Ecology and conservation of spotted hyena (Crocuta crocuta Erxleben 1777) in human- dominated landscapes in northern Ethiopia

gidey.yirga@yahoo.com

Cover photos: Gidey Yirga, Hans de Iongh
Photos: Gidey Yirga, Hans de Iongh
Lay out: Sjoukje Rienks, Amsterdam
Language corrections: Selses Roche

ISBN 978-90-6464-714-7

Universiteit Antwerpen

Faculteit Wetenschappen
Departement Biologie

Ecology and Conservation of Spotted Hyena (*Crocuta crocuta* Erxleben 1777) in Human-dominated Landscapes in Northern Ethiopia

Proefschrift voorgelegd tot het behalen van de graad van
Doctor in de Wetenschappen: biologie
aan de Universiteit Antwerpen en de Universiteit Leiden

te verdedigen door

Gidey Yirga Abay

Ecology and Conservation of Spotted Hyena (*Crocuta crocuta* Erxleben 1777) in Human-dominated Landscapes in Northern Ethiopia

PROEFSCHRIFT

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van de Rector Magnificus prof.mr. C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
ter verdedigen op donderdag 5 december 2013
klokke 15.00 uur

door

Gidey Yirga Abay

Geboren te Asgede-Tsimbla, Ethiopia
in 1983

PROMOTIE COMMISSIE

Promotores:	Prof. dr. H. Leirs (Universiteit Antwerpen)
	Prof. dr. G.R. de Snoo (Universiteit Leiden)
Co-promotor:	Prof. dr. ir. H.H. de Iongh (Universiteit Leiden)
Overige leden:	Prof. dr. E. Matthysen (Universiteit Antwerpen)
	Prof. dr. C. Sillero (Universiteit Oxford)
	Prof. dr. H.A. Udo de Haes (Universiteit Leiden)

Universiteit Leiden

Table of Contents

PART I
Background

1

General Introduction

1.1 Carnivore conservation

Human activities have caused a decline in carnivore populations worldwide (Woodroffe, 2000). Conservation of large carnivores is very challenging due to expanding human populations and their associated impacts. These challenges are particularly acute in sub-Saharan Africa, where there is a rapid increase in human populations (Ceballos & Ehrlich, 2006). In this region, the rising demand for agriculture and husbandry (Mearns, 1997) results in land degradation and habitat fragmentation. Carnivores are declining very rapidly in some regions due to loss of habitat, depletion of prey, hunting, diseases and trade in body parts as well as conflict with humans (Novaro et al., 2000; Sillero-Zubiri & Laurenson, 2001). Habitat fragmentation and persecution by humans is linked to the disappearance of large carnivores such as wild dogs (*Lycaon pictus,* Temminck, 1820), cheetahs (*Acinonyx jubatus,* Schreber, 1775), lions (*Panthera leo,* L. 1758) (Woodroffe, 2001; Ogada et al., 2003; Patterson et al., 2004; Packer et al., 2005) and spotted hyenas (*Crocuta crocuta*) (Woodroffe, 2001; Treves & Karanth, 2003; Kolowski & Holekamp, 2006; Kissui, 2008). Spotted hyenas (*Crocuta crocuta* Erxleben 1777), here after referred as hyenas, experience declines outside of protected areas due to habitat loss and poaching (Honer et al., 2008).

In Western Europe, hyena's extinction coincided with a decline in grasslands 12,500 years ago (Stiner, 2004). Around that time, hyenas were outcompeted by wolves and humans when the grasslands favored by hyenas became depleted. Populations of hyenas began to shrink and disappeared completely from Western Europe between 14,000 and 11,000 years ago (Stiner, 2004). Habitat and prey loss may explain the hyena's eventual disappearance not only from Europe but Asia as well (Stiner, 2004).

Persecution can reduce the population size of large carnivores, including hyenas (Woodroffe, 2001). This often represents a leading source of mortal-

ity (Woodroffe & Ginsberg, 2000) and is often associated with human-carnivore conflicts (Woodroffe, 2000; Ogutu et al., 2005; Johnson et al., 2006). For example, in some areas of Africa farmers may saturate a goat or cow carcass with fast-acting poison, leave this out for hyenas to feed on during the night and in this way kill numerous hyenas simultaneously (Holekamp & Smale, 1992). This kind of mass poisoning as retaliation for livestock depredation has been documented for hyenas in eastern Africa, but it may also occur in the rest of Africa (Holekamp & Smale, 1992).

Large carnivores are usually at the top of food chain and are always present in low densities (Van Orsdol et al., 1985; Hemson, 2003; Loveridge et al., 2007; Croes et al., 2011). They will always be less abundant than their herbivore prey and therefore be more vulnerable to extinction (Noss et al., 1996; Sillero-Zubiri & Laurenson, 2001). Large carnivores have a high propensity for conflict with humans. They have extensive home ranges and need large prey populations to survive, and therefore only large areas can support viable populations (Msuha, 2009). Coexistence between large carnivores and local communities is almost impossible in human-dominated landscapes (Woodroffe & Ginsberg, 2000); they need extensive areas with few people (Lindsey et al., 2013). It is difficult to maintain such ecosystems mainly because of human population growth and the associated demand for land and other resources (Msuha, 2009). As a consequence, large carnivores tend to suffer when human populations expand into intact habitats (Woodroffe & Ginsberg, 1998; Woodroffe, 2000; Sillero-Zubiri & Laurenson, 2001). Retaliatory killing as a cause of mortality is probably more important in Africa, where large carnivores are more abundant and where management may be ineffective because of a lack of sufficient financial and human capacity, than in developed countries (Msuha, 2009).

Low species population density, small geographical range size, long gestation period and high trophic level are factors associated with high extinction risk in carnivores (Cardillo et al., 2004). Moreover, survival of large carnivores depends on their level of conflict with human interests and their social acceptability to humans, particularly outside protected areas (Linnell et al., 2001; Kleiven et al., 2004; Lindsey et al., 2005; Tumenta et al., 2010). Conflict-related mortality can be very high (Woodroffe & Ginsberg, 1998; Macdonald & Sillero-Zubiri, 2002; Kolowski & Holekamp, 2006).

Most of Africa's protected areas are too small to conserve viable populations of large, wide-ranging carnivores (EWCA, 2012a). Such species must utilize adjacent dispersal areas to obtain supplementary food (Woodroffe &

Frank, 2005). There are many designated protected areas of land, including National Parks, Wildlife Reserves, Biosphere Reserves, Priority Forests and Community Conservation Areas in Ethiopia (Young, 2012). However, these protected areas are severely degraded (Young, 2012). Protected grasslands are used for livestock grazing and timber is used for fuel and construction (Young, 2012). Land is being converted for subsistence and commercial agriculture. The primary goal of the Ethiopian Government is poverty alleviation through food production and investment policies (Young, 2012). There is limited and only imprecise information on the status and distribution of large carnivores in Ethiopia (EWCA, 2012a; EWCA, 2012b). Non-protected areas play a vital role in maintaining the existence of carnivores, both in order to increase population size and to allow greater genetic exchange between populations (Linnell et al., 2001; Treves & Karanth, 2003).

As suggested above, most scientific literature on hyena-human interactions in Africa suggests conflict situations, often resulting in the killing of hyenas (Woodroffe, 2001; Treves & Karanth, 2003; Kolowski & Holekamp, 2006; Kissui, 2008). The present dissertation will present an exceptional case of peaceful coexistence between hyena and humans. A high density of hyenas persists peacefully with dense human habitations in non-protected areas in northern Ethiopia. Hyenas are highly adapted to dense human habitations, and their survival is dependent on anthropogenic food (Yirga et al., 2012a). The main objective of this research is to study the ecology and behavior of hyena in a human-dominated landscape in northern Ethiopia.

1.2 Ecology of hyena

1.2.1 Distribution and status

Hyena has a remarkable behavioral plasticity that facilitates its adaptive adjustment to an increasingly precarious lifestyle in proximity to humans (Woodroffe, 2000; Sunquist & Sunquist, 2001; Boydston et al., 2003). They can be nocturnal or diurnal and breed at any time of the year (Van Meter et al., 2009). Hyenas inhabit very wide historical range with relatively stable populations and this shows that hyenas have high behavioral and ecological plasticity (Kolowski & Holekamp, 2009). During the Pleistocene era, hyenas inhabited large parts of Eurasia but currently occur only in Africa (Kurten, 1968; Werdelin & Solounias, 1991). Hyenas are large (45-80 kg), gregarious carnivores that occur throughout sub-Saharan Africa except for true deserts and alpine areas above 3000 m (Mills, 1990; Frank et al., 1995; Mills &

Harvey, 2001). Hyenas are also generally absent from tropical rainforests, except for Odzala National Park in Congo (Wilson & Reeder, 1993; Ray et al., 2005). Their large range may be due to the hyena's versatile choice of prey, as its food is known to vary across ecosystems (Mills & Hofer, 1998). In Central Africa, the hyena has mainly been reported to inhabit savannahs (Mills & Hofer, 1998; IUCN, 2008), although hyenas have been reported in Odzala National Park, Congo. There have not been recent records inside Algeria, Djibouti, Egypt, Equatorial Guinea, Gabon, Gambia and Liberia. The current distribution of hyenas is limited to Ethiopia, Kenya, Tanzania, Botswana, Namibia, South Africa, Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Ivory Coast, Democratic Republic of Congo, Ghana, Lesotho, Guinea Bissau, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Senegal, Somalia and Sierra Leone (Mills & Hofer, 1998).

A tentative estimate of the total population of hyena in Africa is between 27,000 and 47,000 (Mills & Hofer, 1998), which is most likely to be an underestimate. The largest known populations occur in the Serengeti ecosystem, Tanzania and the Kruger National Park, South Africa with estimates of 8,700 and 3,900 hyenas, respectively (Mills & Hofer, 1998). Most hyena populations in protected areas of southern Africa are stable but in protected areas of eastern and western Africa they are declining due to incidental snaring and poisoning (Mills & Hofer, 1998; Craigie et al., 2010). Diseases, habitat loss and persecution by humans make hyenas dependent on conservation areas (Mills & Hofer, 1998).

1.2.2 Feeding habits

Hyena is an opportunistic carnivore, foraging on locally abundant prey species (Cooper et al., 1999). Hyena densities are usually positively correlated with prey biomass densities (Ogutu et al., 2005). The most common prey species include various antelopes (such as *Cephalophus dorsalis*, *Cephalophus niger*, and *Tragelaphus strepsiceros*), zebra (*Equus spp.*), buffalo (*Syncerus caffer*) and juvenile rhinos (*Diceros bicornis*), hippos (*Hippopotamus amphibius*) and giraffes (*Giraffa camelopardalis*) (Mills & Hofer, 1998; Hayward, 2006). Hyenas kill and scavenge on small, medium and large-sized species (Kruuk, 1972; Salnicki et al., 2001). Hyenas detect their prey by sight, sound and smell. They find carrion by the sound of other carnivores feeding, by distress calls, by smell, or during day light hours by watching vultures descend on carcasses (Mills & Hofer, 1998). They are able to hear noises coming from predators killing prey or feeding on carcasses over dis-

tances of up to 10 km (Mills, 1990). An analysis of 14 published studies and one unpublished study about the diet of hyenas throughout their range in Africa was used by Hayward (2006) to establish prey preference and avoidance of large carnivores, including the hyena. He concluded that hyenas do not have a significant preference for a particular prey species. Hyenas eat almost any mammal, bird, fish or reptile, irrespective of size or species (Mills, 1990; Henschel & Skinner, 1990; Sillero-Zubiri & Gottelli, 1992; Salnicki et al., 2001). They have a reputation for killing and scavenging domestic livestock, mostly cattle, sheep and goats, but also poultry, cats, dogs, horses, donkeys, and camels (Mills & Hofer, 1998; Abay et al., 2011; Sogbohossou et al., 2011). Hyenas are opportunistic scavengers of human waste, bones, and dung, and may forage on anthrax-infested carcasses without detrimental consequences. They are capable of eating and digesting all parts of their prey except hair and hooves (Smith & Holekamp, 2010). Hyenas can totally digest bones and only the inorganic components are excreted in the their droppings (Smith & Holekamp, 2010). Hyenas are known to be most active during the night (Kruuk, 1972; Mills, 1990). They are flexible hunters, cooperating to bring down larger prey, but foraging alone for smaller animals (Kruuk, 1966) up to 75% of the time (Holekamp et al., 1997). They feed with remarkable speed, 18 kg food per hour (Kruuk, 1972), compared to lions (Kolowski et al., 2007). Hyenas can travel over vast distances. For example, Kolowski et al. (2007) showed that hyena from the Maasai Mara travel on average 12.4 km per night. Length of travel is thought to be dependent on home range size and prey availability.

Ranging behavior of hyenas is typically, but not always, nocturnal, with individuals often moving long distances when active (Kruuk, 1972; Mills, 1990). Previous studies have shown that onset and cessation of movement of hyenas are closely associated with sunrise and sunset and the majority of daytime movement occurred in the early morning (Kolowski et al., 2007). Male hyenas tended to exhibit higher movement rates than females over a 24-h period (Kolowski et al., 2007). Movement rates of males peaked at 00:00–01:00 h, but movements of females did not show a clear peak (Kolowski et al., 2007). The maximum distance moved in a single hour was 4,680 m by a male hyena and 4,513 m by a female (Kolowski et al., 2007). Various studies indicated seasonal variation in movements of hyenas due to fluctuations in prey abundance (Hofer & East, 1993; Trinkel et al., 2004).

1.2.3 Sex and social organization

The secondary reproductive organs of hyena are very similar in males and females (Mills & Hofer, 1998). The female clitoris is very similar in size and shape to the male penis. It can be erected and it is situated in exactly the same position as the penis in a male hyena (Mills & Hofer, 1998). Differentiating male and female hyenas by observation in a field is quite problematic. Teats or udders may be visible anterior to the hind legs of an adult female, and the adult female often has 'baggy' appearance whereas males are generally quite leggy and trim (Mills & Hofer, 1998). Unlike with most mammals, adult female hyenas are roughly 10% larger than adult males, and are more aggressive and socially dominant (Smith & Holekamp, 2010). Male hyenas disperse after puberty whereas female hyenas generally spend their entire lives in their natal clans (Henschel & Skinner, 1987; Smale et al., 1997; Holekamp & Smale, 1998). Males that successfully immigrate are subordinate to all natal females and their offspring in the new clan (Tilson & Hamilton, 1984; Smale et al., 1993).

Hyenas live in social groups called clans (Kruuk, 1972; Holekamp et al., 1997, 2000) containing 6–90 individuals (Smith & Holekamp, 2010). The mean clan size across Africa is approximately 21 hyenas, but abundance of local prey animals determines clan size (Smith & Holekamp, 2010). Within the territory defended by each clan, individuals travel, rest, and forage alone or in subgroups (Holekamp et al., 2000). Composition of subgroups typically changes several times during the course of a single day and sizes of subgroups range from one to tens of animals (Holekamp et al., 1997, 2000). Hyenas assemble for reasons ranging from such cooperative activities as territorial defense (Henschel & Skinner, 1991; Boydston et al., 2001) to intense direct competition during group feeding at kills of ungulates (Tilson & Hamilton, 1984; Frank, 1986). Hyenas also frequently congregate at the communal den, which serves as the clan's social center (Boydston et al., 2003). Females with young cubs visit the den regularly to nurse their dependent offspring, and sub-adults, adult males, and adult females without den-dwelling cubs also visit the communal den frequently (Boydston et al., 2003).

1.2.4 Hyena-human interrelation

Conflicts between predators and humans have intensified across Africa due to human population growth and economic activities (Woodroffe, 2000; Conover, 2002). Human–hyena conflict is a common problem on the Afri-

can continent (Ogada et al., 2003; Patterson et al., 2004; Kolowski & Holekamp, 2006; Holmern et al., 2007). Conflict between predators and humans is the main threat to the survival of carnivore species, including hyenas (Woodroffe & Ginsberg, 1998), but this problem is worse in other countries of Africa than Ethiopia. In Ethiopia, depredation of livestock by hyenas appears to be tolerable and is relatively low compared to reports on livestock depredation across Africa (Abay et al., 2011; Yirga et al., 2012b).

A large number of studies reported serious conflicts between hyenas and humans in Africa, resulting in persecution of the hyenas. In the Maasai steppe, Tanzania, the impact of livestock depredation by hyenas was high enough to provoke pastoralists into retaliating against hyenas (Kissui, 2008). Hyenas were the most frequent predators on livestock, followed by lions and leopards and as a result 71 hyenas were reported to have been poisoned in three villages (Kissui, 2008).

Persecution has led to the decline of many populations of large carnivores outside protected areas (Gittleman et al., 2001; Woodroffe, 2001). Studying human-carnivore conflict, including attitudes and actions of local communities toward large carnivores, is very important for the conservation of large carnivores outside protected areas (Sillero-Zubiri & Laurenson, 2001; Naughton-Treves et al., 2003).

Even through hyenas are regarded in a generally negative light in most African cultures, being seen as selfish, foolish, sly, immoral, and dirty (Jürgen, 1998; Glickman, 1995; Middleton & Winter, 2004), they have a positive reputation in some parts of Africa. For example, in the East African Tabwa mythology, hyenas represent the animal that first brought the sun to warm the cold earth (Jürgen, 1998). In Tanzania, killing a hyena in retaliation of an attack is believed to be dangerous because the bond between the hyena and its 'owner' is strong and could result in death of the hyena's killer (Middleton & Winter, 2004). This demonstrates that people across the African continent have different beliefs and practices in relation to hyenas.

The hyena has been hunted for the use of its body parts in traditional medicine (Glickman, 1995; Mills & Hofer, 1998). In the African continent, the hyena body parts are used for medicinal and magical purposes. For example, In Burkina Faso, the hyena's tail, in Cameroon, Côte d'Ivoire and Senegal, the hyena's whole body, in Malawi and Tanzania, the genitalia, nose tips and tails, and in Mozambique the hyena paws are used for traditional medi-

cine (Mills & Hofer, 1998). Hyena's bone is used traditionally for Bouda (evil eye) treatment in Ethiopia.

1.3 Research aims

This study focused on hyena, which is the largest predator in Tigray regional state of Ethiopia. Anthropogenic food sources are of major importance for the survival of hyenas, because natural prey biomass is highly depleted. Overall, this research project aimed to investigate hyena ecology and behavior in human-dominated areas in the Tigray region. This included studies on abundance and distribution, diet, economic impact, human perception, and adaptability of spotted hyenas to changing anthropogenic food sources. The Ethiopian Orthodox Tewahedo Church has unique rules and guidelines for fasting. There are seven fasting periods in a year and all fasts are mandatory for all members of the church. The longest fasting period is the Great Fast (Lent) which is a 55-day fast before Easter. The majority of people in the region do not eat meat and dairy products during this period.

Based on regular observations of hyenas and anecdotal reports, I hypothesized that hyenas in Tigray survive in human-dominated landscapes because of a unique combination of adaptation to anthropogenic food and cultural tolerance towards hyenas.

The specific research questions were:

1. What does hyena diet in Tigray consist of and how does it vary in space and time?
   - a. What are the changes in diet before, during and after the Orthodox fasting periods?
   - b. What are the differences in diet between inside and outside protected areas?
2. To what extent are hyenas tolerated by local communities?
3. Which factors influence the abundance, density and distribution of hyenas?
   - a. What is the abundance and density in prey-depleted areas?
   - b. What is the influence of human settlement?
4. What is the level of livestock depredation by hyena compared to leopard and jackal in time and space?
   - a. Which livestock species are preferred?
   - b. What is the trend of livestock depredation?

1.4 Study area

1.4.1 Ethiopia

Ethiopia is the third populous country in Africa with about 85 million people with in an area of 1.1 million square kilometers. The weather is usually sunny and dry with the short ('belg') rains occurring from February to April and the big ('meher') rains beginning in mid-June and ending in mid-September. The livestock population of Ethiopia is among the largest in the world and the largest in Africa, totaling up to 134 million (NABC, Netherlands- African Business Council, 2010).

1.4.2 Tigray regional state

Tigray National Regional State (hereafter Tigray), established in 1993 as one of the nine regional states of Ethiopia, is located in the northeastern part of the country and covers an area of approximately 53,000 square kilometers (Solomon, 2005 cited in Sara, 2010). Administratively, it is divided into six zones, 34 rural districts and 12 town districts (Fig. 1). Each district is subdivided into sub-district (*tabias*) and each tabia is divided into kushet (*hamlets*) which are the lowest unit in the administrative hierarchy. The delineation is made based on natural boundaries such as rivers, escarpments and mountain peaks, population size, agro-ecology and proximity to administrative centers (Sara, 2010). Annual mean temperatures of the region range from 12 °C in some highland areas to 37 °C in Humera (lowland area). The annual mean temperature for most of the region is between 15-21 °C (Sara, 2010). Severe droughts have affected the region every 2-3 years. The region belongs to the African dry lands, which is often called the Sudano-Sahelian region (Warren & Khogali, 1992).

According to Sara (2010) average annual rainfall varies from about 200 mm in the northeastern lowlands to over 1000 mm in the southwestern highlands. The major types of land cover are bush and shrubland (36.2%), cultivated land (28.2%) and grassland (22.8%). Other forms of land cover account for about 11% of the land mass. Cultivated land is the dominant land use in the highlands of Tigray, where there is high human population density (Sara, 2010). Tigray has approximately 4.3 million inhabitants, most of them (81.2%) living in rural areas, with an average family size of five persons per household (Central Statistical Agency, 2008). The population is growing at 2.5% per year and population density in the region is 63 persons per square km (Central Statistical Agency, 2008). Other studies, however, have

indicated that in the highland areas the average density is 137 persons per square km, indicating that there is high population pressure in these areas (Pander & Gebremedehin, 2004). Agriculture is the mainstay of the region's economy, contributing about 57% of the gross domestic product (GDP), of which 36% is from crops, and about 1 and 4% from livestock and forestry, respectively. Forests have been completely converted into farms and grazing lands throughout the region over centuries, except for patchy remnants of old-growth Afromontane forests around most of the old Ethiopian Orthodox Tewahido Churches (Aerts et al., 2007; Alemayehu., 2007). In this study, Wukro and Enderta districts were selected, as they are very near to Mekelle, the regional capital.

1.4.3 Enderta district

Enderta district is one of the eight districts of the southern zone of Tigray (Fig. 1). Mekelle is located in the middle of Enderta district. The district is geographically located between 13°-14° North and at 39°-40° 30' East (Sara, 2010). The total rural human and livestock population is about 115,000 and 56,000, respectively (Bureau of Agricultural and Natural Resources Development (BOANR), 2009). Average family size is five and population density of the district is 79 persons per square km (Sara, 2010). The altitude of the district ranges from below 1400 m a.s.l. to 2700 m a.s.l. 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. The average annual rainfall of the district is about 550 mm. The mean maximum temperature ranges between 12 ºC (November and December) and 27 ºC (January and March).

There are 17 *tabias* in Enderta district: Dergi-Ajen, Meseret, Lemlem, May-Genet, Didba, May–Tsedo, Shibta, Felege-Selem, Arato, May-Alem, May-Anbesa, Debri, Mehabere- Genet, Mesebo, Felege-Mayat, Maryam-Liham and Chelekot (Teferi et al., 2011). Landscape formation of the district varies from mountainous, undulating, rugged valleys and gorges, and hilly areas to flat plains (Sara, 2010). The land is severely eroded as a result of continuous human land exploitation and deforestation and natural calamities such as drought. The district has a total area of 193,309 ha, of which the total area of agriculture covers about 49.03%. The average land holding per household is 0.75 ha (Sara, 2010). More than 80% of the population living in the district is engaged in subsistence farming, with land size of less than one ha. The agricultural fields are fragmented over a wide range of different landforms. There are a few established 'exclosures' in the district, mainly for environmental rehabilitation of sensitive areas.

Figure 1.1
Map of Ethiopia showing regional states and map of Tigray regional state showing Wukro and Enderta districts

1.4.4 Wukro district

The Wukro district is found in eastern zone of Tigray region located at 13° 36' North and 39° 36' East at an altitude of 1,800 to 3,069 m a.s.l (Sara, 2010). The annual temperature and rainfall of the district ranges from 17.25 to 28 °C, and 350 to 450 mm, respectively. 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. The district has a population of 112,235

persons, giving a human population density of 98 persons per square km (Office of Agriculture and Rural Development of Wukro district, 2010). Average family size is five persons. About 95% of the population of the district depends on rain-fed agriculture and practice livestock husbandry and crop production simultaneously. The average land holding per household is about 0.5 ha. According to Sara (2010) the main crops grown in the district are barley, wheat, teff, maize and sorghum. The livestock population of the district is 209,024 (Sara, 2010). The district has a total area of 100,228 ha. Food insecurity and poverty are severe. The area is generally a seriously degraded landscape with some acacia (*Acacia etbaica, Acacia saligna* and *Dodonaea angustifolia*), eucalyptus (*Eucalyptus camaldulensis* and *Eucalyptus globulus*) and African olive (*Olea africana)* vegetation and few large or medium-sized natural prey. There are a few established 'exclosures' in the district; these are very small protected areas mainly for environmental rehabilitation of sensitive areas.

1.5 Outline of the thesis

The first part of the thesis is a general introduction and review of the ecology of hyena and presents the objectives of the study. The country and the area where the study took place are described.

The second part describes the ecology of the spotted hyena:

- In chapter 2, the ecology of peri-urban hyenas in northern Ethiopia is presented. This examines spotted hyena abundance and contribution of livestock depredation and scavenging to hyena food intake.
- Chapter 3 reports on the adaptability of large carnivores to changing anthropogenic food sources. In this chapter, diet change of hyenas during Christian fasting periods is investigated.
- Chapter 4 reports the coexistence of hyena at high density with people in a degraded and prey-depleted district.
- In chapter 5, ecological factors influencing hyena abundance and distribution in anthropogenic landscapes are identified.
- Chapter 6 is about hyena dependence on anthropogenic food across Ethiopia. This chapter presents the diet of spotted hyena based on scat analysis in protected and non-protected areas across Ethiopia.
- Chapter 7 presents the ecology of large carnivores in the highlands of northern Ethiopia. This chapter reports prey preferences of three large carnivores with regard to livestock, and depredation in time and space.

The third part of the thesis (Chapter 8) discusses the implications of the study and mentions some aspects that remain to be better studied.

References

Abay, G.Y., Bauer, H., Gebrihiwot, K. & Deckers, J. (2011). Peri-urban spotted hyena (*Crocuta crocuta*) in northern Ethiopia: diet, economic impact and abundance. European Journal of Wildlife Research **57**, 759-765.

Aerts, R., Negussie, A., Maes, W., November, E., Hermy, M. & Muys, B. (2007). Restoration of dry Afromontane forest using pioneer shrubs as nurse plants for *Olea europaea* ssp. Euspidata. Restoration Ecology **15**, 129-138.

Alemayehu, W.E. (2007). Ethiopian Church Forests: opportunities and challenges for restoration. PhD thesis, Wageningen University, Wageningen, The Netherlands.

Boydston, E.E., Kapheim, K.M., Watts, H.E., Szykman, M. & Holekamp, K.E. (2003). Altered behavior in spotted hyenas associated with increased human activity. Animal Conservation **6**, 207-219.

