitou and Nei, 1987). Clade stability of the NJ tree was assessed by boots trapping with 10000, respectively. The evolutionary distances and divergence were computed using the p-distance method and are in the units of the number of base differences per site or within clades were computed as uncorrected *p* distances with the software Mega version 6.1 (Nei and Kumar, 2000; Tamura *et al.*, 2013). Divergence times for all branching points in the topology were calculated with the Real-time method using the branch lengths contained in the inferred tree (Tamura *et al.*, 2012). The distance between populations could be defined either on the basis of their pedigree relationship or their genetic composition (Farshadfar, 2012). In most cases, the bootstrap values for nodes are presented only when more than 75% support (Van Vuuren *et al.*, 2004) was obtained for at least one method of analysis.

The evolutionary history was inferred using the Neighbour-Joining method. The optimal tree with the sum of branch length was also determined for each tree. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (10000 replicates) branches used (Felsenstein, 1985). The evolutionary distances were computed using the p-distance method and are in the units of the number of base differences per site. In constructing the phylogeogratic tree, 1st+2nd+3rd+Noncoding codon positions were included and all positions containing gaps and missing data were eliminated (Tamura *et al.*, 2013).

5.3.7. Ectoparasite

The host species were identified using field guide books (Kingdon, 1997; 2004; 2013; Happold and Happold, 2013; Happold, 2013) and by comparing the prepared voucher specimen with museum collections. Cryptic and sibling species were identified by using molecular technique in the laboratory of A.N. Severtsov Institute of Ecology and Evolution, Russian Academy of Sciences and in Estacion Biologica de Donana (Spain). Preserved ectoparasites were sorted based on their morphology. Species were identified using field guide books and by the help of experts to lowest possible taxonomic category.

Preliminary identification of the preserved ectoparasites was made under dissecting microscope by flushing the content from vial to clean petridish. Preserved ectoparasites were sorted based on their morphology (Madinah *et al.*, 2011). All preserved ectoparasites, excluding ticks, were later mounted for identification. A cover slip was used. Occasional light pressure was exerted using a sharpened applicator stick, on areas of the cover slip surrounding each specimen. Mounted slides were then incubated at 40ºC for a week. The cover slips were ringed with nail polish to prevent desiccation of the medium during storage (Madinah *et al.*, 2011).

All preserved ectoparasites were later treated and voucher specimens (slides) were prepared in Pathology and Parasitology Laboratory of College of Veterinary and Agriculture of Addis Ababa University. Based on their size and visibility, the slides were examined under compound and dissecting microscope (magnification 40x, 100x, 400x and 1,000x) for identification in the laboratory. Larger ectoparasites were identified using a stereo microscope or dissecting microscope.

The prepared slides were photographed with Sony digital camera as well as under binocular microscope at 100x zoom and photographed by PC-digital camera. Ectoparasites were identified to families, genera and species levels when possible using available keys, published taxonomic drawings and references and by consultation with experts. The species composition of the parasitic arthropods was identified by means of morphological marks and based on different modern references.

For the statistical analyses, only the first capture and adult animal was used. Juveniles were excluded because they are likely to have different parasite loads than adults.

For ectoparasite and host association analysis, the definition provided by Margolis *et al.* (1982) for ecological terms in parasitology were used. Additionally the modified methods used by Lareschi *et al.* (2006), Meheretu Yonas *et al.* (2011), Presley (2011) and Saraiva *et al.* (2012) were also followed. The parameters used in the analysis were prevalence (P), Abundance (A), mean abundance (MA), Relative Abundance (RA), mean intensity (MI) and constituent ratio (C). These parameters were calculated using the following formula:

Prevalence (P) was obtained as the percent of hosts infected with 1 or more individuals of a particular parasite species/taxon divided by the number of hosts examined for that parasite species/taxon.

$$P = \frac{Hpi}{Ht} x100$$

Where:

Hpi = the number of the host species or taxon infested with 1 or more individuals of a particular parasite species or taxon

Ht = the total number of host examined for that particular parasite taxon (infested and none infested)

Abundance (A) is the total number of individuals of ectoparasites of the same species recovered from a particular host txon.

Mean abundance is the total number of individuals of a particular parasite species in a sample of a particular host species divided by the total number of hosts of that species examined (including both infected and uninfected hosts). It is thus the average abundance of a parasite species among all members of a particular host population. Mean abundance (MA) was obtained by using the formula:

$$MA = \frac{Pi}{Hti}$$

Where:

Pi = total number of individuals of a particular parasite species infesting a particular host species

Hti = total number of hosts of that species including both infected and non-infected hosts

Relative Abundance (RA) is mean number of individuals of a particular parasite species per host examined. It is computed by dividing the total number of individuals of a particular parasite species in a sample by total number of individuals of the examined host species (infested and none infested) in the sample.

$$RA = \frac{Pti}{Ht}$$

Where:

RA = relative abundance

Pti= total number of a particular parasite species/taxon i

Ht = total number of host examined

Mean intensity (MI) is the average intensity of a particular species of parasite among the infected members of a particular host species. It is computed by dividing the total number of parasites of a particular species found in a sample by the number of hosts infected with that parasite. Mean intensity (MI) was calculated as:

$$MI = \frac{Pti}{Hpt}$$

Where:
Pti = refers total number of ectoparasite collected
Hpt = refers total number of parasitized host

Constituent ratio (C) was computed as:

$$C = \frac{Pti}{Pt} x100\%$$

Where:
Pti = represents the total number of individual ectoparasites in group *i*
Pt = represents the total number of ectoparasites in the sample (Wei *et al.,* 2010).

Non-parametric Chi-Square test was used to test significance of differences among the selected parameters.

The potential public risk was documented based on the presence or absence of the ectoparasites that can serve as vector or transmission of diseases that attack human and domestic animals (Changbunjong *et al.,* 2010).

5.3.8. Pest mammals and conservation of small mammals

The surveyed data from the questionnaire were encoded, entered in Microsoft Excel 2007 spreadsheet and checked prior to analysis. Then data were exported to SPSS for Windows, version 16.0 for analysis. Frequencies and percentage were calculated using cross tabulation. Percentages were based on either the total number of respondents or total responses, details of which are provided in the respective tables or figures. For some questions since some farmers gave multiple responses to the same questions, the percentages may exceed 100. Chi-squared tests in SPSS were used to examine the pair-wise association of provisionally selected variables to check their level of significance.

6. RESULTS

6.1. Species composition

Species composition of small mammals collected during the study period is given in Table 5. A total of 36 species of small mammals were recorded comprising 18 species of rodents five species of shrews and 13 species of bats. These species belonged to three orders namely Order Rodentia, Order Chroptera and Order Philodotyphylla and 10 families and 21 genera. Relatively from Order Chiroptera more number of families whereas from Order Philodotyphylla only one family and Genus were recorded. The family with more number of species (13) was recorded for Muridae contrary to this Hystricidae, Spalacidae, Hipposideridae and Rhinolophidae had only one Genus and species.

From the 36 recorded species, one endangered, two vulnerable (VU), three near ‘threatened (NT), three data deficient (DD) and two not evaluated (NE) species and the remaining 25 (69.4%) were least concern (LC). Small mammals threatened, data deficient and not evaluated comprise 30.56% of the recorded small mammals. In addition, out of the 36 species at least 18 species or 50% were endemic to Ethiopia (Plate 4).

Table 5. Species of small mammals recorded from the study area

Family	Species	Common name	Determintor(s)	IUCN 2016
Hystricidae	*Hystrix cristata*	Crested Porcupine	Linnaeus, 1758	LC
Muridae	*Arvicanthis abyssinicus**	Ethiopian (Abyssinian) Grass Rat	Ruppell, 1842	LC
	*Arvicanthis blicki**	Blick’s Grass Rat/Blick’s Arvicanthis	Frick, 1914	NT
	*Lophuromys brevicaudus**	Short-Tailed Brush-Furred Rat	Osgood, 1936	NT
	*Lophuromys chrysopus**	Golden-Footed Brush-Furred Rat (Ethiopian Forest Brush-Furred Rat)	Osgood, 1936	DD
	*Lophuromys melanonyx **	Black-Clawed Brush-Furred Rat	Petter, 1972	VU

	Mastomys natalensis	Natal Multimammate Mouse	Smith, 1834	LC
	*Mus imberbis**	Ethiopian back-striped Mouse	Ruppell, 1842	LC
	*Mus mahomet**	Mahomet Pygmy Mouse	Rhoads, 1896	LC
	*Otomys helleri**	Ethiopian Vlei Rat	Frick, 1914	NE
	Rattus rattus	House Rat, Roof Rat, Black Rat	Linnaeus, 1758	LC
	*Stenocephalemys albipes**	White-Footed Ethiopian Rat	Ruppell, 1842	LC
	*Stenocephalemys albocaudata**	White-Tailed Ethiopian Rat/Ethiopian Narrow-Headed Rat	Frick, 1914	LC
	*Stenocephalemys griseicauda**	Grey-Tailed Ethiopian Rat /Gray-Tailed Narrow-Headed Rat	Petter, 1972	LC
Nesomyidae	*Dendromus* sp.1*	Undescribed new African Climbing Mouse	-	NE
	*Dendromus lovati**	Lovat's Climbing Mouse	de Winton, 1900	LC
	*Dendromus nikolausi**	Nikolaus's Mouse	Dieterlen and Rupp, 1978	E
Spalacidae	*Tachyoryctes splendens*	African Root-Rat/ East African Mole Rat	Rüppell, 1835	LC
Soricidae	*Crocidura fumosa*	Smoky Mountain White-Toothed Shrew	Thomas, 1904	LC
	*Crocidura glassi**	Glass's Shrew (Ethiopian Mountain Shrew)	Heide Balsac, 1966	NT
	*Crocidura lucina**	Lucina's (Moorland)Shrew	Dippenaar, 1980	VU
	Crocidura olivieri	African Giant Shrew / Olivier's Shrew	Lesson, 1827	LC
	*Crocidura thalia**	Thalia's Shrew	Dippenaar, 1980	LC
Hipposideridae	*Hipposideros caffer*	Sundevall's Leaf-Nosed Bat/Cape Leaf-Nosed Bat	Sundevall, 1846	LC
Miniopteridae	*Miniopterus inflatus*	Greater Long-Fingered Bat	Thomas, 1903	LC
	Miniopterus natalensis	Natal Long-Fingered Bat (Natal Clinging Bat)	A. Smith, 1834	LC

Pteropodidae	*Epomophorus gambianus*	Gambian Epauletted Fruit Bat	Ogilby, 1835	LC
	Stenonycteris lanosus	Long-Haired Rousette	Thomas, 1906	LC
Rhinolophida	*Rhinolophus fumigatus*	Ruppell’s Horseshoe Bat	Ruppell, 1842	LC
Vespertilionidae	*Kerivoula lanosa*	Lesser Woolly Bat	A. Smith, 1847	LC
	Myotis tricolor	Temminck’s Hairy Bat)	Temminck, 1832	LC
	Neoromicia capensis	Cape Pipistrelle Bat/Cape House Bat	A. Smith, 1829	LC
	Neoromicia nanus	Banana Pipistrelle (Banana Bat)	Peters, 1852	LC
	Pipistrellus aero	Mt Gargues Pipistrelle	Heller, 1912	DD
	Pipistrellus hesperidus	Dusk Pipistrelle/African Pipistrelle	Temminck, 1840	LC
	*Plecotus balensis**	Bale Long-Eared Bat	Kruskop and Lavrenchenko	DD

E= endangered, LC=least concern, DD= data defiant, NT= near threatened, VU=Vulnerable, NE= not evaluated, *=endemic species to Ethiopia

6.2. Trap status and trap success

The highest (78%) trap success and highest (85.71%) effective trap success was recorded for grid CH-03. The least (27%) trap success was recorded for Grid CH-02 and CH-AS3 (Table 6). The extra ordinary highest trap success of 136.7% and 152% for effective trap success was spotted for Gal-04 from extensive study grids because of more number of nocturnal and diurnal capture rates. It was followed by Gal-03 (100%) and 120% whereas the least was recorded for CHE-05 with trap success and effective trap success of 56.67% and 62.96%, respectively (Table 6).

From the intensive study grids, traps that captured animals (C) were 4014 whereas those traps that did not captured any (NC) were 12661, the closed (Cl) 538 and the damaged, lost and removed from its station were 69 and without food (NF) were 718 during the entire 18000 day and night trapping sessions (Table 6).

Table 6. Trap status and success for each study grids

Type	Grid	Trap status						TN	TS (%)	ETN	ETS (%)
		C	Cl	DL	NF	NC	Total				
Intensive	CH-23	234	33	-	21	312	600	300	78.00	273.00	85.71
	CH-22	233	37	2	17	311	600	300	77.67	272.00	85.66
	CH-24	224	30	2	6	338	600	300	74.67	281.00	79.72
	CH-03	184	14	1	66	335	600	300	61.33	259.50	70.91
	CH-05	180	32	2	17	369	600	300	60.00	274.50	65.57
	CH-18	179	27	2	19	373	600	300	59.67	276.00	64.86
	CH-21	178	29	5	19	369	600	300	59.33	273.50	65.08
	CH-01	171	17	9	26	377	600	300	57.00	274.00	62.41
	CH-16	170	18	-	69	343	600	300	56.67	256.50	66.28
	CH-14	168	25	7	12	388	600	300	56.00	278.00	60.43
	CH-15	162	21	-	15	402	600	300	54.00	282.00	57.45
	CH-09	150	18	-	54	378	600	300	50.00	264.00	56.82
	CH-19	143	14	5	66	372	600	300	47.67	257.50	55.53
	CH-04	130	12	-	18	440	600	300	43.33	285.00	45.61
	CH-17	127	16	-	20	437	600	300	42.33	282.00	45.04
	CH-Ag	123	14	-	40	423	600	300	41.00	273.00	45.05
	CH-08	116	12	-	36	436	600	300	38.67	276.00	42.03
	CH-AS2	112	26	-	27	435	600	300	37.33	273.50	40.95
	CH-13	112	12	-	15	461	600	300	37.33	286.50	39.09
	CH-12	108	12	-	12	468	600	300	36.00	288.00	37.50
	CH-Wal	105	9	6	10	470	600	300	35.00	287.50	36.52
	CH-11	97	5	-	27	471	600	300	32.33	284.00	34.15
	CH-As1	94	15	1	4	486	600	300	31.33	290.00	32.41
	CH-20	91	10	-	2	497	600	300	30.33	294.00	30.95
	CH-06	87	13	11	3	486	600	300	29.00	286.50	30.37
	CH-AS4	86	12	-	27	475	600	300	28.67	280.50	30.66
	CH-AS3	81	12	1	42	464	600	300	27.00	272.50	29.72
	CH-07	80	20	-	4	496	600	300	26.67	288.00	27.78
	CH-02	70	10	7	4	509	600	300	23.33	289.50	24.18
	CH-10	19	13	8	20	540	600	300	6.33	279.50	6.80
Sub-total		4014	538	69	718	12661	18000	9000	44.60	8337.5	48.14
Extensive	CH-Bat	13	2	-	4	11	30	15	86.67	12.00	108.3
	CHE-01	23	-	-	3	34	60	30	76.67	28.50	80.70
	CHE-02	22	-	-	3	35	60	30	73.33	28.50	77.19
	CHE-03	22	-	-	2	36	60	30	73.33	29.00	75.86
	CHE-04	42	-	-	3	45	90	45	93.33	43.50	96.55

	CHE-05	51	4	4	10	111	180	90	56.67	81.00	62.96
	GAL-01	19	2	-	3	36	60	30	63.33	27.50	69.09
	GAL-02	40	5	1	5	39	90	45	88.89	39.50	101.3
	GAL-03	15	3	-	2	10	30	15	100.0	12.50	120.0
	GAL-04	41	2	1	3	13	60	30	136.7	27.00	151.9
	S. Total	288	18	6	38	370	720	360	80.00	329.00	87.54
	G. Total	4302	556	75	756	13031	18720	9360	45.96	8666.50	49.64

C= captured, Cl=closed, DL= damaged, lost or removed from the station, NF= no food, NC= not captured, TN= trap night, TS= trap success, ETN= effective trap night and ETS= effective trap success, (-)= absence , S.Total=sub Total, G. Total=Grand total


a

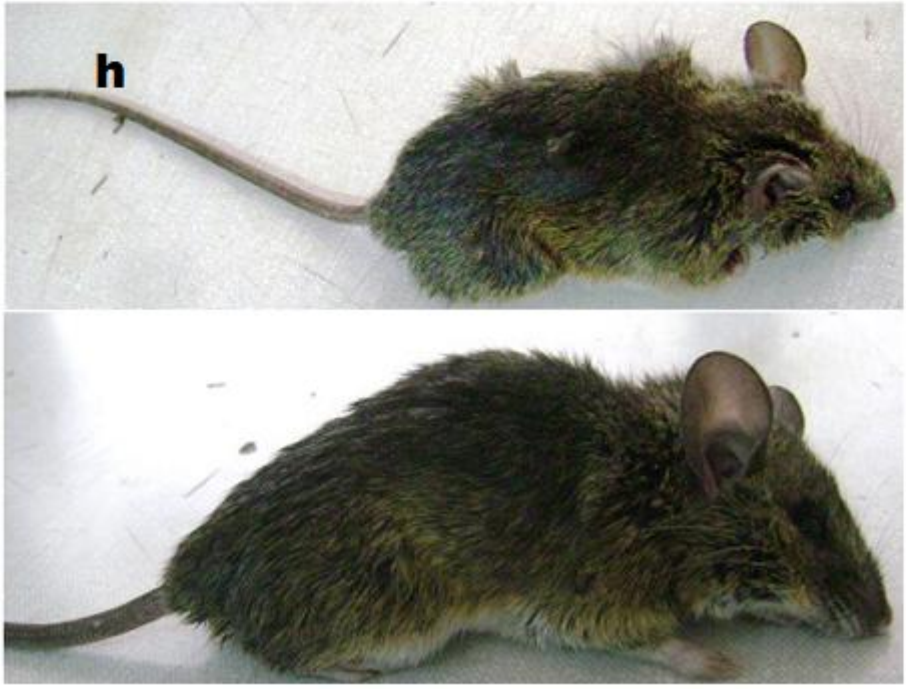

b
A
B
B
A
A. Lophuromys melanonyx, A. Lophuromys brevicaudus


c
d


e


f


g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i

Plate 4. Some species of rodents and shrews captured from the study area

(a. *Arvicanthis abyssinicus,* b. *Lophuromys brevicaudus* and *L. melanonyx* c. *Dendromus lovati* d. *Dendromus* sp.1 e. *Arvicanthis blicki* f. *Mastomys natalensis* g. *Muriculus imberbis* h. *Stenocephalemys griseicauda* i. *Otomys helleri* j. *Tachyoryctes splendens* k. *Crocidura glassi*)

The occasions in which Sherman live traps captured two individuals of species of small mammals at one time is given in Table 7. The double capture in a single episode of trapping was recorded for *Arvicanthis blicki*, *C. glassi*, *L. brevicaudus*, *L. chrysopus*, *L. melanonyx*, *M. mahomet*, *S. albipes* and *S. griseicauda*. Out of the 17 occasions or episodes of double capture, the majority 5 (29.41%) was recorded for *L. brevicaudus* followed by *L. melanonyx* 3 (17.65%). Only in one occasion, double capture was observed for *C. glassi*, *M. mahomet* and *S. griseicauda*.

In 7 (41.18%) occasions adult female and sub-adults double capture were documented and followed by adult male and female 3 (17.65%) and sub-adult male 2 (11.76%) (Table 7).

Table 7. Number of occasions and trap status description for two captures of small mammals at single trapping Sherman live trapping session

Trap status description	Species and number of occasions								Total	%
	Ab	Cg	Lb	Lc	Lm	Mm	Sp	Sg		
Adult female and sub-adult	1	-	2	1	1	-	1	1	7	41.18
Adult male and female	-	-	1	1	-	1	-	-	3	17.65
Sub-adult male	1	-	1	-	-	-	-	-	2	11.76
Adult male and sub-adult	-	-	1	-	-		-	-	1	5.88
Adult female	-	1	-	-	-	-	-	-	1	5.88
Adult one male and other escaped	-	-	-	-	1	-	-	-	1	5.88
Adult male one with recapture	-	-	-	-	-	-	1	-	1	5.88
Sub-adult female	-	-	-	-	1	-	-	-	1	5.88
Total	2	1	5	2	3	1	2	1	17	100
Proportion (%)	11.76	5.88	29.41	11.76	17.65	5.88	11.76	5.88	100	

Ab=*A. blicki*, Cg=*C. glassi*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mm=*M. mahomet*, Sp=*S. albipes*, Sg=*S. griseicauda*

6.3. Habitat types, grids in each habitat and total captures of rodents and shrews

Habitat types, grids in each habitats and all individual capture of rodents and shrews are presented in Table 8. Overall, 4302 individuals of rodents and shrews were captured, of which, 4074 were rodents 228 were shrews. The variation was strongly statistically significant (χ^2 = 3435.335, df = 1, $p<0.05$). The majority (234) of rodents and shrews are captured from Grid CH-23 whereas the minimum number (19) of rodents and shrews were captured from Grid CH-10. The overall variation among the number of captures from intensive study grids were statistically significant (χ^2 = 573.922, df = 29, $p<0.05$).

From the small mammals captured from intensive study grids, the highest number (850) individuals were recorded for *L. brevicaudus* followed by *S. griseicauda* (717) and *S. albipes* (650). From the shrew species, *Crocidura thalia* (109) was the dominant captured species (Table 8).

Table 8. Habitat types of each grid and individuals captured from intensive and extinsive study grids

Habitat	Grid	Rodentia																Philodotyphylla					Total
		Aa	Ab	Di	Dl	Lb	Lc	Lm	Mn	Md	Mi	Mm	Oh	Rr	Sp	Sc	Sg	Cf	Cg	Cl	Co	Ct	
AL*	CH-Ag	1	-	-	-	-	-	-	36	-	1	30	-	4	31	-	14	-	-	-	6	-	123
BL*	CH-06	-	-	-	-	9	8	-	2	-	-	-	-	-	58	-	10	-	-	-	-	-	87
	CH-Wal	1	-	-	-	-	16	-	11	-	-	2	-	2	73	-	-	-	-	-	-	-	105
EF*	CH-03	-	-	-	-	54	-	-	-	-	-	-	-	-	33	-	78	-	-	-	-	19	184
	CH-04	-	-	-	-	72	-	-	-	-	-	-	4	-	-	4	19	3	16	-	-	12	130
	CH-09	-	-	2	-	46	-	-	-	-	-	-	6	-	-	34	24	6	4	2	-	26	150
	CH-13	2	-	-	1	36	-	-	17	-	-	-	1	-	18	-	35	-	-	-	-	2	112
	CH-14	-	8	-	-	-	-	-	23	-	-	-	-	-	85	-	52	-	-	-	-	-	168
	CH-23	-	30	-	-	128	-	22	-	-	-	-	6	-	-	6	24	-	10	-	-	8	234
ES*	CH-07	-	-	-	-	4	-	-	-	-	-	52	20	-	-	-	4	-	-	-	-	-	80
	CH-08	-	-	-	-	58	-	-	-	-	-	-	8	-	-	3	33	-	5	-	4	5	116
	CH-11	-	-	-	-	36	-	-	-	-	-	2	1	-	6	4	42	-	-	-	-	6	97
	CH-12	2	-	-	-	36	-	-	15	-	-	-	1	-	18	-	34	2	-	-	-	-	108
	CH-16	-	2	-	-	6	-	31	15	1	-	-	-	-	12	36	67	-	-	-	-	-	170
	CH-17	-	-	1	1	67	-	-	-	-	-	-	-	-	-	-	48	1	-	-	-	9	127
	CH-19	-	-	-	-	38	6	-	-	-	-	-	-	-	-	36	63	-	-	-	-	-	143
	CH-20	-	-	-	-	10	-	-	-	-	-	50	20	-	-	-	11	-	-	-	-	-	91
GL*	CH-15	-	6	-	-	36	-	22	-	-	-	-	1	-	-	50	39	-	-	-	-	8	162
	CH-AS4	4	-	-	-	-	1	-	18	-	-	6	-	3	32	-	22	-	-	-	-	-	86
MF*	CH-01	-	-	-	-	24	41	-	6	-	-	-	-	-	88	-	12	-	-	-	-	-	171
	CH-AS1	-	-	-	-	-	4	-	6	-	-	-	-	2	82	-	-	-	-	-	-	-	94
	CH-AS2	3	-	-	-	-	4	-	19	-	-	4	-	-	60	-	22	-	-	-	-	-	112

ML*	CH-05	-	88	-	-	-	-	52	-	-	-	-	-	-	-	32	-	-	5	-	-	3	180
	CH-18	-	66	1	-	10	-	39	-	-	-	-	2	-	-	47	-	-	5	6	-	3	179
	CH-21	-	66	1	-	21	-	39	-	-	-	-	2	-	-	47	-	-	1	1	-	-	178
	CH-22	-	58	-	-	88	-	57	-	-	-	-	4	-	-	4	12	-	6	-	-	4	233
	CH-24		84	-	-	63	-	42	-	-	-	-	2	-	-	20	-	-	9	-	-	4	224
PL*	CH-02	2	-	-	-	6	2	-	14	-	-	4	-	-	24	-	18	-	-	-	-	-	70
	CH-10	-	-	-	-	2	2	-	2	-	-	-	1	-	9	-	1	-	-	-	2	-	19
	CH-AS3	3	-	-	-	-	14	-	7	-	-	3	-	-	21	-	33	-	-	-	-	-	81
Sub-total		18	408	5	2	850	98	304	191	1	1	153	79	11	650	323	717	12	61	9	12	109	4014
BL#	CHE-05	-	-	-	-	6	-	-	2	-	-	-	-	-	5	-	-	-	-	-	-	-	13
ES#	CHE-02	-	-	-	-	-	14	-	-	-	-	-	-	-	7	-	2	-	-	-	-	-	23
	GAL-01	-	-	-	-	6	8	-	-	-	-	-	-	-	6	-	2	-	-	-	-	-	22
GL#	CHE-04	-	-	-	-	7	-	3	-	-	-	-	3	-	-	5	-	-	4	-	-	-	22
	GAL-02	-	-	-	-	15	-	3	-	-	-	-	3	-	-	-	9	-	8	-	-	4	42
MF#	CH-Bat	-	-	-	-	12	13	-	-	-	-	5	-	-	18	-	3	-	-	-	-	-	51
	CHE-01	-	-	-	-	7	-	3	-	-	-	-	-	-	-	-	7	-	-	-	-	2	19
ML#	CHE-03	-	-	-	-	3	-	14	-	-	-	-	4	-	-	5	13	-	1	-	-	-	40
	GAL-03	-	-	-	-	2	-	2	-	-	-	-	3	-	-	2	6	-	-	-	-	-	15
	GAL-04	-	-	-	-	-	-	20	-	-	-	-	3	-	-	9	3	-	4	-	-	2	41
Sub-total		0	0	0	0	58	35	45	2	0	0	5	16	0	36	21	45	0	17	0	0	8	288
Grand total										4074										228			4302

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cf=*C. fumosa*, Cg=*C. glassi*, Cl=*C. lucina*, Co=*C. olivieri*, Ct=*C. thalia*, Di=*Dendromus* sp.1, Dl=*D. lovati*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mi=*M. imberbis*, Mm=*M. mahomet*, Oh=*O. helleri*, Rr=*R. rattus*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*, Al=Agricultural land, BL=Bushland, EF=*Erica* forest, ES=*Erica* scrub, GL=Grassland, MF=Montane forest, ML=Moorland, PL= Plantation, * - intensive study grid habitat, # - extensive study grid habitats

6.4. Abundance of rodents and shrews

Out of the total of 4302 individuals of small mammals, 4014 were captured from the intensive study grids and the rest 288 were from extensive study grid. Out of these, 3679 (264 from extensive study grids and 3415 from intensive study grids) were new captures (Table 9) whereas the remaining 623 (599 from intensive and 24 from extensive study grids) individuals were recaptures. Recaptures were not recorded for *C. lucina*, *D. nikolausi*, *M. imberbis* and *R. rattus* (Table 9).

Table 9. Captures and recaptures from Extensive and intensive study grids and the relative abundance for each species of rodents and shrews

Species	Extensive			Intensive			Grand Total	Total New capture	Relative abundance (%)
	N	R	Total	N	R	Total			
L. brevicaudus	56	2	58	730	120	850	908	786	21.36
S. griseicauda	41	4	45	603	114	717	762	644	17.50
S. albipes	33	3	36	572	78	650	686	605	16.44
A. blicki	-	-	-	346	62	408	408	346	9.40
L. melanonyx	39	6	45	257	47	304	349	296	8.05
S. albocaudata	18	3	21	273	50	323	344	291	7.91
M. natalensis	2		2	150	41	191	193	152	4.13
M. mahomet	4	1	5	130	23	153	158	134	3.64
L. chrysopus	32	3	35	81	17	98	133	113	3.07
C. thalia	8		8	92	17	109	117	100	2.72
O. helleri	15	1	16	70	9	79	95	85	2.31
C. glassi	16	1	17	52	9	61	78	68	1.85
A. abyssinicus	-	-	-	14	4	18	18	14	0.38
C. fumosa	-	-	-	10	2	12	12	10	0.27
R. rattus	-	-	-	10	1	11	11	10	0.27
C. olivieri	-	-	-	9	3	12	12	9	0.24
C. lucina	-	-	-	7	2	9	9	7	0.19
Dendromus sp.1	-	-	-	5	-	5	5	5	0.14
D. lovati	-	-	-	2	-	2	2	2	0.05
D. nikolausi	-	-	-	1	-	1	1	1	0.03
M. imberbis	-	-	-	1	-	1	1	1	0.03
Total	264	24	288	3415	599	4014	4302	3679	100.0

N =new capture R= recaptures

The highest (21.36%) relative abundance was recorded for *L. brevicaudus* followed by *S. griseicauda* (17.50%) and *S. albipes* (16.44%). The least relative abundance was recorded for *D. nikolausi* and *M. imberbis* each having 0.03% (Table 9).

6.5. Species composition, abundance and distribution of rodents and shrews from Intensive study

Out of the 21 species of rodents and shrews captured from the intensive study grids, *L. brevicaudus* had the highest (730) abundance and highest (21.38%) relative abundance. It was followed by *S. albocaudata* with abundance of 603 and relative abundance of 17.66% whereas *M. imberbis* and *D. nikolausi* were the least in abundance and relative abundance each with 1(0.03%) individual (Table 10).

High number of new captures was documented from *Erica* forest habitat (844) followed by moorland (826) whereas the least (141) capture was from plantation habitat. There was variation in abundance of small mammals among habitats. The variation was statistically significant ($\chi^2 = 1842.47$, df = 7, $p<0.05$).

Table 10. captures, relative abundance and distribution of rodents and shrews from each habitat of intensive study grid

Species	AL T=300	BL T=600	EF T=1800	ES T=2400	GL T=600	MF T=900	ML T=1500	PL T=900	Total T=9000	R. Abundance (%)
L. brevicaudus	-	8(1)	287(49)	228(27)	32(4)	21(3)	146(36)	8	730(120)	21.38
S. griseicauda	13(1)	7(3)	198(34)	258(44)	53(8)	24(10)	7(5)	43(9)	603(114)	17.66
S. albipes	28(3)	114(17)	121(15)	30(6)	28(4)	203(27)	-	48(6)	572(78)	16.75
A. blicki	-	-	35(3)	1(1)	5(1)	-	305(57)	-	346(62)	10.13
S. albocaudata	-	-	37(7)	69(10)	42(8)	-	125(25)	-	273(50)	7.99
L. melanonyx	-	-	19(3)	27(4)	15(7)	-	196(33)	-	257(47)	7.53
M. natalensis	30(6)	11(2)	34(6)	22(8)	16(2)	21(10)	-	16(7)	150(41)	4.39
M. mahomet	26(4)	2	-	88(16)	5(1)	4	-	5(2)	130(23)	3.81
C. thalia	-	-	56(11)	19(1)	7(1)	-	10(4)	-	92(17)	2.69
L. chrysopus	-	21(3)	-	3(3)	1	41(8)	-	15(3)	81(17)	2.37
O. helleri	-	-	15(2)	44(6)	1	-	9(1)	1	70(9)	2.05
C. glassi	-	-	27(3)	4(1)	-	-	21(5)	-	52(9)	1.52
A. abyssinicus	1	1	2	2	3(1)	2(1)	-	3(2)	14(4)	0.41
R. rattus	4	2	-	-	2(1)	2	-	-	10(1)	0.29
C. fumosa	-	-	8(1)	2(1)	-	-	-	-	10(2)	0.29
C. olivieri	4(2)	-	-	3(1)	-	-	-	2	9(3)	0.26
C. lucina	-	-	2	-	-	-	5(2)	-	7(2)	0.20
Dendromus sp.1	-	-	2	1	-	-	2	-	5	0.15
D. lovati	-	-	1	1	-	-	-	-	2	0.06
M. nikolausi	-	-	-	1	-	-	-	-	1	0.03
M. imberbis	1	-	-	-	-	-	-	-	1	0.03
Total	107(16)	166(26)	844(134)	803(129)	210(38)	318(59)	826(168)	141(29)	3415(599)	100.0

T= total trap night, AL= Agricultural land, BL= bushland, EF=*Erica* forest, ES=*Erica* scrub, GL= Grassland, MF=Montane forest, ML=Moorland, PL= Plantation, (-)= absence of record, number in bracket shows total recaptures

Capture per trap night was highest (55) for moorland habitat followed by *Erica* forest (47). The least (16) capture rate was recorded for plantation habitats. Relatively, the capture rate in bushland habitat was also low (28). The capture rate variation among the habitats was not statistically significant (χ^2 = 26.75, df = 6, p<0.05). However, in abundance, *Erica* forest habitat was the highest followed by moorland (826) and *Erica* scrub (803). The least abundance was from agricultural land (107) followed by grassland habitat (210) (Figure 4). The abundance of small mammals among the habitat was not statistically significant (χ^2 = 1842’47, df = 7, p<0.005).

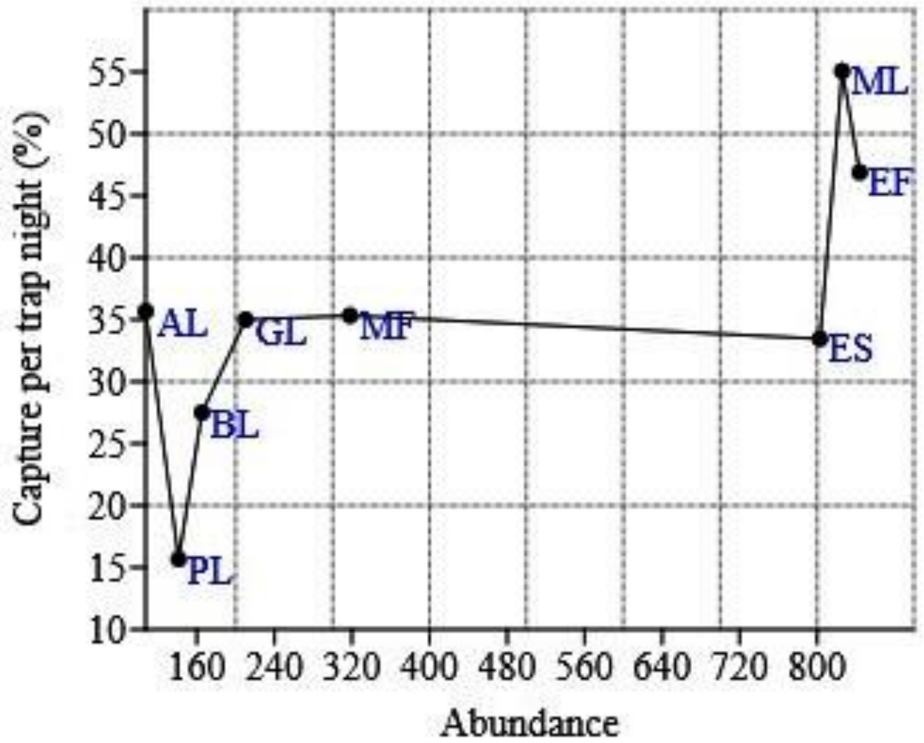

Figure 4. Abundance of rodents and shrews and captures per trap night in each habitats of intensive study grids
(AL= Agricultural land, BL= bushland, EF=*Erica* forest, ES=*Erica* scrub, GL= Grassland, MF=Montane forest, ML=Moorland, PL= Plantation)

The total mean abundance was highest (207) for *S. albipes* followed by *L. brevicaudus* (136), *S. griseicauda* (132) whereas it was least for *C. fumosa*, *C. lucina* and *M. imberbis* (1) (Table 11).

Mastomys natalensis has the highest (30) mean abundance in agricultural land habitat similarly *S. albipes* (57), (68) and 16 in bushland, montane forest and plantation respectively. *Arvicanthis blicki* (61) was the most dominant in abundance in the moorland habitat (Table 11).

Stenocephalemys griseicauda was the most widely distributed species. It was captured from almost all or eight habitats (Table 11). The second most widely distributed species was *L. brevicaudus* captured from seven habitats with the exception of agricultural land. Likewise, *S. albipes* and *M. mahomet* was also captured from all habitats except in moorland habitats. All the remaining species excpt *C. fumosa*, *C. lucina*, Co=*C. olivieri* and *M. imberbis* were captured at least from three habitats (Table 11).

Table 11. Mean abundance, distribution and habitat preference of rodents and shrews from intensive study grids

	AL (1)	BL (2)	EF (6)	ES (8)	GL (2)	MF (3)	ML (5)	PL (3)	Total	No. of habitat
S. albipes	28	57	20	4	14	68	0	16	207	7
L. brevicaudus	0	4	48	29	16	7	29	3	136	7
S. griseicauda	13	4	33	32	27	8	1	14	132	8
A. blicki	0	0	6	0	3	0	61	0	70	3
M. natalensis	30	6	6	3	8	7	0	5	65	7
S. albocaudata	0	0	6	9	21	0	25	0	61	4
L. melanonyx	0	0	3	3	8	0	39	0	53	4
M. mahomet	26	1	0	11	3	1	0	2	44	6
L. chrysopus	0	11	0	0	1	14	0	5	31	4
C. thalia	0	0	9	2	4	0	2	0	17	4
O. helleri	0	0	3	6	1	0	2	0	12	4
C. glassi	0	0	5	1	0	0	4	0	10	3
R. rattus	4	1	0	0	1	1	0	0	7	4
A. abyssinicus	1	1	0	0	2	1	0	1	6	5
C. olivieri	4	0	0	0	0	0	0	1	5	2
C. fumosa	0	0	1	0	0	0	0	0	1	1
C. lucina	0	0	0	0	0	0	1	0	1	1
M. imberbis	1	0	0	0	0	0	0	0	1	1
Total	107	83	141	100	105	106	165	47	854	
No of species	8	8	15	18	13	8	10	9		

Dendromus sp.1, *D. lovati* and *M. nikolausi* excluded as the mean rounded to zero, number in bracket refers total number of grids, AL= Agricultural land, BL= bushland, EF=*Erica* forest, ES=*Erica* scrub, GL= Grassland, MF=Montane forest, ML=Moorland, PL= Plantation.

Mastomys natalensis, *M. mahomet*, *R. Rattus* and *M. imberbis* prefered more agricultural land. *Lophuromys brevicaudus*, *S. griseicauda*, *C. thalia* and *C. glassi* frequent *Erica* Scrub habitat. Grassland habitat was more preferred by *A. abyssinicus*. In the same way, *S. albipes* and *L. chrysopus* were dominantly recorded from montane forest whereas *A. blicki*, *S. albocaudata*, *L. melanonyx* and *C. glassi* preferred moorland habitat (Table 11).

From all habitats *Erica* scrub habitat was preferred by 18 species of small mammals followed by *Erica* forest (15) and grassland habitat (13). Relatively, agricultural land (8), bushland (8) and plantation (9) habitats were less preferred (Table 11).

6.6. Diversity indices and species refraction curve for each habitat

Erica scrub habitat has the highest (18) species richness followed by *Erica* forest with 15 species of rodents and shrews. The least species richness was recorded for montane forest, agricultural land and bushland each with eight species (Table 12).

Grassland had the highest Shannon Weiner Index (H) (2.057) and has the highest (0.8418) Simpson similarity index. However, the evenness index was highest (0.6446) for agricultural land. Based on the Chao-1 estimate, *Erica* scrub habitats have 20 species.

Table 12. Diversity indices for each habitat

Habitat	Taxa	Individuals	Dominance	Simpson	Shannon (H)	Evenness	Chao-1
AL	8	107	0.2239	0.7761	1.64	0.6446	9
BL	8	166	0.4964	0.5036	1.116	0.3817	8
EF	15	844	0.2028	0.7972	1.926	0.4575	15
ES	18	803	0.2102	0.7898	1.89	0.3677	20
GL	13	210	0.1582	0.8418	2.057	0.6015	13.5
MF	8	318	0.4388	0.5612	1.223	0.4248	8
ML	10	826	0.2478	0.7522	1.583	0.4871	10
PL	9	141	0.2383	0.7617	1.673	0.592	9

AL= Agricultural land, BL= bushland, EF=*Erica* forest, ES=*Erica* scrub, GL= Grassland, MF=Montane forest, ML=Moorland, PL= Plantation

The pooled species refraction curve for all habitats are shown on Figure 5. Relatively moorland habitat was more smoothed and maintained the asymptote followed by montane forest habitat and *Erica* forest. However, for the remaining habitats, the asymptote was not maintained as such and hence it seems as it needs further survey.

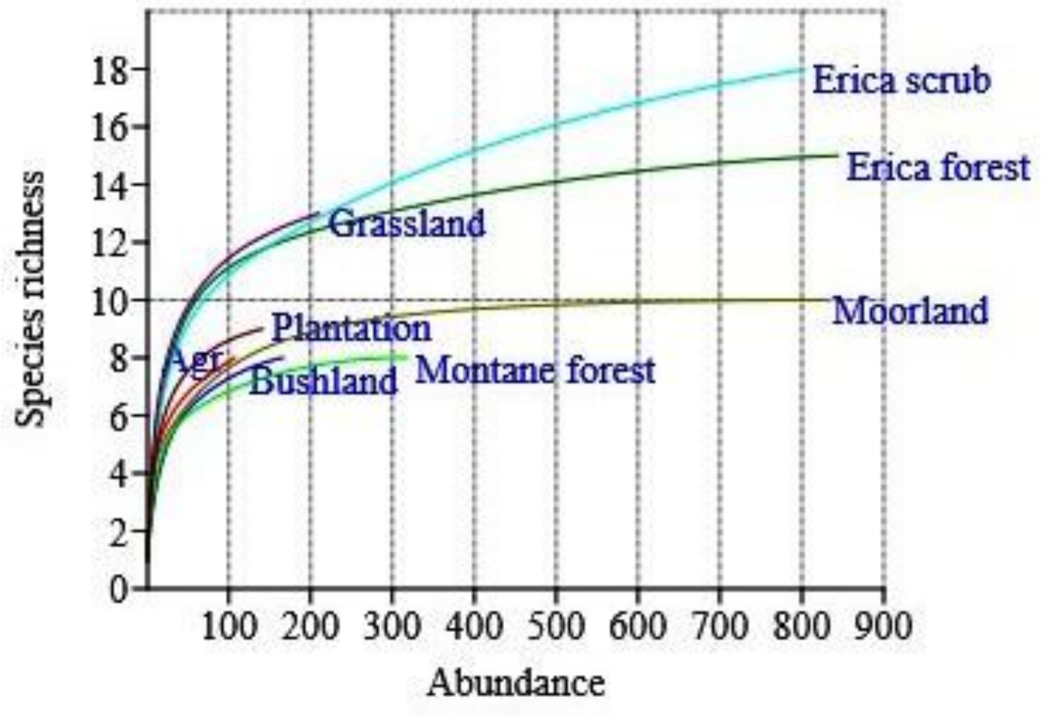

Figure 5. Species refraction curves of all habitats

The total species refraction curve was comparatively smoothed (Figure 6). The detail of the conditional 95% confidence interval for common and independent habitat is shown in Figure 6.

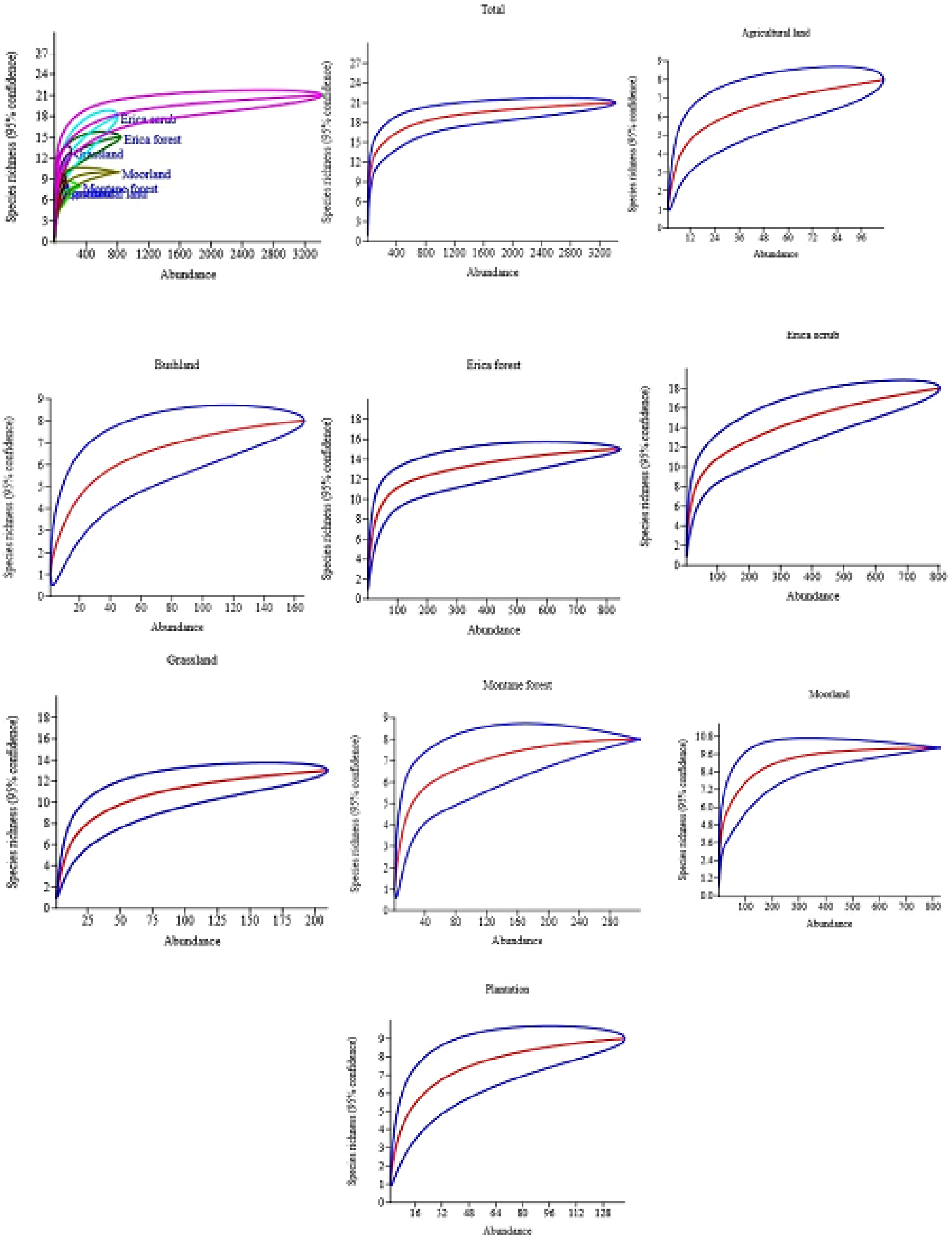

Figure 6. Conditional 95% confidence interval species refraction curve for all habitats

6.7. Seasonal distribution and abundance of rodents and shrews

These were seasonal distribution variations for each species (Table 13). Relatively more individuals of small mammals were captured during the wet season. Comparatively more individuals of *L. brevicaudus* (56.16%), *S. griseicauda* (50.91%), *S. albipes* (58.74%), *L. melanonyx* (50.19%), *C. thalia* (56.62%), *L. chrysopus* (65.43%) were captured during wet season than in the dry season. However, more individuals of *A. blicki* (62.43%), *M. natalensis*, (57.33%) and *O. helleri*, (68.57%) were captured during dry season than the wet season(Table 13). All individuals of *C. lucina* and *D. nikolausi* were only captured during dry season (Table 13).

Table 13. Seasonal capture of small mammals from intensive study grids for each trapping sessions and percentage capture per each season.

Species	Dry			Wet			Total
	ii	iv	Total (%)	i	iii	Total (%)	
L. brevicaudus	153	167	320(43.84)	182	228	410(56.16)	730
S. griseicauda	154	142	296(49.09)	151	156	307(50.91)	603
S. albipes	130	106	236(41.26)	154	182	336(58.74)	572
A. blicki	96	120	216(62.43)	73	57	130(37.57)	346
S. albocaudata	76	72	148(54.21)	64	61	125(45.79)	273
L. melanonyx	60	68	128(49.81)	72	57	129(50.19)	257
M. natalensis	40	46	86(57.33)	17	47	64(42.67)	150
M. mahomet	19	62	81(62.31)	27	22	49(37.69)	130
C. thalia	22	18	40(43.48)	26	26	52(56.52)	92
L. chrysopus	8	20	28(34.57)	31	22	53(65.43)	81
O. helleri	26	22	48(68.57)	11	11	22(31.43)	70
C. glassi	20	8	28(53.85)	8	16	24(46.15)	52
A. abyssinicus	4	1	5 (35.71)	2	7	9(64.29)	14
C. fumosa	3	3	6(60)	1	3	4(40)	10
R. rattus	2	1	3(30)	4	3	7(70)	10
C. olivieri	2	4	6(66.67)	3	0	3(33.33)	9
C. lucina	0	0	0	6	1	7(100)	7
Dendromus sp.1	1	0	1(20)	2	2	4(80)	5
D. lovati	1	1	2(100)	0	0	0	2
D. nikolausi	0	0	0	1	0	1(100)	1
M. imberbis	1	0	1(100)	0	0	0	1
Total	818	861	1679(49.17)	835	901	1736(50.83)	3415

-i, ii, iii and iv- refers trapping sessions in their respective seasons

Rodent and shrew species showed habitat preference differences based on seasonal variations (Figure 7). However, there was only a slight seasonal variation between seasonfor *S. griseicauda*, *S. albocaudata* and *C. glassi* (Table 13). Except in agricultural land, *Erica* scrub and moorland, the majority of small mammals were captured during the wet season.

