1

General Introduction

1.1 Background

In a natural ecosystem, wildlife interacts with its biotic and abiotic environment through various ecological processes and these processes determine the population dynamics of a species (Crawley, 1997). Understanding the factors impacting these ecological processes and monitoring their impact on the ecosystem is essential for wildlife population management (Odum, 1974, Månsson and McGlade, 1993).

Ethiopia has ecologically diverse ecosystems ranging from the desert at 116 m below the sea level to the Afroalpine ecosystem at 4500 m above sea level. This diversity brings about the evolution of a variety of endemic animal and plant species. The flora of Ethiopia is estimated between 6500 to 7000 species, of which 12% are endemic (Teketay, 2001). The fauna is also highly diverse; 277 species of mammals, 861 species of birds, 201 species of reptiles, 63 species of amphibians, 150 species of fish and 324 species of butterflies (Yalden and Largen, 1992). Among these, 31 mammals, 16 birds, 24 amphibians, 9 reptiles and 40 fishes are believed to be endemic (Yalden and Largen, 1992). Especially those species confined to Afroalpine ecosystem, such as the gelada baboon (*Theropithecus gelada*), walia ibex (*Capra walia*), Spalacidae and Murinae rodents, mountain nyala (*Tragelaphus buxtoni*), and the charismatic top predator of the Afroalpine ecosystem, the emblematic Ethiopian wolf (*Canis simensis Rüppell 1835*), are unique to Ethiopia.

The main threat to wildlife conservation in Ethiopia is habitat destruction. The rapidly expanding human population has converted highland wildlife habitats into agricultural land (Ashenafi, 2001, Marino, 2003b). The highlands of the country, which are rich in biodiversity, are inhabited by more than 80% of the total population of Ethiopia, practicing traditional poor and unsustainable agriculture that destroys natural habitats (Woldemariam, 1991, Ashenafi, 2001). These highland areas, although extensively modified

by man and densely settled, still represent a unique habitat for wildlife; particularly the land above the limit of agriculture, currently between 3500 and 4000 m above see levels across the Ethiopian highlands. The total area of Afroalpine highlands under any form of protection covers over 80% of the remnant habitats (Marino, 2003b, EWCP, 2013); yet conflicts resulting from wildlife conservation and land demand for agriculture and livestock grazing in the protected area are increasing. To solve these rising conflicts, research based solutions within the context of chronic poverty exist in the country are needed.

The Ethiopian wolf is one of the Ethiopian endemic species listed as Endangered by the IUCN Red list (Marino and Sillero-Zubiri, 2011). It occupies a specialist niche, living only in Afroalpine habitats and feeding on a diet of rodents, many of which are also endemic to the Ethiopian highlands (Gottelli and Sillero-Zubiri, 1992, Sillero-Zubiri and Gottelli, 1995, Ash, 2001, Marino, 2003b, Ashenafi *et al*., 2005). The long term impacts of development in Afroalpine ecosystem are affecting these and other endemic species, and the sustainability of important ecosystem services (Power, 2010). For example, overgrazing of Afroalpine pastures is a particular concern, due to its potential cascading effect on food webs and ecosystem services (Mwendera and Saleem, 1997, Vial *et al*., 2011b). Because of these growing threats, my thesis focuses on the interactions between Ethiopian wolves, rodents and human communities in Afroalpine ranges of North Ethiopia, which serves as habitat for the wolf, rangeland for livestock and a source for other products.

1.2 Canidae and the Ethiopian wolf

The family Canidae is one of the most widely distributed families of the Order Carnivora (Bekoff *et al*., 1984). It is composed of 34 living species of dogs and foxes (Macdonald, 1990, Ginsberg and Macdonald, 1990). The rich diversity of this family reflects the success of the different species (Hunt, 1996), with a wide variety of behavioural and ecological adaptations. Canids display a considerable intra-specific variation in social structure, habitat use and food preference (Bekoff *et al*., 1984) and also exhibit strong flexibility to environmental constraints (Carbone *et al*., 2007). This makes them potentially strong competitors (Johnson, 1973). Besides their socio-cultural value, they play a critical role in maintaining a healthy ecosystem, mainly by regulating predator-prey dynamics (Martin, 1989).

The Ethiopian wolf is a close relative of the grey wolves (*Canis lupus*) and coyotes (*Canis latrans*), rather than to jackals (*Canis aureus*) and the African wild dog (*Lycaon pictus*) (Gottelli *et al*., 2004). Throughout Ethiopia, the Ethiopian wolf is also known as *Key Kebero*, *Seren* and *Walge* by the Amharic speakers of the North and *Jedella Ferda* and *Arouaye* by the Oromifa speak-

ers of the South (Ashenafi, 2001). Morphologically, Ethiopian wolves are medium-sized canids with a reddish coat, distinctive white markings, long legs and elongated muzzle. Males are considerably larger (with a mean weight of 16.2 kg) than females (12.8 kg) in terms of body mass (Gotteli *et al*., 1994).

The Ethiopian wolf is the rarest canid in the world and the most threatened African carnivore. They are social canids with the smallest distribution range in the world. Fewer than 500 individual wolves survive, distributed over six isolated mountain ranges of Ethiopia at altitudes of 3200-4500 m above sea level (Gottelli and Sillero-Zubiri, 1992, Marino, 2003b, Marino and Sillero-Zubiri, 2011). More than half of the population lives in the Bale Mountains National Park in southern Ethiopia. The other populations in the Northern Ethiopia are very small, most of them with less than 50 individuals and restricted to areas above 3700 m above sea level threatened by agriculture and overgrazing (Marino, 2003b).

The Ethiopian wolf is a good flagship species for the conservation of the Afroalpine ecosystem. Their rodent prey are also key components of the Afroalpine biodiversity, because they are the dominant herbivores and burrowers that play a role as ecosystem engineers (Davidson *et al*., 2008, Vial *et al*., 2011a).

1.3 Afroalpine ecosystem

The Afroalpine landscape consists of mosaics of different micro habitats, which are subjected to natural and human caused disturbances (Stephens *et al*., 2001, Vial *et al*., 2011a). Some disturbances have complex impacts on the ecosystem and the organisms living in it, such as livestock grazing and trampling, which have been shown to affect spatial distribution and habitat selection of rodents (Sillero-Zubiri *et al*., 1995a, Ashenafi *et al*., 2012). Therefore, protecting Afroalpine biodiversity and ecosystem services they provide is critical to sustain populations of important species of rodents and internationally recognized threatened species like the Ethiopian wolf, the gelada baboon and the walia ibex.