Boydston, E.E., Morelli, T.L. & Holekamp, K.E. (2001). Sex differences in territorial behavior exhibited by the spotted hyena (*Crocuta crocuta*). Ethology **107**, 369-385.

Cardillo, M., Purvis, A., Secrest, W., Gittleman, J.L., Bielby, J. & Mace, G.M. (2004). Human population density and extinction risk in the world's carnivores. PLOS Biology **2**, 0909-0914.

Ceballos, G. & Ehrlich, P.R. (2006). Global mammal distribution, biodiversity hotspots and conservation. PNAS **103**, 19374-19379.

Central Statistical Agency (2008). Summary and Statistical Report of the year 2007. Population and housing census, Federal Democratic Republic of Ethiopian Population Census Commission.

Conover, M. (2002). Resolving Human – Wildlife Conflicts: The Science of Wildlife Damage Management. Lewis Publishers, Boca Raton, USA.

Cooper, S.M., Holecamp, K.E. & Smale, L. (1999). A seasonal feast: long-term analysis of feeding behavior in the spotted hyena (*Crocuta crocuta*). African Journal of Ecology **37**, 149-160.

Craigie, I.D., Baillie, J.E.M., Balmford, A., Carbone, C., Collen, B., Green, R.E. & Hutton, J.M. (2010). Large mammal population declines in Africa's protected areas. Biological Conservation **143**, 2221-2228.

Croes, B.M., Funston, P.J., Rasmussen, G., Buij, R., Saleh, A., Tumenta, P.N. & De Iongh, H.H. (2011). The impact of trophy hunting on lions (*Panthera leo*) and other large carnivores in the Bénoué Complex, northern Cameroon. Biological Conservation **144**, 3064-3072.

EWCA (2012a). National Action Plan for the Conservation of Cheetahs and African Wild Dogs in Ethiopia, Addis Ababa, Ethiopia.

EWCA (2012b). National Action Plan for the conservation of the African Lion *Panthera leo* in Ethiopia. Addis Ababa, Ethiopia.

Frank, L.G. (1986). Social organization of the spotted hyena (*Crocuta crocuta*). II. Dominance and reproduction. Animal Behavior **34**, 1510-1527.

Frank, L.G., Holekamp, K.E. & Smale, L. (1995). Dominance, demography, and reproductive success of female spotted hyenas. In: Sinclair, A.R.E. & Arcese, P. eds. Serengeti II: dynamics, management, and conservation of an ecosystem (pp. 364–384). University of Chicago Press: Chicago, Illinois, USA.

Gittleman, J.L., Funk, S.M., Macdonald, D.W. & Wayne, R.K. (eds.). (2001). Carnivore conservation. Cambridge University Press: Cambridge, United Kingdom.

Glickman, S. (1995). The Spotted Hyena from Aristotle to the Lion King: Reputation is Everything - In the Company of Animals. Social Research **62**, 501-537.

Hayward, M.W. (2006). Prey preferences of the spotted hyena *Crocuta crocuta* and evidence of dietary competition with lion *Panthera leo*. Journal Zoology (London) **270**, 606-614.

Hemson, G. (2003). The ecology and conservation of lions: human–wildlife conflict in semi-arid Botswana. PhD thesis, University of Oxford, Oxford, United Kingdom.

Henschel, J.R. & Skinner, J.D. (1987). Social relationships and dispersal patterns in a clan of spotted hyenas *Crocuta crocuta* in Kruger National Park. South African Journal of Zoology **22**, 18-24.

Henschel, J.R. & Skinner, J.D. (1990). The diet of the spotted hyena (*Crocuta crocuta*) in Kruger National Park. African Journal of Ecology **28**, 69-82.

Henschel, J.R. & Skinner, J.D. (1991). Territorial behavior by a clan of spotted hyenas *Crocuta crocuta*. Ethology **88**, 223-235.

Hofer, H. & East, M.L. (1993). The commuting system of Serengeti spotted hyenas: how a predator copes with migratory prey. I. Social organization. Animal Behavior **46**, 547-557.

Holekamp, K.E. & Smale, L. (1992). SSC Hyena Specialist Group. pp. 19-20. IUCN.

Holekamp, K.E. & Smale, L. (1998). Dispersal status influences hormones and behavior in the male spotted hyena. Hormones and Behavior **33**, 205-216.

Holekamp, K.E., Boydston, E.E. & Smale, L. (2000). Group travel in social carnivores. In: Boinski, S. & Garber, P. eds. On the move: how and why animals travel in groups (pp. 587–627). University of Chicago Press: Chicago, IL, USA.

Holekamp, K.E., Smale, L., Berg, R. & Copper, S.M. (1997). Hunting rates and hunting success in the spotted hyena (*Crocuta crocuta*). Journal of Zoology (London) **242**, 1-15.

Holmern, T., Nyahongo, J.W. & Røskaft, E. (2007). Livestock Loss Caused by Predators Outside the Serengeti National Park, Tanzania. Biological Conservation **135**, 518-542.

Honer, O., Holekamp, K.E. & Mills, G. (2008). *Crocuta crocuta*. In: IUCN 2008. IUCN Red List of Threatened Species. Retrieved 22 March 2009. Database entry includes a brief justification of why this species is of least concern.

IUCN, (2008). In-depth information on hyena biology and conservation. The Hyena Specialist Group, member of the Species Survival Commission of the World Conservation Union. www.hyaenidae.orgs.

Johnson, A., Vongkhamheng, C., Hedemark, M. & Saithongdam, T. (2006). Effects of human – carnivore conflict on tiger (*Panthera tigris*) and prey populations in Lao PDR. Animal Conservation **9**, 421-430.

Jürgen, W. (1998). The Magicality of the Hyena: Beliefs and Practices in West and South Asia. Asian Folklore Studies **57**, 331-344.

Kissui, B.M. (2008). Livestock predation by lions, leopards, spotted hyenas, and their vulnerability to retaliatory killing in the Maasai steppe, Tanzania. Animal Conservation **11**, 422-432.

Kleiven, J., Bjerke, T. & Kaltenborn, B. (2004). Factors influencing the social acceptability of large carnivore behaviors. Biodiversity and Conservation **13**, 1647-1658.

Kolowski, J.M. & Holekamp, K.E. (2006). Spatial, temporal, and physical characteristics of livestock depredations by large carnivores along a Kenyan reserve border. Biological Conservation **128**, 529-541.

Kolowski, J.M. & Holekamp, K.E. (2009). Ecological and anthropogenic influences on space use by spotted hyenas. Journal of Zoology **277**, 23-36.

Kolowski, J.M., Katan, D., Theis, K. & Holekamp, K.E. (2007). Daily Patterns of Activity in the spotted hyena. Journal of Mammalogy **88**, 1017-1028.

Kruuk, H. (1966). Clan-system and feeding habits of spotted hyenas (*Crocuta crocuta*). Nature **209**, 1257-1258.

Kruuk, H. (1972). The Spotted Hyena: A Study of Predation and Social Behavior. The University of Chicago Press: Chicago, USA.

Kurten, B. (1968). Pleistocene mammals of Europe. Weidenfeld and Nicholson, London.

Lindsey, P.A., du Toit, J.T. & Mills, M.G.L. (2005). Attitudes of ranchers towards African wild dogs *Lycaon pictus*: conservation implications on private land. Biological Conservation **125**, 113-121.

Lindsey, P.A., Havemann, C.P., Lines, R., Palazy, L. & Price, A.E. (2013). Determinants of Persistence and Tolerance of Carnivores on Namibian Ranches: Implications for Conservation on Southern African Private Lands. PLoS ONE **8**, e52458.

Linnell, J.D.C., Swenson, J. & Andersen, R. (2001). Predators and people: conservation of large carnivores is possible at high human densities if management policy is favorable. Animal Conservation **4**, 345-350.

Loveridge, A.J., Searle, A.W., Murindagomo, F. & Macdonald, D.W. (2007). The impact of sport hunting on the population dynamics of an African lion population in a protected area. Biological Conservation **134**, 548-558.

Macdonald, D.W. & Sillero-Zubiri, C. (2002). Dimensions of the problem. In: Loveridge, A.J., Lynam, T. & Macdonald, D.W. eds. Lion conservation research, workshop 2: Modeling conflict (pp. 1-8). Wildlife Conservation Research Unit, University of Oxford: Oxford, United Kingdom.

Mearns, R. (1997). Livestock and environment: potential for complimentarily. World animal review FAO **1**, 2-14.

Middleton, J. & Winter, E.H. (2004). Witchcraft and Sorcery in East Africa, Routledge.

Mills, M.G.L. & Harvey, M. (2001). African predators. Cape Town: Struik.

Mills, M.G.L. & Hofer, H. (1998). Hyenas. Status Survey & Conservation Action Plan. IUCN/SSC Hyena Specialist Group. IUCN, Gland, Switzerland and Cambridge, United Kingdom (compilers).

Mills, M.G.L. (1990). Kalahari hyenas: comparative behavioral ecology of two species. London. Unwin Hyemn.

Msuha, M.J. (2009). Human impacts on carnivore biodiversity inside and outside protected area in Tanzania, PhD thesis, University College London, United Kingdom.

NABC, Netherlands- African Business Council, (2010). Livestock in Ethiopia and opportunity analyses for Dutch investment. www.nabc.nl, downloaded January, 2013.

Naughton-Treves, L., Grossberg, R. & Treves, A. (2003). Paying for tolerance: rural citizens' attitudes toward wolf depredation and compensation. Conservation Biology **17**, 1500-1511.

Noss, R.F., Quigley, H.B., Hornocker, M.G., Merrill, T. & Paquet, P.C. (1996). Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology **10**, 949-963.

Novaro, A.J., Funes, M.C. & Walker, R. (2000). Ecological extinction of native prey of a carnivore assemblage in Argentine Patagonia. Biological Conservation **92**, 25-33.

Ogada, M., Woodroffe, R., Oguge, O.N. & Frank, G.L. (2003). Limiting depredation by African carnivores: the role of livestock husbandry. Conservation Biology **17**, 1521-1530.

Ogutu, J.O., Bhola, N. & Reid, R. (2005). The effects of pastoralism and protection on the density and distribution of carnivores and their prey in the Mara ecosystem of Kenya. Journal of Zoology (London) **265**, 281-293.

Packer, C., Ikanda, D., Kissui, B. & Kushnir, H. (2005). Lion attacks on humans in Tanzania. Nature **436**, 927-928.

Pander, J. & Gebremedehin, B. (2004). Impacts of polices and technologies in dry land agriculture; Evidence from northern Ethiopia.

Patterson, B.D., Kaski, S.M., Selempo, E. & Kays, R.W. (2004). Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighboring Tsavo national parks, Kenya. Biological Conservation **119**, 507-516.

Ray, J., Hunter, L. & Zigouris, J. (2005). Setting conservation and research priorities for larger African carnivores. WCS Working Paper No. 24. Wildlife Conservation Society, New York.

Salnicki, J., Teichmann, M., Murindagomo, F. & Wilson, V. (2001). Spotted hyenas *Crocuta crocuta* prey on new-born elephant calvesin Hwange National Park, Zimbabwe. Koedoe **44**, 79-83.

Sara, A.A. (2010). Mitigating drought: Policy Impact Evaluation A case of Tigray region, Ethiopia, Msc. Thesis, University of Twente. The Netherlands.

Sillero-Zubiri, C. & Gottelli, D. (1992). Population ecology of spotted hyenas in an equatorial mountain forest. African Journal of Ecology **30**, 292-300.

Sillero-Zubiri, C. & Laurenson, K. (2001). Interaction between local communities and carnivores: conflict or co-existence? In: Gittleman, J.L., Funk, S.M., Macdonald, D. & Wayne, R.K. eds. Carnivore Conservation (pp. 282-312). Zoological Society of London: London.

Smale, L., Frank, L.G. & Holekamp, K.E. (1993). Ontogeny of dominance in free-living spotted hyenas: juvenile rank relations with adults. Animal Behavior **46**, 467-477.

Smale, L., Nunes, S. & Holekamp, K.E. (1997). Sexually dimorphic dispersal in mammals: patterns, causes, and consequences. Advances in the Study of Behavior **26**, 181-250.

Smith, J.E. & Holekamp, K.E. (2010). Spotted Hyenas Michigan State University, East Lansing, MI, USA ã 2010 Elsevier Ltd. All rights reserved.

Sogbohossou, E.A., De Iongh, H.H., Brice, S., Snoo, G.R. & Funstone, P. (2011). Human-carnivore conflicts around Pendjari Biosphere reserve, northern Benin. Oryx **6**, 1-10.

Solomon, H. (2005). Scio-economic infrastructure of the Tigray region, department of geography, Mekelle University (unpublished).

Stiner, M.C. (2004). Comparative ecology and taphonomy of spotted hyenas, humans, and wolves in Pleistocene Italy Revue de Paléobiologie. Genève **23**, 771-785.

Sunquist, M.E. & Sunquist, F. (2001). Changing landscapes: consequences for carnivores. In *Carnivore conservation*: 399 – range and area reached by animal vocalizations. Journal of experimental Biology **200**, 421-431.

Teferi, M., Yirga, G., Hailemichael, T. & Amare, S. (2011). Prospects of beekeeping in the Northern Ethiopian highlands. Scientific Research and Essays **6**, 6039-6043.

Tilson, R.T. & Hamilton, W.J. (1984). Social dominance and feeding patterns of spotted hyenas. Animal Behavior **32**, 715-724.

Treves, A. & Karanth, K.U. (2003). Human–carnivore conflict and perspectives on carnivore management worldwide. Conservation Biology **17**, 1491-1499.

Trinkel, M., Fleischmann, P.H., Steindorfer, A.F. & Kastberger, G. (2004). Spotted hyenas (*Crocuta crocuta*) follow migratory prey. Seasonal expansion of a clan territory in Etosha, Namibia. Journal of Zoology (London) **264**, 125-133.

Tumenta, P.N., Kok, J.S., Rijssel, J.C.V., Buji, R., Croes, B.M., Funston, P.J. &. Haes, H.A.U. D. (2010). Threat of rapid extermination of the lion (*Panthera leo*) in Waza National Park, Northern Cameroon. African Journal of Ecology **48**, 808-894.

Van Meter, P.E., French, J.A., Dloniak, S.M., Watts, H.E., Kolowski, J.M. & Holekamp, K.E. (2009). Fecal glucocorticoids reflect socio-ecological and anthropogenic stressors in the lives of wild spotted hyenas. Hormones and Behavior **55**, 329-337.

Van Orsdol, K.G., Hanby, J.P. & Bygott, J.D. (1985). Ecological correlates of lion social organization (*Panthera leo*). Journal of Zoology (London) **206**, 97-112.

Warren, A & Khogali, M. (1992). Assessment of desertification and drought in the Sudano-Sahelian region 1985-1991, New York, UNESCO.

Werdelin, L. & Solounias, N. (1991). The Hyaenidae: taxonomy, systematics and evolution. Fossils Strata **30**, 1-104.

Wilson, D.E. & Reeder, D.M. (1993). Mammal Species of the World: A Taxonomic and Geographic Reference, 2nd edition. Smithsonian Institution Press: Washington and London.

Woodroffe, R. & Frank, G.L. (2005). Lethal control of African lions (*Panthera leo*): local and regional population impact. Animal Conservation **8**, 91-98.

Woodroffe, R. & Ginsberg, J.R. (1998). Edge effects and the extinction of populations inside protected areas. Science **280**, 2126-2128.

Woodroffe, R. & Ginsberg, J.R. (2000). Ranging behavior and vulnerability to extinction in carnivores. In: Gosling, L.M. & Sutherland, W.J. eds. Behavior and conservation (pp. 125–140). Cambridge University Press: Cambridge, United Kingdom.

Woodroffe, R. (2000). Predators and people: using human densities to interpret declines of large carnivores. Animal Conservation **3**, 165-173.

Woodroffe, R. (2001). Strategies for carnivore conservation: lessons from contemporary extinctions. In: Gittleman, J.L., Wayne, R.K., Macdonald, D.W. & Funk, S.M. eds. Carnivore conservation (pp. 61-92). Cambridge University Press: Cambridge, United Kingdom.

Yirga, G., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Deckers, J. & Bauer, H. (2012a). Adaptability of large carnivores to changing anthropogenic food sources: diet change of spotted hyena (*Crocuta crocuta*) during Christian fasting period in northern Ethiopia. Journal of Animal Ecology **81**, 1052-1055.

Yirga, G., Ersino, W., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Deckers, J. & Bauer, H. (2012b). Spotted hyena (*Crocuta crocuta*) coexisting at high density with people in Wukro district, northern Ethiopia, doi.org/10.1016/j.mambio.2012.09.001.

Young, J. (2012). Ethiopian Protected Areas, A 'Snapshot'. A reference guide for future strategic planning and project funding. Addis Ababa, Ethiopia.

PART II
Ecology of the spotted hyena

2

Peri-urban Hyena (*Crocuta crocuta*) in Northern Ethiopia: Diet, Economic Impact, and Abundance

Gidey Yirga Abay[1] *Hans Bauer*[2], *Kindeya Gebrihiwot*[1] *and Jozef Deckers*[2]

Published, *European Journal of Wildlife Research*

Abstract

Global declines of carnivores are related to difficult integration with human land use, in particular conflicts caused by livestock depredation. Hyenas 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 five 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.

[1]Department of Biology, Mekelle University P.O.Box 3072, Mekelle, Ethiopia, gidey1998ec@yahoo.com
[2]Department of Earth and Environmental Sciences, Catholic University of Leuven, Celestijnenlaan 200E, B-3001 Heverlee, Belgium, bauer@casema.nl

2.1 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 (Wilcove et al., 1998; Czech et al., 2000; McKinney, 2002). 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 & Ginsberg, 1998). Carnivores have been considered indicators of the overall fate of ecosystems, due to their trophic position (Noss et al., 1996; Estes et al., 2001; Crooks, 2002).

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 & Hofer, 1998; Woodroffe, 2001). Hyenas 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 (Kruuk, 1972; Bertram, 1979; Mills, 1984; Sillero-Zubiri & 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 hosts several carnivore species; hyena (*Crocuta 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 domes-

tic 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.

2.2 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. 2.1). 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.

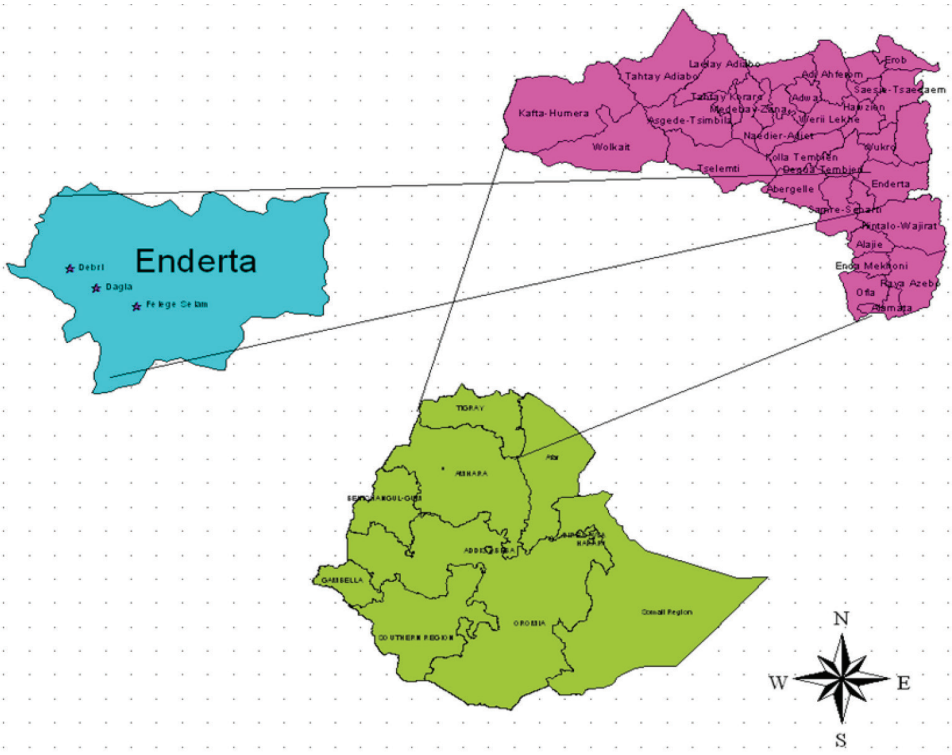

Figure 2.1
Map showing location of the study area

2.3 Methods

2.3.1 Scat analysis

The techniques used to study the diets of carnivores can be divided into three: (1) direct observation of feeding, foraging, and hunting (Schaller,

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

2.3.2 Assessment of abundance

Minimum hyena population size was established with calling stations (Ogutu & Dublin, 1998; Mills et al., 2001; Bauer, 2007) 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.

2.3.3 Semi-structured interviews

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

spondents (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 & 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).

2.4 Results

2.4.1 Scat analysis

The diet of hyenas contained only prey items of domestic origin (Table 2.1). 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.

2.4.2 Semi-structured 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 2.2). 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 but one at night. Nine men and one woman were injured, aged between 26 and 60. Most at-

Table 2.1
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 percentage

	Debri		Aynalem	
Prey species	**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*	18	3	24	4
Hairless samples	7	1.2	0	0
Total	**598**	**100**	**602**	**100**

*Reference hair collection also included natural prey species, but these did not match the unidentified hairs.

tacks (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.

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.

2.4.3 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 was 31,565 kg (Table 2.2) over the last 5 years. Thus, depredation accounted for

Table 2.2

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

	Stock			Depredation (% of stock)			Predated biomass (kg)			Economic loss (US$)		
Species	**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)	8160	8800	9760	3139	3483	3790
Sheep	409	140	107	21(5.1)	33(23.6)	6(5.6)	1365	2145	390	861	1385	168
Goats	161	163	276	15(9.3)	23(14.1)	30(10.9)	1050	1610	2100	554	711	965
Cows	720	525	485	4(0.6)	17(3.2)	20(4.1)	1000	4250	5000	554	1875	2611
Poultry	2395	856	1870	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)	1750	2000	5000	1005	535	1338
Oxen	1316	697	840	3(0.2)	7(1)	14(1.7)	1050	2450	4900	354	2688	5376
Calves	231	85	44	19(8.2)	4(4.7)	8(18.2)	1140	240	480	614	120	240
Mules	42	53	37	3(7.1)	1(1.9)	5(13.5)	1080	360	1800	308	101	448
Horses	13	5	5	3(23)	1(20)	2(40)	1680	560	1120	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**	**5,066**	**128(100)**	**174(100)**	**190(100)**	**18,345**	**22,752**	**31,565**	**8,200**	**11,224**	**15,784**

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.

2.5 Discussion

In Tigray, hyenas seem to consume exclusively domestic prey species. 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 declined dramatically 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 these to 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 & 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 & 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 large 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 (Rasmussen, 1999; Patterson et al., 2004; Woodroffe et al., 2005; Kolowski & Holekamp, 2006; Holmern et al., 2007). Predation on livestock is an important cause of human–wildlife conflict (Jackson & Nowell, 1996; Frank, 1998; 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 peoples' 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, however, mitigation of depredation is highly recommended. This can be done through improved animal husbandry (Ogada et al., 2003) and through ecosystem regeneration.

Acknowledgments

The authors acknowledge VLIR-UOS for financial assistance. We thank Adhena Shumoy, Adhanom Gebereselase, Derejaw Misganaw, Tefera Debebe, and Sidelel Aweke for their respective contributions. We are grateful to

households of the study area for their hospitality and kind response. Finally, we thank Mekelle University for providing a laboratory for scat analysis.

References

Aerts, R., Negussie, A., Maes, W., November, E., Hermy, M. & Muys, B. (2007). Restoration of dry Afromontane forest using pioneer shrubs as nurse plants for *Olea europaea* ssp. Euspidata. Restoration Ecology **15**, 129-138.

Alemayehu, W.E. (2007). Ethiopian Church Forests: opportunities and challenges for restoration. PhD thesis, Wageningen University, Wageningen, The Netherlands.

Bauer, H. (2007). Status of large carnivores in Bouba Ndjida National Park, Cameroon. African Journal of Ecology **45**, 448-450.

Bertram, B.C. (1979). Serengeti predators and their social systems. In: Sinclair, A.R.E. & Norton-Griffiths, M. eds. Serengeti: dynamics of an ecosystem (pp. 221–285). University of Chicago Press: Chicago, USA.

Cooper, S.M., Holekamp, K.E. & Smale, L. (1999). A seasonal feast: long-term analysis of feeding behavior in the spotted hyena *Crocuta crocuta* (Erxleben). African Journal of Ecology **37**, 149-160.

Crooks, K.R. (2002). Relative sensitivities of mammalian carnivores to habitat fragmentation. Conservation Biology **16**, 488-502.

Cuesta, L., Barcena, F., Palacios, F. & Reig, S. (1991). The trophic ecology of the Iberian wolf (*Canis lupus*). A new analysis of stomach data. Mammalia **55**, 239-254.

Czech, B.P., Krausman, R. & Devers, P.K. (2000). Economic associations among causes of species endangerment in the United States. Bioscience **50**, 593-601.

Estes, J., Crooks, K. & Holt, R. (2001). Ecological role of predators. In: Levin, S. ed. Encyclopedia of biodiversity (pp. 857-878). Academic press: San Diego, California.

Frank, L.G. (1998). Living with lions: carnivore conservation and livestock in Laikipia District, Kenya. Report published by DAI for USAID.

Green, G.I., Mattson, D.J. & Peek, J.M. (1997). Spring feeding on ungulate carcasses by grizzly bears in Yellowstone National Park. Journal of Wildlife Management **61**, 1040-1055.

Henschel, J.R. & Tilson, R.L. (1988). How much does a spotted hyena eat? Perspective from the Namib Desert. African Journal of Ecology **26**, 247-255.

Holmern, T., Nyahongo, J. & Roskaft, E. (2007). Livestock loss caused by predators outside the Serengeti National Park, Tanzania. Biological Conservation **135**, 534-542.

Jackson, P. & Nowell, K. (1996). Problems and possible solutions in management of felid predators. Journal of Wildlife Research **1**, 304-314.

Kohn, M.H. & Wayne, R.K. (1997). Facts from feces revisited. Trends in Ecology and Evolution **12**, 223-227.

Kolowski, J.M. & Holekamp, K.E. (2006). Spatial, temporal, and physical characteristics of livestock depredations by large carnivores along a Kenyan reserve border. Biological Conservation **128**, 529-541.

Kolowski, J.M., Katan, D., Theis, K.R. & Holekamp, K.E. (2007). Daily patterns of activity in the spotted hyena. Journal of Mammalogy **88**, 1017-1028.

Kruuk, H. (1972). The spotted hyena: a study of predation and social behavior. University of Chicago Press: Chicago.

Leykun, A. (2000) .The challenges of conserving Ethiopian wildlife: overview. Walia **21**, 56-61.

Madden, F. (2004). Creating coexistence between humans and wildlife: global perspectives on local efforts to address human wildlife conflict. Human Dimensions of Wildlife **9**, 247-257.

McKinney, M.L. (2002). Urbanization, biodiversity, and conservation. Bioscience **52**, 883-890.

Mech, L.D. (1966). The wolves of Isle Royale. US National Park Service Fauna Series No. 7.

Mills, M.G.L. & Hofer, H. (1998). Status survey and conservation action plan hyenas. IUCN/SSC Hyena Specialist Group, IUCN, Switzerland.