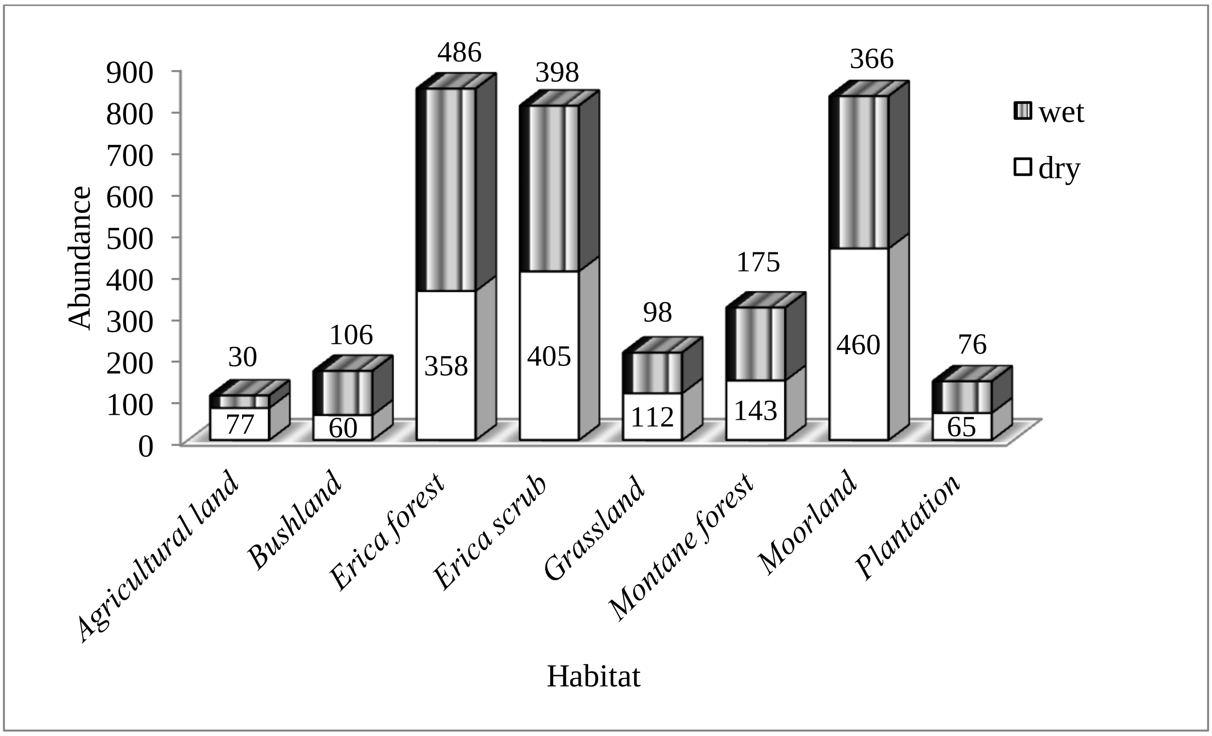

Figure 7. Seasonal abundance of rodents and shrews for each habitat

Rodent and shrew species showed variation in sex and age distribution (Table 14). More number of male (1783) accounting for 52.21% small mammals were captured from intensive study grids (Table 14). However, female and male sex ratio variations were not significant.

Only male individuals for *Dendromus* sp.1 and *D. Lovati* were captured. In contrary to this only female was captured for *M. nikolausi* (Table 14). Nevertheless, for the remining species, both sexes were recorded. From all the females captured, 396 (11.60%) were contributed by *L. brevicaudus* and similarly for the male *S. albipes* contributed 351 (10.28%) (Table 14).

The numbers of adults captured were 2571 accounting for 75.29% of all captures and the remaining 844 (24.71%) were sub-adults (Table 14). The age structure variation of species of rodents and shrews was statistically significant.

When each species was considered, most adults belonged to *L. brevicaudus* and most sub-adults belonged to *S. albipes*. Sub-adults were not captured for *C. lucina*, *D. nikolausi* and *M. imberbis* (Table 14).

Table 14. Sex and age distribution of captured rodents and shrews

Species	Sex		Age		Total
	Female	Male	Adult	Sub-adult	
L. brevicaudus	396	334	610	120	730
S. griseicauda	292	311	414	189	603
S. albipes	221	351	371	201	572
A. blicki	144	202	222	124	346
S. albocaudata	150	123	223	50	273
L. melanonyx	154	103	236	21	257
M. natalensis	59	91	82	68	150
M. mahomet	59	71	122	8	130
C. thalia	44	48	87	5	92
L. chrysopus	37	44	65	16	81
O. helleri	32	38	57	13	70
C. glassi	22	30	37	15	52
A. abyssinicus	4	10	10	4	14
C. fumosa	3	7	7	3	10
R. rattus	4	6	8	2	10
C. olivieri	4	5	6	3	9
C. lucina	6	1	7	0	7
D. sp.1	0	5	4	1	5
D. lovati	0	2	1	1	2
D. nikolausi	1	0	1	0	1
M. imberbis	0	1	1	0	1
Grand Total	1632	1783	2571	844	3415
Proportion (%)	47.79	52.21	75.29	24.71	

The overall seasonal abundance and relative abundance for each species is given in Table 15. Relatively more *A. blicki*, *C. fumosa*, *C. glassi*, *C. olivieri*, *D. lovati*, *M. natalensis*, *M. imberbis*, *M. mahomet*, *O. helleri* and *S. albocaudata* were captured during dry season whereas *A. abyssinicus*, *C. thalia*, *Dendromus* sp.1, *L. brevicaudus*, *L. chrysopus*, *L. melanonyx*, *D. nikolausi*, *R. rattus*, *S. albipes* and *S. griseicauda* were captured during the wet season (Table 15).

Relatively female sub-adults were recorded for *S. griseicauda* but for *L. brevicaudus* more males were recorded during the dry season. In the same way, 65 and 52 sub-adults of females and male sub adults were captured during the wet season (Table 15).

Table 15. Seasonal relative abundance, sex and age distribution of rodents and shrews

	Dry						Wet					
Species	Female		Male		Total	RA (%)	Female		Male		Total	RA (%)
	A	SA	A	SA			A	SA	A	SA		
Lb	151	8	119	42	320	9.37	196	41	144	29	410	12.01
Sp	39	57	113	27	236	6.91	60	65	159	52	336	9.84
Sg	96	69	101	31	296	8.67	81	46	136	43	307	8.99
Ab	36	36	101	43	216	6.33	40	32	45	13	130	3.81
Lm	72	9	47	0	128	3.75	63	10	54	2	129	3.78
Sc	57	23	68	0	148	4.33	46	24	52	3	125	3.66
Mn	20	12	33	21	86	2.52	6	21	23	14	64	1.87
Lc	13	3	12	0	28	0.82	12	9	28	4	53	1.55
Ct	19	0	18	3	40	1.17	25	0	25	2	52	1.52
Mm	35	1	44	1	81	2.37	19	4	24	2	49	1.43
Cg	8	0	14	6	28	0.82	6	8	9	1	24	0.70
Oh	12	5	31	0	48	1.41	7	8	7	0	22	0.64
Aa	2	0	3	0	5	0.15	1	1	4	3	9	0.26
Rr	1	0	2	0	3	0.09	1	2	4	0	7	0.20
Cl	0	0	0	0	0	0.00	6	0	1	0	7	0.20
Cf	2	0	4	0	6	0.18	1	0	0	3	4	0.12
Di	0	0	0	1	1	0.03	0	0	4	0	4	0.12
Co	3	0	2	1	6	0.18	1	0	0	2	3	0.09
Md	0	0	0	0	0	0.00	1	0	0	0	1	0.03
Dl	0	0	1	1	2	0.06	0	0	0	0	0	0.00
Mi	0	0	1	0	1	0.03	0	0	0	0	0	0.00
Total	566	223	714	177	1679	49.19	572	271	719	173	1736	50.81

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cf=*C. fumosa*, Cg=*C. glassi*, Cl=*C. lucina*, Co=*C. olivieri*, Ct=*C. thalia*, Di=*Dendromus* sp.1, Dl=*D. lovati*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mi=*M. imberbis*, Mm=*M. mahomet*, Oh=*O. helleri*, Rr=*R. rattus*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*

Moorland habitat had highest mean abundance 92 and relative mean 10.71% during the dry season and highest total mean abundance of 166. *Erica* forest had highest mean abundance (81) and relative abundance (9.43%). In both wet and dry seasons, the plantation habitat had the lowest mean abundance and mean relative abundance (Table 16).

Agricultural land (8.96%), grassland (6.64%) and moorland (10.71%) habitats harboured more small mammals during the dry season than the wet season. However, bushland (6.29%), *Erica* forest (9.43%), montane forest (6.87%) and plantation (3.03%) had more abundance of small mammals during the wet season (Table 16). There was no seasonal variation in mean abundance and relative mean abundance for *Erica* scrub habitat.

The number of sub-adults in each habitat is lower than the adults in both wet and dry season except in a plantation habitat during both seasons and agricultural land during wet season (Table 16). In each habitat, the numbers of sub-adult do not show much variation.

Table 16. Mean and relative mean abundance and age distribution among intensive study grid habitats

Species	Dry			Wet			Total
	Adult	Sub-adult	Total (%)	Adult	Sub-adult	Total (%)	
Moorland(5)	75	17	92(10.71)	59	15	74(8.61)	166
Erica forest(6)	46	14	60(6.98)	63	18	81(9.43)	141
Agricultural land (1)	67	10	77(8.96)	13	17	30(3.49)	107
Montane forest(3)	32	16	48(5.59)	38	21	59(6.87)	107
Grassland (2)	38	19	57(6.64)	30	19	49(5.7)	106
Erica scrub(8)	39	11	50(5.82)	41	9	50(5.82)	100
Bushland (2)	24	6	30(3.49)	38	16	54(6.29)	84
Plantation(3)	10	12	22(2.56)	11	15	26(3.03)	48
Grand Total	331	105	436(50.76)	293	130	423(49.24)	859

Number in bracket shows the number of grids in each habitat

The total reproductively active individuals captured were 1281(37.51%) of which the dry and wet season captures were 646(18.91%) and 635(18.59%) respectively. Pregnant or lactating females recorded during the dry season were 68(1.99%) and similarly reproductively active scrotal males were 578(16.93%). For both sexes, the reproductive activity seems to be higher during the dry season than the wet season (Table 17).

Reproductively active females were not recorded during both seasons for *A. abyssinicus*, *C. fumosa*, *C. glassi*, *C. lucina*, *Dendromus* sp.1, *D. lovati*, *L. melanonyx*, *M. imberbis* and *M. mahomet*. Similarly, reproductive active males were not recorded during both seasons for *C. lucina*, *C. olivieri*, *D. lovati* and *M. natalensis* (Table 17). The majority of reproductive active females were contributed by *S. albocaudata* during both season and likewise reproductive active males during both seasons were contributed by *S. albipes* (Table 17).

Table 17. Seasonal reproductive status of rodents and shrews

Species	Dry				Wet				Total
	Female		Male		Female		Male		
	im	pr/lac	i	s	im	pr/lac	i	s	
L. brevicaudus	149	10	80	81	229	8	72	101	730
S. griseicauda	153	12	51	81	118	9	64	115	603
S. albipes	90	6	42	98	112	13	79	132	572
A. blicki	72	-	58	86	68	4	23	35	346
S. albocaudata	58	22	-	68	52	18	12	43	273
L. melanonyx	81	-	15	32	73	-	11	45	257
M. natalensis	31	1	36	18	27	-	30	7	150
M. mahomet	36	-	1	44	23	-	2	24	130
C. thalia	15	4	16	5	25	-	5	22	92
L. chrysopus	9	7	-	12	18	3	5	27	81
O. helleri	15	2	-	31	12	3	5	2	70
C. glassi	6	2	9	11	11	3	3	7	52
A. abyssinicus	2	-	-	3	2	-	3	4	14
C. fumosa	2	-	-	4	1	-	3	-	10
R. rattus	-	1	-	2	2	1	-	4	10
C. olivieri	2	1	3	-	1	-	2	-	9
C. lucina	-	-	-	-	6	-	1	-	7
Dendromus sp.1	-	-	1	-	-	-	-	4	5
D. lovati	-	-	1	1	-	-	-	-	2
D. nikolausi	-	-	-	-	-	1	-	-	1
M. imberbis	-	-	-	1	-	-	-	-	1
Total	721	68	313	578	780	63	320	572	3415
Proportion (%)	21.11	1.99	9.17	16.93	22.84	1.84	9.37	16.75	100
Reproductive (%)	646 (18.92)				635 (18.59)				1281 (37.51)

im=impregnant, pr/lac=pregnant/lactating, i=inguinal, s=scrotal, - refers absence of record

Mean abundance of seasonal reproductive activity of rodents and shrews in each habitat are shown on Table 18.

The proportion of reproductive activity during the wet and dry seasons was 20.02% and 18.15%, respectively. The overall mean of reproductive active individuals was 38.17% (Table 18).

With the exception of scrotal males, there was no record of reproductively active female during both seasons in agricultural land. Relatively more reproductively active female small mammals were recorded from bushland (Table 18).

Comparatively more reproductive males were recorded in both seasons than reproductive active females. Moorland habitat had more reproductively active small mammals during dry (32) and wet (21) seasons (Table 18).

Table 18. Mean abundance of seasonal reproductive activity of rodents and shrews in each habitat

Habitat	Dry				Wet				Total
	im	pr/lac	i	s	im	pr/lac	i	s	
Agricultural land	46	-	-	31	13	-	8	9	107
Bushland	8	4	5	13	20	5	9	21	83
Erica forest	25	2	13	19	37	2	18	25	141
Erica scrub	23	3	8	17	21	2	7	20	100
Grassland	18	-	16	23	18	-	14	18	105
Montane forest	19	1	10	17	30	3	9	16	106
Moorland	40	2	17	32	37	4	11	21	165
Plantation	10	2	5	5	9	-	7	9	47
Total	189	14	74	157	185	16	83	139	854
Proportion (%)	22.13	1.64	8.67	18.38	21.66	1.87	9.72	16.28	100
Reproductive (%)	171(20.02)				155 (18.15)				326 (38.17)

im=impregnant, pr/lac=pregnant/lactating, i=inguinal, s=scrotal, - refers absence of record

6.8. Impact of *Erica* fire on small mammals

A total of 1372 small mammals out of which 1174 were new captures and 198 were recaptures in 3150 trap nights were captured from the nine conventional categories of time since *Erica* fire (Table 19). See Plate 5 for the different stages of *Erica* regeneration during post *Erica* fire.

The highest capture per trap night (50) was recorded for categories of time since *Erica* fire above six years, then 48 and 47 for time following *Erica* fire of five and six years, respectively. The capture per trap night in each categories was statistically significant (χ^2 = 21.19, df = 7, $p<0.05$). There was no capture from habitats since the time *Erica* fire of less than a month (Table 19).

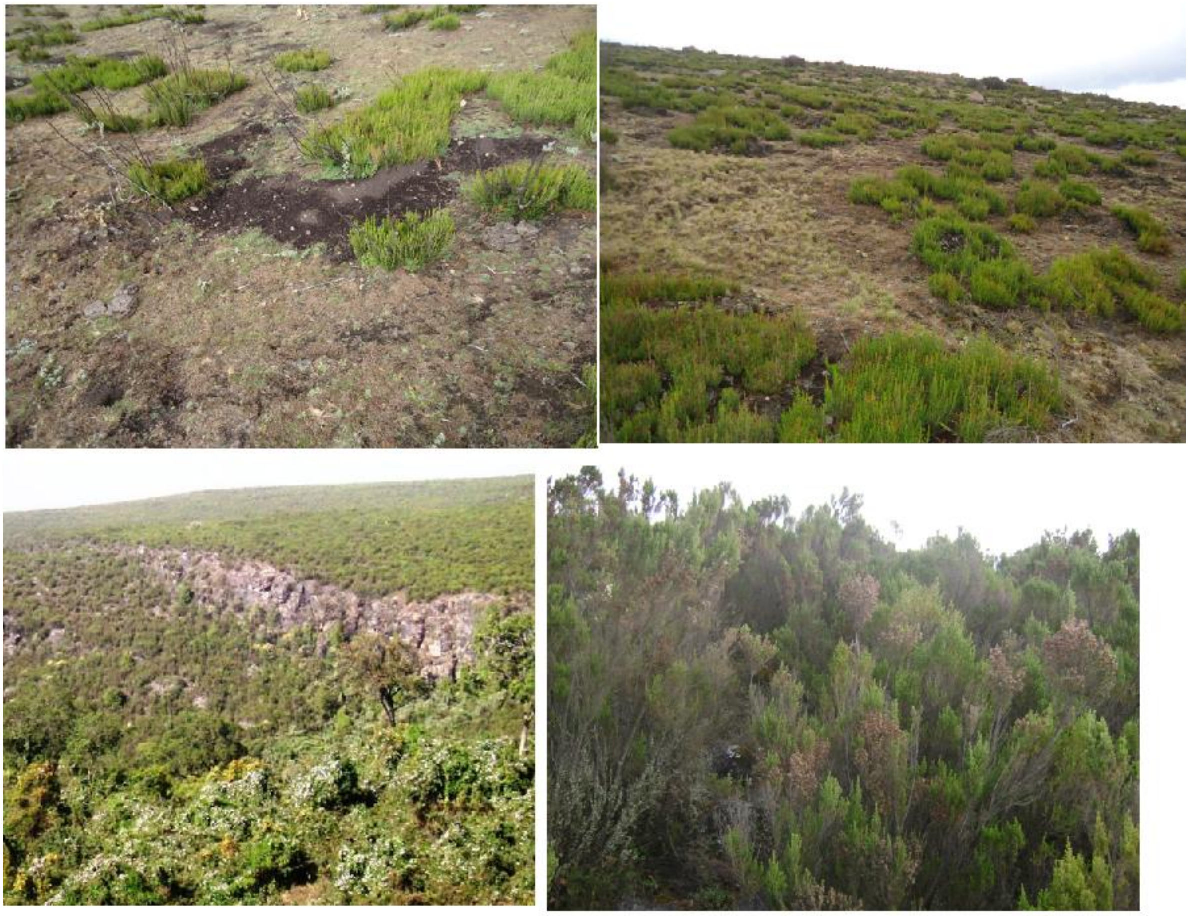

Plate 5. Different stage of Regenration of *Erica* post fire

Table 19. Abundance of small mammals, trap night and capture per 100 trap-night since *Erica* fire

Time Since *Erica* fire	Grid	Trap night per Grid	Capture per Grid	Total trap-night	Total New Capture	Capture per 100 trap night
Above six years	CH-13	300	98(14)	600	297	50
	CH-23	300	199(35)			
Five years	CH-16	300	143(27)	300	143	48
Six years	CH-03	300	158(26)	600	283	47
	CH-09	300	125(25)			
Four years	CH-08	300	104(12)	300	104	35
Three years	CH-17	300	110(17)	300	110	37
Two years	CH-12	300	95(13)	300	95	32
One year	CH-20	300	73(18)	300	73	24
Six month	CH-07	300	69(11)	300	69	23
Less than month	CH-04	75	0	150	0	0
	CH-11	75	0			
Total	12	3150	1174(198)	3150	1174	296

Number in bracket shows recapture

The total mean capture per 100 trap night in all conventional categories of time since *Erica* fire was 318 (Table 20). The maximum (17.3%) capture per trap night for rodents and shrews were recorded for *Erica* fire above 6 years and followed by six years time since *Erica* fire.

There was no capture for *Erica* habitat time since *Erica* fire less than a month and capture rate was least for *Erica* habitat time since *Erica* fire of six month (Table 19). *Erica* fire above six years old time since *Erica* fire had more (12) species followed by six years since the last *Erica* fire. The numbers of species were least (4) for categories time since *Erica* fire of one year and six month. Even for time since *Erica* fire of less than a month, species of rodents and shrews were not recorded (Table 19).

Although capture rate seems lower for two years since *Erica* fire than three years, however, in species richness, it was higher (Table 19).

The capture rate and relative abundance were high for *L. brevicaudus* and *S. griseicauda*. Except in habitat time since *Erica* fire of less than a month, *L. brevicaudus* and *S. griseicauda* were recorded from all categories of *Erica* fire. *Otomys helleri* was also recorded from six different categories with the exception of habitats since time *Erica* fire of five years, three years and less than a month (Table 20).

Lophuromys brevicaudus, *M. mahomet*, *O. helleri* and *S. griseicauda* were the only captured small mammals from *Erica* fire of less than 18 months (Table 20).

Table 20. Mean capture per 100 trap night and relative abundance of each species in different years of time since *Erica* fire

Species	Above six years (600)	Six years (600)	Five years (300)	Four years (300)	Three years (300)	Two years (300)	One year (300)	Six months (300)	Less than a month (150)	Total	R. abundance (%)	Species occurrence
A. abyssinicus	1(2)	0	0	0	0	1(2)	0	0	0	2(4)	0.63	2
A. blicki	5(29)	0	1(1)	0	0	0	0	0	0	6(30)	1.89	2
C. fumosa	0	1(5)	0	0	1(1)	1(1)	0	0	0	3(7)	0.94	3
C. glassi	2(10)	1(2)	0	2(4)	0	0	0	0	0	5(16)	1.57	3
C. lucina	0	1(2)	0	0	0	0	0	0	0	1(2)	0.31	1
C. olivieri	0	0	0	1(3)	0	0	0	0	0	1(3)	0.31	1
C. thalia	2(10)	6(35)	0	2(5)	3(8)	0	0	0	0	13(58)	4.09	4
Dendromus sp.1	0	1(2)	0	0	1(1)	0	0	0	0	2(3)	0.63	2
D. lovati	1(1)	0	0	0	1(1)	0	0	0	0	2(2)	0.63	2
L. brevicaudus	23(134)	15(89)	2(6)	19(56)	20(59)	11(31)	2(6)	1(3)	0	93(384)	29.25	8
L. melanonyx	4(19	0	9(27)	0	0	0	0	0	0	13(46)	4.09	2
M. natalensis	3(13)	0	4(10)	0	0	4(12)	0	0	0	11(35)	3.46	3
D. nikolausi	0	0	1(1)	0	0	0	0	0	0	1(1)	0.31	1
M. mahomet	0	0	0	0	0	0	14(41)	15(45)	0	29(86)	9.12	2
O. helleri	1(5)	1(6)	0	3(7)	0	1(1)	6(18)	6(17)	0	18(54)	5.66	6
S. albipes	3(15)	6(31)	3(9)	0	0	6(17)	0	0	0	18(72)	5.66	4
S. albocaudata	1(6)	5(28)	11(32)	1(1)	0	0	0	0	0	18(67)	5.66	4
S. griseicauda	9(53)	14(83)	19(57)	10(2	14(40)	11(31)	3(8)	2(4)	0	82(304)	25.79	8
Total	55(297)	51(283)	50(143)	38(104)	40(110)	35(95)	25(73)	69(24)	0	318(1174)	100.00	
%	17.3	16.04	15.72	11.95	12.58	11.01	7.86	7.55	0			
No. species	12	10	8	7	6	7	4	4	0	17		

Number in bracket shows new capture

6.9. Species composition and distribution of rodents and shrews along altitudinal zonation

The number of individuals captured (new, recaptures and total) is presented in Table 21. Out of the total 4014 individuals captured, 3415 were new captures and 599 were recaptures (Table 21).

The bulk number of rodents and shrews were captured from altitudinal zonation band of 3301-3600 m asl (1311) followed by 3601-3900 (761) and above 3900 m asl (581) (Table 21). The least new captures were recorded from the altitudinal zonation of 2701-3000 m asl (123) (Table 21).

Table 21. Altitudinal zonation and number of individuals of small mammal capture

Altitude band (m asl)	Captures			Altitude band (m asl)	Captures		
	New	Recapture	Total		New	Recapture	Total
2400-2700 (5)	409	69	478	3301-3600(10)	1311	217	1528
CH-AS1	86	8	94	CH-03	158	26	184
CH-AS2	93	19	112	CH-09	125	25	150
CH-AS3	67	14	81	CH-11	84	13	97
CH-AS4	73	13	86	CH-12	95	13	108
CH-Wal	90	15	105	CH-13	98	14	112
2701-3000(1)	107	16	123	CH-14	147	21	168
CH-Ag	107	16	123	CH-15	137	25	162
3001-3300(6)	462	81	543	CH-16	143	27	170
CH-01	139	32	171	CH-19	125	18	143
CH-02	56	14	70	CH-23	199	35	234
CH-06	76	11	87	3601-3900(5)	642	119	761
CH-07	69	11	80	CH-04	117	13	130
CH-08	104	12	116	CH-05	151	29	180
CH-10	18	1	19	CH-17	110	17	127
>3900(3)	484	97	581	CH-20	73	18	91
CH-18	147	32	179	CH-22	191	42	233
CH-21	146	32	178				
CH-24	191	33	224	Grand Total	3415	599	4014

Numbers in bracket indicate number of grids in each altitudinal zonation bands

The altitudinal zonation band above 3900 m asl had highest mean capture (161) followed by altitudinal zonation band of 3301-3600 m asl with mean capture of 131. The least mean capture (77) was for the altitudinal zonation of 3001-3300 m asl (Table 22).

Table 22. Number of total new captures, mean capture and number of grids in each altitudinal zonation bands

Altitudinal zonation band (m asl)	Number of grid	Capture	Mean Capture
Above 3900	3	484	161
3301-3600	10	1311	131
3601-3900	5	642	128
2701-3000	1	107	107
2400-2700	5	409	82
3001-3300	6	462	77
Total	30	3415	687

Altitudinal zonation above 3900 m asl had relatively the highest mean abundance 161(23.4%) and followed by altitudinal zonation band 3301-3600 and 3601-3900 m asl with mean abundance of 131(19.1%) and 128(18.6%), respectively. The least in mean abundance of 77(11.2) was for altitudinal zonation band of 3001-3300 m asl (Table 23).

The most abundant species along altitudinal zonation band of 2400-2700 m asl was *S. albipes* followed by *S. griseicauda* (Table 23). Correspondingly for altitudinal zonation band of 2701-3000 m asl *M. natalensis*, for 3001-3300 m asl, *S. albipes*; for 3301-3600 m asl, *S. griseicauda* for 3601-3900 m asl *L. brevicauda* and above 3900 m asl, *A.blicki*, were the most abundant species (Table 23).

Table 23. Altitudinal distribution, abundance, mean abundance and number of incidences for each species of rodents and shrews along different altitudinal zonations

	2400-2700 (5)		2701-3000 (1)		3001-3300 (6)		3301-3600 (10)		3601-3900 (5)		>3900 (3)		Total	
Species	Abundance	Mean	Abundance	Mean	Abundance	Mean	Abundance	Mean	Abundance	Mean	Abundance	Mean	Abundance	Mean
Lb	0	0	0	0	96	16	359	36	202	40	73	24	730	116
Sp	235	47	28	28	158	26	151	15	0	0	0	0	572	116
Ab	0	0	0	0	0	0	41	4	120	24	185	62	346	90
Sg	64	13	13	13	60	10	394	39	72	14	0	0	603	89
Lm	0	0	0	0	0	0	61	6	94	19	102	34	257	59
Sc	0	0	0	0	1	0	144	14	33	7	95	32	273	53
Mn	51	10	30	30	13	2	56	6	0	0	0	0	150	48
Mm	14	5	26	26	47	8	2	0	41	8	0	0	130	45
Ct	0	0	0	0	5	1	58	6	24	5	5	2	92	14
Lc	32	5	0	0	46	8	3	0	0	0	0	0	81	14
Oh	0	0	0	0	25	4	14	1	26	5	5	2	70	12
Cg	0	0	0	0	4	1	12	1	24	5	12	4	52	11
Rr	6	6	4	4	0	0	0	0	0	0	0	0	10	5
Co	0	0	4	4	5	1	0	0	0	0	0	0	9	5
Aa	7	7	1	1	2	0	4	0	0	0	0	0	14	2
Cf	0	0	0	0	0	0	6	1	4	1	0	0	10	2
Cl	0	0	0	0	0	0	2	0	0	0	5	2	7	2
Di	0	0	0	0	0	0	2	0	1	0	2	1	5	1
Mi	0	0	1	1	0	0	0	0	0	0	0	0	1	1
Dl	0	0	0	0	0	0	1	0	1	0	0	0	2	0
Md	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Total	409	81	107	107	462	77	1311	129	642	128	484	163	3415	685
%	12	11.8	3.1	15.6	13.5	11.3	38.4	18.8	18.8	18.7	14.2	23.4	100	100
No. sp	7	7	8	8	12	10	18	11	12	10	9	9	21	19

The trend of species richness and mean abundance along the altitudinal zonation bands is shown in Figure 8.

Species richness peaked (18) at altitudinal zonation band of 3301-3600 and then declined in both directions to it. The lowest (7) species richness was recorded for altitudinal zonation band of 2400-2700 m asl (Figure 8).

The mean abundance of small mammals along altitudinal zonation had the increase trend although there was irregularity in mean abundance (Figure 8). The peak of mean abundance was recorded for altitudinal zonation above 3900 m asl and the lowest was for 3001-3300 m asl (Figure 8).

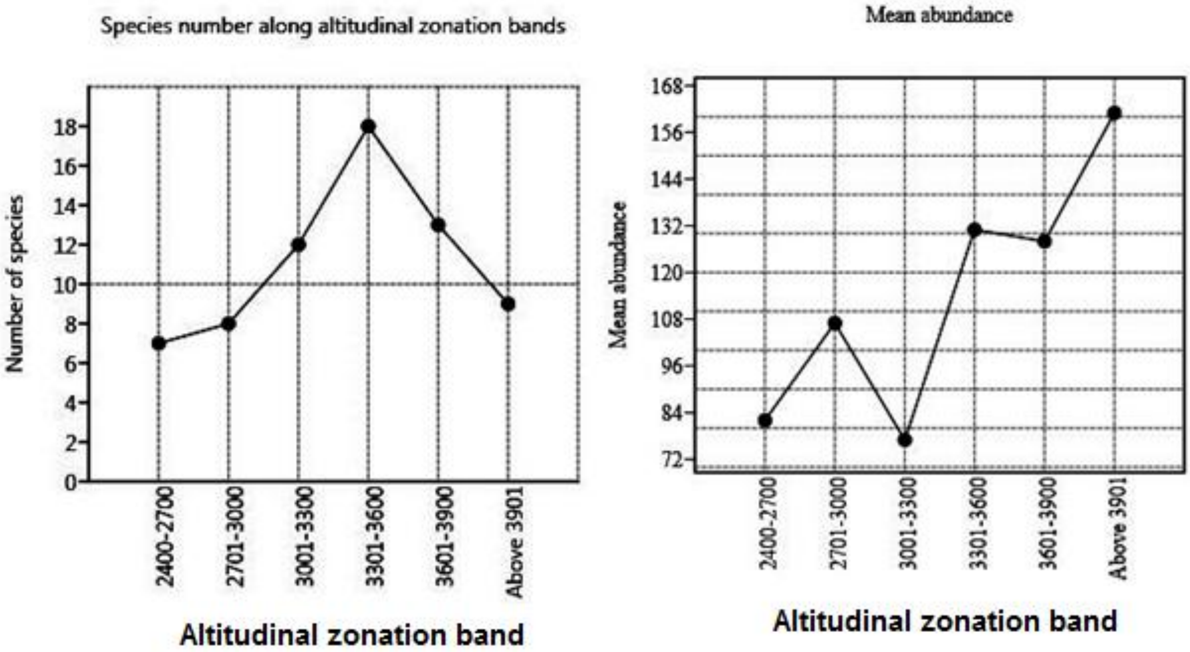

Figure 8. Species richness and abundance of small mammals along altitudinal zonations

The diversity indices for altitudinal zonation band are presented in Table 24. All the diversity indices except evenness indicated as altitudinal zonation band of 3301-3600 m asl had high diversity. Furthermore the Chao-1 species estimation also showed the species richness was 27 (Table 24). The second highly diverse altitudinal zonation was 3600- 3900 m asl. However for altitudinal zonation band of 2400-2700 m asl the diversity indices indicated lowest diversity with the exception of evenness diversity index (Table 24).

Table 24. Diversity indices of rodents and shrews along altitudinal zonations

Altitudinal zonation (m asl)	Taxa S	Individuals	Dominance	Simpson	Shannon	Evenness	Chao-1
2400-2700	7	84	0.3605	0.6395	1.371	0.5628	7
2701-3000	8	107	0.2239	0.7761	1.64	0.6446	9
3001-3300	12	82	0.1862	0.8138	1.956	0.589	22
3301-3600	18	128	0.1696	0.8304	2.139	0.4719	27.33
3601-3900	12	117	0.177	0.823	2.011	0.6227	15
Above 3901	9	164	0.2483	0.7517	1.582	0.5408	9

6.10. Land use and impacts of artificial plantation on rodents and shrews

The abundance of small mammals in plantation habitat of grid CH-02 (56) was much lower than the abundance of small mammals in nearby Montane forest habitat of Grid CH-01 (139) and *Erica* forest habitats of Grid CH-03 (158) (Table 25).

Table 25. Species composition and abundance of small mammals in plantation and nearby natural habitats

Species	MF* CH-01	PL# CH-02	EF* CH-03	PL# CH-10	ES* CH-11	AL# CH-Ag	MF* CH-AS1	PL# CH-AS3	Total
Sp	77	21	31	8	4	28	76	19	264
Sg	5	15	63	1	36	13	0	27	160
Lb	21	6	49	2	32	0	0	0	110
Lc	35	2	0	2	0	0	3	11	53
Mn	1	8	0	2	0	30	5	6	52
Mm	0	2	0	0	2	26	0	3	33
Ct	0	0	15	0	6	0	0	0	21
Co	0	0	0	2	0	4	0	0	6
Rr	0	0	0	0	0	4	2	0	6
Aa	0	2	0	0	0	1	0	1	4
Sc	0	0	0	0	3	0	0	0	3
Oh	0	0	0	1	1	0	0	0	2
Mi	0	0	0	0	0	1	0	0	1
Total	139	56	158	18	84	107	86	67	715
No. of species	5	7	4	7	7	8	4	6	13

Aa=*A. abyssinicus*, Co=*C. olivieri*, Ct=*C. thalia*, Lb=*L.brevicaudus*, Lc= *L. chrysopus*, Mn=*M. natalensis*, Mi=*M. imberbis*, Mm=*M. mahomet*, Oh=*O. helleri*, Rr=*R. rattus*, Sa=*S. albipes*, Sg=*S. griseicauda*, Sc= *S. albocaudata*, Al=Agricultural land, BL=Bushland, EF=*Erica* forest, ES=*Erica* scrub, GL=Grassland, MF=Montane forest, ML=Moorland, PL= Plantation, *- gird more or less natural habitat nearby the modified habitat, # - grid with modified habitat

However, for species richness, the modified plantation habitat had a higher number of species than the two natural habitats (Table 25). The abundance in relatively older plantation habitat of Grid CH-10 was lower than the nearby *Erica* scrub habitat even though both had equal species richness. The agricultural land habitat of Grid CH-Ag had relatively more abundance than the other plantation habitat close to it. However, in species richness, it was the highest. The plantation habitat of grid CH-AS3 had lower abundance of rodents and shrews than the nearby relatively natural montane forest habitat of Grid CH-AS1 though it had more species (Table 25). The highest species richness was recorded in agricultural land.

The similarity cluster for modified habitats and nearby semi-natural habitat based on abundance data is shown in Figure 9. According to the dendrogram, except for the plantation habitat of CH-10, all the remaining modified habitats were more closely related. In particular, the two modified plantation habitats of Grid CH-AS3 and Grid CH-01 were much related. In the same way, the semi- natural montane forest habitats and both the *Erica* habitats showed high similarity (Figure 9).

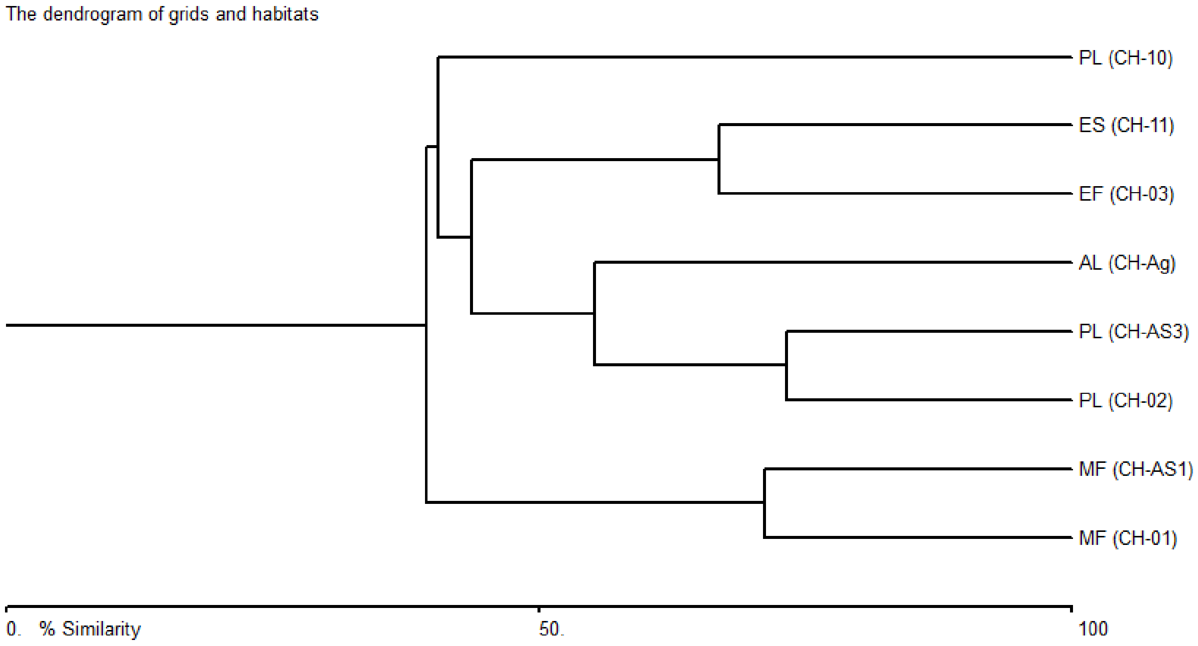

Figure 9. Dendrogram for selected modified habitats and nearby semi-natural habitat using Bray-Curtez similarity based on abundance data

6.11. Diurnal and nocturnal activity of rodents and shrews

Out of the 3415 species captured 2114 (61.9%) were active during the night time. The diurnal and nocturnal activity of rodents was statistically significant (χ^2 = 193.549, df = 1, $p<0.05$).

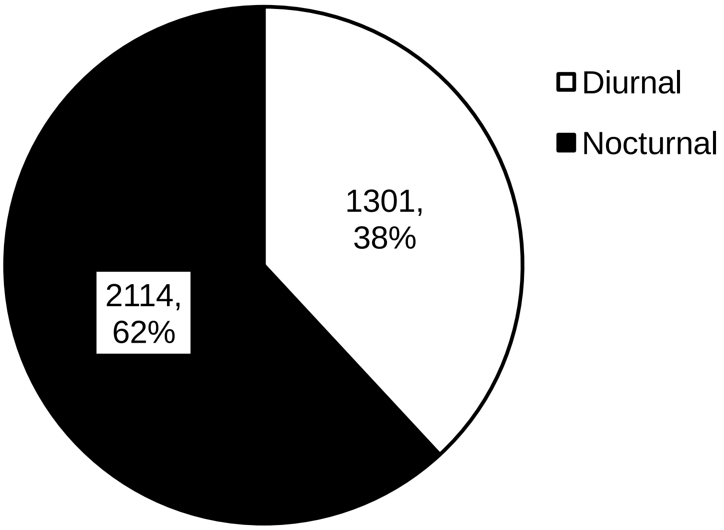

Figure 10. Overall captures of small mammals during diurnal and nocturnal trapping sessions

The daily activity of each species of rodents and shrews is given in Figure 11. *Lophuromys brevicaudus*, *A. blicki* and *L. melanonyx* were dominantly captured during day light (diurnal) but *S. griseicauda*, *S. albipes*, *S. albocaudata* and *M. mahomet* were dominantly captured during the night time (Figure 11). *Lophuromys chrysopus* and *O. helleri* and *C. glassi* were crepuscular.

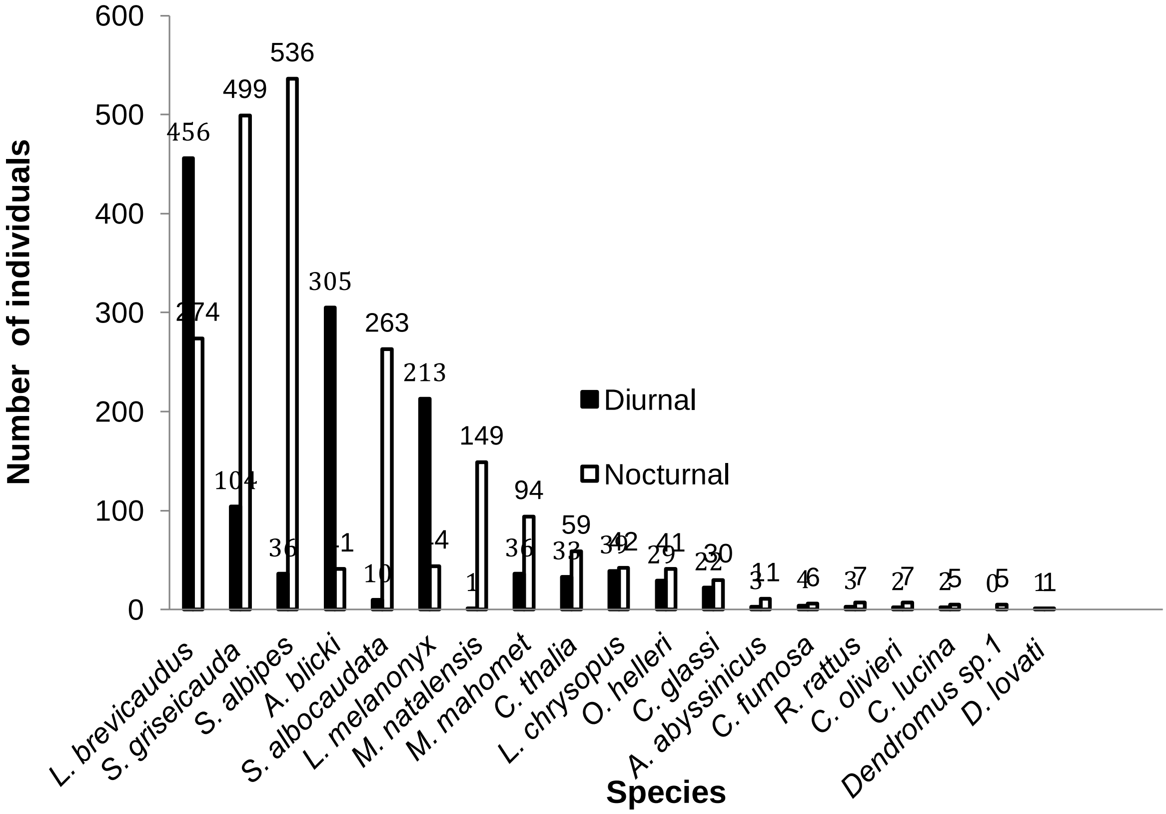

Figure 11. Number of rodents and shrews captured during day and night trapping sessions

**M. imberbis* and *D. nikolausi* were excluded

6.12. Population size of rodents and shrews

Total estimation for population size of small mammals was 25451. *Erica* forest had the highest (6565) followed by *Erica* scrub (6282) and moorland (5794) while agricultural land (840) and plantation habitats (889) had low population estimation (Table 26).

Lophuromys brevicaudus (5950) had the largest population estimation and followed by *S. albipes* (5194) and *S. griseicauda* (3988) and *A. blicki* (2601) (Table 26).

Agricultural land, bushland, plantation and montane forest habitats had the highest population estimation during both dry and wet seasons. In *Erica* forest, the population estimation was highest for *S. albipes* but during the dry season, the highest was *L. brevicaudus* (Table 26). In *Erica* scrub, *L. brevicaudus* was the dominant species during both seasons. For moorland habitats, *A. blicki* had the highest population estimation during wet and dry seasons (Table 26).

Table 26. Seasonal population size of rodents and shrews from each habitats of intensive study girds

	AL		BL		EF		ES		GL		MF		ML		PL		Total
	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	
Lb	0	0	72	0	638	1364	1414	878	264	60	72	98	919	171	0	0	5950
Sp	306	72	323	572	883	382	13	233	144	84	646	1085	0	0	242	209	5194
Sg	0	42	12	12	646	705	957	862	237	168	79	11	0	5	109	143	3988
Ab	0	0	0	0	544	12	0	2	12	0	0	0	1394	637	0	0	2601
Sc	0	0	0	0	0	159	534	20	199	91	0	0	615	331	0	0	1949
Lm	0	0	0	0	139	0	0	209	0	47	0	0	901	508	0	0	1804
Mm	233	2	0	0	0	0	349	229	0	12	0	0	0	0	6	12	843
Mn	139	42	30	42	183	60	0	83	72	72	59	8	0	0	29	23	842
Lc	0	0	40	182	0	0	0	6	0	0	69	185	0	0	32	72	586
Cg	0	0	0	0	84	240	6	0	0	0	0	0	210	19	0	0	559
Oh	0	0	0	0	20	132	343	30	0	0	0	0	0	30	0	0	555
Ct	0	0	0	0	129	215	110	0	12	0	0	0	12	24	0	0	502
Cf	0	0	0	0	30	0	0	2	0	0	0	0	0	0	0	0	32
Aa	0	0	0	0	0	0	0	0	0	2	6	0	0	0	0	12	20
Cl	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	18
Co	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	6
Total	682	158	477	808	3296	3269	3726	2556	940	538	931	1387	4051	1743	418	471	25451
	840		1285		6565		6282		1478		2318		5794		889		

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cf=*C. fumosa*, Cg=*C. glassi*, Cl=*C. lucina*, Ct=*C. thalia*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mn=*M. natalensis*, Md=, Mm=*M. mahomet*, Oh=*O. helleri*, , Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*, Al=Agricultural land, BL=Bushland, EF=*Erica* forest, ES=*Erica* scrub, GL=Grassland, MF=Montane forest, ML=Moorland, PL= Plantation, D=dry, W=wet, *Dendromus* sp.1, *D. lovati*, *D. nikolausi*, *M. imberbis*, *R. rattus* and *C. olivieri* were excluded due to their biased low population estimation

The seasonal population estimations of small mammals were given on Figure 12. Almost all species had more number of estimation during dry season than wet season with the exception of *S. albipes* and *L. chrysopus* (Figure 12).

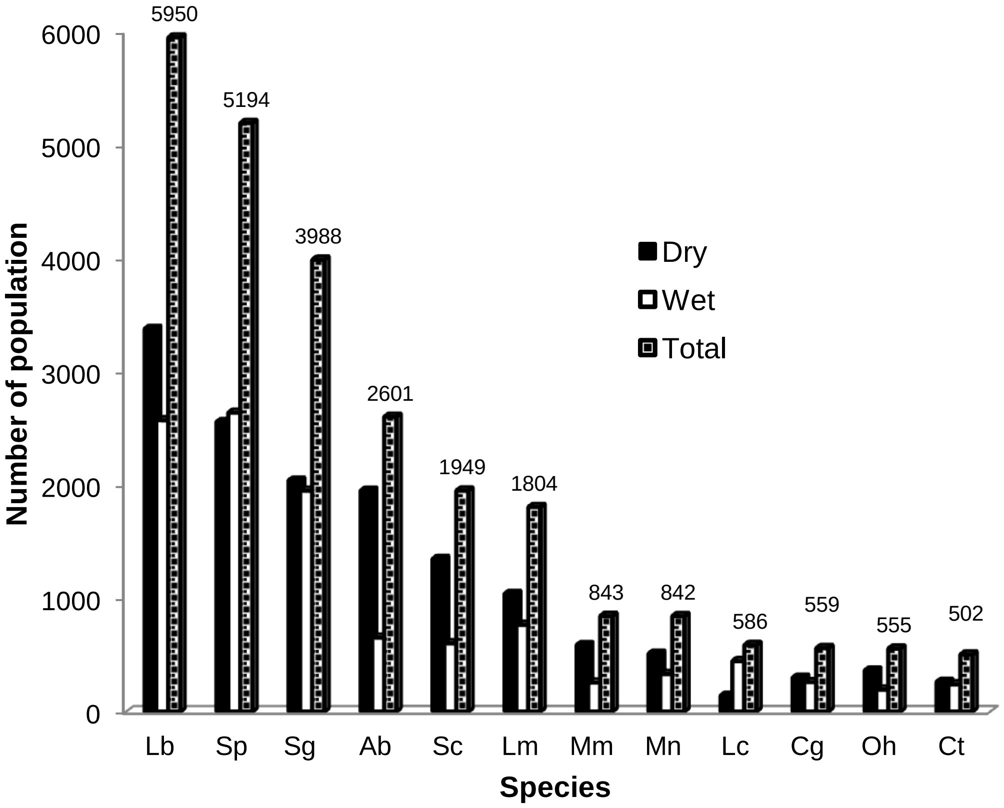

Figure 12. Population size for each species during wet and dry seasons from intensive study grids

Di, Dl, Cl, Cf , Aa, Cl, Co and Rr were excluded, Aa=*A. abyssinicus*, Ab=*A. blicki*, Cf=*C. fumosa*, Cg=*C. glassi*, Cl=*C. lucina*, Co=*C. olivieri*, Ct=*C. thalia*, Di=*Dendromus* sp.1, Dl=*D. lovati*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mn=*M. natalensis*

In agricultural land, montane forest and bushland habitat high mean population was estimated for *S. albipes* during both dry and wet seasons (Table 27). For *Erica* forest, the highest population estimation was measured for *S. albipes* during the dry seasons, but *L. brevicaudus* was highest during the wet season. In the grassland habitat *L. brevicaudus* (132) during the dry season and *S. griseicauda* (56) during the wet season had the highest population estimation. The maximum population estimation in moorland habitat was recorded for *A. blicki* during both seasons.

Over all the maximum total mean population estimation was estimated for moorland habitat and *Erica* forest during the dry season (Table 27).

Table 27. Species composition and mean population size per each habitat for dry and wet seasons

Species	AL		BL		EF		ES		GL		MF		ML		PL		T
	D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W	
Sp	306	72	162	286	147	64	2	39	72	28	215	362	0	0	81	70	1906
Lb	0	0	36	0	106	227	177	146	132	20	24	33	184	34	0	0	1119
Sg	0	42	6	6	108	118	120	144	119	56	26	4	0	1	36	48	834
Ab	0	0	0	0	91	2	0	0	6	0	0	0	279	127	0	0	505
Sc	0	0	0	0	0	27	67	3	100	30	0	0	123	66	0	0	416
Mn	139	42	15	21	31	10	0	14	36	24	20	3	0	0	10	8	373
Lm	0	0	0	0	23	0	0	35	0	16	0	0	180	102	0	0	356
Mm	233	2	0	0	0	0	44	38	0	4	0	0	0	0	2	4	327
Lc	0	0	20	91	0	0	0	1	0	0	23	62	0	0	11	24	232
Cg	0	0	0	0	14	40	1	0	0	0	0	0	42	4	0	0	101
Ct	0	0	0	0	22	36	14	0	6	0	0	0	2	5	0	0	85
Oh	0	0	0	0	3	22	43	5	0	0	0	0	0	6	0	0	79
Aa	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	4	7
Cf	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	5
Cl	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4
Co	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Rr	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Di	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Md	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T	682	158	239	404	549	545	466	426	470	179	310	462	810	349	139	157	6354

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cf=*C. fumosa*, Cg=*C. glassi*, Cl=*C. lucina*, Co=*C. olivieri*, Ct=*C. thalia*, Di=*Dendromus* sp.1, Dl=*D. lovati*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mi=*M. imberbis*, Mm=*M. mahomet*, Oh=*O. helleri*, Rr=*R. rattus*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*, D=dry, W=wet, T=total

6.13. Density and biomass of rodents and shrews

The overall density of rodents and shrews was 11288 individuals per hectare (Table 28). The maximum density 2061 was recorded from moorland and *Erica* forest (1948) and *Erica* scrub (1587). The minimum density was traced from plantation habitat which was 529 ha. Rodents and shrews show variation in density among the habitats (Table 28).

Table 28. Density per hectare of rodents and shrews in different habitats

Species	AL	BL	EF	ES	GL	MF	ML	PL	Total
Sp	672	796	375	73	178	1026	0	268	3388
Lb	0	64	592	574	270	101	388	0	1989
Sg	75	21	402	469	311	53	2	149	1482
Ab	0	0	165	0	11	0	722	0	898
Sc	0	0	48	124	231	0	336	0	739
Mn	322	64	73	25	107	41	0	32	664
Lm	0	0	41	62	28	0	501	0	632
Mm	418	0	0	146	7	0	0	11	582
Lc	0	197	0	2	0	151	0	62	412
Cg	0	0	96	2	0	0	82	0	180
Ct	0	0	103	25	11	0	12	0	151
Oh	0	0	44	85	0	0	11	0	140
Aa	0	0	0	0	2	4	0	7	13
Cf	0	0	9	0	0	0	0	0	9
Cl	0	0	0	0	0	0	7	0	7
Rr	0	0	0	0	2	0	0	0	2
Co	0	0	0	0	0	0	0	0	0
Di	0	0	0	0	0	0	0	0	0
Dl	0	0	0	0	0	0	0	0	0
Md	0	0	0	0	0	0	0	0	0
Mi	0	0	0	0	0	0	0	0	0
Total	1487	1142	1948	1587	1158	1376	2061	529	11288

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cf=*C. fumosa*, Cg=*C. glassi*, Cl=*C. lucina*, Co=*C. olivieri*, Ct=*C. thalia*, Di=*Dendromus* sp.1, Dl=*D. lovati*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mi=*M. imberbis*, Mm=*M. mahomet*, Oh=*O. helleri*, Rr=*R. rattus*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*, Al=Agricultural land, BL=Bushland, EF=*Erica* forest, ES=*Erica* scrub, GL=Grassland, MF=Montane forest, ML=Moorland, PL= Plantation

The total biomass recorded from all intensive study grids was 199169 g, the mean was 58.32 with standard deviation 58.32. There was slight seasonal biomass variation in which the maximum was recorded during the dry season. The highest total biomass was contributed by *S. greiseicauda* during both seasons (Table 29). The seasonal biomass of small mammals is given in Table 30.

Table 29. Mean and standard deviation of biomass (g) for each species of rodents and shrews in wet and dry seasons

Species	Dry			Wet			Total		
	Sum	Mean	Std	Sum	Mean	std	sum	mean	Std
Sg	18906	63.66	19.27	18947	61.92	13.61	37853	62.77	16.65
Lb	15500	48.44	8.53	19483	47.52	8.02	34983	47.92	8.25
Ab	22006	101.88	25.77	12897	99.21	25.81	34903	100.88	25.78
Sp	12062	51.11	15.94	16346	48.65	14.29	28408	49.66	15.03
Sc	12783	86.37	22.11	11519	92.15	21.12	24302	89.02	21.81
Lm	9827	76.77	14.19	8886	68.88	16.61	18713	72.81	15.92
Oh	4277	89.1	20.79	1539	69.95	25.74	5816	83.09	24.01
Mn	3215	37.38	9.38	2154	33.66	7.12	5369	35.79	8.66
Lc	1247	44.54	7.75	2221	41.91	10.3	3468	42.81	9.53
Mm	827	10.21	1.05	453	9.24	1.76	1280	9.85	1.43
Aa	426	85.2	22.2	738	82	26.22	1164	83.14	24.02
Ct	497	12.43	1.81	620	11.92	1.62	1117	12.14	1.71
Rr	244	81.33	7.09	504	72	21.96	748	74.8	18.79
Cg	294	10.5	1.62	250	10.42	1.32	544	10.46	1.47
Co	92	15.33	4.46	42	14	5.2	134	14.89	4.43
Cf	77	12.83	1.94	36	9	1.63	113	11.3	2.63
Cl	0	0	0	80	11.43	1.9	80	11.43	1.9
Di	10	10	0	63	15.75	0.96	73	14.6	2.7
Mi	30	30	0	0	0	0	47	47	0
Md	0	0	0	47	47	0	30	30	0
Dl	24	12	2.83	0	0	0	24	12	2.83
Total	102344	60.92	30.24	96825	55.81	26.22	199169	58.32	28.38

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cf=*C. fumosa*, Cg=*C. glassi*, Cl=*C. lucina*, Co=*C. olivieri*, Ct=*C. thalia*, Di=*Dendromus* sp.1, Dl=*D. lovati*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mi=*M. imberbis*, Mm=*M. mahomet*, Oh=*O. helleri*, Rr=*R. rattus*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*

Table 30. Biomass (g) for each species of rodents and shrews per hectare from each habitat and season

		AL		BL		EF		ES		GL		MF		ML		PL		
	Wt	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Total
Sp	50	27015	6356	14302	25249	12978	5650	177	3443	6356	2472	18981	31959	0	0	7151	6180	168319
Lb	48	0	0	3067	0	9030	19338	15079	12438	11245	1704	2045	2811	15675	2897	0	0	95377
Ab	101	0	0	0	0	16320	359	0	0	1076	0	0	0	50037	22777	0	0	90670
Lm	73	0	0	0	0	2977	0	0	4530	0	2071	0	0	23299	13203	0	0	46153
Mn	36	8844	2672	954	1336	1972	636	0	891	2291	1527	1273	191	0	0	636	509	23768
Lc	43	0	0	1522	6926	0	0	0	76	0	0	1750	4719	0	0	837	1827	17700
Oh	83	0	0	0	0	443	3250	6352	739	0	0	0	0	0	886	0	0	11753
Mm	10	4080	35	0	0	0	0	770	665	0	70	0	0	0	0	35	70	5735
Cg	10	0	0	0	0	260	744	19	0	0	0	0	0	781	74	0	0	1888
Ct	12	0	0	0	0	475	777	302	0	129	0	0	0	43	108	0	0	1846
Aa	83	0	0	0	0	0	0	0	0	0	148	296	0	0	0	0	591	1118
Rr	75	0	0	0	0	0	0	0	0	0	133	0	0	0	0	0	0	208
Co	15	106	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	121
Cf	11	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	111
Cl	11	0	0	0	0	0	0	0	0	0	0	0	0	0	81	0	0	92
Md	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47
Mi	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30
Di	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
Dl	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Sc	89	0	0	0	0	0	4273	10603	475	15826	4748	0	0	19466	10445	0	0	65925

Sg	63	0	4687	670	670	12052	13168	13391	16069	13279	6249	2901	446	0	112	4017	5356	93130
Total		40045	13751	20515	34181	56608	48195	46693	39326	50203	19122	27246	40126	109301	50582	12677	14533	623104

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cf=*C. fumosa*, Cg=*C. glassi*, Cl=*C. lucina*, Co=*C. olivieri*, Ct=*C. thalia*, Di=*Dendromus* sp.1, Dl=*D. lovati*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mi=*M. imberbis*, Mm=*M. mahomet*, Oh=*O. helleri*, Rr=*R. rattus*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S.* griseicauda, Al=Agricultural land, BL=Bushland, EF=*Erica* forest, ES=*Erica* scrub, GL=Grassland, MF=Montane forest, ML=Moorland, PL= Plantation

6.14. Body measurements and embryo count for rodents and shrews

From all the rodents and shrews, *Tachyoryctes splendens* has the largest mean body weight of 224±73.49 g and body length (20.1 ± 73.4 cm) while the smallest body weight was measured for C. fumosa (6±0) g and body length (6.9±0.7) cm for *M. mahomet* (Table 31). Tail length without tip hair was 15.7±2 cm and the least was for *C. lucina* (Table 31).

Table 31. Mean body measurements (weight in g and length in cm) of rodents and shrews

Species	Weight ($\bar{x}$±sd)	Body length ($\bar{x}$±sd)	Tail length without tip hair ($\bar{x}$±sd)	Tail length with tip hair ($\bar{x}$±sd)	Foot length without nail ($\bar{x}$±sd)	Foot length with nail ($\bar{x}$±sd)	Ear length ($\bar{x}$±sd)
Aa (5)	85.2±13.4	14.7±0.5	11.6±0.6	11.7±0.6	2.9±0.1	3.2±0.1	1.8±0.1
Ab (1)	104.0±0	14.0±0.	10.3±0	10.7±0.	3.0±0	3.2±0	2.0±0
Cf (1)	6.0±0	8.5±0	5.0±0	5.0±0	1.5±0	1.7±0	0.6±0
Cg (8)	13.3±2.6	9.0±0.4	6.0±0.7	6.3±0.7	1.5±0.2	1.7±0.1	1.0±0.1
Cl (2)	7.0±2.8	7.9±0.1	5.1±0	5.5±0.1	1.3±0.4	1.6±0.4	1.1±0.2
Co (1)	25.0±0	12.0±0	6±0	2.0±0	8.0±0	0.83±0	1.0±0
Ct (8)	14.5±5.4	9.0±1.0	5.8±0.6	6.1±0.7	1.7±0.2	1.9±0.2	1.0±0.2
Di(2)	10.0±5.7	7.0±0.7	6.3±0.4	6.4±0.4	1.8±0	2.1±0.1	1.8±0.4
Dl(3)	10.5±2.3	7.0±0.5	8.9±1.6	8.9±1.6	1.9±0.2	2.0±0.1	1.6±0.4
Lb (17)	49.6±11.4	11.8±0.9	5.7±0.8	5.9±0.8	2.1±0.1	2.4±0.2	1.8±0.1
Lc (4)	50.8±8.8	12.6±0.8	6.2±1.1	6.4±1.1	2.1±0.1	2.35±0.1	1.9±0.1
Lm (3)	63.3±19.4	12.8±1.6	5.2±0.5	5.4±0.6	2.3±0.2	2.7±0.2	1.8±0.2
Mn (11)	53.4±14.7	12.9±1.2	13.1±2.9	13.2±3.3	2.6±0.1	2.9±0.1	2.3±0.2
Md (1)	47.0±0	11.0±0	9.5±0	9.6±0	2.1±0	2.4±0	2.5±0
Mi (1)	30.0±0	10.0±0	5.3±0	5.3±0	1.7±0	1.9±0	1.3±0
Mm (7)	8.4±2.07	6.9±0.7	4.8±0.6	4.9±0.5	1.6±0.2	1.7±0.3	1.2±0.1
Oh (8)	95.8±30.8	14.2±1.1	6.4±1.9	6.4±2.0	2.2±0.6	2.5±0.7	2.2±0.1
Rr (1)	63.0±0	14.5±0	14.8±0	15.0±0	3.0±0	3.2±0	2.3±0
Sp (18)	60.8±20.7	13.6±1.4	15.7±2.0	15.8±2.0	2.7±0.1	2.9±0.2	2.4±0.2
Sc (11)	87.0±25.6	14.1±1.9	12.0±3.5	12.1±3.4	3.0±0.2	3.2±0.2	2.8±0.3
Sg (22)	66.9±16.7	14.0±1.4	13.0±1.5	13.1±1.6	2.7±0.2	3.0±0.2	2.4±0.3
Ts (4)	224.3±73.4	20.1±4.0	8.1±4.3	8.6±4.2	2.7±0.2	3.1±0.2	1.2±0.1

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cf=*C. fumosa*, Cg=*C. glassi*, Cl=*C. lucina*, Co=*C. olivieri*, Ct=*C. thalia*, Di=*Dendromus* sp.1, Dl=*D. lovati*, Lb=*L. brevicaudus*, Lc=*L. chrysopus*, Lm=*L. melanonyx*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mi=*M. imberbis*, Mm=*M. mahomet*, Oh=*O. helleri*, Rr=*R. rattus*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*, TS= *Tachyoryctes splendens*, number in bracket shows number of individuals

Relatively the largest foot length was measured for *S. albocaudata* and *A. blicki* whereas the least was *C. lucina*. Ear length was the largest for *S. albocaudata* (2.8±0.3) and the least was for *C. fumosa* (0.6±0) (Table 31).

Embryo counts were made for 40 pregnant small mammals belonging to 10 species (Table 32). About 37% of rodents and shrews have left horned embryo. The double number of embryo number in the left horn accounts for 25 % and single number of embryo on right horn accounts for 17.5% of small mammals. The largest mean embryo was counted for *M. natalensis* and the least was for *S. albipes* (Table 32).

Table 32. Number of embryos in the left horn and right horn and mean number of embryos per female

Species	No. of embryo in the left horn			No. of embryo in the right horn		Total embryo in both horn					Mean embryo	Total
	Two	Three	Eight	One	Two	Two	Three	Four	Five	Nine		
Cg	1	-	-	-	1	-	-	1	-	-	4	3
Ct	-	1	-	-	1	-	-	-	1	-	5	3
Lb	4	-		3	-	-	3	-	-	-	3	10
Mn	-	-	1	1	-	-	-	-	-	1	9	3
Md	1	-	-	-	1	-	-	1	-	-	4	3
Mm	-	1	-	-	1	-	-	-	1	-	4	3
Oh	1	-	-	-	-	1	-	-	-	-	5	2
Sp	1	1	-	1	1	-	1		1	-	2	6
Sc	1	-	-	1	-	-	1	-	-	-	4	3
Sg	1	1	-	1	-	-	-	1	-	-	3	4
Total	10	4	1	7	5	1	5	3	3	1	-	40
Proportion (%)	25	10	2.5	17.5	12.5	2.5	12.5	7.5	7.5	2.5	-	100
	37.5			30		32.5						

Cg=*C. glassi*, Ct=*C. thalia*, Lb=*L. brevicaudus*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mm=*M. mahomet*, Oh=*O. helleri*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*

6.15. Abundance and distribution of *Tachyoryctes splendens* and *Hystrix cristata*

Agricultural land has the largest mean of *Tachyoryctes splendens* abundance although *Erica* scrub habitat had high gross abundance. The second high mean abundance (12.5±6.4) was in grassland (Table 33). The habitat with least mean abundance of *T. splendens* was plantation 4.3±3.8.

Hystrix cristata was relatively higher in abundance in agricultural land and bushland habitat followed by *Erica* forest habitat. There was no observation of *Hystrix cristata* in moorland habitat and the mean abundance was relatively low in grassland habitat (Table 33).

Table 33. Abundance *Tachyoryctes splendens* and *Hystrix cristata* in different habitats

Habitat	*Tachyoryctes splendens*		*Hystrix cristata*	
	Abundance	Mean abundance (x̄±sd)	Abundance	Mean abundance (x̄±sd)
Agricultural land	18	18±0	3	3±0
Bushland	10	5±7.1	6	3±1.4
Erica forest	36	6±5.7	17	2.8±2.7
Erica scrub	44	5.5±4.6	11	1.4±1.7
Grassland	25	12.5±6.4	2	1±1.4
Montane forest	20	6.7±1.5	8	2.7±1.2
Moorland	34	6.8±4.7	0	0±0
Plantation	13	4.3±3.8	6	2±1
Total	200	6.7±5.1	53	1.8±1.8

The distribution of *T. splendens* and *H. cristata* along altitudinal zonation is shown in Figure 10. The peak mean abundance of *T. splendens* was from altitudinal zonation band of 2400- 2700 m asl and the least was for altitudinal zonation band of 3601-3900 m asl. The altitudinal zonation above 3900 m asl had relatively high mean abundance of *T. splendens*.

Mean abundance of *H. cristata* seams to decrease along altitudinal zonation although its mean abundance was maximum in altitudinal zonation band of 2701-3000 m asl. There was no observed record of *H. cristata* along altitudinal zonation band above 3900 m asl (Figure 13).

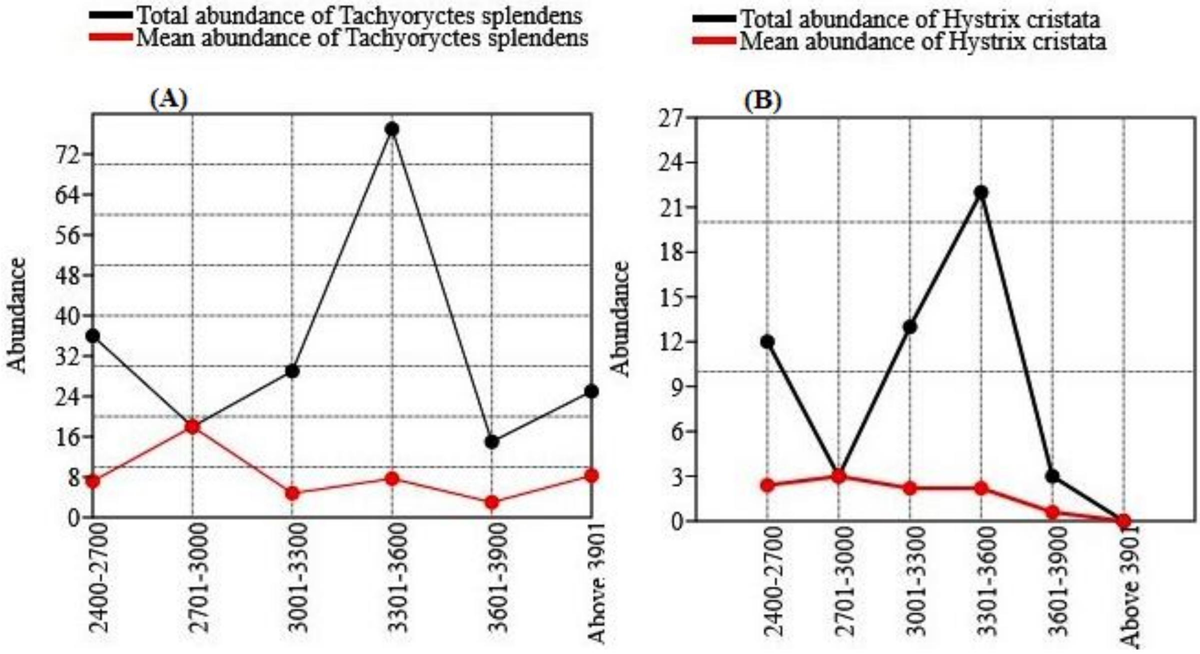

Figure 13. Total and mean abundance of *Tachyoryctes splendens* and *Hystrix cristata* along different bands of altitudinal zonation

6.16. Bat species composition and relative abundance

During 60 netting nights (230 net-nights) or 8770.7,701 net-meter-hours (TNMH) (Table 3) a total of 219 bats were captured of which 197 (89.95%) were new captures, 16 (7.31%) were recaptures and the rest 6 (2.74%) escaped before their precise identification to species level or lacked other information such as standard body measurements, mass, sex or reproductive conditions (Table 34). The whole netting success during 230 net-night was 0.95 bats/net-night (Table 3). The overall capture rate was 0.83 bats/net-h. The average capture rate per site was 0.93 ± 0.32 bats/net-h. The highest capture rate (4.05 bats/net-h) was from Wolkessa River and Bridge, followed by Child Care compound (3.48 bats/net-h), whereas the least was from Koropta (0.2 bats/net-h). Even though trapping attempts were carried out in 16 sites, bats were captured at 10 (62.5%) of the sampling sites. There was no bat capture from Bora Luku, Checho Plantation, Chilalo-Muda, Jawi Juniperus Forest, Jitu Tena and Chilalo-Summit even though irregularly high flying vesper and mollossid bats call was recorded by bat call detector (Table 34). The majority (65.75%) of bat captures were recorded from four sites namely Child Care, Dankaka Juniperus forest, Gefersa Forest and Wolkessa River and Bridge. The average number of individuals of bats captured at each sampling site was 13.69 ± 4.08 (Table 34).

Table 34. Number of bats captured and trapping effort unit from each bat sampling site

Site name	Trapping effort	Number of bats capture				Capture rate
		New	Recaptured	Escaped	Total	
WR	11.86	43	4	1	48	4.05
CC	14.06	44	3	2	49	3.48
DJ	9.67	18	3	0	21	2.17
GF	15.13	25	0	1	26	1.72
AS	18.51	19	0	1	20	1.08
GW	19.01	12	2	0	14	0.74
AR	22.30	14	2	0	16	0.72
KS	39.39	16	1	0	17	0.43
KB	18.17	4	1	0	5	0.28
KO	14.89	2	0	1	3	0.20
BL	11.92	0	0	0	0	0.00
CP	13.52	0	0	0	0	0.00
CM	18.19	0	0	0	0	0.00
CS	15.11	0	0	0	0	0.00
JJ	10.69	0	0	0	0	0.00
JT	10.59	0	0	0	0	0.00
Total	263.01	197	16	6	219	14.87
Mean±SE	16.44±1.77	12.31±3.7	1±0.34	0.15±0.15	13.69±4.08	0.93±0.32

AR=Anku River Bridge, AS=Asella 07, CC=Child Care, DJ=Dankaka Juniperus Forest, GF=Gefersa Forest, GW=Gefersa Wolkessa Stream, KB=Kombolcha Bridge, KS=Kombolcha Stream, KO=Korobta and WR=Wolkessa River and Bridge, BL= Bora Luku, CP=Checho Plantation, CM=Chilalo-Muda, JJ=Jawi Juniperus Forest, JT=Jitu Tena and CS=Chilalo-Summit

A total of 13 species were captured (Table 5; Plate 6). Out of these species, the most abundant was *Myotis tricolor* 42 (20.69%) followed by *Pipistrellus hesperidus* 40 (19.70%). The least abundant species was *Epomophorus gambianus* 1 (0.49%). The unknown species of bats account for 2.96% of the total capture (Table 35).

Table 35. Relative abundance of each species of bats

Species	Recapture	New	Total	Relative Abundance (%)
Myotis tricolor	3	42	45	20.69
Pipistrellus hesperidus	2	40	42	19.70
Pipistrellus aero	2	22	24	10.84
Hipposideros caffer	1	21	22	10.34
Miniopterus inflatus	3	20	23	9.85
Neoromicia capensis	4	17	21	8.37
Miniopterus africanus	1	12	13	5.91
Rhinolophus fumigatus	0	7	7	3.45
Neoromicia nana	0	6	6	2.96
Stenonycteris lanosus	0	4	4	1.97
Plecotus balensis	0	3	3	1.48
Kerivoula lanosa	0	2	2	0.99
Epomophorus gambianus	0	1	1	0.49
Unknown species	0	6	6	2.96
Grand Total	16	203	219	100

The overall average of bat capture was 14.29±3.60. The highest bat capture was from Wolkessa River and Bridge (6.29±2.12) and the least (1.5±0.5) was from Korobta sampling site (Table 36).

More species (9) of bats were captured from Child Care Compound sampling site. The second highest numbers of species richness wise were Gefersa Forest and Wolkessa River and Bridge, whereas the least in species richness was from Korobta sampling site from where only single species was captured (Table 36).

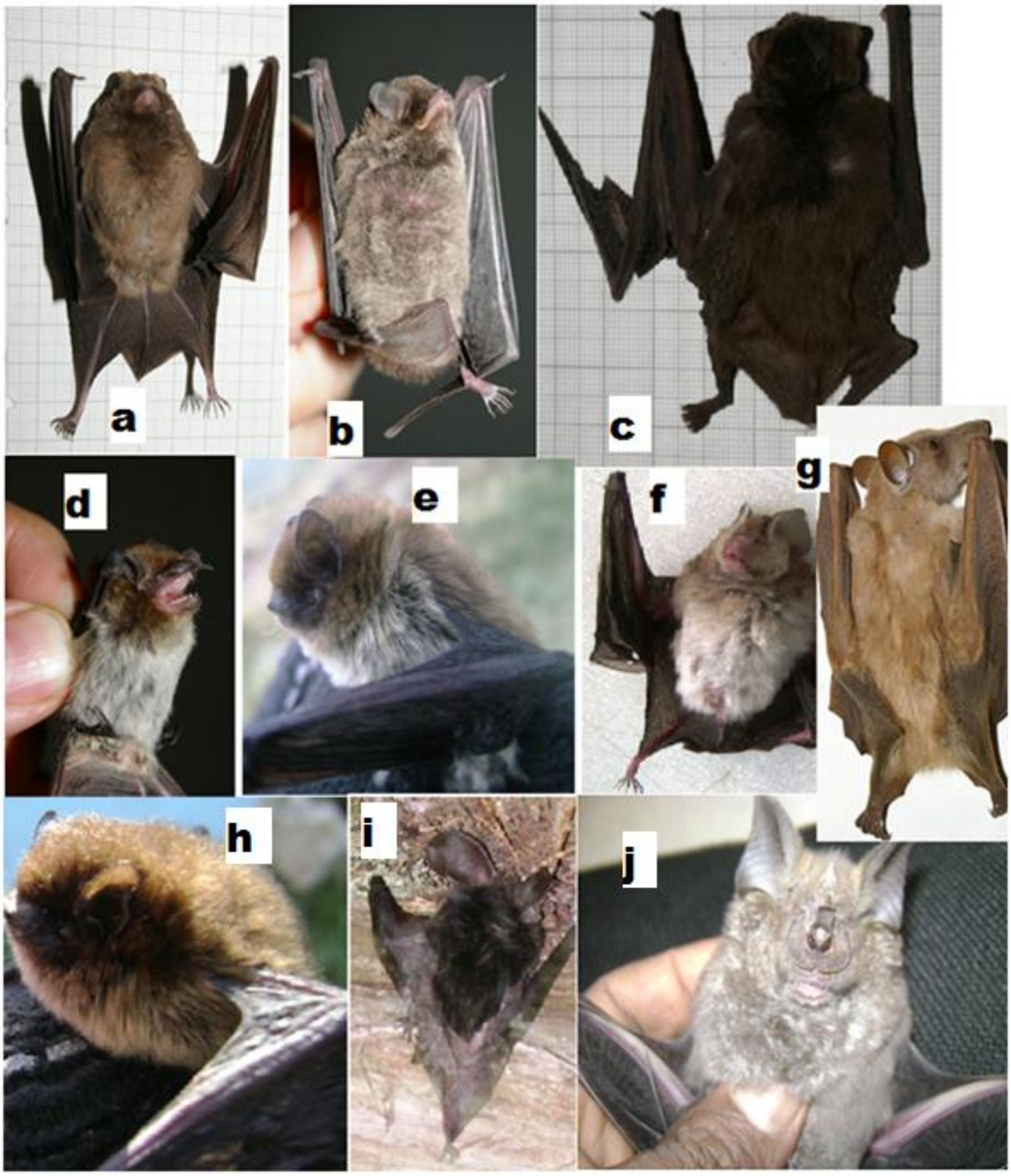

Plate 6. Some species of captured bats from the study area

(a. Miniopterus africanus b. *Miniopterus inflatus* c. *Pipistrellus hesperidus* d. *Neoromicia capensis* e. *Myotis tricolor* f. *Hipposideros caffer* g. *Epomophorus gambianus* h. *Kerivoula lanosa* i. *Plecotus balensis* j. *Rhinolophus fumigatus*)

Table 36. Distribution of bat species in each trapping site

Species	AR	AS	CC	DJ	GF	GW	KB	KS	KO	WR	Total
M. tricolor	2	1	6	4	6	4	0	4	0	15	42
P. hesperidus	2	8	7	0	8	4	0	0	0	11	40
P. aero	4	0	8	1	0	0	0	0	0	9	22
H. caffer	3	4	5	0	0	0	2	7	0	0	21
M. inflatus	3	0	6	0	7	4	0	0	0	0	20
N. capensis	0	1	3	0	1	0	2	5	0	6	18
M. africanus	0	0	1	9	0	0	0	0	2	0	12
R. fumigatus	0	0	4	2	0	0	0	0	0	1	7
N. nana	0	5	0	0	0	0	0	0	0	0	5
S. lanosus	0	0	4	0	0	0	0	0	0	0	4
P. balensis	0	0	0	2	1	0	0	0	0	0	3
K. lanosa	0	0	0	0	2	0	0	0	0	0	2
E. gambianus	0	0	0	0	0	0	0	0	0	1	1
Unknown	0	1	2	0	1	0	0	0	1	1	6
Total	14	20	46	18	26	12	4	16	3	44	203
Number of Species	5	5*	9*	5	6*	3	2	3	1*	6*	14
Average	2.80	3.33	4.6	3.6	3.71	4	2	5.33	1.5	6.29	14.29
Std. error	0.37	1.17	0.70	1.43	1.19	0	0	0.88	0.5	2.12	3.60

AR=Anku River Bridge, AS=Asella 07, CC=Child Care, DJ=Dankaka Juniperus Forest, GF=Gefersa Forest, GW=Gefersa Wolkessa Stream, KB=Kombolcha Bridge, KS=Kombolcha Stream, KO=Korobta and WR=Wolkessa River and Bridge * refers the species of unknown bats excluded)

Myotis tricolor was the most widely distributed species. It was captured from eight sampling sites followed by *Hipposideros caffer* and *Neoromicia capensis* which were recorded from six sampling sites (Figure 14). They were almost infrequently captured throughout the study area except from few sites. *Neoromicia nana*, *Stenonycteris lanosus*, *K. lanosa* and *Epomophorus gambianus* were captured from a single sampling site (Figure 14). The distribution of species in the sampling site from where bats were recorded was statistically significant ($\chi^2 = 37.5$, df = 1, $P < 0.0001$).

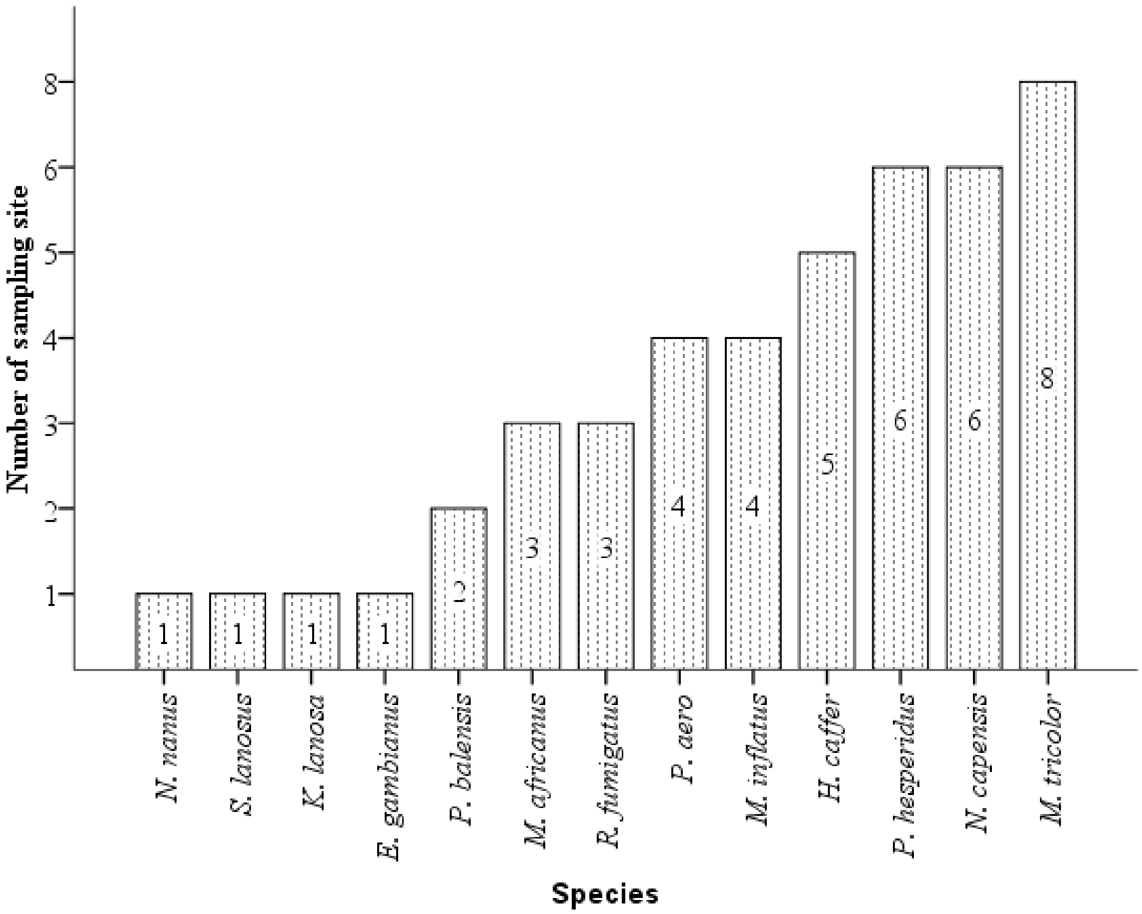

Figure 14. Distribution of bat species in sampling sites

Relatively more males than females were captured (Table 37). However, the difference between number of males (102) and females (95) of captured bats were not statistically significant (χ^2 = 0.249, df = 1, P > 0.05). Over all 37 (18.78%) of new captured bats were sub-adults (Table 37), with sub-adult captures totalling 11(5.58%) for *Pipistrellus hesperidus* and 10(5.08%) for *Myotis tricolor* (Table 37). Only two sub-adults for *Miniopterus africanus* were recorded. More adults 160 (81.22%) were captured (Table 37). The age variations among the captured bats were statistically significant (χ^2 =76.797, df = 1, P < 0.05).

Out of the 102 captured males, most were not reproductively active. Out of 95 captured female bats, 66 (69.47%) were reproductively inactive whereas the rest 29 (30.53%) were either pregnant or lactating (Table 37). The reproductive status for both male and female was statistically significant (χ^2 =10.039, df = 1, $P < 0.05$ and χ^2 =14.411, df = 1, $P < 0.05$, respectively).

Table 37. Sex, age and reproductive status of each species of captured bat

Species	Sex		Age		Male reproductive status		Female reproductive status		Total
	M	F	A	SA	I	S	IM	PR/L	
M. tricolor	22	20	32	10	16	6	16	4	42
P. hesperidus	18	22	29	11	12	6	16	2 (4)	40
P. aero	14	8	19	3	5	9	8	0	22
H. caffer	6	15	16	5	1	5	7	1 (7)	21
M. inflatus	11	9	20	0	5	6	7	2	20
N. capensis	10	8	12	6	9	1	7	0 (1)	18
M. africanus	8	4	10	2	8	0	2	2	12
R. fumigatus	4	3	7	0	3	1	0	3	7
N. nanus	3	2	5	0	2	1	0	2	5
S. lanosus	2	2	4	0	2	0	1	1	4
P. balensis	2	1	3	0	2	0	1	0	3
K. lanosa	2	0	2	0	2	0	0	0	2
E. gambianus	0	1	1	0	0	0	1	0	1
Total	102	95	160	37	67	35	66	17(12)=29	197

M= male. F= female, A= adult, Sa= sub-adult, I=inguinal, S=scrotal, IM=impregnant, L= lactating, PR=pregnant

Out of the 13 identified species recorded from the study area, nine species were captured from Child Care Compound. All the diversity indices except the evenness indicated Child Care compound is the most diverse sampling site (Table 38). The Shannon Weiner’s (H) is also highest (H = 2.098) followed by Anku River and Bridge with H’ = 1.574. The least Shannon-Weiner (H’) indice was obtained for Kombolcha River Bridge (H’ = 0.693). The highest evenness was obtained for Gefersa Wolkessa Stream, Kombolcha Bridge, Korobta and the least was measured from Dankaka Juniperus Forest (E = 0.756) (Table 38).

Simpson similarity index was highest (S = 0.87) for Child Care followed by Anku River and Bridge (S = 0.786) whereas, it is least for (S = 0) for Koropta (Table 38).

The second and the third sampling sites with high diversity were Anku River and Bridge and Gefersa Forest, respectively (Table 38). All the diversity indices with the exclusion of evenness indicated Koropta sampling site was least diverse (Table 38).

Table 38. Bat diversity indices for different trapping sites

Site	Taxa (s)	Abundance (N)	Dominance (D)	Simpson (S)	Shannon (H)	Evenness (E)	Chao-1
AR	5	14	0.214	0.786	1.574	0.965	5
AS	5	19	0.296	0.704	1.353	0.774	6
CC	9	44	0.13	0.87	2.098	0.906	9
DJ	5	18	0.327	0.673	1.33	0.756	5
GF	6	25	0.248	0.752	1.523	0.764	6.5
GW	3	12	0.333	0.667	1.099	1	3
KB	2	4	0.5	0.5	0.693	1	2
KS	3	16	0.352	0.648	1.072	0.974	3
KO	1	2	1	0	0	1	1
WR	6	43	0.252	0.749	1.493	0.742	7
Total	13	197	0.136	0.864	2.186	0.685	13

AR=Anku River Bridge, AS=Asella 07, CC=Child Care, DJ=Dankaka Juniperus Forest, GF=Gefersa Forest, GW=Gefersa Wolkessa Stream, KB=Kombolcha Bridge, KS=Kombolcha Stream, KO=Korobta and WR=Wolkessa River and Bridge

The refraction of species accumulation curve is shown in Figure 15. Species richness accumulation curves seem smoothed even though they did not maintain the asymptote (Figure 15). Out of all the sampling sites the rarefied species accumulation curve indicated as Kombolcha Stream, Asella 07 and Child care Compound relatively achieved the asymptote (Figure 15).

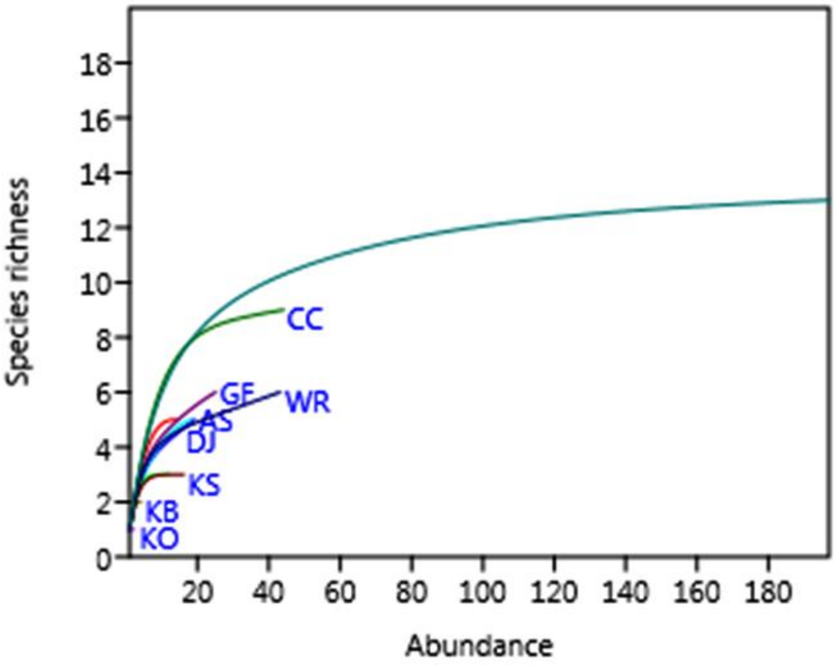

Figure 15. Rarefied species accumulation curves for each sampling site and total abundance of captured bats from Chilalo-Galama Mountains range and its surroundings

Embryos was counted for six species of bats namely *Hipposideros caffer*, *Miniopterus inflatus*, *Myotis tricolor*, *Neoromicia nanus*, *Pipistrellus hesperidus* and *Stenonycteris lanosus*. The embryo count was one except for *Myotis tricolor*.

The mean weight, foot length, arm length, body length, tail length and ear length with their standard deviation from the mean is shown in Table 39.

Table 39. Standard body measurements of the captured bat species.

Species	Wt±Std	FL±std	AL±std	BL±Std	TL±Std	EL±std
E. gambianus (1)	35±0	1.50±0	6.00±0	9.50±0	1.50±0	1.10±0
H. caffer(16)	5.03±1.7	0.93±0.1	4.29±1.2	5.27±0.49	3.20±0.57	1.65±0.12
K. lanosa(2)	3.50±0.7	0.70±0.1	3.25±0.35	4.90±0.14	3.80±0.0	1.10±0.14
M. africanus (10)	10.13±1.8	0.89±0.1	5.10±0.08	5.69±0.19	4.98±0.39	1.11±0.09
M. inflatus(20)	10.08±1.2	1.05±0.1	4.80±0.11	5.90±0.13	4.96±0.58	1.10±0.12
M. tricolor(31)	7.84±1.5	0.82±0.2	4.83±0.12	4.72±0.13	2.67±0.46	1.23±0.25
N. capensis(12)	5.08±1.4	0.71±0.2	3.2±0.29	7.25±1.71	3.10±0.19	1.01±0.22
N. nana(5)	4.6±1.1	0.52±0.1	3.5±1.12	3.78±0.63	3.38±0.49	1.26±0.47
P. aero (19)	4.47±0.23	0.76±0.1	3.24±0.23	4.64±0.44	3.02±0.40	1.16±0.27
P. hesperidus(32)	5.43±1.58	0.54±0.1	3.09±0.6	4.63±0.53	3.42±0.4	0.88±0.31
P. balensis(3)	7.33±0.58	0.80±0.0	3.87±0.06	4.70±0.1	4.60±0.1	3.03±0.06
R.fumigatus(7)	11.29±1.11	2.04±0.5	5.56±0.11	6.66±0.92	2.70±0.2	1.94±0.18
S. lanosus(4)	76±10.42	2.05±0.1	7.55±0.17	13.0±0.82	1.38±0.25	2.20±0.14

6.17. Karyotypes of some selected model species

In total, seven species comprising of 37 specimens were karyotyped. These species were: *L. melanonyx*, *L. brevicaudus*, *O. helleri*, *S. griseicada*, *S. albocaudata*, *T. splendens* and *Dendromus* sp.1 (Table 40).

Table 40. List of species karyotyped and number of specimens of small mammals from Chilalo-Galama Mountains Range

Species	Number of karyotyped specimens
Lophuromys melanonyx	2
Lophuromys brevicaudus	2
Otomys helleri	9
Stenocephalemys griseicauda	7
Stenocephalemys albocaudata	12
Tachyoryctes splendens	4
Dendromus sp.1	1

6.17.1. Lophuromys melanonyx

The karyotype of *Lophuromys melanonyx* from Chilalo-Galama Mountains Range was characterized by 60 diploid number of chromosomes (2n) and autosomal foundamental number, FNa= 86. The karyotype is composed of 12 pairs of biarmed and 17 pairs of uniarmed autosomes. The autosome chromosomal set comprised 12 pairs of metacentric and 17 pairs of acrocentric chromosomes. The sex chromosomes were metacentric and characterized by elaborated progresive decrease in size. Most of the metacentric autosome chromosomes were medium in size eventhough the first pair was slightly larger than the others. The largest pair of acrocentric chromosome had a confusing faint arm like structure. All autosomes were found to be biarmed and gradually decrease in size (Figure 16).

The X chromosome was metacentric and larger whereas the Y chromosome was approximately equal in size to the smallest autosomal pair and most likely acrocentric.

Figure 16. Representative karyotype of *Lophuromys melanonyx* (male)

6.17.2. Lophuromys brevicaudus

The chromosomal set of *Lophuromys brevicaudus* from Chilalo-Galama Mountains Range was characterized by diploid number of chromosomes 2n= 68 and autosomal foundamental number FNa = 78 (Figure 17). The chromosal set comprises four medium sized metacentric, three subtelocentric including the sex chromosomes and 27 acrocentric chromosomes slightly decreased by size (Figure 17). One of the autosomal chromosomes possesses secondary constriction.

Both sex chromosomes are biarmed, with the X-chromosome being a large metacentric and the Y being a small metacentric chromosome.

Figure 17. Representative karyotype of *Lophuromys brevicaudus* (female)

6.17.3. Otomys helleri

Otomys helleri from Chilalo-Galama Mountains Range was characterized by 58 diploid (2n) and 56 autosomal fundamental (FNa) numbers. The autosome set of chromosomes hold only one pair of small metacentric and 27 acrocentric pairs of chromosomes that portrayed slight decrease in size. The X and Y sex-chromosomes were acrocentric, however, the using of routine Giemsa staining only did not allow its clear identification (Figure 18).

Figure 18. Representative karyotype of *Otomys helleri* (female)

6.17.4. Stenocephalemys griseicauda

Stenocephalemys griseicauda from the study area was characterised by diploid number of chromosomes (2n= 54) and autosomal foundamental number (FNa = 58). The karyotype comprises one pair of small metacentric chromosomes, 2 pairs of large and small subtelocentric chromosomes and 23 pairs of acrocentric chromosomes (Figure 19). The sex chromosomes are represented by large metacentric (X) and medium subtelocentric (Y) (Figure 19).

Figure 19. Representative karyotype of *Stenocephalemys griseicauda* (male)

6.17.5. Stenocephalemys albocaudata

The karyotype of *S. albocaudata* from Chilalo-Galama Mountians Range indicated 2n= 54 and FNa = 62. The chromosomal set possessed one pair of small metacentric, four subtelocentric and 22 acrocentric chromosomes. Almost all subtelocentric chromosomes were equal in size, however, there was trivial decrease of size. Sex (X) chromosomes were large metacentric (Figure 20).

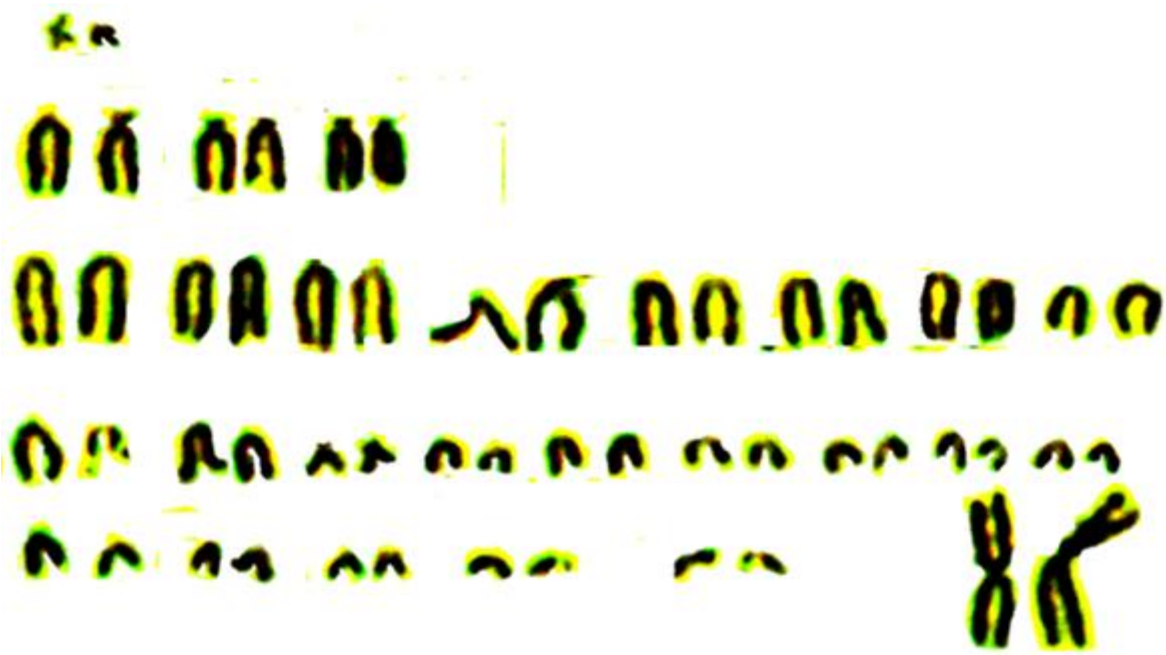

Figure 20. Representative karyotype of *Stenocephalemys albocaudata* (female)

6.17.6. Tachyoryctes splendens

Tachyoryctes splendens from Chilalo-Galama Mountains range was characterized by diploid number of chromosomes (2n=48) and autosomal foundamental number (FNa=64). It comprised one pair of medium sized and two pairs of small sized metacentric chromosomes, five pairs of large sized subtelocentrics chromosomes and 15 pairs of chromosomes which is probably acrocentric. The karyomorph of some chromosomes had confusing arm-like structures (Figure 21). The sex chromosomes were large metacentric; X chromosome was large while the Y chromosome was relatively smaller. Similarly, decrease in size of metacentric and subtelocentric chromosomes was observed although the decrease in size for acrocentric chromosmes was not clearly visible (Figure 21).

Figure 21. Representative karyotype of *Tachyoryctes splendens* (male)

6.17.7. *Dendromus* species

The diploid chromsome number for the undescriped new *Dendromus* species was 2n=50 and the autosomal foundamental chromosome number (FNa) was 80. The karyotype was characterized by one pair of small metacentric, 16 pairs of subtelocentric and 7 pairs of acrocentric chromosomes. The sex chromosomes were metacentric of which X chromosome was large and Y chromosome was relatively smaller. The subtelocentric chromosomes are equal medium sized with the exception of one large pair. In the same way, the acrocentric chromosomes exhibit insignificant size varation (Figure 22).

Figure 22. Representative karyotype of *Dendromus* sp.1 (male)

6.18. Phylogeography and genetic variability of selected model species

6.18.1. Crocidura glassi

The evolutionary history and phylogeography for *Crocidura glassi* are shown on Figure 23. The optimal tree had sum of branch length of 0.336. The analysis involved 18 nucleotide sequences and 316 positions in the final dataset.

The phylogeography and the evolutionary relationship of *C. glassi* from Arsi and Bale Mountains were supported by bootstrap index of 77%. However, there was a clear distinct clade separation between *C. glassi* of Arsi Mountains and Bale Mountains by 99% bootstrap support (Figure 23). In both the Arsi and Bale Mountains, there were at least two distinct clades with 94% and 91%, bootstrap support, respectively (Figure 23).

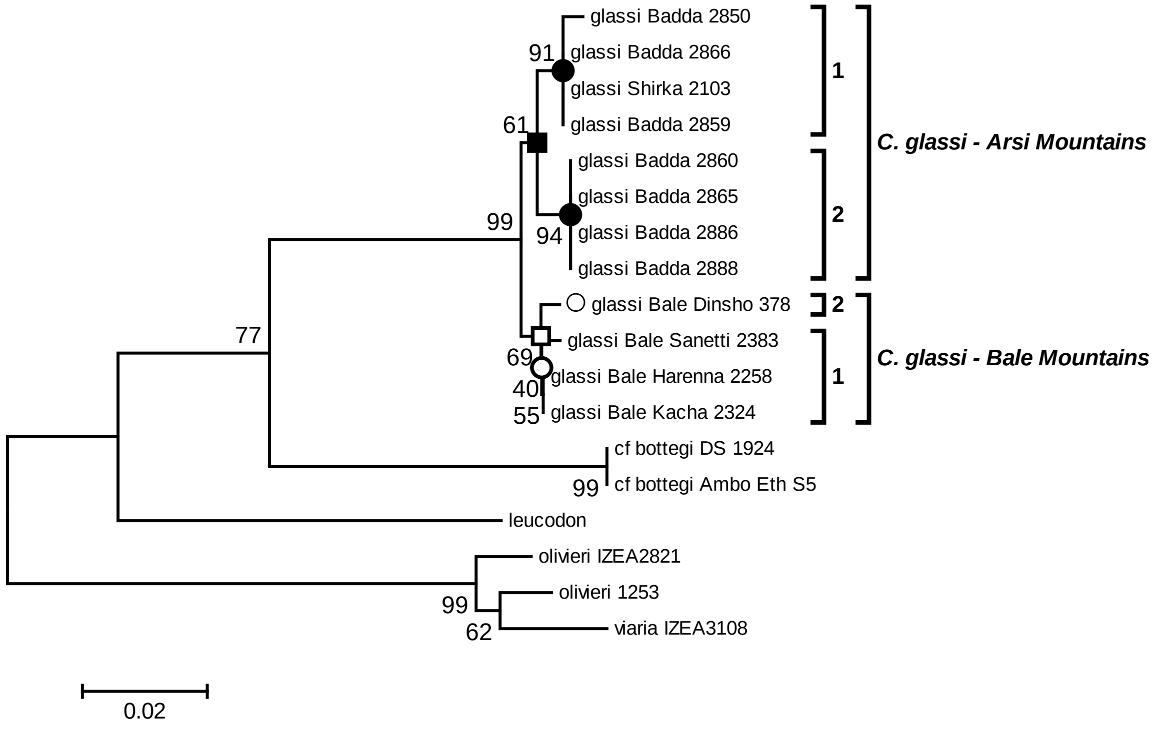

Figure 23. The evolutionary and phylogeographic relationship of *Crocidura glassi* from Arsi and Bale Mountains.

Genetic distance between *C. glassi* from Arsi and Bale Mountains seems moderate with about 1%. The genetic distance between the two clades of *C. glassi* of Chilalo-Galama Mountains Range (Arsi Mountains) and with two clades from Bale Mountains was also 1%.

There was no (0%) genetic distances between the two clades from Bale Mountains (Table 41). *Crocidura glassi* from Arsi had at least two distinct clades.

Table 41. Percentage estimates of evolutionary divergence over sequence pairs of *Crocidura glassi* clades from Arsi and Bale Mountains

Crocidura glassi clade 1	*Crocidura glassi* – clade 2	Distance (%)
Arsi 1	Arsi 2	1
Arsi1	Bale 2	1
Arsi 2	Bale 2	1
Arsi1	Bale 1	1
Arsi 2	Bale 1	1
Bale 2	Bale 1	0

6.18.2. *Mus mahomet* and *Mus imberbis*

The best possible phylogentic tree of total branch length of 0.759 was produced from the analysis of 22 nucleotide sequences at 664 positions in the final dataset. The phylogenetic position of *M. mahomet* from Chilalo-Galama Mountains Range (Arsi Mountains) was mixed with some groups from Bale Mountains forming Arsi-Bale Mountains clade. Interestingly, the Arsi Mountains *M. mahomet* had two distinct clades (Figure 24).

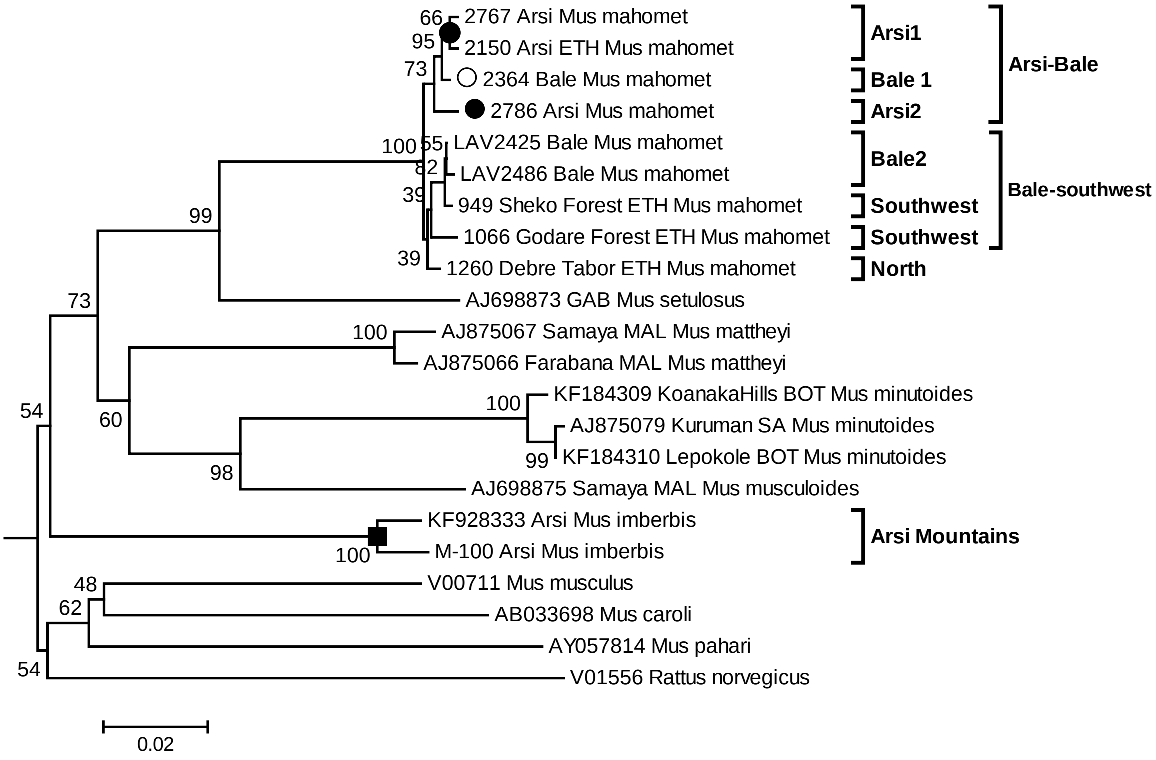

Figure 24. Evolutionary relationships and phylogeography of *Mus mahomet* and *Mus imberbis*

The evolutionary distance between the two clades of Arsi Mountains and others was 1% (Table 42)

Table 42. Estimates of evolutionary divergence over sequence pairs between *Mus mahomet* and *Mus imberbis*

	South west	Northern	Arsi 1	Bale 2	Bale 1	Arsi 2
Southwest						
Northern	0.01					
Arsi 1	0.01	0.01				
Bale 2	0.00	0.01	0.01			
Bale 1	0.01	0.01	0.00	0.01		
Arsi 2	0.01	0.01	0.01	0.01	0.01	0.01

6.18.3. *Dendromus* sp.1 and *D. nikolausi*

The optimal tree had a total branch length of 1.154. The evolutionary distances were computed using the p-distance by using an analysis that involved 20 nucleotide sequences at 864 positions in the final dataset.

The undescribed new species of *Dendromus* sp.1 from Arsi Mountains has close relationship with *Dendromus* species from Debra Sina with the bootstrap support of 100% (Figure 25). *D. nikolausi* from Arsi and Bale forms one clade with the bootstrap support of 100%. The topology of the phylogenetic tree indicates that it forms a basal when compared with the position of *Dendromus* sp. 1 form Arsi and Bale Mountains.

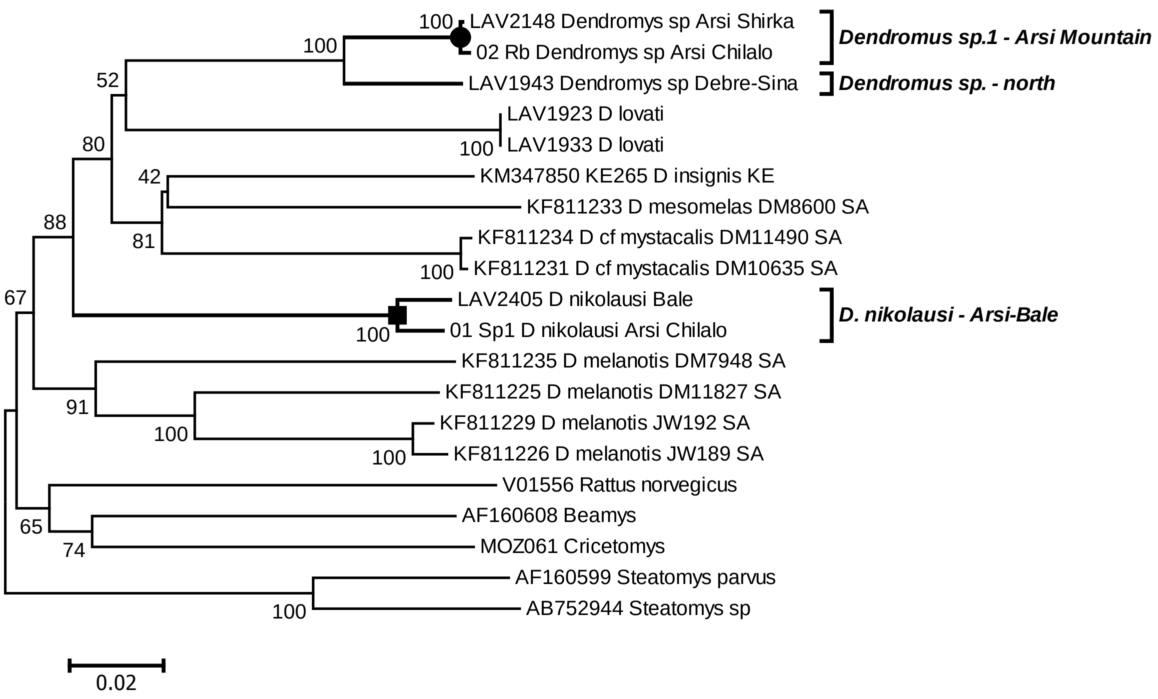

Figure 25. Evolutionary relationships and phylogeography of *Dendromus* sp.1 and *D. nikolausi*

6.18.4. *Lophuromys melanonyx, L. brevicaudus* and *L. chrysopus*

The total branch length of optimal tree was 0.323. The analysis involved 30 nucleotide sequences at 539 positions in the final dataset.

Lophuromys melanonyx from Chilalo-Galama Mountains range (Arsi Mountains) had two distinct clades. *Lophuromys melanonyx* 2- Arsi clade possesses a unique haplotype. However, the second clade *L. melanonyx* 1 –Arsi had a haplotype of *L. menageshae* and *L. simensis*. It had also formed a very close evolutionary distance more than the other clade of *L. melanonyx* from Arsi Mountains (Figure 26).

The evolutionary distance between the two distinct clades of *L. melanonyx* from Arsi was 6%, which is even larger than the evolutionary distance between the Bale Mountains clades (Table 43). The genetic distances between the *L. melanonyx* of Arsi 1 and Bale was only 1%, however, the evolutionary distance between the Bale and Arsi 2 was 5% (Table 43).

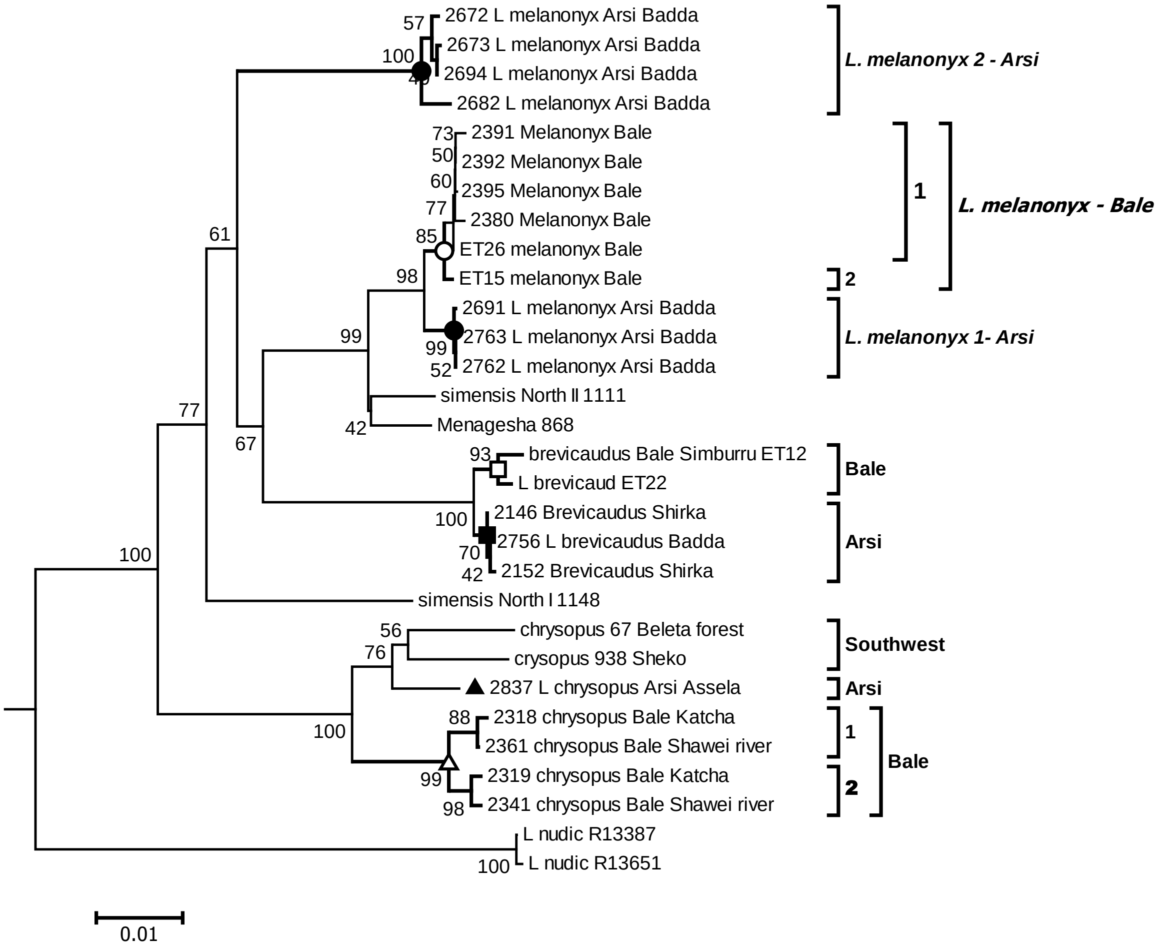

Figure 26. The Evolutionary relationship and phylogeography of *L. melanonyx*, *L. brevicaudus* and *L. chrysopus*.

Lophuromys brevicaudus from Arsi and Bale Mountains forms two distinct clades with bootstrap support of 100% (Figure 26). The genetic distance between the two clades was 1% (Table 43).

Unlike *L. melanonyx* and *L. brevicaudus*, *L. chrysopus* of Arsi Mountains forms a common clade with the south-western group of *L. chrysopus*. The clade of *L. chrysopus* containing the Arsi Mountains and Bale Mountains was supported by 100% bootstrap (Figure 26). The genetic distance or evolutionary distance between the Arsi and southwest and Bale clade of *L. chrysopus* was 3% and 4% respectively (Table 43).

Table 43. Evolutionary distance between Arsi and Bale Mountains *Lophuromys* species

Lophuromys 1	*Lophuromys* 2	Distance
Arsi 1 - *L. melanonyx*	Bale - *L. melanonyx*	1%
Arsi 1 - *L. melanonyx*	Arsi 2 - *L. melanonyx*	6%
Bale - *L. melanonyx*	Arsi 2 - *L. melanonyx*	5%
Arsi - *L. chrysopus*	Southwest - *L. chrysopus*	3%
Arsi - *L. Chrysopus*	Bale - *L. chrysopus*	4%
Southwest - *L. chrysopus*	Bale - *L. chrysopus*	4%
Bale - *L. brevicaudus*	Arsi - *L. brevicaudus*	1%

6.18.5. Otomys helleri

The optimal tree had 0.290 total branch lengths and 15 nucleotide sequences at 237 positions in the final dataset. According to the topology of the phylogenetic and phylogeography *O. helleri* from Arsi forms a clade with Bale group with bootstrap of 89%. There was no genetic distance between the Arsi and Bale Mountains *O. helleri* (Figure 27).

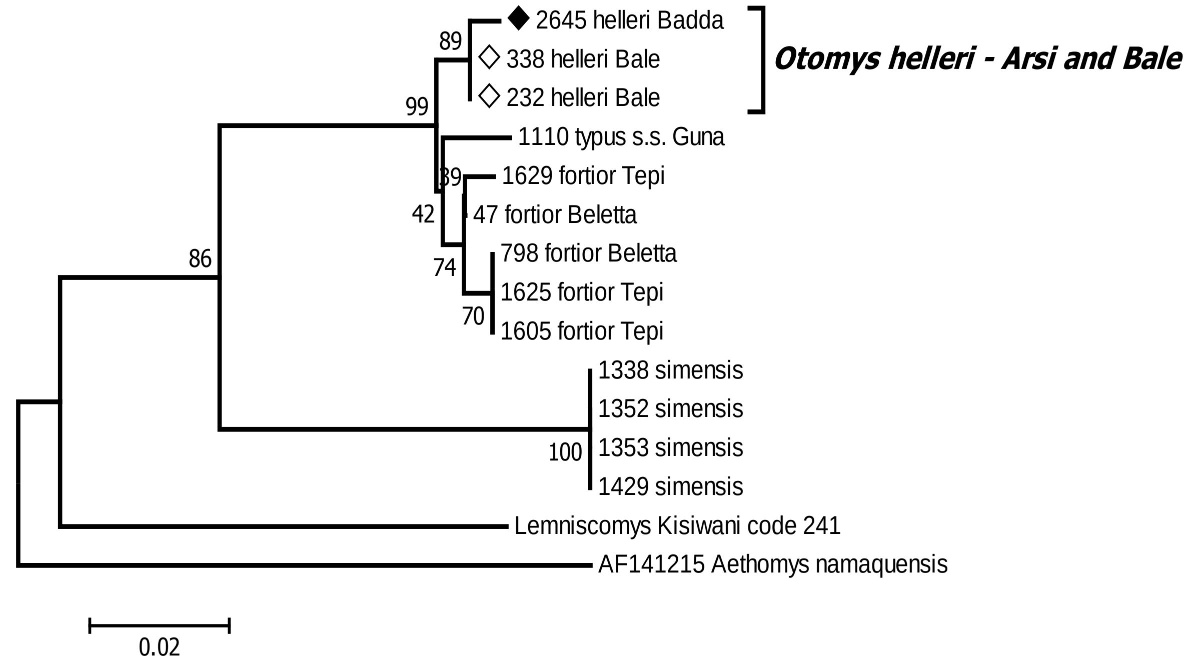

Figure 27. Evolutionary relationships and phylogeography of *Otomys helleri*

6.18.6. Stenocephalemys albocaudata, S. griseicauda **and** *S. albipes*

The most favourable tree with the sum of branch length of 0.410 constructed based on 53 nucleotide sequences of 236 positions.

Based on the topology of the phylogentic and phylogeography tree, *Stenocephalemys albocaudata* from Chilalo-Galama Mountains Range (Arsi Mountains) had more than two clades. At least two clades of *S. albocaudata* from Arsi were distinct while others share some haplotypes with the *S. albocaudata* of Bale and Guwassa (Figure 28).

Stenocephalemys griseicauda from Chilalo-Galama Mountains Range (Arsi) had at least three distinct lineages. The two lineages had a unique haplotype while the third lineage shares haplotype with Bale Mountains group. The Bale Mountains also had unique haplotype that forms a sister clade with at least two lineages of *S. griseicuada* from Arsi and Bale Mountains.

*Stenocephalemys albipe*s is also similar to other species of the genus *Stenocephalemys*. It had two distinct lineages and the other lineage that was shared with the Bale Mountains. The common clade of *S. albipes* from Arsi Mountains and Bale Mountains was supported by 73% bootstrap (Figure 28). *Stenocephalemys albipes* from Arsi and Bale Mountains forms a sister lineage with the northern *S. albipes* with 99% of bootstrap support (Figure 28).

The genetic distance between the two distinct lineages of Arsi Mountains of *S. albocaudata* was 2% while it was 1% with Bale Mountains and 3% with Guwassa. The evolutionary distance between the two distinct lineage of *S. griseicauda* of Chilalo-Galama Mountains Range (Arsi Mountains) was 2% though it ranged from 1% to 3% with other groups of *S. griseicauda* (Table 44). Similarly, the genetic distance of *S. albipes* between the distinct groups of Arsi Mountains was 3% while for the other groups, it ranges from 1 % to 4% (Table 44).

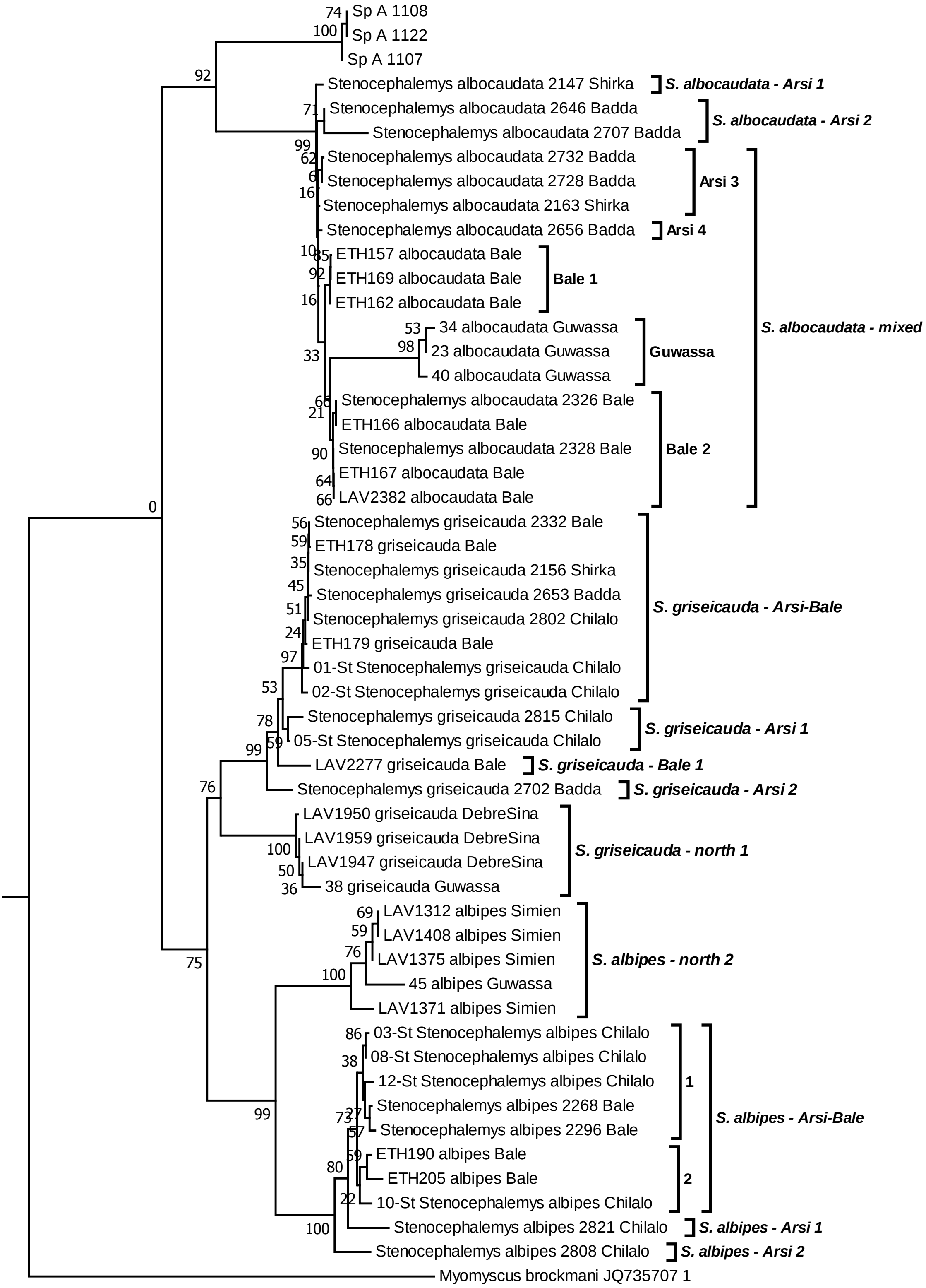

Figure 28. Evolutionary relationships and phylogeography of *S. albocaudata*, *S. griseicauda* and *S. albipes*

Table 44. The percentage of evolutionary distance among different groups of *Stenocephalemys albocaudata*, *S. griseicauda* and *S. albipes*

Stenocephalemys sp1	*Stenocephalemys* sp 2	Distance (%)
S. griseicauda Bale	*S. griseicauda* north1	3%
S. griseicauda Arsi-Bale	*S. griseicauda* north1	3%
S. griseicauda Arsi-Bale	*S. griseicauda* Arsi1	1%
S. griseicauda Arsi1	*S. griseicauda* north1	3%
S. griseicauda Arsi1	*S. griseicauda* Arsi 2	2%
S. griseicauda Arsi-Bale	*S. griseicauda* Arsi 2	2%
S. griseicauda Arsi Bale	*S. griseicauda* Bale	2%
S. griseicauda Arsi 2	*S. griseicauda* Bale	3%
S. griseicauda Arsi 1	*S. griseicauda* Bale	2%
S. griseicauda Arsi	*S. griseicauda* north1	3%
S. albocaudata Guwassa	*S. albocaudata* Arsi 4	3%
S. albocaudata Bale 2	*S. albocaudata* Guwassa	3%
S. albocaudata Bale 1	*S. albocaudata* Guwassa	3%
S. albocaudata Arsi 3	*S. albocaudata* Arsi 1	1%
S. albocaudata Arsi 2	*S. albocaudata* Bale 2	1%
S. albocaudata Arsi 2	*S. albocaudata* Bale 1	1%
S. albocaudata Arsi 2	*S. albocaudata* Arsi 4	1%
S. albocaudata 2	*S. albocaudata* Arsi 1	2%
S. albipes Bale	*S. albipes* north 2	4%
S. albipes Arsi2	*S. albipes* Arsi 3	3%
S. albipes Arsi1	*S. albipes* Arsi 3	1%
S. albipes Arsi1	*S. albipes* Bale	1%
S. albipes Arsi 4	*S. albipes* north 2	4%
S. albipes Arsi 3	*S. albipes* north 2	4%
S. albipes Arsi 2	*S. albipes* north 2	4%
S. albipes Arsi 2	*S. albipes* Arsi1	3%
S. albipes Arsi 2	*S. albipes* Arsi 4	3%
S. albipes Arsi 2	*S. albipes* Bale	3%
S. albipes Arsi 1	*S. albipes* Arsi 4	1%

6.18.7. Tachyoryctes splendens

The optimal tree with the sum of branch length 0.2022569 was reconstructed from 40 nucleotide sequences and 144 positions in the final dataset. *Tachyoryctes splendens* from Chilalo-Galama Mountains Range (Arsi Mountains) consist two distinct clades and the third clade shares with Bale Mountains (Figure 29). The third (Arsi-Bale Mountains) clade forms a sister group with *T. splendens* from central Ethiopia (Figure 29).

The evolutionary distance between the two distinct clades of Arsi Mountains was 5%. The highest (8%) estimated evolutionary divergence was recorded between clades of Arsi-Bale Mountains and Arsi 1 and Arsi-Bale Mountains and Bale Mountains (Table 45). In general, the genetic distance among different clades of *T. splendens* from Arsi, Bale and central ranges vary 5-8%.

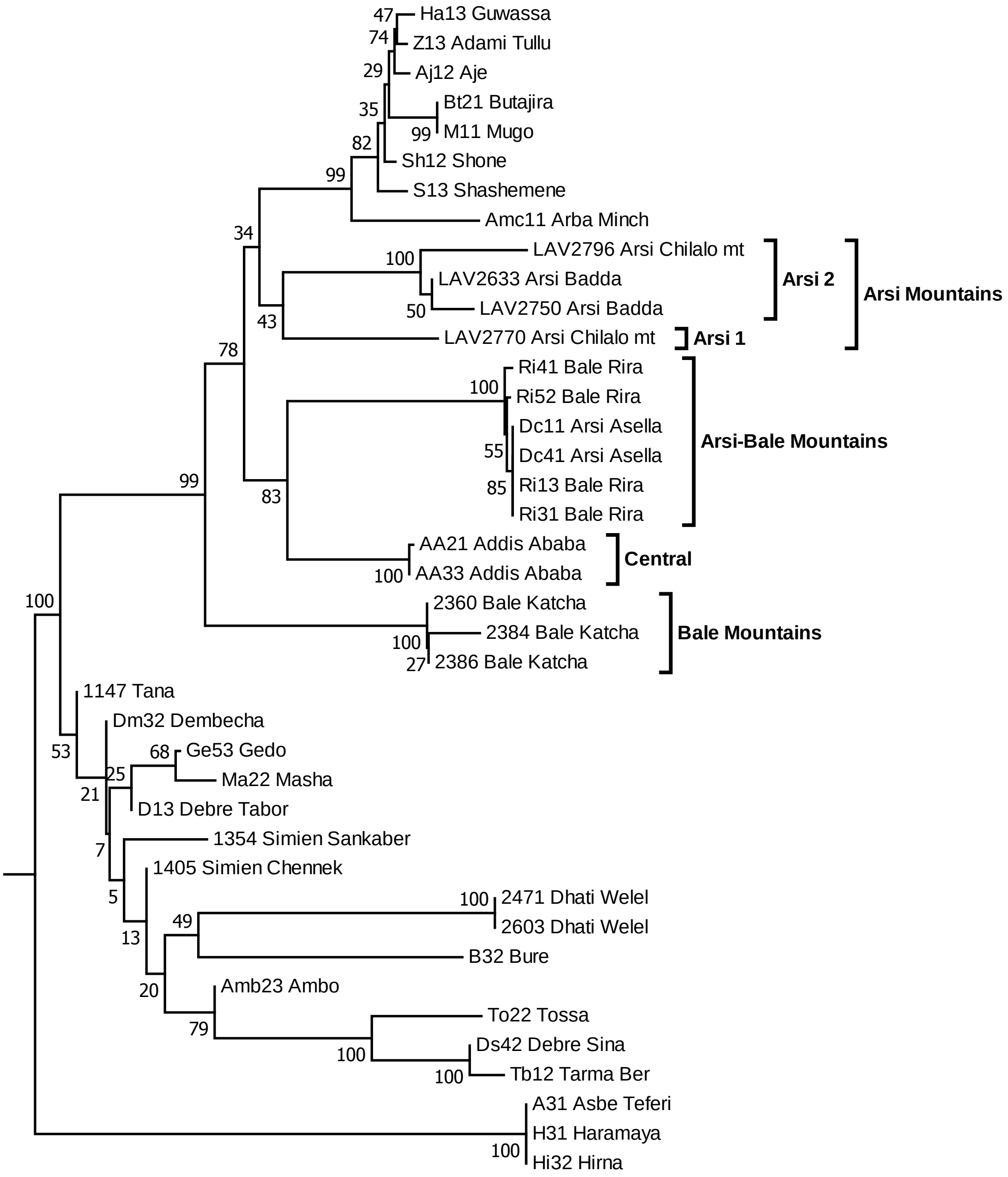

Figure 29. Evolutionary relationships of *T. splendens*

Table 45. Estimates of evolutionary divergence over sequence pairs between groups of *T. splendens*

Tachyoryctes splendens- clade 1	*Tachyoryctes splendens*- clade 2	Distance
Bale Mountains	Arsi-Bale Mountains	8%
Bale Mountains	Central	6%
Arsi-Bale Mountains	Central	5%
Bale Mountains	Arsi 2	7%
Arsi-Bale Mountains	Arsi 2	7%
Central	Arsi 2	5%
Bale Mountains	Arsi 1	6%
Arsi-Bale Mountains	Arsi 1	8%
Central	Arsi 1	5%
Arsi 2	Arsi 1	5%

6.19. Ectoparasite prevalence in small mammal species

A total of 204 (89 female and 115 male) individuals of small mammals comprising 28 species were examined for ectoparasites. Out of the total small mammals examined, 150 were infected by one or more group of ectoparasite taxa. The overall prevalence of ectoparasite was 73.53% (Table 46). One hundred percent prevalence was recorded for *E. gambianus*, *M. natalensis, D. nikolausi*, *P. balensis*, *S. albocaudata* and *S. griseicauda*. The second highest ectoparasite prevalence was recorded for *S. albipes* (86.67%). Relatively the least (50%) ectoparasite prevalence was recorded for *C. lucina, N. capensis* and *P. hesperidus* (Table 46).

For *E. gambianus, K. Lanosa* and *D. nikolausi* only females and for *P. aero* and *R. rattus* only males were examined. However, for the remaining species of small mammals both sexes were considered (Table 46).

Table 46. Small mammals examined and their prevalence rate

Species	Sex		Host examined		Total	Prevalence (%)
	Female	Male	Uninfested	Infested		
Epomophorus gambianus	1	0	0	1	1	100
Mastomys natalensis	2	3	0	5	5	100
Dendromus nikolausi	1	0	0	1	1	100
Plecotus balensis	1	2	0	3	3	100
Stenocephalemys albocaudata	5	7	0	12	12	100
Stenocephalemys griseicauda	8	8	0	16	16	100
Stenocephalemys albipes	7	8	2	13	15	86.67
Lophuromys brevicaudus	7	5	2	10	12	83.33
Miniopterus inflatus	5	6	2	9	11	81.82
Arvicanthis blicki	3	2	1	4	5	80
Hipposideros caffer	4	1	1	4	5	80
Lophuromys melanonyx	2	3	1	4	5	80
Rattus rattus	0	4	1	3	4	75
Lophuromys chrysopus	3	4	2	5	7	71.43
Otomys helleri	3	7	3	7	10	70
Arvicanthis abyssinicus	1	5	2	4	6	66.67
Dendromus lovati	2	4	2	4	6	66.67
Kerivoula lanosa	3	0	1	2	3	66.67
Myotis tricolor	3	6	3	6	9	66.67
Pipistrellus aero	0	5	2	3	5	60
Stenonycteris lanosus	3	2	2	3	5	60
Crocidura glassi	5	2	3	4	7	57.14
Mus mahomet	3	4	3	4	7	57.14
Tachyoryctes splendens	5	2	3	4	7	57.14
Neoromicia nanus	2	9	5	6	11	54.55
Crocidura lucina	4	4	4	4	8	50
Neoromicia capensis	3	5	4	4	8	50
Pipistrellus hesperidus	3	7	5	5	10	50
Total	89	115	54	150	204	73.53

Out of the 204 individuals examined, the majority 35 (17.16%) were infested by Myobiidae mites followed by *Ambyloma* 29(14.22%) and *Polyplax* 21(10.29%). Relatively few individuals of small mammals were infested by *Leptopsylla* 3(1.47%), Trombiculidae 3 (1.47%), *Dinopsyllus* 1(0.49%) and Streblidae 1(0.49%).

From the 28 species of hosts examined, Myobiidae mites infested half of them. The second and third ectoparasites were *Ambyloma* and *Polyplax*, infesting 9 and 7 species of small mammals in respective order (Table 47). Comparatively only one species of small mammal was infested by *Dinopsyllus*, Trombiculidae and Streblidae.

Table 47. The ectoparasite taxon, total number of individuals of host infested and percentage

Ectoparasite		Total host	Percentage (%)	Ectoparasite		Total host	Percentage (%)
Flea	Ct	9	4.41	Tick	Am	29	14.22
	Di	1	0.49		Hy	11	5.39
	Hy	7	3.43		Ix	16	7.84
	Le	3	1.47		Or	3	1.47
	Xe	11	5.39		Rh	3	1.47
Lice	Da	5	2.45	Mite	La	11	5.39
	Eu	7	3.43		Ls	6	2.94
	Ha	5	2.45		Ma	20	9.80
	Hp	12	5.88		My	35	17.16
	Li	12	5.88		Sp	12	5.88
	Po	21	10.29		Tr	3	1.47
Flies	Ni	20	9.80				
	St	1	0.49				

Ct=*Ctenocephalides*, Di=*Dinopsyllus*, Hy=*Hystrichopsylla*, Le=*Leptopsylla*, Xe=*Xenopsylla*, Da=*Damalinia*, Eu=*Eulinognathus*, Ha=*Haematopinus*, Hp=*Haplopleura*, Li=*Linognathus*, Po=*Polyplax*, Am=*Ambylomma*, Hy=*Hyalomma*, Ix=*Ixodes*, Or=*Orithodorus*, Rh=*Rhipicephalus*, La=Laelapidae, Ls=Listrophoridae, Ma=Macronyssidae, My=Myobiidae, Sp=Spinturnicidae, Tr=Trombiculidae, Ny=Nycteribiidae, St=Streblidae

A total of 1993 individuals of ectoparasites that belonged to 24 taxa in 5 different groups namely fleas, lice, ticks, mites and flies were recorded (Plate 7). Fleas and ticks each had five genera, lice six genera, mite six families and bat flies two families were collected from small mammals examined for ectoparasite (Table 48).

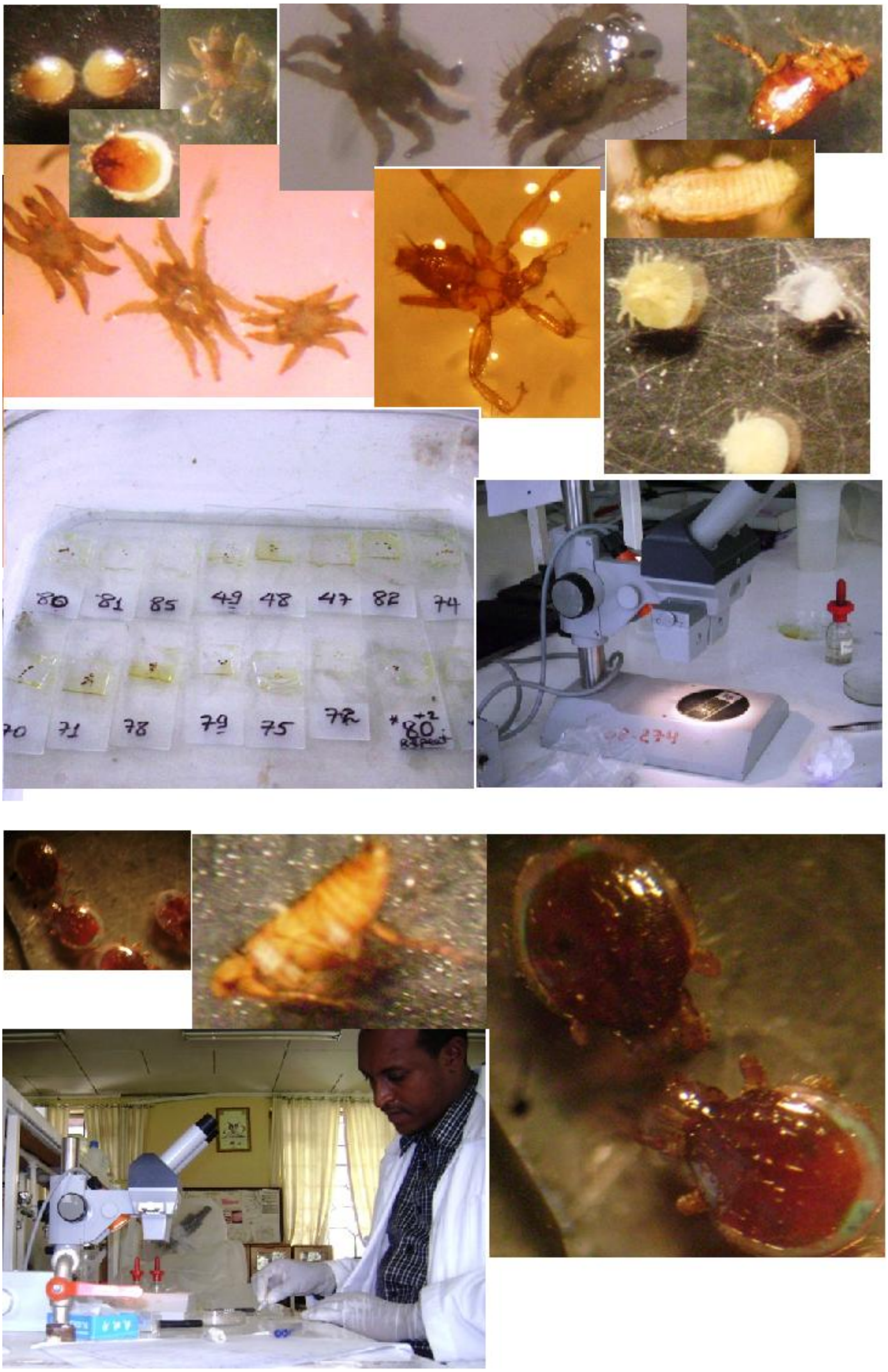

Plate 7. Ectoparastes collected from small mammals from the study area

These taxa were *Ctenocephalides*, *Dinopsyllus*, *Hystrichopsylla*, *Leptopsylla*, *Xenopsylla*, *Damalinia*, *Eulinognathus*, *Haematopinus*, *Haplopleura*, *Linognathus*, *Polyplax*, *Ambylomma*, *Hyalomma*, *Ixodes*, *Orithodorus*, *Rhipicephalus*, Laelapidae, Listrophoridae, Macronyssidae, Myobiidae, Spinturnicidae, Trombiculidae, Nycteribiidae and Streblidae. *Stenocephalemys griseicauda* was infested by maximum number (323) of ectoparasite and followed by *P. aero* (227), *S. albocaudata* (177). *Epomophoru gambianus* was the only host that infested by minimum (5) abundance of ectoparasite (Table 48).

The majority of ectoparasites (373) abundance was contributed by Myobiidae followed by 213 *Ambylomma* and 186 *Polyplax* while the least was contributed by Streblidae (3) and *Leptopsylla* (6) (Table 48).

Table 48. Abundance and intensity of ectoparasite on each host species

Species	Flea					Lice						Tick					Mite					Flies		Total
	Ct	Di	Hy	Le	Xe	Da	Eu	Ha	Hp	Li	Po	Am	Hy	Ix	Or	Rh	La	Ls	Ma	My	Sp	Ni	St	
Sp	0	12	0	0	0	0	3	5	42	3	23	27	28	49	14	0	13	21	18	65	0	0	0	323
Pa	7	0	0	0	0	3	0	0	2	0	39	4	0	0	0	8	0	10	0	154	0	0	0	227
Sg	0	0	2	0	9	0	19	0	2	1	0	78	15	9	0	0	41	0	0	1	0	0	0	177
Lc	20	0	0	4	7	0	0	0	12	12	87	0	4	0	0	0	10	0	0	14	0	0	0	170
Ts	0	0	0	0	0	0	0	0	4	0	0	0	0	21	0	0	0	95	0	9	0	0	0	129
Sl	0	0	13	0	0	2	0	15	6	0	18	9	13	25	0	9	0	0	16	0	0	0	0	126
Ab	0	0	0	0	0	0	0	0	0	95	0	0	0	0	0	0	0	0	0	5	0	0	0	100
Mi	0	0	0	2	0	17	0	0	0	0	1	26	0	2	0	0	0	0	28	21	0	0	0	97
Mt	0	0	0	0	0	12	25	0	0	1	0	0	5	1	0	0	23	0	0	28	0	0	0	95
Aa	0	0	0	0	0	0	0	0	0	0	0	54	0	0	0	0	0	0	0	10	0	0	0	64
Lm	12	0	0	0	15	0	0	0	0	4	0	0	0	0	0	0	0	0	0	31	0	0	0	62
Rr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	25	0	44
Cl	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	27	0	0	0	0	41
Sc	0	0	0	0	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39
Kl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	6	3	37
Mn	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	30	2	0	0	0	33
Nc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	21	0	30
Ph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	28
Lb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	21	0	27
Pb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	0	0	27
Cg	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	6	0	0	0	0	0	0	24
Hc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	9	0	19
Nn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	4	0	17

Oh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	15
Md	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	14
Dl	9	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
Mm	0	0	0	0	0	0	9	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	10
Eg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5
Total	54	12	19	6	71	34	56	20	68	116	186	213	65	107	14	17	93	126	132	373	89	92	3	1993

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cg=*C. glassi*, Cl=*C. lucina*, Dl=*D. lovati*, Eg=*E. gambianus*, Sl=*S. lanosus*, HC= *H. caffer*, Kl= *K. Lanosa*, Lb= *L. brevicaudus*, Lc= *L. chrysopus*, Lm= *L. melanonyx*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mi=*M. inflatus*, Mm= *M. mahomet*, Mt= *M. tricolor*, Nc=*N. capensis*, Nn=*N. nanus*, Oh=*O. helleri*, Pb=*P. balensis*, Pa= *P. aero*, Ph=*P. hesperidus*, Rr= *R. rattus*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*, Ts=*T. splendens*, Ct=*Ctenocephalides*, Di=*Dinopsyllus*, Hy=*Hystrichopsylla*, Le=*Leptopsylla*, Xe=*Xenopsylla*, Da=*Damalinia*, Eu=*Eulinognathus*, Ha=*Haematopinus*, Hp=*Haplopleura*, Li=*Linognathus*, Po=*Polyplax*, Am=*Ambylomma*, Hy=*Hyalomma*, Ix=*Ixodes*, Or=*Orithodorus*, Rh=*Rhipicephalus*, La=Laelapidae, Ls=Listrophoridae, Ma=Macronyssidae, My=Myobiidae, Sp=Spinturnicidae, Tr=Trombiculidae, Ny=Nycteribiidae, St=Streblidae

From the flea groups the genus *Xenopsylla* was highly intense and similarly for lice group *Polyplax*, for ticks *Ixodes* for mites Myobiidae and for bat flies Nycteribiidae were the most abundant (Table 49). Myobiidae mites had the highest (1.83%) relative abundance followed by *Ambyloma* (1.04%), *Polyplax* (0.9%) and Macronyssidae (0.65%). The least was for Streblidae (0.01) (Table 49). The constituent ratio was maximum (18.72%) for Myobiidae mite followed by *Ambylomma* (10.91%), *Polyplax* (9.33%) and Macronyssidae (6.62%). The constituent ratio was least for Streblidae (0.15%) (Table 49).

Table 49. Ectoparasite intensity of particular ectoparasite (pti), constituent ratio (CR) and relative abundance (RA) of ectoparasite of small mammals

Group	Taxon	Pti	**CR**	RA	**Group**	**Taxon**	**Pti**	**CR**	RA
Flea	Ct	54	0.26	2.71	Tick	Am	213	1.04	10.69
	Di	12	0.06	0.6		Hy	65	0.32	3.26
	Hy	19	0.09	0.95		Ix	107	0.52	5.37
	Le	6	0.03	0.3		Or	14	0.07	0.70
	Xe	71	0.35	3.56		Rh	17	0.08	0.85
Lice	Da	34	0.17	1.71	Mite	La	93	0.46	4.67
	Eu	56	0.27	2.81		Ls	126	0.62	6.32
	Ha	20	0.1	1		Ma	132	0.65	6.62
	Hp	68	0.33	3.41		My	373	1.83	18.72
	Li	116	0.57	5.82		Sp	89	0.44	4.47
	Po	186	0.91	9.33		Tr	27	0.13	1.35
					Flies	Ni	92	0.45	4.62
						St	3	0.015	0.15
					Total		1993		100

Ct = *Ctenocephalides*, Di = *Dinopsyllus*, Hy = *Hystrichopsylla*, Le = *Leptopsylla*, Xe = *Xenopsylla*, Da = *Damalinia*, Eu = *Eulinognathus*, Ha = *Haematopinus*, Hp = *Haplopleura*, Li = *Linognathus*, Po = *Polyplax*, Am = *Ambylomma*, Hy = *Hyalomma*, Ix = *Ixodes*, Or = *Orithodorus*, Rh = *Rhipicephalus*, La = Laelapidae, Ls = Listrophoridae, Ma = Macronyssidae, My = Myobiidae, Sp = Spinturnicidae, Tr = Trombiculidae, Ny = Nycteribiidae, St = Streblidae

The mean intensity for ectoparasite taxon on all species of small mammals is given in Table 50. The maximum mean intensity of *Linognathus* (1.83) on *A. blicki*, Myobiidae (1.64) on *O. helleri*, *Polyplax* (1.61) was on *L. brevicaudus* (Table 50). The least mean intensity was recorded for Myobiidae on *S. albipes*. Furthermore the mean intensity was relatively low for *Linognathus* on *M. mahomet* and *S. albipes*, *Polyplax* on *D. nikolausi*, *Ambylomma* on *M. natalensis*, Myobiidae on *M. inflatus*, each with mean intensity of 0.02 (Table 50).

From the five groups of ectoparasites with 24 taxa recorded in the present study, almost all the taxa comprises at least one species that has potential risk of causing a zoonotic disease in humans and domestic aninals.

Table 50. Table Mean Intensity (MI) of ectoparasites on small mammals

(Di (16) = Sg 0.75, Or(19)=Sg 0.88, Tr (93)=Pa 9, St (4) Hc 0.75)

Species	Ct (30)	Hy (29)	Le (15)	Xe (40)	Da (28)	Eul (34)	Hae (28)	Hap (62)	Lin (52)	Po (54)	Am (62)	Hy (55)	Ix (54)	Rh (19)	La (47)	Li (27)	Ma (50)	My (94)	Sp (20)	Nic (28)
Aa	0	0	0	0	0	0	0	0	0	0	0.87	0	0	0	0	0	0	0.11	0	0
Ab	0	0	0	0	0	0	0	0	1.83	0	0	0	0	0	0	0	0	0.05	0	0
Cg	0	0	0	0	0	0	0	0	0	0.33	0	0	0	0	0.13	0	0	0	0	0
Cl	0	0	0	0	0	0	0	0	0	0	0.23	0	0	0	0	0	0.54	0	0	0
Dl	0.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.2
Fb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11	0	0.3
Hc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0.2
K l	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.8
Lb	0.7	0	0.27	0.18	0	0	0	0.19	0.23	1.61	0	0.07	0	0	0.21	0	0	0.15	0	0
Lc	0.4	0	0	0.38	0	0	0	0	0.08	0	0	0	0	0	0	0	0	0.33	0	0
Lm	0.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.09	0	0
Mn	0	0	0.13	0	0.61	0	0	0	0	0.02	0.42	0	0	0	0	0	0.56	0.22	0	0
Mn	0	0	0	0	0	0.26	0	0	0		0.02	0	0	0	0	0	0	0	0	0
M i	0	0	0	0.03	0	0	0	0	0	0	0	0	0	0	0	0	0.6	0.02	0	0
Mm	0	0	0	0	0.43	0.74	0	0	0.02	0	0	0.09	0		0.49	0	0	0.3	0	0
Mt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0.8
Nc	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.26	0	0	0.1
Nn	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.16	0	0
Oh	0.2	0	0	0	0.11	0	0	0.03		0.72	0.06	0	0	0.42	0	0.4	0	1.64	0	0
Pb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1.4	0
Pa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Ph	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.9
Rr	0	0	0	0.98	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sa	0	0.07	0	0.23	0	0.56	0	0.03	0.02	0	1.26	0.27	0.2	0	0.87	0	0	0.01	0	0
Sal	0	0.45	0	0	0.07	0	0.5	0.1	0	0.33	0.15	0.24	0.5	0.47	0	0	0.32	0	0	0
Sg	0	0	0	0	0	0.09	0.2	0.68	0.06	0.43	0.44	0.51	0.9	0	0.28	0.8	0.36	0.69	0	0
Ts	0	0	0	0	0	0	0	0.06	0	0	0	0	0.4	0	0	3.5	0	0.1	0	0

Aa=*A. abyssinicus*, Ab=*A. blicki*, Cg=*C. glassi*, Cl=*C. lucina*, Dl=*D. lovati*, Eg=*E. gambianus*, Sl=*S. lanosus*, HC= *H. caffer*, Kl= *K. Lanosa*, Lb= *L. brevicaudus*, Lc= *L. chrysopus*, Lm= *L. melanonyx*, Mn=*M. natalensis*, Md=*D. nikolausi*, Mi=*M. inflatus*, Mm= *M. mahomet*, Mt= *M. tricolor*, Nc=*N. capensis*, Nn=*N. nanus*, Oh=*O. helleri*, Pb=*P. balensis*, Pa= *P. aero*, Ph=*P. hesperidus*, Rr= *R. rattus*, Sp=*S. albipes*, Sc=*S. albocaudata*, Sg=*S. griseicauda*, Ts=*T. splendens*, Ct=*Ctenocephalides*, Di=*Dinopsyllus*, Hy=*Hystrichopsylla*, Le=*Leptopsylla*, Xe=*Xenopsylla*, Da=*Damalinia*, Eu=*Eulinognathus*, Ha=*Haematopinus*, Hp=*Haplopleura*, Li=*Linognathus*, Po=*Polyplax*, Am=*Ambylomma*, Hy=*Hyalomma*, Ix=*Ixodes*, Or=*Orithodorus*, Rh=*Rhipicephalus*, La=Laelapidae, Ls=Listrophoridae, Ma=Macronyssidae, My=Myobiidae, Sp=Spinturnicidae, Tr=Trombiculidae, Ny=Nycteribiidae, St=Streblidae, number in the bracket refers total number of hosts infested by each parasite

6.20. Small mammal pests and local community attitudes

All respondents perceived rodents as the principal pests that cause great damage to their agricultural and household items and even difficult to control. Wild animals like hyena, jackal, cerval and carcal were also considered as major pests by 28.92% of the respondents. Shrews were mentioned as pest animal by only few two (0.54%) of the respondents (Table 51).

Table 51. Types of pest animals perceived by local community causing problem to their agricultural products or household items

Pests	No. of Respondent	Percentage (%)
Rodent	370	100.00
Wild animals	107	28.92
Invertebrates	53	14.32
Birds	20	5.41
Bats	5	1.35
Shrews	2	0.54

The local communities' perceptions on extent of problems caused by different groups of animals are presented in Table 52. Rats and mice were reported to cause serious damage to 94.32% of the respondents. None of the respondents perceived rats and mice and mole rats not damaging their crops (Table 52). The majority 62.7% of respondents perceived mole rats to cause moderate level of damage even though 7.3% of them perceived to cause serious damage (Table 52).

More than 55% of the respondents reported as porcupines to cause moderate or serious damage. Regarding the bats, the majority (95.68%) of respondents considered that they did not cause any damage. However, about 2.7% of the respondents considered them to cause some damage (Table 52).

Almost all respondents perceived that shrews did not cause any damage (Table 52).

Table 52. Pest small mammals and perceived extents of damage by respondents

Pest	Perceived extent of damage			
	No damage (%)	Least (%)	Moderate (%)	Serious (%)
Rats and mice	0 (0)	6 (1.62)	15 (4.05)	349 (94.32)
Mole rats	0 (0)	101(27.3)	232 (62.7)	27 (7.3)
Porcupine	9 (2.43)	151(40.81)	55 (14.86)	155 (41.89)
Bats	354 (95.68)	5 (1.35)	1 (0.27)	10 (2.7)
Shrews	368 (99.46)	2 (0.54)	0 (0)	0 (0)

The local community perception on pest small mammals causing damage is shown in Table 53. Rats and mice caused damage by means of feeding, mechanical damage, contamination, discomfort and disease transmission (Table 53). All the respondents mentioned rats and mice caused damage through their feeding activity. Mole rats were dominantly blamed for damage in feeding and mechanical damage. More than 89% of the respondents believed bats caused damage to them through diseases. Besides this, few respondents pointed out that bats caused contamination and discomfort (Table 53). Most respondents stated discomfort was also type of damage caused by shrews (Table 53).

Table 53. Local communities perception on how pest small mammals cause damage

Pest	Feeding		Mechanical damage		Contamination		Discomfort		Disease causing and transmission	
	No	%	No	%	No	%	No	%	No	%
Rats and mice	370	100	368	99.46	264	71.35	243	65.68	233	62.97
Mole rat	356	96.22	233	62.97	0	0	0	0	0	0
Porcupine	341	92.16	276	74.59	0	0	2	0.54	0	0
Bats	0	0	0	0	5	1.35	2	0.54	331	89.46
Shrews	0	0	0	0	0	0	170	45.95	0	0

The extent of damage on agricultural and household items is shown in Table 54. The extent of damage caused by rodents on barley was stated as high to moderate by 21.62% and 20.27%, respectively. However, 48.65% perceived low damage by rodents on barley (Table 54). Beans, peas, peas, linseed and maize were not perceived for high level of damage even though up to the moderate level of damage was caused for linseed. The level of potato damage was estimated as high and moderate by relatively few respondents, however, the majority perceived it as low (Table 54).

The perceived level of damage by rodents on kitchen utensils, cloth and electronics and on grain storage materials and equipment as high and moderate by the majority of respondents (Table 54). Most respondents (71.35%) estimated damage to house walls, floors and ceiling as low (Table 54).

Table 54. The extent of damage by pest rodents on agriculture and household items

Type	Items	High		Moderate		Low		No damage	
		No	%	No	%	No	%	No	%
Agricultural Crops	Barley	80	21.62	75	20.27	180	48.65	35	9.46
	Wheat	55	14.86	67	18.11	203	54.86	45	12.16
	Beans	0	0	45	12.16	75	20.27	250	67.57
	Peas	0	0	40	10.81	65	17.57	265	71.62
	Linseed	0	0	0	0.00	70	18.92	300	81.08
	Maize	0	0	63	17.03	97	26.22	210	56.76
	Potato	25	6.76	30	8.11	250	67.57	65	17.57
	Vegetables	0	0	0	0	82	22.16	288	77.84
Household items	Kitchen utensils	168	45.41	85	22.97	57	15.41	60	16.22
	Cloth and electronics	160.	43.24	63	17.03	93	25.14	54	14.59
	Food and water	103	27.84	109	29.46	90	24.32	68	18.38
	Wall, floor and ceiling	24	6.49	29	7.84	53	14.32	264	71.35
	Grain storage materials and equipment	173	46.76	85	22.97	95	25.68	17	4.59

Hunting and trapping, use of cats, dogs, poisioning, and combination of either two or more of these methods listed are used by local communities. The majority of local communities dominantly employ a combination of different methods for the control of pest small mammals.

Some respondents also mentioned, as they did not have effective and efficient methods for controlling some pest animals (Figure 30).

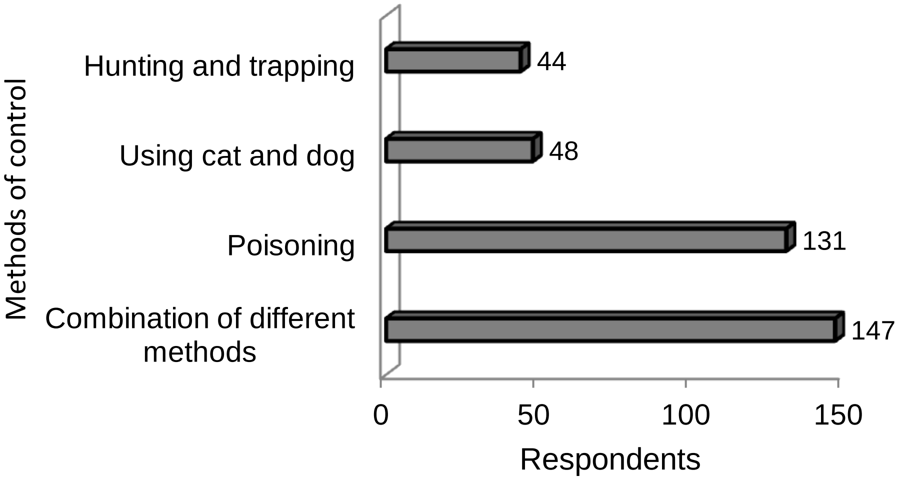

Figure 30. Methods of control for pest small mammals

More than 78% of local communities did not know whether bats caused damage on agricultural crops and only 21% confidently stated that bats did not cause any damage on agricultural crops (Figure 31). Eighty percent of the respondents stated that, household items were not damaged by bats but 5.41% assumed the damage caused on household items during roosting in the house. The principal damage stated by more than 80 percent of the respondents was disease transmission and for 89.46% of the respondents they cause discomfort (Figure 31).

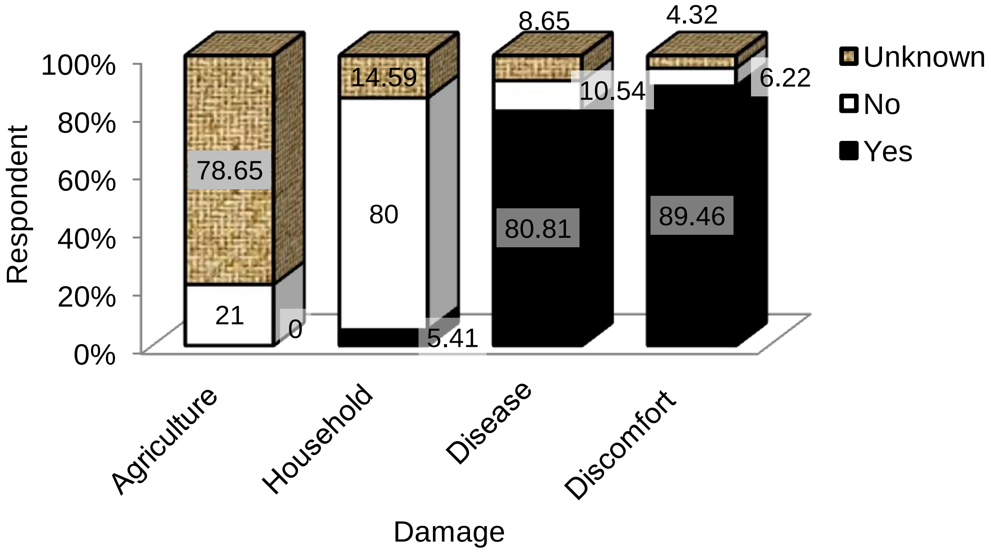

Figure 31. Local community’s perception on the damage caused by bats

For the control of pest small mammals, the majority 334 (90.27%) of local communities believe individual-based controlling method as effective and efficient whereas 31 (8.38%) believe a group-based controlling methods as efficient and effective controlling method. The rest believe that both methods are effective and efficient or difficult for them to select.

6.21. Conservation of small mammals and their habitats

More than 81% of the local communities were very happy (59.7%) for the protection Chilalo-Galama Mountains Range (Table 55). Their feelings on the establishment and protection of the AMNP in particular the Chilalo-Galama Mountains Range, showed variation based on their place of residence. The majority of respondents who were very happy(43%) and happy (50%) belonged to local communities dwelling far-way from the protected area. Comparatively, 47.8% of the respondents who were not happy for the park establishment and protection were dwelling inside the Park (Table 55). About 26% of the respondents who were unhappy of Park establishment and protection were the nomadic and far away local communities (Table 55). The reasons for unhappiness of residents inside the park were fear of exclusion and deprivation of access to the resources inside the Park. In contrast, the unhappiness of resident respondents faraway from the Park was due to the perception of weak enforcement of laws and persistence of encroachment and illegal use of the area.

The respondents agreement on the Park boundary varied among the respondents based on location of residences (Table 55). Over 50% of the respondents who agreed on boundary demarcation were those far away from the Park.

Table 55. Respondents' residence location in relation to protected area and their feeling on the establishment and protection of the Park and agreement on the boundary of the Park

Place of residence	Feelings on park establishment and protection						Agreement on park boundary				Total	
	Very Happy		Happy		Unhappy		Agree		Not agree			
	No	%	No	%	No	%	No	%	No	%	No	%
Adjacent	34	15.4	18	22.5	0	0	37	16	15	10.8	52	14.1
Faraway	95	43	40	50	18	26.1	117	50.7	36	9.7	153	41.4
Inside	44	19.9	15	18.8	33	47.8	29	12.6	63	45.3	92	24.9
Nomadic	48	21.7	7	8.8	18	26.1	48	20.8	25	18	73	19.7
Total	221	100	80	100	69	100	231	100	139	100	370	100
Proportion (%)	59.7	-	21.6	-	18.7	-	62.4	-	37.6	-	100	-

Out of the total respondents, 46.49% do not get specific resources inside the protected area whereas the rest 53.51% use different resources inside the protected area.

The types of properties owned by local communities inside the protected areas are given in Table 56. About 41.41% possessed farmland, house and barn, garden and plantation (Table 56).

Table 56. Types of properties owned by local communities in different residential locations.

Type of resource	Adjacent	Faraway	Inside	Nomadic	Total	Percent (%)
Farmland, house and barn, garden and plantation	15	0	67	0	82	41.41
House and barn	0	0	0	46	46	23.23
Farm land and house	0	0	25	0	25	12.63
Farmland and plantation	18	0	0	0	18	9.09
House, barn and plantation	0	0	0	18	18	9.09
House, barn and garden	0	0	0	9	9	4.55
Total	33	0	92	73	198	100.00

All the respondents had some interest in the conservation of Chilalo-Galama Mountains Range although these were slight variations for the purpose of its protection and conservation. The most commonly mentioned interest was usage of water source (Figure 32). The second reason is for conservation of endemic animals like Ethiopian Wolf, Mountain Nyala and other biodiversity.

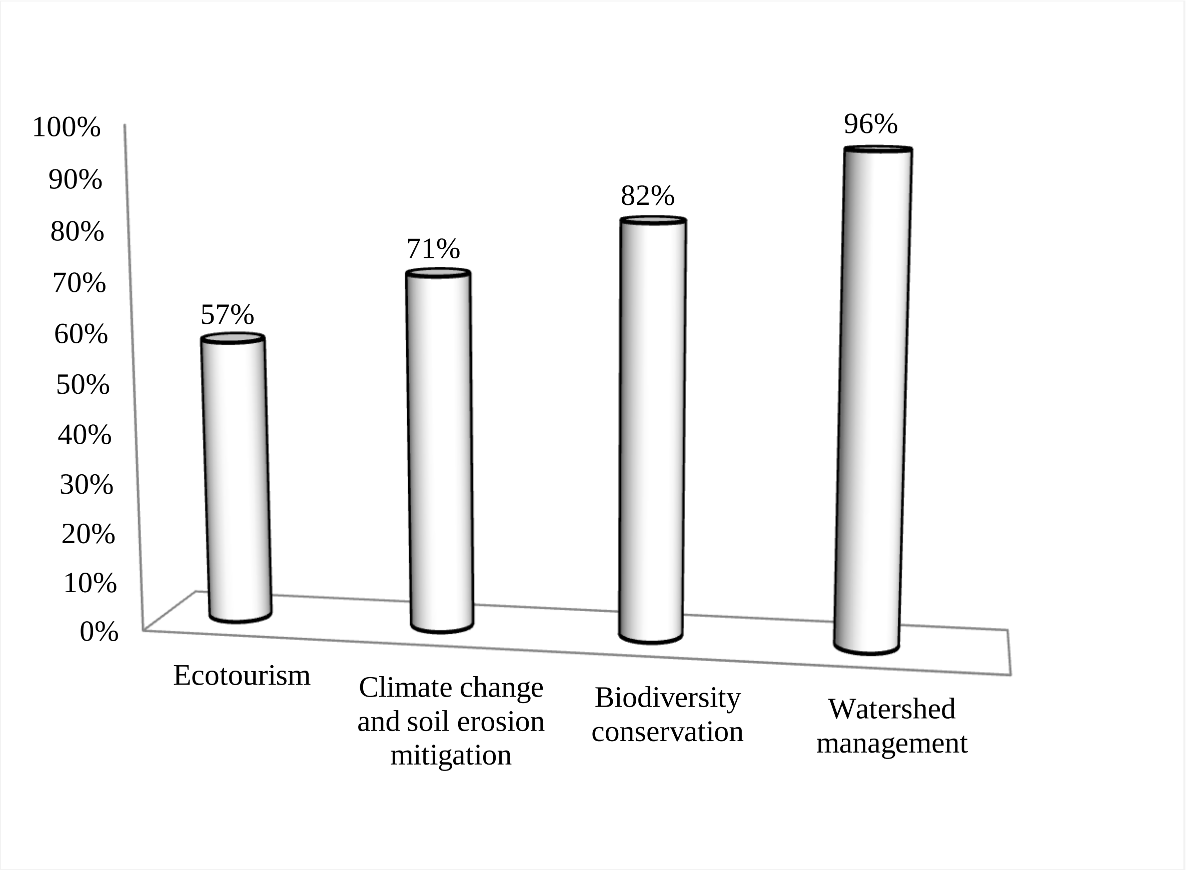

Figure 32. Local communities interest towards conservation of Chilalo-Galama Mountains Range as part of AMNP

Factors that threatened the conservation of Chilalo-Galama Mountains Range were revealed by local communities and shown in Table 57. Out of all the factors overpopulation was considered as the major threat to conservation as perceived supported by more than 86% of respondents. The other threatening factors were uncontrolled hunting, poaching and deforestation (85.68%) (Table 57). Some of the major threats are also shown on Plate 8.

More than 77% of the respondents did not notice exotic species expansion as a threat to conservation of the area (Table 57).

Table 57. Factors that are believed as threat to the park conservation

Threats	Yes		No	
	No	%	No	%
Overpopulation	319	86.22	51	13.78
Uncontrolled hunting, poaching and deforestation	317	85.68	53	14.32
Destruction of habitats by agriculture expansion and settlement	301	81.35	69	18.65
Resource conflict and scrambling to seize park land among the neighboring communities	295	79.73	75	20.27
High demand for charcoal and fuel wood	293	79.19	77	20.81
Poverty, unemployment and lack of food	264	71.35	106	28.65
Presence of predators and pest animals	212	57.30	158	42.70
Climate change	168	45.41	202	54.59
Poor agricultural practice	161	43.51	209	56.49
Price inflation and increment of unemployment rate	152	41.08	218	58.92
Exotic species expansion	82	22.16	288	77.84

Plate 8. Some of the impacts on *Erica* due to Charcoal production and fuelwood collection and high encroachment

More than 47% of the respondents confirmed the availability of protection rules and regulations as well as better enforcement (Table 58).

The effort towards preservation protection of domestic animals entrance into the park was judged as poor by 36.49% of respondents and in contrary, it was followed by very good (31.89%) (Table 58). However, the conservation practice in Sherka, Lemu Bilbilo, Tana, Robe and Honkolo were very good. Inparticular the Honkolo protection from livestock entrance can be used as role model for others and for the practice of community based conservation (Plate 9).

About 46% of the respondents evaluated the suitability of Chilalo-Galama Mountains range conservation by reducing or avoiding the influence of infrastructure as very poor.

Comparatively, most of the respondents evaluated the Park as poor based on its suitability for all wildlife (Table 58).

Plate 9. Community based conservation practices and sustainable utlization of the resources in Honkolo and northern part of Chilalo-Galama Mountains Range

Table 58. Local communities evaluation on the suitability on Chilalo-Galama Mountains range for the conservation of wildlife and their habitats

Items	level			
	Very Good	Good	Poor	Unknown
Availability of protection rules and regulation and their enforcement	177 (47.84%)	83 (22.43%)	84(22.70%)	26(7.03%)
Availability of corridors that allow animals to move freely	122 (32.97%)	117(31.62%)	40(10.81%)	91(24.59%)
Efforts of protection of domestic animals from park entrance	118 (31.89%)	83(22.43%)	135(36.49%)	34(9.19%)
Influence of infrastructures	107(28.92%)	61(16.49%)	170(45.95%)	32(8.65%)
Habitat suitability for all wildlife	102(27.57%)	62(16.76%)	119(32.16%)	87(23.51%)
Extent of protection from illegal encroaching, hunters	102(27.57%)	113(30.54%)	125(33.78)	30(8.11%)
Influence from artificial plantation and exotic species expansion	70(18.92%)	80(21.62%)	143(38.65%)	77(20.81%)

The local communities had different attitudes towards on the priority of conservation for different groups of animals and plants. For the conservation of forest and grassland, nearly everyone had positive attitude (Figure 33). Local communities had positive attitude towards the conservation of large mammals and birds. However, for small mammals and invertebrates local communities gave it low priority (Figure 33).

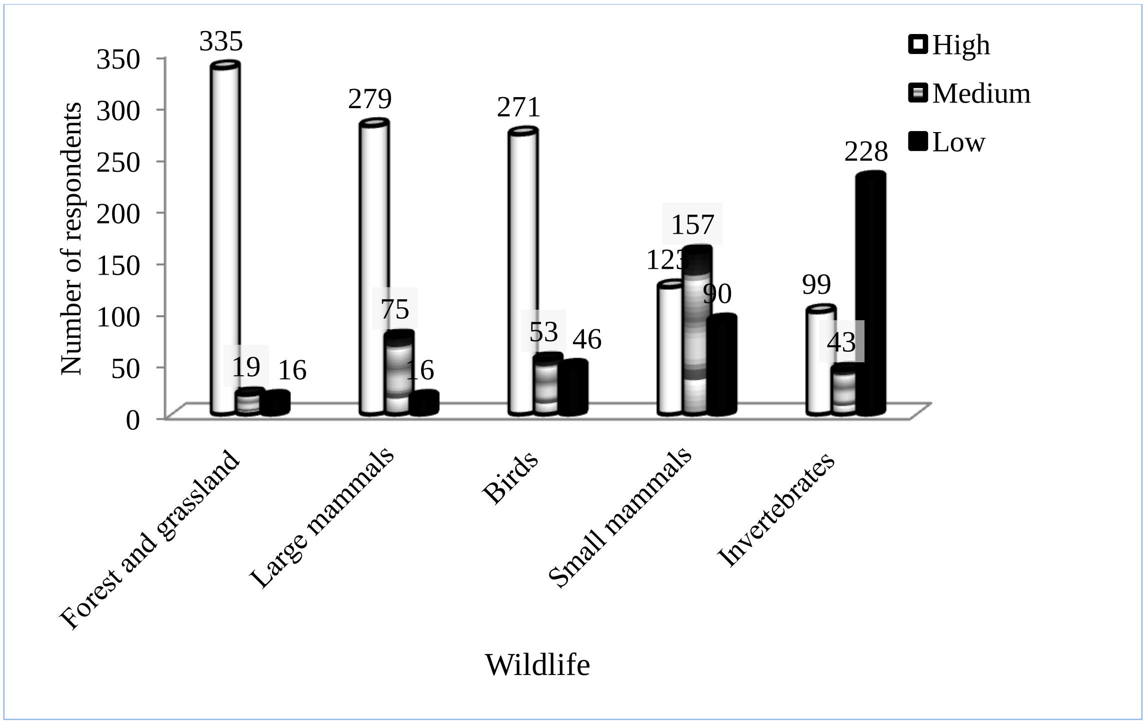

Figure 33. Attitudes in the conservating different wildlife

Providing management responsibility to the local community was supported by 98.11% of respondents.

More than half the number of the respondents supported recognition of the local communities rights to use natural resources and cultural practices within the protected area (Table 59).

Table 59. Conservation of management plan to be implemented for the Park

Actions	Agree		Disagree	
	No	%	No	%
Giving management responsibility to local community to manage and use the park	363	98.11	7	1.89
Encouraging participation of local community in co-management activities of the park	363	98.11	7	1.89
Allowing the local community to use the park resource in a sustainable way	264	71.35	106	28.65
Strictly protecting local community from access of any resource and protecting the area for wildlife only	242	65.41	128	34.59
Sharing responsibility and income with local community	195	52.70	175	47.30
Recognizing the local communities rights to use to natural resources and culture within the protected area	188	50.81	182	49.19

7. DISCUSSION

The number of small mammal species recorded during the present investigation from Chilalo-Galama Mountains range is higher than the previous records in and around the same area. The number of species recorded from Chilalo-Galama Mountains range also is higher than species richness recorded from the other northern, central and western highlands (Mesele Yihunie and Afework Bekele, 2012; Zelalem Tefera *et al.*, 2012). For instance, Mohammed Kasso *et al.*, (2010) previously recorded 17 species of rodents and shrews from same study area and its surroundings. In addition, Mohammed Kasso and Afework Bekele (2017) recorded 10 species of rodents from around Asella town. The increase in the number of species recorded in the current study mainly contributed by the record of new species. Some species that were previously reported are omitted from this report due to their misidentification. Those species were *Arvicanthis dembeensis*, *Otomys typus* and *Crocidura flavescens*. As Mohammed Kasso *et al.* (2010) suggested, *L. flavopunctatus* is a complex species among the Ethiopian endemic species. In the present study, the occurrence of *L. chrysopus* and *L. brevicaudus* in Chilalo-Galama Mountains Range is confirmed. Furthermore, except for *Leminscomys barbatus*, other species like *Dendromus lovati*, *Dendromus* (*Megadendromus*) *nikolausi* and *Mus* (*Muriculus*) *imberbis* which were reported to exist around Chilalo-Galama Mountains range by Yalden and Largen (1992), but which were not captured by Mohammed Kasso *et al.* (2010) were fortunately recorded in this study. The other newly recorded species are *C. fumosa*, *C. lucina*, *C. olivieri*, *Dendromus* sp.1 and *O. helleri*. The additional major reason that contributed toincrease in the number of reported species in this study is due to the addition of 13 more species from Order Chiroptera. Mohammed Kasso *et al.* (2010) recorded similar number of taxa with exclusion of bats. Comparably Demeke Datiko *et al.* (2007) recorded fourteen species of rodents and two species of insectivores from Arba Minch Forest and farmlands. *Leminscomys barbatus*, which was reported to exist in the area, was not captured in the curren study and previously by Mohammed Kasso *et al.*, (2010) and in the present study. This might be attributed to changes in microhabitat, types of traps used, rareness or different behavioural patterns and ecological factors. It might have been also misidentified due to its similarity with *D. lovati* based on striped pelage colouration.

Relatively, Order Chiroptera has more number of families whereas Order Philodotyphylla has only one family and genus even though proportionally it comprised of more species. The family with more species (13) was recorded for Muridae in contrast to Hystricidae, Spalacidae, Hipposideridae and Rhinolophidae where only one genus and species were recorded. When all the bat species recorded from Ethiopia are considered, the Vespertilionidae contain the largest number of both genera (11) and species (30), followed by the Molossidae (17) and Pteropdidae (12) (Kaipf *et al.*, 2015; Kruskop *et al.*, 2016). At a higher taxonomic level, the following families were recorded in Ethiopia to date: one family of megabats (Pteropodidae with 12 species) and ten bat families (Rhinopomatidae with 2 species, Rhinolophidae with 9 species, Hipposideridae with 10 species, Emballonuridae with 4 species, Nycteridae with 6 species, Megadermatidae with 2 species, Molossidae with 17 species, Miniopteridae with 3 species and Rhinonycteridae with probably 2 species and Vespertilionidae with 30 species (Lavrenchenko *et al.*, 2010; Kalpf *et al.*, 2015; Kruskop *et al.*, 2016). More than 90 species of bats have been recorded from Ethiopia, where micro-chiropterans are better represented than the mega-chiropterans (Kalpf *et al.*, 2015). Among the Micro-chiroptera, high numbers of species are from the family Vespertilionidae, followed by the families Rhinolophidae, Hipposideridae, Emballonuridae, Molossidae, Rhinopomatidae and Megadermatidae. Among these, at least five species, namely, *Myotis scotti* (Vespertilionidae), *Plecotus balensis* (Vespertilionidae) and *Kerivoula eriophora* (Vespertilionidae) and *Scotophilus ejetai* (Vespertilionidae) and *Lasioncteris petra* (Pteropodidae) are endemic to the country (Kaipf *et al.*, 2015).

The presence of diverse climate and topography facilitated AMNP to possess different favourable habitats that harbour many animals and plants species. It is also home for a number of endemic wildlife. Chilalo-Galama Mountains Range of AMNP is one of the most important conservation areas that is comparable to its nearest protected area of Bale Mountains National Park. However, due to limited studies in the area, it did not attract international, national and regional attention (Mohammed Kasso *et al.*, 2010; Mohammed Kasso and Afework Bekele, 2011; Zerihun Girma *et al.*, 2012). Arsi Mountains represents the largest area of Afroalpine and sub-Afroalpine vegetation next to Bale Mountains in Ethiopia and in Africa (Yalden, 1983). It possesses many endemic species which are associated with the abundance of high altitude moorland and grassland (Yalden, 1983). *Stenocephalemys, Muriculus, Nilopegamys, Desmomys* and *Megadendromus* are treated as endemic genera to Ethiopia (Yalden *et al.*, 1996; Afework Bekele and Yalden, 2013; Lavrenchenko *et al.*, 2017). Recently axonomic revision was carried out on genus *Muriculus* by Meheretu Yonas *et al.* (2015) and on *Megadendromus* by Lavrenchenko *et al.* (2017). Ethiopian eastern plateau is a key area for Ethiopian small mammal endemism with the highest generic and species level endemism.

Wildlife populations in Ethiopia are under continuous threat due to deforestation, farm expansion, drought and illegal hunting (Mohammed Kasso and Afework Bekele, 2017). Their recent rapid decrease in both size and number of species is due to habitat destruction as result of rapid human population growth. The loss of wildlife for the most part is associated with the destruction of habitats by encroachment to protected areas by local communities in search of pasture, farmland, settlement, forest products, hunting or illegal killings (Meinig and Boye, 2009). The alterations of habitats due to climate change can also affect the presence and availability of wildlife. It leads to the reduction in population of some wild animals to categorize as rare species or near extinction (Meinig and Boye, 2009).

Habitat fragmentation influences mammals by isolation and loss of genetic diversity by inbreeding and suppression of migration (Meinig and Boye, 2009). From the existing habitats of small mammals of Chilalo-Galama Mountains Range, the most endangered are the remnant Afromontane forests and the habitats of Cheleleka (moorland, grassland and wetland). Cheleleka has a saddle like land feature that connects Mount Chilalo and Galama Mountains Range. Despite its flat plain and fertile soil occurring at altitude between 3200-3400 m asl it was previously unoccupied by human settlement and agriculture due to the condition of its temperature. However, currently due to high rates of human encroachment from both east and west side, it is highly threatened. Encroachment on both sides at alarming rate is making Mount Chilalo to be isolated from Galama Mountains Range. In addition, Cheleleka harbours good habitat for Ethiopian Wolf and other mammals and birds. Habitat degradation and encroachment should be stopped immediatly. The highland lakes that occur in Cheleleka are also important for wetland birds and watershed management increases its significance for conservation.

Climate change has significant impacts on biodiversity and causes shifts in the distribution of species to new and suitable habitat. In the case of the protected areas, these shifts can be to outside the boundaries of protected areas or it can also cause new species to move into the protected area. Such change due to climate change has already affected biodiversity in many parts of the world. Afroalpine habitats occupied most of the areas that are suitable for wildlife in Chilalo-Galama Mountains range, and sub-Afroalpine are highly sensitive to climate change. Besides this, more than 30% of its currently recorded small mammal species are threatened but some are data deficient on their conservation status. From the three orders of small mammals recorded in this study, proportionally the highest (two out of five species) number of threatened and data deficient species belonged to Order Philodotyphylla. Similarly, from the 29 *Crocidura* species recorded from Ethiopia, the majority were endemic and threatened by habitat loss and degradations (Afework Bekele and Yalden, 2013; Lavrenchenko *et al.*, 2017). Likewise, out of the 224 species of bats in Africa, 14% are regarded as threatened, 64% least concern and the rest (22%) are data deficient because their conservation status cannot be assessed from the available information (Happold and Happold, 2013). Therefore, the protection and conservation of these threatened small mammal species are mandatory.

The abundance of small mammal variation is compared using average trap success rates at different areas. The trap success recorded shows variations from place to place or from habitat to habitat (Getachew Bantihun and Afework Bekele, 2015). The overall trap success from the intensive study grid was 44.6%. Likewise, a study conducted by Mohammed Kasso and Afework Bekele (2011) in the same area measured the overall trapping success of 44.1%. Relatively high trap success was obtained for rodents than shrews. Studies conducted by Mohammed Kasso and Afework Bekele (2011) and Demeke Datiko and Afework Bekele (2014) showed of insectivore capture, probably because of low population density. In general, the trap success computed in this study was relatively higher than the previous recorded by Afework Bekele (1996) from Menagesha State Forest (36.8%), central Ethiopia and by Getachew Bantihun and Afework Bekele (2015), 15.8% from Arditsy Forest, Awi Zone and Demeke Datiko *et al.* (2007), 17.6% from Arbaminch Forest and Farmlands. Mengistu Adam *et al.* (2015) recorded a trap status that ranges from 3.5% to 5.1% with overall trap success of 4.1% from northern Ethiopia. Trap success was significantly higher during wet seasons than in the dry season mainly due to the influence of rainfall, which facilitates the growth of ground cover and availability of food, which in turn, enhances breeding (Getachew Bantihun and Afework Bekele, 2015). For instance, Tadesse Habtamu and Afework Bekele (2008) recorded that the overall trap success varied from 12 to 64% among different habitats. Demeke Datiko and Afework Bekele (2014) indicated highest (29%) trap success for agricultural land and lowest (2%) for the riverine forest (2 %). The high trap success rate during the present study indicates the greater abundance and activity of small mammals in Chilalo-Galama Mountains Range. However, the extra ordinary highest trap success (136.7%) was because of single trapping occasion and high abundance of small mammals during both day and night trapping sessions. Otherwise, when the capture and abundance were compared with similar habitats from intensive study grid in similar seasons and sessions, there was no such obvious difference in capture. Beside this, few multiple captures documented also contributed for such increase. There was variation in trap success among the different habitat types and seasons. The high trap success observed in the grids with dense vegetation ground cover, which directly provides good shelter for small mammals and accounts for more capture rate. The lowest trap success may also be related to negative interaction or activities of predators and raptors and other disturbances (Getachew Bantihun and Afework Bekele, 2015). Small mammal communities are also negatively affected by human activities in an area. The seasonal changes on cover and food availability cause significant seasonal variation in the total catch and trap success of small mammals (Demeke Datiko and Afework Bekele, 2014)

Traps closed without capturing any animal or open with bait eaten by small mammals due to failure of trap by wind or other form of disturbance and due to damage on Sherman live trap treadle mechanisms. Besides this, some traps can be damaged, lost and removed from trapping station by predators, baboons or shepherds. In line with this, Aplin *et al.* (2003) also mentioned factors like the behaviour of small mammals, trap arrangement, trap mechanism, age and sex composition of the population, the weather conditions, type of baits and availability of alternative food around the grid would influence trap status and success. Trap trigger variation may also contribute for multiple captures that affects trap status and success (Feldhamer *et al.*, 2008).

Multiple individuals of small mammals captured in a single episode of live trappings are rare and random events (Bergstrom, 1986). In this study, in 17 occasions, multiple captures by Sherman Live traps were recorded. Multiple captures reported in most studies are generally rare relative to single captures, although percentages are highly variable (Drickamer *et al.*, 2003). Previous reports of multiple captures in Ethiopia are limited or scant. However, Mohammed Kasso *et al.* (2010) observed double capture in the current study area. Other studies by Spencer *et al.* (1982) recorded 24 multiple captures, Taulman *et al.* (1994) reported 16 double captures and Drickamer *et al.* (2003) 172 double captures. The multiple captures were only recorded for eight species namely *A. blicki*, *C. glassi*, *L. brevicaudus*, *L. chrysopus*, *L. melanonyx*, *M. mahomet*, *S. albipes* and *S. griseicauda*. The majority of multiple captures were recorded for *L. brevicaudus* followed by *L. melanonyx*. Similarly, Jenkins and Llewellyn (1981) and Spencer *et al* (1982) also reported a multiple capture rate variations among different species. The reason for small mammal simultaneous trap entry remains controversial (Bergstrom and Sauer, 1986). One of reasons of multiple captures is a positive relationship between both abundance and the proportion of multiple captures and population size (Taulman *et al.*, 1994). The high rate of multiple captures for *L. brevicaudus* and *L. melanonyx* may be due to their population density. The increased proportion of double captures in large population sizes support the hypothesis of synchronous entry of socially affiliated animals into traps. In the present study, capture of different sex and age combination is probably related to social and reproductive condition and parental bond. Several investigators have also concluded that double or multiple captures are indicative of social interaction that primarily occurred because of social bonding and high densities. In such cases, Taulman *et al.* (1994) indicated single capture traps as better inference for social travelling because animals must enter nearly simultaneously to be captured together. Relatively few reproductively active individuals are captured multiple times (Feldhamer *et al.*, 2008). Adult male-female captures accounted for about 11.76 % of double captures. A greater number of adult male-female double captures is attributed to reproductive activity and mating (Feldhamer *et al.*, 2008).

More number of individuals of rodents than shrews were captured in this study. A study conducted by Mohammed Kasso *et al.* (2010) in the same study area and Zerihun Girma *et al.* (2012) in the nearby Kaka and Hunkolo showed more captures of rodents than shrews. In most studies conducted in different parts of the country they revealed more captures of rodents than shrews (Demeke Datiko *et al.* 2007; Demeke Datiko and Afework Bekele, 2014; Getachew Bantihun and Afework Bekele, 2015). The reasons for relatively few shrew captures than rodents may be related to the type of trap and bait used. Species that are more neophilic to traps tend to be captured at faster rate than the neophobics (Smith *et al.*, 1975). For shrews, pitfall traps is considered as more effective and productive than other traps (Shore *et al.*, 1995) like the Sherman Live traps that were used in the present study. The abundance of animals estimated from traps also depends on the behaviour of animals to traps (Smith *et al.*, 1975). Even though, the abundance of shrews is lower than rodents, it might also relate to the behaviour of shrews. Furthermore, their low trap success can also correlate with their comparatively low species richness and abundance (Zerihun Girma *et al.*, 2012).

The abundance and species composition of small mammals depend on the vegetation structure and complexity of habitats. Habitats with high vegetation diversity and dense ground cover support more mammal diversity than open and less diverse habitats (Mengistu Adam *et al.*, 2015). Relative abundance of small mammals expresses their population size (Henke and Knowlton, 1995). The abundance of small mammals was significantly different among the grids in the present study area probably due to the aforementioned factors.

Relatively more individuals of *L. brevicaudus* followed by *S. griseicauda* and *S. albipes* were recorded. *Lophuromys brevicaudus* is endemic to Ethiopia in Afromontane and Afroalpine habitast and high altitudes ranging from 2400 to 3750 m (Lavrenchenko *et al.* 1998). Mostly it occurs in Afroalpine grasslands and *Erica* bush especially on mesa tops (Sillero-Zubiri *et al.* 1995; Lavrenchenko *et al.* 1998) and occurs also (in smaller numbers) in montane forest. In habitats where they occur, they are abundant when compared with other animals captured in the area (Lavrenchenko *et al.* 1998). The genus *Stenocephalemys* is endemic to Ethiopia, mostly in the Afromontane and Afroalpine habitats. *Stenocephalemys griseicauda* is widely spread both east and west of the Ethiopian Rift Valley from Simien in the north to Bale in the south (Yalden *et al.* 1976; Yalden and Largen, 1992). It is the most abundant in highland grassland communities and is dominantly captured in its appropriate habitats (Yalden, 1988). *Stenocephalemys albipes* is also widely distributed in many mid-elevation highland habitats

(Yalden and Largen, 1992; Afework Bekele, 1996). It occurs in different habitats including bush, grassland, forest and *Erica* scrub even though it prefers forest habitats than shrub and grassland (Afework Bekele, 1996).

Out of the five species of Order Philodotyphylla, *C. thalia* was the dominantly captured species. *Crocidura thalia* is endemic in Ethiopia highland and is most widespread both east and west of the Ethiopian Rift Valley (Yalden and Largen, 1992). Its abundance varies from place to place, even though in mostly they are rare (Lavrenchenko, 2000). However, in the present study area, it was one of the most abundant and dominant species compared to other *Crocidura* species. From the three species recorded by Mohammed Kasso *et al.* (2010) from the same study area *C. thalia* is widely distributed and is the most abundant. However, *C. olivieri*, which is considered as widely distributed throughout many biotic zones from the Sahel Savannah Biotic Zone to Rainforest Biotic Zones and grassland (Lavrenchenko *et al.*, 2001; Happold and Happold, 2013), it was rare in this present study. It occasionally occurs in plantations (Happold and Happold, 2013), farmland, around houses and food stores. Their abundance varies from habitat to habitat and from county to country (Happold and Happold, 2013).

The mark-recapture method is a powerful method for estimating abundance as long as the underlying assumptions are met (Lettink and Armstrong, 2003). The absence of recaptures for *D. nikolausi*, *Dendromus* sp. 1, *M. imberbis* and *R. rattus* was related to their rareness and low abundance. The highest relative abundance was recorded for *L. brevicaudus* followed by *S. griseicauda* and *S. albipes* and corrosponds with previous study by Mohammed Kasso *et al.* (2010) and Zerihun Girma *et al.* (2012) from Chilalo-Galama and its surrounding mountains. The least relative abundance was recorded for *D. nikolausi* and *M. imberbis*. Both species are endemic and very rarely recorded (Meheretu Yonas *et al.*, 2015; Lavrenchenko *et al.*, 2017). *Dendromus nikolausi* is an endemic and very rare rodent species in the Afromontane and Afroalpine habitats of *Hagenia-Erica arborea* forest and *Erica arborea* scrub of Ethiopia (Lavrenchenko *et al.*, 2017). Among the endemic rodent species of Ethiopia, both *Mus* (*Muriculus*) *imberbis* and *Dendromus* (*Megadendromus*) *nikolausi* are some of the most enigmatic taxa. They have been reported to occur on limited area and very rare in abundance (Meheretu Yonas *et al.*, 2015; Lavrenchenko *et al.*, 2017). It is one of the very rare rodent species of Arsi Mountains. One of the reasons for its rarity may be due to habitat degradation and destruction by agricultural practice and *Erica* fire that leads to local extinction (Lavrenchenko *et al.*, 1997). *Mus* (*Muriculus*) *imberbis* was recorded from both sides of the Ethiopian Rift Valley (Yalden *et al.*, 1996; Meheretu Yonas *et al.*, 2015). It is becoming rarer because of habitat destruction (Yalden *et al.*, 1996) although there is also suggestion of scarcity of records due to problems related to trapping methods rather than its rarity (Meheretu Yonas *et al.*, 2015). However, based on the current rate of capture for the close related species, *M. mahomet*, by Sherman Live trap may contradict the reason of its rarity due to the type of trap. Similarly, few specimens of *D. nikolausi* were collected from Bale Mountains. In general, it was very rare when compared with other species of rodents recorded in this study.

Small mammal species become adapted to certain habitat types where their need for food, shelter, moisture and others necessary requirements are met (Smith *et al.*, 1975). The species composition and abundance show variation among different habitats based on quality and preference of the species to the habitat (Mohammed Kasso and Afework Bekele, 2017). Habitat use associated with vegetation characteristic is an important factor governing the assemblage of small mammals both within and between habitats (Demeke Datiko *et al.*, 2007; Sintayehu Workeneh *et al.*, 2011). This may be due to the difference in vegetation cover, foliage and availability of food in the habitat type (Sintayehu Workeneh *et al.*, 2011). Many studies showed close relationships among small mammal distribution and abundance and habitat structure.

Studies on the relationship between small mammal assemblages and habitat structure have revealed that habitat structure is a good predictor of assemblage of small mammals (Demeke Datiko *et al.*, 2007; Sintayehu Workeneh *et al.*, 2011). In the present study, similar trend of variation in abundance and species composition and habitat preference was observed among different habitats. From the gross abundance, more new captures were documented from *Erica* forest habitat followed by moorland whereas the least abundance was noticed from plantation habitat.

The habitat types, the degree of heterogeneity and spatial features determine the abundance and habitat preference of small mammals (Smith *et al.*, 1975). The plantation habitat in the current study was more homogenous than other natural habitats. In matured plantations, bare understory and closed canopy were observed. The lowest abundance of small mammals was recorded in this habitat. The abundance of small mammals in the mature plantations with bare ground and closed canopy was very lower than in young, sparse and open canopy plantation with ground vegetation and mixed with thickets and bushes.

Small mammal habitats preference is based on their resources requirements for food, shelter and refugia. Their evolutionary history of the small mammals, degree of specialization and behaviour also determine their habitat preference (Corominas, 2004). The reason for high capture and higher species richness from *Erica* forest is probably due to its high quality. This habitat is relatively less disturbed and possess different understory herbs, grass, ferns, mosses and lichens that serve as food, shelter and cover from predators for different species of small mammals. In addition, more grids were selected due to its high proportional area coverage in Chilalo-Galama Mountains Range. Thus, the selection of more grids from *Erica* forest habitat also contributed to high abundance of small mammals. However, when the mean abundance per grid was considered, the abundance seemed to be comparable with other moorland habitats. The vertical stratification of habitats allows many species to coexist. Certain habitats features influence the movement patterns and intensity of small mammals and contact between them (Smith *et al.*, 1975). Their habitat selection varies at temporal and spatial scales and their populations experience dramatic seasonal variations in abundance (Mohammed Kasso and Afework Bekele, 2011; Tilahun Chekol *et al.*, 2012). Similar seasonal abundance change was observed in the Agricultural land habitat.

Lophuromys brevicaudus was not only the most abundant but it was also the widely distributed small mammal in all habitats except in Agricultural land habitat. As stated by Corominas (2004), dominant individuals also expected to occupy better habitats preferentially than its subordinate contributing to its wide distribution and high abundance. *L. brevicaudus* is a common small mammal in different parts of the country (Mohammed Kasso *et al.*, 2010; Afework Bekele and Yalden, 2013). It was also the most widely distributed and abundant species of small mammals in the current study area and was recorded from all habitat types.

The second and the third highly abundant and widely distributed species were *S. griseicauda* and *S. albipes*. Demographic processes and feedback structure also affect habitat selection of some species. *Stenocephalemys griseicauda* was recorded, as it is widely distributed small mammal species in different highlands of Ethiopia (Sintayehu Workeneh *et al.*, 2011).

The effect of habitat change on species abundance and distribution varies among species (Tadesse Habtamu and Afework Bekele, 2008). Although the exact causes are not known during the current study, some species such as *C. olivieri*, *C. lucina*, *Dendromus* sp.1, *D. lovati*, *M. nikolausi* and *M. imberbis* can be categorized as rare (that are represented fewer than 10 individuals). Some were trapped only in one season but not in the other. Despite variation in the list of species, records of rare and uncommon species from different parts of the country have often been reported (Tadesse Habtamu and Afework Bekele, 2008).

Each small mammal species is distributed in different habitats according to its unique requirements for food, space and shelter. According to Sintayehu Workeneh *et al.* (2011) their diversity, abundance and distribution can be affected by several biological and physical factors like predator avoidance, competition and the amount of resource available. Small mammals in the current study area showed seasonal movements between habitats. Low abundance of small mammals was observed in the riverine habitat during the wet season and were comparatively more abundant during the dry season (Sintayehu Workeneh *et al.*, 2011).

The distribution of small mammal is strongly influenced by microhabitat factors and hence the distribution of rodents and insectivores is not uniform in all habitat types (Tilahun Chekol *et al.*, 2012). Almost all species recorded in the present study showed variation in habitat preference. *Stenocephalemys griseicauda* occurred in all the habitat type of *Erica* scrub and *Erica* forest than other habitats. However, bushland and moorland habitats were least preferred by *S. griseicauda*. Similarly *L. brevicaudus* and *S. albipes* also occurred in all habitats except in agricultural land and moorland habitats in respective order. *Lophuromys brevicaudus* preferred *Erica* scrub and *Erica* forest whereas *S. albipes* preferred more montane forest. Similarly, different studies hypothesized that habitat complexity and heterogeneity at different altitudes influence the diversity and distribution of small mammals (Mohammed Kasso *et al.*, 2010). Dominant individuals were also expected to occupy better habitats preferentially, whereas less dominant individuals will occupy suboptimal habitats, the so-called source sink dynamics (Wolff, 2007).

Many studies showed sharp relationships among small mammal distribution and abundance and habitat structure (Tilahun Chekol *et al.*, 2012). The abundance of each species recorded in a given habitat can also highlight the level of its preference by a particular species. The results of the current study indicated agricultural land habitat was most preferred by *M. natalensis*; bushland and plantation habitats by *S. albipes*; *Erica* forest habitat by *L. brevicaudus*; *Erica* scrub and grassland habitats by *S. griseicauda* and moorland habitat by *A. blicki*. Small mammal species like *A. blicki*, *S. albocaudata*, *L. melanonyx*, *O. helleri* and *C. thalia* were recorded from similar habitats in relatively higher altitude. They were recorded in *Erica* forest, *Erica* scrub, and grassland and moorland habitats. The other species that was confined in similar habitats in Afroapline zone with the exception of grassland was *C. glassi*. *Crocidura glassi* is a specialized moorland species, whereas *C. thalia* is a species of mountain grassland (Lavrenchenko *et al.*, 2001). The results on their habitat preference agrees with previous work by Yalden (1988) and Sillero-Zubiri *et al.* (1995); Mohammed Kasso *et al.* (2010). Although the abundance of small mammals from moorland habitats is lower than *Erica* forest, it had relatively highest captures per trap night. This was mainly due to more captures and activity of the highly abundant and dominant moorland specialist rodents like *A. blicki* and *L. melanonyx* during the daytime and *S. albocaudata* during the night time. As Wolff (2007) stated, their demographic processes and feedback and structure also might contribute to their dominance and habitat selection. That means, habitats with higher quality in terms of food and refugia are more preferred (Wolff, 2007). Moorland habitats in Chilalo-Galama Mountains Range occur at higher elevation and summit of the peaks which is comparably less affected by human encroachment. Thus, it becomes the most preferred habitat for abundant moorland specialist rodents. However, as moorland and Afroalpine grassland habitats are more fragile due to its unfavourable climatic condition, it demands urgent conservation measures to protect their unique biodiversity. The moorland and grassland habitats that occur around Cheleleka have more moorland specialist small mammals. The endangered Ethiopian Wolf also frequently occurs in this habitat due to high abundance of their prey rodent species.

Among the selected habitats, the least capture rate was recorded in the plantation habitat. Although, the current study on the impact of plantation on small mammals was a retrospective survey, the comparison of abundance and species composition of small mammal with the nearby natural habitats can be used as a clue for its impact on the diversity and abundance of small mammals. The difference in abundance and species composition of small mammals in plantation habitat and the nearby natural habitats clearly indicates that plantation with exotic plant species has impact on small mammal abundance and diversity. In the present study, the abundance and distribution of small mammals showed significant variation among the different girds of the plantation with different stages of growth and structure of vegetation. Simialrly, studies conducted by Carey (1995) showed that abundance and diversity of small mammal differs among different stages of growth of plantations. This is, mainly related to variation in habitat factors like fallen trees and understory vegetation that provides cover and food to forest floor small mammals (Carey, 1995). Understory vegetation and its structure determines the interaction of canopy closure, site conditions and stand history (Carey, 1995) which in turn affects the diversity and abundance of small mammals. For instance, the fallen trees are important to small mammals inhabiting the forest floor by providing moist microclimates, protective cover, travel ways, nests and burrow sites and food (Carey, 1995). In the current study, relatively more small mammals were captured from girds of young plantation than the matured old-growth plantation of *Pinus*, *Eucalyptus* and *Cupressus* with open canopy and understory vegetation. In contrast this, the old growth forests in the Pacific Northwest characterized by high diversity of vegetation structure and composition were habitats for many small mammals than young plantation (Carey, 1995). Plantation management like clear cutting, site preparation, and thinning can substantially reduce the amount of coarse woody debris. The manipulations of canopy of vegetation can strongly influence the understory vegetation and enhance tree growth as well (Carey, 1995). These results suggest that old plantation with bare floor and closed canopy limits the abundance and distribution of small mammals whereas the young plantation with understory vegetation holding grass, herbs, shrubs and tufts of *Erica* was more diverse in small mammal community. In addition, the species of plantation, canopy, thinning, spacing and other environmental and altitudinal factors are important determinants of species abundances. Hence, the forest management or plantation practice in Chilalo-Galama Mountains Range (Arsi Mountains) with exotic plantation can be considered as one of the most important threatening factors for small mammals. Meinig and Boye (2009) also reported that plantation practices significantly affect the diversity of small mammals that previously exist in a natural forest. Species composition variation was also observed in grids of plantation habitat located in lower elevation and higher elevation. This variation agrees with Carey’s (1995) hypothesis as species responses are nonlinear and influenced by surrounding environmental condition and forest structure and composition.

Grassland and agricultural land habitats had relatively low abundance of small mammals. The low abundance of small mammals in agricultural habitat was due to its low number of girds and low abundance of small mammal record during the dry season and non-cropping season. The analysis made by Meinig and Boye (2009) also identified forest management, agriculture and habitat fragmentation had strong negative impact on the mammal fauna. Small mammals are dependent on available resources and are able to disperse to suitable sites and leave unsuitable sites (Getachew Bantihun and Afework Bekele, 2015).

The overall mean abundance was highest for *S. albipes, L. brevicaudus, S. griseicauda* whereas it was least for *C. fumosa, C. lucina* and *M. imberbis*. *Mastomys natalensis* had high mean abundance in agricultural land habitat and *S. albipes* had high abundance in bushland, montane forest and plantation, *L. brevicaudus* in *Erica* forest and *S. griseicauda* in *Erica* scrub and in grassland and *A. blicki* were the most dominant species in moorland habitat. Over all the current abundance of small mammals among the habitat showed similarly with reports from other highlands in the country (Mohammed Kasso *et al.*, 2010; Zerihun Girma *et al.*, 2012; Gutema Jira *et al.*, 2013).

Erica scrub habitat was the most preferred habitat with more than 18 species of small mammals. The next mostly preferred habitat with 15 species of small mammals was *Erica* forest. Grassland habitat was preferred, with 13 species of small mammals. However, agricultural land, bushland and plantation habitats were relatively less preferred. The low preference of the habitats by small mammals might relate to their disturbance and modification by human activity.

Diversity indices provide more information than simply the number of species present. They serve as valuable tools that enable us to quantify diversity in a community and describe its numerical structure (Colwell *et al.*, 2004). The results of biodiversity indices showed that the diversity and evenness of the relatively undisturbed habitats like *Erica* scrub, *Erica* forest, and moorland habitats are much higher than in relatively disturbed habitats like bushland, montane forest, plantation and grassland habitats. For instance, small mammals species richness was highest in *Erica* scrub and *Erica* forest habitats and relatively lowest in bushland, montane forest and plantation. The Chao-1 species richness estimator also confirmed highest species richness estimate for this habitat. However, grassland had the highest Shannon-Weiner and had the highest Simpson Similarity Index. The lowest Shannon-Weiner diversity index was recorded for bushland and followed by montane forest. Although other diversity indices for agricultural land were relatively low the habitat had the highest evenness index. The different levels of disturbance have different effects on small mammal diversity (Gotelli and Colwell, 2011). Habitat disturbance by anthropogenic activity therefore, affects the diversity of small mammals and other biodiversity in the study area.

Species accumulation curves are used to indicate as rate at which new species are found in a given habitat and can be used to extrapolate the estimation of its species richness (Gotelli and Colwell, 2011). In the current study, the species accumulation curves for all habitats were smoothed and maintained the plateau. The relatively stabilized curve indicates that all common species expected to occur in the study area more or less were sampled. However, when species accumulation curves for each habitat was considered, moorland habitat was comparatively more smoothed and maintained the asymptote followed by montane forest habitat and *Erica* forest. The curve is also used to make decision on the quality of the survey, and for how long to conduct the survey in order to get sufficient data for the biodiversity analysis. The asymptote for curves from *Erica* scrub, agricultural land and bushland habitats were not comparatively maintained when compared with the curves for moorland and grassland habitats. This can be used for signal for potential of more additional record of rare small mammals if further survey was conducted.

Species accumulation curves showed a sharp quick inclination because of high potential to record for many more species that are new to the study. The slope of the curve progressively decreases as surveying for small mammals proceeded and as the most abundant in the area are found relatively easily and quickly sampled. The curve that maintains plateau can use for the assurance for the record of all the common species in the study area although the second plateau starts as rare species recorded. Therefore, depending on the aim of the study, one can stop the survey after the first plateau is reached (Gotelli and Colwell, 2011). There is no way to know for sure if one found all the species available at the site even after several plateaus have passed. Logically due to time and money constraints, the survey has to stop at some point or another and cannot go on forever. Extrapolation can be used for the estimation of the richness of a larger sample and the complete richness of the assemblage and to visualize the asymptote of the accumulation curve. Once this asymptote is reached, the species accumulation curve is flat and additional sampling will not yield any additional species (Gotelli and Colwell, 2011). However, in reality, the curve becomes asymptote since the larger areas accumulate species at a constant or even an increasing rate due to its diverse habitat types that support distinctive species assemblages. Consequently, the species accumulation curve continues to increase, and will not reach a final asymptote until it approaches the total area (Gotelli and Colwell, 2011).

Small mammal experience dramatic seasonal and inter-annual variations in diversity, distribution and abundance (Roberts *et al.*, 2008). Their distribution and pattern of abundance largely depends on the seasonal availability of food and water (Demeke Datiko and Afework Bekele, 2014). In the current study, relatively more individuals of small mammals were captured during the wet season than the dry season. Similarly, Mohammed Kasso and Afework Bekele (2011) captured more small mammals during the wet season than the dry season from Mount Chilalo. Opposing to the current study, Demeke Datiko *et al.* (2007), Tadesse Habtamu and Afework Bekele (2008), Sintayehu Workeneh *et al.* (2011) recorded more number of individuals of small mammals during the dry season than the wet season in different part of the country. Such seasonal variation might also occur due to changes in food availability, cover and reproductive conditions. For instance, the drying up of grasses and herbs from many habitats make the capture of small mammals to decline during dry season (Mohammed Kasso and Afework Bekele, 2011). The seasonal change in small mammal population structure like age, sex and reproductive conditions and their activity during unfavourable season or hibernation and aestivation can also contribute to seasonal variation in abundance (Smith *et al.*, 1975).

The number of individuals captured for each species showed seasonal variation. Comparatively more *L. brevicaudus*, *S. griseicauda*, *S. albipes*, *L. melanonyx*, *and C. thalia* and *L. chrysopus* were captured during in the wet season than their respective capture during the dry season. However, more number of individuals for *A. blicki*, *M. natalensis*, *D. nikolausi* and *O. helleri* captured during the dry season than wet season whereas *C. lucina* and *D. nikolausi* were captured during the dry season. The seasonal variation in the capture of small mammals depends on different factors like weather that affect the movement and behavioural response to trapping. Furthermore, the reproductive condition and age also affect trapability because of the animals' prior experience and social rank (Smith *et al.*, 1975). The previous studies in the same study area and its surrounding and other parts of the country also showed similar trend in the number of individuals capturred (Tadesse Habtamu and Afework Bekele, 2008).

Although there were no significant seasonal sex variations, the current study showed male biased sex ratio. Almost for all species, both were sexes recorded except for *Dendromus* sp.1, *D. lovati* and *M. nikolausi*. The absence of both sexes in these species is most likely related to its rarity and only a few individual were captured. The male biased sex ratio in the current study was consistent with the findings of Smith *et al.* (1975) and Tilahun Chekol *et al.* (2012) who recorded higher capture frequency of males. Studies by Mohammed Kasso and Afework Bekele (2011) in Mount Chilalo also recorded similar observation. Sex biased trapability of small mammal can be influenced by complicated responses based on age and breeding condition (Smith *et al.*, 1975). The higher capture frequency of males might be because males are more active than females and their ability to be attracted to bait. Males move longer distances than females which increases the probability to encounter trap whereas the female and sub-adults are intermediate and the juveniles are the lowest (Smith *et al.*, 1975). Relatively females have restricted movements for activities related to lactation and nursing. The loger distances moved by males increases the probality of captures in traps. The differences in movement behaviour rather than unequal reproductive effort by parents lead to a male biased sex ratio.

Individuals of all age groups (juvenile, young, sub-adult and adult) were represented during the wet season trapping. More of young animals during the wet season were recorded although individuals in few species were also represented during the dry season. The present findings showed that the number of juveniles (young) was high during the wet season and less during the dry season. This shows that breeding of most of the small mammal species in the study area is during the wet season. It is already known that reproduction of small mammals in Africa is highly correlated with the availability of rainfall (Sintayehu Workeneh *et al.*, 2011). The age distribution in a population of small mammals in various seasons is directly related to the seasonality in reproduction of the species. The more young members accounted for 34.3% of the total population during the wet season. The correlation between rainfall and the seasonality of reproduction for the majority of the small mammals in Africa has been reported by many workers (Afework Bekele and Leirs, 1997; Tadesse Habtamu and Afework Bekele, 2008).

Not all rodent species show a discrete breeding season. However, most of the pest rodents seem to stop breeding during periods of extended fallow, when food is scarce or of low quality. As per the study by Afework Bekele and Leirs (1997) and Mohammed Kasso (2010), food limitation constrains the reproductive success of small mammals. Direct effect of rainfall on reproduction, especially for species with poor ability to conserve water and its influence on population dynamics was reported by Afework and Leirs (1997). Therefore, reproductive success and population dynamics of rodents are greatly influenced by variations in the rainfall patterns. Other results indicated that, population size increases during the rainy season (Workneh Gebresilassie *et al*., 2006; Tadesse Habtamu and Afework Bekele, 2008; Sintayehu Workeneh *et al.*, 2011; Getachew Bantihun and Afework Bekele, 2015). Pregnancy and lactation are adaptively timed to ensure a high survival rate for the young. Because small rodents have relatively short gestations (ca. 25–40 days), they can be very responsive to changes in climate. Hence the start of the wet season, or the end of ‘winter’ initiates the reproductive process, and the young are born and weaned while the favourable conditions last

(Happold, 2013). The presence of pregnant or lactating females, juveniles and young individuals during the wet season trapping goes in line with the statement. The wet season breeding behaviour of small mammals also will enble them to reach their trappable age of sub-adult and adult during the dry season (Mohammed Kasso and Afework Bekele, 2011). Within this period, many species show high reproductive activity (Happold, 2013).

More pregnant individuals of small mammals were recorded during the wet season than during the dry season. This is supported by previous investigations that explained that reproduction mostly is linked with the rainy season and with the availability of sufficient resources for rearing the young. Reproductive success and population dynamics of rodents are greatly influenced by variations in the rainfall patterns. Similar results indicated that, population size increases during the rainy season (Workneh Gebresilassie *et al*., 2006; Tadesse Habtamu and Afework Bekele, 2008; Sintayehu Workeneh *et al.*, 2011). It was suggested that seasonal variations in weather, particularly rainfall, influence the nutritional aspects, which affects the life strategies of rodents (Makundi *et al.*, 2006). Climatic factors, availability of food, adequate cover and minimum human interference might have contributed to the diversity of small mammals in the area. However, this is exceptional to moorland and agricultural land habitats which had more pregnant individuals during the dry season than the wet season. This might be due to the presence of nutritious food during the dry season, which was favoured by habitat specialist species.

Small mammals display fluctuation in terms of reproductive condition, age structure, distribution, occurrence and abundance across habitats (Getachew Bantihun and Afework Bekele, 2015). Fluctuations in small mammal populations can be attributed to changes in reproductive parameters, such as the proportion of reproductively active females among trapping seasons. The proportion of reproductively active females in the population of *L. flavopunctatus* was significantly different among trapping seasons. Pregnant females were more in number during the wet season than in the dry season. Makundi *et al.* (2006) reported that reproductively active *L. flavopunctatus* were present in the population almost throughout the year, but there was a seasonal peak during the wet season. Numerous studies have reported that reproductive characteristics of populations of small mammals was correlated with the rainy season (Afework and Leris, 1997).

In the present study, all age categories of small mammals were constituted through all trapping periods. Seasonally, there were variations in the age distribution in populations of most species. The capture frequency of adults outnumbered the other age categories. This might be due to the movement and faster trapability of adults than the other age groups. Smith *et al.* (1975) have noted that older animals frequently rank higher in social level and may be caught first and more often than other age groups. Comparatively, there were more young individuals during the wet season than the dry season. This may be due to the correlation between rainfall and seasonality in reproduction. This also is reflected by other investigators. For instance, Afework and Leirs (1997) and Makundi *et al.* (2006) have revealed the effect of rainfall on population dynamics. The observations made in the current study suggest that breeding of most of the small mammal species in the study area was during the wet season. According to Makundi *et al.* (2006), rainfall could indirectly influence reproductive success by affecting the supply of food.

Moorland habitat had highest abundance during the dry season whereas the *Erica* forest had highest abundance during the wet season. In both wet and dry seasons, plantation habitat had the lowest mean abundance and mean relative abundance. Agricultural land, grassland and moorland habitats harbour more small mammals during the dry season than the wet season. However, bushland, *Erica* forest, montane forest and plantation had higher abundance of small mammals during the wet season. There were no seasonal variations in mean abundance and relative mean abundance for *Erica* scrub habitat. However, the dry season forest fire and excessive grazing remove most of the cover and food of small animals (Mohammed Kasso and Afework Bekele, 2011). Such seasonal variation of abundance of small mammals in different habitats may be due to different reasons such as the drying of herbaceous vegetation that serves as food and cover contributing for the decrease in the number of individuals captured (Mohammed Kasso and Afework Bekele, 2011). Previous studies also noted that the abundance and habitat preference of rodents positively correlated with vegetation cover and heterogeneity, availability of food and water resources, and reproductive conditions of the species (Demeke Datiko *et al.*, 2008). Besides this some animals might be specialists on a particular vegetation type. These all make the number of trapped individuals to decrease during the dry season compared to the wet season. Mohammed Kasso and Afework Bekele (2010) also hypothesised vegetation cover, food and water sources, reproductive condition, migration and death due to burning of the *Erica* used as factors for such seasonal fluctuation of small mammals. Similarly, Tadesse Habtamu and Afework Bekele (2008) reported the movements of animals between refugia and affected habitats following seasonal changes in food supply and habitat conditions.

The number of sub-adults in each habitat is lower than adults in both wet and dry seasons except in the plantation habitat during both seasons. In each habitat, the numbers of sub-adult does not show much variation. Proportionally, more reproductively active individuals were captured during the wet than dry seasons. However, there was slight seasonal variation on the number of sub adults. Older animals frequently rank higher in social structure and may be caught first and more often than young individuals. Reproductive males were captured at higher rate during the breeding time (Smith *et al.*, 1975).

The proportion of reproductively active mammals during the wet season was higher than the dry season. With the exception of scrotal males, there was no record of reproductively active females during both seasons in agricultural land. Relatively more reproductively active females of small mammals were recorded from bushland. Comparatively more reproductively active males were recorded in both seasons than reproductively active females. Not all small mammal species show a discrete breeding season. However, most of the pest rodents seem to stop breeding during periods of extended fallow, when food is scarce or of low quality (Mohammed Kasso *et al.*, 2010). Thus food limitation can be considered as one constraint for the reproductive success of small mammals. Moorland habitat had more reproductively active small mammals during the dry than the wet seasons. Besides rainfall, which determines the influences the dietary requirements of small mammals, change in quality and quantity, increases during the wet season. Such variations certainly determine the peak period of pregnancy and survival of the small mammal species (Mohammed Kasso and Afework Bekele, 2011).

Relatively more female sub-adults were recorded for *S. griseicauda* and males for *L. brevicaudus* during the dry season. Reproductively active females were not recorded during both seasons for *A. abyssinicus*, *C. fumosa*, *C. glassi*, *C. lucina*, *Dendromus* sp.1, *D. lovati*, *L. melanonyx*, *M. imberbis* and *M. mahomet*. The absence of reproductively active individuals during a given season clearly indicates that the reproduction of these species is seasonal. However, Serekebirhan Takele *et al.* (2011) and Mohammed Kasso and Afework Bekele (2011) have noted that there is a continuous breeding throughout the year for some species of rodents. Hence, in the current study the absence of reproductively active individuals is probably linked to their seasonality in reproduction or due to chance in sampling the reproductive active individuals.

Fire was used for hunting, to drive game, heating, cooking lighting and to improve pasture (Kelly *et al.*, 2012). At present, also fire is used as a traditional land management practice in different parts of the word including Ethiopia. Large amount of African vegetation is managed by fire mainly during the dry season from November to April in Africa from Senegal to Ethiopia (Kamiya e*t al.*, 2013). Whether it is natural or human induced fire is widespread and the occurrence depends on vegetation type and state, climatic and meteorological conditions and land use (Kamiya e*t al.*, 2013). Human induced fires are mostly related to land use and management issues. It causes significant impact when combined with other ecosystem disturbance factors like grazing.

Fire is a natural process that shapes the structure and function of ecosystems across the globe (Bagne and Finch, 2010). It is a major driver of ecosystem structure and function worldwide. It is also widely used as a management tool to achieve conservation goals. It could be beneficial or disadvantageous at local and landscape levels depending upon its magnitude and extent. The magnitude of fire is determined by the type of fire, season of the fire, timing and duration of fire, and meteorology and weather conditions and fuel load and soil moisture (Kelly *et al.*, 2012). The study made by Andersen *et al.* (2012) in the Australian savannah indicated a decline of the diversity of many small mammal species that are sensitive to frequent fire. As a result, many species have shown a dramatic population decline over recent decades although the causes are poorly understood. The most important impact of fire on small mammals is indirect through changes in habitat, resource availability and predation risk, rather than through direct mortality (Andersen *et al.*, 2012). The direct impact of fire on vegetation are through plant and seed death or indirectly through subsequent increase in soil temperature and decrease in soil moisture content. In Ethiopia, fire incidence and occurrence have increasingly become rampant (Tadesse Habtamu and Afework Bekele, 2008). A scientific investigation on fire ecology in the country has not been extensive and as a result, its influence on fauna and flora is poorly understood. The reasons behind are mainly technical problems and ecological knowledge gaps in characterizing fire regimes, lack of institutional and infrastructural facilities to regulate and control and due to lack of fire policy at national and local levels. The most reliable information on the ecological effects of fire is obtained from controlled field experiments.

The Arsi Mountains particularly Chilalo-Galama Mountains Range hosts several endemic species of flora and fauna some of which are threatened with extinction.

The regeneration and recovery of *Erica* and other vegetation post *Erica* fire showed significant variation from place to place. This variation is influenced by soil fertility, moisture, temperature and fire intensity and severity. In places with good soil fertility, moisture, relatively high temperature and with weak intense fire, the *Erica* and other vegetations regenerate faster. Grass and other herbaceous vegetation grow much earlier than *Erica* shooting. In the current study, in most places where *Erica* fire occurred in old and mature are intensity and the severity of the fire was high. It affects the *Erica* regeneration resulting into open space or gaps due to death of some *Erica* bundle. Except with some herbs and sparsely sprouting grasses, there was no *Erica* regeneration in habitats of less than a month burn since time of *Erica* fire and even up to one year in areas with thin soil and moisture and temperature stress and dominated by bare land. Contrary to this, Gutema Jira *et al.* (2013) stated that six months time since *Erica* fire habitat did not show any *Erica* recovery because of the effect of fire. However, the *Erica* sprouting and growth of grasses and herbs during one and above a year since the time *Erica* fire in line with the present study. In two year the since time of *Erica* fire showed good levels of recovery with shrubs, herbs and grasses and reached a height more than a meter within three to four years since the time of *Erica* fire under good soil, moisture and temperature condition. In five years time, *Erica* habitat showed a significant recovery in canopy cover compared to unburned *Erica* habitat. Six years time *Erica* habitat had better recovered vegetation comparable to the old and matured habitat that was not brunt for long time. The *Erica* recovery condition in Chilalo-Galama Mountains Range was almost similar to the recovery condition with nearby Bale Mountains (Gutema Jira *et al.*, 2013). Mohammed Kasso and Afework Bekele (2011) reported that *Erica* fire had a long effect on small mammals. In addition, the decline of individuals trapped might be due to the drying of herbaceous vegetation that serves as food and cover (Mohammed Kasso and Afework Bekele, 2011; Gutema Jira *et al.*, 2013) and also due to direct death by fire. Fire affects shelter sites, such as hollow logs and dense tussocks of grass. Extensive fire, excessive grazing effects and absence of surface water during the dry season are the most important threats for the survival of small mammals (Tadesse Habtamu and Afework Bekele, 2008).

The record of some species in relatively recently burnt *Erica* shows their overall resilience to fire and suggests that they are secure under all but the most extreme fire regimes. However, it is clear that more fire-sensitive groups such as small mammals need special fire management attention. This needs to involve less frequent and finer-scale burning, along with the protection of some large, infrequently burnt source areas. Many previous studies also showed the abundance and habitat preference of rodents are positively correlated with vegetation cover and heterogeneity, availability of food and water resources, and reproductive conditions of the species (Afework Bekele *et al.*, 2003; Demeke Datiko *et al.*, 2007). The vegetation structure and cover affect the microclimate and protect small mammals against predators (Demeke Datiko and Afework Bekele, 2014).

Information on the effects of fire on small mammals is immense. Its effects have been shown in lowering the species diversity, in the destruction of vast areas of their habitat and food, changing their behaviour and leading to population fluctuation (Clausnitzer, 2003). The data on capture per trap night in the current study revealed variations among the habitat categories since time of *Erica* fire. The highest capture per trap night was recorded for categories of time since *Erica* fire above six years. From these observations, a matured *Erica* has a closed canopy with many mosses, ferns and lichens and the open understory was mostly covered with different shrubs, herbs and grasses. Such habitats become the home for many species of small mammals to their level of climax succession. Previously Mohammed Kasso and Afework Bekele (2011) also concluded that number and abundance of small mammals increased with the age of post *Erica* fire. However, Gutema Jira *et al.* (2013) from Bale Mountains National Park hypothesised the intermediate community succession by stating high species diversity and abundance recorded from the intermediate succession stages of post *Erica* fire. In the present study, there was no capture from *Erica* habitat in *Erica* fire less than a month and capture rate was least for *Erica* habitat time since *Erica* fire of six month. Similar to the present result, Mohammed Kasso and Afework Bekele (2011) reported the absence of record of small mammals from recently burnt *Erica* from Mount Chilalo. There was also no small mammls from habitats up to one-year time since *Erica* fire from Bale Mountains National Park (Gutema Jira *et al.*, 2013). This demonstrates the impacts of *Erica* fire on small mammals are severe. This is mainly due to direct mortality by fire, change in vegetation composition and structure affecting shelter and food as well as availability of water in the habitat (Clausnitzer, 2003).

The capture per trap night variations among habitats and grids of different categories since time of *Erica* fire clearly indicated the extent of impact of *Erica* fire on small mammals and extent of their resilience to it. In most grids, there were few small mammals captured from grids less than six months of post *Erica* fire. Fire results in to mortality, and emigration of rodents to nearby habitats. Post-fire emigration of small mammals attributed to lack of vegetation for food and shelter (Clausnitzer and Kitty, 2000). Nevertheless, some grids of the recently burnt *Erica* harboured small mammals particularly in places where there was patches of unburnt *Erica* close to it. This remnant unburnt of *Erica* patch serves as stock for small mammals to recollonize the regenerated *Erica* and other vegetation post fire. This shows that habitat quality is important to sustain rodent populations in their natural habitat. Similarly, Clausnitzer (2003) also reported increase growth of annual and perennial forbs in burned habitats to attract high diversity of small mammals. In the present study, grasses of scrub vegetation such as *Helichrysum* and *Alchemilla* regenerated in good condition after *Erica* fire provided shelter and food for small mammals. The maintenance of ‘fire mosaics’ comprising spatially heterogeneous patches of differing fire history enhances the conservation of fauna even though there is unclear properties of fire mosaics that enhance efficient conservation efforts (Kelly *et al.*, 2012) .

The species richness is relatively highest for *Erica* above six years old since *Erica* fire. In contrast Gutema Jira *et al.* (2013) recorded least abundance and density of small mammals from unburned *Erica* vegetation. There was no record of any species of small mammals for *Erica* fire of less than a month. The absence of record from the recently burnt *Erica* habitat might be related to the direct effect on food resources particularly seeds, stems and leaves of grasses and forbs, a critical resource for many rodent species. Changed fire regimes may also force longer-term changes in grass species composition, and therefore the availability of preferred seeds (Andersen *et al.*, 2012).

A total of 18 species of small mammals was recorded from all categories of time since *Erica* fire in the current study area. Out of the 18 species recorded, 15 were endemics to the country of which some are local endemics to the Eastern plateau of Ethiopia (Yalden *et al.*, 1992; Mohammed Kasso *et al.*, 2011; Afework Bekele and Yalden, 2013). This high endemicity of the small mammals shows the existing challenges for which *Erica* fire requires urgent intervention and conservation action. The number of the recorded species was higher than the number of small mammals previously recorded from the same habitat from Arsi Mountains by Mohammed Kasso *et al.* (2010), Mohammed Kasso and Afework Bekele (2011), Zerihun Girma *et al.* (2012) and by Gutema Jira *et al.* (2013) from Bale Mountains National Park. Overall, the distribution and occurrences of the small mammals listed in the current study area agree with the previous finding in similar habitats.

Nearly 26% of the world human population has inhabited mountains. It is among the most fragile environments in the world and is also home to a wealth of biodiversity, water and other ecosystem services. Of these, the East African Mountains, which include Ethiopia, are among the most biologically diverse regions in the world. Chilalo-Galama Mountains Range similar to the Bale Mountains National Park is comparatively less occupied by human settlement and for agriculture in its summit although all the entire Mountains is used for grazing of livestock unlike the northern Ethiopia Mountains (Yoseph Assefa *et al.*, 2011). The patterns of diversity are often associated with elevation gradients in many parts of the world. Range size and position along the gradient reflect the influence of environmental conditions on species survival and reproduction (Novillo and Ojeda, 2012). Moreover, as noted by Mohammed Kasso *et al.*

(2010) different factors like precipitation, temperature and other resources contribute to the variation in distribution and abundance of fauna and flora along with altitudinal zonation. Shanker (2001) also elaborated the distribution of small mammals was determined by the habitat complexity resulting from altitudinal gradients. Besides altitudinal zonation variations, the availability and quality of food, shelter and rainfall also determine the distribution of small mammals (Demeke Datiko and Afework Bekele, 2014).

In the current study, the distribution and abundance of small mammals showed significant variations along altitudinal gradients. The majority of rodents and shrews were captured from altitudinal zonation band of 3301-3600 m asl followed by 3601-3900 and above 3900 m asl whereas the least number of capture was recorded from the altitudinal zonation of 2701-3000 m asl. However, when the mean capture of small mammals was considered, there is slight difference in abundance of small mammals along altitudinal zonation bands. The altitudinal zonation band above 3900 m asl had highest mean capture followed by altitudinal zonation band of 3301-3600 m asl whereas the least mean capture was from the altitudinal zonation of 3001-3300 m asl. The difference in abundance of small mammals along the band of altitude zonation is mainly determined by the habitat complexity and disturbance (Demeke Datiko and Afework Bekele, 2014). In particular, the least number of captures from lower altitudinal zonation is due to the disturbance and habitat degradation. The habitat complexity along altitudinal gradient in turn influences the other factors for overall distribution and abundance of small mammals like food availability, shelter and cover from predators. Interestingly, the result contradicts the report from a study conducted in western Rwenzori, which showed that number, and abundance of rodent species decreased with increasing altitude (Demeke Datiko and Afework Bekele, 2014). Furthermore a study conducted by Clausnitzer and Kityo (2001) on Mount Elgon also showed that species richness depended upon habitat complexity, rather than altitude alone.

As expected, there were also differences in the overall small mammal species richness along altitudinal zonation. Overall small mammals diversity showed bell shaped pattern with altitude. The species richness gets its peak at altitudinal zonation band of 3301-3600 then declines in both directions. The lowest species richness was recorded for altitudinal zonation band of

2400-2700 m asl due to the impact of human disturbance and habitat degradation in the lower part of altitudinal zonation. Our results showed a positive and monotonic relationship between small mammal mean abundance along altitudinal zonation, whereas species richness patterns showed a mid-elevation peak. The species richness pattern along the altitudinal zonation portrayed a hump-shaped pattern when the total species richness was plotted against elevation gradient. A similar hump-shaped richness pattern along the elevation domain substantiates previous results involving small mammal richness patterns along different altitudinal gradients (Heaney, 2001; McCain, 2005; Novillo and Ojeda, 2012). The decline of species richness at higher altitudes is attributed to harsh climatic conditions, less vegetation composition and structures based on their ecological and historical processes (Yoseph Assefa *et al.*, 2011). In general, the overall species richness along the altitudinal zonation shows the highest richness in the centre of the altitudinal zonation. However, the trend of mean abundance of small mammals along altitudinal zonation shows irregularity. The peak of mean abundance was recorded for altitudinal zonation above 3900 m asl and the lowest was for 3001-3300 m asl. The area hypothesis proposes that regions with largest area will have more species than smaller ones (Novillo and Ojeda, 2012). Along elevational gradients, area influences richness patterns in diverse manners (McCain, 2009). Previous studies regarding small mammal diversity at smaller scales along the Andes, such as the Puna and Atacama Desert, have found a positive relationship between elevation, area and species richness (Novillo and Ojeda, 2012). This conforms to an earlier study in which it was noted that the structure and species richness of small mammal community were related to variables such as habitat structure and complexity, rainfall, productivity, predation, trampling and nature of surrounding geographical extent of the habitat (Demeke Datiko and Afework Bekele, 2014).

The most general finding of these case studies is the peak in species richness at intermediate elevations and it seemingly declines continuously with increasing elevation (Brown, 2001). This can be explained in three general cases: one case occurs when species have specialized but partially overlapping requirements so that their ranges overlap somewhat but tend to be restricted to different parts of the gradient. The second case occurs when the species show nested subset pattern of requirements and ranges. If the overlap is such that all occur at the centre of the gradient but they vary in how far they range toward the extremes. The result is again a peak in species richness at some intermediate position. The third case occurs when there is also a nested subset pattern of requirements and ranges, but the overlap occurs at one extreme of the environmental gradient, resulting in a continuous change in diversity with elevation (Brown, 2001).

In the current study, the distribution of species of small mammals showed variation along different altitudinal zonations. Some species exclusively inhabited the lower altitude range of the bushland, montane forest, shrubland and agricultural habitats. Others occurred along the montane forest and dense *Erica* forest and then replaced by other Afroalpine habitat specialists like *S. griseicauda*, *S. albocaudata*, *A. blicki* and *L. Melanonyx*. This is because many small mammals are adapted to living in different habitats with different characteristics. For example, Afroalpine habitats (altitudinal range above 3,400 m asl.) are characterized by short, sparse vegetation, heavy frosts and low rainfall (Sillero-Zubiri *et al.*, 1995). The ericaceous belt that encircles the Afroalpine belt above the tree line at altitude ranging from 3,400-3,800 m asl is characterized with a uniform *Erica* scrub (Sillero-Zubiri *et al.*, 1995). Thus, these habitat differences created by the altitude zonation affect the distribution and habitat preference of small mammals. The two Ethiopian endemic species, *S. albocaudata* and *S. griseicauda* overlap in habitats above 3,000 m asl, even though they appeared to be separated by habitat and certainly differed in their altitudinal preference. *Stenocephalemys griseicauda* is numerous at lower altitudes (2,400- 3,300 m asl) apparently in bushy areas, whereas *S. albocaudata* was most abundant at higher altitudes in the rocky grassland (Sillero-Zubiri *et al.*, 1995; Mohammed Kasso *et al.*, 2010). The result of the present study agrees with species distribution reports from different highlands of Ethiopia (Yalden and Largen, 1992; Sillero-Zubiri, *et al.*, 1995; Lavrenchenko *et al.*, 1998b; Mohammed Kasso *et al.*, 2010; Zerihun Girma *et al.*, 2012).

The most abundant species along altitudinal zonation band of 2400-2700 m asl was *S. albipes* followed by *S. griseicauda*. The relic forests and alpine plateaux of Ethiopia are real centres of diversification and endemism for the genus *Lophuromys.* Three endemic species, *L. chrysopus*, *L. brevicaudus* and *L. melanonyx* replace each other in the different altitudinal belts each time with a small overlap suggesting an adaptive pattern of speciation (Lavrenchenko *et al.*, 1998a).

The relative habitat association of rodents and insectivores showed variation across habitat types in both total catch and number of species. The study of Demeke Datiko and Afework Bekele (2014) also confirmed that population size of small mammals fluctuates greatly as a result of change in quality and quantity of resources in an environment beside the altitudinal zonation. The small mammal species composition and distribution along altitudinal distribution were similar with previous reports from different highlands of the country (Mohammed Kasso *et al.*, 2010; Gutema Jira *et al.*, 2013). Climate conditions, especially temperature, are thought to be the most important factors shaping range limits of plants along elevational gradients (Halbritter *et al.*, 2013).

The diversity indices of small mammals also varied along the altitudinal zonation. For instance, all the diversity indices except evenness were high at altitudinal zonation band of 3301-3600 m asl whereas 2400-2700 m asl had lowest diversity indices with the exception of evenness index. In addition, the highest Chao-1 species estimation indicates high potential for the existence of more rare species. This might be attributed to the presence of several microhabitats such as habitat cover and diverse resources. The lower diversity in lower altitudinal zonation band might have resulted from more anthropogenic impacts on its habitat and sampling of relatively few grids. In addition, the sparse ground vegetation under the forest may expose the animals to predation (Demeke Datiko and Afework Bekele, 2014). The second highly diverse altitudinal zonation was 3600- 3900 m asl. However, climate change scenario has driven scientific interest in mountain ecosystems in relation to shifts in species geographic ranges along environmental gradients, particularly as a threat to endemic species with narrow geographic ranges (Novillo and Ojeda, 2012).

Land use practices play a great role in affecting structure and function of the ecosystem. For instance, forest practices and agriculture are a tool that can dramatically alter habitat structure and ecological succession. It can cause profound impact on wildlife and their habitats. Small mammals may play an integral role in natural habitat as prey, benefitting mammalian and avian predators. Thus, the different landuse practices cause a cascading ecosystem-level effect on small mammals and other biodiversity. They are an ideal subject for examination of the response of animal communities to land use practices. They are also ubiquitous and sufficiently fecund to be a useful tool for scientific investigations across landscapes responding quickly to disturbances in a particular well developed habitat (Getachew Bantihun and Afework Bekele, 2015).

In the current study, substantial variation in abundance of small mammals was detected in different modified habitats and grids compared to its nearby natural habitats and grids. The abundance of small mammals in plantation habitats was much lower than the nearby natural montane forest and *Erica* forest habitat, although the modified plantation habitat had more species. Relatively, the abundance of small mammals in older plantation was lower than the nearby *Erica* scrub habitat. Coverage of ground, coarse woody debris, and downed trees are critical factors for the small mammal species. Changes in vegetation cover may expose small mammals during foraging and increase their predation risk. The resulting predator avoidance behaviour may force small mammals to alter their feeding, activity ranges and thus distribution (Puan *et al.*, 2011). However, such conditions are not common in plantations in the current study area. On the other hand grids with *Eucalyptus* plantation and sparsely planted with open canopy and ground vegetation coverage seem to attract more small mammals. The diversity of species, capture probability, and population size vary with vegetation types. Small mammals are mobile to disperse to suitable sites and leave unsuitable sites (Getachew Bantihun and Afework Bekele, 2015). Habitat has a very strong influence on small mammal community structure (Happold, 2013). In plantations, regular control of ground cover may influence small mammals feeding behaviour, activity ranges and distribution and foraging because they must avoid predators in open habitats (Puan *et al.*, 2011). The occurrence of such variations implies the difference in the levels of resources, levels of exploitation of these resources by small mammals and the numbers and diversity of predators in each habitat (Happold, 2013). It is clear that the highest proportions are found at higher altitudes in forest and forest scrub, although in heathland, at the highest elevations, the proportion begins to decline. The lowest occurrence of *M. albipes* recorded in this survey is in forest at 1800 m, although the species can be found in scrub at higher elevations (Afework Bekele and Corti, 1997).

The abundance of small mammals in agricultural land habitat was relatively higher when compared with other grids of plantation habitat. Furthermore, the highest species richness was recorded for the modified habitat in agricultural land. Several studies have shown that changes in habitats associated with agricultural practices alter small mammal assemblages (Puan *et al.*, 2011). Land management is one of the most important factors threatening mammal species (Meinig and Boye, 2009). Natural forest diversity is significantly reduced by common management practices like the exclusion of clear cutting, natural fires and cattle grazing. Even in a developed country like Germany, agriculture is considered to cause strong negative impact on wildlife (Meinig and Boye, 2009). The high altitude residents of Chilalo-Galama Mountains Ranges traditional livelihood system was based on livestock herding and beekeeping. However, currently the increase in population made them to change their livelihoods dominantly on crop cultivation than livestock rearing. The population increase around Chilalo-Galama Mountains range creates more pressure on the natural resources and the landscape. Residents use the land for crop cultivation, grazing and settlement even under insecure land use rights. In this process, many forest land and grazing land have been converted to agricultural land due to lack of effective land administration and land management systems. These agricultural land habitats attract many pest rodents and other small mammals that are able to survive in human modified habitats.

The similarity cluster for modified habitats and nearby semi-natural habitat based on abundance clearly shows that plantation habitat with heterogeneous type of vegetation harbour more species richness of small mammals. In the same way, the semi- natural montane forest habitats and both the *Erica* habitats showed high similarity. Many studies have suggested that reductions in vegetation cover or complexity affects small mammal assemblage (Torre *et al.*, 2007).

In the current study, the majority of small mammals were captured during the night. Except in few occasions, all shrews were captured during the night. Most rodents are nocturnal, but some are diurnal and a few are crepuscular or cathemeral (Macdonald, 1984). The activity patterns are affected by weather condition (Mohammed Kasso and Afework Bekele, 2011). They increase their activity pattern on warm, cloudy night and much enhanced if it is accompanied by rainfall (Smith *et al.*, 1975). The effect of weather on the abundance and capture rate of small mammals is difficult to ascertain due to its complex interaction with rainfall, humidity, temperature, moonlight, pressure, sex, age habitat and species (Macdonald, 1984). Out of the species recorded in the current study *L. brevicaudus*, *A. blicki* and *L. melanonyx* were dominantly captured during the day whereas *S. griseicauda*, *S. albipes*, *S. albocaudata* and *M. mahomet* were dominantly captured during the night time. Some species like *L. chrysopus* and *O. helleri* and *C. glassi* were active during the day and night time. Even though both *M. imberbis* and *D. nikolausi* were captured during the night trapping session only a few individuals wer captured and therefore is unclear. Many Afroalpine small mammals show diurnal behaviour due to harsh temperature condition during the night. *Stenocephalemys albocaudata* resists cold temperature due to its large size, slow metabolic rate and dense pelage (Sillero-Zubiri *et al.,* 1995; Mohammed Kasso *et al.*, 2010; Meheretu Yonas *et al.*, 2014).

The population estimation showed seasonal variation among habitats. Agricultural land, bushland, plantation and montane forest had the highest population estimats during both dry and wet seasons. Similar to present results, Mohammed Kasso and Afework Bekele (2011) also reported non-seasonal variation with the exception of montane and *Erica* forest habitats. The population decline in montane forest habitat is due to the drying of herbaceous vegetation that serves as food and cover (Mohammed Kasso *et al.*, 2010). Previous studies noted that abundance and habitat preference are correlated with vegetation cover and heterogeneity, availability of food and water resources and reproductive condition of the species (Afework Bekele *et al.*, 2003). In *Erica* forest, the population estimation was highest for *S. albipes* but during the dry season the highest was *L. brevicaudus*. In *Erica* scrub *L. brevicaudus* was dominant during both seasons. For a moorland habitat *A. blicki* had the highest population estimation during the dry and wet seasons. Species that occupy relatively constant and predictable environments throughout the year experience only small population fluctuations whereas those in environments that are less predictable and have large seasonal variations in climate and resources exhibit larger fluctuations (Happold, 2013).

Over all the maximum total mean population estimation was estimated for moorland habitat and *Erica* forest during the dry season.

Estimation of density of small mammals is based on the number of captured and the size of the area. Such estimation usually results in an overestimate of density because the sampling area is larger than the grid (Smith *et al.*, 1975). The mean density of small mammals observed in the current study is within the ranges reported by Happold (1974) in western Nigeria. However, density obtained during the present study was higher when compared to other studies in Africa. Likewise, the study conducted in Mount Chilalo by Mohammed Kasso and Afework Bekele (2011) recorded low density in open area with short grass habitats. The availability of cover and feeding behaviour in the forest, shrub and scrub or dense vegetation contributed to high abundance of small mammals (Sintayehu Workeneh *et al.*, 2011).

The total biomass recorded from all intensive study grids was 199,169 g/ha. The total biomass of small mammals measured from the current study is comparable with the reports of previous studies (Sintayehu Workeneh *et al.*, 2011). For instance, Mohammed Kasso and Afework Bekele (2011) recorded comparatively high biomass during the wet than the dry seasons and the maximum biomass was recorded from the grassland habitat. The total biomass obtained in the present study is more or less comparable with the total biomass obtained in different parts of Ethiopia. The relatively lower biomass is also due to lower biomass of shrews that were excluded in other studies. There was slight seasonal biomass variation in which the maximum was recorded during the dry season. The highest total biomass was contributed by *S. greiseicauda* during both seasons. Small mammal biomass recorded from different habitat types during the present study showed great range. This variation may be due to the difference in food and water supply (Happold, 1974), as body weight of small mammals decrease during the dry season. Mohammed Kasso and Afework Bekele (2011) also reported similar results. This might be related to shortage of food and water, both in quality and quantity during the dry season than during the wet season. This increase in the biomass corresponds to the growth and development of the more young born during the wet season (Sintayehu Workeneh *et al.*, 2011).

From all the rodents and shrews, *T. splendens* has the largest mean body weight and body length while the smallest body weight was measured for *C. fumosa* and body length for *M. mahomet*. Although slight variation was reported among the individuals of small mammal species, their morphometric result lies within the range of features of their respective species described by Yalden (1976), Kingdon (1997; 2004; 2013), Afework Bekele and Yalden (2013), Happold (2013) and Happold and Happold (2013).

The average number of young per litter is an important determinant of the potential rate of population increase (Aplin *et al.*, 2003). This is usually estimated from the number of embryos present in pregnant females or from counts of recent scars in recent post-natal females. Because some mortality occurs at all stages of pregnancy including birth, these counts are likely to slightly overestimate actual litter sizes (Aplin *et al.*, 2003). The largest mean embryo count was recorded for *M. natalensis* embryo and the least was for *S. albipes*. About 37% of rodents and shrews have left horned embryo. The embryo number of two accounts for 25% of single embryo on right horn accounts for 17.5% of small mammals. Mohammed Kasso and Afework Bekele (2011) recorded comparable number of embryos among pregnant females that varied between species and seasons. There was also positional difference in embryo implantation as obtained by Mohammed Kasso and Afework Bekele (2011). The maximum number of embryo counted for *M. natalensis* was 15 during the wet season from bushland habitats. The high number of records of embryo during the wet season compared to the dry season might be associated with the availability of food and cover (Mohammed Kasso and Afework Bekele, 2011). The number of dissected embryos observed varied from species to species and season to season. A higher embryo count was during the wet season than the dry season. The embryo count of *M. natalensis* showed fluctuation, even though for both species, the highest record was during the wet season. Seasonal fluctuation of embryos may be related to availability of food. Similarly, Afework Bekele and Leris (1997) described that litter size varied among species of rodents and seasons.

Agricultural land has the largest mean abundance for *T. splendens* abundance although *Erica* scrub habitat had high gross abundance followed by grassland habitat whereas the mean abundance was least in plantation habitats. The burrow construction of subterranean animal influences the distribution and their habitat preference. Most subterranean rodents tend to live in porous soils or at least in well-drained soils of poor water holding capacity (Jarvis and Sale, 1971). Under favourable soil conditions, the absence of suitable vegetation precludes occupation by subterranean rodents. That means, appropriate plant species must be available to support the animals. Thus, the local distribution of any subterranean rodent is influenced by topography, soil and vegetation characteristics of the habitat (Jarvis and Sale, 1971). The distribution pattern of *Tachyoryctes splendens* is discontinuous ranging from Ethiopia and parts of Somalia as far as Eastern Zaire, Burundi and Northern Tanzania. They seldom occur in areas with less than 500 mm rainfall per annum, but better established in wet uplands (Kingdon, 1997).

The distribution of *T. splendens* and *H. cristata* along altitudinal zonation shows variations. The peak mean abundance of *T. splendens* was from altitudinal zonation band of 2400- 2700 m asl and the least was for altitudinal zonation band of 3601-3900 m asl. The altitudinal zonation above 3900 m asl had relatively high mean abundance for *T. splendens*. Their distribution pattern varies and fluctuates seasonally based upon altitude and vegetation cover as well as precipitation of climatic factors. It favours deep, well-drained, often-volcanic soils, high to moderate rainfall and vegetation cover of grass to open forests (Jarvis and Sale, 1971). It occurs over a considerable altitude reaching a height of over 4000 m asl. Since it is a ubiquitous feeder, its habitats provide grass roots, rhizomes, stems and leaves, herbs, shrub and tree roots, tubers, bulbs and corms (Jarvis and Sale, 1971). It is endemic to Africa in Afromontane and Afroalpine biotic zone and some adjacent areas. It is recorded from highland areas in Ethiopia. It occurs at altitudes above 1200 - 4000 m asl (Happold, 2013). It prefer deep well-drained soils in savannah, grasslands, open forests, Afroalpine regions, agricultural fields and gardens. Its abundance is patchy and disjunct, but may be very common in suitable localities. Densities can be very high in cultivated land (Happold, 2013).

Mean abundance of *H. cristata* seems to decrease along altitudinal zonation although its mean abundance was maximum in altitudinal zonation band of 2701-3000 m asl. *Hystrix cristata* were not recordedalong altitudinal zonation band above 3900 m asl. It is widely distributed in different biomes in Africa and in Afromontane and Afroalpine Biotic zones. In Ethiopia, it occurs from sea level to about 3550 m asl. It prefers different habitats like semi-desert, woodland and grassland savannas and farmlands where rocks and crevices are present (Yalden *et al.* 1976). Its existence is mostly uncertain and occurance is based on observations of discarded quills, faecal materials and nesting sites. In general, *T. splendens* and *H. cristata* occurrence and distribution in the current study area agrees with the previous study reported by Mohammed Kasso *et al.* (2010).

Ethiopia is home to a high mega- and microbat diversity, due to its special geographical position between the sub-Saharan region, East Africa and the Arabian Peninsula (Afework Bekele and Yalden, 2013). Still, there is great gap in number and type of species in Ethiopia as many areas were not surveyed. Until recently, there was also limited information on the diversity, distribution, and relative abundance of bats in Ethiopia. To date, 12 fruit bat species out of 95 bat species including five more ambiguous bats species were recorded for Ethiopia of which 5 of them are endemic to the country (Kaipf *et al.*, 2015). Still the number of new species records and range expansion is increasing from time to time (Yalden and Largen, 1992; Kruskop and Lavrenchenko, 2000, Lavrenchenko *et al.*, 2004; Lavrenchenko *et al.,* 2010; Kruskop and Lavrenchenko, 2006; Kaipf *et al.*, 2015; Kruskop *et al.*, 2016). Of the about 90 bat species recorded in Ethiopia, at least 13 were shown to occur around AMNP Based on the presentation of information on all known synonyms. The presently accepted taxa of African bat species belong to 13 families, 56 genera and 321 species excluding the extinct (ACR, 2016). Out of these, 11 (85%) families, 35(63%) genera and at least 90 (28%) species occur in Ethiopia (Yalden and Largen, 1992; Kruskop and Lavrenchenko, 2000; Lavrenchenko *et al.*, 2004; Lavrenchenko *et al.*, 2010, Kruskop and Lavrenchenko, 2006, Kaipf *et al.*, 2015; Kruskop *et al.*, 2016). Most parts of the country have high conservation value due to the high bat species diversity and a complex structure of the fauna including elements with various zoogeographic affinities (Kaipf *et al.*, 2015; Kruskop *et al.*, 2016).

The diversity of bats of Arsi Mountains is very patchy and scarce even though the study in the nearest Bale Mountains National Park indicated the existence of 10 species of bats (Addisu Asefa, 2011). More than this number was reported by Lavrenchenko *et al.* (2004). Recent studies by Kruskop *et al.* (2016) documented 21 bat species belonging to eight families and twelve genera from Alatish National Park. From Kafa Biosphere Reserve more than 29 different bat species were recorded in a short bat survey of which 6 new species were from Kafa Biosphere Reserve and one new to Ethiopia (Kaipf *et al.*, 2015). In both cases, the species list is supplemented by acoustic analysis but which was not carried out in the current study.

The information on bat fauna from Chilalo-Galama Mountains Range of AMNP was scant except unpublished reports by JERBE. Hence the current investigation was initiated as part of PhD dissertation work on diversity distribution and conservation of small mammals of Chilalo Galama Mountains, South Eastern Ethiopia. The current results on bat survey of Chilalo-Galama Mountains Range of AMNP can be as an used indication that the as area has high potential for bat diversity comparable to the different highlands of the country. In particular, the record of the endemic threatened *Plecotus balensis* for the first time from the area can be used as pinpoint bat conservation of the study area. Molecular approaches in evolutionary studies of the Chiroptera have detected a surprising number of cryptic species. Long-eared bats of the genus *Plecotus* are essentially restricted to the Palaearctic Region but extend to the Ethiopian and the Indomalayan Regions (Larsen *et al.*, 2007).

Mist netting is a common method used to capture bats even if several studies have found its capture data are biased by survey effort, type of net, the surrounding habitat, bat activity, weather, and the avoidance and echolocation abilities of bats (Larsen *et al.*, 2007). It is extremely difficult to determine the abundance of bats accurately. For most African species, there are no data. For others, it has only been possible to indicate comparative abundance, very roughly, from how often they are encountered and how well they are represented in collections. Even these estimations are of dubious value because bats are seldom encountered in countable numbers (except sometimes when their day-roosts are known) and, in most parts of Africa, methodical and comprehensive collecting and/ or recording of bats has not been carried out. Also, the fact that a species is well represented in collections does not necessarily mean that it is comparatively abundant – it might just be easier to collect for one or more of several reasons. Species that roost in large numbers in accessible caves, mines and buildings may be collected from their roosts much more easily than those that roost singly or in small groups in inconspicuous roosts (Happold and Happold, 2013).

Catching and/or detecting bats while they are flying around at night is very difficult and estimations of abundance based on these methods are unreliable (Happold and Happold, 2013). Although bats have been mist-netted and trapped close to the ground for some time, the setting of mist-nets and traps in and above the canopy is a recent and comparatively rare activity and, consequently, bats that fly in these environments are likely to be under-represented in collections (Happold and Happold, 2013). Furthermore, even the most sophisticated bat-traps and mist-nets only operate in a minute fraction of the space utilized by bats, and species that fly high (such as emballonurids, molossids and some vespertilionids) and species that are good at detecting and dodging mist-nets and traps (such as nycterids and *Kerivoula* spp.), are often poorly represented in surveys and collections (Happold and Happold, 2013). The data from mist netting may be used as an index of relative abundance for comparing yearly or seasonal changes in bat abundance if appropriate measures are taken to standardized (Perry *et al.*, 2012). The present netting success was 0.95 bats/net-night. It was more or less comparable to other studies conducted in different parts of the country (Kruskop and Lavrenchenko, 2000; Lavrenchenko *et al.*, 2010; Kruskop and Lavrenchenko, 2006; Kaipf *et al.*, 2015; Kruskop *et al.*, 2016). The highest capture rate was from Wolkessa River and Bridge and followed by Child Care compound whereas the lowest was from Koropta. Such variations in capture rate among the sampling sites might be affected by the variation among species to their differential agility, wing loading, mode and power of echolocation calls, characteristic foraging pattern, and the facultative use of their other senses including vision and olfaction (Larsen *et al.*, 2007). The detection and perception of the net by a bat are also greatly affected by habitat complexity and structure, frequency of precipitation, wind, and ambient light levels. Furthermore, the avoidance-learning behaviour in bats nights also contributes for such variation in trap success variation among the sampling sites. For instance, Larsen *et al.* (2007) revealed a 5.4% of bats in the airspace came into contact with the net giving an overall capture rate of 3.2% (range 0–10.3%). In the present study, only 62.5% of sampling sites were productive. The absence of bat capture from Bora Luku, Checho Plantation, Chilalo-Muda, Jawi Juniperus Forest, Jitu Tena and Chilalo-Summit was mostly due to foraging nature of the bat species in the area and type of mist net used for sampling. The majority (65.75%) of bat captures were recorded from four sites. These sites were: Child Care, Dankaka Juniperus forest, Gefersa Forest and Wolkessa River and Bridge. Even though not analyzed, the bat echolocation call detector used (i.e. Anabat II detectors; Titley Electronics, Balina, NSW, Australia) recorded echolocation calls. The acoustic detectors provide a useful tool for measuring species richness within and across large geographical areas and habitat types. It typically detects more species than active capture devices. It is also used to detect individuals over a greater area without the limitation of local resources that may be necessary when using capture devices (Flaquer *et al.*, 2007).

