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ORIGINAL PAPER

Peri-urban spotted hyena (*Crocuta crocuta*) in Northern Ethiopia: diet, economic impact, and abundance

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Abstract Global declines of carnivores are related to difficult integration with human land use, in particular conflicts caused by livestock depredation. Spotted hyenas (*Crocuta crocuta*) live in remarkably close proximity to humans in the degraded and prey-depleted Enderta district, northern Ethiopia. Their diet and interaction with people were investigated in sub-districts close to the regional capital, Mekelle. We interviewed 1,686 randomly selected households from three sub-districts, Debri, Aynalem, and Felege Selam, about livestock management and incidence of depredation from 2005 to 2009. Livestock loss amounted to 492 heads over 5 years; an annual mean of 0.6% worth US$ 7,042. We also performed a survey giving a minimum population estimate of 60 hyenas in the three sub-districts; all but four were found in church forests where they are traditionally tolerated and protected. A total of 1,200 hyena scats were analyzed to determine prey species; the diet contained only domestic species, with sheep being by far the most common prey species. About 5.5% of fecal analysis contained human hairs. We conclude that hyenas depended entirely on domestic prey species, partly through depredation but more importantly through scavenging on (peri-) urban waste. Under the particular local circumstances, continued coexistence appears possible, provided that damage remains tolerable.

Keywords Spotted hyena · Depredation · Livestock · Conflict

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Introduction

Most large carnivore species are experiencing ongoing global decline caused almost entirely by human activities. Habitat loss and fragmentation are among the primary threats to global biodiversity (Czech et al. 2000; McKinney 2002; Wilcove et al. 1998). Large carnivores have disappeared from areas of high human density, and the species most exposed to conflicts with people are the most prone to extinction (Woodroffe 2001). Mammalian carnivores tend toward large home ranges, low population densities, and slow population growth rates, making them especially vulnerable to extinction brought on by habitat loss or human persecution (Noss et al. 1996; Woodroffe and Ginsberg 1998). Carnivores have been considered indicators of the overall fate of ecosystems, due to their trophic position (Crooks 2002; Estes et al. 2001; Noss et al. 1996).

The diets of carnivores, in conjunction with their predatory habits, frequently bring them into conflict with humans. Such conflict has resulted in persecution by humans leading to population decline, range contraction, and in some cases, extinction (Mills and Hofer 1998; Woodroffe 2001). Spotted hyenas (*Crocuta crocuta),* hereafter simply referred to as hyena, feed on a wide array of prey (Cooper et al. 1999) and frequently interact with other predators and scavengers at kills (Kruuk 1972). Hyenas are crepuscular nocturnal hunters and scavengers

that occur in habitats ranging from arid lands to open grassland to savanna and even forest (Bertram 1979; Kruuk 1972; Mills 1984; Sillero-Zubiri and Gottelli 1992).

Hyenas are the most abundant large carnivore in Africa, occurring in many countries, including Ethiopia. Ethiopia is rich in biodiversity with a high level of endemism (World Conservation Monitoring Center 1991). The challenges facing the conservation of Ethiopian wildlife today are becoming increasingly formidable. Since the level of agricultural productivity has remained low, increase in food production has largely depended on increase in cultivated and grazing land. Usually, these expansions are at the expense of wildlife resources and habitats (Leykun 2000).

Tigray, the northern region of Ethiopia, hosts several carnivore species; hyena (*C. crocuta),* leopard (*Panthera pardus),* three species of mongoose (*Herpestes ichneumon*, Herpestes sanguine and *Ichneumia albicauda*), caracal (*Caracal caracal*), wildcat (*Felis silvestris*), jackal (*Canis aureus*), honey badger (*Mellivora capensis*), serval (*Felis serval*), genet (*Genetta genetta*), and civet (*Civettictis civetta*) (Aerts, unpubl. data; pers. obs.). No scientific studies have been done on these species in the region. The problem of depredation of domestic animals in Tigray is primarily caused by hyenas. The species is formally protected in Ethiopia, but there is some persecution. Human–hyena conflict issues are poorly known and documented in Ethiopia. Therefore, quantifying livestock depredation and investigation of hyena diets are fundamental to allow the implementation of management for mitigation of losses and for conservation of hyenas. Our main objectives were (1) to assess hyena diet and minimum abundance, (2) assess attacks on humans and on livestock by hyenas, and (3) to assess local stakeholders' perceptions of hyenas.