There are three ecological zones in the highlands of Ethiopia, according to their altitude and climate, known as Afroalpine zone, subafroalpine zone and Afromontane forests or grassland zone (Kingdon, 1990). The altitudinal ranges of these ecological zones lay between 3200-4500 m above sea level. About 2% (22,750 km^2) of the total land area of Ethiopia is above 3000 m (Yalden, 1983). Of that, ~ 10% consists of Afroalpine steppes and montane grasslands suitable for the Ethiopian wolf. Wolves are solitary diurnal predators of endemic rodent communities in these high mountains of the Afroalpine ecosystem (Sillero-Zubiri and Gottelli, 1995, Tallents *et al*., 2012). Agriculture and growth of human-livestock populations result in increased

pressure on the Afroalpine ecosystem during the last decades and this has led to the confinement of the ecosystem only in a few localized high mountain pockets (Gottelli and Sillero-Zubiri, 1992, Marino, 2003b). For example, Bale Mountains National Park has been under increasing pressure from a rapidly growing livestock and human population, with an increasing household numbers from estimated 7000 in 1992 to 35,000 in 2009 (Vial *et al*., 2011). Around these mountains a wide range of farming systems has developed with unsustainable agricultural practices and the cumulative area used for crop farming increased by 10% with crops being grown at altitudes as high as 3500 m in Bale and up to 3700 m in North Ethiopia (Marino, 2003, Vial *et al*., 2011). Moreover, the livelihoods of local communities depend on Afroalpine natural resources that threaten the rodent biodiversity through grazing, firewood collection, water extraction, and unprecedented land encroachment (Ashenafi *et al*., 2012, Eshete *et al*., 2015). As natural resources become overexploited, the loss of natural habitats threatens many rare and endemic fauna and flora. For example, land degradation shows a similar history across the African savanna ecosystem, which declines in surface and is progressively losing populations of lions (*Panthera leo*) and numerous ungulates (Riggio *et al*., 2013).

1.4 Rodents as an indicator of Afroalpine ecosystem quality and Ethiopian wolf prey

Small mammals are important components of most of the terrestrial natural ecosystems of the world (MacCracken *et al*., 1985, Kerley, 1992). They play a vital role in the ecological integrity of a given ecosystem, being the most numerous of the small mammals, both in abundance and species diversity (Delany, 1986), and also distributed worldwide (Kingdon and Pagel, 1997, Nowak, 2005). In East Africa, rodents account for 28% of the total number of mammal species (Delany, 1986, Kingdon and Pagel, 1997, Clausnitzer *et al*., 2003). In Ethiopia, rodents comprise 25% of the Ethiopian mammal fauna and about 50% to the total number of endemic species (Yalden and Largen, 1992, Bekele, 1996). In particular, the Afroalpine ecosystem contains the highest number of all mammals' endemics, including 14 endemic species of rodents (Yalden and Largen, 1992). The Afroalpine landscape lacks many larger ungulates, but harbours many smaller mammals, including molerats (Spalacidae) and grass rats (Murinae) in high abundance (Sillero-Zubiri *et al*., 1995a, Vial *et al*., 2011a). Temperature extremes can limit mammalian distribution but the rodents confined to the Afroalpine habitat avoid extreme cold by digging burrows of about 50 cm depth to retain constant temperature despite its fluctuation (Sillero-Zubiri *et al*., 1995a, Marino *et al*., 2003a).

Within ecosystems rodents can play an important role in seed dispersal, pollination, and habitat modification (Johnson *et al*., 2001, Dickman, 2003) and they are also the prey base supporting carnivores and raptors. Moreover, because of their rapid responses to environmental changes, rodents in Afroalpine ecosystem are viewed as model organisms for the study of on-going ecological processes and serve as good indicators of environmental quality (Clausnitzer *et al*., 2001, Avenant, 2011, Vial *et al*., 2011a). In general, changes in habitat structure and complexity are associated with changes in rodent community structure and species richness (Delany, 1986, Avenant, 2000, Vial *et al*., 2011a). An ecological disturbance of the rodent habitat is often associated with decreases in rodent diversity (Bekele *et al*., 1993, Ashenafi *et al*., 2012). Therefore, the biodiversity of rodents can be used as an indicator of disturbance in an ecosystem (Avenant, 2011). As a result, monitoring of rodents is becoming the quickest and cheapest method of indicating the quality of ecosystem functioning for example, in the grasslands of South Africa (Avenant and Cavallini, 2007).

The diversity, abundance and distribution of rodents can be affected by several biological and physical factors, including predator number, competition within or with other species, resource levels (especially the availability of food and water) and human land uses, particularly livestock grazing (Kelt, 1996, Bekele, 1996). Many studies have related the structure and species richness of rodent communities to variables such as changes in habitat structure, vegetation cover, climatic and physiological factors (Avenant, 2000, Avenant, 2011, Vial *et al*., 2011a, Ashenafi *et al*., 2012).

As rodents in Afroalpine ecosystem are the dominant herbivores of the food chain and the main prey of the Ethiopian wolf (Sillero-Zubiri *et al*., 1995a, Sillero-Zubiri and Gottelli, 1995) ecological studies of the rodent community are important in their own right, given their high levels of endemism and additionally, to assess habitat quality for their predators (Sillero-Zubiri *et al*., 1995a, Ashenafi *et al*., 2005). For example, as top predators of the Afroalpine ecosystem, Ethiopian wolves attain densities as high as 1.2 animals per km^2 in prime or quality habitats without other known predator except man (Sillero-Zubiri and Gottelli, 1995).

1.5 Feeding ecology and foraging behaviour

Members of the Order Carnivora are distinguished from other mammals by their carnassial dentition and the high proportion of vertebrates in their diet (Bekoff *et al*., 1984). However, there are many differences between the species in terms of their feeding ecology and foraging behaviour (Bekoff *et al*., 1984, Carbone *et al*., 2007). These patterns on feeding and foraging behaviour change in response to variations in biotic and abiotic factors, such

as prey preferences, prey density, predator density, seasonality and weather (Hayward and Kerley, 2005, Stahler *et al*., 2006, Bauer *et al*., 2008).