The average number of individuals of bats captured at each sampling site was 13.69 ± 4.08. These results are within the range of bat capture by mist netting report from different parts of Ethiopia (Lavrenchenko *et al.*, 2010; Kaipf *et al.*, 2015; Kruskop *et al.*, 2016). However, the number of listed species was low since unlike cases where species were identified from acoustics analysis (Kruskop and Lavrenchenko, 2000; Kaipf *et al.*, 2015; Kruskop *et al.*, 2016). Acoustic analysis enables bats to be studied in detail and is employed by most researchers in censuses of bat faunas and in the analysis of habitat use. It also seem to yield greater species richness than captures (Flaquer *et al.*, 2007). Acoustic sampling of bat communities can detect the presence of those species that routinely fly at great heights or are otherwise beyond the sampling capabilities of mist nets and harp traps. However, because echolocation characteristics are very similar among some species, identification of bats to species level may not always be possible with acoustic sampling (Flaquer *et al.*, 2007).

Out of the identified 13 species, *M. tricolor* and *P. hesperidus* were the most abundant whereas the least abundant species was *E. gambianus*. In addition, *K. lanosa* was also relatively rare species. All bat species are not easily captured, because of their behaviour, morphology, and/or flight patterns, and therefore most capture techniques are biased towards the more easily captured species. Indices of abundance are affected by true abundance, observer effect, environmental effects and aspects of animal behaviour such as catch ability (Perry *et al.*, 2012). Therefore, current estimate of relative abundance is affected by extraneous variables such as bat activity, weather, net location and net placement than their actual abundance in the area.

The present surveys indicate, as with many other tropical species, that there is a highly uneven distribution of species richness and also some are relatively rare species. The record of more species of bats from Child Care Compound sampling site is most likely due to the good remnant natural montane forest. Roosts and food are two resources that are vital to bats, suggesting that either could be used to advantage when assessing changes in habitats (Fenton *et al.*, 1994; Fenton, 1995). Gefersa Forest and Wolkessa River and Bridge seems to be relatively ideal habitats for bats. Although the habitat more or less seems good from Koropta, the single capture is most likely due to short trap night of sampling in the area. Bats depend highly on the suitable roost areas. They are absolutely defenceless, so they have to hide from predators in relatively secured and undisturbed habitat (Yavruyan *et al.*, 2010). Bat diversity and richness vary based on spatio-temporal scales, survey intensity, duration, detector or mist net orientation. The abundance and distribution of most bat species seem to be significantly influenced by the type of vegetation cover. The undisturbed continuous forest and fragments are important drivers of the bat community composition and species abundance.

Variation in the distribution of species among the sampling site was recorded from the present study area. The rareness in capture might have resulted from a bias in the trapping method or sample design, or a true reflection of local abundance. Some species may be more common in sub-habitats not represented like canopy, sub-canopy, streams, bamboo groves, or may be relatively adept at avoiding mist netting capture (Keith *et al.*, 2007). Other species like *Hipposideros* and *Rhinolophus* might be more common in roost sites than foraging sites (Keith *et al.*, 2007). In the present study, *M. tricolor* was the widely distributed species. It was captured from eight sampling sites followed by *H. caffer* and *N. capensis* that were recorded from six sampling sites. However, *N. nana*, *S. lanosus*, *K. lanosa* and *E. gambianus* were captured from single sampling sites. Species represented by single captures during the survey could be considered as rare but this could be misleading (Keith *et al.*, 2017). The flying distances to the foraging places also play a great role in their distribution. The distance vary depending on the species' flying abilities, location of the closest foraging places (usually, near water) and season (Yavruyan *et al.*, 2010). For example, horseshoe-nosed bats (*Rhinolophus*), long-eared bats (*Plecotus*), barbastelles (*Barbastella*), myotis (*Myotis*) and pipistrelles (*Pipistrellus*) hunt at the distance of 0.1-6 km from daytime roosts whereas *Eptesicus serotinus* and noctules (*Nyctalus*) fly for a longer distances 5-10 km; and *Miniopterus schreibersii* fly for 3 to 40 km (Yavruyan *et al.*, 2010).

Although relatively more males than females were captured, the differences were not statistically significant. Many bats are migratory and sex-biased migration may occur in some species. Their sex difference also depends on their tendency to migrate, distances travelled or geographic location (Kunz *et al.*, 2011; Happold and Happold, 2013). In addition, the sex based difference in capture can resulte from their roosting functionality. In nursery roosts, female bats with their young will dominate. In summer roosts, males and those non-reproductive females live separately. Such roosting functionality can contribute in capture ratio of age and sex. Only few studies have demonstrated geographic changes in abundance and sex ratios throughout a season.

In the curren study area, more adults than sub adults were captured. The strong association between long life span and slow reproductive rate of bats might also contribute for the adult age dominance in capture than sub-adults. In the current study the slow reproduction rate of bats might have contributed for the capture of most none reproductive male and female bats.

All the diversity indices except the evenness indicated Child Care compound was the most diverse sampling site. The use of degraded habitats also depends on the biological characteristics of the species and their use of existing resources. Bats can be less sensitive to the effects of fragmentation due to their capacity to fly, which allows their dispersal across long distances between fragments (ACR, 2016). The high difference in Shannon-Weiner's indices of Anku River and Bridge and Kombolcha River Bridge was most likely due to differences in the quality of surrounding habitat and roosting place. Biodiversity assessments and conservation guidelines based on short-term mist net surveys alone are not sufficient or reliable for bats. A pragmatic solution to reduce mist net bias is to repeatedly sample a target region, utilize a variety of netting sites, use variable net sets, and carefully analyze species accumulation curves (Larsen *et al.*, 2007). Species accumulation curves are used to standardize samples among sites, to predict the species richness of sites and to estimate the minimum effort required for adequate completeness of inventories (Merlin *et al.*, 2005). The whole species richness accumulation curve seems smoothed even though it did not maintain the asymptote. Out of all the sampling sites, the rarefied species accumulation curve shown in Kombolcha Stream, Asella 07 and Child care Compound relatively achieved the asymptote. Species accumulation curves are important to extrapolate species richness to investigate how the alpha diversity of habitats or sites compare with the gamma diversity of a wider area. Several authors have proposed that species richness increases with increasing food diversity and habitat diversity. In our study area, species richness was probably related to the diversity of both food resources and habitat types. The embryo count was single except for *M. tricolor*. This is in agreement with the general reproductive characteristics of bats (Happold and Happold, 2013).

For many species, cytogenetic methods represent the most economical and efficient means of initially recognizing inter-population genetic variation (Zima, 2000). The process of evolution often produces changes in the shape, number, or size of the chromosomes (Primus *et al.*, 2006). The major elements considered in the description of karyotypes are chromosome number, shape, and size. Every species of plant and animal has a specific number of chromosomes. Hence, its morphology and number can be used for species identification, for the construction of phylogenies and for diagnose is diseases and abnormalities associated with chromosomal aberrations (Tolliver and Robbins, 1991; Zima, 2000). The cytological information is used for karyotypic evolution, cytotaxonomy and phylogenetic relationships. Its contribution is high in breeding, systematic, phylogenetic and evolutionary studies and conservation programmes (Zima, 2000; Bickmore, 2001).

The occurrence of cryptic species makes the classical morphological approach inadequate to determine the entire small mammals' diversity in many geographical areas (Castiglia *et al.*, 2006). Comparison of karyotypes can provide valuable insight into relationships among species (Primus *et al.*, 2006). The morphology of chromosomes is a reliable feature for evolutionary study since it evolves slowly than other anatomical features that depend on environmental changes (Baker and Bradley, 2006). Its study provides valuable insights into taxonomic relationships and furnishes distinctive evidence on the phylogeny of extant taxa (Zima, 2000) and reveal the biological diversity of small mammals in different part of the world. In the process, many cryptic species of small mammals that possess unique karyotypes are discovered. Even in the times of advanced molecular methods, conventional karyotyping is often a simple and indispensable method for the identification of various taxa (Zima, 2000). The analysis of chromosome numbers represents an important approach in the studies of genetic variation, phylogeny, taxonomy and evolution. It is also important in studies on the structure and diversity of genomes.

The occurrence of several new sibling or cryptic species has been recorded from different parts of Ethiopia (Lavrenchenko *et al.,* 1998b; Fadda *et al.,* 2001; Corti *et al.,* 2005) resulting from speciation processes leading to an increment in genetic diversity linked with little morphological variation (Fadda *et al.*, 2001). However, habitat destruction and fragmentation causes losses to such unique genetic diversity. For many small mammals of Ethiopia, the chromosomal and molecular methods beside the classical morphological methods have not been used to clarify the systematics of controversial groups and even to describe new species (Lavrenchenko *et al.*, 1998b; Bulatova and Lavrenchenko, 2005; Corti *et al.*, 2005). The karyotypic data reported from Ethiopia clearly indicated certain expectations regarding the chromosome features of populations of the most abundant rodents like *Arvicanthis, Mastomys, Myomys*, however, the results were not simply predictable for *Stenocephalemys, Lophuromys, Otomys, Tachyoryctes and Mus* (Bulatova and Lavrenchenko, 2005). Karyotypic study from multiple individuals from different localities for species that exhibit karyotypic variation within and among populations is very important for the assessment of genetic diversity and their conservation (Primus *et al.*, 2006). Its descriptions also constitute the primary tool for small mammal species identification (Fadda *et al.*, 2001; Corti *et al.*, 2005). Although there was some effort for characterizing of chromosomal variation in small mammals from Ethiopia, the karyotypes of many small mammals of Chilalo-Galama Mountains Range (Arsi Mountains) remain unknown. In particular, when compared with efforts made in karyotyping small mammals from the nearby mountains of Bale, it was negligible. In the current study, the karyotype of representative specimens of the seven selected species from different sites of Chilalo-Galama Mountains Range revealed diversity in chromosome number and morphology.

The karyotype of *Lophuromys melanonyx* from Chilalo-Galama Mountains Range of Arsi Mountains was characterized by diploid number of chromosomes 2n=60 and autosomal foundamental number, FNa= 86. However, Lavrenchenko *et al.* (1997) reported FNa of 90 even though similar number of chromosomes was reported from its nearby Bale Mountains. Regarding the FNa comparisons, one more correction has to be made as it may be influenced based on the quality of field chromosome preparations and bias in recognising the arms in members of the smallest pair (Lavrenchenko *et al.*, 2014). A decrease in diploid or fundamental numbers by Robertsonian fusions would be important as an initial event in phyletic divergence.

A rearrangement in one chromosome also could affect nuclear structure or recombination in other chromosomes. The number of count of arms shapes and size of chromosome shows similarity with the previous report with the exception of slight variations. For instance, the existence of unpaired or autosomal chromosome reported by Lavrenchenko *et al.* (1997) was not recorded in the current study. Our results also indicate as no elaborate chromosomal polymorphism in the populations examined. The shape and size of the sex chromosome of *L. melanonyx* from Arsi Mountains was similar to speciemes from Bale Mountains. The intraspecific chromosome variation within populations indicated great diversity due to their fast rate of chromosomal rearrangements. Hence the strong varation in karyotype structure development reaveled that *L. melanonyx* had a long evolutionary history that is related to adaptation to Afroalpine habitat since the Pleistocene period (Lavrenchenko *et al.*, 1997).

The diploid chromosome of *Lophuromys brevicaudus* from Chilalo-Galama Mountains Range show similarity with previous report by Aniskin *et al.* (1997) and Lavrenchenko *et al.* (2001) who described the karyotype of *L. brevicaudus* as 2n=68 and NFa=78.

The 58 or equal diploid and autosomal fundamental for *O. helleri* was recorded from Chilalo-Galama Mountains Range. Likewise, almost similar diploid and autosomal fundamental number that range from 57 to 58 was recorded among the specimens from Bale Mountains (Lavrenchenko *et al.*, 1997). In addition, a high genetic variability between its different populations was previously recorded. However, in the current study such variations were not observed even though the detailed cytogenetic analysis on markers and allozyme data were not studied.

The genus *Stenocephalemys* has been included in the genera of *Praomys, Mastomys, Hylomyscus, Colomys* but it was recently placed under a separate genus, *Stenocephalemys* (Lavrenchenko *et al.*, 1997; Corti *et al.*, 2005). At present, the genus includes the more than four Ethiopian endemic species namely *S. albocaudata*, *S. griseicauda* and *S. albipes*, *S. ruppi* (Bryja *et al.*, 2017). The results of the current study karyological data were in agreement with the available previous of 2n = 54 and FNa = 60 for *S. albocaudata* and 2n = 54 and FNa = 54 for *S. griseicauda* (Lavrenchenko *et al.*, 1997; Corti *et al.*, 2005). In addition a new karyotype of 2n=50 was also recorded for *Stenocephalemys* sp. for northern montane by Bulatova and

Lavrenchenko *et al.* (2005). Such variation most likely happens due to the simple chromosome rearrangements of a fusion type because of the presence of two more bi-armed pairs (large submetacentric and medium metacentric).

Similarly Corti *et al.* (1999) reported that the diploid number is 2n = 54, and the FNa is 60 for *S. albocaudata*. They also described as its autosomal set is composed of three pairs of large subtelocentric chromosomes, 22 pairs of acrocentrics decreasing in size, and a pair of small metacentrics. As in present situation a polymorphism was found for the X-chromosome, being either a large metacentric or a submetacentric and the Y chromosome is a medium-size heterochromatic submetacentric (Corti *et al.*, 1999). Furthermore, such karyotype (2n=54, NFa=58) has been also described earlier for *S. griseicauda* from Bale (Lavrenchenko *et al.*, 1999). The karyotype of *S. griseicauda* from Arsi was identical to those from Debre Sina located on the opposite sides of the Ethiopian Rift Valley (Bryja *et al.*, 2017). Similarly, the chromosomal sets of *S. albocaudata* (2n=54, NFa=62) from Arsi (N=17) were identical to those from Bale (Lavrenchenko *et al.*, 1997; 1999; Bryja *et al.*, 2017).

Robertsonian translocations are fusions and fissions in which the rearrangements are involve whole chromosome arms. The variation in their diploid number may be related to Robertsonian translocations as it the most easily recognized and played a key role in the mammalian karyotype evolution. When a Robertsonian fusion and fission become fixed, the fundamental number remains the same, while the diploid number either increases (fission) or decreases (fusion) by two units. Therefore, if a karyotype is only evolved through Robertsonian translocations, the fundamental number in the ancestor determines all possible derived karyotypes. The similarity in diploid number of chromosome but varying in the autosomal fundamental number between the two species of *Stenocephalemys* clearly indicated speciation of the genus based on its chromosome arrangement (Lavrenchenko *et al.*, 1997). The analysis of the karyotype of *S. griseicauda* and *S. albocaudata* from Chilalo-Galama Mountians Range almost show similarity with that previously described by Lavrenchenko *et al.* (1999). The variation in number of autosomal fundamental may rise due to differences in the visibility of armed chromosome pairs (Bryja *et al.*, 2017). Despite its similarity in number of diploid chromosome and autosomal chromosomes there is a high genetic variation between different populations of *S. albocaudata* and also *S. griseicauda* based on their altitudinal zonations (Lavrenchenko *et al.*, 1997).

The variation in the number of biarmed autosomes (from 3 to 7 pairs) for *S. albipes* may be associated with different degrees of chromosomal contraction carrying very short arms in different studies (Bryja *et al.*, 2017). The karyotype of *S. albipes* described as 2n=46, NFa=50 is widespread across Ethiopia although there is rare autosomal heteromorphism from different geographical regions (Lavrenchenko *et al.*, 1999; Bulatova and Lavrenchenko, 2005; Bryja *et al.*, 2017). There is also a report on the variation in the karyomorph on their sex chromosomes.

The cytogenetic analyses revealed complex karyotypic differences among the different population of *T. splendens*, regarding chromosome morphology and fundamental number that ranges FNa=65–86 (Aniskin *et al.*, 1997). However, such FNa difference was uncertain whether it had any taxonomic value or reflected specific adaptations of populations to a limited ecological niche under isolation conditions (Lavrenchenko *et al.*, 2014). The differences in karyotypes between closely related species indicate existence of chromosome mutations that play a special role in the formation of new species (Lavrenchenko *et al.*, 2014). Even though 2n=48 for *Tachyoryctes splendens* from Chilalo-Galama Mountains range was similar with the previusly reported, its FNa=64 was out of the range of prevousily report of FNa=68-86 (Lavrenchenko *et al.*, 1997). Furthermore, the new karyotype of 2n=50 descriptions for *Tachyoryctes* cf. *splendens* from the north (Bulatova and Lavrenchenko, 2005) reveals high potential differences from the Arsi Mountains. Almost similar submetacentric pair of sex chromosomes corresponds to XX chromosomes and Y chromosome reported by Aniskin *et al.* (1997) and Lavrenchenko *et al.* (2014) was described from Arsi mountains. Similarly, the decreases in size of metacentric and subtelocentric chromosomes were observed although the decrease in size for acrocentric chromosmes were not clearly visible. The existing chromosome variation should be considered to describe geographical variation unless supported by further morphometric and molecular analysis (Bulatova *et al.*, 2002).

Systematically, *Dendromus* is one of the most difficult genera of African rodents. The distributional limits of many species are unresolved, and karyological information is unavailable for most species (Happold, 2013). The karyotype of the undescriped new *Dendromus* species with 2n=50 and the autosomal foundamental chromosome number (FNa) 68 from Arsi Mountains was different from the closely related Karyptype of *Dendromus lovati* from Bale which is charactrised by 2n=44 and FNa=82 (Lavrenchenko *et al.*, 1997). However, its sex chromosome show simility in size and shape with *D. lovati* reported by Lavrenchenko *et al.*, (1997). For the description and validation as new species further molecular and morphological analysis is requred.

The richness of small mammals species and its karyotypes diversity is high in East Africa. It is also considered centre of diversification due to the reinforcement of savannas and highlands surrounding the Ethiopian Rift Valley (Castiglia *et al.*, 2006). There was a clear historical connection between Afroalpine habitats of Bale and Arsi massifs on the eastern side of Ethiopian Rift Valley with those of the Chercher Mountains in eastern Ethiopia (Bryja *et al.*, 2017).

Crocidura glassi, *C. thalia* and *C. macmillani* are very similar in their morphology and were previously lumped under *C. fumosa* Thomas, 1904 (Yalden *et al.*, 1976). Even though Lavrenchenko *et al.* (2001) proposed a monophyletic group among endemic *Crocidura glassi* complex group based on the phylogenetic analysis. In the current study, the phylogeograpic analysis revealed clear separation between *C. glassi* from Arsi and Bale Mountains. Besides that there are two distinct clades whith in Arsi sample of this species. There were also two clades in Bale even though their genetic distance was negligible. Hence, population of C. *glassi* of Arsi Mountains showed higher genetic diversity than its nearby Bale Mountains population.

The genus Dendromus shows high morphological variability (Denys *et al.*, 1995). It forms a monophyletic group with Steatomys, and *Malacothrix* and former *Megadendromus* (Denys *et al.*, 1995; Lavrenchenko *et al.*, 2017). However, the phylogenetic analysis by Lavrenchenko *et al.* (2017) revealed that both *D. nikolausi* and *D. lovati*, morphologically differing from other *Dendromus* and formerly considered as monotypic genus and subgenus, respectively, clearly represent the internal lineages of the genus *Dendromus.* The distribution and karyological information genus *Dendromus* is missing for most species (Denys and Aniskin, 2012). The undescribed new species of *Dendromus* sp.1 from Arsi Mountains and Debra Sina forms a monophyletic group with *D. lovati*. The high genetic diversity and the existence of potential of yet undescribed new species within genus *Dendromus* was indicated by Lavrenchenko *et al.* (2017). In the same way, *D. nikolausi* from Arsi and Bale forms one clade with the boostrap support of 100%. *Dendromus nikolausi* is unambiguously placed at most basal branch of the clade comprising *Dendromus mesomelas*, *D.* cf. *mystacalis*, *Dendromus insignis*, *Dendromus lovati*, and one presumably undescribed species from Ethiopia (Lavrenchenko *et al.*, 2017).

The present phylogenetic tree showed *L. chrysopus* was relatively in the basal topology like the analysis of chromosome by Aniskin *et al.* (1997) and allozyme by Milishnikov *et al.*, (2000) which showed *L. brevicaudus* occupies an the middle position between *L. melanonyx* and. *L. chrysopus* (Lavrenchenko *et al.*, 2001). Their evolutionary relation is also linked with adaptive pattern to elevation gradient and habitat. Thus, *L. brevicaudus* occupies intermediate altitudes whereas *L. melanonyx* occupies Afroalpine zone and *L. chrysopus* ininhabits Afromonate forest (Lavrenchenko *et al.*, 2001). Contrary to this, the phylogenetic analyses by Lavrenchenko *et al.* (2000) from allozyme data set showed the basal position occupation of *L. melanonyx* and *L. chrysopus* on the top lineage. The results of the analysis of interrelationships among three populations of *L. chrysopus* are to some extent controversial (Lavrenchenko *et al.*, 2001). The centre of origin of *L. chrysopus* has been supposed to be in a montane forest block east to the Ethiopian Rift Valley (Lavrenchenko *et al.*, 2000).

Lophuromys melanonyx from Chilalo-Galama Mountains range (Arsi Mountains) had two distinct haplotypes of which one unique haplotype although the second one had the haplotype related with *L. menagasha* and *L. simensis*. The evolutionary distance between different clades of *L. melanonyx* range 1% to 6%. This can be used interpreted as a high genetic diversity of *L. melanonyx* among the Arsi Mountains population. Similarly, *Lophuromys brevicaudus* from Arsi and Bale Mountains forms two distinct clades with the genetic distance 1%. Unlike the *L. melanonyx* and *L. brevicaudus*, *L. chrysopus* of Arsi Mountains forms, a common clade with the south-western group of *L. chrysopus*.

The phylogenetic analysis of *Stenocephalemys* species demonstrate early divergence of Afroalpine species *S. albocaudata* and recent origin of forest dweller *S. albipes* (Lavrenchenko *et al.*, 1999: Bryja *et al.*, 2017). Some species of *Stenocephalemys* from Arsi Mountains also share some haplotyes with Guwassa. These probably indicated as Arsi Mountains is a centre of origin to the eastern and western part of the Ethiopian Rift Valley and to south. The oldest divergence separated the group of *S. albocaudata* and *S. griseicauda* east of Ethiopian Rift Valley from all other groups living mostly west of the Ethiopian Rift Valley (Bryja *et al.*, 2017) forming the Arsi Bale to be more related.

Stenocephalemys griseicauda from Chilalo-Galama Mountains Range (Arsi) had at least three distinct lineages. The two lineages had a unique haplotype while the third lineage shares haplotype with Bale Mountains group. The Bale Mountains also had unique haplotype that forms a sister clade with at least two lineages of *S. griseicuada* from Arsi and Bale Mountains.

The evolutionary distance between the two distinct clades of *T. splendens* of Arsi Mountains was 5%. Sister species of mammals that have been recognized as species based on morphology often have *cyt-b* distance values >5% and this magnitude of divergence in the *cyt-b* gene has been associated with taxa recognized as species (Bradley and Baker, 2001). Therefore, the probability of occurrences of at least two distinct species of *T. splendens* from Arsi is high. The highest (8%) estimated evolutionary divergence was recorded between haplogroups. In general, the genetic distance among different clades of *T. splendens* from Arsi, Bale and central range from 5-8%.

The current century is a critical period for the conservation of biodiversity in particular in biodiversity and endemicity rich areas (Tagliaro *et al.*, 2000). The continuous descriptions of new species and subspecies of plants and animals in such restricted geographical areas or from peculiar habitats, while habitat destruction is occurring at high rate may make many species to become extinct before they are described (Mohammed Kasso *et al.*, 2010). The identification of populations or groups with independent evolutionary histories, species distributions, phenotypic variation and landscape history, provide conservation agencies with valuable information for establishing suitable management strategies that may reduce the chances of local genetic depletion (Van Vuuren *et al.*, 2004). To minimize the depletion, conservation of Chilalo-Galama Mountains range is a must.

Molecular genetics that can be considered as new approach to taxonomic classification play a great role in the evaluation of biodiversity and in decision-making for conservation. Particularly, mitochondrial genes were extensively used for the molecular phylogenetics and for the rediscovered and possibly extinct species (Singh and Bahuguna, 2016). Methodological advances in molecular biology have led to generation of several genetic-based data sources such as karyotype, starch-gel allozymic and DNA-sequence. Examination of these data sets demonstrates that there are cryptic species of mammals that would likely not be recognized based solely on classical studies of morphology of voucher specimens housed in museums (Baker and Bradley, 2006). This helps cryptic species of mammals to be identified by karyotypes and allozymes. There are several examples of mammals that are sympatric and behave as separate species that probably would not have been recognized without data from karyotypes and allozymes (Baker and Bradley, 2006). The detection of cryptic and sibling helps us to give more attention for their conservation to maintain biological diversity and to give priority for the taxa at high risk of extinction (Tagliaro *et al.*, 2000). The possibility of the existence of different species and/or subspecies surely necessitates a re-evaluation of their conservation status (Tagliaro *et al.*, 2000; Singh and Bahuguna, 2016). Thus, the aim of this study is to find the evolutionary relationship and taxonomic rank of species of small mammals of Chilalo Galama Mountains Range. In general in present phylogeography analysis based on mitochondrial gene identify as Chilalo-Galama Mountains Range was characterized by endemic haplotypes necessitating particular attention for conservationists. There is also high level of genetic diversity of the Arsi small mammals displaying high phyloeographic relation to their conspecific Bale Mountains.

Prevalence index is more commonly used in studies of ectoparasites since it is straight forward to implement even in highly skewed distributions of abundance which often hinder analyses and interpretations (Eads *et al.*, 2013). There were no studies that focus on small mammal ectoparasite infestation and prevalence in this area. This is the first report on study of prevalence of ectoparasites in Chilalo-Galama Mountains Range of AMNP. The findings of this survey confirm the presence of ectoparasites on volant and non-volant small mammals in Chilalo Galama Mountains Range. Out of 204 individuals of small mammals comprising 28 species examined for ectoparasites, 150 were infected by one or more groups of ectoparasite taxa resulting in the overall prevalence of 73.53%. The overall prevalence recorded from Chilalo–Galama Mountains Ranges seems to be slightly higher than the report of ectoparasite prevalence on rodents from northern Ethiopia. Ectoparasite prevalence (P) was less than 50% for almost all the parasites in each of the host species (except the 64.7% P of *Laelaps* sp. on *M. awashensis*) (Meheretu Yonas *et al.*, 2011). The prevalence of ecto parasite showed variation among species of small mammals. For instance, higher prevalence was recorded for many small mammals. Similar trend in prevalence variation among small mammals was recorded in different parts of the world (Mbora *et al.*, 2009; Valdez *et al.*, 2009; Wei *et al.*, 2010; Meheretu Yonas *et al.*, 2011; Eads *et al.*, 2013; Kowalski *et al.*, 2014). The prevalence of ectoparasite on small mammals depends on different factors. Animals in degraded habitats should be prone to an increase in the prevalence and richness of directly transmitted parasites. Notably, foraging space and travel routes are limited within habitat fragments. Thus, unlike in continuous habitat where social groups can travel longer distances to occupy separate areas and avoid faecal contamination of the environment, animals in habitat fragments have to reuse the same habitat space intensively. This repeated use of the same space increases the levels of contamination of the environment with infective stages of parasites such as eggs and larvae (Mbora *et al.*, 2009). Social species living in large family groups are characterized by a higher prevalence of parasites than less social and solitary species (shrews). In a more social animal, contacts between individuals frequently promote the exchange of ectoparasites (Kowalski *et al.*, 2014).

Most of the collected ectoparasites (ticks, mites, lice flea and bat flies) corresponded with those obtained in previous studies (Changbunjong *et al.*, 2010; Meheretu Yonas *et al.*, 2011). The majority of individuals of small mammals were infested by Myobiidae mites followed by *Ambyloma* and *Polyplax*. Mites(Acari) were the most common ectoprarsites found in 96.7% of the small mammals with ectoparasites (Kanchev *et al.*, 2012). Mites of the family Myobiidae are cosmopolitan ectoparasites of insectivores, bats, rodents and marsupials (Fain *et al.*, 1984). *Amblyomma* sp. is the dominant tick among cattle in eastern Ethiopia and its patterns of infestation is associated with local wildlife fauna, including rodents, which might have played an important role by maintaining a population of the ticks and, ultimately, transferring them to cattle (Meheretu Yonas *et al.*, 2011). Similarly, *Polyplax* a group of louse are important ectoparasites of small mammals that are carriers of dangerous infectious human diseases (Kanchev *et al.*, 2012). The lice are known to be permanent ectoparasites of birds and mammals, spending their entire life cycle on the bodies of their hosts. This close association of lice and its hosts facilitates coevolution between host and parasite. Relatively few individuals of small mammals were infected by some flea species in particular *Leptopsylla* species and *Dinopsyllus* species and family Trombiculidae and Streblidae. The host specificity or generality of ectoparasite is conflicting among scholars study (Lareschi *et al.*, 2006). For example, Meheretu Yonas *et al.*, (2011) identified different species of ectoparasites from rodents innorthern Ethiopia. The occurrence of a particular ectoparasite species on host species might be related to several factors like the behaviour and microhabitat choice of the host species (Meheretu Yonas *et al.*, 2011). The family Laelapidae is an ectoparasite species of small mammals which has usually been reported in the fur of mammals, as well as in their nests (Lareschi *et al.*, 2006). Especially the mites from the family Laelapidae are commonly found on small mammals (Saraiva *et al.*, 2012). Comparatively *Dinopsyllus,* Trombiculidae and Streblidae infested a few speciesof small mammals in the current study. The infestation of small mammals by few species of ectoprasites is related to their host specificity. Nycteribiidae and Streblidae have a high degree of specialization differing greatly from other Dipteran both in morphology and behaviour (Dahal and Thapa, 2010). However, Zhan *et al.* (2013) stated that most species of chigger mites had a wide range of hosts and low host specificity and their low host specificity may increase their probability of encountering different hosts.

The number of individuals and taxa of ectoparasites recovered in the present study is comparatively higher than the number reported by Meheretu Yonas *et al.* (2011) from northern Ethiopia. However, Wei *et al.* (2010) collected 3622 individual ectoparasites belonging to 55 species divided into four groups. The highest number of ectoparasites collected during the pesent work belonged to mites and is in agreement with previous studies (Saraiva *et al.*, 2012). The collection of ectoparasites may depend on the season, animal species, ectoparasite species, location, method of catching, geographical situation, ecological condition, rodent predator, seasonal activities and population dynamics (Changbunjong *et al.*, 2010). Fleas and ticks each have five genera, louse six genera, mite six families and batflies two families collected from small mammals examined for ectoparasites. From all species of host, *S. griseicauda* was infested by high numbers of ectoparasites followed by *P. aero* and *S. albocaudata*. *Epomophoru gambianus* was the only host that was infested by few ectoparasites. Parasite diversity is not randomly distributed among host species (Kamiya *et al.*, 2013). Parasite species richness appears to follow variation in host species traits such as body size, diet breadth or home range size (Kamiya *et al.*, 2013). Host body size frequently shows a strong positive correlation with parasite species richness (Kamiya *et al.*, 2013). Larger-bodied host species provide greater surface area and other resources to parasites, encounter them at higher rates, and also represent longer lived habitat patches. Parasites may also be absent from or limited in host populations because competitive interactions and parasite-induced immune responses in the host exclude certain parasite species from co-occurring (Harris *et al.*, 2013).

In the current study, different mean intensities for ectoparasite taxa were recorded for different species of small mammals. For instance, the maximum mean intensity for ectoparasite taxon was recorded for *Linognathus* on *A. blicki*, Myobiidae on *O. helleri*, *Polyplax* on *L. brevicaudus*. The least mean intensity was recorded for Myobiidae on *S. albipes*. Such differences might depend on species that exhibit either high specialism or generalism toward their hosts (Wilkinson *et al.*, 2016).

Ectoparasites serve as vector of zoonotic diseases and degrade the welfare of the animal. Knowledge in ectoparasite distribution and taxonomic composition leads to better understanding of vector and vector-borne diseases (Portugaliza and Bagot, 2015). The majority of ectoparasites of small mammals recorded in the current study have potential for zoonotic disease transmission as recognized in many Sub-Saharan African countries. Some of them were also reported as they are potential vectors of certain diseases of medical and veterinary importance in different parts of Ethiopia (Meheretu Yonas *et al.*, 2011). Small mammals, especially those that live in close proximity with humans (synanthropic) play a significant role in the transmission of diseases to humans and animals while others act as reservoir hosts (Paramasvaran *et al.*, 2009). Ectoparasites can be important agents of zoonotic diseases in many ways. Most notably, they can be biological vectors of disease-causing organisms, including those organisms that cause filariasis, yellow fever, dengue fever, plague, babesiosis, typhus, Lyme disease, Chagas disease and many others. Other are passive carriers (i.e., mechanical vectors) of disease-causing organisms that transport pathogenic microorganisms. Several species are ectoparasites (scabies mites, chiggers, lice, ticks, and fleas) or subdermal or visceral parasites (myiasis-causing flies, *Tunga* fleas, and pentastomids) and may cause localized pain, itching, dermatitis, or vesicular eruptions (Paramasvaran *et al.*, 2009).

Chigger mites that are related to many human diseases are represented as the most numerous of the ectoparasite groups collected (Wei *et al.*, 2010). Some species of chigger mites are important vectors of scrub typhus caused by the pathogen *Orientia tsutsugamushi*. In addition, they have potential for vectors of haemorrhagic fever with renal syndrome (Zhan *et al.*, 2013).

Relatively few species fleas are important for zoonotic disease. The most medically important genus is *Xenopsylla*, for its role in the transmission of *Yersinia pestis*, the causative agent of plague, and *Rickettsia typhi*, the agent of murine typhus; *Ctenocephalides* are intermediate hosts for cestodes and can transmit agents of bacterial and rickettsial diseases; *Tunga* sp. are unusual fleas in that the females reside beneath the surface of the skin and *Pulex irritans* is a nuisance through its biting (Wei *et al.*, 2010; Eads *et al.*, 2013; MohdZain *et al.*, 2015). Fleas are also vectors of cat scratch disease (*Bartonella henselae*) and other diseases of medical and veterinary significance (Zuo and Guo, 2011). Although there is no report of plague presence in Ethiopia, other flea-borne diseases like typhus have been reported from the central part of the country (Meheretu Yonas *et al.*, 2011).

Lice transmit and serve as reservoir of pathogens like swinepox and Rickettsia. Their chewing and blood feeding habit results in anaemia, skin irritation and decrease in production capacity among poultry and livestock. Therefore, ectoparasites are serious pests with vital role in disseminating vector-borne diseases, decreasing animal production and debilitating animal welfare. Although sucking lice of small mammals do not generally transmit diseases between humans and wild animals, they have medical significance as they can preserve and extend the infection focus of some zoonoses, such as endemic typhus, rabbit tularaemia and even plague

(Zuo and Guo, 2011). Blood sucking lice are more adept at transmitting pathogens to domestic animals than chewing lice, although chewing lice on cattle can also transmit *T.verrucosum*.

Ticks and tick-borne diseases can cause major production losses in ruminants and threat to public health by transmitting zoonotic bacteria, viruses and protozoa. Ticks are among the most important vectors of human and animal diseases caused by protozoa rickettsiae, bacteria, viruses and some helminths. They rank second only to mosquitoes as vectors of life threatening or debilitating human and animal diseases. Moreover, ticks transmit a greater variety of infectious agents than any other arthropod group (Paramasvaran *et al.*, 2009). Ornithodoros are also important vectors of several diseases. Although several argasids are important pests, the vast majority of ticks infesting livestock and domestic animals belong to the family Ixodidae. Of the 14 genera of Ixodidae, species in the genera of *Amblyomma*, *Anocentor*, *Boophilus*, *Dermacentor*, *Haemaphysalis*, *Hyalomma*, *Ixodes*, *Nosomma* and *Rhipicephalus* are principal pests to domesticated animals. They are potential vectors for several pathogens (Paramasvaran *et al.*, 2009).

Bats are reservoirs of numerous infectious agents of which bat flies may be important in the epidemiology and transmission of some of these bat-borne infectious diseases. Bat flies commonly have associations with heritable bacterial endosymbionts that inhabit insect cells to ensure their transmission (Wilkinson *et al.*, 2016). Many mammalian reservoirs and vectors however are still unknown, hindering our understanding of pathogen ecology and obscuring epidemiological connections. However, the recently identified New Bartonella genotypes in the blood-feeding bat flies (Diptera, Hippoboscoidea, Nycteribiidae, Streblidae) suggesting an important role of bat flies in harbouring bartonellae. The recovery of unique clades, uniting Bartonella genotypes from bat flies and bats, supports previous ideas of these flies potentially being vectors for Bartonella (Morse *et al.*, 2012).

Several studies and reviews have suggested that the risk of disease transmission from wildlife to humans increases with biodiversity loss and the expansion of human populations, as humans will get into contact with a large pool of known and unknown zoonotic pathogens from wildlife (Gay *et al.*, 2014).

Research on pest small mammals in particular rodent damage studies in Africa are relatively recent. More than 50% of all rodent pest research carried out in Africa has been conducted in Tanzania, Ethiopia, Nigeria and Kenya. The high research intensity from Tanzania is due to strong focus on rodent pests in agricultural systems by Pest Management Centre of Sokoine University of Agriculture. In Ethiopia, although rodents are known as pest animals in most parts of the country, their economic impact and the local communities attitudes and perceptions are not well known (Abdurahman Abdulahi *et al.*, 2009; Ejigu Alemayehu and Afework Bekele, 2013; Mohammed Kasso, 2013; Meheretu Yonas, 2015). The assessment of farmers' knowledge, perceptions and practices of pests and their management is essential for the development of management strategies that are likely to be adopted easily by them.

In the current study, all respondents perceived rodents as principal pests that cause great damage to their agricultural and household items and even difficult for them to control. Beside rodents, some predatory wild animals like hyaena, jackal, cerval and carcal were also considered as major pests. Out of the three groups (rodents, bats and shrews) of small mammals treated in this study, shrews and bats were considered pests by very few respondents. The serious damage by rodent pests in agriculture and public health is mainly aggravated due to their abundance, diversity, generalist feeding habits and high reproductive potential. Previous studies conducted on vertebrate pest species indicated rodents were the principal and difficult pests to control (Abdurahman Abdulahi *et al.*, 2009; Meheretu Yonas *et al.*, 2011; Ejigu Alemayehu and Afework Bekele, 2013; Mohammed Kasso, 2015).

Local communities group rodents conventionally to classify them into three groups namely rats and mice, mole rats and porcupines. Out of the three groups rats and mice were considered causing severe damage. Survey of mole rat damage in different parts of the country also indicated heavy damage (Abdurahman Abdulahi *et al.*, 2009).

More than half of the respondents perceived porcupines causing moderate or serious damage although the serious damage perception surpasses it. The studies conducted in eastern Ethiopia around Dire Dawa Administration by Mohammed Kasso (2013) indicated porcupines are the leading pest rodents on potatoes and sweet potatoes.

This study indicated that pest small mammals have a significant negative effect on agriculture and household items and human health. Even though damage estimates varied considerably between items and the type of pest, the local communities perception to estimate ranges from total damage to low or no damage. The extent of damage on agricultural and household varies from one commodity to another. The damaged seedlings cause serious missing stands in the field. This in certain cases, may force the farmer to replant the missing stands which invariably result in unequal growth of plants, different cob maturation times and harvesting periods (Fayenuwo *et al.*, 2007). The level of damage caused by rodents on barley was reported as high by most local communities whereas beans, peas, peas, linseed and maize have low level of damage. Rodents also contaminate stored foods with their faeces, urine and hairs. This contamination is often more serious than the actual food losses because of the public health aspects and the possibility of disease transmission. Foods must be cleaned before being prepared for human consumption (Brooks *et al.*, 1999). The impact of mouse plagues can be classified as off-farm and on-farm. Off-farm impacts include mouse damage to stock, electrical equipment, and intensive animal holding facilities (insulation, electrics, other infra-structure); costs associated with labour for trapping and cleaning up after mice; and losses associated with consumption, spoiling, and contamination in premises of rural suppliers, food retail outlets, schools, hospitals, telephone exchanges, and accommodation venues (Brown and Singleton, 2002). In general, the level of damage is comparable to the extent of damage reported in different parts of Ethiopia (Meheretu Yonas *et al.*, 2011; Mohammed Kasso, 2013).

The majority of local communities did not know whether small mammal pests are successfully controlled or not. In the present study, hunting and trapping, using of cats and dogs, poisoning and combination of either two or more of these methods were listed as used by local communities. However, they are only able to invest little in rodent control and current methods may be inappropriate or poorly implemented. Some respondents also mentioned they did not have effective and efficient methods to control some pest animals. In order to reduce the impact of pest small mammals, ecologically-based management strategies need to be developed that specifically target the pest rodents in a sustainable manner (Stuart *et al.*, 2011). Although efficient techniques exist to kill rodents, none of the traditional methods are able to control outbreak populations (Stenseth *et al.*, 2001). The ultimate goal of most rodent management activities is to reduce the impact of rodents on crop production (Aplin *et al.*, 2003). Mount Chilalo and the surroundings are known for their high endemicty of small mammals (Mohammed Kasso *et al.*, 2010). Ineffective and efficient small mammal management sometimes leads to massive killing of pest species without necessarily achieving desired reductions in crop damage, either physical or financial, as reported for quelea control in Africa (Ezealor and Giles, 1997). Small mammal pest management practice is weak due to limited research efforts in understanding their biology, behaviour and habitat use (Singleton *et al.*, 1999). Research into habitat use, population dynamics and breeding biology of the small mammal pests are required, as well as an understanding of the habitat use and population ecology of non-pest rodent species that occur in this agro-ecosystem (Stuart *et al.*, 2011). Thus, during the application of pest control, non-target risks should be reduced and conservation issue needs to be addressed.

For the control of pest small mammals, the majority of local communities believe individual based controlling method as effective and efficient whereas few of them believe a group based controlling method is efficient and effective controlling method. A sound biological knowledge of the pest rodent species is a prerequisite for the development of more effective, ecologically based, rodent management strategies (Stenseth *et al.*, 2001). Unfortunately, poor African farmers are by necessity risk-averse low-capital investors to rodent control measures unless they are convinced that it will be economically beneficial on a short-term basis (Stenseth *et al.*, 2001). Beside this, ecologically-based practice for pest control has recently been developed on the basis of long-term field studies of small mammal populations (Kaboodvandpour and Leung, 2010). It has gained momentum over the past 20 years as an alternative, effective and sustainable pest small mammal control.

The results showed that the majority of the local communities did not know whether bats caused damage on agricultural crops and even some confidently cited, as bats did not cause any damages on agricultural crops and household items except damage to the roof during roosting in houses due to urine and guano. Local communities also face problems of discomfort related to fear and terror. Similarly, Mohammed Kasso and Balakrishnan (2013) reported that bats are hosts to a range of zoonotic and potentially zoonotic pathogens of several diseases like rabies, Ebola, leptospirosis, histoplasmosis, and pseudotuberculosis. The authors pinpointed bats are grouped among the world gentlest animals that provide many positive ecological and economic benefits. Few of them are considered as pests on human, livestock and agricultural crops, airplane strike, building, and infrastructure infestation, and rarely become aggressive or bite humans during self defence.

The AMNP was recently established as a key biological resource conservation area based on the diversity of large mammal fauna and flora and as a unique ecosystem of the area. It has a unique highland ecosystem and is the centre of Oromia Regional State of Ethiopia harbouring many, rare, endemic or endangered fauna and flora with special ecological, biological, social and cultural and conservation interest (Mohammed Kasso *et al.*, 2010). Almost all local communities have positive feelings for the conservation of Chilalo-Galama Mountains Range as protected area. However, these feelings particularly on the establishment and protection of Chilalo-Galama Mountains Range as AMNP varied based on their place of residence. Local communities residing far-way from the protected area were very happy tendency to its protection. In particular, the local communities residing inside the Park comparatively were not happy for the Park establishment and protection. Their major reasons for being unhappy on the protection of the area was fear of exclusion and deprivation of access to the resources inside the Park. Frequently, communities are forbidden from extracting natural resources that are important for their livelihoods and removed from their lands with little consultation or adequate compensation (Andrade and Rhodes, 2012). There was also similar complaints on the existing boundary of the Chilalo-Galama Mountains Range based on their location of residence. Land is a critical resource for livelihood earning of the people of Ethiopia due to their dependence largely on agriculture. Yet, this valuable asset is being affected by climate change impacts irreversibly.

They are engaged in mixed farming even though most farmers living near ericaceous zone are more inclined to animal rearing than crop production. Currently, there is good tendency and practice by the local community for the conservation of the area. Many districts like (Shirka, Tana, Dikisi, Robe and Lemmu-Bilbilo) are taking measures to control illegal human settlement and agricultural expansions with removal of illegal settlement and farmland that occur in demarcated protected areas. In areas where such measures have been practiced it is promising for the conservation of the area which benefit the local community and world with its ecosystem functioning like source of water, biodiversity and climate change mitigation (Mohammed Kasso *et al.*, 2010).

The majority of respondents have specific resource requrments from the protected area. Inhabitants farawy from the protected area have no access to the resource and hence do not have any resource inside the protected area with the exception of nomadic pastoralists. The park's establishment is associated with expulsion and exclusion of the local community which influences the local people's perceptions about protected areas (Hartter, 2009). Removing local communities from lands that they have been exploiting for generations without consultation or adequate compensation can result in retaliation and hostile attitudes toward protected area objectives (Hartter, 2009; Andrade and Rhodes, 2012). In addition, restricting local access to natural resources might favour biodiversity conservation in the short term. However, in the long term, such strategies fail to preserve biodiversity (Andrade and Rhodes, 2012). Generally, land degradation which is manifested by deforestation, soil erosion and overgrazing, coupled with climatic variability and environmental instability could escalate the severity of climate change-induced hazards, hence destabilizing the livelihood of local farmers in the region by deteriorating their existence and natural resource basis essential for their survival. All the respondents were interest in the conservation of Chilalo-Galama Mountains Range. Climate change will exacerbate the other sources of environmental degradation and may generate new threats with devastating consequences for both biodiversity and human welfare, especially for the poorest and most vulnerable communities and nations (Lopoukhine *et al.*, 2012). Areas like highlands of Arsi, west Arsi, Bale, East and West Hararge, and central Shewa zones that were formerly considered to receive sufficient rainfall have now begun to get inadequate rainfall. This also resulted in progressive decrease in water resources both in quantity and in spatial distribution (BoFED, 2008).

Increase of human population density is a threat to biodiversity (Luck, 2007). The rapid increase in human population growth and activities that pose greatest threats to bats in Africa include destruction of natural habitats, interference with day-roosts, hunting, and use of pesticides (Happold and Happold, 2013). Local communities also identified overpopulation as a major threat to conservation. In addition to the indirect negative effect of human activities through habitat disturbance, humans in many poor areas of the world rely to an ever increasing extent on hunting and poaching of mammals for food or trade (Istvan and Derbowka, 2011). Conflicts over natural resources between the communities living adjacent to forest have increased because of changes in land use and accompanying new ideas about wildlife resource management and utilization.

The prominent alien species that cause damage across the country include *Parthenium hysterophorus*, *Prosopis juliflora*, *Eichornia crassipes* and *Lantana camara* (IBC, 2005). In the current study, the majority of local communities did not consider exotic species expansion as a threat for conservation of the area. However, they realized exotic species like *Eucalyptus*, *Cupressus* and *Pinus* were affecting the indigenous plants. Other factors like climate change, poor agricultural practice and price inflation and high unemployment rate were also considered as threat for the conservation of the area by less than half percent of the respondents.

The rapid increase in population growth has led to rapid deforestation, land clearing, and wetland draining for cropland areas. These actions reduce the area of core habitat for wild animals and eliminate corridors for migration. The current study area is considered to the relatively better in the availability of corridor that allows animals to move freely. However, the high rate of encroachment and agriculture and settlement in Cheleleka area severely fragments the existing corridor between Mount Chilalo and Galama Mountains Range.

Grazing was mentioned by local communities as one of threating factor for the conservation of small mammals and their habitat in the study area. Cattle grazing has strong impact on the structure and dynamics of grassland plant communities (Torre *et al.*, 2007). Effects of grazing on plants and soil could also affect the animal communities inhabiting grasslands, as they depend on vegetation for food and rely on cover and soil for foraging safely and/or for building temporary or permanent burrow systems (IBC, 2005; Torre *et al.*, 2007). Areas which were earlier used as pasture lands for livestock grazing and browsing of animals in farming communities have currently shrunk and converted into farmlands because of great pressure imposed from land for crop cultivation. Abundance and diversity of small mammals are usually affected strongly by grazing due to either decreased food availability or quality, decreased suitability of soil for building burrow systems and increased predation risk in the structurally simpler grazed areas (Torre *et al.*, 2007).

Effective management of protected areas is one of the best methods to harmonize nature conservation in a given ecosystem. However, the implementation of conservation management plans on protected areas also has many conservation challenges in Ethiopia. Many studies argue that the knowledge and attitudes of people with regard to mammals constitute a critical issue for the improvement of conservation efforts and people's livelihoods (Jalilova and Vacik, 2012). The results of this study indicate that the local people's knowledge of mammals varied between communities. Even for those who have awareness and knowledge it was mostly related to the relatively high-density species that the local people had more opportunities to observe. Income generating activities had a positive influence on local people's perceptions of the benefits of wildlife and the awareness of the project's activities. Local residents generally held positive attitudes towards wildlife because it attracts tourists, creates hunting opportunities during drought, provides a source of income and generates pride in the traditional tribal culture. Negative attitudes are mostly related to human–wildlife conflicts (Jalilova and Vacik, 2012). The local communities had different attitude on the priority of conservation for different groups of animals and plants. For the conservation of forest and grassland nearly everyone had positive attitude. The second and the third groups for which local communities had positive attitudes on conservation were large mammals and birds respectively. However, for small mammals and invertebrates, local communities had low priority. Studies by Mohammed Kasso (2013) in Dire Dawa demonstrated that people's negative attitudes were primarily linked with problems associated with damage caused by small mammals. Small mammals were rarely mentioned, which indicated that people did not pay attention to smaller species. The awareness level of mammals varies (Jalilova and Vacik, 2012).

If conservation is to take account of the needs of the poor, then there must be appropriate safeguards to ensure that poor people are not made worse off, or their rights infringed (Roe *et al.,* 2011). Giving management responsibility to local community to manage and utilise the resources and encouraging the participation of local communities in co-management activities of the Park was accepted by most respondents. The conservation of biodiversity can be achieved through active participation of local people, which would allow the gaps between policy and its implementation to be overcome (Jalilova and Vacik, 2012).

Even where conservation actions are designed to benefit the poor, there may still be winners and losers among the poor (Roe *et al.,* 2011). The second option of the management plan that need to be implemented was allowing the local community to use the Park resources in sustainable way agreed by most respondents. The importance of incorporating a more participatory approach into protected area decision-making processes in order to foster the implementation of conservation strategies has been widely recognized (Andrade and Rhodes, 2012). When local communities are excluded from protected area management and their needs and aspirations are ignored, it becomes extremely difficult to enforce conservation policies.

The majority of respondent agree on the recognition of the local communities' rights to use natural resources and culture within the protected area. The inclusion of local communities in protected area decision-making processes may promote a sense of ownership, where locals cooperatively protect reserves from outsiders and also regulate their own use of natural resources (Andrade and Rhodes, 2012). Decision-making about natural resources management cannot be detached from public involvement. For wildlife management science alone may not be sufficient hence, stakeholder involvement is vital to aceive biodiversity conservation objectives (Tisdell *et al.,* 2007).