Mills, M.G.L. (1984). The comparative behavioural ecology of the brown hyena *Hyaena brunnea* and the spotted hyena *Crocuta crocuta* in the southern Kalahari. Koedoe **27**, 237-247.

Mills, M.G.L., Juritz, J.M. & Zuccini, W. (2001). Estimating the size of spotted hyena (*Crocuta crocuta*) populations through playback recordings allowing for nonresponse. Animal Conservation **4**, 335-343.

Mizutani, F. (1993). Home range of leopards and their impact on livestock on Kenyan ranches. In: Dunstone, N. & Gorman, M.L. eds. Mammals as predators. Proceedings of the Symposium Zoological Society of London (pp. 425-439). Clarendon, Oxford: United Kingdom.

Murie, A. (1985). The grizzlies of Mount McKinley. University of Washington Press, Seattle, 251 pp.

Noss, R.F., Quigley, H.B., Hornocker, M.G., Merrill, T. & Paquet, P.C. (1996). Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology **10**, 949-963.

Nyssen, J., Mitiku, H., Naudts, J., Munro, R.N., Poesen, J., Moeyersons, J., Frankl, A., Deckers, J. & Pankhurst, R. (2009). Desertification? Northern Ethiopia re-photographed after 140 years. Science of the Total Environment **407**, 2749-2755.

Ogada, M.O., Woodroffe, R., Oguge, N.O. & Frank, L.G. (2003). Limiting depredation by African carnivores: the role of livestock husbandry. Conservation Biology **17**, 1521-1530.

Ogutu, J.O. & Dublin, H.T. (1998). The response of lions and spotted hyenas to sound playbacks as a technique for estimating population size. African Journal of Ecology **36**, 83-95.

Patterson, B.D., Kasiki, S.M., Selempo, E. & Kays, R.W. (2004). Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighbouring Tsavo National Parks, Kenya. Biological Conservation **19**, 507-516.

Putman, R.J. (1984). Facts from faeces. Mammal Review **14**, 79-97.

Ramakrishean, U., Coss, R.G. & Pelkey, N.W. (1999). Tiger decline caused by the reduction of large ungulate prey: evidence from a study of leopard diets in southern India. Biological Conservation **89**, 113-120.

Rasmussen, G.S.A. (1999). Livestock predation by the painted hunting dog *Lycaon pictus* in a cattle ranching region of Zimbabwe: a case study. Biological Conservation **88**, 133-139.

Schaller, G.B. (1972). The Serengeti lion. University of Chicago Press: Chicago.

Sillero-Zubiri, C. & Gottelli, D. (1992). Population ecology of spotted hyenas in an equatorial mountain forest. African Journal of Ecology **30**, 292–300.

Sillero-Zubiri, C. & Laurenson, M.K. (2001). Interactions between carnivores and local communities: conflict or co-existence? In: Gittleman, J.L., Funk, S.M., Macdonald, D.W. & Wayne, R.K. eds. Carnivore conservation (pp. 282–312). Cambridge University Press: Cambridge, United Kingdom.

Smith, D.W., Drummer, T.D., Murphy, K.M., Guernsey, D.S. & Evans, S.B. (2004). Winter prey selection and estimation of wolf kill rates in Yellowstone National Park, 1995–2000. Journal of Wildlife Management **68**, 153-166.

Taylor, R.A. (1964). Columbian ground squirrel and cambium found in grizzly bear stomachs taken in the fall. Journal of Mammalogy **45**, 476-477.

Treves, A. & Karanth, K.U. (2003). Human–carnivore conflict and perspectives on carnivore management worldwide. Conservation Biology **17**, 1491-1499.

Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A. & Losos, E. (1998). Quantifying threats to imperiled species in the United States. Bioscience **48**, 607-615.

Woodroffe, R. & Ginsberg, J.R. (1998). Edge effects and the extinction of populations inside protected areas. Science **280**, 2126-2128.

Woodroffe, R. (2001). Strategies for carnivore conservation: lessons from contemporary extinctions. In: Gittleman, J.L., Funk, S., Macdonald, D.W. & Wayne, R.K. eds. Carnivore conservation (pp. 61-92). Cambridge University Press: Cambridge, United Kingdom.

Woodroffe, R., Lindsey, P.A., Romanach, S.S., Stein, A. & Ole Ranah, S.M.K. (2005). Livestock predation by endangered African wild dogs (*Lycaon pictus*) in northern Kenya. Biological Conservation **124**, 225-234.

World Conservation Monitoring Center (WCMC) (1991). Biodiversity guide to Ethiopia. A report for the Commission of the European Community, Cambridge.

3

Diet Change of Hyena (*Crocuta crocuta*) during Christian Fasting Period in Northern Ethiopia

Gidey Yirga[1], *Hans H. de Iongh*[2, 3], *Herwig Leirs*[3, 4], *Kindeya Gebrihiwot*[5], *Jozef Deckers*[6] *and Hans Bauer*[6]

Published, Journal of Animal Ecology

[1]Department of Biology, Mekelle University, P.O. Box 3072, Mekelle, Ethiopia;
[2]Institute of Environmental Sciences, Leiden University, P.O. Box 9518, Leiden, The Netherlands;
[3]Evolutionary Ecology Group, University of Antwerp, Groenenborgerlaan 171, 2020 Antwerp, Belgium;
[4]Department of Agro-Ecology, Aarhus University, Forsøgsvej 1, 4200 Slagelse, Denmark;
[5]Department of Land Resource Management and Environmental Protection, Mekelle University, P.O. Box 231, Mekelle, Ethiopia; and
[6]Department of Earth and Environmental Sciences, Catholic University of Leuven, Celestijnenlaan 200E, B-3001 Heverlee, Belgium

3.1 Introduction

Across the globe, there are several ecosystems in which viable populations of large carnivores can only survive because they coexist in a landscape with people who introduce anthropogenic resources such as livestock, garbage, and pet food (Linnell et al., 2001; Conover, 2002; Woodroffe et al., 2005). Many large carnivores readily use anthropogenic food sources, and this often leads to conflict (Woodroffe & Ginsberg, 1998; Beckmann & Berger, 2003; Packer et al., 2005). Understanding details of the foraging behavior of carnivores in an anthropogenic environment can help reveal the specific causes of conflict, leading to better strategies for reducing the availability of anthropogenic food to prevent clashes (Breck et al., 2009). Urban ecosystems are typically characterized by reduced species diversity but increased abundance of a few species able to exploit anthropogenic food sources (Newsome et al., 2010).

Hyenas show evidence of many particular behaviors that set them apart from other mammals, making them a fascinating model organism for the study of animal behavior (Smith & Holekamp, 2010). They can adapt to habitats with dense human population (Woodroffe, 2001) eating almost any organic matter, even putrid carrion and anthrax-infected carcasses (Johnson, 2006). Hyenas have been known to eat almost any mammal, bird, fish or reptile but they also feed on garbage, cooked porridge and dung (Mills & Hofer, 1998). Although hyenas do scavenge opportunistically, they are efficient hunters, and kill 60–95% of the food they eat in natural habitats of the Maasai Mara ecosystem, Kenya (Smith & Holekamp, 2010). They are capable of eating and digesting all parts of their prey except hair and hooves (Smith & Holekamp, 2010). Bones are digested so completely that only the inorganic components are excreted in the hyena's droppings (Smith & Holekamp, 2010).

An analysis of 15 studies throughout its range in Africa showed that hyenas are both scavengers and active hunters and show a preference for prey in the range of 56-182 kg, but no clear preference for any particular species (Hayward, 2006). Hyenas hunt alone or in a group; an adult hyena is capable of bringing down a prey animal weighing up to four times its own body mass (Mills & Hofer, 1998). They depend primarily on wild prey in East Africa but have long been known to depend more on anthropogenic food sources in the Horn of Africa (Gade, 2006). We have previously demonstrated that hyenas in northern Ethiopia depend exclusively on anthropogenic food sources; mostly scavenged livestock remains (Abay et al., 2011).

In the calendar of the Ethiopian Orthodox Tewahedo Church there are various fasting periods in a year but the longest (55 days) is 'Abye Tsome' or 'Hudade' (Lent), before Easter. During this period, the majority of people in northern Ethiopia do not consume animal products, leading to a sharp decline in demand for meat. The aim of our study was to investigate possible changes in the diet of hyenas before, during and after this fasting period. We hypothesized that reduced availability of waste from slaughtering forces hyenas to supplement their diet with alternative food sources during this period.

3.2 Study area

The research was conducted in three study sites bordering the regional capital of Mekelle (200,000 inhabitants). The first is 12 km to the West and is called Debri, with a total human and livestock population of approximately 7,000 and 12,000, respectively. The second, Aynalem, is five km to the South, with a total human and livestock population of approximately 6,000 and 12,000, respectively. The third site is Arid, the main campus of Mekelle University and an adjacent army camp, three km East of the town with a resident population of approximately 20,000 people. All sites are severely degraded highland of 2200-2300 m a.s.l.

In all areas, the majority of the population is Orthodox Christian. Despite the rampant poverty and scarce resources, people scrupulously follow religious restrictions on the animal parts that may be eaten. The remains of slaughtered animals and all abandoned animals are left at the nearest convenient site, usually simply just outside the peoples' compounds.

3.3 Methods

In March-May 2010, permanent plots were established in each study site by describing natural landscape elements as virtual borders around areas of approximately one ha containing hyena scats as identified using the method of Stuart and Stuart (2000). The plots were demarcated with sticks in each corner. Firstly, all droppings in the plots were collected on the first day of fasting, representing hyena diet before fasting. Secondly, all droppings were collected from the same plots on the last day of the fasting; these droppings had accumulated during the fasting period. Finally we collected all droppings 55 days later, representing the diet after fasting. Scat samples

were put in plastic bags while avoiding cross sample contamination. Following the method of Ramakrishean et al. (1999), hair was extracted from scat and compared with hair in our reference collection to establish prey species composition. Our reference collection contains hair of all domestic and wild species in the study area and includes human hair. We tested for differences in species composition between collection periods with a non-parametric Wilcoxon test using JMP-5 Software. We conducted a randomization nonparametric vander Waerden test to examine whether the differences between the time periods are significant by taking the total number of samples for each species, and randomly assigning each sample to each period.

3.4 Results

A total of 553 hyena scats were analyzed; the number of scat samples collected after the fasting period was low because the Arid and Aynalem plots had been plowed by farmers (Data deposited in the Dryad Repository: doi:10.5061/dryad.pq050620). There was a statistically significant difference in hair composition between scat collected before and during fasting ($P < 0.05$) and between scat collected during and after fasting ($P < 0.005$). There was no significant difference between scat collected before and after the fasting. These results were further corroborated by the randomization tests using nonparametric vander Waerden test, with observed differences falling outside the distribution of randomized samples ($P < 0.01$, $\chi^2 = 21$, $df = 8$).

3.5 Discussion

Our study shows a remarkable change in diet of hyena during the fasting period, from predominantly scavenging on waste to active predation on donkeys. In northern Ethiopia, the natural prey base has been greatly depleted and hyenas are highly dependent on human-related resources (Gade, 2006; Abay et al., 2011). The rural and urban populations of the district are predominantly Orthodox Tewahedo Christians and their vegan diet during fasting leads to a sharp reduction in available animal waste. This is apparently compensated for by increased donkey depredation.

We previously reported that hyenas obtain most of their food from scavenging on urban and rural waste; depredation accounted for less than 20%

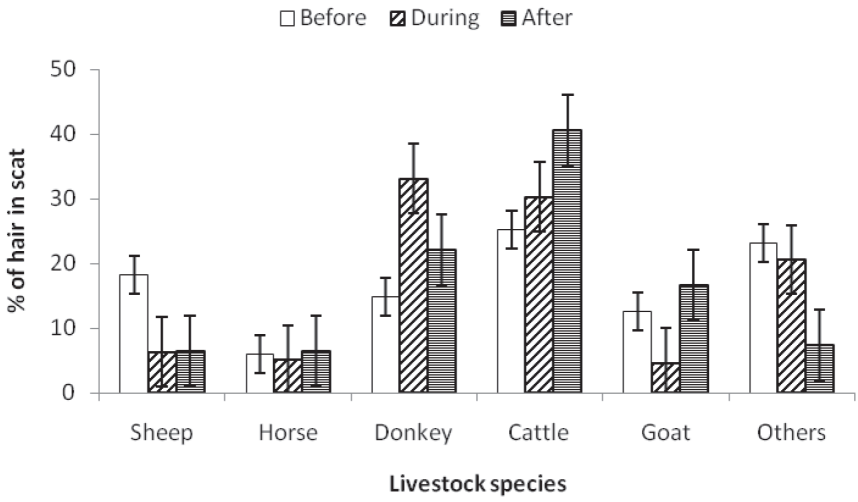

Figure 3.1
Percentage of hair in scat before, during and after the fasting period in 2010, error bars on the columns indicate variations

of food intake in Debri and Aynalem (Abay et al., 2011). We infer that hyenas scavenge less and hunt more during fasting, selecting opportunistically for donkeys. Donkeys are in the preferred prey body mass range suggested by Hayward (2006), and in northern Ethiopia they are extremely abundant (Ghebreab et al., 1999). In contrast to other livestock species, donkeys are kept outside the compound at night, and weak donkeys are abandoned altogether, which makes them a relatively easy food source.

Despite the overall statistically significant diet change, cattle hair remained prevalent in hyena scat from Arid, also during fasting. This may have two reasons. First, the 35th anniversary of Tigray People's Liberation Front (TPLF) was celebrated by the soldiers during the fasting period, which included some slaughtering. Secondly, the College of Veterinary Science continued its activities and continued discarding some carcasses. In Arid and Mekelle, hyenas clean up the organic waste; they are the most efficient means of maintaining sanitation of the campus.

Despite incidences of depredation, hyenas are tolerated as efficient means of sanitation. People are aware of the presence of hyenas; they can easily be observed and heard almost every night. Hyenas almost never attack people; people are afraid of them but accept their presence. Hyenas clear up butchers' and household waste from the city, and are traditionally known as 'mu-

nicipal workers'. This is in fact opposite to the findings of Croes et al. (2011) who found that hyenas avoid villages in Cameron, because of persecution. This indicates that hyenas are highly adaptable to human behavior.

Our study contributes further evidence that wildlife species can modify their behavior to successfully survive in their environment. This may have implications for urban carnivore management, which may differ considerably from rural habitats. Certain animal species have adapted well to human-dominated habitats and benefit directly or indirectly from human activities including food (Shochat et al., 2004; Faeth et al., 2005; Adams et al., 2006). Diet supplementation with anthropogenic food augmented predator's densities and altered their diets in the Santa Monica Mountains, California, USA (Fedriani et al., 2001). Refuse and livestock carcasses at pastoral villages may influence the frequency of hyena visits to these areas (Mills & Hofer, 1998; Kolowski & Holekamp, 2007). Seasonal variation in the use of refuse sites has been documented in a number of carnivores and is often associated with variation in prey availability (Craighead & Craighead, 1971; Salvador & Abad, 1987). Kolowski and Holekamp (2007) reported that hyenas were more likely to be found near open refuse pit during times of relative prey scarcity, indicating the potential impact of human refuse at pastoral villages on livestock losses to hyenas. They also found that livestock depredation was higher where hyenas were more abundant due to their attraction to waste. In our case the scarcity of food is not due to natural prey fluctuations, but to religiously inspired changes in human behavior; the result is the same, however. In addition to the abundant literature on improved livestock management to mitigate depredation (Ogada et al., 2003; Bauer et al., 2010) these observations suggest mitigation by improved waste management.

In the context of prey-depleted northern Ethiopia, waste management would immediately impact hyena abundance, with possible impacts on their viability and subsequently on the ecology of the region. In our study, carrying capacity and hyena survival are dependent on anthropogenic food. Bauer (2003) included livestock in his assessment of an area's carrying capacity, as livestock constituted a large share of lion (*Panthera leo*) diet and therefore had a substantial impact on lion population viability. However, tolerance for lion depredation is very low in Nechisar National Park, southern Ethiopia; reportedly any lion that ventures anywhere near herds of livestock are preemptively shot (Yirga et al., subm.). Advanced substitution of ungulates by cattle there has meant a reduction in carrying capacity, leading to very low lion population viability. These cases confirm that changes in

the availability of anthropogenic food may affect carnivore population density (Borkowski et al., 2011).

In conclusion, our study showed that hyenas mainly scavenge for butchers' and households waste, but during fasting periods, donkeys provided an alternative food source. We conclude that hyenas are highly adaptable and opportunistic scavengers and hunters. Frequencies with which the various prey species occur among collections of scats are easily compiled to describe the diet, and can be used to compare diets between periods.

Acknowledgements

We are grateful to VLIR-UOS (Flemish Interuniversity Council) for financial assistance. We thank Meheret Hadu and Solomon Amare for their respective contributions. We acknowledge statistical advice from Said Musa. We are grateful to Mekelle University for providing laboratory space and materials.

References

Abay, G.Y., Bauer, H., Gebrehiwot, K. & Deckers, J. (2011). Peri-urban spotted hyena (*Crocuta crocuta*) in northern Ethiopia: diet, abundance and economic impact. European Journal of Wildlife Research **57**, 759-765.

Adams, C.E., Lindsey, K.J. & Ash, S.J. (2006). Urban wildlife management. CRC Press, Boca Raton, Florida.

Bauer, H. (2003). Lion Conservation in West and Central Africa. Integrating Social and Natural Science for Wildlife Conflict Resolution around Waza National Park Cameron. PhD thesis, University of Leiden, The Netherlands.

Bauer, H., De Iongh, H. H. & Sogbohossou, E. (2010). Assessment and mitigation of human-lion conflict in West and central Africa. Mammalia **74**, 363-367.

Beckmann, J.P. & Berger, J. (2003). Using black bears to test ideal free distribution models experimentally. Journal of Mammalogy **84**, 594–606.

Borokowski, J., Zalewski, A. & Manor, R. (2011). Diet composition of golden jackals in Israel. Annales Zoologici Fennici **48**, 108-118.

Breck, S.W., Lance, N. & Seher, V. (2009). Selective foraging for anthropogenic resources by black bears: minivans in Yosemite national park. Journal of Mammalogy **90**, 1041–1044.

Conover, M.R. (2002). Resolving human–wildlife conflicts: the science of wildlife damage management. Lewis Publishers, CRC Press LLC, Boca Raton, Florida.

Craighead, J.J. & Craighead, F.C. (1971). Grizzly bear-man relationships in Yellowstone National Park. BioScience **21**, 845–857.

Croes, B.M., Funston, P.J., Rasmussen, G., Buij, R., Saleh, A., Tumenta, P.N. & De Iongh, H.H. (2011). The impact of trophy hunting on lions (*Panthera leo*) and other large carnivores in the Bénoué Complex, northern Cameroon. Biological Conservation **144**, 3064–3072.

Faeth, S.H., Warren, P.S., Shochat, E. & Marussich, W.A. (2005). Trophic dynamics in urban communities. BioScience **55**, 399–407.

Fedriani, J.M., Fuller, T.K. & Sauvajot, R.M. (2001). Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. Ecography **24**, 325–331.

Gade, D.W. (2006). Hyenas and humans in the Horn of Africa. Geographical Review **96**, 609-632.

Ghebreab, F., Gebrewold, A., Kelemu, F., Ibro, A. & Yilm, K. (1999). Donkey utilization and management in Ethiopia. Animal Traction Network for Eastern and Southern Africa. Improving donkey utilization and management. Debre Zeit, Ethiopia: ATENSA. p. 46–52.

Hayward, M.W. (2006). Prey preferences of the spotted hyena (*Crocuta crocuta*) and degree of dietary overlap with the lion (*Pantera leo*). Journal of Zoology **270**, 606-614.

Johnson, R. (2006). Epizootiology and Ecology of Anthrax. USDA, Washington. Available at: http://www.aphis.usda.gov/animal_health/emergingissues/downloads/anthrax.pdf.

Kolowski, J.M. & Holekamp, K.E. (2007). Effects of an open refuse pit on space use patterns of spotted hyenas. African Journal of Ecology **46**, 341–349.

Linnell, J.D.C., Swenson, J.E. & Andersen, R. (2001). Predators and people: conservation of large carnivores is possible at high human densities if management policy is favorable. Animal Conservation **4**, 345–349.

Mills, M.G.L. & Hofer, H. (1998). Hyenas: Status Survey and Conservation Action Plan. IUCN, Gland, Switzerland.

Newsome, S.D., Ralls, K., Job, C.V., Fogel, M.L. & Cypher, B.L. (2010). Stable isotopes evaluate exploitation of anthropogenic foods by the endangered San Joaquin kit fox (*Vulpes macrotis mutica*). Journal of Mammalogy **91**, 1313–1321.

Ogada, M.O., Woodroffe, R., Oguge, N.O. & Frank, L.G. (2003). Limiting depredation by African carnivores: the role of livestock husbandry. Conservation Biology **17**, 1521-1530.

Packer, C., Ikanda, D., Kissui, B. & Kushnir, H. (2005). Lion attacks on humans in Tanzania—understanding the timing and distribution of attacks on rural communities will help to prevent them. Nature **436**, 927–928.

Ramakrishean, U., Coss, R.G. & Pelkey, N.W. (1999). Tiger decline caused by the reduction of large ungulate prey: evidence from a study of leopard diets in southern India. Biological Conservation **89**, 133-120.

Salvador, A. & Abad, P.L. (1987). Food habits of a wolf population (*Canis lupus*) in Leon province, Spain. Mammalia **51**, 45–52.

Shochat, E., Lerman, S.B., Katti, M. & Lewis, D.B. (2004). Linking optimal foraging behavior to bird community structure in an urban desert landscape: field experiments with artificial food patches. American Naturalist **164**, 232–243.

Smith, J.E. & Holekamp, K.E. (2010). Spotted hyenas. Michigan State University, East Lansing, MI, USA

Stuart, C. & Stuart, T. (2000). Tracks and signs of Southern and East African Wildlife. Struik Publishers, Cape Town.

Woodroffe, R. & Ginsberg, J.R. (1998). Edge effects and the extinction of populations inside protected areas. Science **280**, 2126–2128.

Woodroffe, R. (2001). Strategies for carnivore conservation: lessons from contemporary extinctions. In: Gittleman, J.L., Funk, S., Macdonald, D.W. & Wayne, R.K. eds. Carnivore conservation (pp. 61–92). Cambridge University Press: Cambridge, United Kingdom.

Woodroffe, R., Thirgood, S. & Rabinowitz, A. (eds.). (2005). People and wildlife: conflict or coexistence? Cambridge University Press: New York.

Yirga, Y., Gebresenbet, F., Deckers, J. & Bauer, H. (subm.). Status of lions (*Panthera leo*) and spotted hyenas (*Crocuta crocuta*) in Nechisar National Park, Ethiopia.

4

Hyena (*Crocuta crocuta*) Coexisting at High Density with People in Wukro District Northern Ethiopia

Gidey Yirga[1], Wondimu Ersino[1,2], Hans H. de Iongh[3,4], Herwig Leirs[4,5], Kindeya Gebrehiwot[6], Jozef Deckers[7] and Hans Bauer[7,8]

Published, *Mammalian Biology*

[1]Department of Biology, Mekelle University P.O. Box 3072, Mekelle, Ethiopia
[2]Department of Biology, Debre-Tabor University P.O. Box 272, Debre-Tabor, Ethiopia
[3]Institute of Environmental Sciences, Leiden University P.O.Box 9518, 2300 RA Leiden, the Netherlands
[4]Evolutionary Ecology Group, University of Antwerp, Groenenborgerlaan 171, 2020 Antwerpen, Belgium
[5]Aarhus University, Department of Agro-ecology, Slagelse, Denmark
[6]Department of land resource management and environmental protection, Mekelle University P.O. Box 231, Mekelle, Ethiopia
[7]Department of Earth and Environmental Sciences, KU Leuven University, Celestijnenlaan 200E, B-3001 Heverlee, Belgium
[8] Wildlife Conservation Research Unit, Zoology, University of Oxford. Tubney House, Tubney OX13 5L, UK

Abstract

We surveyed the density and abundance of hyena in the highly degraded and prey depleted Wukro district, northern Ethiopia, with a human population density of 98 persons per square kilometer. A total of 117 hyenas responded to callups, giving a hyena density of 52 hyenas per 100 km^2 or a total population of 535 hyenas in the district. We quantified the economic impact of hyena predation on livestock using semi-structured interviews with randomly selected households. Respondents indicated a total loss of 203 domestic animals to hyena depredation over the past five years. Average annual depredation per household was 0.13 livestock, worth US$ 6.1. The diet of hyenas was assessed in three sub-districts by scat analysis and showed that 99% of prey items were of domestic origin, with only three of 211 scat containing hair of the Ethiopian hare (*Lepus fagani*) and porcupine (*Hystrix cristata*). We conclude that hyenas in northern Ethiopia live at high density, eat almost exclusively anthropogenic food and are not dependent on conservation areas.

4.1 Introduction

The literature suggests that large carnivores occur at low densities, with large home ranges and a high propensity for conflict with humans (Hemson, 2003; Loveridge et al., 2007; Croes et al., 2011). Generally there is little tolerance within local communities in Africa towards large carnivores. As a rule, carnivores risk being killed in retaliation for livestock attacks and they consequently avoid villages and urban areas (Croes et al., 2011). Few studies are available demonstrating coexistence between hyenas and local communities. The present work covers a remarkable case of coexistence between hyena and local communities.

Hyena is a common, large carnivore occurring throughout sub-Saharan Africa (Frank et al., 1995; Mills & Harvey, 2001). It is present in a large range of habitats, including semi-desert, savanna and open woodland, dense dry woodland, and in montane habitats, such as in the Aberdares, Mt Kenya, and the Ethiopian highlands, up to 4,100 m in altitude (Sillero-Zubiri & Gottelli, 1992; Smith & Holekamp, 2010). It is absent from, or present only at very low densities in extreme desert conditions and tropical rainforests, where the striped hyena (*Hyaena hyaena*) occurs (Smith & Holekamp, 2010). Hyenas breed throughout the year and they eat carrion as well as a

wide range of live prey (Mills, 1990; Sillero-Zubiri & Gottelli, 1992; Hofer & Mills, 1998; Holekamp et al., 1999).

A tentative estimate of the total hyena population in Africa is between 27,000 and 47,000 (Mills & Hofer, 1998). The largest known populations occur in the Serengeti ecosystem, Tanzania (Kruuk, 1966; Schaller, 1972; Ray et al., 2005) and the Kruger National Park, South Africa (Ray et al., 2005). In protected areas of southern Africa, most populations are considered to be stable, whereas many populations in East, Central and West Africa, even in protected areas, are considered to be declining, mostly due to incidental snaring and poisoning (Hofer & Mills, 1998). The decline of hyena populations in some areas is mainly due to habitat loss, persecution and disease, and this makes hyenas dependent on the continued existence of conservation areas (Mills & Hofer, 1998).

In northern parts of Ethiopia, grazing and ox-drawn ploughing may have induced land degradation through the loss of vegetation cover for more than 2000 years (Mengistu et al., 2005). The natural forest habitat of the region has been overexploited and covers only about 0.2% of the total land area (Sara, 2010). The natural prey base for carnivores has been greatly depleted due to habitat degradation and fragmentation, and hyenas are almost entirely dependent on anthropogenic food (Abay et al., 2011). This is, however, starting to change with the establishment of exclosures (partially protected areas of a few hectares dotted across the landscape) and a general ecological restoration program, which may change the situation in the future (Nyssen et al., 2009). The establishment of exclosures to keep livestock outside is a common ecological restoration practice in Ethiopia (Mengistu et al., 2005).

Survival of hyenas in Ethiopia is largely dependent on the management of livestock conflicts and waste disposal (Yirga et al., unpublished data). Hyenas can be encountered in many parts of Ethiopia, but their density and population size is not known. Based on regular sightings of hyenas, it was hypothesized that our study area has moderately high densities of hyena, in spite of the absence of native prey. We estimated population size and density of hyenas and assessed conflict with people in the degraded and prey-depleted Wukro district, northern Ethiopia.

4.2 Study area

Research was conducted in Wukro district, located in the eastern zone of Tigray regional state of Ethiopia, a completely human-dominated landscape. Geographically the district is located at 13° 36' North and 39° 36' East, with an area of approximately 1,138 square km at an altitude of 1800 to 3069 m a.s.l (Sara, 2010). The annual temperature and rainfall of the district ranges from 17 to 28 °C, and 350 to 450 mm, respectively. The district has a population of 112,235 persons, giving a human population density of 98 persons per square km (Office of Agriculture and Rural Development of Wukro district, 2010). There are 24,583 households with an average household size of five persons. About 95% of the population of the district depends on rain-fed agriculture, practicing mixed farming. The average land holding per household is about 0.5 ha. The main crops grown in the district are barley, wheat, teff, maize and sorghum. The livestock population of the district comprised approximately 21,908 oxen, 30,588 cows, 15,431 goats, 82, 950 sheep, 9416 donkeys, 1,333 mules, 79 horses, 54 camels, and 47,265 poultry in 2009 (Sara, 2010). The average annual household income of the district was approximately US$ 871. The area is generally a severely degraded landscape with some acacia (*Acacia etbaica*, *Acacia saligna* and *Dodonaea angustifolia*), eucalyptus (*Eucalyptus camaldulensis* and *Eucalyptus globulus*) and African olive (*Olea africana*) vegetation and hardly any large or medium-sized natural prey. There are a few established 'exclosures' in the district; these are very small protected areas mainly for environmental rehabilitation in sensitive areas. Three sub-districts were selected for hyena scat collection and for semi-structured interviews, namely Awaleo, Hadnat, and Tsaedanaele (Fig. 4.1).

4.3 Methods

4.3.1 Abundance assessment

The population size of hyenas was established with calling stations (Abay et al., 2011) from 17 to 19 January 2011 between 18:00 and 22:00. Continuous gnu-hyena distress and hyena sounds were played at full volume for about an hour on an MP3 player connected to a megaphone (Monacor 45) mounted onto the roof of the vehicle 2.2 m above ground. Each callup consisted of two cycles of 20 minutes of broadcasting and 10 minutes silence. The speaker was turned 90 degrees after each 5 min of broadcasting. Calling stations were selected along the main roads and located in open areas to

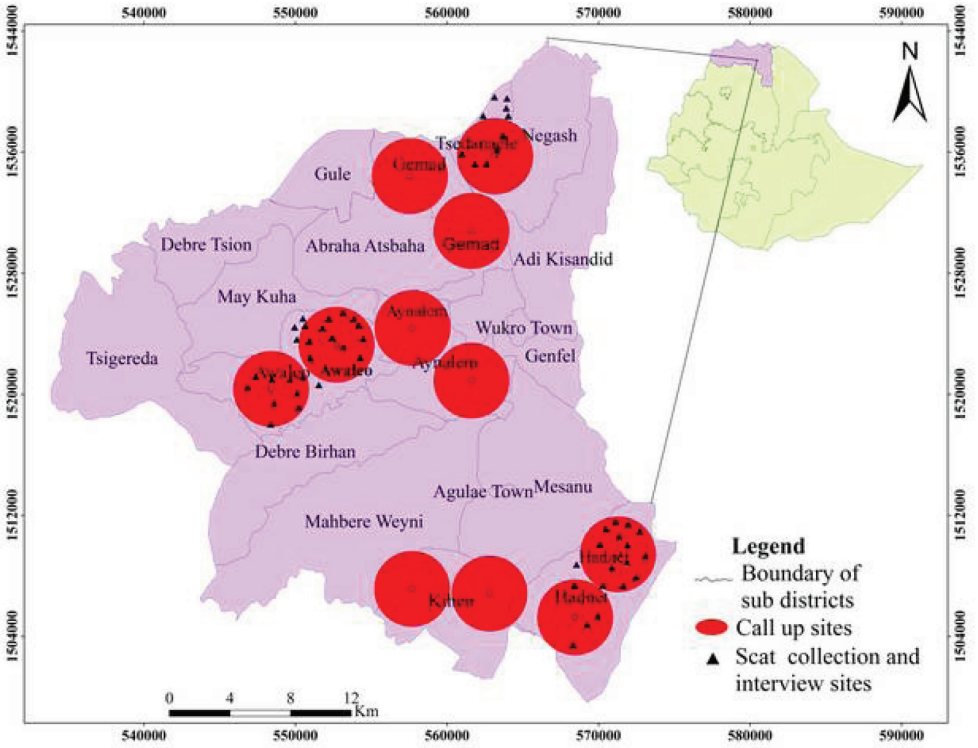

Figure 4.1
Map of Wukro district with UTM coordinates, showing the callup locations (points), scat collection and interview sites

enable observation of responding hyenas. Responding spotted hyenas were counted in the dark, based on sounds and with a spotlight during several short counting sessions, taking the maximum number observed during any single counting session. Four observers counted responding predators using powerful torches immediately after the last broadcast.

Callups require local calibration and habitat-specific predictive models (Ogutu & Dublin, 1998; Mills et al., 2001; Ferreira & Funston, 2010). We conservatively assumed an effective range of 2.8 km and a response rate of 83% ,which was estimated based on 18 calibration experiments for 102 hyenas conducted to estimate the distance within which hyenas heard and responded to the playbacks in a similar landscape in the region (Yirga et al., unpublished data). About 26% (270.8 km^2) of the total area of the district was covered by 11 randomly placed callups, as indicated in Fig. 4.1. Finally, hyena density was calculated by dividing the number of spotted hyenas

observed by the area covered by callups. Then, the resultant density was extrapolated to the total area of the district. To minimize the likelihood of duplicate counting, calling stations were at least 8 km apart. Neighboring stations were sampled consecutively on the same day to minimize the probability of duplicate counts. GPS coordinates of the exact locations of all calling stations were recorded.

4.3.2 Semi-structured interview

We interviewed 312 randomly selected heads of households from three sub-districts (Awaleo, n = 104; Hadnat, n = 127, and Tsaedanaele, n = 81), which constituted 14% of the total households of each sub-district. Selection was done by numbering the households and drawing the numbers from a randomized table. Respondents were asked questions relating to the number of livestock owned and number of livestock lost to predation and disease from 2005 to 2010. To quantify the economic cost of livestock depredation, the species, age, number, and sex of livestock losses were recorded. Estimates of current average market prices of different classes of livestock species by age and sex were obtained from traders. Prices were translated to US$ at the exchange rate of the time of the study (March 2011) and expressed as annual average per household.

4.3.3 Scat analysis

A total of 211 hyena scats were collected from three study sites during walking transects: Awaleo (n = 83), Hadnat (n = 70) and Tsedanaele (n = 58). Scat samples were put into plastic bags to avoid cross-sample contamination. Following the method of Ramakrishean et al. (1999), hairs were extracted from scat and compared under a microscope with hair in our reference collection to establish prey species composition. Our reference collection, collected during the study period, contained hair of all domestic and wild species in the study area and included human hair. Hairs were analyzed on form, length and color with the naked eye as well as on scale patterns using a microscope at 10x magnification. Scat analysis is based mainly on identification of mammalian hairs, and is a valuable technique (Mills, 1992) as most prey species can be reliably determined, field collection is rapid, costs are low and the scats can be stored and processed at a convenient time. We tested for differences between species and between sites with χ^2 test using JMP-5 Software.

4.4 Results

4.4.1 Spotted hyena density and abundance

A total of 117 hyenas responded to 11 different callups. Assuming an 83% response rate, this gives a hyena density of 52 hyenas per 100 km^2 or a total population of 535 hyenas in the district. Also, 10 jackals (*Canis aureus aureus*) responded to three different callups; three in Awaleo, three in Hadnat and four in Qihan sub districts.

4.4.2 Livestock losses

A total of 203 livestock were depredated by spotted hyena over the past five years, mainly goats (26.6%) and donkeys (23.2%), worth US$ 9,538 (Table 4.1). The average annual depredation per household was 0.13 livestock worth US$ 6.1, which was about 0.7% of the average annual income of households of the district. The estimated economic loss caused by animal disease was approximately 1.6 times higher.

Table 4.1
Stock number and estimates of economic loss by hyena and disease in Awaleo, Hadnat and Tsedanaele sub-districts (n = 312), northern Ethiopian

Species	Stock	Depredation	US$	Disease	US$
Goat	315	54	1486	79	1997
Donkey	223	47	3452	21	1661
Cattle	761	41	3749	80	7511
Dog	180	37	130	21	79
Sheep	698	22	715	86	3029
Cat	153	2	6	13	38
Camel	3	0	0	1	293
Poultry	918	0	0	277	667
Mules	4	0	0	0	0
Total	**3,255**	**203**	**9,538**	**578**	**15,275**

4.4.3 Diet of spotted hyena

The diet of hyenas showed only prey items of domestic origin except in Hadnat and Awaleo, where Ethiopian hare *(Lepus fagani*) and porcupine (*Hystrix cristata*) were observed (Table 4.2). There was a significant differ-

ence in species frequency ($P < 0.01$, $\chi^2 = 23.65$, $df = 10$) but no significant difference among sub-districts. Cattle, donkey, goat and sheep, in decreasing order, were most common species of livestock in the scats analyzed and were positively correlated with the stock number during the study period ($R = 0.31$, $P < 0.05$). About 11% of the hairs from the scats were not identified. Our reference hair collection also included natural prey species, but these did not match the unidentified hairs.

Table 2
Diet of hyena in three sub-districts (Awaleo, Hadnat and Tsedanaele) based on analysis of 211 scats expressed as the number of prey items observed and relative frequency of occurrence in 2011

Prey species	Count			Relative frequency (%)		
	Awaleo	Hadinat	Tsedanaele	Awaleo	Hadinat	Tsedanaele
Donkey	17	13	16	20.5	18.6	27.6
Poultry	0	0	0	0.0	0.0	0.0
Cattle	35	28	23	42.2	40	39.7
Goat	7	8	5	8.4	11.4	8.6
Sheep	3	3	5	3.6	4.3	8.6
Human	0	4	0	0.0	5.7	0.0
Horse	0	3	0	0.0	4.3	0.0
Dog	10	0	4	12.1	0.0	6.9
Cat	0	0	0	0.0	0.0	0.0
Hare	0	1	0	0.0	1.4	0.0
Porcupine	2	0	0	2.4	0.0	0.0
Unidentified	9	10	5	10.8	14.3	8.6
Total	**83**	**70**	**58**	**100**	**100**	**100**

4.5 Discussion

4.5.1 Hyena abundance

A total of 117 hyenas responded to callups, leading to a density estimate of 52 hyenas per 100 km^2. This confirms that a moderately high density of hyenas persists in human-dominated landscapes, outside of conservation areas. It is even higher than densities found in some protected areas. For example, according to Graf et al. (2008) the hyena population density in Hluhluwe-iMfolozi Park is about 33 hyenas per 100 km^2 and this population

was the second-largest protected population in South Africa. Trinkel (2009) reported a hyena density of 2 hyenas per 100 km^2 in Etosha National Park, Namibia and Sillero Zubiri and Gottelli (1992) reported the highest known density: 134 hyenas per 100 km^2 in Aberdares National Park in Kenya.

In the present study, anthropogenic food seems to have substantial impact on hyena density and supports a viable population of spotted hyena. The natural ecosystem of the area is affected by anthropogenic activities, which have ultimately depleted native prey species. Carnivore densities in natural ecosystems generally reflect the abundance of their prey (Bertram, 1975; Fuller & Sievert, 2001). Various researchers have reported a positive relationship between carnivore and natural prey abundance elsewhere (Van Orsdol et al., 1985; Laurenson, 1995; Hofer & East, 1995; Stander et al., 1997; Karanth et al., 2004; Hetherington & Gorman, 2007; Croes et al., 2011). However, maintaining viable populations of large carnivores in various ecosystems of the world would require that they coexist in a landscape with people (Linnell et al., 2001; Conover, 2002; Woodroffe et al., 2005). In the context of prey-depleted northern Ethiopia, waste management would immediately impact hyena abundance, with possible impacts on their viability (Yirga et al., 2012). It is likely that hyenas get most of their food from scavenging on waste, as livestock depredation figures were remarkably low during the study period. We previously reported that spotted hyenas get their food from scavenging on urban and rural waste; depredation accounted for less than 20% of food intake in nearby Debri and Aynalem (Abay et al., 2011). Many large carnivores readily use anthropogenic food sources, which often leads to conflict (Woodroffe & Ginsberg, 1998; Beckmann & Berger, 2003; Packer et al., 2005). Hyenas can easily be observed feeding on urban waste as they concentrate around garbage dumping places (Yirga pers. obs.). We conclude that in our study area, a population of 535 hyena lives close to communities without any reports of retaliatory killing. This demonstrates a rare case of coexistence, where hyenas benefit from waste disposal and human communities benefit from the waste clearing service by spotted hyenas. It also demonstrates the high adaptability of hyenas, which in our case specialize entirely in waste consumption.

Efficient and reliable methods of rapid assessment of a carnivore's abundance are crucial to determine conservation priorities. Playbacks have proved to be an efficient technique for estimating spotted hyenas abundance in Wukro district; they are easy to carry out, fast, relatively cheap, and effective for monitoring spotted hyena populations. The method has been used to assess density and abundance of other carnivores such as lions

(Ogutu & Dublin, 1998; Mills et al., 2001; Bauer, 2007). Reliable estimators are precise and unbiased (Norton-Griffiths, 1978), and reliability could be optimized by making suitable choices of sample size and design, and counting animals correctly (Caughley, 1974; Eltringham, 1980; Burnham et al., 1980).

4.5.2 Livestock losses

The economic loss of livestock predation by spotted hyenas is remarkably low compared to other areas (Holmern et al., 2007; Kissui, 2008; Yirga & Bauer, 2010). We found losses of about 0.7% while other studies found losses of about 19% of the average annual income of households (Holmern et al., 2007; Kissui, 2008). However, even this could be considerable in relation to the local standard of living. Food insecurity and poverty are severe; a majority of households chronically depends on food aid for part of the year. The estimated economic loss caused by animal disease was 1.6 times higher. Livestock depredation is not considered a major loss factor compared to diseases. From studies done across Africa, it appears that disease as a loss factor is 3-6 times larger in magnitude than livestock depredation (Mizutani, 1993; Karani et al., 1995; Rasmussen, 1999; Frank et al., 2005). From a development perspective, improving veterinary care would be much more effective and efficient than conflict mitigation. In many parts of Africa, people coexist with large carnivores without receiving any benefits (O'Connell-Rodwell et al., 2000).

The decline of prey populations is one of the major reasons for carnivores to shift their diets to livestock (Woodroffe et al., 2005; Kolowski & Holekamp, 2006), possibly because of hunting efficiency. In Hato Pinero commercial cattle ranch in Venezuela, the highest depredation rates have been recorded in areas where prey abundance and diversity are relatively low (Polisar et al., 2003). A primary financial impact of spotted hyena presence in our study area was depredation on donkeys. Unlike the other livestock species, donkeys are kept outside the compound at night, and weak donkeys are abandoned altogether (Yirga et al., 2012). This may explain their prominent place in the predation statistics of hyena.

4.6 Conclusion

Our research shows a population of hyena coexisting with humans, both at fairly high densities. In stark contrast to the literature, hyenas in northern Ethiopia eat almost exclusively anthropogenic food and are not dependent on conservation areas. The cost to people is marginal and apparently tolerable as this coexistence is remarkably peaceful.

Acknowledgments

We are grateful to VLIR-UOS (Flemish Interuniversity Council) for financial assistance and respondents of the study area for their hospitality and cooperation during the study period.

References

Abay, G.Y., Bauer, H., Gebrihiwot, K. & Deckers, J. (2011). Peri-urban spotted hyena (*Crocuta crocuta*) in northern Ethiopia: diet, economic impact, and abundance. European Journal of Wildlife Research **57**, 759-765.

Bauer, H. (2007). Status of large carnivores in Bouba Ndjida National Park, Cameroon. African Journal of Ecology **45**, 448-450.

Beckmann, J.P. & Berger, J. (2003). Rapid ecological and behavioral changes in carnivores: the responses of black bears (*Ursus americanus*) to altered food. Journal of Zoology (London) **261**, 207-212.

Bertram, B.C.B. (1975). Social factors influencing reproduction in wild lions. Journal of Zoology (London) **177**, 463-482.

Burnham, K.P., Anderson, D.R. & Laake, J.L. (1980). Estimation of density from line transect sampling of biological populations. Wildlife Management **72**, 1-202.

Caughley, G. (1974). Bias in aerial survey. Journal of Wildlife Management **38**, 921-933.

Conover, M.R. (2002). Resolving human – wildlife conflicts: the science of wildlife damage management. Lewis Publishers, CRC Press LLC, Boca Raton, Florida.

Croes, B.M., Funston, P.J., Rasmussen, G., Buij, R., Saleh, A., Tumenta, P.N. & De Iongh, H.H. (2011). The impact of trophy hunting on lions (*Panthera leo*) and other large carnivores in the Bénoué Complex, northern Cameroon. Biological Conservation **144**, 3064-3072.

Eltringham, S.K. (1980). A quantitative assessment of range usage by large African mammals with particular reference to the effects of elephants on trees. African Journal of Ecology **18**, 53-71.

Ferreira, S.M. & Funston, P.J. (2010). Estimating lion population variables: prey and disease effects in Kruger National Park, South Africa. Wildlife Research **37**, 194-206.

Frank, L.G., Holekamp, K.E. & Smale, L. (1995). Dominance, demography, and reproductive success of female spotted hyenas. In: Sinclair, A.R.E. & Arcese, P. eds. Serengeti II: dynamics, management, and conservation of an ecosystem (pp. 364-384). University of Chicago Press: Chicago, USA.

Frank, L.G., Woodroffe, R. & Ogada, M.O. (2005). People and predators in Laikipia District, Kenya. In: Woodroffe, R., Thirgood, S. & Rabinowitz, A. eds. People and Wildlife: Conflict or Coexistence (pp. 286-304)? Cambridge University Press: Cambridge, United Kingdom.

Fuller, T.K. & Sievert, P.R. (2001). Carnivore demography and the consequences of changes in prey availability. In: Gittleman, J.L., Funk, S.M., Macdonald, D.W. & Wayne, R.K. eds. Carnivore Conservation (pp. 163-178). Cambridge University Press and the Zoological Society of London: Cambridge, United Kingdom.

Graf, J., Somers, M.J., Szykman, M. & Slotow, R. (2008). Heterogeneity in the density and distribution of spotted hyenas in Hluhluwe-iMfolozi Park, South Africa. Acta Therioligica **54**, 333-343.

Hemson, G. (2003). The ecology and conservation of lions: human–wildlife conflict in semi-arid Botswana. PhD thesis, University of Oxford, Oxford, United Kingdom.

Hetherington, D.A. & Gorman, M.L. (2007). Using prey densities to estimate the potential size of reintroduced populations of *Eurasian lynx*. Biological Conservation **137**, 37-44.

Hofer, H. & East, M.L. (1995). Population dynamics, population size, and the commuting system of Serengeti spotted hyenas. In: Sinclair, A.R.E. & Arcese, P. eds. Serengeti II: Dynamics, Conservation, and Management of an Ecosystem (pp. 332-363). University of Chicago Press: Chicago, USA.

Hofer, H. & Mills, M.G.L. (1998). Population size, threats and conservation status of hyenas. In: Mills, M.G.L. & Hofer, H. (compilers). Hyenas: status survey and conservation action plan (pp. 64-79). IUCN/SSC Hyena Specialist Group. Gland, Switzerland.

Holekamp, K.E., Szykman, M., Boydston, E.E. & Smale, L. (1999). Association of seasonal reproductive patterns with changing food availability in an equatorial carnivore, the spotted hyena (*Crocuta crocuta*). Journal of Reproduction and Fertility **116**, 87-93.

Holmern, T., Nyahongo, J.W. & Røskaft, E. (2007). Livestock Loss Caused by Predators Outside the Serengeti National Park, Tanzania. Biological Conservation **135**, 518-542.

Karani, I.W., Dublin, H.T. & Koehler, G.M. (1995). Livestock depredation by predators in pastoral areas adjacent to Masai Mara National Reserve, Kenya. In: Bi-

sonette, J.A. & Krausman, P.R. eds. Integrating People and Wildlife for a Sustainable Future (pp. 360-363). Wildlife Society : Maryland, USA.

Karanth, K.U., Nichols, J.D., Kumar, N.S., Link, W.A. & Hines, J.E. (2004). Tigers and their prey: predicting carnivore densities from prey abundance. Proceedings of the National Academy of Science, USA **101**, 4854-4858.

Kissui, B.M. (2008). Livestock predation by lions, leopard, and spotted hyenas, and their vulnerability to retaliatory killing in the Maasai steppe, Tanzania. Animal Conservation **11**, 422-432.

Kolowski, J.M. & Holekamp, K.E. (2006). Spatial, temporal, and physical characteristics of livestock depredations by large carnivores along a Kenyan reserve border. Biological Conservation **128**, 529-541.

Kruuk, H. (1966). Clan-system and feeding habits of spotted hyenas (*Crocuta crocuta* Erxleben). Nature **209**, 1257-1258.

Laurenson, M.K. (1995). Implications of high offspring mortality for cheetah population dynamics. In: Sinclair, A.R.E. & Arcese, P. eds. Serengeti II: Dynamics, Management and Conservation of an Ecosystem (pp. 385-399). University of Chicago Press: Chicago, USA.

Linnell, J.D.C., Swenson, J.E. & Andersen, R. (2001). Predators and people: conservation of large carnivores is possible at high human densities if management policy is favorable. Animal Conservation **4**, 345-349.

Loveridge, A.J., Searle, A.W., Murindagomo, F. & Macdonald, D.W. (2007). The impact of sport hunting on the population dynamics of an African lion population in a protected area. Biological Conservation **134**, 548-558.

Mengistu, T., Teketay, D., Hulten, H. & Yemshaw, Y. (2005). The role of enclosures in the recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia. Journal of Arid Environments **60**, 259-281.

Mills, G.G.L. & Harvey, M. (2001). African predators. Cape Town: Struik.

Mills, G.G.L. (1990). Kalahari hyenas: comparative behavioral ecology of two species. London. Unwin Hyemn.

Mills, M.G., Juritz, J.M. & Zuccini, W. (2001). Estimating the size of spotted hyena (*Crocuta crocuta*) populations through playback recordings allowing for non-response. Animal Conservation **4**, 335-343.

Mills, M.G.L. & Hofer, H. (1998). Hyenas. Status Survey and Conservation Action Plan. IUCN/SSC Hyena Specialist Group. IUCN, Gland, Switzerland and Cambridge, United Kingdom (compilers).

Mills, M.G.L. (1992). A comparison of methods used to study food habits of large African carnivores. In: McCulloch, C. & Barret, R.H. eds. Wildlife 2001: Populations (pp. 1112-1123). Elsevier: London.

Mizutani, F. (1993). Home range of leopards and their impact on livestock on Kenyan ranches. In: Dunstone, N. & Gorman, M.L. eds. Mammals as Predators (pp. 425-439). Clarendon Press: Oxford, United Kingdom.

Norton-Griffiths, M. (1978). Counting Animals, 2nd Ed. African Wildlife Leadership Foundation, Nairobi, Kenya.

Nyssen, J., Mitiku, H., Naudts, J., Munro, R.N., Poesen, J., Moeyersons, J., Frankl, A., Deckers, J. & Pankhurst, R. (2009). Desertification? Northern Ethiopia re-photographed after 140 years. Science of the Total Environment **407**, 2749-2755.

O'Connell-Rodwell, C.E., Rodwell, T., Rice, M. & Hart, L.A. (2000). Living with the modern conservation paradigm: can agricultural communities co-exist with elephants? A five year case study in East Caprivi, Namibia. Biological Conservation **93**, 381-391.

Ogutu, J.O. & Dublin, H.T. (1998). The response of lions and spotted hyenas to sound playbacks as a technique for estimating population size. African Journal of Ecology **36**, 83-95.

Packer, C., Hilborn, R., Mosser, A., Kissui, B., Borner, M., Hopcraft, G., Wilmshurst, J., Mduma, S. & Sinciar, A.R.E. (2005). Ecological change, group territoriality, and population dynamics in Serengeti lions. Science **307**, 390-392.

Polisar, J., Maxit, I., Scognamillo, D., Farrell, L., Sunquist, M.E. & Eisenberg, J.F. (2003). Jaguars, pumas, their prey base, and cattle ranching: ecological interpretations of a management problem. Biological Conservation **109**, 297-310.

Ramakrishean, U., Coss, R.G. & Pelkey, N.W. (1999). Tiger decline caused by the reduction of large ungulate prey: evidence from a study of leopard diets in southern India. Biological Conservation **89**, 133-120.

Rasmussen, G.S.A. (1999). Livestock predation by the painted hunting dog *Lycaon pictus* in a cattle ranching region of Zimbabwe: a case study. Biological Conservation **88**, 133-139.

Ray, J.C., Redford, K.H., Steneck, R.S. & Berger, J. eds. (2005). Large Carnivores and the Conservation of Biodiversity. Island Press: Washington, D.C.

Sara, A.A. (2010). Mitigating drought: Policy Impact Evaluation A case of Tigray region, Ethiopia, Msc. Thesis, University of Twente. The Netherlands.

Schaller, G.B. (1972). The Serengeti lion. University of Chicago Press: Chicago.

Sillero-Zubiri, C. & Gottelli, D. (1992). Population ecology of spotted hyenas in an equatorial mountain forest. African Journal of Ecology **30**, 292-300.

Smith, J.E. & Holekamp, K.E. (2010). Spotted hyenas. Michigan State University, East Lansing, MI, USA.

Stander, P.E., Haden, P.J. & Kaqece, G. (1997). The ecology of asociality in Namibian leopards. Journal of Zoology (London) **242**, 343-364.

Trinkel, M. (2009). A keystone predator at risk? Density and distribution of the spotted hyena *Crocuta crocuta* in the Etosha National Park, Namibia. Canadian Journal of Zoology **87**, 928-935.

Van Orsdol, K.G., Hanby, J.P. & Bygott, J.D. (1985). Ecological correlates of lion social organization (*Panthera leo*). Journal of Zoology (London) **206**, 97-112.

Woodroffe, R. & Ginsberg, J.R. (1998). Edge effects and the extinction of populations inside protected areas. Science **280**, 2126-2128.

Woodroffe, R., Thirgood, S. & Rabinowitz, A. (eds.). (2005). People and wildlife: conflict or coexistence? Cambridge University Press: New York.

Yirga, G. & Bauer, H. (2010). Livestock Depredation of the Spotted Hyena (*Crocuta crocuta*) in Southern Tigray, Northern Ethiopia. International Journal of Ecology and Environmental Sciences **36**, 67-73.

Yirga, G., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Deckers, J. & Bauer, H. (2012). Adaptability of large carnivores to changing anthropogenic food sources: diet change of spotted hyena (*Crocuta crocuta*) during Christian fasting period in northern Ethiopia. Journal of Animal Ecology **81**, 1052-1055.

Yirga, G., De Iongh, H.H., Leirs, H., Asmelash, T., Gebrihiwot, K. & Bauer, H. (subm.). Spatial distribution of large carnivores in human-dominated landscape in northern Ethiopia.

5

Hyena (*Crocuta crocuta*) Concentrate around Urban Garbage Dumps in Northern Ethiopia

Gidey Yirga[1], Hans H. De Iongh[2,3], Herwig Leirs[3,4], Kindeya Gebrihiwot[1], Jozef Deckers[5] and Hans Bauer[5]

Submitted to *Journal of Environmental Management*

[1]Department of Biology, Mekelle University P.O. Box 3072, Mekelle, Ethiopia
[2]Institute of Environmental Sciences, Leiden University P.O. Box 9518, Leiden, the Netherlands
[3]Department of Evolutionary Ecology Group, University of Antwerp, Groenenborgerlaan 171, Antwerpen 2020, Belgium
[4]Danish Pest Infestation Laboratory, Lyngby, Denmark
[5]Department of Earth and Environmental Sciences, Catholic University of Leuven, Celestijnenlaan 200E, B-3001 Heverlee, Belgium

Abstract

Hyenas live in remarkably close proximity to humans in the degraded and prey-depleted Mekelle district, northern Ethiopia, feeding on waste and to a lesser degree on livestock. We surveyed spotted hyena abundance in two garbage dumps and two open natural areas. Four callups were performed, giving a minimum population estimate of 157 hyenas; all but one in open natural areas. This confirms that the presence of hyena is restricted to garbage dumps. Tolerated as efficient means of sanitation, spotted hyenas remove waste from butchers and households from the city and this contributes substantially to their persistence. Our findings confirm 'commuting' movements and raise questions about local hyena social structure.

5.1 Introduction

Hyena is the most common large carnivore in the highlands and lowlands of Ethiopia, Eritrea, and Somalia (Gade, 2006). Despite a certain amount of depredation, spotted hyenas have been tolerated when scavenging from domestic waste, abandoned traction animals and, during famine and armed conflict, people (Gade, 2006). Hyenas are known to occur in prey-depleted areas across Ethiopia. Hyenas are reported to avoid villages in areas where they are persecuted (Croes et al., 2011). However, in many parts of their range, they occur in close association with human habitations (Mills & Hofer, 1998; Woodroffe, 2001). They live in remarkably close proximity to humans in Mekelle district, northern Ethiopia, feeding on waste and to a lesser degree on livestock, but not on natural prey (Abay et al., 2011).

Population size is a key ecological parameter for understanding the biology and conservation status of a species (Williams et al., 2002). Robust estimates of hyena abundance in Ethiopia have not been published, although some studies are currently in progress by our research team. Data on environmental factors influencing hyena abundance are also limited.

We previously reported that hyenas get most of their food from scavenging on urban and rural waste; scat analysis at small forest patches within 10 km of Mekelle showed that depredation accounted for less than 20% of food intake (Abay et al., 2011). Based on our previous experience and personal observations, we hypothesized that hyena 'commute' between rural forest fragments in the daytime ('church forests', Aerts et al., 2007) and urban food sources at night. As a consequence, hyena abundance would be higher at

the garbage dumping sites than in other open urban areas. We thus aimed to identify key ecological factors influencing hyena abundance and distribution within close proximity of Mekelle, northern Ethiopia.

5.2 Study area

The study was conducted in the vast growing city of Mekelle (regional capital, 200,000 inhabitants) located in northern Ethiopia at an elevation of about 2,230 m a.s.l. Its size increased from 16 km^2 in 1984 to over 100 km^2 in 2004 (Tadesse et al., 2008). For waste disposal, households use communal containers, dumps in open areas and along roadsides, and burning. With the expansion of the city, there is growing pressure on municipal services such as waste collection and disposal. Household solid waste collection and disposal in the city of Mekelle is largely the responsibility of the municipality (Tadesse et al., 2008). There were two dumping sites during the study period, i.e., Adikolemey and Kelamino, both directly on the edge of town.

Average annual rainfall of the area is about 550 mm. The mean maximum temperature ranges between 12 °C and 27 °C. 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. There are forest fragments around the many churches scattered throughout the region, however; these are the so-called 'church forests' (Aerts et al., 2007). The remains of slaughtered animals and all redundant pack animals create an abundant food resource for hyenas in and around Mekelle city.

5.3 Methods

Two garbage dumps (Adikolemey and Kelamino) and two open natural areas (Mesebo and Kiha), each >10 km apart were selected in consultation with the municipality workers of Mekelle city. This avoided double counting of spotted hyenas. Minimum hyena population size was established with a calling station at each site (Ogutu & Dublin, 1998; Mills et al., 2001; Bauer, 2007; Abay et al., 2011) between 18:00 and 22:00. Continuous gnu-hyena distress and hyena sounds were played for one hour on an MP3 player connected to a megaphone (Monacor 45) positioned on top of a vehicle. The speaker was rotated every 15 minutes. Responding hyenas were counted in the dark, based on sounds and with a spotlight during several short count-

ing sessions, taking the maximum number observed during any counting session as the minimum population size.

5.4 Results

A total of 158 hyenas responded to four different callups; 81 at Adikolemey and 76 at Kelamino, and one in the open area (Table 5.1). Spotted hyenas at the two dumps were congregations from various directions, apparently fusing without aggression.

Table 5.1
Total number of responding hyenas in garbage dumps and open areas of Mekelle in 2011 based on four callups

Calling station	Count (%)	Site
Adikolemey	81(51.3)	Garbage collection
Kelamino	76(48.1)	Garbage collection
Mesebo	1(0.6)	Open area
Kiha	0(0)	Open area
Total	**158(100)**	**4**

5.5 Discussion

Our study supports our commuting hypothesis that hyenas commute between protected church forests during the day and waste dumping sites at night and previous inference that hyenas in northern Ethiopia survive partly through depredation but more importantly through scavenging on (peri-) urban waste (Abay et al., 2011). This is in stark contrast with findings in other parts of Africa, where hyenas are reported to avoid human settlements as a result of persecution (Croes et al., 2011). The relative abundance of hyenas in garbage dumping sites reflects their dependence on anthropogenic food sources rather than natural prey in the district. Urban waste availability and distribution influenced spatial distribution and abundance of hyenas in the distinct. This is remarkable, as other studies demonstrated consistent avoidance of human settlements by hyena (Croes et al., 2011). Our study raises the question how such commuting between rural church forests and urban dump sites affects social structure, such as territoriality and clan or kinship relationships.

Information on the feeding ecology of large carnivores contributes substantially to the understanding of their behavioral ecology (Mills, 1992). Waste from butchers and households appears to be a key ecological factor influencing the abundance and distribution of spotted hyenas within close proximity of human settlements. Hyenas are highly adaptable to human behavior. In contrast, Croes et al. (2011) reported hyena avoidance of human settlements because of retaliatory killings following livestock depredation. Documentation of such changes in abundance and distribution is important for the development of our understanding of human-hyena interactions and the extent to which spotted hyenas can adapt to human presence. Such changes in hyena abundance and distribution within close proximity of human settlements can potentially be used as indicators of the extent and severity of natural prey depletion and human disturbance. Waste provides an alternative food sources for spotted hyenas, which are locally regarded as "municipal workers".

Acknowledgments

We are grateful to VLIR-UOS (Flemish Interuniversity Council) for financial assistance.

References

Abay, G.Y., Bauer, H., Gebrihiwot, K. & Deckers, J. (2011). Peri-urban spotted hyena (*Crocuta crocuta*) in northern Ethiopia: diet, economic impact, and abundance. European Journal of wildlife Research **57**, 759-765.

Aerts, R., Negussie, A., Maes, W., November, E., Hermy, M. & Muys, B. (2007). Restoration of dry Afromontane forest using pioneer shrubs as nurse plants for *Olea europaea* ssp. Euspidata. Restoration Ecology **15**, 129-138.

Bauer, H. (2007). Status of large carnivores in Bouba Ndjida National Park, Cameroon. African Journal of Ecology **45**, 448-450.

Croes, B.M., Funston, P.J., Rasmussen, G., Buij, R., Saleh, A., Tumenta, P.N. & De Iongh, H.H. (2011). The impact of trophy hunting on lions (*Panthera leo*) and other large carnivores in the Bénoué Complex, northern Cameroon. Biological Conservation **144,** 3064-3072.

Gade, D.W. (2006). Hyenas and humans in the Horn of Africa. Geographical Review **96**, 609-632.

Mills, M.G.L. & Hofer, H. (1998). Hyenas. Status Survey and Conservation Action Plan. IUCN/SSC Hyena Specialist Group. IUCN, Gland, Switzerland and Cambridge, United Kingdom (compilers).

Mills, M.G.L. (1992). A comparison of methods used to study food habits of large African carnivores. In: McCulloch, C. & Barret, R.H. eds. Wildlife 2001: Populations (pp. 1112-1123). Elsevier: London.

Mills, M.G.L., Juritz, J.M. & Zuccini, W. (2001). Estimating the size of spotted hyena (*Crocuta crocuta*) populations through playback recordings allowing for nonresponse. Animal Conservation **4**, 335-343.

Ogutu, J.O. & Dublin, H.T. (1998). The response of lions and spotted hyenas to sound playbacks as a technique for estimating population size. African Journal of Ecology **36**, 83-95.

Tadesse, T., Ruijs, A. & Hagos, F. (2008). Household waste disposal in Mekelle city, Northern Ethiopia. Waste Management **28**, 2003-2012.

Wiliams, B.K., Nichols, J.D. & Conroy, M.J. (2002). Analysis and management of animal populations. Academic Press: San Diego, California.

Woodroffe, R. (2001). Strategies for carnivore conservation: lessons from contemporary extinctions. In: Gittleman, J.L., Funk, S., Macdonald, D.W. & Wayne, R.K. eds. Carnivore conservation (pp. 61-92). Cambridge University Press: Cambridge, United Kingdom.

6

Hyenas (*Crocuta crocuta*) Depend on Anthropogenic Food across Ethiopia

Gidey Yirga[1], Hans H. de Iongh[2,3], Herwig Leirs[3,4], Kindeya Gebrihiwot[1], Jozef Deckers[5], Tsion Asfaw[1], Alemayehu Acha[1] and Hans Bauer[5,6]

Submitted to the *Journal of Animal Ecology*

[1]Department of Biology, Mekelle University P.O. Box 3072, Mekelle, Ethiopia
[2]Institute of Environmental Sciences, Leiden University P.O.Box 9518, Leiden, the Netherlands
[3]Department of Evolutionary Ecology Group, University of Antwerp, Groenenborgerlaan 171, Antwerpen 2020, Belgium
[4]Danish Pest Infestation Laboratory, Lyngby, Denmark
[5]Department of Earth and Environmental Sciences, KU Leuven University, Celestijnenlaan 200E, B-3001 Heverlee, Belgium
[6]Wildlife Conservation Research Unit, Zoology, University of Oxford. Tubney House, Tubney OX13 5L, UK

Abstract

Livestock depredation and scavenging of waste by hyena occurs widely across Ethiopia. Here we report on an extensive survey of depredation in 10 areas across the country. We found that even hyena from national parks predominantly feed on anthropogenic waste. We quantified the economic impact of hyena predation on livestock using semi-structured interviews with 3,080 randomly selected households. They reported losses of 2,230 domestic animals, 3.9% of their stock or an average annual financial loss of US $10.3 per household, over the past five years. The diet of hyenas was assessed in 17 areas across the country, including national parks, by scat analysis and showed only prey items of domestic origin except in Chebera Churchura national park where a few items of prey of wild species were found. Frequencies of prey remains of cattle, sheep, donkey, and goat were highest in decreasing order. Some hairs in scat originated from depredation, but most food intake was from waste dumps and slaughterhouses. Survival of hyenas in Ethiopia is thus largely and widely dependent on management of livestock conflict and waste. Further research should identify the specific causes of domestic animal loss and options to mitigate depredation.

6.1 Introduction

Large carnivores need areas so vast that they usually include human-dominated landscapes, leading to conflict. Human-carnivore conflict in terms of livestock depredation and human attack is common across the world. Examples include the lynx (*Lynx pardinus*) (Odden et al., 2002), puma (*Puma concolor)* and jaguar (*Panthera onca*) (Conforti & Azevedo, 2003; Zimmermann et al., 2005), lion (*Panthera leo*) (Ogada et al., 2003; Patterson et al., 2004; Bauer et al., 2010; Sogbohossou et al., 2011), tigers (*Panthera tigris*) (Wang & Macdonald, 2006), wild dogs (*Lycaon pictus*) and hyenas (Kolowski & Holekamp, 2006; Yirga & Bauer, 2010; Abay et al., 2011). Across species, predator home range size is related to metabolic energy requirements based on body mass (Gittleman & Harvey, 1982) and loss of resources to intraspecific competitors (Jetz et al., 2004). For example, servals (*Leptailures serval*) have an average home range of 1.5 km^2, leopards (*Panthera pardus*) 23.6 km^2, and lions 240.0 km^2 (Gittleman & Harvey, 1982). Hyenas have a lower critical reserve size (179 km^2) than expected for a social carnivore that runs down its prey, but this may be due to scavenging and kleptoparasitism (Mills, 1990). This combination of hunting, passive

scavenging, and power scavenging (kleptoparasitism), may allow for greater resource utilization over a smaller range (Mills, 1990).

The diet of hyenas has received considerable attention in the scientific literature (Kruuk, 1972; Bearder, 1977; Mills, 1990; Yirga et al., 2012). Hyenas are opportunistic feeders and do not have distinct prey species preference (Hayward, 2006). They are highly adaptive feeders; they are hunters of large or medium prey and scavengers of human waste, bones, dung and even anthrax-infested carcasses (Yirga et al., 2012). They are able to quickly adapt to seasonal fluctuations of prey abundance (Kruuk, 1972; Holekamp et al., 1997; Cooper et al., 1999). In many parts of their range, spotted hyenas have adapted well to dense human populations (Mills & Hofer, 1998; Woodroffe, 2001; Yirga et al., 2012). They primarily feed on wild prey in East Africa but have long been known to depend more on anthropogenic food sources in the Horn of Africa (Gade, 2006). In northern Ethiopia, due to the lack of wild prey, hyenas depend entirely on domestic prey species, partly through depredation but more importantly through scavenging on (peri-) urban waste (Abay et al., 2011; Yirga et al., 2012). Cultural-religious conditions allow coexistence between hyenas and humans in Ethiopia. The present study was initiated to investigate the diet of spotted hyenas in protected and non-protected areas in Ethiopia.

6.2 Study area

Ethiopia is the second populous landlocked country located in the horn of Africa with a total area of 1.1. million km^2. Our research focused on five regional states (17 sub-districts, Oromia (4), Tigray (9), Afra (2), Amhara (1) and Southern Nation Nationalities Peoples Regional State (1)) of Ethiopia (Fig. 6.1). The sub-districts are located in similar ecological regions (>2000 m a.s.l.) except the Afar region which is a low land area (Fig. 6.1).

6.3 Methods

6.3.1 Semi-structured interviews

We interviewed 3,080 randomly selected heads of households from 10 sub-districts in four regional states of Ethiopia from October, 2009 through April, 2010. Households were selected assigning numbers and using a randomized table per study area. Respondents were asked questions relating to

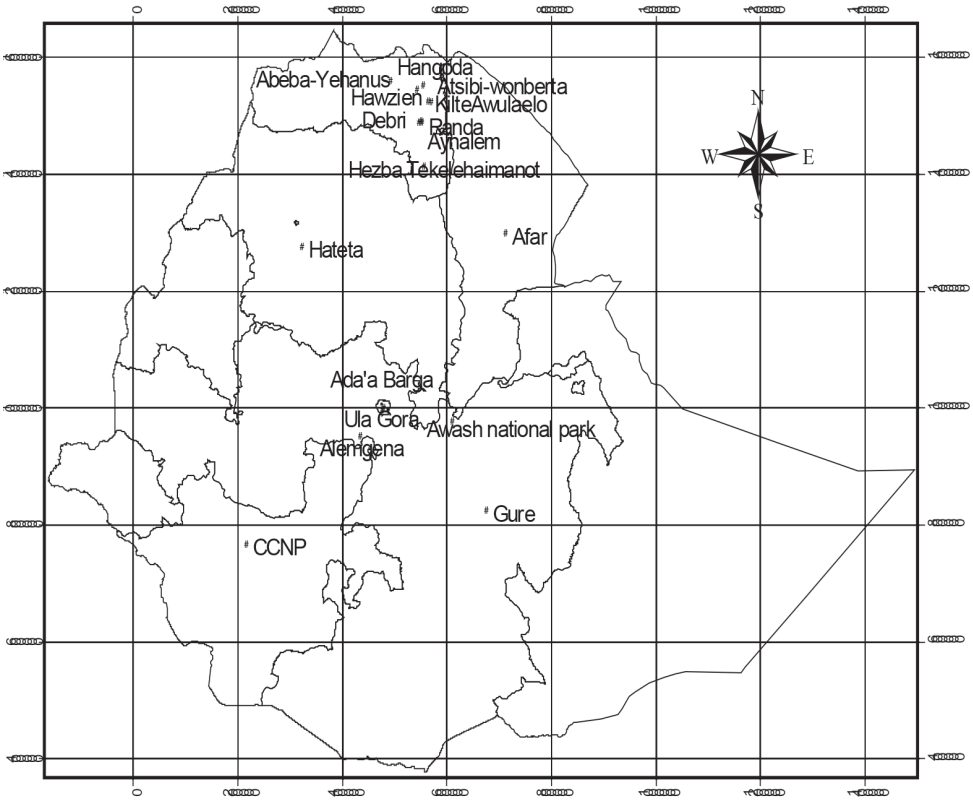

Figure 1
Location of 17 sites across five regional states of Ethiopia

number of domestic animals owned, management and number of domestic animals lost to hyena predation from 2006-2010, the period for which depredation was recorded. To quantify the economic cost of livestock depredation, the species, age, number, and sex of domestic animals lost were recorded. Estimates of current average market prices of different classes of domestic animals by age and sex were obtained from traders. Prices were translated to US$ at the exchange rate of the time of the study (March-May, 2010). The reported predation events or financial costs may not be entirely accurate, as depredation counts are based on reports by farmers. However, there have never been any incentives (monetary compensation for livestock depredation) in the study area for interviewees to exaggerate depredation claims. We established a correlation between livestock abundance and reported depredations obtained from interviews. All statistical tests and correlations were performed using JMP-5 Software (Yirga et al., 2012).

6.3.2 Scat analysis

During the study period, a total of 2,006 putative hyena scats were collected from 15 sub-districts in four regional states. Also, scats were collected from Awash and Chebera Churchura national parks, located in Afar and Southern Nation Nationalities Peoples Regional States of Ethiopia, respectively. Hyena droppings were identified using Stuart and Stuart (2000). 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. Scat analysis, which is based mainly on identification of mammalian hairs, is a valuable technique (Mills, 1992), as most prey species can be reliably determined, field collection is rapid, the scats can be stored and processed at a convenient time, and costs are low. Also, usually only one or a few prey species are represented in the scat, which makes determination possible. However, hair frequency does not necessarily correlate with prey volume. The method also does not differentiate between hunting and scavenging.

The procedure described here was adapted from Ramakrishean et al. (1999). After collection of the faeces, 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 the basis of form, length and color with the naked eye as well as on scale patterns using a microscope at 10x magnification. The hairs were compared with our hair reference collection. This reference hair collection contained hairs from all domestic and wild animal species that live in and around the study area.

Jacobs' indices were calculated to determine preference for each domestic prey species compared to availability. Data obtained from interviews was used as the measure of prey abundance and reported depredations were used as the measure of prey selection. To identify the preferable species of livestock, Jacobs' index was calculated using the formula

$$D = \frac{r - p}{r + p - 2rp}$$

where r is the proportion of the total kills at site made up by a species and p is the proportional availability of the prey species, the resulting value ranges from +1 to -1, where +1 indicates maximum preference and -1 indicates maximum avoidance (Jacobs, 1974).

6.4 Results

6.4.1 Prey preference

The diet of hyenas showed only prey items of domestic origin except in Chebera Churchura national park, where a few wild prey items were found (Table 6.1). Frequencies of prey remains of cattle, sheep, donkey and goat were highest, in decreasing order. Table 6.3 presents Jacobs' index scores derived from 2,030 reported losses of 12 domestic prey species.

Table 6.1
Frequency of occurrence of hair from prey species in hyena scat (n = 2,006) in five regional states of Ethiopia

Species	Oromia	Tigray	Afar	SNNPRS	Amhara	Total	Relative frequency (%)
Donkeys	21	252	9	0	3	285	14.2
Sheep	8	301	4	8	3	324	16.2
Goats	6	161	14	7	8	196	9.8
Cattle	50	317	24	19	10	420	20.9
Camel	0	26	6	0	0	32	1.6
Human	1	102	0	0	0	103	5.1
Mules	8	86	0	0	6	100	5
Poultry	0	24	0	0	0	24	1.2
Dog	0	127	0	0	0	127	6.3
Cat	0	9	0	0	0	9	0.5
Porcupine	0	1	0	0	0	1	0.05
Hare	0	1	0	0	0	1	0.05
Horse	2	239	0	0	0	241	12
Waterbuck	0	0	0	8	0	8	0.4
Bushbuck	0	0	0	7	0	7	0.3
Kudu	0	0	0	6	0	6	0.3
Common duiker	0	0	0	3	0	3	0.2
Unidentified	2	82	7	2	0	93	4.6
Hairless samples	0	26	0	0	0	26	1.3
Total	**98**	**1754**	**64**	**60**	**30**	**2006**	**100**

*The reference hair collection also included natural prey species, but these did not match the unidentified hairs. The wild prey waterbuck, bushbuck, kudu and common duiker were from CCNP. SNNPRS-Southern Nation Nationalities Peoples Regional State.

Table 6.2

Stock quantities, depredation and economic impact of hyenas from 2006-2010 in 10 sub districts in four regional states of Ethiopia, Oromia (number of respondents, n = 1,400), Tigray (n = 1,330), Afar (n = 150) and Amhara (n = 200)

	Stock				Depredation (% of stock)				Economic loss (US$)			
Species	**Oromia**	**Tigray**	**Afar**	**Amhara**	**Oromia**	**Tigray**	**Afar**	**Amhara**	**Oromia**	**Tigray**	**Afar**	**Amhara**
Donkeys	1710	785	63	0	152(8.9)	113(14.4)	5(7.9)	0(0)	10640	7910	350	0
Sheep	7617	4835	1836	1339	382(5)	140(2.9)	116(6.3)	170(12.7)	6112	2800	2088	3400
Goats	2617	2028	2115	0	133(5.1)	41(2.02)	129(6.1)	0(0)	1995	652	2064	0
Cows	5102	2131	1543	617	78(1.5)	20(0.9)	90(5.8)	19(3.1)	11700	3300	14400	3040
Poultry	4843	3369	0	849	23(0.5)	7(0.2)	0(0)	0(0)	57	18	0	0
Dogs	1577	844	123	75	113(7.2)	39(4.6)	6(4.9)	12(16)	226	78	12	28
Bulls	923	1197	447	12	16(1.7)	24(2)	45(10.1)	0(0)	5120	7680	14400	0
Oxen	3363	1511	344	231	70(2.1)	13(0.9)	25(7.3)	2(0.9)	14000	2600	5000	400
Calves	631	423	65	188	12(1.9)	25(5.9)	15(23.1)	43(22.9)	768	1700	1020	2752
Mules	46	12	0	13	18(39.1)	0(0)	0(0)	3(23.1)	2592	0	0	432
Horses	861	29	0	367	45(5.2)	1(3.5)	0(0)	78(21.3)	7560	168	0	13104
Camels	0	14	250	0	0(0)	0(0)	19(7.6)	0(0)	0	0	7308	0
Total	**29,290**	**17,178**	**6,786**	**3,691**	**1,030(3.5)**	**423(2.5)**	**450(6.6)**	**327(8.9)**	**60,770**	**26,906**	**46,642**	**23,156**

6.4.2 Depredation of domestic animals

Respondents indicated a total loss of 2,230 domestic animals to hyena predation, or 3.9% of their stock, over the past five years. This predation represented an estimated financial loss of US$ 157,474 over five years, or an annual mean damage US$ 31,497 (Table 6.2). The costs due to domestic animal loss were on average US $10.30 per household.

Table 6.3
Prey preference of hyena based on analysis of 2,030 depredated livestock from 3,080 respondents in four regional states of Ethiopia over the last five years

	Jacobs index value			
Species	**Oromia**	**Tigray**	**Afar**	**Amhara**
Donkeys	0.47	0.77	0.1	0
Sheep	0.25	0.12	-0.03	0.31
Goats	0.2	-0.11	-0.06	0
Cows	-0.44	-0.48	-0.08	-0.53
Poultry	-0.79	-0.87	0	0
Dogs	0.37	0.33	-0.16	0.29
Bulls	-0.33	-0.11	0.22	0
Oxen	-0.28	-0.5	0.05	-0.83
Calves	-0.3	0.43	0.56	0.48
Mules	0.84	0	0	0.45
Horses	0.21	0.17	0	0.48
Camels	0	0	0.07	0

6.5 Discussion

The majority of prey items found in the scat analyses came from livestock species. It is likely that most of the human hairs found (n=103) came from scavenging at garbage dumps and cemeteries, as we do not have reports of people killed by hyenas at the time of study. Even within the two national parks, Awash and Chebera Churchura, prey remains of domestic species were dominant. This presents a new finding on hyena diets in national parks, as previous studies showed a variety of prey, predominantly wild prey (Honer et al., 2002; Hayward, 2006; Trinkel, 2010). This is probably due to very low densities of natural prey in these national parks, and/or due

to scavenging around the houses of park rangers and near villages. There is also extensive illegal grazing and livestock encroachment in these parks, as is evident in almost all Ethiopian national parks.

We have shown how important domestic animals are in the diet of hyenas. We postulate that depletion of natural prey species forces hyena to depend on anthropogenic food sources, which is why hyenas commonly occur in suburban and urban areas across Ethiopia. Carnivore densities in natural ecosystems generally reflect the abundance of their prey (Bertram, 1975; Fuller & Sievert, 2001). A positive correlation exists between carnivore density and natural prey abundance in many ecosystems of the world (Karanth et al., 2004; Hetherington & Gorman , 2007; Croes et al., 2011).

Hyenas have adapted to human-dominated habitats across Ethiopia and benefit from waste disposal. Cultural-religious practices allow coexistence between hyenas and humans. Scavengers such as raccoons (*Procyon lotor*), opossums (*Didelphis virginiana*), crows (*Corvus* spp.), and gulls (*Larus* spp.) and some opportunistic generalist carnivores such as foxes (*Vulpes* spp.) and coyotes (*Canis latrans*) are increasingly common in urban habitats, suggesting that the relatively high abundance of food attracts wildlife to urban areas (Adams et al., 2006; Sauter et al., 2006). Urban ecosystems are typically characterized by increased abundance of a few species able to exploit anthropogenic food sources (Newsome et al., 2010). In our case, hyena is increasingly common in suburban and urban habitats, as it is attracted by garbage left in the streets and open areas. In many towns in Ethiopia such as Addis Ababa, Gondar, Jijiga and Mekelle, hyenas have the role of scavenger (Gade, 2006). They have nocturnal access to garbage left in the streets, and are especially attracted to towns with slaughterhouses such as Mekelle (Nikoru, 1972; Henze, 1977). This removal of waste of butchers and households near towns or cities contributes substantially to their persistence in dense human populations.

Hyenas are common across Ethiopia, and in most of those areas prey populations appear small (Abay et al., 2011). Hyenas are highly adaptable and opportunistic hunters and scavengers (Yirga et al., 2012). Their nocturnal and opportunistic foraging behavior, together with the ability of hyenas to take long-distance commuting trips, makes them particularly adaptable to anthropogenic environments (Kruuk, 1972; Hofer & East, 1995; Mills & Hofer, 1998).

In the present study, frequencies of prey remains of cattle, sheep, donkey and goat were highest, in decreasing order. Unlike other large carnivores, hyenas do not exhibit a preference for any species of prey (Hayward, 2006). The lack of prey preferences might be due to the fact that they are able to meet their food requirements through scavenging (Hayward, 2006). Hyenas in Ethiopia have mostly lived in anthropogenic context rather than, as in East Africa, on wildlife (Gade, 2006).

Quantifying hyena predations on livestock might be important to mitigate the effects and to promote a more stable coexistence of hyenas and humans. More detailed information on the intensity of predation on livestock is important for developing strategies for conserving carnivores (Polisar et al., 2003). Herd management has been identified as a factor in predation rate (Patterson et al., 2004; Frank et al., 2005). More thoughtful and informed herd management has the potential to reduce losses (Rasmussen, 1999). Conservation efforts can be improved by raising the tolerance of pastoralists for wild carnivores through educational and economic incentives (Marker et al., 2003). Ogada et al. (2003) found improved enclosures to be effective against large carnivores.

In this study, 170 dogs were declared victims of hyena predation. Most likely, this is an underestimate of the numbers of field or stray dogs preyed upon. About 70% of dogs have no owners and would not be reported in depredation surveys. It is clear that in this case, hyena actively chased and killed domestic dogs. Various researchers have reported that dogs do not reduce nocturnal livestock predation by hyenas and lions (Kolowski & Holekamp, 2006; Ikanda & Packer, 2008), but Woodroffe et al. (2007) reported that dogs improved livestock security both in the daytime grazing fields and in the bomas at night. Since their early domestication, dogs have acted as an early warning system for approaching predators and visitors to human settlements (Coppinger & Coppinger, 2001). In our study, domestic dogs were clearly ineffective in protecting villages from hyena attacks.

Our study has shown that scavenging of waste and livestock depredation by hyenas occurs widely across Ethiopia. Hyenas in Ethiopia predominantly depend on anthropogenic food sources rather than natural prey. Survival of hyenas is largely and widely dependent on management of livestock conflict and waste disposal.

Acknowledgments

The authors are grateful to VLIR-UOS (Flemish International Council) for financial assistance. We are grateful to households of the study area for their hospitality and kind response. Many thanks to Ayalew Kasahun, Bruk Kisy, Habtamu Taddese, Dinka Chalchisa, Abrehet Tesfay, Woldu Gidey, Edris Seid, Adhana Abera, Bihaylu Abera, Brhane Gebremedhin and Girmay Gebrhannes for their field assistance. We thank Meheret Hadu and Solomon Amare for their assistance in laboratory analyses. Finally, we thank Mekelle University for providing a laboratory for scat analysis.

References

Abay, G.Y., Bauer, H., Gebrihiwot, K. & Deckers, J. (2011). Peri-urban spotted hyena (*Crocuta crocuta*) in northern Ethiopia: diet, economic impact, and abundance. European Journal of Wildlife Research **57**, 759-765.

Adams, C.E., Lindsey, K.J. & Ash, S.J. (2006). Urban Wildlife Management. CRC Press, Boca Raton, FL.

Bauer, H., De Iongh, H.H. & Sogbohossou, E. (2010). Assessment and mitigation of human-lion conflict in West and central Africa. Mammalia **74**, 363-367.

Bearder, S.K. (1977). Feeding habits of spotted hyenas in woodland habitat. East African Wildlife Journal **14**, 233-235.

Bertram, B.C.B. (1975). Social factors influencing reproduction in wild lions. Journal of Zoology (London) **177**, 463-482.

Conforti, V.A. & Azevedo, C.C. (2003). Local perceptions of jaguars (*Panthera onca*) and pumas (*Puma concolor*) in the Iguacu National Park area, south Brazil. Biological Conservation **111**, 215-221.

Cooper, S.M., Holecamp, K.E. & Smale, L. (1999). A seasonal feast: long-term analysis of feeding behavior in the spotted hyena (*Crocuta crocuta*). African Journal of Ecology **37**, 149-160.

Coppinger, R. & Coppinger, L. (2001). Dogs: A Startling New Understanding of Canine Origin, Behavior, and Evolution. Scribner, New York.

Croes, B.M., Funston, P.J., Rasmussen, G., Buij, R., Saleh, A., Tumenta, P.N. & De Iongh, H.H. (2011). The impact of trophy hunting on lions (*Panthera leo*) and other large carnivores in the Bénoué Complex, northern Cameroon. Biological Conservation **144**, 3064-3072.

Frank, L.G., Woodroffe, R. & Ogada, M.O. (2005). People and predators in Laikipia District, Kenya. In: Woodroffe, R., Thirgood, S. & Rabinowitz, A. eds. People and Wildlife: Conflict or Coexistence (pp. 286-304)? Cambridge University Press: Cambridge, United Kingdom.

Fuller, T.K. & Sievert, P.R. (2001). Carnivore demography and the consequences of changes in prey availability. In: Gittleman, J.L., Funk, S.M., Macdonald, D.W. & Wayne, R.K. eds. Carnivore Conservation (pp. 163-178). Cambridge University Press and the Zoological Society of London: Cambridge, United Kingdom.

Gade, D.W. (2006). Hyenas and humans in the Horn of Africa. Geographical Review **96**, 609-632.

Gittleman, J.L. & Harvey, P.H. (1982). Carnivore home-range size, metabolic needs and ecology. Behavioral Ecology and Sociobiology **10**, 57-63.

Hayward, M.W. (2006). Prey preferences of the spotted hyena *Crocuta crocuta* and evidence of dietary competition with lion *Panthera leo*. Journal of Zoology (London) **270**, 606-614.

Henze, P.B. (1977). Ethiopian Journeys: Travels in Ethiopia 1969-72. London: Ernest Benn.

Hetherington, D.A. & Gorman, M.L. (2007). Using prey densities to estimate the potential size of reintroduced populations of *Eurasian lynx*. Biological Conservation **137**, 37-44.

Hofer, H. & East, M.L. (1995). Population dynamics, population size, and the commuting system of Serengeti spotted hyenas. In: Sinclair, A.R.E. & Arcese, P. eds. Serengeti II: Dynamics, Conservation, and Management of an Ecosystem (pp. 332–363). University of Chicago Press: Chicago, USA.

Holekamp, K.E., Smale, L., Berg, R. & Cooper, S.M. (1997). Hunting rates and hunting success in the spotted hyena (*Crocuta crocuta*). Journal of Zoology (London) **242**, 1-15.

Höner, O.P., Wachter, B., East, M.L. & Hofer, H. (2002). The response of spotted hyenas to long-term changes in prey populations: functional response and interspecific kleptoparasitism. Journal of Animal Ecology **71**, 236-246.

Ikanda, D.K. & Packer, C.C. (2008). Ritual vs. retaliatory killing of African lions in the Ngorongoro Conservation Area. Tanzania. Endangered Species Research **6**, 67-74.

Jacobs, J. (1974). Quantitative measurement of food selection – a modification of the forage ratio and Ivlev's electivity index. Oecologia **14**, 413-417.

Jetz, W., Carbone, C., Fulford, J. & Brown, J.H. (2004). The scaling of animal space use. Science, **306,** 266-268.

Karanth, K.U., Nichols, J.D., Kumar, N.S., Link, W.A. & Hines, J.E. (2004). Tigers and their prey: predicting carnivore densities from prey abundance. Proceedings of the National Academy of Science USA **101**, 4854-4858.

Kolowski, J.M. & Holekamp, K.E. (2006). Spatial, temporal, and physical characteristics of livestock depredations by large carnivores along a Kenyan reserve border. Biological Conservation **128**, 529-541.

Kruuk, H. (1972). The Spotted Hyena: a Study of Predation and Social Behavior. University of Chicago Press: Chicago.

Marker, L.L., Mills, M.G.L. & Macdonald, D.W. (2003). Factors influencing perceptions of conflict and tolerance toward cheetahs on Namibian farmlands. Conservation Biology **17**, 1290-1298.

Mills, G. & Hofer, H. (1998). Hyenas: Status Survey and Conservation Action Plan. World Conservation Union, Gland, Switzerland.

Mills, G.G.L. (1990). Kalahari hyenas: comparative behavioral ecology of two species. London. Unwin Hyemn.

Mills, M.G.L. (1992). A comparison of methods used to study food habits of large African carnivores. In: McCulloch, C. & Barret, R.H. eds. Wildlife 2001: Populations (pp. 1112-1123). Elsevier: London.

Newsome, S.D., Ralls, K., Job, C.V., Fogel, M.L. & Cypher, B.L. (2010). Stable isotopes evaluate exploitation of anthropogenic foods by the endangered San Joaquin kit fox (*Vulpes macrotis mutica*). Journal of Mammalogy **91**, 1313-1321.

Nikoru, C.W. (1972). From the Roof of Africa. New York: Alfred Knopf

Odden, J., Linnell, J.D.C., Moa, P.F., Herfindal, I., Kvam, T. & Andersen, R. (2002). Lynx predation on domestic Sheep in Norway. Journal of Wildlife Management **66**, 98-105.

Ogada, M.O., Woodroffe, R., Oguge, N.O. & Frank, L.G. (2003). Limiting depredation by African carnivores: the role of livestock husbandry. Conservation Biology **17**, 1521-1530.

Patterson, B.D., Kasiki, S.M., Selempo, E. & Kays, R.W. (2004). Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighboring Tsavo National Parks, Kenya. Biological Conservation **119**, 507-516.

Polisar, J., Maxit, I., Scognamillo, D., Farrell, L., Sunquist, M.E. & Eisenberg, J.F. (2003). Jaguars, pumas, their prey base, and cattle ranching: ecological interpretations of a management problem. Biological Conservation **109**, 297-310.

Ramakrishean, U., Coss, R.G. & Pelkey, N.W. (1999). Tiger decline caused by the reduction of large ungulate prey: evidence from a study of leopard diets in southern India. Biological Conservation **89**, 133-120.

Rasmussen, G.S.A. (1999). Livestock predation by the painted hunting dog *Lycaon pictus* in a cattle ranching region of Zimbabwe: a case study. Biological Conservation **88**, 133-139.

Sauter, A., Bowman, R., Schoech, S.J. & Pasinelli, G. (2006). Does optimal foraging theory explain why suburban Florida scrub-jays (*Aphelocoma coerulescens*) feed their young human-provided food? Behavioral Ecology and Sociobiology **60**, 465-474.

Sogbohossou, E.A., De Iongh, H.H., Sinsin, B., De Snoo, G.R. & Funston, P.J. (2011). Human-carnivore conflicts around Pendjari Biosphere reserve, northern Benin. Oryx **6**, 1-10.

Stuart, C. & Stuart, T. (2000). Tracks and signs of Southern and East African Wildlife. Struik Publishers, Cape Town, pp 310.

Trinkel, M. (2010). Prey selection and prey preferences of spotted hyenas *Crocuta crocuta* in the Etosha National Park, Namibia. Ecological Research **25**, 413-417.

Wang, S.W. & Macdonald, D.W. (2006). Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. Biological Conservation **129**, 558-565.

Woodroffe, R. (2001). Strategies for carnivore conservation: lessons from contemporary extinctions. In: Gittleman, J.L., Wayne, R.K., Macdonald, D.W. & Funk, S.M. eds. Carnivore conservation (pp. 61-92). Cambridge University Press: Cambridge, United Kingdom.

Woodroffe, R., Frank, L.G., Lindsey, P.A., Ole Ranah, S.M.K. & Roman˜ ach, S. (2007). Livestock husbandry as a tool for carnivore conservation in Africa's community rangelands: a case–control study. Biological Conservation **16**, 1245-1260.

Yirga, G., & Bauer, H. (2010). Livestock depredation of the spotted hyena (*Crocuta crocuta*) in Southern Tigray, Northern Ethiopia. International Journal of Ecology and Environmental Sciences **36**, 67-73.

Yirga, G., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Deckers, J. & Bauer, H. (2012). Adaptability of large carnivores to changing anthropogenic food sources: diet change of spotted hyena (*Crocuta crocuta*) during Christian fasting period in northern Ethiopia. Journal of Animal Ecology **81**, 1052-1055.

Zimmermann, A., Walpole, M. & Leader-Williams, N. (2005). Cattle ranchers' attitudes to conflicts with jaguar *Panthera onca* in the Pantanal of Brazil. Oryx **39**, 406-412.

7

The Ecology of Large Carnivores in the Highlands of Northern Ethiopia

Gidey Yirga[1], Hans H. de Iongh[2,3], Herwig Leirs[3,4], Kindeya Gebrehiwot[5], Gebrehiwot Berhe[1], Tsehaye Asmelash[6], Haftu Gebrehiwot[7] and Hans Bauer[8]

Published, African Journal of Ecology

[1]Department of Biology, Mekelle University P.O. Box 3072, Mekelle, Ethiopia
[2]Institute of Environmental Sciences, Leiden University P.O.Box 9518, Leiden, the Netherlands
[3]Evolutionary Ecology Group, University of Antwerp, Groenenborgerlaan 171, 2020 Antwerp-en, Belgium
[4]Aarhus University, Department of Agro-ecology, Slagelse, Denmark
[5]Department of land resource management and environmental protection, Mekelle University P.O. Box 231, Mekelle, Ethiopia
[6]Department of microbiology, Mekelle University P.O.Box 231, Mekelle, Ethiopia
[7]Department of statistics, Mekelle University P.O.Box 231, Mekelle, Ethiopia
[8]Department of Earth and Environmental Sciences, Catholic University of Leuven, Celestijnen-laan 200E, B-3001 Heverlee, Belgium

Abstract

The degradation and fragmentation of the northern Ethiopian highlands has resulted in frequent encounters of large carnivores with humans and their livestock. We interviewed 500 randomly selected households to estimate the economic impact of livestock predation by hyena, leopard (*Panthera pardus*) and jackal (*Canis aureus aureus*) in the highlands of northern Ethiopia. The annual mean economic loss per household was approximately US $20.2, about 7% of the average annual income of households in the area. Households surveyed reported losses of a total of 3,122 livestock to hyena, leopard and jackal predation over the past five years. This loss equated to a total financial loss of US$ 50,381. Livestock predation incidents of hyena, leopard and jackal demonstrated that hyenas had a preference for dog, donkey, goat and sheep, leopards for goat, dog, and sheep, and jackals for goat and sheep. Livestock predation of hyenas and leopards were mainly during the night. We conclude that assessing depredation problems is important to develop actions for management, with either livestock practices or wildlife conservation.

7.1 Introduction

Human population growth is rapidly reducing and fragmenting the available habitat for large carnivores (Holmern et al., 2007). The increasing interface between large carnivores and humans is resulting in human–carnivore conflicts across the world (Treves & Karanth, 2003; Madhusudan & Mishra, 2003). Predation on livestock (Cozza et al., 1996; Woodroffe, 2000; Treves & Karanth, 2003) and attacks on humans (Kerbis Peterhans & Gnoske, 2002; Packer et al., 2005) are the most important factors causing the decline of most large carnivore species. Human conflict with carnivores is a serious management issue, often causing opposition towards conservation efforts (Holmern et al., 2007).

In the highland areas of Tigray, a regional state in northern Ethiopia, the mean population density is about 137 persons per km², much denser than the Tigray regional average of 63 persons per km² (Pander & Gebremedhin, 2004; Sara, 2010). Hyenas, leopards (*Panthera pardus*), and common jackals (*Canis aureus aureus*) are common in this landscape but other large carnivores are virtually absent. The degradation and fragmentation of the landscape has resulted in frequent encounters of large carnivores with humans and their livestock. The prey base of the area is greatly depleted and hyenas,

leopards and jackals are presumably largely dependent on anthropogenic food sources. The high human density and depletion of prey are perhaps the most important causes of human-carnivore conflicts in the area. It is known that human population growth increases human-carnivore conflicts (Graham, et al., 2005), and coincides with declines in carnivore population levels and contraction of their geographic ranges (Woodroffe, 2000).

Understanding ecological issues of human–carnivore conflict is important for the formulation of effective conflict resolution and conservation management strategies (Bagchi & Mishra, 2006), and this necessitates interdisciplinary applied research (Hotte & Bereznuck, 2001; Nyhus et al., 2003; Ogada et al., 2003). We therefore aimed to investigate livestock depredation of large carnivores in time and space and prey preference with regard to livestock in the highlands of northern Ethiopia.

7.2 Study area

The study was conducted in Degua-Temben district, situated in the highlands of northern Ethiopia (Figure 7.1). It is an area with an agricultural history of over 2000 years (McCann, 1995), characterized by high soil erosion rates (Hurni, 1993; Desta Gebremichael et al., 2005; Nyssen et al., 2007). The uppermost level of the landscape is at about 2,700-2,800 m a.s.l. (Nyssen et al., 2007). Degua-Temben district has an average annual rainfall of about 769 mm and covers slightly more than 1,100 km^2 with around 120,000 inhabitants (Segers et al., 2008). The district has 18 Tabyas, or sub-districts, which is the lowest formal administrative level. The main crops cultivated in the area are barley (*Hordeum vulgare* L.), wheat (*Triticum* sp.) and teff (*Eragrostis tef*), an endemic cereal crop (Nyssen et al., 2007). Low agricultural productivity, poverty and land degradation are very severe in the highlands of Tigray (Pender & Gebremedhin, 2004). The average farm size is about one ha, and most households subsist on incomes of less than one $US per day (Pender & Gebremedhin, 2004). According to Pender and Gebremedhin (2004), the average per capita income among the sampled households in the highlands of Tigray was less than $US 60 per year. A majority of households chronically depend on food aid for part of the year. Our study focused on one of the sub-districts, Adiwalka sub-district (Figure 7.1). The area is generally a barren landscape, and the prey base is highly depleted. There are a few established 'exclosures' in the district; these are very small protected areas mainly for environmental rehabilitation in sensitive areas.

Figure 7.1
Map showing the location of Adiwalka sub-district in Tigray region and Degua-Temben district

7.3 Methodology

We interviewed 500 randomly selected households from Adiwalka sub-district, northern Ethiopia. Random selection was done by numbering the households and drawing the numbers from a randomized table. Respondents were interviewed about number of livestock owned, livestock management, number of livestock lost to predation from 2006 to 2010 due to leopards, spotted hyenas and jackals. To quantify the economic cost of livestock depredation, the species, age, number and sex of lost livestock were recorded. Estimates of current average market values of different classes of livestock species by age and sex were obtained from traders. Prices were converted to $US at the exchange rate of the time of the study. Predation counts are based on reports by farmers and the financial costs are estimates based on these reports. Hence, the reported predation events or financial costs may not be entirely accurate. However, we tried to avoid under- or over-estimation during data collection by explaining the objectives of the study for informants to report the actual losses. In addition there have not been any incentives (monetary compensation for livestock depredation) in the study area for interview subjects to exaggerate depredation claims. Hyenas, leopards and jackals were the large carnivores causing depredation in this landscape. Farmers were able to identify which carnivores were responsible for the depredation of livestock based on sighting, spoor and call. They were able to identify spotted hyena, leopard and jackal spoors on pictures. Jacobs's indices were calculated to determine preference of each species compared to availability. Data obtained from interviews were used as the measure of prey abundance and reported depredations were used as the measure of prey selection. To identify the preferred species of livestock, Jacobs's indices were used i.e., $D = \frac{r - p}{r + p - 2rp}$ Where r is the proportion of the total kills at site made up by a species and p is the proportional availability of the prey species; the resulting value ranges from +1 to -1, where +1 indicates maximum preference and -1 indicates maximum avoidance (Jacobs, 1974). We used the $\chi 2$-test to test the observed frequency of predation on various types of livestock and contexts of livestock attack events by the three carnivores. The differences in livestock predation between hyenas, leopards and jackals were calculated according to the number of attack events on each type of livestock. All statistical tests were performed using JMP-5 Software (Yirga et al., 2012).

7.4 Results

7.4.1 Depredation of livestock

A total of 3,122 livestock were depredated by hyenas, leopards and jackals over the past five years: 48.2% (n = 1,505) by jackals, 34.2% (n = 1,067) by hyenas and 17.6% (n = 550) by leopards. Table 7.1 presents the number of attack events according to the type of livestock and valuation of livestock losses. Of the 252 attack events on dogs, 77% were by hyenas, 23% by leopards and none by jackals (Table 7.1). Jackals were responsible for 91.3% of the 346 attack events on poultry; 8.7% were by leopards and none by hyenas. The three carnivore species showed a significant difference ($\chi^2 = 896$, d.f. = 10, $P < 0.0001$; n = 3122) in the number of attack events on each type of livestock. The average livestock holding among the respondent households excluding poultry and dog from the analysis was found to be 12.1 head of animals per household. About 8.3% of stock was lost over the past five years. Mean annual livestock loss per household was 1.3 head of stock. There was no significant increase in livestock depredation by hyenas, leopards, and jackals over the last five years (Figure 7.2).

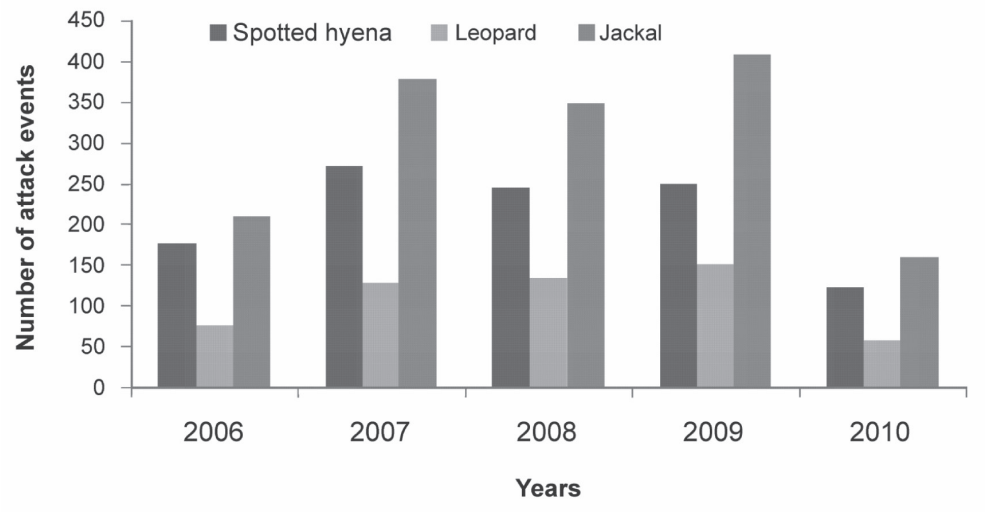

Figure 7.2
Trends of livestock losses by hyena, leopard and jackal from 2006-2010 in the highlands of northern Ethiopia, based on interviews (n = 500)

Table 7.1
Stock number and economic valuation of livestock depredation by large carnivores over the past five years in the highlands of northern Ethiopia, based on interviews (n = 500)

	Depredation (% of stock)					Economic valuation in $US (% of losses)			
Species	**Stock**	**Hyena**	**Leopard**	**Jackal**	**Total**	**Hyena**	**Leopard**	**Jackal**	**Total**
Cattle	1469	6(0.9)	8(1.2)	0(0)	14(2.1)	681	1080	0	1761(3.5)
Goat	2615	487(19)	348(13)	762(29)	1597(61)	8100	6771	12793	27664(55)
Sheep	1405	222(16)	106(8)	427(30)	755(54)	4139	1240	7738	13117(26)
Donkey	557	158(28)	0(0)	0(0)	158(28)	6149	0	0	6149(12.2)
Poultry	2035	0(0)	30(2)	316(16)	346(18)	0	88	958	1046(2.1)
Dog	439	194(44)	58(13)	0(0)	252(57)	549	95	0	644(1.3)
Total	**8520**	**1067(13)**	**550(7)**	**1505(18)**	**3122(37)**	**19618**	**9274**	**21489**	**50381(100)**

7.4.2 Prey preference among livestock

Jacobs's indices scores were derived from kills of seven prey species of livestock recorded as being prey of the hyena, leopard and jackal (Table 2). Livestock predation incidents of hyena, leopard and jackal demonstrated that spotted hyenas had a preference for dog, donkey, goat and sheep, leopards for goat, dog, and sheep, and jackals for goat and sheep.

Table 7.2
Prey preference of hyena, leopard and jackal based on analysis of 3,122 depredated livestock in the highlands of northern Ethiopia

	Prey preference index		
Species	**Hyena**	**Leopard**	**Jackal**
Cattle	-0.95	-0.87	–
Goat	0.31	0.59	0.4
Sheep	0.14	0.1	0.34
Donkey	0.43	–	–
Poultry	–	-0.69	-0.09
Dog	0.61	0.37	–

7.4.3 Time and location of depredation incidents

Overall, livestock predation occurred more during the night (53.6%) than during daytime (46.4%). Comparing day vs. night attacks, hyenas (95%, n = 1,014) and leopards (90%, n = 495) were more likely to attack livestock dur-

ing the night while jackals mostly attacked livestock during the day (89%, n = 1,341). Figure 7.3 shows the time of livestock depredation by hyenas, leopards and jackals. The three carnivore species showed a significant difference (χ^2 = 2133, d.f. = 2, P < 0.0001; n = 3,122) in the number of attack events during the day vs. night.

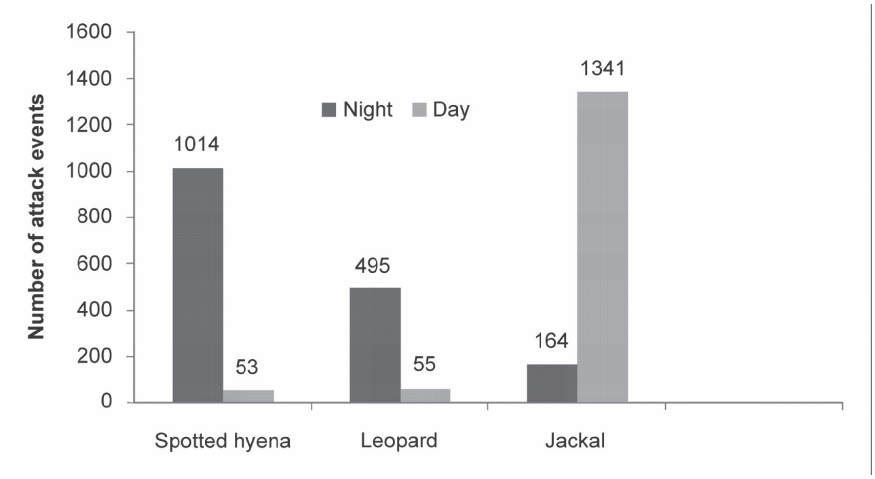

Figure 7.3
Time of livestock depredation by hyena, leopard and jackal over the past five years in the highlands of northern Ethiopia, based on interviews (n = 500)

With regard to place of predation, predation occurred in two distinct contexts. Livestock predation occurred in grazing fields during the day (64.2%, n=1,927) when livestock were separated from the herdsmen. Livestock predation also occurred inside traditional kraals (enclosures) during the night (35.8%, n=1,195) when hyenas break through kraals, while leopards can jump over the kraals. Figure 4 presents the principal contexts of livestock predation by jackals, hyenas and leopards. Comparing attacks in field vs. enclosures, jackals and spotted hyenas (to some extent) were more likely to attack grazing livestock during the day while leopards mostly attacked livestock during the night (χ^2=36, d.f.=2, P<0.0001, n=298) (Figure 4). .

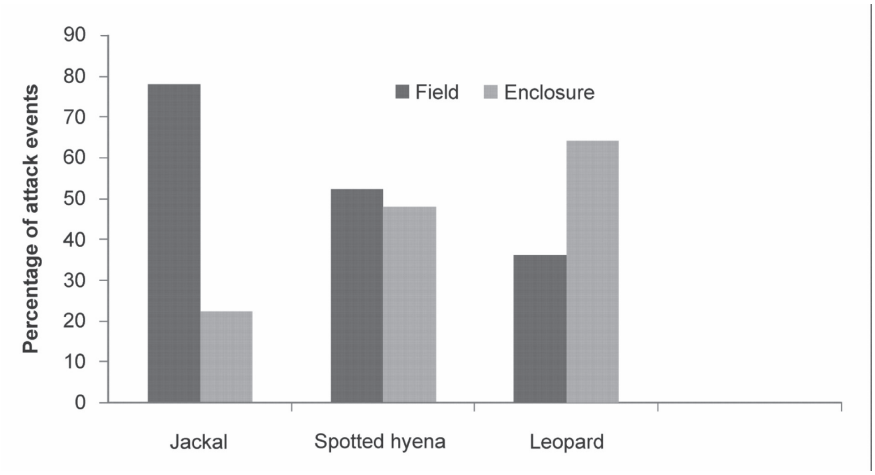

Figure 7.4
Principal contexts of livestock predation by jackal (n = 1,505), hyenas (n = 1,067) and leopards (n = 550)

7.4.4 Economic valuation of loss

The total estimated economic loss corresponding to the 3,122 predated livestock was US $50,381 (Table 1). Jackals, hyenas and leopards contributed to about 42.7, 38.9 and 18.4% of the economic value of livestock and dog kills, respectively. The annual mean economic loss per household was estimated to be US $20.2, which represents about 7% of the average annual income of households in the area. This was based on Pender & Gebremedhin (2004) who stated that the average per capita income among sampled households in the highlands of Tigray was less than $US 60. There was a significant difference in terms of economic valuation of losses of livestock species ($\chi 2=11$, d.f.=5, $P<0.047$, n=3,122) but there was no significant difference among the three carnivores in terms of their economic impact (Table 1).

7.5 Discussion

7.5.1 Depredation of livestock

The predominance of jackals, hyenas, and leopards as livestock-killing predators on the northern Ethiopian highlands is consistent with the results of Hawkes's (1991) survey of Bulilima Mangwe communal land and Madzudzo's (1994) survey of Tsholotsho communal land. In both of these studies, hyenas and jackals were the most common predators of livestock,

the former attacking cattle and donkeys, and the latter killing goats, whereas leopard predation was relatively rare. Hyenas were also identified as predominant predators of goat and sheep (Bauer et al., 2010; Abay et al., 2011; Sogbohossou et al., 2011). In our study, jackals and hyenas were predominant predators of livestock species. In terms of total numbers of livestock killed, jackals were the most serious predators, followed by spotted hyenas.

Livestock depredation by these large predators could be attributed to depletion of the natural prey, habitat loss and proximity to human settlements. In the northern region of Ethiopia, the natural prey base is highly depleted and hyenas are largely dependent on anthropogenic food sources (Abay et al., 2011; Yirga et al., 2012). Various studies have demonstrated that livestock depredation is more common in areas with low prey abundance (Sillero-Zubiri & Laurenson, 2001; Polisar et al., 2003; Treves et al., 2004; Rabinowitz, 2005; Bagchi & Mishra, 2006; de Iongh & Bauer, 2008). Local environmental conditions such as rainfall (Patterson et al., 2004; Woodroffe & Frank, 2005), livestock husbandry practices (Stahl et al., 2001; Madhusudan, 2003; Ogada et al., 2003; Polisar et al., 2003; Rabinowitz, 2005) and characteristics of attacked villages and livestock enclosures (Mech et al., 2000; Ogada et al., 2003) have been found to influence livestock depredation. Livestock depredation occurs more frequently in deforestation frontiers (Crawshaw, 2003) because carnivores respond to these problems by expanding their diets to include livestock (Woodroffe, 2001).

Some researchers (Sagor et al., 1997; Stahl et al., 2001; Stoddart et al., 2001; Madhusudan & Mishra, 2003) clearly documented increases in livestock depredation rates with increases in carnivore density and livestock population. With regard to hyenas, however, in spite of the absence of native prey and high densities of hyenas, the livestock depredation rate was remarkably low in Wukro district, northern Ethiopia (Yirga et al., 2013). Hyenas obtain more food from scavenging on urban and rural waste than from depredation in northern Ethiopia (Abay et al., 2011; Yirga et al., 2012).

7.5.2 Prey preference among livestock species

Preferred species of hyenas were dog, donkey, goat and sheep, in decreasing order. Hyenas mostly prefer prey with a body mass range of 56-182 kg, with a mode of 102 kg (Hayward, 2006). However, hyenas are known in northern Ethiopia to be highly adaptable and opportunistic scavengers and hunters (Yirga et al., 2012) that mainly scavenge on butchers' and household waste. Hyenas changed their diet opportunistically from scavenging on waste be-

fore and after fasting to predation on donkeys during the longest Christian fasting period in northern Ethiopia (Yirga et al., 2012).

In this study, of the 252 attack events on dogs, 77% were by spotted hyenas and the rest by leopards. A number of dogs were victims of predation in the Maasai steppe, Tanzania, especially by leopards (Kissui, 2008). Different reports have shown that dogs did not reduce nocturnal livestock predation by hyenas and lions (Kolowski & Holekamp, 2006; Ikanda & Packer, 2008). However, Woodroffe et al. (2007) and Frank et al. (2005) reported that dogs improved livestock security both in the day-time grazing fields and in the bomas at night. The presence of dogs was not associated with reduction of predation by leopards or hyenas (Ogada et al., 2003).

Leopards preferentially prey upon goat, dog and sheep, in decreasing order; upon species within a weight range of 10-40 kg (Hayward et al., 2006). Other researchers have also found that hyenas and leopards prey upon small stock (goats, sheep and calves) and dogs (Patterson et al., 2004; Kolowski & Holekamp, 2006; Kissui, 2008).

As for jackals, their preferred species were goat, sheep and poultry. This is consistent with results of Atickem et al. (2010) who reported that jackal killed only sheep and goats in the Bale Mountain, Ethiopia whereas hyenas were reported to kill all livestock types found in the Web Valley. However, leopards primarily killed goats and occasionally sheep and cattle (Atickem et al., 2010). The more abundant a preferred species in an area is, the more likely it is to fall prey (Schaller, 1972).

7.5.3 Time and location of depredation incidents

Hyenas, leopards and jackals showed divergent predatory behavior toward livestock with regard to the type of prey they attacked, time of day and location of livestock attacks. Comparing attacks inside traditional kraals vs. field (grazing areas), jackals were more likely to attack grazing livestock during the day while hyenas and leopards mostly attacked livestock at night. According to Atickem et al. (2010), hyenas and leopards were the only carnivores to attack livestock at night with characteristic methods of accessing the bomas at night in Bale Mountain, Ethiopia. Leopards jumped over the walls whilst hyenas penetrated the bomas by digging. Leopards were reported to kill livestock during both day (93 kills, 73%) and night (34 kills, 27%) while common jackal depredated during the day only (Atickem et al., 2010). On the other hand all hyena kills occurred at night (99%) with few

exceptions occurring when livestock approached a hyenas den. They are highly adapted to human settlement and do not appear to be afraid of humans especially at night (Kolowski & Holekamp, 2006).

7.5.4 Economic valuation of loss

In terms of values, jackal was the most important predator as it kills mainly poultry. Hyenas were capable of killing the largest species, cattle and donkeys, which were the most valuable. The question remains as to whether losses to large carnivores in the study area were substantial in comparison to other African studies. In terms of economic losses, the value of livestock predation may be significant as the rural population is extremely poor and chronically dependent on food aid. Despite being an estimate, and perhaps a conservative one, the annual mean economic loss per household was about US $20.2, about 7% of the average annual income of households in the area. However, the true severity of livestock losses to predators can only be estimated with accurate household income data from the study area and these were not collected by this study.

Studies of the economic value of livestock losses to large carnivores in Ethiopia are very limited. However, those that exist indicate that the costs are significant compared to the living standards of the farmers (Abay et al., 2011). Livestock depredation can cause considerable monetary losses (Bauer et al., 2010). For example, Mishra (1997) reported an economic loss of $15,418 from livestock depredation, or $128 loss per family per year among the Indian-trans Himalayan communities. Livestock depredation on a Kenyan ranch is estimated to represent 2.6% of the herd's economic value, worth $8,749 per annum (Patterson et al., 2004). Similarly Butler (2000) reported depredation losses of 12% of each household's net annual income ($13) in Zimbabwe. The economic impact of the current livestock depredation might be very considerable and farmers may become intolerant to large carnivores. The economic impact to an individual livestock owner is disastrous, which might result in damaging retaliatory attacks. For instance, in 1990, 16 hyenas were killed in a single poisoning event following a depredation incident in Maasai Mara National Reserve, Kenya (Holekamp & Smale, 1992). Because of livestock loss to predators, pastoralists have had a long history of intolerance against large carnivores (Sillero-Zubiri & Laurenson, 2001).

7.6 Conclusion and recommendations

Assessing depredation problems is an important step in developing proper management. The depletion of natural prey and the degradation and fragmentation of the habitat due to high human population pressure may be reasonable predictors of the extent of predation by large carnivores. More livestock predation was observed during the nighttime for spotted hyenas and leopards and daytime for jackal. In addition, knowledge of prey preference of each carnivore species with regard to livestock can offer important insights into the effectiveness of depredation prevention measures. It should be noted that majority of these high value losses to large carnivores occurred in grazing fields during the day. Mitigation of livestock depredation is highly recommended, either through improved animal husbandry (Ogada et al., 2003) or through ecosystem regeneration (Abay et al., 2011) which might restore the natural habitat and native prey species. Improving enclosures (Bauer et al., 2010) and changing herding methods, for example herding livestock with more than one herder, or building stronger bomas for livestock at night could decrease livestock depredation figures (Frank et al., 2005; Van Bommel et al., 2007).

Acknowledgments

We are truly grateful to households of the study area for their hospitality and kind response.

References

Abay, G.Y., Bauer, H., Gebrihiwot, K. & Deckers, J. (2011). Peri-urban spotted hyena (*Crocuta crocuta*) in northern Ethiopia: diet, economic impact and abundance. European Journal of Wildlife Research **57**, 759-765.

Atickem, A., Williams, S., Bekele, A. & Thirgood, S. (2010). Livestock predation in the Bale Mountains, Ethiopia. African Journal of Ecology **48**, 1076-1082.

Bagchi, S. & Mishra, C. (2006). Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). Journal of Zoology **268**, 217-224.

Bauer, H., De Iongh, H.H. & Sogbohossou, E. (2010). Assessment and mitigation of human-lion conflict in West and central Africa. Mammalia **74**, 363-367.

Butler, J.R.A. (2000). The economic costs of wildlife predation on livestock in Gokwe communal land, Zimbabwe. African Journal of Ecology **38**, 23-30.

Cozza, K., Fico, R., Battistini, M.L. & Rogers, E. (1996). The damage–conservation interface illustrated by predation on domestic livestock in central Italy. Conservation Biology **78**, 329–336.

Crawshaw, P.G. (2003). A personal view on the depredation of domestic animals by large cats in Brazil. Natureza & Conservação **1**, 71-73.

De Iongh, H.H. & Bauer, H. (2008). Ten Years of Ecological Research on Lions in Waza National Park, Northern Cameroon. Cat News **48**, 29-32.

Desta, G., Nyssen, J., Poesen, J., Deckers, J., Mitiku, H., Govers, G. & Moeyersons, J. (2005). Effectiveness of stone bunds in controlling soil erosion on cropland in the Tigray Highlands, northern Ethiopia. Soil Use and Management **21**, 287-297.

Frank, L.G., Woodroffe, R. & Ogada, M.O. (2005). People and predators in Laikipia District, Kenya. In: Woodroffe, R., Thirgood, S. & Rabinowitz, A. eds. People and Wildlife: Conflict or Coexistence (pp. 286-304)? Cambridge University Press: Cambridge, United Kingdom.

Graham, K., Beckerman, A.P. & Thirgood, S. (2005). Human-predator-prey conflicts: ecological correlates, prey loss and patterns of management. Biological Conservation **122**, 159-171.

Hawkes, R.K. (1991). Crop and Livestock Losses to Wild Animals in the Bulilima Mangwe Natural Resources Management Project Area. CASS/MAT working paper. Centre for Applied Social Sciences, University of Zimbabwe, Harare.

Hayward, M.W. (2006). Prey preferences of the spotted hyena *Crocuta crocuta* and evidence of dietary competition with lion *Panthera leo*. Journal of Zoology (London) **270**, 606-614.

Hayward, M.W., Henschel, P., Obrien, J., Hofmeyr, M., Balme, G. & Kerley, G.I.H. (2006). Prey preferences of the leopard (*Panthera pardus*). Journal of Zoology **270,** 298-313.

Holekamp, K.E. & Smale, L. (1992). Human–Hyena Relations in and Around the Masai Mara National Reserve, Kenya. IUCN Hyena Specialist Group Newsletter **5**, 19-20.

Holmern, T., Nyahongo, J. & Roskaft, E. (2007). Livestock loss caused by predators outside the Serengeti National Park, Tanzania. Biological Conservation **135**, 534-542.

Hotte, M. & Bereznuck, S. (2001). Compensation for livestock kills by tigers and leopards in Russia. Carnivore Damage Prevent. News **3**, 6-7.

Hurni, H. (1993). Land degradation, famines and land resource scenarios in Ethiopia. In: Pimentel, D. ed. World soil erosion and conservation (pp. 27-61). Cambridge University Press: Cambridge, United Kingdom.

Ikanda, D.K. & Packer, C.C. (2008). Ritual vs. retaliatory killing of African lions in the Ngorongoro Conservation Area. Tanzania. Endangered Species Research **6**, 67-74.

Jacobs, J. (1974). Quantitative measurement of food selection – a modification of the forage ratio and Ivlev's electivity index. Oecologia **14**, 413-417.

Kerbis Peterhans, J.C. & Gnoske, T.P. (2002). The science of man-eating among lions *Panthera leo* with a reconstruction of the natural history of the man-eaters of Tsavo. Journal of East African Natural History **90**, 1-40.

Kissui, B.M. (2008). Livestock predation by lions, leopards, spotted hyenas, and their vulnerability to retaliatory killing in the Maasai steppe, Tanzania. Animal Conservation **11**, 422-432.

Kolowski, J.M. & Holekamp, K.E. (2006). Spatial, temporal, and physical characteristics of livestock depredations by large carnivores along a Kenyan reserve border. Biological Conservation **128**, 529-541.

Madhusudan, M.D. & Mishra, C. (2003). Why big, fierce animals are threatened: conserving large mammals in densely populated landscapes. In: Saberwal, V. & Rangarajan, M. eds. Battles over nature: science and the politics of conservation (pp. 31–55). Permanent Black: New Delhi, India.

Madhusudan, M.D. (2003). Living Amidst Large Wildlife: Livestock and Crop Depredation by Large Mammals in the Interior Villages of Bhadra Tiger Reserve, South India. Environmental Management **31**, 466-475.

Madzudzo, E. (1994). Crop and Livestock Damage by Wildlife in Tsholotsho. Centre for Applied Social Sciences, University of Zimbabwe, Harare.

McCann, J. (1995). People of the plow: an agricultural history of Ethiopia*, 1800-1990*. Madison & London: University of Wisconsin Press.

Mech, D.L., Harper, E.K., Meier, T. & Paul, W.J. (2000). Assessing factors that may predispose Minnesota farms to wolf depredations on cattle. Wildlife Society Bulletin **28**, 623-629.

Mishra, C. (1997). Livestock depredation by large carnivores in the Indian trans-Himalaya: conflict perceptions and conservation prospects. Environmental Conservation **24**, 338-343.

Nyhus, P., Fischer, H., Madden, F. & Osofsky, S. (2003). Taking the bite out of wildlife damage: the challenges of wildlife compensation schemes. Conservation in Practice **4**, 37-40.

Nyssen, J., Poesen, J., Desta, G., Vancampenhout, K., D'aes, M., Gebremedhin, Y., Govers, G., Leirs, H., Moeyersons, J., Naudts, J., Nigussie, H., Mitiku, H. & Deckers, J. (2007). Interdisciplinary on-site evaluation of stone bunds to control soil erosion on cropland in Northern Ethiopia. Soil & Tillage Research **94**, 151-163.

Ogada, M., Woodroffe, R., Oguge, O.N. & Frank, G.L. (2003). Limiting depredation by African carnivores: the role of livestock husbandry. Conservation Biology **17**, 1521-1530.

Packer, C., Ikanda, D., Kissui, B. & Kushnir, H. (2005). Lion attacks on humans in Tanzania—understanding the timing and distribution of attacks on rural communities will help to prevent them. Nature **436**, 927-928.

Pander, J. & Gebremedehin, B. (2004). Impacts of polices and technologies in dry land agriculture; Evidence from northern Ethiopia.

Patterson, B.D., Kasiki, S.M., Selempo, E. & Kays, R.W. (2004). Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighboring Tsavo National Parks, Kenya. Biological Conservation **119**, 507-516.

Polisar, J., Maxit, I., Scognamillo, D., Farrell, L., Sunquist, M.E. & Eisenberg, J.F. (2003). Jaguars, pumas, their prey base, and cattle ranching: ecological interpretations of a management problem. Biological Conservation **109**, 297-310.

Rabinowitz, A. (2005). Jaguars and livestock: living with the world´s third largest cat. In: Woodroffe, R., Thirgood, S. & Rabinowitz, A. eds. People and wildlife, Conflict or coexistence (pp. 176-191). Cambridge University Press: Cambridge, United Kingdom.

Sagor, J.T., Swenson, J.E. & Roskaft, E. (1997). Compatibility of brown bear *Ursus arctos* and free-ranging sheep in Norway. Biological Conservation **81**, 91-95.

Sara, A.A. (2010). Mitigating drought: Policy Impact Evaluation A case of Tigray region, Ethiopia, Msc. Thesis, University of Twente, The Netherlands.

Schaller, G.B. (1972). The Serengeti Lion: A study of Predator-Prey Relations. University of Chicago Press: Chicago.

Segers, K., Dessein, J., Nyssen, J., Haile, M. & Deckers, J. (2008). 'Developers and farmers intertwining interventions: the case of rainwater harvesting and food-for-work in Degua Temben, Tigray, Ethiopia'. International Journal of Agricultural Sustainability **6**, 173-82.

Sillero-Zubiri, C. & Laurenson, M.K. (2001). Interactions between carnivores and local communities: conflict or co-existence? In: Gittleman, J.L., Funk, S.M., Macdonald, D.W. & Wayne, R.K. eds. Carnivore conservation (pp. 282-312). Cambridge University Press: Cambridge, United Kingdom.

Sogbohossou, E.A., De Iongh, H.H., Brice, S., Snoo, G.R. & Funstone, P. (2011). Human-carnivore conflicts around Pendjari Biosphere reserve, northern Benin. Oryx **6**, 1-10.

Stahl, P., Vandel, J.M., Herrnschmidt, V. & Migot, P. (2001). Predation on livestock by an expanding reintroduced lynx population; long-term trend and spatial variability. Journal of Applied Ecology **38**, 674-687.

Stoddart, L.C., Griffiths, R.E. & Knowlton, F.F. (2001). Coyote responses to changing jackrabbit abundance affect sheep predation. Journal of Range Management **54**, 15-20.

Treves, A. & Karanth, K.U. (2003). Human–carnivore conflict and perspectives on carnivore management worldwide. Conservation Biology **17**, 1491-1499.

Treves, A., Naughton-Treves, L., Harper, E.K., Mladenoff, D.J., Rose, R.A., Sickley, T.A. & Wydeven, A.P. (2004). Predicting human carnivore conflict: a spatial model derived from 25 years of data on wolf predation on livestock. Conservation Biology **18**, 114-125.

Van Bommel, L., Bij de Vaate, M.D., De Boer, W.F. & De Iongh, H.H. (2007). Factors affecting livestock predation by lions in Cameroon. African Journal of Ecology **45**, 490-498.

Woodroffe, R. & Frank, G.L. (2005). Lethal control of African lions (*Panthera leo*): local and regional population impact. Animal Conservation **8**, 91-98.

Woodroffe, R. (2000). Predators and people: using human densities to interpret declines of large carnivores. Animal Conservation **3**, 165-173.

Woodroffe, R. (2001). Strategies for carnivore conservation: lessons from contemporary extinctions. In: Gittleman, J.L., Wayne, R.K., Macdonald, D.W. & Funk, S.M. eds. Carnivore conservation (pp. 61-92). Cambridge University Press: Cambridge, United Kingdrom.

Woodroffe, R., Frank, L.G., Lindsey, P.A., Ole Ranah, S.M.K. & Romañach, S. (2007). Livestock husbandry as a tool for carnivore conservation in Africa's community rangelands: a case-control study. Biological Conservation **16**, 1245-1260.

Yirga, G., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Deckers, J. & Bauer, H. (2012). Adaptability of large carnivores to changing anthropogenic food sources: diet change of spotted hyena (*Crocuta crocuta*) during Christian fasting period in northern Ethiopia. Journal of Animal Ecology **81**, 1052-1055.

Yirga, G., Ersino, W., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Deckers, J. & Bauer, H. (2013). Spotted hyena (*Crocuta crocuta*) coexisting at high density with people in Wukro district northern Ethiopia. Mammalian Biology **78**, 193-197.

PART III
Synthesis and General Discussion

8

Synthesis and General Discussion

8.1 Hyena diet

The main aim of my study was to study hyena-human interactions and the behavior of hyenas in a human-dominated landscape. The results of my study support the hypothesis that hyenas in Tigray survive in a human-dominated landscape because of a unique combination of adaptation to anthropogenic food and cultural tolerance towards hyenas.

During my research, I found that hyenas depended entirely on domestic prey species, partly through depredation but much more through scavenging on (peri-) urban waste (chapter 2). For hyenas in the study area, I found that anthropogenic foods are of major nutritive importance. About 99% of the hyenas' diet was found to consist of domestic animals, especially cattle, donkeys, goats and sheep. They obtain most of their food from scavenging on urban and rural waste; depredation accounted for <10% of food intake in Debri and Aynalem (Abay et al., 2011).

Scavenging is mutually beneficial. The hyenas benefit from the waste humans dispose of, while human communities are provided with a waste-clearing service. Despite their reputation as scavengers, hyenas acquired over 82% of their total food intake by hunting rather than scavenging in the Ngorongoro Crater, Tanzania (Kruuk, 1972). In the Serengeti (Kruuk, 1972) and throughout southern Africa (Cooper, 1990; Henschel & Skinner, 1990; Mills, 1990; Gasaway et al., 1991) hyenas typically acquire about 70% of their food by hunting and the rest through scavenging. These findings demonstrate that hyenas prefer wild prey, if available. However, in my study, the environment is prey depleted, as the habitat is degraded and fragmented as a result of intensive agriculture. Hyenas are flexible hunters, foraging alone for smaller items (Kruuk, 1970) up to 75% of the time (Holekamp et al., 1997). They are opportunistic predators with a high behavioral plasticity, hunting whatever species are locally most abundant (Susan et al., 1999).

As a consequence they are quick to take advantage of seasonally changing prey resources (Kruuk, 1972; Cooper, 1990; Mills, 1990). Hyenas are also known to exploit carrion as a food resource (Kruuk, 1972; Cooper, 1990; Mills, 1990). They can apparently switch between scavenging and hunting as the opportunity arises (Susan et al., 1999) and do not have clear dietary preferences, other than the avoidance of desiccated carcasses in drought situations (Cooper, 1990; Gasaway et al., 1991).

The relatively high abundance of hyenas at garbage dumping sites reflects their dependence on anthropogenic food and disease resistance. Animals that hunt and scavenge are likely exposed to a broad array of pathogens (Schulenburg et al., 2009). Hyenas have descended within the last million years from carrion-feeding ancestors (Werdelin, 1989; Lewis & Werdelin, 2000). They have been documented to survive anthrax and rabies infections, as well as outbreaks of several other viral diseases that decimated populations of sympatric carnivores (East et al., 2001; East et al., 2004; Harrison et al., 2004; Watts & Holekamp, 2009; Lembo et al., 2011).

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 them to species level. Researchers have examined the diet of predators in Africa (Mills, 1992; Bailey, 1993; Hayward, 2006), in Europe (Gade-Jorgensen & Stagegaard, 2000; Jedrzejewski et al., 2000; Capitani et al., 2004) and in North America (Kohira & Rexstad, 1997; Marquard-Petersen, 1998) using scat analyses. The approach is inexpensive, relatively quick to apply, and large samples can be collected (Litvaitis, 2000). It is useful to construct a basic description of a carnivore's diet (Mills, 1996). Scat analysis is also a particularly useful supplement to radio-tracking, direct observation, and snow-tracking in studies of diet selection (Marucco et al., 2008). If the sample size is too small, tests of hypotheses lack power (Bros & Cowell, 1987; Sheppard, 1999), especially in tests to compare diets (Reynolds & Aebischer, 1991). When the sample size is very large, the power of a specific test may be adequate, but effort may have been wasted in collecting and processing so many scats (Marucco et al., 2008). Frequencies with which particular prey species occur among collections of scats are easily compiled to describe the diet, and can be used to compare diets between periods. The human hairs in the scats probably came from cemeteries and from garbage dumps on which hyenas scavenge. They were certainly not from the attacks on humans, as these are extremely rare. During my study I documented 10 attacks on humans but no fatal cases (Abay et al., 2011).

I found that hyenas are common in many parts of Ethiopia. In the region of northern Ethiopia the natural prey base is very low and hyenas are known to depend on anthropogenic food (Abay et al., 2011; Yirga et al., 2012). They are very common near urban environments, where humans provide them with organic waste. This confirms that they are highly adapted to the environment. Figure 8.1 demonstrates human-predator interaction in northern Ethiopia. Jackal and leopard are common livestock predators in northern Ethiopia, while other large carnivores are almost absent (Abay et al., 2011).

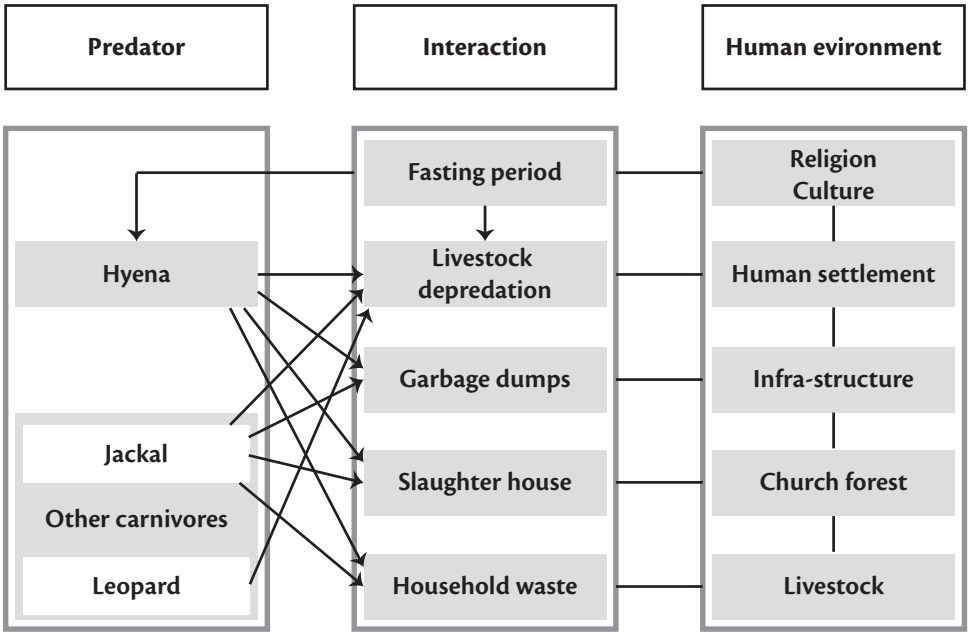

Figure 8.1
The interaction of large carnivores with humans in a human dominated landscape in northern Ethiopia

My study shows a significant change in diet of hyenas during the Orthodox Tewahedo Christians fasting period, from predominantly scavenging on waste to active predation on donkeys. The vegan diet of humans during fasting leads to a sharp reduction in available animal waste. This is apparently compensated for by increased donkey depredation. Changes in human diet have a dramatic impact on the diet of hyenas. By providing this unique insight into the effect of changes in human diet on local hyenas, the results illustrate that hyenas are highly adaptable and opportunistic scavengers and hunters.

Table 8.1
Percentage of occurrences of livestock and wild prey species in scats of large carnivores across Africa

Source	Location/country	Diet
Tumenta, 2012	Waza National Park, Cameroon	Wild prey 75 % Livestock 25 %
Cooper et al., 1999	Masai Mara National Reserve, Kenya	Wild prey 96 % Livestock 0 %
Sogbohossou, 2011	Pendjari Reserv, Benin	Wild prey 97 % Livestock 0 %
Breuer, 2005	Faro National Park/ Cameroon	Wild prey 98 % Livestock 0 %
Di Silvestre et al., 2000	Niokolo Koba National Park, Senegal	Wild prey 99 % Livestock 0 %
This study	Chebera Churchura National Park, Ethiopia	Wild prey 40 % Livestock 56 %
This study	Non protected area across Ethiopia	Wild prey 0.1 % Livestock 99.9 %
This study	Wukro, Ethiopia	Wild prey 1 % Livestock 99 %

Table 8.1 presents diet of large carnivores in various ecosystems across Africa. The hyenas in different ecosystems across Africa depend on wild prey species (Eloff, 1964; Kruuk, 1972; Bearder, 1977; Smuts, 1979; Tilson et al., 1980; Henschel, 1986; Mills, 1990).

8.2 Hyena-human coexistence

The conventional wisdom about large carnivores in general, that they depend on protected areas, does not apply to hyenas in Ethiopia. They are more abundant in human-dominated landscapes than in protected areas (Yirga et al., unpublished data). Hyenas are conventionally thought to be greatly dependent on protected areas or zones of low human density with sufficient numbers of suitable prey (Mills & Hofer, 1998). Hyenas can survive in environments from which other large predators such as cheetahs (*Acinonyx jubatus* (Schreber, 1775), lions, and wild dogs have disappeared (Mills & Hofer, 1998). Hyena density is strongly correlated with prey density in the Etosha National Park, Namibia (Trinkel, 2009). However, despite depletion of natural prey, the region of northern Ethiopia still supports a high density of spotted hyenas. The higher density of hyenas in garbage dumping

areas was perhaps due to highly concentrated scavengable food resources. Scavengable food availability and distribution is more likely to impact large carnivore abundance and distribution in human landscapes. Certain animal species have adapted to human-dominated habitats well and benefit directly or indirectly from human activities including food (Shochat et al., 2004; Faeth et al., 2005; Adams et al., 2006). Diet supplementation with anthropogenic food augmented predator's densities (Fedriani, et al., 2001). It has been reported that refuse and livestock carcasses at pastoral villages may influence the frequency of hyena visits to these areas (Mills & Hofer, 1998; Kolowski & Holekamp, 2007). Hyenas are frequent visitors to garbage dumps and other sources of scavengable food, including cemeteries (Sutcliffe, 1970; Horwitz & Smith, 1988; Leakey et al., 1999; Abay et al., 2011).

I found that the use of playback recordings to attract predators works effectively for estimating hyena and jackal abundance and distribution. It is a powerful method for estimating predator population sizes across Africa, and characterizing their spatial distributions (Mills, 1985; Sillero-Zubiri & Gottelli, 1992; Creel & Creel, 1996; Mills & Gorman, 1997; Ogutu & Dublin, 1998; Mills et al., 2001; Maddox, 2003; Ogutu et al., 2005). It would have been important to collect simultaneous data on hyenas and jackal abundance to compare how well response probabilities reflect true densities, using camera traps or other census methods.

My research also showed that hyenas live in significant numbers in proximity to human communities in Ethiopia and the cost of livestock predation to the local residents is relatively low. Various travelers' observations indicate that hyenas were more numerous in Ethiopia in the past (Gade, 2006). Examples include Bruce (1790), who wrote that the "plains are infested with hyenas. Gobat (1851) also wrote that hyenas were a plague in Abyssinia (former name for Ethiopia), in every situation in city and field. Therefore, coexistence must have developed over centuries. Behavioral flexibility of hyenas facilitates their adaptive adjustment to precarious lifestyles in proximity to humans (Woodroffe, 2000; Sunquist & Sunquist, 2001; Boydston et al., 2003). Increasing human population density is often associated with a decline or extinction of local carnivore populations (Woodroffe & Ginsberg, 2000). Growing human populations negatively affect habitat quality for carnivores (Gittleman & Harvey, 1982). It is important to understand how anthropogenic food resources can affect hyena abundance and distribution. Knowledge of the ecological effects of human-derived subsidies can aid conservation efforts in and around humanized landscapes (Ehrenfeld & Toth, 1997). Anthropogenic food sources would impact hyena abundance

and their viability. I conclude that changes in waste management might greatly affect hyena abundance and distribution. Other authors also suggested that changes in the availability of anthropogenic food affect carnivore population density (Borkowski et al., 2011).

As local people often perceive predators to be a direct threat to themselves or their livestock, sustained coexistence between humans and large carnivores is rarely possible outside of protected areas (Woodroffe & Ginsberg, 2000). Multiple studies have demonstrated carnivore avoidance of areas characterized by intense human activity (mountain lions – Van Dyke et al., 1986; coyotes – Gese et al., 1989; bears – Mattson, 1990; Reinhart, 1990; Olson, 1994; wolves – Thurber et al., 1994). Species exhibiting greater behavioural plasticity are expected to be able to adapt more readily than others to life in proximity to humans (Woodroffe, 2000).

Coexistence between humans and carnivores over a sustained period is a central issue in conservation science and policy (Woodroffe et al., 2005; Dickman et al., 2011). Conservation approaches such as state-managed reserves, community-managed areas, and privately owned sanctuaries have been suggested to promote coexistence between humans and carnivores (Berkes, 2007; Dudley, 2008). Protected areas are designed to facilitate coexistence at a regional scale (Dudley, 2008; Western et al., 2009) and community-based conservation approaches are designed to facilitate coexistence at smaller intermediate scales (Western et al., 1994; Berkes, 2007). The growing human population and a long history of competition between people and carnivores for limited resources such as food (Woodroffe et al., 2005) have led to a general conclusion among conservation practitioners and policy-makers that large carnivores cannot coexist with humans (Brashares et al., 2001; Parks & Harcourt, 2002; Karanth et al., 2010). Remarkably, I found that hyenas coexist in significant numbers in a human-dominated landscape. Such information is very important, as the world population is anticipated to increase with 1.4 billion people over the next two decades, forcing human and carnivore populations to share the same space (United Nations, 2010).

I found a density estimate of 52 hyenas per 100 km^2 outside of conservation areas. This density is even higher than densities found in some protected areas (Table 8.2). Hyenas are the most abundant large carnivore in Africa with current population between 27,000 and 47, 000 individuals (Honer et al., 2008).

Table 8.2
Hyena density in different parts of Africa

Source	Location/country	Density
Ogutu et al., 2005	Mara Ecosystem,Kenya	0.463/km^2
Mills et al., 2001	Kruger National Park/ South Africa	0.12/ km^2
Ogutu and Dublin, 1998	Masai Mara National Reserve/ Kenya	1.4/ km^2
Graf et al. 2008	Hluhluwe-iMfolozi Park/ South Africa	0.33/ km^2
Trinkel, 2009	Etosha National Park/ Nambia	0.02/ km^2
Sillero Zubiri, and Gottelli, 1992	Aberdare National Park in Kenya	1.34/ km^2
This study	Tigray, northern Ethiopia	0.52/ km^2

8.3 Livestock depredation in time and space

In general, depredation of domestic animals is low compared to other studies in Africa. The livestock loss reported in this study is among the lowest recorded. However, it can still be an economic constraint to households, as they are subsistence farmers who depend on food aid for part of the year. In general, depredation of domestic animals remains tolerable and people have a positive perception of hyenas. This would also contribute to hyena persistence in this environment. Various factors account for livestock depredation, such as livestock husbandry practices, low prey abundance, livestock enclosures and characteristics of attacked villages (Sillero-Zubiri & Laurenson, 2001; Madhusudan, 2003; Polisar et al., 2003; Ogada et al., 2003; Treves et al., 2004; Bagchi & Mishra, 2006; De Iongh & Bauer, 2008). In my study, dogs were reported as victims of hyena predation, which confirms that domestic dogs were not effective in protecting villages from hyena attacks.

In all studies reported above, livestock predation occurred in grazing fields during the day when livestock were separated from the herdsmen. Comparing attacks in the fields with attacks in enclosures, jackals and hyenas were more likely to attack grazing livestock during the day while leopards mostly attacked livestock during the night. In terms of total numbers of livestock killed, jackals were the most serious predators, followed by hyenas. Higher livestock predation was observed at nighttime for hyenas and leopards and during the day for jackals. Assessing depredation problems is an important step in developing actions for management. Fortunately, despite the occur-

rence of livestock predator conflicts, retaliatory killing of carnivores was not common in the study area.

Coexistence of hyenas in a human-dominated landscape in Ethiopia has several explanations. Ethiopia has more than 80 million domesticated hoofed animals (Mitchell, 2003). The depletion of wild prey has meant that livestock more readily supports carnivorous need for prey. Availability of waste, culture/religion, history and awareness of clearing role of hyenas have contributed to human-hyena coexistence. In my study hyenas scavenged on livestock that died from disease or by accident and also preyed on live domestic animals. Waste management is poor in many cities of Ethiopia and solid wastes are dumped along roadsides and in open areas (Tadesse et al., 2008). Hyenas with dens near towns or cities in Ethiopia live on garbage or other organic refuse (Gade, 2006). Hyenas are formally protected in Ethiopia and that people are not allowed to kill hyenas.

The relative abundance of hyenas is also associated with its accepted role in removing garbage and carrion from households and urban dumps. When feeding on waste, hyenas reduce fly and rat populations as well as fetid odors (Gade, 2006; Yirga et al., unpubl.).

Viable populations of large carnivores across the globe coexist in a landscape with people that bring anthropogenic resources (Linnell et al., 2001; Conover, 2002; Woodroffe et al., 2005). The ability of large carnivores to persist in human-dominated landscapes has stimulated debate in recent years (Woodroffe, 2000; Linnell et al., 2001; Basille et al., 2009). Human density, human activities and associated human–carnivore conflict are key factors determining large carnivores' occurrence and persistence in human dominated landscapes (Woodroffe, 2000; Woodroffe et al., 2005). In anthropogenic landscapes, the occurrence and persistence of large carnivores seem to be modulated by food availability (Fuller & Sievert, 2001; Basille et al., 2009), and factors that affect survival such as human activity or landscape context, which can reduce human pressure (Woodroffe & Ginsberg, 1998). My study has revealed an exceptional case of coexistence. In northern Ethiopia, high density of hyenas persists in anthropogenic landscapes where human densities are remarkably higher.

8.4 Conclusions

The following conclusions can be drawn from this study:

1 Hyenas in Tigray depend entirely on domestic prey species, partly through depredation but much more importantly by scavenging on (peri-) urban waste. Scavenging on waste and livestock depredation by hyenas occurs widely across Ethiopia. Spotted hyenas in Ethiopia predominantly depend on anthropogenic food sources rather than natural prey. Hyenas scavenge less and hunt more during fasting, selecting opportunistically for donkeys. My study showed a remarkable change in hyenas' diet during the fasting period, from predominantly scavenging on waste to active predation on donkeys. Hyenas are highly adaptable and opportunistic scavengers and hunters. They show fast reaction to change in human behavior.

2 A population of 535 hyenas lives close to human communities without any reports of retaliatory killing in Wukro district. This demonstrates a rare case of coexistence, where hyenas benefit from waste disposal and human communities benefit from the waste clearing. It also demonstrates the high adaptability of hyenas which in this case specialize entirely in waste consumption.

3 The use of playback recordings to attract predators works successfully for estimating hyena abundance and distribution. It is also effective for characterizing the hyena population's spatial distribution.

4 Under the particular local circumstances (solid wastes are dumped along roadsides and into open areas), continued coexistence between spotted hyenas and local communities appears possible, provided that livestock depredation remains tolerable.

5 The depletion of natural prey and habitat degradation and fragmentation due to high human population pressure may be reasons for livestock predation by carnivores. Assessing depredation problems is important in order to develop actions for managing either livestock practices or wildlife conservation. More livestock predation was observed at night for spotted hyenas and leopards and during the day for jackals., making night-time a high risk period for livestock depredation by hyenas and leopards, and daytime for livestock depredation by jackals.

8.5 Recommendation for management of waste dumps

Hyena population persistence is secure under the present conditions, as waste management is poor and solid wastes are dumped along roadsides and into open areas. Waste management changes from open to closed systems would immediately impact on the ecology and viability of the spotted hyena population. Hyenas in my study area live predominantly on garbage and other organic refuse. Reduction in the availably of waste could force hyenas to prey on live domestic animals, which might impact the human-hyena relationship. At this time, Mekelle city is considering improving solid waste management from an open to a closed system, by fencing the garbage dumps. For long term conservation, it is therefore recommended that dumps should have openings to allow hyenas to enter. Mutual benefit of hyenas and the municipality should be considered in the management of waste dumps. Hyenas are efficient means of sanitation; they remove garbage and carrion from the garbage dumps, reduce fetid odors, and help control rat and housefly populations.

References

Abay, G.Y., Bauer, H., Gebrihiwot, K. & Deckers, J. (2011). Peri-urban spotted hyena (*Crocuta crocuta*) in northern Ethiopia: diet, economic impact, and abundance. European Journal of Wildlife Research **57**, 759-765.

Adams, C.E., Lindsey, K.J. & Ash, S.J. (2006). Urban Wildlife Management. CRC Press, Boca Raton, FL.

Bagchi, S. & Mishra, C. (2006). Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). Journal of Zoology **268**, 217-224.

Bailey, T.N. (1993). The African leopard. Columbia University Press, New York.

Basille, M., Herfindal, I., Santin-Janin, H., Linnell, J.D.C., Odden, J., Andersen, R., Arild Høgda, K. & Gaillard, J. (2009). What shapes *Eurasian lynx* distribution in human dominated landscapes: selecting prey or avoiding people? Ecography **32**, 683-691.

Bearder, S.K. (1977). Feeding habits of spotted hyenas in woodland habitat. East African Wildlife Journal **14**, 233-235.

Berkes, F. (2007). Community-based conservation in a globalized world. Proceedings of the National Academy of Sciences USA **104**, 15188-15193.

Borokowski, J., Zalewski, A. & Manor, R. (2011). Diet composition of golden jackals in Israel. Annales Zoologici Fennici **48**, 108-118.

Boydston, E.E., Kapheim, K.M., Watts, H.E., Szychman, M. & Holekamp, K.E. (2003). Altered behavior in spotted hyenas associated with increased human activity. Animal Conservation **6**, 1-10.

Brashares, J.S., Arcese, P. & Sam, M.K. (2001). Human demography and reserve size predict wildlife extinction in West Africa. Proceedings of Biological Sciences **268**, 2473-2478.

Breuer, T. (2005). Diet choice of large carnivores in northern Cameroon. African Journal of Ecology **43**, 97-106.

Bros, W.E. & Cowell, B.C. (1987). A technique for optimizing sample size (replication). Journal of Experimental Marine Biology and Ecology **114**, 63-71.

Bruce, J. (1790). Travels to Discover the Source of the Nile in the Years 1768, 1769, 1770, 1771, 1772 and 1773. 3rd ed. 7 vols. Edinburgh: A. Constable.

Capitani, C., Bertelli, I., Varuzza, P., Scandura, M. & Apollonio, M. (2004). A comparative analysis of wolf (*Canis lupus*) diet in three different Italian ecosystems. Mammalian Biology **69**, 1-10.

Conover, M.R. (2002). Resolving human–wildlife conflicts: the science of wildlife damage management. Lewis Publishers, CRC Press LLC, Boca Raton, Florida.

Cooper, S.M. (1990). The hunting behavior of spotted hyenas (*Crocuta crocuta*) in a region containing both sedentary and migratory populations of herbivores. African Journal of Ecology **28,** 131-141.

Cooper, S.M., Holekamp, K.E. & Smale, L. (1999). A seasonal feast: long-term analysis of feeding behavior in the spotted hyena (*Crocuta crocuta*). African Journal of Ecology **37**, 149-160.

Creel, S. & Creel, N.M. (1996). Limitation of African wild dogs by competition with larger carnivores. Conservation Biology **10**, 526-538.

De Iongh, H.H. & Bauer, H. (2008). Ten Years of Ecological Research on Lions in Waza National Park, Northern Cameroon. Cat News **48**, 29-32.

Di Silvestre, I., Novelli, O. & Bogliani, G. (2000). Feeding habits of the spotted hyena in the Niokolo Koba National Park. Senegal. African Journal of Ecology **38**, 102-107.

Dickman, A.J., Macdonald, E.A. & Macdonald, D.W. (2011). A review of financial instruments to pay for predator conservation and encourage human-carnivore coexistence. Proceedings of the National Academy of Sciences USA **108**, 13937-13944.

Dudley, N. (2008). Guidelines for Applying Protected Area Management Categories (International Union for Conservation of Nature, IUCN), Gland, Switzerland.

East, M., Moestl, K., Benetka, V., Pitra, C., Höner, O.P., Wachter, B. & Hofer, H. (2004). Corona virus infection of spotted hyenas in the Serengeti ecosystem. Veterinary Microbiology **102**, 1-9.

East, M.L., Hofer, H., Cox, J.H., Wulle, U., Wiik, H. & Pitra, C. (2001). Regular exposure to rabies virus and lack of symptomatic disease in Serengeti spotted hyenas. Proceedings of the National Academy of Sciences USA **98**, 15026-15031.

Ehrenfeld, J.G. & Toth, L.A. (1997). Restoration ecology and the ecosystem perspective. Restoration Ecology **5**, 307-317.

Eloff, F.C. (1964). On the predatory habits of lions and hyenas. Koedoe **7,** 105–112.

Faeth, S.H., Warren, P.S., Shochat, E. & Marussich, W.A. (2005). Trophic dynamics in urban communities. BioScience **55**, 399-407.

Fedriani, J.M., Fuller, T.K. & Sauvajot, R.M. (2001). Does availability of anthropogenic food enhance densities of omnivorous mammals? An example with coyotes in southern California. Ecography **24**, 325-331.

Fuller, T.K. & Sievert, P.R. (2001). Carnivore demography and the consequences of changes in prey availability. In: Gittleman, J.L., Funk, S.M., Macdonald, D. & Wayne, R.K. eds. Carnivore conservation (pp. 163–178). Cambridge University Press: Cambridge, United Kingdom.

Gade, D.W. (2006). Hyenas and humans in the Horn of Africa. Geographical Review **96**, 609-632.

Gade-Jorgensen, I. & Stagegaard, R. (2000). Diet composition of wolves *Canis lupus* in east-central Finland. Acta Theriologica **45**, 537-547.

Gasaway, W.C., Mossestad, K.T. & Stander, P.E. (1991). Food acquisition by spotted hyenas in Etosha National Park, Namibia: predation versus scavenging. African Journal of Ecology **29,** 64-75.

Gese, E.M., Rongstad, O.J. & Mytton, W.R. (1989). Changes in coyote movements due to military activity. Journal of Wildlife Management **53**, 334-339.

Gittleman, J.L. & Harvey, P.H. (1982). Carnivore home-range size, metabolic needs and ecology. Behavioral Ecology and Sociobiology **10**, 57-63.

Gobat, S. (1851). Journal of Three Years' Residence in Abyssinia. New York: Negro Universities Press.

Graf, J., Somers, M.J., Szykman, M. & Slotow, R. (2008). Heterogeneity in the density and distribution of spotted hyaenas in Hluhluwe-iMfolozi Park. South Africa. Acta Therioligica **54**, 333-343.

Harrison, T.M., Mazet, J.K., Holekamp, K.E., Dubovi, E., Engh, A.L., Nelson, K., Van Horn, R.C. & Munson, L. (2004). Antibodies to canine and feline viruses in spotted hyenas (*Crocuta crocuta*) in the Masai Mara National Reserve. Journal of Wildlife Diseases **40**, 1-10.

Hayward, M.W. (2006). Prey preferences of the spotted hyena *Crocuta crocuta* and evidence of dietary competition with lion *Panthera leo*. Journal of Zoology (London) **270**, 606-614.

Henscel, J.R. (1986). The socio-ecology of a spotted hyena *Crocuta crocuta* clan in the Kruger National Park. PhD thesis, University of Pretoria, Pretoria, South Africa.

Henschel, J.R. & Skinner, J.D. (1990). The diet of the spotted hyenas *Crocuta crocuta* in Kruger National Park. African Journal of Ecology **28,** 69-82.

Holekamp, K.E., Smale, L., Berg, R. & Cooper, S.M. (1997). Hunting rates and hunting success in the spotted hyena (*Crocuta crocuta*). Journal of Zoology (London) **242**, 1-15.

Honer, O., Holekamp, K.E. & Mills, G. (2008). *Crocuta crocuta*. In: IUCN 2008. 2008 IUNC Red List of Threatened Species www.iucnredlist.org. Downloaded November, 2012.

Horwitz, L.K. & Smith, P. (1988). The effects of striped hyena activity on human remains. Journal of archaeological Science **15**, 471-482.

Jedrzejewski, W., Jedrzejewska, B., Okarma, H., Schmidt, K., Zub, K. & Musiani, M. (2000). Prey selection and predation by wolves in Białowie_za Primeval Forest, Poland. Journal of Mammalogy **81**, 197-212.

Karanth, K.K., Nichols, J.D., Karanth, K.U., Hines, J.E. & Christensen, N.L. (2010). The shrinking ark: Patterns of large mammal extinctions in India. Proceedings of Biological Sciences **277**, 1971-1979.

Kohira, M. & Rexstad, E.A. (1997). Diets of wolves, *Canis lupus*, in logged and unlogged forests in southeastern Alaska. Canadian Field-Naturalist **111**, 429–435.

Kolowski, J.M. & Holekamp, K.E. (2007). Effects of an open refuse pit on space use patterns of spotted hyenas. African Journal of Ecology **46**, 341-349.

Kruuk, H. (1970). Interactions between populations of spotted hyenas (*Crocuta crocuta*) and their prey species. In: Watson, A. ed. Animal populations in relation to their food resources (pp. 359-374). Blackwell Scientific Publications: Oxford, United Kingdom.

Kruuk, H. (1972). The Spotted Hyena: a Study of Predation and Social Behavior. University of Chicago Press: Chicago.

Leakey, L.N., Milledge, S.A.H., Leakey, S.M., Edung, J., Haynes, P., Kiptoo, D.K. & McGeorge, A. (1999). Diet of striped hyena in northern Kenya. African Journal of Ecology **37**, 314-326.

Lembo, T., Hampson, K., Auty, H., Beesley, C.A., Bessell, P., Packer, C., Halliday, J., Fyumagwa, R., Hoare, R. & Ernest, E. (2011). Serologic Surveillance of Anthrax in the Serengeti Ecosystem, Tanzania, 1996-2009. Emerging Infectious Diseases **17**, 387-394.

Lewis, M. & Werdelin, L. (2000). The evolution of spotted hyenas (*Crocuta crocuta*). IUCN Hyena Specialist Group Newsletter **7**, 34-36.

Linnell, J.D.C., Swenson, J.E. & Andersen, R. (2001). Predators and people: conservation of large carnivores is possible at high human densities if management policy is favorable. Animal Conservation **4**, 345-349.

Litvaitis, J.A. (2000). Investigating food habits of terrestrial vertebrates. In: Boitani, L. & Fuller, T.K. eds. Research techniques in animal ecology: Controversies and consequences (pp. 165-190). Columbia Press: New York, USA.

Maddox, T.M. (2003). The ecology of cheetahs and other large carnivores in a pastoralist-dominated buffer zone. PhD thesis, University College London, Institute of Zoology, London, United Kingdom.

Madhusudan, M.D. (2003). Living Amidst Large Wildlife: Livestock and Crop Depredation by Large Mammals in the Interior Villages of Bhadra Tiger Reserve, South India. Environmental Management **31**, 466-475.

Marquard-Petersen, U. (1998). Food habits of arctic wolves in Greenland. Journal of Mammalogy **79**, 236-244.

Marucco, F., Daniel, H.P. & Luigi, B. (2008). Accuracy of scat sampling for carnivore diet analysis: wolves in the alps as a case study. Journal of Mammalogy **89**, 665-673.

Mattson, D.J. (1990). Human impacts on bear habitat use. International Conference on Bear Research and Management **8,** 33-56.

Mills, M.G.L. & Gorman, M.L. (1997). Factors affecting the density and distribution of wild dogs in the Kruger National Park. