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## Synthesis

### 6.1 Introduction

As set out in the introduction, the Ethiopian wolf is one of the rarest canids in the world and the rarest carnivore in Africa (Gottelli and Sillero-Zubiri, 1992) listed as Endangered on the global IUCN Red list (Marino and Sillero-Zubiri, 2011). It is an endemic species that feeds primarily on endemic rodents (Ash, 2001). For their conservation and protection three aspects are important: a) habitat protection, b) the protection of rodents in the unique Afroalpine ranges of Ethiopia and c) collaboration by local communities. In my thesis I have described the ecology and socio-economic context of the conservation of Ethiopian wolves, with an emphasis on diet ecology, rodent prey dynamics and human–Ethiopian wolf interactions in the highlands of South and North Wollo, in three Afroalpine ranges: Borena Sayint National Park (BSNP) and surrounding areas, Abune Yosef and the Aboi Gara massifs. Here I synthesise these findings, integrating them to discuss the diet of the Ethiopian wolf, the impact of livestock grazing on prey communities, the use of resources by local communities, attitude towards conservation, human–wolf conflict, and the factors driving these conflicts.

### 6.2 Diet ecology of the Ethiopian wolf

Much of the Ethiopian wolf's diet is made up of rodents that dominate the Afroalpine plateaux where they live (Sillero-Zubiri *et al.*, 1995). The abundance of rodents in the Afroalpine ecosystem is phenomenal. However, the Afroalpine ecosystem itself has decreased in size and become fragmented because it has been subject to increasing human pressure and has been impacted by global climate change (Marino, 2003, Eshete *et al.*, 2015). With increasing livestock grazing, the loss and degradation of Afroalpine habitats are expected to impact the rodent community, challenging wolves to adapt

to an anthropogenic landscape (Stephens *et al.*, 2001, Ashenafi *et al.*, 2005). Particularly in North Ethiopia, where human population densities are higher than in South Ethiopia and habitat degradation is more acute, livestock contributes to the diet of wolves, albeit in relatively small proportions. In addition, most people consider jackals to be a principal predator of small stock (sheep) (Marino *et al.*, 2010).

In chapter 2, I described the diet of the Ethiopian wolf and quantified the contribution of each prey species. I could verify that wolves are rarely involved in livestock killing, but the perceived damage is enough to trigger negative attitudes among the local pastoralists affected in the South Wollo highlands around the BSNP in North Ethiopia. My results showed the relatively limited contribution of livestock to the Ethiopian wolf's diet and the reported losses were not consistent with the negative perception of the Ethiopian wolf held by most households that lost sheep. So my hypothesis that Ethiopian wolves feed predominantly on wild prey in the study area is supported by my findings. Scats collected from there comprised mainly five species of rodent, a few remains of medium-sized mammals, and only a small proportion (5%) of livestock and bird prey remains. Rodents of the families Murinae and Spalacidae were the food items most frequently found in scats. In general, my finding suggests that Ethiopian wolves prefer hunting their natural rodent prey species whenever possible. This may be due to the fact that small mammals are a very cost-effective food resource, requiring less search and manipulation effort than other medium and large prey in the Afroalpine ranges. However, the livestock remains found in scat and the negative perception of households is a wake-up call for pastoralists and conservationists, urging them to work together to maintain a healthy natural prey population of rodents and to avoid a dietary shift towards livestock. In this study Ethiopian wolves do not seem to rely heavily on livestock, but will readily prey if given the opportunity. For example, the availability of so many unattended small stock within easy reach of Ethiopian wolf habitat in the Afroalpine ecosystem may encourage wolves to switch to livestock disregarding their natural rodent prey. Large predators such as lion (*Panthera leo*), snow leopard (*Uncia uncia*) and tiger (*Panthera tigris*) have been found to kill livestock in areas where livestock densities are higher than wild prey (Woodroffe *et al.*, 2005, Bagchi and Mishra, 2006). My study in South Wollo found that the grass rat (*A. abyssinicus*) was the most frequently consumed rodent and not the swamp rat (*O. typus*), as described in a previous study (Marino *et al.*, 2010). A possible explanation is the extensive drying out of swampy habitats in the study area (personal observation). Unfortunately, it was not possible to measure the availability of *O. typus* because the species tends to be trap-shy (Yalden, 1988, Sillero-Zubiri *et al.*, 1995). As a final point, this is the first in-depth study to combine scat analysis with a socio-economic survey in order to describe the diet of Ethiopian wolves in this area.

