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Does livestock predation reflect in negative local perceptions of Ethiopian wolves in South Wollo?

GIRMA ESHETE[1,2,4], CLAUDIO SILLERO-ZUBIRI[3,4], ELLEN CIERAAD[1], C. J. M. MUSTERS[1], G. R. DE SNOO[1], H. H. DE IONGH[1] & JORGELINA MARINO[3,4]

[1]*Institute of Environmental Sciences, Conservation Biology Department, University of Leiden, P. O. Box 9518, NL-2300 RA Leiden, the Netherlands*

[2]*North Wollo Zone Environmental Protection Department, P.O. Box 461, Woldia, Ethiopia*

[3]*Wildlife Conservation Research Unit, Zoology Department, University of Oxford, The Recanati-Kaplan Centre, Tubney House, Tubney OX13 5QL, UK*

[4]*Ethiopian Wolf Conservation Programme, P.O. Box 215, Robe, Bale, Ethiopia*

Abstract: The conservation of rare and endangered carnivores in human dominated landscapes is particularly challenging when predators are perceived as a threat to livestock. This study verifies whether the human perception of Ethiopian wolves as predators of livestock accurately reflects the actual damage done by this specialist predator of highland rodents. With that purpose, we quantified the contributions of prey species, including livestock, to the diet of Ethiopian wolves by analysing 118 scats. We then compared them to the reported livestock losses and attitudes in 300 households surrounding wolf habitat in the highlands of South Wollo in north Ethiopia. We found 10 prey species, totalling 222 prey occurrences in the study sample. The most common prey were diurnal rodents, with 79.2% of all prey occurrences. Only 5.4% were livestock (sheep) remains, a result similar to that obtained in other wolf populations. The proportion of households reportedly affected by Ethiopian wolf predation was relatively low (17%), and these households lost an average of 1.0 sheep per year over the previous five years. Even though the proportion of households affected by livestock predation was relatively low, 88% of the households that reported losing sheep to Ethiopian wolves had a negative perception of the species, compared with only 9% of the households unaffected. Clearly current levels of livestock predation in South Wollo lead to widespread negative attitudes among the people affected, an emerging problem that requires the attention of conservationists and wildlife authorities.

Key words: Afroalpine ecosystem, Borena Sayint National Park, faecal analysis, foraging ecology, human–wildlife conflict, rodents.

Introduction

The conservation of rare and threatened carnivores in human dominated landscapes is always challenging. Humans often modify habitats, introducing livestock and other domesticated animals, and subsequently perceive carnivores as a significant threat (Athreya *et al.* 2013; Mamo & Bekele 2011). The Ethiopian wolf (*Canis simensis*) is a rare and endangered canid, with an estimated total population of less than 500 individuals restricted to six populations in Afroalpine high-

Corresponding Author; e-mail: genbere@cml.leidenuniv.nl; girma.eshete@ethiopianwolf.org

lands of Ethiopia (Marino & Sillero-Zubiri 2011). They are unusual among canids in that their diet is composed almost entirely of the small rodents that dominate the Afroalpine ecosystem (Ashenafi *et al.* 2005; Marino *et al.* 2010; Sillero-Zubiri *et al.* 1995; Sillero-Zubiri & Gottelli 1995), yet emergent conflicts due to predation on livestock have been reported in some areas (Eshete *et al.* 2015; Eshete *et al.* 2017; Marino *et al.* 2010; Yihune *et al.* 2008). Feeding patterns of carnivores, and thus, diet composition, can change in response to variations in biotic and abiotic factors such as habitat, prey preference and density, predator density, season and weather (Bauer *et al.* 2008; Hayward & Kerley 2005; Stahler *et al.* 2006). In the case of the Ethiopian wolf, diet may be affected by the presence of humans and livestock in Afroalpine areas (Ashenafi *et al.* 2005; Marino *et al.* 2010). With increasing human and livestock densities within Ethiopian wolf range, the possibility of wolves turning to livestock as prey increases (Marino 2003; Vial *et al.* 2011). The prospect of a potential escalation of human–wildlife conflict necessitates a better understanding of the feeding ecology of these endemic animals to ensure their effective conservation.

Ethiopian wolves typically live in packs and communally defend a territory, but unlike most other carnivores they are solitary foragers (Sillero-Zubiri & Macdonald 1998). In the Bale Mountains in the southern Ethiopian massif, the diet of Ethiopian wolves is dominated by the Bale endemic giant molerat (*Tachyoryctes macrocephalus),* and three species of small Murinae grass rats (*Arvicanthis blicki*, *Lophuromys melanonyx*, *Otomys typus*); followed by Starck's hares (*Lepus starcki*) (Morris & Malcom 1977; Sillero-Zubiri & Gottelli 1995). Due to the absence of giant molerats in the Central and Northern highlands, Ethiopian wolves there rely more heavily on the relatively smaller East African molerat (*Tachyoryctes splendens*) when this is available, and on other diurnal rats, including *A. abyssinicus*, *Lophuromys flavopunctatus,* and the swamp rat *O. typus* (Ashenafi *et al.* 2005; Marino *et al.* 2010).

Where the density of rodents is relatively low and human interference is severe, Ethiopian wolves might become more crepuscular or nocturnal preying more frequently on livestock that leads to increasing conflict with local communities (Brown 1964; Eshete *et al.* 2015; Marino 2003; Marino *et al.* 2010; Sillero-Zubiri & MacDonald 1997). Indeed, Ethiopian wolves have been observed hunting sheep and small antelope in small packs (Harper 1945; Sillero-Zubiri & Gottelli 1995). However, discrepancies between alleged and real livestock losses to wild carnivores are not uncommon in human–carnivore conflict situations. In general, conflicts often stem from perceived, rather than real, threats to property (Treves & Karanth 2003). To aid the conservation of this endemic carnivore, increasingly threatened by human encroachment, it is important to examine if pastoralists' perceptions of Ethiopian wolves are built on convincing evidence or unfounded belief.

This is particularly important for the Ethiopian wolf population in the South Wollo highlands, including the Borena Sayint National Park, an Afroalpine relict with an estimated wolf population of 50 individuals (EWCP 2014). This area is under enormous pressure from agriculture encroachment, extensive grazing, and firewood collection (EWCP 2014; Marino 2003). To asses actual predation we conducted a detailed analysis of the Ethiopian wolf diet from prey remains in scats, a non-invasive method commonly used to study feeding ecology in carnivores, and to clarify predator-prey relationships (Bauer *et al.* 2008; Corbett 1989; Hayward & Kerley 2005; Jedrzeiewski *et al.* 2002; Klare *et al.* 2011; Maria *et al.* 2012). We also conducted socioeconomic surveys of shepherds and local people to quantify reported livestock losses; this method is especially valuable to verify the human perception of livestock predation by wild carnivores (Marker *et al.* 2003).

This research allowed us to assess whether diurnal rodents remain the preferred prey of Ethiopian wolves in this human-dominated landscape, and whether human perceptions of Ethiopian wolves reflected the actual or reported damage to livestock in the South Wollo highlands.

Methods

Study area

The study was carried out in Northern highlands of Ethiopia, encompassing almost the totality of Afroalpine habitats in South Wollo, including the original Borena Sayint National Park and its proposed extension area currently together called Borena Sayint National Park (BSNP), located between 10°50′45.4″–10°57′03″ latitude and 38°40′28.4″–39°10′39″ longitude (Fig. 1). The study site covers approximately 153 km^2 within an altitudinal range between 3,200 and 4,280 m asl (Adal 2014). The original BSNP (~44 km^2) has been fully protected from livestock grazing and resource