Information on diet composition is crucial to understand predator-prey relationships (Jedrzejewski *et al*., 2002, Hayward and Kerley, 2005, Bauer *et al*., 2008), particularly when predators are perceived as a threat to livestock (e.g. cheetahs *Acinonyx jubatus* Marker *et al*., 2003) or when rare prey species need to be protected (e.g. the prey of the endangered Andean cat *Leopardus jacobita*, Napolitano *et al*., 2008). More generally, information on the feeding ecology of carnivores contributes substantially to the understanding of their behavioural ecology and management (Mills, 1992, Sogbohossou *et al*., 2011). For example, being a highly adaptive and behaviourally flexible carnivore, wolves have evolved to hunt prey of different size and they are most commonly categorized as cursorial hunters of large ungulates (Peterson and Ciucci, 2003, Stahler *et al*., 2006). As a result, much of the physical, behavioural, and ecological characteristics of wolves are directly related to their predation and feeding ecology (Stahler *et al*., 2006).

When the Ethiopian wolf was first recorded in the Simien Mountains of North Ethiopia, it was described that they were hunting in small packs and killing sheep and small game (Harper, 1945) a rare behaviour also observed in the Bale Mountains, where wolves occasionally kill young antelopes (Sillero-Zubiri and Gottelli, 1995). However, Brown (1964) was the first to note that small rodents were the main diet of the wolves and that, they forage mostly alone. Later, research by Morris and Malcolm (1977) and Sillero-Zubiri and Gottelli (1995) in the Bale Mountains suggested that giant molerats (*Tachyoryctes*) were the most important food source, followed by grass rats (*Arvicanthis blicki*), swamp rats (*Otomys typus*) and Starck's hare (*Lepus starcki*).

Ethiopian wolves live in packs that communally defend their territory and pack members come together for social greetings and to conduct patrols at dawn and dusk (Sillero-Zubiri *et al*., 1997). In contrast, and unlike social carnivores, Ethiopian wolves are solitary when foraging and feeding on rodents (Sillero-Zubiri and Macdonald, 1998). It is believed that in areas of lower prey densities, Ethiopian wolves may prey livestock in small groups, and to become crepuscular and nocturnal where human interference is severe (Sillero-Zubiri *et al*., 1997, Marino *et al*., 2010). Ethiopian wolves use different tactics to ambush and kill rodents, digging prey out, running in zigzag across rat colonies and stalking their prey (Sillero-Zubiri and Gottelli, 1995). While in the Bale Mountains the giant molerat is one of the main prey of the Ethiopian wolf (Sillero-Zubiri *et al*., 1995a) this species is absent elsewhere and in many areas, it is replaced in the diet by the smaller east African molerat (*Tachoryctes splendens*) (Ashenafi *et al*., 2005; Marino *et al*., 2010). Similarly, *Arvicanthis blicki*, and *Lophurmys melanonyx* are common prey in Bale, their respective relatives' *A. abyssinicus* and *L. flavopunctatus* are common in the

diet of wolves in the other populations. The swamp rat (*O. typus*) is a rare common prey in Bale and Guassa-Menz populations (Ashenafi *et al*., 2005) but common in other populations in the northern highlands (Marino *et al.,* 2010). Other rare prey species of Ethiopian wolf includes rock hyrax (*Procavia capensis*), young antelopes, goats and lambs (Morris and Malcolm, 1977, Yalden and Largen, 1992, Gottelli and Sillero-Zubiri, 1992, Marino, 2003a, Ashenafi *et al*., 2005).

1.6 Impacts of human land use

Nowadays, ecosystem degradation and habitat loss due to unsustainable land uses universally considered as important threats to wildlife conservation (Newmark, 1996). Understanding the linkages between social and ecological systems is therefore important for biodiversity conservation (Berkes, 1998). Biodiversity conservation will ensure well-functioning ecosystems that contribute to local people's livelihood through diverse subsistence requirements in a sustainable way, for example fodder, fuel, housing and farming implements (Haverkort and Millar, 1994, Ashenafi and Leader-Williams, 2005, Eshete *et al*., 2015). On the other hand, unsustainable natural resource use and human activity in the ecosystem affects these subsistence requirements and associated animal communities (Ashenafi and Leader-Williams, 2005, Vial *et al*., 2011a). For instance, in the last 40 years in the African Savanna extensive conversion of land to agricultural farm and grazing land has shrunk the ecosystem from 11.9 million km^2 to 9.9 million km^2, which also shrank the habitat of free ranging lions causing population decline and local extinction (Riggio *et al*., 2013).

Farmers in the highlands of Ethiopia also depend on natural pastures and other resources harvested from the Afroalpine ecosystem, to support their agricultural livelihood (Ashenafi and Leader-Williams, 2005, Eshete *et al*., 2015). The Afroalpine habitats provide many goods and services to sustain people's demand for food, fuel, water, medicine and fibers (Ashenafi and Leader-Williams, 2005, Eshete *et al*., 2015). Thus, the management of the Afroalpine ecosystem must balance the importance of the natural resources used by local communities with the intrinsic value of the biological heritage of the area (IUCN/SSC, 2011). However, Afroalpine ecosystem is one of the few areas in Ethiopia where the long-term anthropogenic land use change influences on mammalian wildlife such as Ethiopian wolf (Stephens *et al*., 2001). Current research also demonstrated how different forms of human land use can affect the community structure and population dynamics of individual species of Afroalpine rodents (Ashenafi *et al*., 2012, Vial *et al*., 2011a). Studies investigating rodent population dynamics elsewhere in Africa have also shown the effect of various human land uses such as livestock

grazing on the abundance and composition of the small mammal fauna (Delany, 1986, Leirs *et al.*, 1997, Keesing, 1998, Keesing, 2000, Hoffmann and Zeller, 2005). Rodent studies in Africa suggested a decline of rodent abundance during land use changes (Delany, 1986, Happold and Happold, 1991). It is possible, however, that proper land use management systems would allow the use of resources from Afroalpine ecosystem without compromising its unique ecological value, and its socio-economic and aesthetic benefits at local, national and international levels, as the Guassa-Menz community-based conservation area has demonstrated (Ashenafi, 2001, Ashenafi and Leader-Williams, 2005). These substantial ecological and economic benefits can positively influence local attitudes towards the Afroalpine ecosystem and towards its flagship species, the Ethiopian wolf, as indicated in similar studies at different parts of the world (Saharia, 1984, Infield, 1988, Lewis *et al.*, 1990).

1.7 Human–carnivore conflict

Globally, carnivores are among the most threatened of the terrestrial mammals (Ceballos *et al.*, 2005). The large home ranges, low population density and slow population growth of carnivore make them vulnerable to extinction (Dickman, 2010). However, the most urgent threats to carnivores, result from habitat degradation, natural prey decline, conflict related persecution and disease (Fuller, 1995, Forester and Machlist, 1996, Nowell and Jackson, 1996, Weber and Rabinowitz, 1996, Kissui and Packer, 2004). For instance, the recent loss of habitat, shrinking of prey populations, and direct persecution has resulted in a dramatic decline of endangered species like cheetah, African wild dog and lion (Kingdon and Pagel, 1997).