### 6.3 Ecological relationships of rodents under different grazing land uses

The Ethiopian wolf, unlike most other canids, relies primarily on rodents for food; and this strategy has allowed them to thrive in the Afroalpine grasslands, where rodent biomass is high (Sillero-Zubiri and Gottelli, 1995). Knowledge of rodent ecology and their distribution under different land use types is therefore an important management tool in the Ethiopian wolf conservation strategy (IUCN/SSC, 2011). The ecology of many of the rodent prey species is little known, though the fate of the Ethiopian wolf and its prey species are closely linked. Any intervention detrimental to the Afroalpine rodent communities in particular would have repercussions for the wolf's survival, while the extinction of the wolf would probably destabilise the dynamics of the rodent communities. Particularly, the indirect effect of high-altitude subsistence agriculture and overgrazing, and the direct effect of rodent predation by other predators are important subjects of study. The interwoven fate of these rare endemics in general emphasises the importance of my study in the BSNP.

In chapter 3 of my study, I investigated how livestock grazing influences rodent species richness and abundance among three plant community types (grassland, shrubland and mixed meadows) managed with or without grazing in and around the BSNP. I found evidence that rodent density is higher in mixed meadow habitats than in grassland or shrubland habitats, in areas both with and without livestock. However, overall rodent population density was higher in land managed without livestock. Rodent density was also associated with a greater level of ground vegetation cover, which offers rodents food and shelter. Since this microhabitat for rodents is removed by livestock in grazed land use, land under heavy grazing does support a smaller rodent population. On the other hand, species richness was similar under the two land uses. This means that the existing livestock grazing practices in the area have affected the rodent population density but not the species richness. I expect overall species losses to occur in overgrazed areas in the future, unless the management approach is adapted (Hoffmann and Zeller, 2005). The diurnal species *L. flavopunctatus*, *A. abyssinicus*, *T. splendens*, *O. typus* and the nocturnal *S. griseicauda* are the common rodents in the diet of the Ethiopian wolf in both types of land use in the area. In my capture-recapture survey across the study area *L. flavopunctatus* and *S. griseicauda* were captured in greater number in mixed meadow habitat whereas *A. abyssinicus* was captured in most abundance in 'guassa' grassland habitat. Across the study area as a whole, *L. flavopunctatus* was the most abundant species, followed by *A. abyssinicus*. My diet study suggests that the Ethiopian wolf prefers *A. abyssinicus* to *L. flavopunctatus*. The greater abundance of *A. abyssinicus* in 'guassa' grassland than in shrubland or mixed meadow, and

its relatively high abundance in ungrazed land use, confirms the importance of 'guassa' grassland management in the area in view of the demand for this grass by the local community to supplement their livelihoods. In this survey, rodents captured in grazed land seem to have a larger home range than those captured in ungrazed land. This could be a way to avoid the shortage of food and lack of shelter present in livestock grazed land use. According to my results, livestock grazing reduces the amount of Afroalpine vegetation cover at ground level and affects rodent trap success, abundance and population density. Therefore, the distribution and structure of rodent communities in the study area was presumably associated with vegetation biomass cover and livestock presence, as a driver of changes in vegetation structure.

When I compared rodent assemblages, in Afroalpine ecosystems across the country, I found high rodent population density in BSNP following Bale and Arsi, and this is also a good indicator for BSNP as a potential wolf habitat succeeding Bale and Arsi National Parks in Ethiopia. Since the relationship between vegetation characteristics and the presence of rodents is evident, grazing management practices should avoid unwanted impacts on the rodent populations and their top predator, the Ethiopian wolf. My study suggests that livestock negatively affect rodents by increasing predation risk and creating competition for food. To ensure the survival of the Ethiopian wolf in the Afroalpine ecosystem of Ethiopia, future conservation strategies will need to assess the connection between rodents and vegetation in order to ensure optimal prey for wolves. The structure and population dynamics of the rodent community in the area should play an essential part in this assessment. As indicated in my study, the small mammal populations, their species richness, their density, the status of the vegetation they depend on, and other related microhabitat factors could be used as criteria to assess the stability and health of the Afroalpine ecosystem.