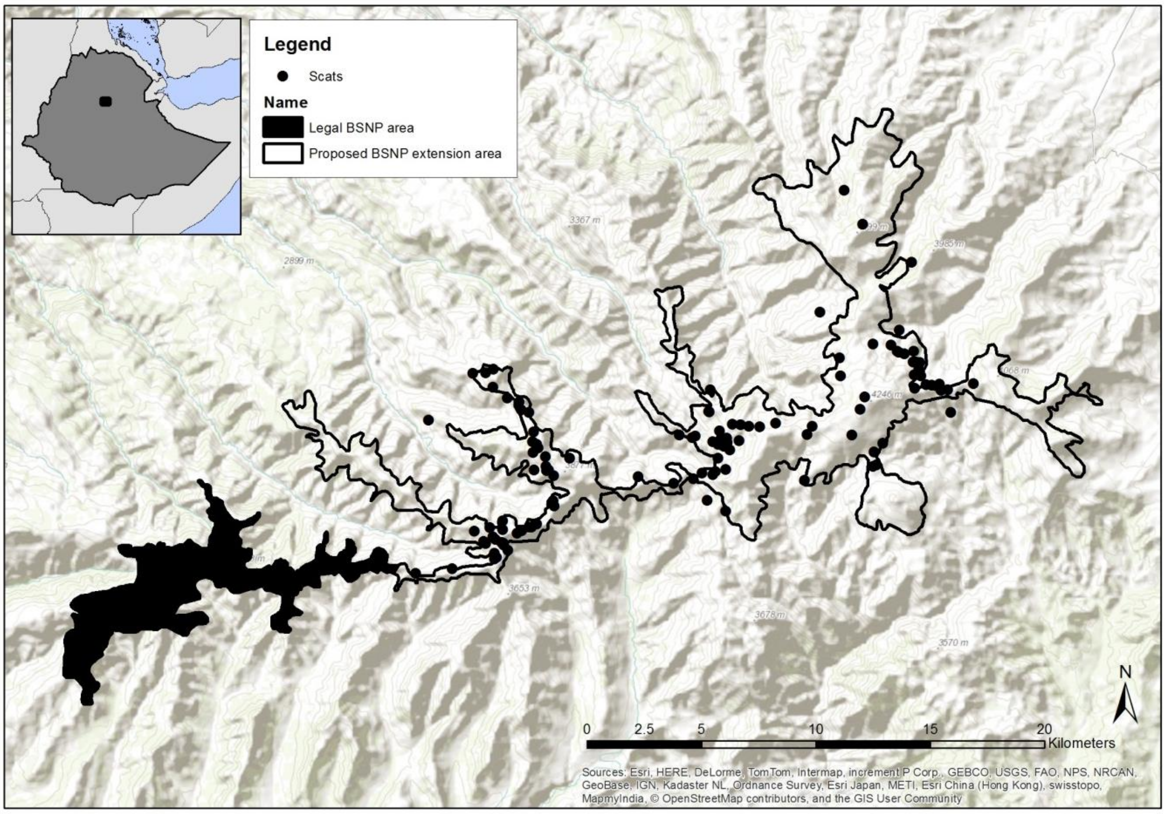

Fig. 1. Study area in the South Wollo highlands of northern Ethiopia, showing the location of the Ethiopian wolf scats analysed in this study.

harvesting for several decades (Eshetu 2014); while the remaining proposed extension area is communal land used as pasture for livestock and to collect firewood and grasses, with some communities implementing some degree of natural resource management. The area is characterised by deeply incised valleys, mountain escarpments, and plateaux. It has a bimodal rainfall pattern, with a long rainy season from June to September, and a short rainy season from March to April. The annual rainfall ranges between 655 and 1,165 mm (Yazezew *et al*. 2011). The annual temperature in Afroalpine ecosystems of Ethiopia ranges from 7.5 to 11 °C, and the climate is characterized by extreme temperature variations between day and night (ESP 2001).

The study site provides a good representation of the high biodiversity of the Ethiopian highlands, endowed with endemic flora and fauna, but it is also subjected to serious human influence resulting in habitat destruction and growing human–wildlife conflict (Eshetu 2014). The area exhibits a mosaic of vegetation types including Afroalpine grasslands and meadows, dominated by '*guassa*' grasses (*Festuca* spp.) and heaths of *Euryops* and *Kniphofia* spp., and patches of *Erica* forest (Adal *et al*. 2015). The area sustains a rich fauna with endemic birds and mammals including; gelada baboon (*Theropithecus gelada*), Menelik's bushbuck (*Tragelaphus scriptus meneliki*), Starck's hare (*Lepus starcki*), and several Murinae and Spalacidae rodent species (five species trapped in 2014 and 2015 in the wolf habitats, Eshete *et al*. 'unpublished'). There are 23 large and medium sized mammals in BSNP (Chane & Yirga 2014; Yazezew *et al*. 2011), including; seven carnivores: leopard (*Panthera pardus*), spotted hyena (*Crocuta crocuta*), golden jackal (*Canis aureus*), serval (*Felis serval*), caracal (*F. caracal*), wild cat (*F. silvestris*), and honey badger (*Mellivora capensis*); three herbivores: common duiker (*Sylvicapra grimmia*), klipspringer (*Oreotragus oreotragus*), and the rock hyrax (*Procavia capensis*); and colobus monkey (*Colobus guereza*). The tourist value of this area is potentially important, due to its endemic animals, scenery and historical sites. The Afroalpine habitat is part of six districts, or woredas: Borena, Sayint, Mehal Sayint, Legambo, Tenta and Mekidella, which combined had a human population of 948,841 in 2015, and 1.6 million livestock including; cattle, pack animals (donkeys, mules, horses), sheep and goats (DoFEAD 2015). The current human and livestock population densities living in the six districts are ~138 people and ~233 heads of livestock per km^2 respectively. The local communities of South Wollo engage in small-scale agriculture and livestock rearing, and depend on Afroalpine natural resources for firewood, building materials, drinking water, grazing, hay, and thatch grass. These land uses are degrading many Afroalpine areas where Ethiopian wolves occur (Ashenafi & Leader-Williams 2005; Eshete *et al.* 2015).

Scat collection and analysis

A total of 118 Ethiopian wolf scats were collected during the dry seasons of 2015 and 2016 (December, February, and May) from the proposed BSNP extension area across the Afroalpine range outside the original BSNP (Fig. 1), by the main author and two research assistants trained to identify Ethiopian wolf scats by shape, colour, and size (only adult size scats were considered). The sample was considered to be representative of this small wolf population, and large enough to detect rare prey items (Trites & Ruth 2005). Our survey routes traversed across the range of suitable wolf habitat only once, to diminish the likelihood that samples from one given area were derived from a few individuals, and collected one independent scat when multiple scats found in the same site to avoid pseudoreplication bias (Marucco *et al.* 2008). To avoid mistakenly collecting domestic dog scats, areas near human settlements were avoided and also domestic dog scats look sufficiently different from wolf scat (Marino *et al.* 2010). We restricted our sample to the dry season because previous studies in the Bale Mountains (Sillero-Zubiri & Gottelli 1995), Menz (Ashenafi *et al.* 2005) and Simien (Yihune & Bekele 2014) found no differences in diet composition between dry and wet seasons.

The scats were collected in plastic bags, promptly sun-dried and stored in sealed bags labelled with the GPS position, date of collection, place, and habitat type. Each dry sample was then broken carefully on a petri dish by hand. Macro components including large bones, jaws, teeth, hooves, hairs, wool, skin, feathers, plant matter, and others were separated and examined using a hand-held lens. Prey remains were categorised as: Murinae rats (small-sized grass rats), common molerat (large rat, Spalacidae), medium-sized mammals (such as hyraxes and hares), birds, and others. Murinae rats could be identified to the level of species by comparing jaws and teeth against a reference collection of rodent species trapped locally, a robust method to characterize the diet of Ethiopian wolves (Marino *et al.* 2010). Hairs of sheep, Starck's hare, and rock hyrax could also be identified microscopically comparing with reference hair collections of these species from the study area.

To describe the diet of the Ethiopian wolf we quantified the relative contribution of each prey type as a proportion of the total number of occurrences in the sample (hereafter named "frequency of occurrence per prey type" = total number of occurrences of that prey divided by the number of all prey occurrences in the scat sample) (Lockie 1959), and as a proportion of the number of scats (hereafter named "frequency of occurrence per scat" = number of occurrences of a prey species divided by the total number of scats, multiplied by 100) (Ciucci *et al.* 1996; Lockie 1959). Predators with large prey relative to their size can produce highly correlated clusters of scats. Conversely, carnivores that eat generally small prey like Ethiopian wolf produce fewer scats per individual prey item, which likely would lead to fewer problems with independence. In such cases, biomass calculation may be too biased for the small prey sizes consumed. Frequency of occurrence, however, can contribute useful additional information about rare food items and also help to understand a carnivore's ecology, such as its role as an opportunist or a specialist (Zabala & Zuberogoitia 2003).

We used Jacob's index to determine preferences of Ethiopian wolves for three common rodent prey species, based on the average population density of *L. flavopunctatus, A. abyssinicus, S. griseicauda,* in the study area (derived from trapping data in 2014 to 2015 at BSNP by Eshete *et al.* 'unpublished'), Jacob's indices were calculated as follows:

$$\text{Jacob's index (D)} = r–p/r+p–2pr$$

Where r is the proportion of each prey species count in the diet of the predator, and p is the proportion of the same prey species availability in the environment/study area. The resulting value ranges from +1 to −1, where +1 indicates maximum preference and −1 indicates maximum avoidance. The preference of Ethiopian wolf goes to the largest value of D (Jacobs 1974).

Interviews

Structured interviews (Table S1) with the local Amharic language were conducted. Between March and April 2015, 300 households were interviewed, selected randomly from a list of 3471 households living in six districts bordering the BSNP in South Wollo. We interviewed people that regularly visit the Afroalpine area to herd their livestock, collect grasses and firewood, fetch water, or just traverse through the habitat. Heads of household were asked the number of livestock they owned, and to report how many of their sheep had been killed by Ethiopian wolves in both the previous 12 months, and five years. Heads of households were also asked about their attitude towards wildlife of the area, which wildlife they loved and which they hated, the reason for their hatred and love, any benefits they obtained and loss related to wildlife, and what they thought about Ethiopian wolves (for example asking a question, is the Ethiopian wolf good (positive) or bad (negative)? For the households that reported predation by Ethiopian wolves, verification questions were asked to assess whether people were certain that wolves and not jackals were responsible for the reported killings.

Statistical analyses

Descriptive statistics and chi-square tests were conducted to describe and compare diet composition and people's attitudes, using the statistical package SPSS, version 16.0 (SPSS Inc., Chicago, IL, USA).

Results

Scat analysis

A total of 222 prey items, categorized into 10 prey species, were found in the sample of 118 Ethiopian wolf scats. Of those 64.4% contained more than one prey species, and the remainder (35.6%) only one (average 1.88 prey types per scat). The remains identified in the scats were mammal bones, jaws, teeth, hooves, hair, sheep wool, skin, bird feathers, and undigested plant materials. Of the prey remains identified, 96.3% were of mammals, comprising five species of rodents, two species of medium sized mammals, and one species of livestock (sheep) (Table 1). Murinae rodents and East African molerats were the food items most frequently encountered, constituting 88.2% of all prey occurrences (Table 1); 79.2% were diurnal and 9% nocturnal rodents. Sheep was the only livestock species found in scats (identified from wool, teeth, hooves and/or skin) and this constituted 5.4% of all prey occurrences. Plant matter, Starck's hare, birds, and rock hyrax contributed 2.3, 1.8, 1.4 and 0.9%, respectively to the wolf diet (Table 1). Considering the relative frequency of occurrences of rodents prey, *A. abyssinicus, L. flavopunctatus* and *T. splendens* were the three most commonly consumed (Table 1), and *O. typus* was the least common. Rock hyrax was the mammal prey with the lowest frequency in the diet (Table 1).

Among the three most common Murinae rodents the diurnal *A. abyssinicus* was the most preferred by the Ethiopian wolf, with a Jacob's index value of 0.4, while the nocturnal *S. griseicauda* seems to be avoided, with a Jacob's index value of −0.4 (Table 2).

Interviews

Out of 300 households interviewed 247 (82%) owned sheep and some other livestock. Of those, 42 (17%) reported losing sheep to Ethiopian wolves, totalling 43 losses in the past year, and 118 over the past five years. This equated to a mean annual loss, across the households that owned livestock, of between 0.2 and 0.5 sheep per household, respectively (Table 3). Considering only the households that lost sheep, these suffered losses averaged 1.0 and 2.8 sheep per household in the last one and the last five years, respectively. Total 110 (44.5%) households lost 222 and 572 sheep in the last one and the last five years, respectively, by common jackal. This is 0.9 and 2.31 sheep per sheep owned households; and 2.0 and 5.0 sheep, respectively, per sheep lost households lone. There was a significant difference ($\chi^2 = 1.24$, $df = 1$, $P = 0.0001$) in attitudes towards the Ethiopian wolf amongst households that lost and did not lose sheep to wolf. Most heads of households that lost sheep to wolves reported a negative perception of the Ethiopian wolf (88% of 42 households), compared with only 9% of the 205 households that did not lose sheep.

Discussion

Our study showed that the diet of Ethiopian wolves in South Wollo was composed of 10 prey species; predominantly rodents and livestock contributed only a small proportion (5.4%). The level of livestock predation coincides with findings from previous dietary studies, and confirms that livestock is not a dominant source of food for Ethiopian wolves, even in human-dominated landscapes with high density of domestic stock (Marino *et al*. 2010). The reported loss across all sheep owned households was also relatively low, and these lost on average was less than one sheep per year over the past five years. These results

Table 1. Frequency of occurrences per prey items and per scats in the diet of Ethiopian wolves of South Wollo.

Grouped prey items	Number of prey occurrences across all scats	Frequency of occurrence per prey (% FO/I*)	Frequency of occurrence per scat (% FO/S*)
Murinae			
Lophuromys flavopunctatus	53	24.0	45.0
Arvicantis abyssinicus	70	31.5	59.3
Stenocephalemys griseicauda	20	9.0	17.0
Otomys typus	17	7.7	14.4
Spalacidae			
Tachyoryctes splendens	36	16.0	30.5
Medium-size mammals			
Livestock (sheep)	12	5.4	10.2
Rock hyrax (*Procavia capensis*)	2	0.9	1.7
Starck's hare (*Lepus Starcki*)	4	1.8	3.4
Birds	3	1.4	2.5
Plant matter	5	2.3	4.2

*I=Total prey item occurrences=222 *S=Total scat numbers collected=118

Table 2. Ethiopian wolf diet preference among the three most commonly captured rodents in the study area. Data for the three rodents was taken from Mark software analysis in Eshete *et al.* (unpublished).

Rodent species	Density (km^{-2})	p	r	Jacob's index value	Preference rank
Lophuromys flavopunctatus	9159	0.5	0.4	−0.2	II
Arvicantis abyssinicus	5451	0.3	0.5	0.4	I
Stenocephalemys griseicauda	3136	0.2	0.1	−0.4	III

Table 3. Size of sheep flock and number of sheep reportedly killed by the Ethiopian wolf, per household, in South Wollo.

	Minimum	Maximum	Sum	Mean	SD
Size of sheep flock owned	1	30	2664	10.8	6.07
Sheep killed by Ethiopian wolf in the last 12 months	0	5	43	0.17	0.62
Sheep killed by Ethiopian wolf in the last five years	0	17	118	0.48	1.81

suggest that even low levels of livestock predation can result in negative perceptions towards Ethiopian wolves among the local communities. While this level of predation may not appear substantial per total sheep owned households (2% of the total sheep owned household's herd), negative attitudes towards wolves among the affected people were prevalent, unlike the households not affected, which were the majority of the affected households presumably lost livestock to other predators and/or the loss is relatively huge (10% of the affected household's herd).