Study area

Our study focused on the sub-districts surrounding the regional capital of Mekelle (200,000 inhabitants), within the Enderta district. The district lies between 12° 13′ and 14° 54′ North and 56° 27′ and 40° 18′ East with an area of approximately 10,000 km^2 at an altitude of 2,300 m a.s.l. (Fig. 1). The rainfall of the area is bimodal with a short rainy season occurring between January and April and a long rainy season from June to August. Average annual rainfall is about 550 mm. The mean maximum temperature ranges between 12°C (November and December) and 27°C (January and March).

The rural population is extremely poor and chronically dependent on food aid. The total rural human and livestock population is about 115,000 and 56,000, respectively (Bureau of Agricultural and Natural Resources Development (BOANR), 2009). The area is a barren landscape with some Eucalyptus (*Eucalyptus camaldulensis*) and cactus (*Opuntia ficus indica)* vegetation and hardly any large or medium-sized natural prey. Despite the rampant poverty and scarce resources, people strictly follow religious restrictions on animal parts that can be eaten; the remains of slaughtered animals and all redundant pack animals create an abundant food resource for hyenas, especially around Mekelle.

Forests have been completely converted into farms and grazing lands throughout the region over centuries, except for patchy remnants of old-aged Afromontane forests around most Ethiopian Orthodox Tewahido Churches (Aerts et al. 2007; Alemayehu 2007). Religion and tradition protect the vegetation around these churches, usually in a circle of approximately 50 m radius. Protection extends to hyenas hiding in these church forests during the day; inside the church compound, they are considered as "God's guards" living peacefully side by side with clergy and visitors (Priest of Michael Tselayo Church, pers. comm.).

Our research focused on three sub-districts bordering Mekelle. The first is Debri, with a total human and livestock population of about 7,025 and 12,000, respectively. It is about 12 km from Mekelle located at about 2,016 m a.s.l. Micheal Tselayo is a local church with a dense church forest known to contain hyenas. Secondly, Aynalem is situated at about 2,281 m a.s.l at 7 km from Mekelle, with a total human and livestock population of about 5,886 and 12,063, respectively. Here, hyenas are known to occur in the forest around St. Michael Church. Our third focal sub-district is Felege Selam, situated at about 2,272 m a.s.l at 28 km from Mekelle, with a total human and livestock population of about 6,577 and 9,325, respectively.

Methods

Scat analysis

The techniques used to study the diets of carnivores can be divided into three: (1) direct observation of feeding, foraging, and hunting (Murie 1985; Schaller 1972); (2) feeding site surveys, including examination of prey or carrion remains (Green et al. 1997; Mech 1966; Smith et al. 2004); and (3) analysis of post-ingestion samples from stomach content (Cuesta et al. 1991; Taylor 1964) or feces (Kohn and Wayne 1997; Putman 1984). Scat analysis, which is based mainly on identification of mammalian hairs, is a valuable technique since most prey species can be reliably determined, field collection is rapid, and the scats can be stored and processed at a convenient time and the costs are low. However, hair frequency does not necessarily