Finally, this work can help to review ecological responses to various grazing management practices in the Afroalpine ecosystem and to develop a conservation strategy that maintains the best rodent prey populations for the small endangered Ethiopian wolf populations. Protecting Afroalpine biodiversity and the ecosystem services they provide is critical and timely in the face of expanding human populations and climate change (Marino, 2003, Eshete *et al.*, 2015). My research on the interface between Ethiopian wolves, their rodent prey and land uses in North Ethiopia, where human density is high and Ethiopian wolf populations small, forms an important contribution to the ongoing monitoring and research work of the Ethiopian Wolf Conservation Programme as mentioned in the Ethiopian Wolf Conservation Strategic Plan (IUCN/SSC, 2011).

## 6.4 Community resource uses and Ethiopian wolf conservation

Ethiopia's Afroalpine ecosystem are immensely important; they form watersheds for the lowlands of north-east Africa (providing water for millions of people), they harbour most of the country's endemic animals and plants, provide local people with thatching grasses, fuel wood, grazing, medicinal substances, construction and farm implements and they are fabulously scenic, so that their value for tourism is also high (Sillero-Zubiri *et al.*, 1997, Ashenafi and Leader-Williams, 2005). The local communities of Abune Yosef also engage in small-scale agriculture and livestock rearing, and depend on the Afroalpine ecosystem for sources of energy, building materials, livestock grazing, and drinking water. Some of these products can be bartered and sold in local markets to access goods and services not locally available (Lewis *et al.*, 1990, Newmark *et al.*, 1993, Winterbach *et al.*, 2013). However, these natural resources are being exploited at an unsustainable rate without formal protection.

In chapter 4, I described how local communities in Mount Abune Yosef support the conservation of the Ethiopian wolf and its Afroalpine habitat. Mount Abune Yosef provides economic benefits to these communities, through unrestricted access to natural resources, while it also sustains a small population of the endangered Ethiopian wolf. I found that people's attitudes towards the Ethiopian wolf and biodiversity conservation were modulated by socio-economic factors, including human-wildlife conflicts and the different benefits derived from accessing natural resources in communal lands. Respondents who had lost livestock to wolves generally had a negative attitude while those without losses were positive about the wolves. This means that if the economic consequences of human-wildlife conflict for local poor households become unbearable, attitudes towards the conservation of biodiversity may change. For example, if the local community stops receiving economic benefits or free access to natural resources, they could disregard biodiversity conservation, as has been observed worldwide, and in particular in Nepal, India and Kenya (Oli *et al.*, 1994, Treves and Karanth, 2003, Naughton-Treves *et al.*, 2005, Thirgood *et al.*, 2005, Woodroffe *et al.*, 2005, Treves, 2007). Furthermore, my study confirms that people's attitudes towards conservation and wildlife are moderated by socio-economic characteristics (economic means, accessibility, literacy) and by conflicts with wildlife, in a particular instance where the use of open resources can conflict with the conservation of a charismatic endemic species such as the Ethiopian wolf. Human-wildlife conflicts and perceived economic benefits were influenced by certain socio-economic factors in my study area, with implications for the conservation. Interestingly, in Abune Yosef, most people considered the protection of the ecosystem and its biodiversity positively, irrespective of whether they used or not natural resources, and were affected or not by

livestock predation. This is probably because their livelihoods depend on the long-term persistence of ecosystem services. Considering the average Gross National Income per capita of Ethiopians (around USD 470 in 2013), the annual income from ecosystem goods and services derived from Mount Abune Yosef represented a substantial economic contribution to the local community (chapter 4). For example, a significant proportion of households benefited financially from tourism-related activities led by local communities. This is an example of tourism becoming an important alternative source of income for landless households, if developed as a community-based initiative (Binns and Nel, 2002, Hutton and Leader-Williams, 2003, Ashenafi and Leader-Williams, 2005, Lindsey *et al.*, 2007, Hoole, 2009, Mbaiwa and Stronza, 2010). In general, interventions designed to ensure community income, while encouraging long-term sustainability, will contribute to maintaining positive attitudes among people and also promote a willingness to co-exist with large carnivores (Kellert *et al.*, 1996, Hutton and Leader-Williams, 2003, Bath *et al.*, 2008, Dickman, 2010, Winterbach *et al.*, 2013). Although Ethiopian wolves are specialised rodent hunters, my study showed that in the heavily populated highlands of North Ethiopia they may become predators of livestock, possibly a reflection of dietary adjustments to less abundant rodent prey and high livestock availability (Sillero-Zubiri and Gottelli, 1995, Marino *et al.*, 2010). Until now, owing to the charisma of the Ethiopian wolf, conflicts have been kept in check; this may change if human and livestock populations in rural Ethiopia continue growing, threatening the sustainability of local livelihoods and prompting the emergence of retaliation, as observed in South Africa for example (Lagendijk and Gusset, 2008). Understanding the root causes of human–wolf conflict and their mitigating measures, and then ensuring sustainable community resource uses within the Ethiopian wolf habitats should be considered priorities for Abune Yosef and other Ethiopian wolf populations.