As shown by previous studies and corroborated here, Ethiopian wolves in the highlands of South Wollo predominantly consume a few small mammal species. Considering its relative large size, the East African molerats contributed an important proportion of the biomass consumed by wolves in South Wollo. Small rodents are an abundant food resource in the Afroalpine ecosystem, and require less searching effort with less manipulation risk than a medium sized, or large herbivore. Clearly, small mammals remains more cost-effective to hunt than sheep, or other herbivores, considering their metabolic energy requirements of a carnivore of less than 20 kg like the Ethiopian wolf (Carbone *et al.* 2007; Mukherjee *et al.* 2004).

Also in accordance with other studies, Ethiopian wolves in South Wollo rarely consumed Starck's hares and rock hyraxes (Ashenafi *et al.* 2005; Sillero-Zubiri & Gottelli 1995; Yihune & Bekele 2014); birds were also uncommon. Plant matter found in scats might have been ingested by chance while swallowing other foods, or may be ingested to assist digestion and parasite control (Sillero-Zubiri & Macdonald 1997).

Ethiopian wolves in South Wollo do not depend on livestock to survive, and appear to consume livestock only opportunistically. However, if the current rate of Afroalpine habitat degradation continues, with declining rodent populations and increasingly availability of domestic stock, the Ethiopian wolf may switch to livestock as an alternative to their preferred natural rodent prey (Meriggi & Lovari 1996). The current trend of agriculture and livestock encroachment in many parts of the study area is a source of concern, as it may encourage livestock raiding by wild carnivores (Personal observation). Even at current perceived levels of livestock predation, Ethiopian wolves are causing concern among most of the households affected in South Wollo (nearly 90%).

The importance of livestock as a prey for other wolf species has been well documented globally (Fuller 1989; Meriggi & Lovari 1996; Vos 2000), and in many cases wolves' dependence on livestock has led to human–carnivore conflict and persecution. In the case of the Ethiopian wolf, authorities and conservationists should consider actions to limit the dependence of wolf packs upon livestock, to avoid potential retaliation. On the other hand, Ethiopian wolves in South Wollo still maintain a diet composed predominantly by rodent species in a human-dominated landscape, demonstrating their ability to survive in close proximity to human habitation, as in Menz and in the Simien Mountains (Ashenafi *et al*. 2005; Yihune & Bekele 2014). *A. abyssinicus*, *L. flavopunctatus* and *T. splendens* remain common in these areas (Ashenafi *et al*. 2005; Yihune & Bekele 2014), while the swamp rat *O. typus* is seemingly less important, suggesting that its availability might be changing, probably in relation to the widespread degradations of wetlands in the highlands of Ethiopia. The contribution of nocturnal rodents to the diet of the Ethiopian wolves in South Wollo was small, and thus, do not support the expected propensity of Ethiopian wolves to forage during night time in response to the presence of humans and livestock, as suggested by the wolves' diet in the Simien Mountains (Marino *et al*. 2010). Indeed, our analysis of food preferences indicated that wolves prefer *A. abyssinicus* and *L. flavopunctatus,* two diurnal rodents, over the nocturnal *S. griseicauda,* as also described for Menz and Simien (Ashenafi *et al*. 2005; Yihune & Bekele 2014).

Conservation implications

Our results confirm that Ethiopian wolves are specialist diurnal rodent predators in the Afroalpine ecosystem, but if rodent populations continue declining due to habitat degradation across this endemic canid range, the wolves might increasingly switch towards domestic livestock for food. The associated costs to the local livelihoods could easily become unbearable for the affected households considering their daily income of less than US$ 1 (Bluffstone *et al.* 2008). Habitat restoration to maintain and enlarge prey populations is therefore a major conservation priority. People in this area tend to be tolerant of Ethiopian wolves (most households reported positive views), but as negative perceptions were prevalent among those affected, in spite of the relative low incidence of livestock predation by wolves, these could soon lead to human–wildlife conflict in BSNP. Emergent conflicts could be curtailed by minimizing predation by Ethiopian wolves, targeting the most vulnerable households. The support of the local population therefore is critical for the conservation of Ethiopian wolves in South Wollo, but conservation success will also depend on the successful maintenance of the wolves' natural prey and education to raise awareness of the need to protect the enigmatic endemic species.

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Supporting Information

Additional supporting information may be found in the online version of this article.

Table S1. Interview questionnaire.