Increasing human population and the subsequent demand for food, space and natural resources pose pressure on carnivore habitats (Inskip and Zimmermann, 2009, Karanth and Chellam, 2009, Dickman, 2010), creating human–carnivore conflicts, where carnivore populations increase, or humans encroach into their habitat (Woodroffe, 2000). This close proximity between humans and carnivores may end up in high levels of conflict and result in retaliatory killing of carnivores by humans leading to population decline, range contraction, and in some cases, extinction (Mishra, 1997, Woodroffe and Ginsberg, 1998, Cardillo *et al.*, 2005, Woodroffe, 2005, Sogbohossou *et al.*, 2011).

Human-carnivore conflicts are common throughout Africa and a real challenge for carnivore conservation (Woodroffe *et al.*, 2005). Livestock depredation is the single most important cause in Africa and elsewhere in the world (Frank *et al.*, 2006). Another common reason of conflict with large carnivores is attacks on humans, or the fear that it creates (Packer *et al.*, 2005). In turn, many factors determined the occurrence of livestock predation by

wild carnivores and people's predisposition to conflict, such as the proximity to a protected area, the time of the year, and the size of the livestock herd (Van Bommel *et al.*, 2007).

Human–carnivore conflict attracts the greatest attention when it involved threatened species or poses a serious threat to human welfare (Saberwal *et al.*, 1994, Packer *et al.*, 2005). Therefore, efforts to identify and implement mitigation strategies for human–carnivore conflicts are required (Inskip and Zimmermann, 2009). In order to propose viable and effective site-specific interventions, spatial and temporal patterns of conflicts have been studied and incorporated as part of the solution (Treves and Karanth, 2003, Woodroffe *et al.*, 2005, Inskip and Zimmermann, 2009, Dickman, 2010).

1.8 Human–Ethiopian wolf conflict

In Ethiopia the main causes of the decline of the Ethiopian wolf are driven by the loss of Afroalpine habitat, habitat fragmentation, diseases transmitted by domestic dogs, and, to a lesser degree, hybridisation with domestic dogs and loss of genetic diversity (Sillero-Zubiri *et al.*, 1997, Laurenson *et al.*, 1998, Ash, 2001, Marino *et al.*, 2003, Randall *et al.*, 2007). This heavy pressure, coupled with other physical and socio-economic factors, is creating conditions for human–Ethiopian wolf conflicts (Ashenafi, 2001, Marino, 2003b). This is most likely to occur in the Northern highlands of Ethiopia where the human population is one of the highest in Africa (Sillero-Zubiri *et al.*, 1997). For example in Tigray, the high human density and depletion of the prey base are perhaps the most important causes for human–hyena (*Crocuta crocuta*) conflict (Yirga *et al.*, 2012).

One of the potential drivers of the human–wolf conflict in the Northern highlands is the economic impact of losing small-stock (sheep and goats) to carnivores (Marino, 2003b, Ashenafi *et al.*, 2005, Yihune *et al.*, 2008). For instance the golden jackal is the main predator of livestock in the Northern Afroalpine habitats including this study area (Marino, 2003b). Although Ethiopian wolves are very rare, they occur locally in fairly high densities and conflict with people whose livestock share their foraging grounds (Sillero-Zubiri *et al.*, 1997). Predation on livestock could indicate the degradation of the Ethiopian wolves' natural habitat, forcing them to prey upon small-stock in areas where agricultural practices and overgrazing have depleted the rodent prey (Sillero-Zubiri *et al.*, 1997, Marino *et al.*, 2010, Stephens *et al.*, 2001, Vial *et al.*, 2011b, Ashenafi *et al.*, 2005), getting in conflict with the local communities (Nievergelt, 1998, Marino *et al.*, 2010). The level of conflict between humans and the Ethiopia wolf, a specialized rodent hunter, is not well-researched, however, conflict mostly stems from perceived rather than real threats to property loss (as observed in other cases involving carnivores

Treves and Karanth, 2003). For poor subsistent farmers the loss of a single livestock due to wildlife can have substantial negative influence on their attitude to co-exist with wildlife. However, so far there is no evidence of people killing Ethiopian wolves for retaliation or for other reasons (Eshete *et al*., 2015).

Other human–wolf conflicts in Afroalpine ecosystem are associated with crop damage caused by primates, several bird species, and rodents; these crop raiders are known to diminish or destroy the farmers' food and cash crops (Personal observation), and farmers often respond to this conflict by poisoning, shooting and trapping targeted and non-targeted animals for example as observed in India (Sekhar, 1998). The damage caused by other Afroalpine species, such as the gelada baboon, hyrax, porcupine, rodents and many bird species to barley and potato fields are also poorly understood. These crop raiders can affect the livelihood of local households, depending on their level of economic security, and influence their attitude towards wildlife and Afroalpine conservation. The Ethiopian wolf can have a positive biological role in controlling rodent populations that can damage crops, which are considered as crop pests, but this role is not often recognized by local people (Personal observation).

1.9 Perception and factors influencing human perception

Wildlife conservation success depends on the attitudes of people towards conservation (Ebua *et al*., 2011). Historically, fear and persecution of wildlife dates back many centuries in some societies. Some wildlife species have long been viewed as a direct threat to human life, for example, wolves in Europe and North America (Boitani, 1995). In the 19th and 20th century, in England and America, people attempted to eliminate wolves from their homeland (Boitani, 1995, Kellert *et al*., 1996).

In Africa, the attitudes and perceptions of local communities towards wildlife and areas of wildlife habitat have been positive historically (Lewis *et al*., 1990, Newmark *et al*., 1993, Siachoono, 1995). However, these attitudes changed with the introduction of the American model of protected area conservation that focused on protecting wildlife denying the needs and aspiration of the people living adjacent to the protected area (Ghimire and Pimbert, 1997). The change of African people's attitude towards wildlife results in loss of wildlife and shrinking of their habitat.

In some areas for example in Tanzania, agreements between communities living adjacent to wildlife areas and the conservation authorities has allowed for an equitable distribution of wildlife costs and benefits (IIED, 1994, Otto *et al*., 1994, Leader Williams *et al*., 1994). From this experience it was learned that, before any alternative conservation strategies is implemented,

the relationship between the wildlife and local people must be clearly understood (Leader Williams *et al*., 1994). So, understanding human attitudes and potential reasons for human–wildlife conflicts in the area is critically important to design long-term conservation strategies (Heinen, 1993, Mordi, 1991).