8. CONCLUSION AND RECOMMENDATIONS

8.1. Conclusion

In the current investigation, all members of Order Rodentia, Order Chiroptera and Order Eulipotyphla were considered since they represent more than 67% of the total species of mammals and more than 97% of endemics recorded from Ethiopia. Among about 320 species of mammals that occur in Ethiopia, more than 216 species (90 rodents, 96 bats and 30 shrews) were member of these orders. Few studies have been carried out to record data on the various aspects of small mammals (rodents, shrews, overlooking or excluding bats) in Ethiopia. Information on the species composition, distribution and conservation of highland bats is lacking from most parts of Ethiopia including Chilalo-Galama Mountains Range. In the current study, in order to fill the existing gap, ecological studies on bats were also conducted in combination with other small mammals. The investigation was carried out on Chilalo-Galama Mountains Range, as one block of AMNP. It is the largest block covering 85.07% of the total area of AMNP. It has the second largest sub-Afroalpine and Afroalpine habitats in Ethiopia and also in Africa even though it is currently under threat. During the investigations 36 species of small mammals were recorded from Chilalo-Galama Mountains Range. More than half of these species were endemic to the Ethiopia and even some Arsi and Bale mountains indicating the region is a key area for small mammal endemism. More individuals of rodents than shrews were captured. The distribution and habitat association of small mammals varies among species, habitats and season. Almost all species recorded in the study showed variation in habitat preference. *Erica* scrub habitat was the most preferred habitat and relatively more individuals of small mammals capture during the wet season than the dry season is comparable with previous studies. In the study, the distribution and abundance of small mammals showed significant variations along altitudinal gradients. Overall small mammal species richness pattern along the altitudinal zonation portrayed a hump-shaped pattern when the total species richness was plotted against elevation gradient. In the study, substantial variation in abundance of small mammals was detected in different modified habitats and grids when compared with the nearby natural habitats and grids. The diversity of bats in Arsi Mountains was very patchy and scarce hence the present preliminary survey attempted to fill the existing gap. In the survey, comparably more bat species were recorded. The findings of this survey confirm the presence of ectoparasites on volant and non-volant small mammals in Chilalo-Galama Mountains Range with the overall prevalence of 73.53%. The majority of ectoparasites of small mammals recorded in the study have a potential for zoonotic diseases tranission. In the study, all respondents perceived, rodents were principal pests that cause great damage to their agricultural and household items. However, shrews and bats were not perceived as pests in agriculture. Chilalo-Galama Mountains Range has a unique highland ecosystem and harbours many unique, rare, endemic or endangered fauna and flora that have a special ecological, biological, social and cultural and conservation interest. Local communities have positive feeling for its conservation and protection with slight variations based on their place of residence due to conflict of interest over the resources. Chilalo-Galama Mountains Range of economic and ecological importance to the local communities for domestic animal rearing, medicinal plant collection, barley and other highland cereal crop cultivation and fuel wood for domestic and commercial purpose, tourist attractions and cultural and religious values like “Muda” on the top of Mount Chilalo. The karyotype of representative specimens of the seven selected species from different sites of Chilalo-Galama Mountains Range are used to describe chromosomal features and reveal diversity in chromosome number and morphology. The phylogeography analysis based on mitochondrial gene also showed that Chilalo-Galama Mountains Range is characterized by endemic haplotypes necessitating particular attention for its conservation.

8.2. Recommendations

- AMNP has attractive climatic conditions and beautiful natural landscape scenery, as well as cultural and traditional heritages. It also possesses several endemic fauna and flora. It is also the closest to the centre of the country. However, the current underutilization and lack of infrastructure and promotion activity should be improved.
- Tourist attraction of AMNP and its surrounding peaks and caves of Arsi Mountains, hot and cold spring waters, water falls (Katar and Indetu), cultural and traditional pilgrimage (Muda, Frankasa, Gate, Delfiker and Ayo Momina), Tulu Gudo Church, Historical Battle Field of Anole Sallan, Manmade lakes (Koka and Melka Wakena) and Natural Lakes (Batu, Abijata, Shala and Langano) are not promoted and are not well

developed. Thus, promotion and development of these potential tourist attaraction sites is needed.

- Threatening factors such as overpopulation, deforestation, illegal high encroachment for agricultural land expansion and settlement, *Erica* fire, over-grazing, over-exploitation for fuel wood and construction materials, habitat degradation and fragmentation should be controlled and awareness creation should be given to the local communities. Protection and rehabilitation activities are needed to maintain the biodiversity.
- Specific and detailed studies on different components of biodiversity and resource mapping should be carried out
- The remnant Afromontane forest and the habitats of Cheleleka are the most endangered habitats due to encroachment. Therefore, urgent intervention and local community awareness are highly needed
- Clearing of natural forest to replace it with exotic species should be prohibited.
- The initiation of local community around Honkolo and districts like Shirka, Tana, Dikisi, Robe and Lemmu-Bilbilo in the control and management of illegal human settlement and agricultural expansion should be encouraged. Such good experience should be used as role model and shared with the other districts surrounding Chilalo-Galama Mountains Range for effective conservation.
- The local communities had different attitude on the priority of conservation for different group of animals and plants. Awareness creation and community education on the importance of small mammals and on their conservation need to be carried out.
- The involvement of local communities in participatory approach in protected area decision-making processes should be encouraged in order to foster the implementation of conservation strategies.
- As the area has high endemicity of small mammals, ecologically based pest management should be given priority. The pest status of small mammals in the area should be studied in detail to quantify the extent of damage caused and the specific species that cause damage
- Encouraging investors for infrastructure and facilities development to attract tourists
- To control the expansion of *Erica* fire, well designed fire breaks should be constructed and the local communities should be regularly awarned

- More scouts and facilities and budget should be allocated for the better protection

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10.APPENDICES

Appendix 1. Major pest rodent species recorded from different part of the country

Pest species	Pest species
Acomys cahirinus	*Mastomys natalensis*
Arvicanthis nairobae	*Mus mahomet*
Arvicanthis natalensis	*Mus masculus*
Arvicanthis somalicus	*Rattus rattus*
Arvicanthus abyssinicus	*Stenocephalemys albipes*
Arvicanthus dembeensis	*Tachoryctes splendens*
Graphiurus murinus	*Tatera robusta*
Heterocephalus glaber	*Thryanomys gregarianus*
Hystrix cristata	*Thryanomys swinderianus*
Lemniscomys striatus	*Xerus rutilus*
Mastomys erythrolocus	

Appendix 2. List of plant species recorded around small mammals study grids in Chilalo-Galama Mountains Range

Scientific name	Family	Habit	Ver. name
Acacia abyssinica Hochst. ex Benth.	Fabaceae	T	Laaftoo
Acacia melanoxylon R.Br.	Fabaceae	T	'Akeeshiya'
Acanthus polystachius Delile	Acanthaceae	S	Qoree
Acanthus sennii Chiov.	Acanthaceae	S	Kosoruu
Achyranthes aspera L.	Amaranthaceae	H	Maxxanne hamoocaa
Achyrospermum schimperi Hochst. ex Briq. Perkins.	Lamiaceae	H	Baala daalacha
Adiantum poiretii Wikstr.	Adiantaceae	H	Amaaquxa
Aeonium leucoblepharum	Crassulaceae	H	Hancuurraa dagaa
Ageratum conyzoides L.	Asteraceae	H	Aramaa
Alchemilla abyssinica Fresen.	Rosaceae	H	
Alchemilla pedata Hochst.	Rosaceae	H	
Alchemilla ellenbeckii Engl.	Rosaceae	H	
Alchemilla haumannii Rothm.	Rosaceae	H	
Alepidea peduncularis Steud. ex A. Rich	Apiaceae	H	Abaaboo baddaa

Allophylus abyssinicus (Hochst.) Radlk.	Sapindaceae	T	Aaraa
*Andropogon abyssinicu*s Fresen.	Poaceae	H	Marga Baallammii
Anthemis tigreensis J. Gay ex A. Rich.	Asteraceae	H	Xoshimaxee
Anthospermum herbaceum L. f.	Rubiaceae	H	Aramaa
Argyrolobium ramosissimum Bak.	Fabaceae	H	Misira hantuutaa
Arisaema schimperianum Schott	Araceae	H	Boqolloo warabeessaa
Artemisia abyssinica Sch. Bip. ex A. Rich.	Asteraceae	H	Ajo
Artemisia schimperi Sch. Bip. ex Engl.	Asteraceae	H	Ajo
Asparagus africanus Lam.	Asparagaceae	S	Sariitii
Aspilia mossabicensis (Oliv.) Wild	Asteraceae	S	Hadaa
Bartsia trixago L.	Scrophulariaceae	H	
Bersama abyssinica Fresen.	Melianthaceae	T	Gatamee/Lolchiisaa
Berula erecta (Hudson) Coville	Apiaceae	H	Baala/Dammaallasee
Bidens ghedoensis Mesfin	Asteraceae	H	Hadaaa gabaabaa
Bidens pachyloma Oliv. & Hiern	Asteraceae	H	Hadaa
Bidens prestinaria (Sch. Bip.) Cufod	Asteraceae	S	Habaaboo birraa
Brassica nigra (L.) Koch	Brassicaceae	H	Feexoo
Brucea antidysenterica J. F.Mill	Simaroubaceae	T	Gatamee
Buddleja polystachya Fresen.	Loganiaceae	T	Bulchaanaa
Caesalpinia decapetala (Roth) Alston	Fabaceae	S	Gorxaa
Calamagrostis epigejos L.	Poaceae	H	Marga
Calpurnia aurea (Ait.) Benth.	Fabaceae	T	Ceekaa
Canthium oligocarpum Hiern subsp.Oligocarpum	Rubiaceae	S/T	Koralla
Cardamine trichocarpa A.Rich.	Brassicaceae	H	Jeeree
Carduus nyassanus (S. Moore) R. E. Fries	Asteraceae	H	Qoree harree
Carduus schimperi Sch. Bip. ex A. Rich subsp. Schimperi	Asteraceae	H	Qoree gabaabdu
Carex monostachya A.Rich.	Cyperaceae	H	Okaya
Carex spicato-paniculata Bock.ex C.B.Clarke	Cyperaceae	H	Okaya
Carissa spinarum L.	Apocynaceae	S	Agamsa
Celtis africana Burm.f.	Ulmaceae	T	Caayii
Cerastium afromontanum Th. Fr. jr. & Weimarck	Caryophyllaceae	H	
Chenopodium ambrosioides L.	Chenopodiaceae	H	Xiroo
Cineraria abyssinica Sch. Bip. ex A. Rich.	Asteraceae	H	Hadaa
Cineraria deltoidea Sond.	Asteraceae	H	
Cirsium dender Friis	Asteraceae	H	Ludata
Cirsium schimperi (Vatke) C. Jeffrey ex Cufod.	Asteraceae	H	

Cirsium vulgare (Savi.) Ten.	Asteraceae	H	
Clematis simensis loijfx	Rununculaceae	C	Galee fiitii
Clutia lanceolata Forssk.	Euphorbiaceae	S	Ulee foonii
Commelina africana L.	Commelinaceae	H	
Conium fontanum Hilliard & B. L. Burtt	Apiaceae	H	Boobaa
Conium maculatum L.	Apiaceae	H	Boobaa harree
Convolvulus kilimandschari Engl.	Convolvulaceae	C	Hidda Annannoo
Conyza abyssinica Sch. Bip. ex A. Rich.	Asteraceae	S	
Conyza pyrrhoappa Sch. Bip. ex A. Rich.	Scrophulariaceae	H	
Conyza stricta Willd.	Asteraceae	H	Kisee
Cordia africana Lam.	Boraginaceae	T	Waddeessa
Cotula abyssinica Sch. Bip. ex A. Rich.	Asteraceae	H	
Crassula alsinoides (Hook.f.) Engl.	Crassulaceae	H	
Crassula schimperi Fisch. & Mey.	Crassulaceae	H	
Crassula vaginata Eckl and Zeyh.	Crassulaceae	H	
Crepis carbonaria Sch.Bip.	Asteraceae	H	
Crepis foetida L.	Asteraceae	H	
Crepis rueppellii Sch. Bip.	Asteraceae	H	
Cupressus lusitanica Mill.	Cupressaceae	T	Hidheessa faranjii
Cyathula cylindrica Moq. A	Amaranthaceae	H	
Cynodon dactylon (L.) Pers.	Poaceae	H	Coqorsa
Cynoglossum amplifolium Hochst.ex A.	Boraginaceae	H	Qoricha michii
Cynoglossum coeruleum Hochst.	Boraginaceae	H	
Cynoglossum lanceolatum Forssk.	Boraginaceae	H	Qoricha michi
Cyperus elegantulus Steud	Cyperaceae	H	Qeexamaa
Cyperus longus L.	Cyperaceae	H	Choqorsa
Datura stramonium L.	Solanaceae	H	Manjii
Delphinium dasycaulon Fresen.	Rununculaceae	H	
Delphinium wellbyi Hemsl.	Ranunculaceae	H	
Diaphananthe candida Cribb	Orchidaceae	E	Irkattu
Dicrocephala chrysanthemifolia DC.	Asteraceae	H	
Digitaria abyssinica (Hochst. Ex A. Rich.)	Poaceae	H	
Dipsacus pinnatifidus Steud. Ex. A.Rich	Dipsacaceae	H	
Disa pulchella Hochst.ex.A.Rich.	Orachidaceae	H	
Discopodium eremanthum Chiov.	Solanaceae	S	Maraaroo
Discopodium peninnervum Huchst.	Solanaceae	S	Maraaroo
Dovyalis abyssinica A. Rich.	Flacourtiaceae	T	Komishoo Qamalee

Drynaria volkensii Hieron.	Polypodiaceae	H	Irkattu
Dryopteris athamantica Kunze	Dryopteridaceae	F	
Echinops ellenbeckii O.Hoffm.	Asteraceae	Sh	Sokoruu
Echinops longisetus A. Rich.	Asteraceae	S	Kosorruu
Echinops macrochaetus Fresen.	Asteraceae	S	Qoraattii harree
Ekebergia capensis Sparrm.	Meliaceae	T	Somboo
Eleusine jaegeri Pilg.	Poaceae	H	Coqorsa
Emilia serpentinus Mesfin & Beentje	Asteraceae	H	
Englerina woodfordioides (Schweinf.) M.Gilbert	Loranthaceae	L	Digaaluu /Irkattu
Epilobium stereophyllum Fresen.	Onagraceae	H	
Eragrostis paniciformis (A.Br.) Steud.	Poaceae	H	Marga
Erica arborea L.	Ericaceae	S/T	Saatoo
Erica tenuipilosa Eng.ex Alm Fries	Ericaceae	S	Saatoo
Erica trimera (Engl.) Beentji	Ericaceae	S/T	Saatoo
Erythrina abyssinica Lam. ex DC.	Fabaceae	T	
Erythrina brucei Schweinf.	Fabaceae	T	Waleenaa
Eucalyptus amygdalina Labill.	Myrtaceae	T	Bargamoo urgooftuu
Eucalyptus camaldulensis Dehnh.	Myrtaceae	T	Bargamoodiimaa
Eucalyptus globulus Labill.	Myrtaceae	T	Bargamoo adii
Euphorbia dumalis S. Carter	Euphorbiaceae	S	Adaamii
Euphorbia schimperiana Scheele	Euphorbiaceae	H	Annannoo Baddaa
Euryops pinifolius A. Rich.	Asteraceae	H	
Ferula communis L.	Apiaceae	H	Ilingiitee
Festuca abyssinica Hochst. ex A. Rich.	Poaceae	H	
Festuca macrophylla Hochst. ex A.Rich.	Poaceae	H	
Festuca richardii Alexeev	Poaceae	H	
Galiniera saxifraga (Hochst.) Bridson	Rubiaceae	S/T	Kooralla
Galium simense Fresen.	Rubiaceae	H	Maxxannee
Geranium arabicum Forssk	Rubiaceae	H	
Girardinia bullosa (Steudel) Wedd.	Urticaceae	H	Doobbii Harbooyyee
Gnaphalium rubriflorum Hilliard	Asteraceae	H	
Gnidia glauca (Fresen.) Gilg.	Thymelaeaceae	T	Diddissaa
Guizotia schimperi Sch. Bip. ex Walp.	Asteraceae	H	Abaaboo hadaa
Hagenia abyssinica (Bruce) J. F. Gmel.	Rosaceae	T	Heexoo
Haplocarpha rueppelii (Sch. Bip.) Beauv.	Asteraceae	H	
Haplocarpha schimperi (Sch. Bip.) Beauv.	Asteraceae	H	
Hebenstretia dentata L.	Scrophulariaceae	H	
Helichrysum arenarium (L.) Moench.	Asteraceae	H	Hadaa badaa

Helichrysum citrispinum Del.	Asteraceae	H	
Helichrysum elephantinum Cufod	Asteraceae	S	Shishanqaa??
Helichrysum formosissimum Sch. Bip. ex A. Rich.	Asteraceae	S	
Helichrysum forsskahlii (J.F. Gmel.) Hilliard & Burtt	Asteraceae	H	
Helichrysum gofense Cufod.	Asteraceae		
Helichrysum schimperi (Sch. Bip.) Beauv.	Asteraceae	H	
Helichrysum stenopterum DC.	Asteraceae	H	
Helichrysum splendidum (Thunb.) Less.	Asteraceae	H	
Helichrysum traversii Chiov.	Asteraceae	S	Kaxxannaa
Hygrophila schulli (Hamilt.) M. R. & S.M.Almeida	Acanthaceae	H	Biichee
Hyparrhenia dregeana (Nees) Stent	Poaceae	H	Marga
Hypericum peplidifolium A. Rich.	Guttiferae	H	
Hypericum quartinianum A.Rich.	Guttiferae	S	Ulee foonii
Hypericum revolutum Vahl	Guttiferae	SH	Garambaa
Hypoestes forskaolii (Vahl) R. Br.	Acanthaceae	H	Darguu
Hypoestes triflora (Forssk.) Roem. & Schult.	Acanthaceae	H	Darguu
Impatiens hochstetteri Warb.	Asteraceae	H	Insooshila
Impatiens rothii Hook.	Balsaminaceae		
Inula confertiflora A. Rich.	Asteraceae	S	
Ipomoea cairica L.	Convolvulaceae	L	
Isodon schimperi (Vatke) J.K. Morton	Lamiaceae	H	Baala kormaa
Jasminum abyssinicum Hochst. ex DC.	Oleaceae	C	Galee beeraa
Juniperus procera Hochst. ex Endl.	Cupressaceae	T	Hindheessa
Justicia diclipteroides Lindau subsp. aethiopicaHedren	Acanthaceae	H	Bokoluu
Justicia schimperiana (Hochst. ex Nees) T.Anders.	Acanthaceae	S	Dhummuugaa
Kalanchoe densiflora Rolfe.	Crassulaceae	H	Hancuurraa
Kalanchoe laciniata L.	Crassulaceae	H	Hancuurraa
Kalanchoe petitiana A.Rich.	Crassulaceae	H	Bosoqqee
Kalanchoe quartiniana A. Rich.	Crassulaceae	H	Hancuurraa
Kniphofia foliosa Hochst.	Asphodelaceae	H	Shushubbe arfaasa
Kniphofia hildebranditii Cufod.	Asphodelaceae	H	Shushubbe arfaasa
Kniphofia insignis Rendle	Asphodelaceae	H	
Lactuca serriola L.	Asteraceae		
Laggera crispata (Vahl) Hepper & Wood	Asteraceae	H	Ajawa
Leonotis oecymifolia (Burm.f.) Iwarsson	Lamiaceae	Sh	Bokoluu
Leucas martinicensis (Jacq.) R. Br.	Lamiaceae	H	Bokkolluu

Lippia adoensis Hochst. ex Walp. V	Verbenaceae	S	Kusaayee
Lobelia giberroa Hemsl.	Lobeliaceae	Sh	Seedaree
Lobelia rhynchopetalum Hemsl.	Lobeliaceae	Sh	Taruuraa
Maesa lanceolata Forssk.	Myrsinaceae	S/T	Abbayyii
Malva verticillata L.	Malvaceae	H	Liitaa
Maytenus arbutifolia (A.Rich)Wilezek	Celastraceae	T	Kombolcha
Maytenus obscura (A.Rich.)Cuf.	Celastraceae	T	Kombolcha
Maytenus undata (Loes.) Sebsebe	Celastraceae	T	Kombolcha
Maytenus undata (Thunb.) Blakelock	Celastraceae	T	Kombolcha
Medicago polymorpha L.	Fabaceae	H	Hamaaquxa
Mentha aquatica L.	Lamiaceae	H	Qoricha lagaa
Merendera schimperiana Hochst	Colchicaceae	H	Worqee lafaa
Mikaniopsis clematoides (Sch.Bip. ex A.Rich.) Milne-Redh.	Asteraceae	C	Qarqooraa
Myrsine africana L.	Myrsinaceae	S/T	Qacama
Myrsine melanophloeos (L.) R. Br.	Myrsinaceae	T	Tuullaa
Notholaena marantae (L.) Desv.	Sinopteridaceae	H	Fernii
Nuxia congeta R.Br. ex Fresen.	Loganiaceae	T	Bixxanna
Ocimum hamiifolium Hochst. ex Benth.	Lamiaceae	sh	Demakessie
Ocimum urticifolium Roth	Lamiaceae	S	Qoricha michii
Oenanthe palustris (Chiov.) Norman	Apiaceae	H	Goondee
Olea europaea L.	Oleaceae	T	Ejersa
Olea hochstetteri Bak.	Oleaceae	T	Aaraa
Olinia rochetiana A.Juss.	Oliniaceae	T	Gunaa
Orobanche minor Smith	Orobanchaceae	H	
Osyris quadripartita Decn.	Santalaceae	S	Kaarroo /Waatoo
Panicum monticola Hook.f.	Poaceae	H	Marga gogoorii
Pavonia urens Cav.	Malvaceae	S	Liitii
Pennisetum riparium Hochst. ex A. Rich.	Poaceae	H	Migira
Pennisetum sphacelatum (Nees) Th. Dur. & Schinz	Poaceae	H	Migira
Peperomia abyssinica Miq.	Piperaceae	E	Irkattu hamoocaa
Periploca linearifolia Quart.-Dill & A.Rich.	Asclepidaceae	C	Gaalee Annannoo
Phagnalon abyssinicum Sch. Bip. ex A. Rich.	Asteraceae	H	
Phragmanthera macrosolen A. Rich.	Loranthaceae	S	Haatoo
Physalis peruviana L.	Solanaceae	H	Mijilo
Phytolacca dodecandra L` Herit.	Phytolaccaceae	S	Handoodee
Pinus patula Schiede ex Schltdl. & Cham.	Pinaceae	T	'Shuwshuwwee'
Pittosporum abyssinicum Del.	Pittosporaceae	T	Aaaraa

Plantago lanceolata L.	Plantaginaceae	H	Qorxoobbii
Plantago major L.	Plantaginaceae		Qorxobbii kormaa
Platostoma rotundifolium (Briq.) A. J. Paton	Lamiaceae	H	Baala kormaa
Plectocephalus varians (A. Rich.) C. Jeffrey ex Cufod.	Asteraceae	H	
Plectranthus lanuginosus (Hochst. ex Benth.)	Lamiaceae	H	
Plectranthus punctatus (L.f.) L` Her.	Lamiaceae	H	
Podocarpus falcatus (Thunb.) R. B. ex. Mirb.	Podocarpaceae	T	Birbirsa
Premna schimperi Engl.	Lamiaceae	S	Urgeessaa
Pterolobium stellatum (Forssk.) Brenan	Fabaceae	S	Haraangamaa
Pycnostachys abyssinica Fresen.	Lamiaceae	H	
Ranunculus oreophytus Hochst	Ranunculaceae	H	Qoricha michii
Ranunculus stagnalis Hochst	Ranunculaceae	H	
Rhamnus prinoides L` Herit.	Rhamnaceae	S	Geeshoo
Ricinus communis L.	Euphorbiaceae	S/T	Qobboo
Rosa abyssinica Lindley	Rosaceae	S	Gora lulufee
Rubus apetalus Poir.	Rosaceae	S	Goraa arbaa
Rubus volkensii Engl.	Rosaceae	S	Hayinaa
Rumex abyssinicus Jecq.	Polygonaceae	H	Shashabbee
Rumex nepalensis Spreng.	Polygonaceae	H	Tuultii /Shaabbee
Rumex nervosus Vahl	Polygonaceae	S	Dhangaggoo
Salvia merjamie Forssk.	Lamiaceae	H	
Salvia nilotica Jacq.	Lamiaceae	H	Dabbaqitii
Satureja paradoxa (Vatke) Engl. ex Seybold	Lamiaceae	H	Baala kormaa
Satureja punctata (Benth.) Briq.	Lamiaceae	H	Xooshimaaxee
Satureja simensis (Benth.) Briq.	Lamiaceae	H	Baala kormaa
Saxifraga hederifolia A. Rich	Crassulaceae	H	
Scabiosa columbaria L.	Dipsacaceae	H	
Schefflera abyssinica (Hochst. ex A. Rich.)Harms	Araliaceae	T/L	Aaraa
Schefflera volkensii (Engl.) Harms	Araliaceae	S/T	Anshaa
Schoenoxiphium sparteum (Wahlenb.) C.B. Clarke	Poaceae	H	
Sedum crassularia Raym	Crassulaceae	H	
Senecio fresenii Sch. Bip. ex Oliv. & Hiern	Asteraceae	H	
Senecio myriocephalus Sch. Bip. ex A. Rich.	Asteraceae	S	Qaxannaa
Senecio schimperi Sch. Bip. ex A. Rich.	Asteraceae	H	hada qaxanna
Silene macrosolen A.Rich	Caryophyllaceae	H	

Snowdenia polystachya (Fresen.) Pilg.	Poaceae	H	Muujia
Solanecio gigas (Vatke) C. Jeffrey	Asteraceae	S	Jirma Jaldeessaa
Solanum giganteum Jacq.	Solanaceae	H	Hiddi
Solanum incanum L.	Solanaceae	S	Hiddii
Solanum marginatum L.f.	Solanaceae	S	Hiddii
Solanum nigrum L.	Solanaceae	H	Mijilo
Sonchus asper L.	Asteraceae	H	Qoree haree
Sphaeranthus suaveolens (Forssk.) DC.	Asteraceae	H	
Sporobolus africanus (Poir.) Robyns &Tournay	Poaceae	H	Marga
Stephania abyssinica (Dillon & A. Rich.) Walp.	Menispermaceae	L	Kalala
Swertia schimperi	Gentianaceae	H	
Tagetes minuta L.	Asteraceae	H	Aramaa ababoo
Thalictrum rhynchocarpum Dill. & A. Rich	Rununculaceae	H	Sarariitii
Thymus schimperi Ronniger	Lamiaceae	H	Xoosinee
Trifolium burchellianum Ser.	Fabaceae	H	
Trifolium chilaloense Thulin	Fabaceae	H	
Trifolium rueppellianum Fresen.	Fabaceae	H	
Triumfetta rhomboidea Jacq.	Tiliaceae	H	
Umbilicus botryoides A.Rich	Crassulaceae	E	
Urera hypselodendron (A.Rich.) Wedd.	Urticaceae	L	Haliilaa/ Laanqisaa
Urtica simensis Steudel	Urticaceae	H	Doobbii
Verbascum sinaiticum Benth.	Scrophulariaceae	H	Gurra harree
Vernonia amygdalina Del.	Asteraceae	T	Eebicha
Veronica glandulosa	Scrophulariaceae	H	
Viola abyssinica Oliv.	Violaceae	H	
Zehneria scabra (Linn.f.) Sond.	Cucurbitaceae	C	Gaalee adii

Appendix 3. List of medium and large mammals observed in the study area

Order	Species	Common name	Species Authority	Local name (Afan Oromo)
Primate	*Chlorocebus pygerythrus*	Vervet Moneky	Cuvier, 1821	Qamalee
	Colobus guereza	Eastern Black-and-white Colobus	Ruppell, 1835	Weennii
	Papio Anubis	Olive Baboon	Lesson, 1827	Jaldeessa
Cetartiodact	*Redunca redunca*	Bohor Reedbuck	Pallas, 1767	Daaloo
	Redunca	Mountain Reedbuck	Afzelius, 1815	

	fulvorufula			
	Sylvicapra grimmia	Common Duiker	Linnaeus, 1758	Kurophee
	Tragelaphus scriptus meneliki	Menelik’s Bushbuck	Neumann 1902	Borofa
	Tragelaphus buxtoni	Mountain Nyala	Lydekker, 1910	Gadamsa
	Phacochoerus africanus	Common Warthog	Gmelin, 1788	Karkarroo
	Oreotragus oreotragus	Klipspringer	Zimmermann, 1783	Gicii
Carnivora	*Canis aureus*	African wolf	Hemprich and Ehrenberg 1833	Jeedala
	Panthera pardus	Leopard	Linnaeus, 1758	Qeerransa
	Canis simensis	Ethiopian wolf	Rüppell, 1840	Jeedala Fardaa
	Caracal caracal	Carcal	Schreber, 1776	Ayyubbee
	Leptailurus serval	Serval	Schreber, 1776	Horbaa
	Civettictis civetta	African Civet	Schreber, 1776	Jeeree
	Crocuta crocuta	Spotted Hyeana	Erxleben, 1777	waraabessa
	Hyaena hyaena	Striped Hyeana	Linnaeus, 1758	Waraabessa adii
	Leptailurus serval	Serval	Schreber, 1776	
	Herpestes sanguineus	Slender Mongoose	Ruppell, 1835	Amaa
	Poecilogale albinucha	African Striped Weasel	Gray, 1864	Curree
Lagomorpha	*Lepus starcki*	Ethiopian Highland Hare	Petter, 1963	Illeetti
	Lepus habessinicus	Abyssinian Hare	Hemprich & Ehrenberg, 1832	Illeettii
Tubulidentata	*Orycteropus afer*	Aardvark	Pallas, 1766	Awaal-deegessa

Hyracoidea	*Procavia capensis*	Rock hyrax	Pallas, 1766	Osolee

Appendix 4. List of birds observed in Chilalo-Galama Mountains Range

Scientific Name	Common Name
Accipiter badius	Shikra
Alopochen aegyptiacus	Egyptian Goose
Anas capensis	Cape Teal
Anas sparsa	African Black Duck
Anas undulata	Yellow-billed Duck
Anthus cervinus	Red-throated Pipit
Anthus cinnamomeus	Grassland Pipit
Aquia rapax	Tawny Eagle
Aquila chrysaetos	Golden eagle
Aviceda cuculoides	African Cuckoo-Hawk
Bostrychia carunculata	Wattled Ibis
Bostrychia hagedash	Hadada Ibis
Bradypterus cinnamomeus	Cinnamon Bracken Warler
Bubo capensis	Cape Eagle- Owl
Bubulcus ibis	Cattle Egret
Buteo augur	Augur Buzzard
Caprimulgus poliocephalus	Montane Nightjar
Cercomela sordida	Moorland Chat
Circus macrourus	Pallid Harrier
Circus pygargus	Montagu’s Harrier
Cisticola lugubris	Ethiopian Cisticola
Colius striatus	Speckled Mousebird
Columba albitorques	White-collared Pigeon
Columba arquatrix	African Olive Pigeon
Columba guinea	Speckled Pigeon
Corvus albus	Pied Crow
Corvus capensis	Cape Crow
Corvus crassirostris	Thick-billed Raven
Cossypha semirufa	Rüppell’s Robin-Chat

Coturnix coturnix	Common Quail
Cyanochen cyanoptera	Blue-winged Goose
Delichon urbicum	Common House Martin
Egretta garzetta	Little Egret
Elanus caeruleus	Black-winged Kite
Euplectes capensis	Yellow Bishop
Falco cherrug	Saker Falcon
Falco tinnunculus	Common Kestrel
Galerida theklae	Thekla Lark
Gypaetus barbatus	Lammergier
Gyps africanus	White-backed Vulture
Hedydipna collaris	Collared Sunbird
Hirunda rustica	Barn Swallow
Lamprotornis chalybaeus	Greater Blue-eared Glossy-Starling
Laniarius aethiopicus	Ethiopian Boubou
Milvus migrans	Black Kite
Monticola saxatilis	Common Rock Thrush
Motacilla citreola	Citrine Wagtail
Motacilla flava	Yellow Wagtail
Necrosyrtes monachus	Hooded Vulture
Nectarina famosa	Malachite sunbird
Onychognathus tenuirostris	Slender-billed Starling
Parisoma griseiventris	Bale Parisoma
Peliperdix coqui	Coqui Francolin
Ploceus baglafecht	Baglafecht Weaver
Psophocichla litsitsirupa	Groundscraper Thrush
Pternistis castaneicollis	Chestnut-naped Francolin
Ptyonoprogne fuligula	Rock Martin
Rougetius rougetii	Rouget’s Rail
Scleroptila psilolaemus	Moorland Francolin
Scopus umbretta	Hamerkop
Serinus citrinelloides	African Citril
Serinus nigriceps	Black-headed Siskin
Serinus reichardi	Reichard's Seedeater
Serinus striolatus	Streaky Seedeater
Serinus tristriatus	Brown-rumped Seedeater
Streptopelia lugens	Dusky Turtle Dove
Tachybaptus ruficollis	Little Grebe

Terpsiphone viridis	African Paradise Flycatcher
Threskiornis aethiopicus	Sacred Ibis
Turdus (olivaceus) abyssinicus	Mountain Thrush
Vanellus leucurus	White-tailed Lapwing
Zosterops poliogastrus	Montane White-eye
Ploceus speekei	Speke's weaver
Macronyx flavicollis	Abssinian Longcaw
Pycnonotus barbatus	Common Bulbul
Phoenicurus phoenicurus	Common Redstart
Pseudoalcippe abyssinica	African Hill babbler
Cinnyris venustus	Variable Sunbird
Lanius collaris	Common Fiscal
Buphagus erythrorhynchus	Red-billed Ox-pecker
Passer swainsoni	Swainson's Sparrow
Buteo oreophilus	Mountain Buzzard
Buteo buteo	Common Buzzard
Aquila pomarina	Lesser Spotted Eagle
Agapornis taranta	Black Winged Lovebird
Tauraco leucotis	White Checked Turaco
Glavcidium periatum	Pearl-spotted Owlet
Tachymarptis melba	Alpine Swift
Meros pusillus	Little Bee-eater
Meros latresnayii	Blue-breasted Bee-eater
Tockus hemprichii	Hemiprich's Hornbill
Campethera mombassica	Nubia Woodpecker
Anas hottentota	Hottentot Teal
Gypus rueppelli	Ruppell's vulture
Melierax metabatei	Dark Chanting Goshawk

Appendix 5. Data sheet for ectopoarsite study in the laboaratory

Hostcode	Taxon and abundance of ectoparasites recovered							Remark
	Re-code	Lice	Ticks	Mite	Flea	Fly	Others	

Appendix 6. Data Sheet for Sherman Live Trapped Small Mammals

Date __________ Time: Diurnal ☐ Nocturnal☐ Transect-line________Grid code ____
GPS ID: Altitude _________ Latitude ____________ Longitude ___________
Vegetation Type _________________ Habitat _________ Session______ Weather____

Block	Trap No.	Trap Status	Sex		Wt	Age			Reprod. Condition					Samples			Species Name
		C/NC/CL/NF/DA	M	F		A	SA	Y	I	S	L	PR	IM	D	S	P	
A	1																
	2																
	3																
	4																
	5																
B	1																
	2																
	3																
	4																
	5																
C	1																
	2																
	3																
	4																
	5																
D	1																
	2																
	3																
	4																
	5																
E	1																
	2																
	3																
	4																
	5																

C: Captured, NC: not captured, RC: recapture, CL: closed, NF: no food, M: Male, F: Female, A: adult, SA: sub-adult, Y: young, I: inguinal, S: scrotal, CV: closed vagina, PV: perforate vagina, PR: pregnant, IM: impregnate, L: lactating; D: DNA; S: skin; P: parasite

Appendix 7. Data Sheet for scarified small mammals from the study area

Date __________ Time: Diurnal ☐ Nocturnal☐ Transect-line________Grid code ____GPS ID: Altitude _________ Latitude
____________ Longitude ___________Vegetation Type _________________ Habitat _________ Session______ Weather____

Grid code	Time	Sex		Body Measurement					Age			Reprod. Cond.							Samples			Species Name	Remark
		M	F	Wt	HB	TL	FL	EL	A	SA	Y	M		F									
												I	S	CV	PV	PR	IM	L	D	S	P		

M: Male, F: Female, Wt: weight, HB: head to body length, TL: tail length, ER: ear length, A: adult, SA: sub-adult, Y: young, I: inguinal, S: scrotal, CV: closed vagina, PV: perforate vagina, PR: pregnant, IM: impregnate, L: lactating

Appendix 8. Data collection sheet for local communities attitude on conservation of Chilalo-Galama Mountain Range

Data Collection Sheet

Dear respondent, this questionnaire is prepared to make a survey on the local communities' attitude and conservation challenges of AMNP of Chilalo-Galama Mountain Range. The study is aimed to identify the local communities' perception and major conservation challenges, to suggest possible conservation plan and strategic development. Therefore, dear respondents, your genuine response will help us achieve the stated objective of conservation of the biodiversity of the area and to bring sustainable development. This questionnaire has two parts based on the above objectives. Thus, we request you to answer it accordingly and we guarantee you that the answer you give will be confidential and used only for the mentioned purpose. So feel free and answer it. We thank you a lot for your cooperation in advance.

Questionnaire to be filled by randomly selected household

Part I: Background Information

1. Name of your Kebele:__________________ Village/Zone/Goxi:_____________
2. Where is the location of your residence or farmland with respect to the park?
   Bordering ☐ Permanently inside ☐ Temporarily inside ☐ Faraway ☐
3. Sex: Male ☐ Female ☐
4. Age: below 17 ☐ 18-35 ☐ 36-45 ☐ Above 46 ☐
5. Level of Education: Unable to read and write ☐ Basic and elementary education ☐
   Secondary and preparatory education ☐ TVET, College and University ☐
6. Marriage status: Single ☐ married ☐ Divorced☐ widowed☐
7. What is your total family size?_______ M____ F______
8. What is your major occupation and source of income?
   Crop cultivation ☐
   Animal rearing ☐
   Mixed farming☐
   Small petty trade ☐
   Daily labour ☐
   Personal business ☐
   Other (specify) ____
9. Which types of agricultural crops you dominantly cultivate per year. Prioritize from level 1 to 3 based on cultivation or production per year.

Level of production	Types of crops cultivated							
	Barley	Wheat	Broad beans	Pea	Linseed	Potato	vegetables	Others
1st level								
2nd level								
3rd level								

Others (specify)____

10. Which type of domestic animals you dominantly rear? Give total number of each group

Amount	Types of domestic animals reared								
	Cattle	Sheep	Goat	Horse	Donkey	Chicken	Dog	Cat	beehive
Number									

Others (specify): ____

Part II: Park and conservation

11. How do you feel about the establishment and protection of Chilalo-Galama Mountain range as part of Arsi Mountains National park?
Very happy ☐ Happy ☐ Neutral ☐ Unhappy ☐
What is your reason?
____
____
____

12. Do you agree on the park boundary ? Yes ☐ No ☐
Why?
____
____
____

13. Do you have any resource inside the park? Yes ☐ No ☐
If "yes" what is/are your resource (s)?
Farmland ☐
Garden ☐
Grazing land ☐
Plantation ☐
House and barn ☐

Any other specify:
____
____

14. What would be the main purpose of Chilalo-Galama Mountains range conservation as part of Arsi Mountains National Park?
Watershed management and source of water ☐
Ecotourism income generation ☐
For conservation of endemic animals like Ethiopian wolf and Mountain nyala and other biodiversity ☐
Climate change and soil erosion mitigation ☐
Others (specify): ____

15. Major reasons for encroachment on high altitude and the park

Reasons	Yes	No
The suitability of area for residence, crop cultivation and animal rearing		
Shortage of land for crop cultivation and pasture		
Farming and pasture land low productivity		
Low successive productivity of land and extensive farming		
Human population growth		

16. Which action do you prefer for the park and its boundary to be protected from anthropogenic impact

Actions	Agree	Disagree
Destroying all illegal houses and plantation inside the park and dislocating all park residents		
Fencing the whole boundary of the park		
Removing all park residents who have land outside the park boundary with the exception who do not have any option		
Strictly protecting the new encroachers but allowing former residents to live inside the park under regulated condition		

17. What are the major benefits you are getting from the park?

Land for crop cultivation ☐

Pasture for livestock ☐

Plantation ☐

Place for residence and garden☐

Fuelwood and charcoal ☐

Construction and medicinal material ☐

Others (specify):____

18. What are the major uses of *Erica* forest?

Uses	Yes	No
Source of construction material		
Fuelwood and charcoal		
Livestock grazing		
Soil erosion control		
Climate change mitigation and other ecosystem function		

19. Have you ever participated on the burning of *Erica* forest? Yes ☐ No ☐

Why? ____

20. Do agree on the burning of *Erica* forest of Chilalo-Galama Mountains range?

Yes ☐ No ☐

Why? ____

21. Do you or any member of your family participate in selling fuel wood, charcoal or thyme? Yes☐ No☐

If your answer is "yes" at what rate the trading activity practiced?

Through out the year☐ During shortage of food and other resource ☐ Occasionally ☐

22. Do you believe the following factors to be considered as threat for the park conservation?

Threats	Yes	No
Poverty, unemployment and lack of food		
Resource conflict and scrambling to seize park land among the neighboring communities		
Destruction of habitats by agriculture expansion and settlement		
Climate change		
Current price inflation and increment of unemployment rate		
Overpopulation		
Poor agricultural practice		
Exotic species expansion		
Presence of predators and pest animals		
High demand for charcoal and fuelwood		
Uncontrolled hunting, poaching and deforestation		

23. How do you evaluate the conservation of wildlife and habitats of the Chilalo-Galama Mountains range regarding the following issues?

Items	level			
	Very Good	Good	Poor	Unknown
Habitat suitability for all wildlife				
Efforts of protection of domestic animals not to inter the park				
Availability of corridors that allow animals to move freely				
Extent of protection from illegal encroaching, hunters				
Influence from artificial plantation and exotic species expansion				
Influence of infrastructures				
Availability of protection rules and regulation and their enforcement				

24. What action you prefer to take when predators or pest animals caused damage to your properties?
Hunting and poisoning ☐
Reporting to police or other concerned governed offices ☐
Destruction of its shelter, nest, den, food and water source ☐
Concentration on only to avoid or prevent any extra damage ☐
Any other :____

25. How do you believe regarding the conservation priority for the following things

Things to be conserved	Level of priority			
	high	Medium	Low	Not known
Forest and grassland				
Small mammals like rodents, shrews and bats				
Large mammals like Ethiopian wolf, Mountain nyala, bushbuck, hyena				
Birds				
Invertebrates				

26. How do you perceive the following likely conditions that might happen if the park is conserved well?

Thing that likely happen	Agree	Disagree
Increase of human wildlife conflict		
Decrease of human wildlife conflict		
Displacement of human settlement		
Shortage of agriculture and grazing land		
Increase of agriculture and grazing land		
Increase of tourists and tourism income		
Favourable climate and weather condition		
Increase of water supply from river, spring and rainfall		
Increase of forest and other biodiversity		

27. Which conservation management plan do you suggest to be implemented for the park

Actions	Agree	Disagree
Strictly protecting local community from access of any resource and protecting the area for wildlife only		
Allowing the local community to use the park resource in a sustainable way		
Giving management responsibility to local community to manage and use the park		
Sharing responsibility and income with local community		
Encouraging participation of local community in co-management activities of the park		
Recognizing the local communities rights to use to natural resources and culture within the protected area		

Appendix 9. Small mammal pest species composition and local communities perceptions on their pest status in Mount Chilalo

Data Collection Sheet

Dear respondents, this questionnaire is prepared to make a survey on the local communities' perception on small mammal pest status and their level of damage. The study is aimed to identify the items that are more affected by small mammal pests and to estimate the extent of damage.

Therefore, your genuine response will help us to:

- identify items that are more damaged by small mammal pests
- determine the level of damage on different agricultural crops
- build a baseline information for policy makers in order to develop effective and efficient controlling strategies

Dear respondents, this questionnaire has two parts based on the above objectives. Thus, we request you to answer it accordingly and we guarantee you that the answer you give will be confidential and used only for the mentioned purpose. So feel free and answer it. We thank you a lot for your cooperation in advance.

Part I: Background Information

28. Name of your Kebele:___________________ Village:_____________
29. Sex: Male ☐ Female ☐
30. Age: below 17 ☐ 18-35 ☐ 36-45 ☐ Above 46 ☐
31. What is your family size? M_________F________T____________
32. What is the major source of your income?
    Crop cultivation ☐ Mixed farming☐
    Animal rearing ☐ Daily labourer ☐
    Small trade ☐ Self employment☐
    Other (specify) ____
33. If your answer for question # 5 is "**agriculture**" what is the total size of your cultivated land in ha/ximadi ____
34. Which types of agricultural crops you dominantly cultivate per year. Prioritize from level 1 to 3 based on cultivation or production per year?

Level of production	Types of crops cultivated							
	Barley	Wheat	Beans	Peas	Potato	Linseed	Vegetables	Others
1st level								

2nd level								
3rd level								

Others (specify):____

Part II: Small mammal Pests Status and Level of Damage

35. Do you have problems related to pest of small mammals
Yes ☐ No ☐
36. Which of the following is a serious pest and challenges your control?
Rodents ☐ Birds ☐
Bats ☐ Wild animals☐
Shrews ☐ Invertebrates☐

Other (specify):____

37. How you rate the frequency of occurrence of pest rodent damage?
Regularly ☐ Rarely ☐
Occasionally ☐ Not known ☐
Other (specify):____
38. At what stages of growth of crops and the estimated level of damage is caused by pest rodents? Mark with “X” or “✓”.

NB: for intensity/level of damage 0-indictes for no damage; 1-limited damage less for ≤25%; 2- moderate damage ≤50% and 3-high damage for >50%

Crops	Seedling (% damage)				Vegetative (% damage)				Matured (% damage)				Storage (% damage)			
	0	≤25	≤50	>50	0	≤25	≤50	>50	0	≤25	≤50	>50	0	≤25	≤50	>50
Barley																
Wheat																
Beans																
Peas																
Linseed																
Potato																
Vegetables																
Others																

39. Which parts of the following crops damaged by small mammals and its perceived damage level? Mark with “X”. NB: H - high, M- medium, L-Low N- No damage

Crops	Leaf				Stem				Root/ tuber				Seed, fruit, flower			
	H	M	L	N	H	M	L	N	H	M	L	N	H	M	L	N
Barley																
Wheat																
Beans																
Peas																
Linseed																
Potato																
Vegetables																
Others																

40. Categorize the following group of small mammas as serious, moderate, least and no damage based on the intensity of damage to your products

Pest animal	Category of pest status			
	Serious	Moderate	Least	No damage
Rats and mice				
Mole rat				
Porcupine				
Bats				
Shrews				

41. Which methods you most use to control small mammals
Poison ☐
Field sanitation ☐
Hunting and trapping ☐
Using cat and dog☐

Combination of different methods ☐
Other
(specify):____

42. How do the following groups of small mammal pests mostly affect you and your products?
Mark with “X” or “✓”

Pest Animal	Ways of damage caused				
	Feeding	Mechanical damage	Contamination	Discomfort	Disease causing and transmission
Rats and mice					
Mole rat					
Porcupine					
Bats					
Shrews					

43. How do you detect the existence of pest small mammals in your house or farmland?

Pest Animal	Ways of detecting their existence				
	Sound and movement	Damage on products	Runways and rubmarks	Burrow and roosting site	Scat, urine, pellet and food remains
Rats and mice					
Mole rat					
Porcupine					
Bats					
Shrews					

44. When will you try to control small mammal pests to reduce or prevent damage?
Just after damage was observed ☐
Every time when the sign of their existence is detected ☐
Before their breeding time and population outbreak ☐
After their breeding time and population outbreak ☐

45. Which way for pest small mammals control you believe to be effective and efficient?
Individually ☐ Group ☐ Both ☐ Difficult to decide ☐
Why?____

46. From where and to what extent you get information for the control of small mammals?

Source of information	Extent		
	Mostly	Sometimes	Rarely
Development agent and agricultural expert and officers			
Radio			
Seminar, workshop and meeting			
Other			

47. To what extent is the damage caused by pest rodents on the following household items

Household items	Level of damage			
	High	Moderate	Low	No damage
Kitchen utensils				
Cloth and electronics				
Food and water				
House wall, floor and ceiling				
Grain and other crop storage materials and equipment				

48. Have you ever observed bat or shrew damage on your crop? Yes ☐ No ☐

49. Do you think bats are pest animals by causing the following impacts?

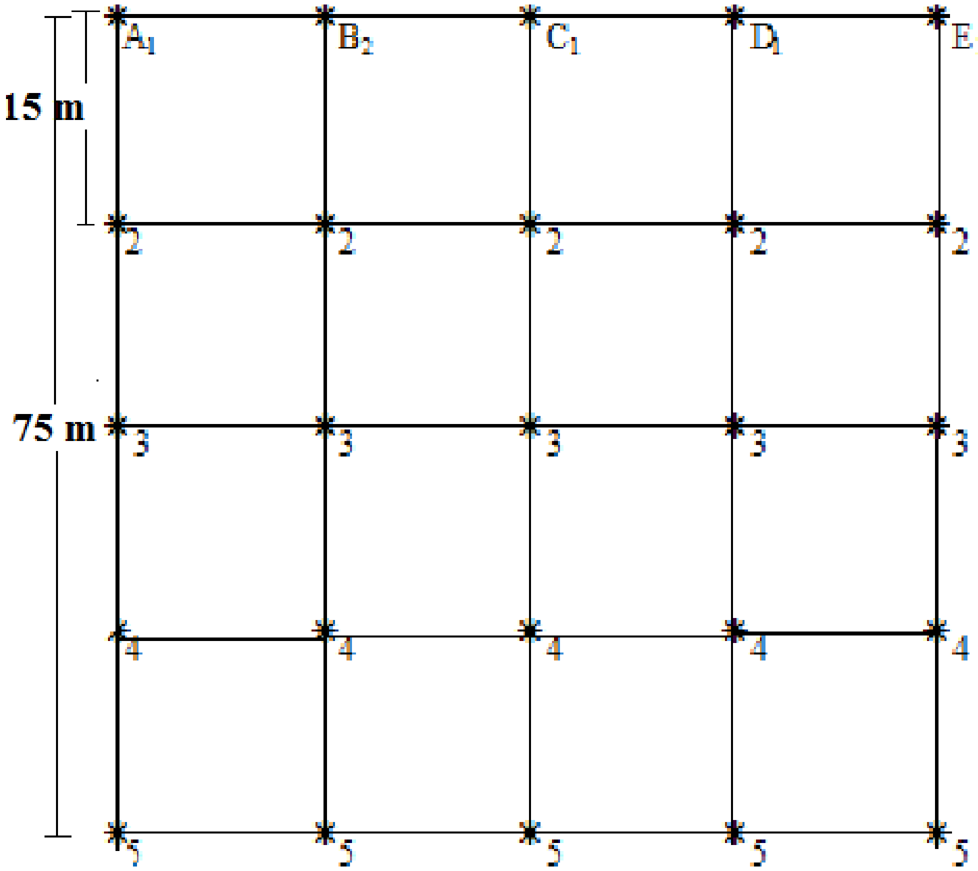
Items	Yes	No	I do not know
Damage to agricultural crops			
Damage and spoilage to household items			
Disease causing and transmission			
Discomfort, terror and biting			

50. Despite their damage, do you believe that the following small mammals provide positive ecological, economical and social functions

Functions Provided	Rodents			Bats			Shrews		
	Yes	No	Not sure	Yes	No	Not sure	Yes	No	Not sure
Source of human food									
Source for other wild animals									
Medicine									
Insect pest control									
Pollination and seed dispersal									
Income generation from tourism									
Soil fertility									
Traditional belief and culture									
Education and research									

Thank you!!

Appendix 10. Diagramtic representation of trapping grid and traping stations



DECLARATION

I, the under signed, declare that the information provided in this work is an original work, and that it has not been presented in other universities or colleges, seeking for similar degree or other purposes and all sources of materials used for the thesis have been duly acknowledged.

Name: Mohammed Kasso Signature:__________________ Date:__________________