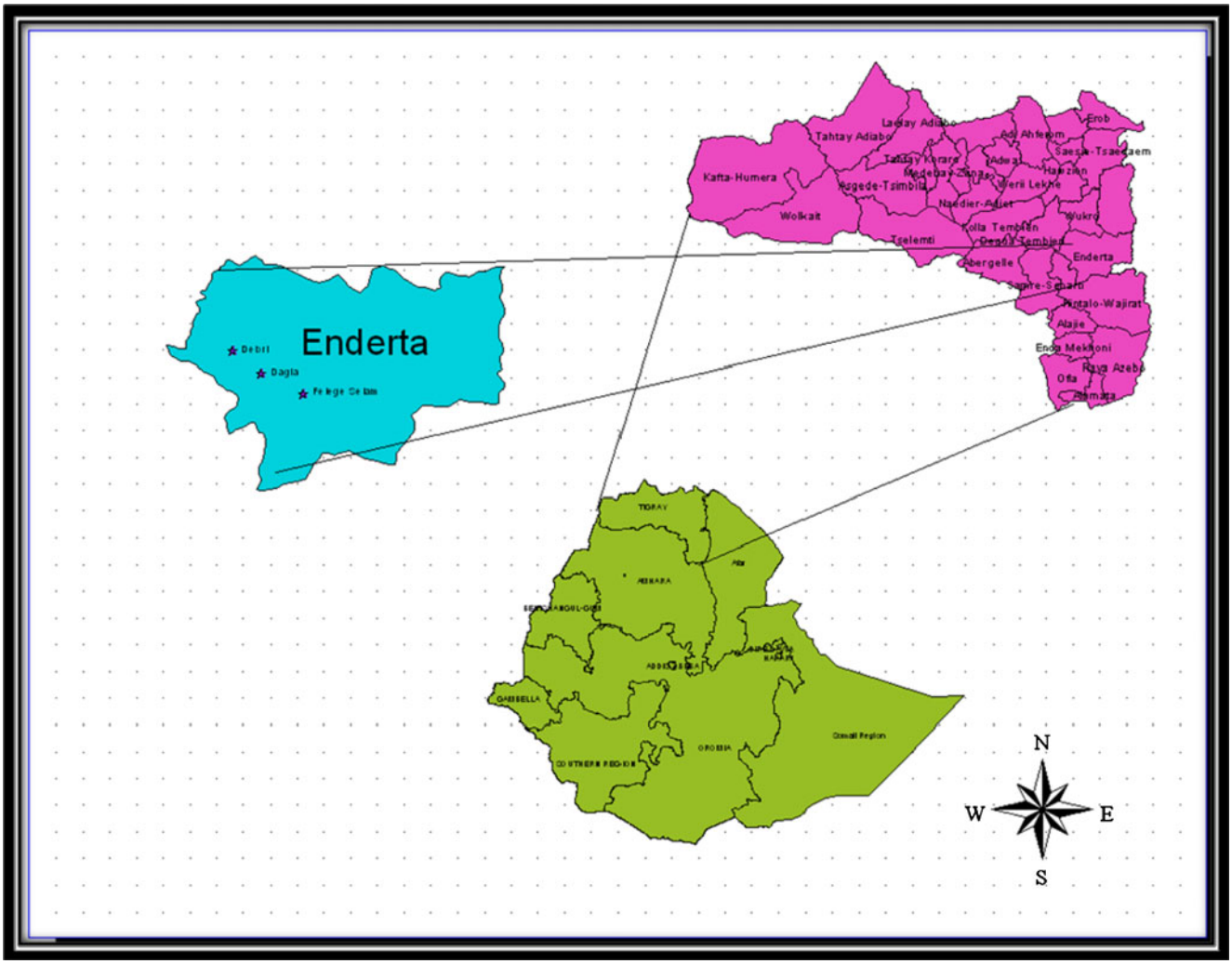

Fig. 1 Map showing location of the study area

correlate with prey volume, thus precluding study of prey preference. The method also doesn't differentiate between hunting and scavenging.

During the study period, a total of 1,200 putative hyena scats were collected from Debri and Aynalem. Scat samples were put in plastic bags with details of collection time, location, and characteristics of the substrate from which the scat was collected. Precaution was taken to ensure that there was no cross sample contamination.

The procedure described here was adapted from Ramakrishean et al. (1999). After collection of the feces, the samples were washed with water, and hairs were extracted. These hairs were washed in acetone and then dehydrated in ethanol and dried on filter paper. Hair was analyzed on form, length, and color with the naked eye as well as on a scale patterns using a microscope at 10× magnification. The hairs were compared with our hair reference collection. This reference hair collection contained hairs from the species of all domestic and wild animals that live in and around the study area.

Abundance assessment

Minimum hyena population size was established with calling stations (Bauer 2007; Mills et al. 2001; Ogutu and Dublin 1998) around church forests between 18:00 and 22:00. Continuous gnu-hyena distress and spotted hyena sounds were played for 1 h on an MP3 player connected to a megaphone (Monacor 45) positioned on top of a vehicle. Responding hyenas were first counted in the dark, based on sounds and eye reflections from a weak torch and through night vision binocular, before turning on the spotlight for a final count. Four call-ups were performed in the three sub-districts, covering all potential hyena hideouts.

Semi-structure interviews

We interviewed 1,686 randomly selected households from the three sub-districts (Debri, $n=600$; Aynalem $n=586$, and Felege Selam, $n=500$). Respondents (the head of the

household or their spouse) were asked questions relating to number of livestock owned, livestock management, number of livestock lost to predation from 2005 to 2009, and human attack. To quantify the economic cost of livestock depredation, the species, age, number, and sex of livestock losses were recorded. Estimates of current average market values of different classes of livestock species by age and sex were obtained from traders. Values were translated to US$ at the exchange rate of the time of the study. The interview also contained questions on conflict perception and management.

As an approximation of the importance of depredation in total hyena food intake, we calculated the diet requirement of hyenas (3.8–4.0 kg of meat daily; Henschel and Tilson 1988) and the biomass of livestock declared lost during the interviews (weights of local livestock species, differentiated by sex and age taken from local veterinary service).