Increasing knowledge and awareness about wildlife are fostering coexistence between people and wildlife in urban areas (e.g. coyotes in the USA Draheim *et al*., 2013). Moreover, assessing attitudes of people living with wildlife populations and identifying the determinants of these attitudes are a key step in learning how to work with people on these issues (Draheim *et al*., 2013). Negative attitudes of humans towards carnivores in Buthan for example, have been linked to restricted resource use rights, livestock depredation, crop raiding, lack of compensation strategies and exclusion of farmers from the conservation planning processes (Wang *et al*., 2006). On the other hand, positive attitudes were associated with an expectation of economic benefits from integrated conservation development programmes in the National park (Wang *et al*., 2006). Other studies on rural communities in developing countries have also found that access to conservation-related benefits can positively influence local attitudes (Saharia, 1984, Infield, 1988, Lewis *et al*., 1990, Brunner *et al* 2011, Eshete *et al*., 2015). However, if benefits are perceived as small in relation to losses or inequitably distributed, they may not achieve this required effect (Homewood *et al*., 1997, Gillingham and Lee, 1999). Therefore, monitoring public concerns and addressing them promptly can help to strengthen conservation efforts by handling properly the human component of wildlife management (Draheim *et al*., 2013).

Overall, Figure 1.1 summarizes and illustrates the existing human–Ethiopian wolf interactions in Afroalpine ecosystem in North Ethiopia.

1.10 Hypotheses, aims and research questions of the thesis

Based on the background information presented above, my proposed model of human–wolf interactions in the Afroalpine ecosystem and field observations, I hypothesise that:

1. Ethiopian wolves are predominantly feeding on wild prey and I expect domestic livestock is not a dominant part of the diet of Ethiopian wolves in the study area.
2. Livestock grazing affects rodent density and species richness and I expect high rodent density and species diversity in areas managed without livestock grazing.

With my research in human dominated Afroalpine landscapes of North Ethiopia, specifically Borena Sayint National Park in South Wollo highlands,

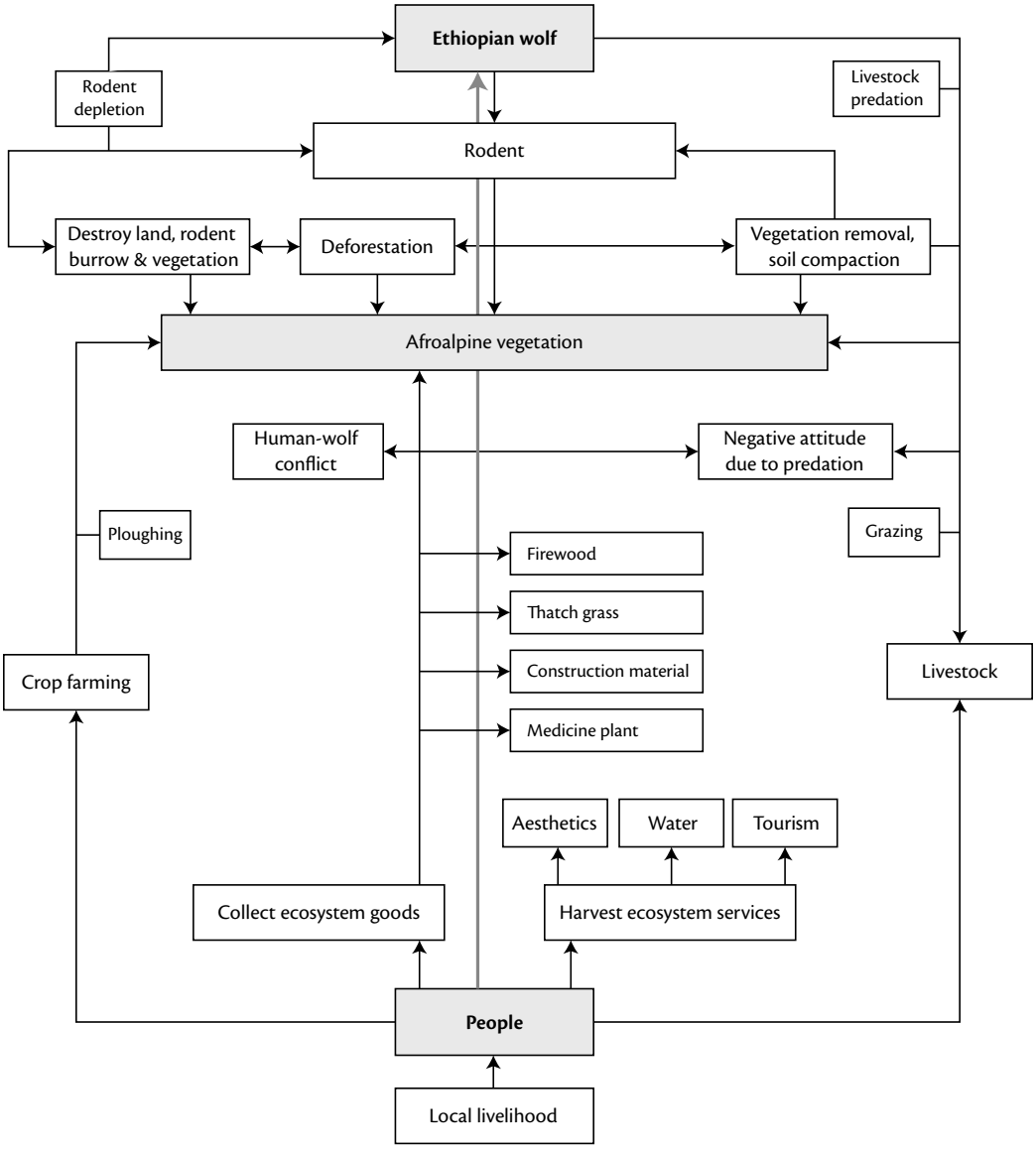

Figure 1.1
Human–wolf interactions in Afroalpine ecosystem

Abune Yosef and Aboi Gara massifs in North Wollo highlands, I investigate the general relationship between Ethiopian wolf, rodent communities and the surrounding human land uses, focusing on both ecological and socio-economic interactions, to answer the following research questions:

1 Are Ethiopian wolves involved in livestock killing/feeding and how does human perception reflect the damage done?
   - **a** What are the prey species in the Ethiopian wolf diet?
   - **b** How much is the contribution of each prey species to the total diet composition of the Ethiopian wolf?
   - **c** Are rodents the prime prey species of the Ethiopian wolf in human dominated North Ethiopia?
   - **d** What feeding preference do Ethiopian wolves have for commonly occurring rodents in the area?
   - **e** What is the perceived damage to livestock and does it affect people's perception of Ethiopian wolf?