### 6.5 Human–Ethiopian wolf conflicts

In the highlands of North Ethiopia, where people, livestock and the Ethiopian wolf live together, there are often human–wolf conflicts due to small-stock predation. This conflict situation in particular in Aboi Gara presents a serious challenge to the conservation of the threatened Ethiopian wolf outside protected areas. Understanding the cultural and socio-economic context of this conflict can help to prevent negative attitudes, the associated retaliatory killing of wolves and also to diminish the economic impact on local pastoralists (Sillero-Zubiri and Laurenson, 2001, Treves and Karanth, 2003, Dickman, 2010, Karlsson and Johansson, 2010).

In chapter 5, I looked at the impact of human–wolf conflicts in the Afroalpine highlands of North Ethiopia. I did this by quantifying the extent and patterns of predation, its economic impact, and how it affected people's attitude towards Ethiopian wolves. I suggested measures that help to ameliorate the relationship between local pastoralists and the Ethiopian wolf. I also proved that while predation on sheep and goats by jackals and wolves in Aboi Gara was relatively low, it still has a considerable economic impact on local households. Because for local farmers relying on small herds and low daily household income, the loss of a small number of animals can have a substantial negative impact on their livelihoods (Mishra, 1997, Butler, 2000, Treves and Karanth, 2003, Yirga *et al.*, 2012). Moreover, when I compared the annual economic loss due to livestock predation per household in Aboi Gara, it turned out to be much higher than reported for Tigray in North Ethiopia (Yirga *et al.*, 2012).

While the frequency of kills by wolves and jackals are not dissimilar, there is a clear difference in the pattern of livestock predation between Ethiopian wolves and common jackals in the study area. Common jackals tend to kill in agricultural fields, around homesteads and in Afroalpine habitats at both day and night, whereas Ethiopian wolves kill only during the daytime and in Afroalpine habitats (Sillero-Zubiri and Gottelli, 1995, Stephens *et al.*, 2001, Marino *et al.*, 2010). I also observed that the small stock losses to wolves varied depending on the season and daylight. For example, more small-stock killing took place during the night and during the wet season. During the wet season the weather in particular the fog rising from the surrounding lowlands, hanging over the mountain and impair the vision of small-stock shepherds or attendants.

In my study most households showed a positive attitude towards the Ethiopian wolf. This positive attitude correlated highly to literate households, households having less/no herd size and households experiencing no predation. However, the combination of illiteracy, having a large herd, living closer to wolf habitat and grazing for longer periods in wolf habitat exposed households to predation, which leads to conflict. My findings suggest that it is important to mitigate conflicts and to promote positive attitudes towards the Ethiopian wolf. It is also important to stimulate formal and informal conservation education for illiterate households in the area and this aspect is of paramount importance. Since education affects human behaviour and attitudes, it can help the pastoralists to practice better livestock husbandry systems, increase their tolerance to predators and to foster human–carnivore coexistence (Kellert and Berry, 1980, Tarrant *et al.*, 1997, Lagendijk and Gusset, 2008). An important aspect of conservation work is changing human behaviour (Mascia *et al.*, 2003, Draheim *et al.*, 2013).

In general, I would advise that steps are taken to minimise livestock predation and to diminish the economic impact of predation on local pastoral-



ists. Co-existence on the start terms should also be promoted until long-lasting policies can be put in place in Aboi Gara; I also suggested an immediate and affordable practical approach that improves the existing traditional livestock guarding techniques. Guarding small stock and taking steps to actively defend them are essential to mitigating predation (Ogada *et al.*, 2003) because leaving small stock unattended during the daytime facilitates predation by wolves.