Results

Scat analysis

The diet of hyenas contains only prey items of domestic origin (Table 1). No prey item of wildlife was found in the feces. Frequencies of prey remains of sheep, horse, donkey, cattle, and goat were highest, in decreasing order. Although hyenas do prey on humans, such incidences are rare. However, 5.5% of fecal analysis contained human hairs. We cannot differentiate hairs from kills from hairs from scavenging. It is likely that most of the human hairs were from scavenging at cemeteries and garbage dumps as we do not have reports of people killed by hyenas at the time of our study. We do not have any report of attacks on humans in or around the churches ever.

Semi-structure interviews

Surveyed households reported losses of 492 domestic animals due to hyena depredation causing an estimated financial loss of about US$ 35,208 over 5 years or an annual mean of 0.6% of stock worth US$ 7,042 (Table 2). Excluding cats, dogs, and poultry from this analysis, mean annual damage to larger livestock amounts to 1% worth US$ 7,027.

Ten human attacks were reported during the survey, all except one at night. Nine males and one female were injured, ages between 26 and 60. Most attacks (50%) where on people sleeping outdoors at night; the other attacks occurred when people were defecating outside, assisting others during an attack, or when hyenas entered into a house.

Farmers do not like the presence of hyenas in the area; 70% of our respondents do not want to conserve the species. Livestock owners try to limit livestock loss primarily through enclosing livestock at night in an enclosure (kraal). Kraals are of variable quality and are made of woody materials. People also employ herders and use dogs to alert them when hyenas are approaching. Furthermore, they attempt to chase hyenas away with torches in attempts to limit stock loss.

Abundance assessment

As for the calling stations, a total of 60 hyenas responded; 40 in Debri, 16 in Aynalem, and 4 in Felege Selam. Dietary requirement for 5 years for 40 hyenas at Debri was 284,700 kg. The biomass of predated livestock in Debri

Table 1 Diet of hyenas at Debri and Aynalem in 2009 based on analysis of 1,200 scats expressed as the number of prey items observed and their relative frequency of occurrence

Prey species	Debri		Aynalem	
	Count	Relative frequency	Count	Relative frequency
Sheep	151	25.3	108	17.9
Horse	146	24.4	54	9
Donkey	83	13.9	90	15
Cattle	45	7.5	92	15.2
Goat	49	8.2	66	11
Dog	43	7.2	57	9.5
Human	36	6	30	5
Mule	20	3.3	29	4.8
Poultry	0	0	24	4
Camel	0	0	20	3.3
Cat	0	0	8	1.3
Unidentified[a]	18	3	24	4
Hairless samples	7	1.2	0	0
Total	598	100	602	100

[a] Reference hair collection also included natural prey species, but these did not match the unidentified hairs

Table 2 Stock number, depredation, predated biomass, and economic impact of spotted hyenas from 2005 to 2009 in the sub-districts Aynalem (n=586), Felege Selam (n=500), and Debri (n=600)

Species	Stock			Depredation (% of stock)			Predated biomass (kg)			Economic loss (US$)		
	Aynalem	Felege Selam	Debri	Aynalem	Felege Selam	Debri	Aynalem	Felege Selam	Debri	Aynalem	Felege Selam	Debri
Donkeys	527	599	490	51 (9.7)	55 (9.2)	61 (12.5)	8,160	8,800	9,760	3,139	3,483	3,790
Sheep	409	140	107	21 (5.1)	33 (23.6)	6 (5.6)	1,365	2,145	390	861	1,385	168
Goats	161	163	276	15 (9.3)	23 (14.1)	30 (10.9)	1,050	1,610	2,100	554	711	965
Cows	720	525	485	4 (0.6)	17 (3.2)	20 (4.1)	1,000	4,250	5,000	554	1,875	2,611
Poultry	2,395	856	1,870	0 (0)	16 (1.9)	11 (0.6)	0	22	15	0	27	22
Dogs	394	183	395	2 (0.5)	9 (4.9)	12 (3)	70	315	420	3	11	10
Bulls	317	149	194	7 (2.2)	8 (5.4)	20 (10.3)	1,750	2,000	5,000	1,005	535	1,338
Oxen	1,316	697	840	3 (0.2)	7 (1)	14 (1.7)	1,050	2,450	4,900	354	2,688	5,376
Calves	231	85	44	19 (8.2)	4 (4.7)	8 (18.2)	1,140	240	480	614	120	240
Mules	42	53	37	3 (7.1)	1 (1.9)	5 (13.5)	1,080	360	1,800	308	101	448
Horses	13	5	5	3 (23)	1 (20)	2 (40)	1,680	560	1,120	808	288	576
Camels	85	123	10	0 (0)	0 (0)	1 (10)	0	0	580	0	0	240
Cats	406	364	313	0 (0)	0 (0)	0 (0)	0	0	0	0	0	0
Total	7,016	3,942	5066	128 (1.8)	174 (4.4)	190 (3.8)	18,345	22,752	31,565	8,200	11,224	15,784

was 31,565 kg (Table 2) over the last 5 years. Thus, depredation accounted for 11% of hyenas' food intake, the rest, by inference, from scavenging. Similarly, biomass of predated livestock accounted for 15.7% of hyenas' food intake in Aynalem and 77.9% in Felege Selam.

Discussion

Hyenas seem to consume exclusively domestic prey species in Tigray. This reflects the virtual absence of natural prey species. Hyenas are common in many parts of Ethiopia, and in most of those areas, prey populations also appear small, suggesting that our results apply more generally.

The reasons for hyena preying on livestock vary and are not fully understood. In some areas, it is thought that individual animals learn that livestock are easier to catch or are forced to switch prey species due to depletion of their natural prey choice (Mizutani 1993). In others, predation may occur simply because there is nothing to prevent it. However, in northern Ethiopia, natural prey species have dramatically declined due to agricultural expansion, deforestation, human settlement, and development projects. This is starting to change with the establishment of exclosures (small partially protected areas) and a general ecological restoration which may change the situation in the future (Nyssen et al. 2009). Clearly, the scat analysis was only suitable for detecting hairy mammals. Small fragments of bones were found together with the hairs, but we were unable to identify to a species level.

The human hairs in 5.5% of the scats are probably from cemeteries and from garbage dumps on which hyenas scavenge; they were certainly not from the attacks documented here. Hyenas are widely feared in Tigray, where they have been known to occasionally attack people at night. Threat of personal injury due to large carnivores is one of the key concerns of people living with wildlife (Sillero-Zubiri and Laurenson 2001). Such concern does not represent actual levels of attacks, with human injury or death a relatively rare occurrence; however, it demonstrates that even a low actual impact can have a large impact on local perceptions (Treves and Karanth 2003). Our data indicate that depredation is substantial in absolute terms, but its contribution to hyena food intake must be modest compared to the contribution from scavenging. Hyenas can easily be observed scavenging garbage left in the streets of Mekelle, Kiha, and Aynalem. Hyenas can travel over vast distances; Kolowski et al. (2007) documented a mean displacement of 12.4 km per night. Length of travel is thought to be dependent on home range size and prey availability. Even small rural clusters of people can be counted on for a reliable flow of unwanted organic material in the form of waste, redundant animals, and carcasses of domestic animals that die before they can be slaughtered.

Although the overall economic impact on animal husbandry caused by depredation of hyenas is not of great concern, it can mean economic ruin for a peasant, for whom the depredation of a few animals represents a considerable loss, difficult to replace. Studies elsewhere have shown that tolerance of predators by local communities usually depends on the extent of predation on their livestock (Holmern et al. 2007; Kolowski and Holekamp 2006; Patterson et al. 2004; Rasmussen 1999; Woodroffe et al. 2005). Predation on livestock is an important cause of human–wildlife conflict (Frank 1998???; Jackson and Nowell 1996; Ogada et al. 2003). The relationship between people and wildlife is affected by a multitude of factors, such as financial benefits derived from wildlife, experiences with conservation authorities, level of education, and cultural background (Madden 2004). These factors can influence people's behavior and, as a result, may affect the outcome of conservation efforts.

In the case of hyenas, an additional aspect is concern over human safety. Ten human attacks were reported during the survey. The findings are consistent with studies elsewhere, e.g., Kruuk (1972) reported hyenas biting over 60 people, mostly women and children. However, in our study, 90% of the victims were males. This could be because men in our study area always try to intervene in incidents to help victims.

In conclusion, it seems most likely that carnivores depended entirely on domestic prey species, partly through depredation and partly through scavenging on (peri-) urban waste. Scavenging alone can probably sustain viable hyena populations, the addition of depredation to hyena carrying capacity is not essential. Depletion of natural prey animals can provoke the onset of attacks on domestic animals. Depredation in the area has occurred for decades and is apparently tolerated; thus, we conclude that there is no reason to assume an immediate threat to hyena persistence. From a development perspective, though, mitigation of depredation is highly recommendable. This can be through improved animal husbandry (Ogada et al. 2003) and through ecosystem regeneration.

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