2 How does livestock grazing affect Afroalpine rodent communities?
   - **a** Is there a difference in rodent density and species richness in areas managed with or without grazing?
   - **b** Which microhabitat factors are affected by livestock grazing and influence rodent density in the study area?

3 What are the Afroalpine resources used by local communities and their perceptions of Afroalpine conservation?
   - **a** Do people who receive economic benefit from Afroalpine natural resources support Ethiopian wolves and their conservation?
   - **b** What socio-economic factors influence people's perception towards Ethiopian wolf and the conservation of its habitat?
   - **c** What is the extent and pattern of livestock (sheep and goat) losses by Ethiopian wolf and its economic implication on local communities in the study area?
   - **d** What are the socio-economic factors influencing livestock predation by the Ethiopian wolves that lead to human–wolf conflict?

1.11 Study area

1.11.1 Ethiopia

Ethiopia is located in the horn of Africa between 3° and 18° North latitude, 33° and 48° East longitude, lying within the tropics. It comprises an area of 1,127,127 km^2. The altitudinal variation ranges from 110 m below sea level to 4620 m above sea level. The Great Rift Valley runs from the Northeast to the Southwest dividing the Ethiopian highlands into the Northern and Southern massifs. The highlands on each side of the rift valley give way to extensive semi-arid lowlands to the east, south and west of the country. Ethiopia has 50% of all the Afrotropical lands that lay above 2000 m and 80% of the land

above 3000 m (Yalden and Largen, 1992). The highlands of Ethiopia are a huge volcanic dome formed from eruptions (70 to 5 million years ago) that deposited a thick layer of basalt, up to 3000 m deep. The Northern highland is the largest highland massif subdivided into the Showa highlands, the Wollo highlands, the Gojam and Gondar highlands, and the Tigrean plateaus (Ashenafi, 2001). My study sites in Ethiopia are located in Afroalpine areas of Northern highlands, including the Borena Sayint National Park of South Wollo, Abune Yosef and Aboi Gara massifs of North Wollo.

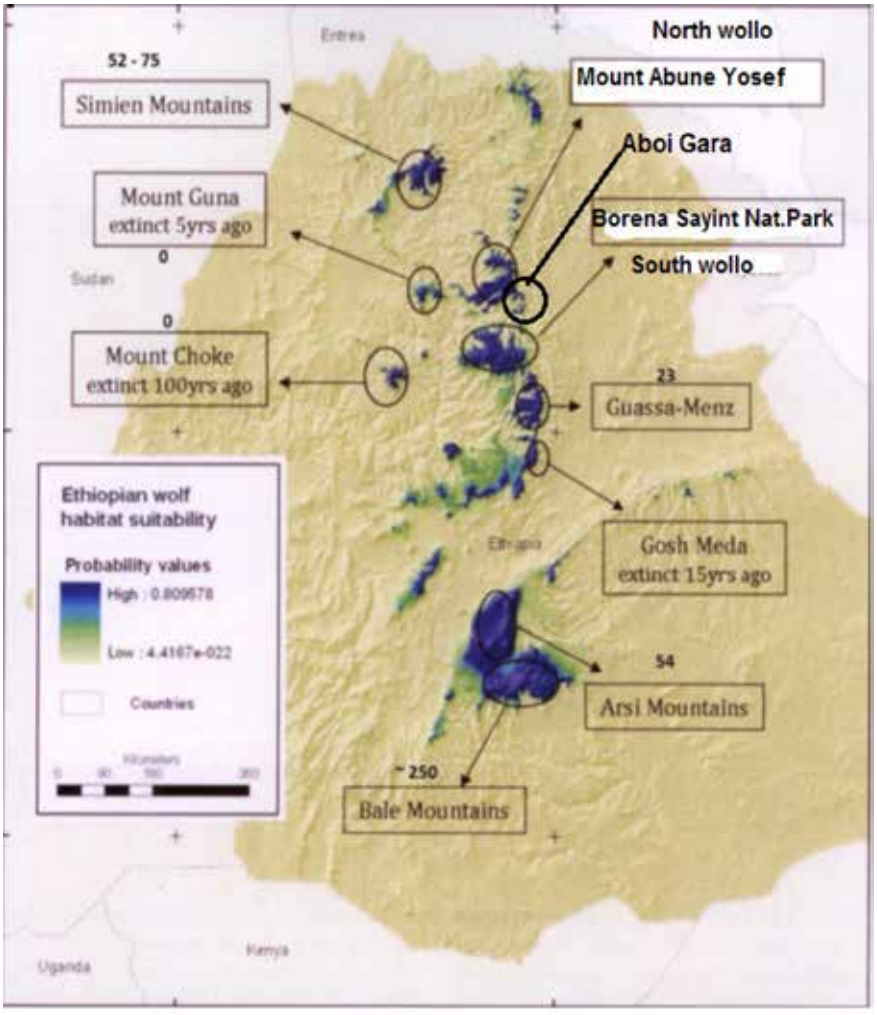

Figure 2
Map indicating areas of Afroalpine ecosystem including areas with extinct wolf populations by years in Ethiopia and the study sites Borena Sayint National Park, Abune Yosef and Aboi Gara in South and North Wollo highlands (© EWCP)

South Wollo highlands and the Borena Sayint National Park (BSNP)

BSNP is located in South Wollo highlands between $10^0$50' 45.4"-10^0 57'03" latitude and $38^0$40'28.4"-$39^0$10'39" longitude within altitudinal ranges of 2300 to 4280 m above sea level. Primarily, BSNP was recognized as '*Denkoro Chaka*' (Personal communication). The Amharic word '*Denkoro Chaka*' means "Deaf forest" in English, inferring communication difficulty inside the thick forest. According to the local legend, the area had received conservation attention since the time of Emperor Zara Yakob in the 15th century (Adal, 2014). It was also believed one of the natural forest areas protected during the reigns of Emperor Menelik II (1844-1913) and Haile Silassie (1930-1974). Later in 1973 it was protected as a priority state forest area. More recently, in 2009 the forest together with its adjacent Afroalpine areas was entitled as BSNP by proclamation number 68/2009 (Adal, 2014, Eshetu, 2014). Currently, BSNP proposed extension into all the South Wollo highlands and covers an area of 153 km^2 (Adal, 2014, Eshetu, 2014), while the overall South Wollo highlands harbour 243 km^2 of suitable habitats for wolves ranking the fourth most important wolf habitat in Ethiopia (EWCP, 2013, Marino, 2003b). This highland consists of a main central plateau with narrow ridges extending in several directions. In most part of the central plateau a suitable wolf habitat is limited by high-altitude agriculture over 3700-3800 m above sea level. However, inside the park where there are protected areas as low as 3400 m above sea levels are still serving as a wolf habitat. Guguftu, one of the suitable wolf habitats to the East of South Wollo highlands, is already dominated by rapidly expanding agriculture. No more than 50 individual Ethiopian wolves were estimated to survive in the South Wollo ranges (EWCP, 2014). BSNP is characterised by rough topography composed of rugged mountain peaks, deeply incised valleys, gorges, escarpments, flat-topped plateaus, rolling plains and cliffs. Geologically, the area has thick tertiary volcanic deposits with soils comprising mainly of lithosols (Yazezew *et al*., 2011).