### 6.6 Conclusions

In line with research questions of the study, the following conclusions have been drawn from my findings:

- 1 Ethiopian wolf populations around BSNP of North Ethiopia consumed a range of prey species but focused predominantly on a few rodent species. Diurnal rodents were their main prey but sometimes they also hunted nocturnal species. Of the dominant Murinae rodent species in the area, the Ethiopian wolf preferred the grass rat. Although Ethiopian wolves are specialised rodent hunters, in the heavily populated highlands of North Ethiopia they are predators of livestock, possibly a reflection of dietary adjustments to less abundant rodent prey and high livestock availability. Although there is evidence indicating that the Ethiopian wolf feeds on livestock at low frequencies, golden jackals are the major culprit of livestock losses in human-dominated landscapes around BSNP.
- 2 Livestock grazing as a form of land use affects rodent population density but not species richness in the highlands of South Wollo. A ground-level vegetation cover correlates positively to rodent density, but livestock grazing reduces ground-level Afroalpine vegetation cover. Thus, the rodent community composition/density correlates positively to vegetation biomass cover and negatively to livestock presence/grazing. With regard to rodent abundance, the South Wollo highlands including BSNP are the third most important area behind Bale and Arsi Mountains National Parks in Ethiopia. It is important, therefore, that grazing management practices applied in Afroalpine habitats be adjusted in order to avoid unwanted impacts on rodent populations and their top predator the Ethiopian wolf. Accordingly, monitoring of the species richness and population density of small Afroalpine mammals, the status of vegetation they depend on, and other related microhabitat factors, is an important management tool for assessing the stability and health of the ecosystem.

- 3 Positive attitudes towards the protection of the Afroalpine ecosystem are associated with livelihood-dependence on natural resources such as water, fuelwood, thatching grass, grazing and other medicinal and construction materials. Human-wildlife conflict and perceived economic benefits are influenced by local socio-economic characteristics and have implication for the conservation of the Afroalpine ecosystem and its flagship species the Ethiopian wolf. For example, to minimise the extent of livestock predation and the associated economic costs, traditional livestock guarding techniques should be improved. In general, interventions designed to ensure income to the community while encouraging long-term sustainability will contribute to maintaining positive attitudes among people and also to promote willingness to co-exist with carnivores. For instance, community-based ecotourism can be an important alternative source of income.

## 6.7 Recommendations

Based on the results, discussion and conclusions of the study, the following recommendations are made:

- 1 It is important and urgent for the extended BSNP to develop a General Park Management Plan. This would take the present study and all other studies into consideration for the purpose of managing and protecting efficiently the biodiversity of the area. The local community should be empowered to regulate, monitor and ensure the sustainability of harvesting natural resources (such as '*guassa*' *Festuca* grass, fuel wood, and others) and plans to maintain healthy wildlife populations and ensure the restoration of degraded habitats.
- 2 To curb the threats posed to Ethiopian wolves and their habitats and to ensure their survival in Ethiopia's Afroalpine habitats, it is necessary that the local and regional awareness of communities be improved, as well as their understanding of the importance of habitat conservation, and that their sense of ownership be strengthened.
- 3 I also recommend establishing school environmental/nature clubs that facilitate awareness and environmental education outreach activities, for example by producing and disseminating teaching materials at regional and national level.

- 4 Pressure on the natural resources of the Afroalpine habitats should have to be reduced through facilitating the diversification of local livelihoods. In particular ecotourism development, implementing improved energy supply technologies, livestock husbandry and guarding techniques will be crucially important and supported.
- 5 Measures should be taken to maintain healthy populations of rodent prey in order to ensure the survival of the Ethiopian wolf
- 6 Pressure on natural resources will also be reduced by facilitating conservation-compatible sustainable development and agricultural practices. These include household and community fuel wood initiatives, alternative livestock fodder systems, the production of privately owned 'guassa' grass and the promotion of more diverse but sustainable agricultural activities.
- 7 A long-term ecological monitoring programme in Afroalpine ecosystems should be conducted in order to inform conservationists and wildlife policy-makers about ecosystem changes. This would involve measuring the ecosystem variables like rodent biomass and density, vegetation cover and the presence of flagship species like the Ethiopian wolf. To ensure successful social-ecological monitoring socio-economic aspects related to human dimension for instance issues like perceptions, community income and economic losses must be included.

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