There are eight intermittent rivers originating from BSNP and flowing down into the Blue Nile or its tributaries (Adal, 2014). Denkoro River is the main river which flows demarcating Borena and Sayint districts from East to West to join directly the Blue Nile. In addition there are many springs, swamps and water bogs inside and outside the park for wildlife, human and livestock. The park includes three agro-climatic zones according to the Ethiopian traditional climatic zone groupings: *Wurch* (the alpine and subalpine), *Dega* (highland) and *Woina dega* (mid-highland). The pattern of rainfall is bimodal, with a long rainy season from June to September and a short rainy season from March to April. The short rainy season is erratic and highly variable. The dry period is characterised by warm temperatures during day time, but the Afroalpine areas is mostly very cold during night and morning.

Based on the altitudinal range from low land to highland there are three types of vegetation in BSNP and the surrounding highlands: the Afromona-

tane forest, the subalpine and Afroalpine vegetation. The Afromontane forest is the narrow remnant strip of forest dominated with big endemic trees of *Hagenia abyssinica, Podocarpus flacatus, Juniperus procera.* The subalpine and Afroalpine vegetation is characterised by moorland and grassland vegetation such as *Erica* trees, *Hypericum revolutum, Helycrisum splendidum*, *Lobelia rhyncopetalum*, *Eurphous pinifolus, Kniphofia foliosa* and *festuca* grasses. Overall, a total of 354 species of vascular plants representing 265 genera and 95 families has been identified in the area (Adal, 2014).

BSNP is a home for different types of wildlife. More than 23 mammals and 77 different birds have been identified so far (Lakew *et al*., 2007). Ethiopian wolf, gelada baboon, Stark's hare *(Lepus starcki)* and Menelik's bushbuck (*Tragelaphus scriptus meneliki*) are the four endemic large mammals ranging in the park. The park is also home for 10 endemic birds of Ethiopia (Lakew *et al*., 2007).

North Wollo highlands: Mount Abune Yosef and Aboi Gara

Mt Abune Yosef (4286 m) and Aboi Gara (4008 m) are located in North Wollo highlands. Mt Abune Yosef, near Lalibela situated between $12^{0}8'7"$N and $39^{0}15'7"$ E, higher Afroalpine massif intermittently connected by a series of narrow ridges with the smaller Aboi Gara to the east covering 140 km^2 suitable wolf habitats (EWCP, 2013). It is one of the long isolated mountain peaks in the Northern massif with a total area of 50 km^2 protected area and the second peak of Amhara National Regional State after Ras Dashen, at 4620 m above sea level, in the Simien Mountains (ESP, 2001, Saavedra, 2009, Eshete *et al*., 2015). Ecologically, all the three Mountains Abune Yosef, Aboi Gara and Ras Dashen are relatively similar. The Abune Yosef massif is part of the mountainous system surrounding and defining the upper Tekeze River, and limited to the east by the fault escarpments of the Rift valley depression. It continues northwards to the Tigrean Plateau and westwards to the Simien Mountains connecting through a chain of ridges and lower mountain systems (1500–2000 m). The area has a rugged topography with a large escarpment surrounded by gorges and very steep slopes, where rocky blocks and stones are scattered all over. There are three high peaks of Mt Abune Yosef: the big Zigit (4080 m), the small Zigit (4035 m) and the Reemgedel (4286 m), providing impressive views over the Afroalpine plateau and fabulously scenic for tourism. Apart from its elevation it is also the largest Afroalpine area left in North Wollo, but small in terms of carrying capacity for Ethiopian wolves. The area is highly disturbed by human activities. Several small villages are located near Abune Yosef that causes extensive interaction with the local community to subsist their livelihood from natural resources of the area. The main threats for this area besides its small size are the loss of Afroalpine habitats due to farming, settlement, deforestation and overgrazing (Marino, 2003, Eshete *et al*., 2015).

The weather conditions in Abune Yosef are extreme, with maximum daytime temperatures close to 20 °C and minimum temperatures below –5 °C during the night, which made the area harsh in terms of climate. According to the traditional climatic zones classification of Ethiopia Abune Yosef belongs to the cold and moist '*Wurch*' (Saavedra, 2009). The climate of the area can be divided into two main seasons, a wet season from June to early September, and a dry season from mid-September to May. Annual rainfall averages some 2000 mm, mostly falling between July and September. Short rains might fall in any month of the year, but mainly in March (ESP, 2001).

A minimum of 43 mammal species, from 19 families and nine orders, have been identified in the Abune Yosef massif. This represents 16% of the species, 49% of the families and 69% of the orders found in Ethiopia (Yalden and Largen, 1992). From the 31 endemic mammal species known for Ethiopia, eight (22%) have been found in the massif (Saavedra, 2009). These endemic mammals are the Ethiopian wolf, gelada baboon, Bailey's shrew (*Crocidura baileyi),* gray-tailed narrow-headed rat (*Stenocephalemys griseicauda*), long-eared bat *(Plecotus balensis),* abyssinian grass-rat *(Arvicanthis abyssinicus, 'dega* rat' *(Desmomys harringtoni)* and Starck's hare. Recently 221 bird species, belonging to 48 families and 16 orders, have been identified in the Abune Yosef massif (Saavedra, 2009). These birds represent 24% of the species, 51% of the families and 70% of the orders found in Ethiopia (Lepage, 2006). From the 16 endemic species found in Ethiopia, six have been found in the massif (35%). The six endemic birds of the area are Yellow-fronted parrot *(Poicephalus flavifrons),* Erlanger's lark *(Calandrella erlangeri),* Abyssinian longclaw *(Paroplasma galinieri),* Abyssinian catbird (*Paroplasma galinieri*), Black-headed siskin (*Serinus nigriceps*) and Ankober serin (*Serinus ankoberensis*). Following the data of the Important Bird Areas of Ethiopia work the Mt Abune Yosef could be the second most important bird area next to Bale in the country (EWNHS, 1996).

The forests around the Abune Yosef massif are characterised by sparsely dotted remnant evergreen forest and with relatively thick strips of *Erica arborea* and *Hypericum revolutum*. The presence of patchy old growth trees indicates the impacts of deforestation in the area. The evergreen forest species are mainly represented by *Juniperus procera*, *Olea africana* and *Hagenia abyssinica*. The Abune Yosef massif shows a complex mosaic of ecosystems where bushlands, woodlands, montane dry forests and Afroalpine grasslands are represented. At the highest altitudes, *juniper* thickets gradually give way to dwarf forests of *Erica arborea* and *Hypericum revolutum*. In the massif, this is the most transformed belt. These ecosystems suffered by diverse levels of human intervention (mainly agricultural activities and livestock grazing) that have dramatically modified their natural (primary) conditions. Its steep slopes are covered by a mosaic of barley cultures and grazed patches of grasses, shrubs, bushes and lobelias. The human impact is lower at the highest al-

titudes, whereas large areas of the middle and lower altitudinal belts are highly modified. Above 3500 m, the '*Wurch*' (alpine) zone occurs, representing the Afroalpine ecosystem. The Afro-subalpine vegetation is characterized by species of the genera *Helychrisum*, *Carex*, *Festuca*, *Agrostis* and the endemic giant lobelia. In the Abune Yosef massif, the Afroalpine ecosystem has been reduced over the last decades as in most of the Ethiopian highlands and it currently remains above 3700 m only (Marino, 2003b). The vegetation of the Afroalpine area consists mainly on large extensions of *Senecio* shrubs with scattered patches of grasslands and rocky areas. On the Northern slopes, grasslands dominate (with *Poa*, *Agrostis*, *Carex*, *Festuca* spp), most of them with short grasses due to heavy overgrazing. Only some areas, characterized by very steep slopes and a high degree of humidity, have long grasses. The moderately steep and large plateau of the Reemgedel is the place where the giant lobelias are abundant, with densities ranging from 800 to 2500 plants per hectare (Saavedra, 2009). Several streams intersect the area and provide a relatively high degree of humidity and water source.

Aboi Gara

Aboi Gara is a small protected area designated as '*community closure area,*' where grazing, agriculture and collection of natural resources are excluded; the area delimited by natural features, has been designated for the purpose of restoring and maintaining biodiversity. This is loosely connected by narrow ridges with the other Afroalpine mountain block of Abune Yosef to the west (ESP, 2001, Marino, 2003b). The area is not legally protected but it is part of the Conservation International's Biodiversity Hotspot (Brooks *et al*., 2004). It has rugged topography surrounded by gorges and steep slopes with shallow rocky soils; depressions and flat plains have deep black soils. Its climate is characterized by extreme diurnal variations with mean annual temperature ranging from 7.5 ^{O}C to 11 ^{O}C. It experiences a bi-modal rainfall pattern, with *'Meher'* the long rainfall period from June to September, followed by *'Belg'*, the short rainfall period from March to April. The annual average rainfall is 2000 mm mostly falling between July and September. Aboi Gara is surrounded by a strip of *Erica arborea* tree patches which serve as distinction boundary to separate the ecosystem from farmlands and settlements. This mountain exhibits a complex mosaic of vegetation including heaths, Afroalpine grasslands and meadows, dominated by *Euryops* spp., *Kniphopia* spp, giant lobelias, '*guassa*' grasses (*Festuca* spp.) and herbs.

It sustains a rich fauna with endemic birds and mammals including Ethiopian wolf, gelada baboon and several Murinae rodent species. The natural resources of the area are also vitally important for the livelihoods of the local communities in providing essential ecosystem goods and services such as fodder, fuel, building materials, farming and household implements for subsistence purposes. Therefore, not to miss all these benefits due to an *area clo-*

sure management, the communities leave aside some Afroalpine areas outside the exclusion zone.

1.12 Outline of the thesis

One of the objectives of this thesis is to investigate the effect of local land uses upon Afroalpine rodent communities and their predator the Ethiopian wolf. I argue that livestock grazing will impact the Ethiopian wolf prey through vegetation biomass removal and soil compaction, and to test these notions. I will measure rodent abundance and species richness under different land uses using live trapping data. There are a number of ecological and sociobiological topics that I will address in this thesis. These are: diet ecology, structure and dynamics of Afroalpine rodent communities under different land uses, resource uses by local communities, and human–Ethiopian wolf conflicts and attitudes. These fields of interest are necessarily interrelated, and the formats of these chapters are outlined as follow:

Chapter 2 describes prey composition of the Ethiopian wolves' diet, based on macroscopic remains such as teeth, bone and hair recovered in wolf droppings from the South Wollo highlands, around the BSNP. By quantifying the contributions of prey species and by comparing them with the reported livestock losses, human perception of Ethiopian wolves as predators of livestock accurately can be verified. This article has been submitted to Tropical Ecology for publication.

Chapter 3 focuses on livestock grazing impacts upon rodent diversity and abundance. This was accomplished by conducting rodent surveys in South Wollo highlands on *state protected area* (BSNP) and *community area closure,* from where livestock grazing has been excluded, and on the adjacent *ranging land,* communal lands with similar plant communities but used for livestock grazing. This article has been submitted to *Biodiversity and Conservation Journal*.

Chapter 4 focus on the uses of natural resources by local community in the Afroalpine ecosystem of Mount Abune Yosef, how these subsidise their livelihood, and how people perceive the conservation of Afroalpine ecosystem and its flagship species the Ethiopian wolf according to their socio-economic status. This article has been already published in *Environmental Management (2015) 56:684-694*

Chapter 5 presents data on the impact of carnivore predation on livestock husbandry in the Afroalpine highlands of Aboi Gara, Northern Ethiopia. A series of interviews were used to quantify the extent and pattern of predation upon small stock, the economic impact on pastoralists, and how this affects people's attitudes towards Ethiopian wolves. By characterizing contemporary patterns of predation and its economic impact this chapter

suggests measures to ameliorate the relationship between local pastoralists and carnivores. This article has been submitted to *Journal of African Ecology*

Chapter Six presents a synthesis of the findings and the general conclusions from chapter two to five. All aspects of the ecology and conservation of the Ethiopian wolf and its rodent prey are considered, specifically with reference to solutions to ameliorate the constraints imposed upon the Afroalpine ecosystem and the local people living by subsistence agriculture.

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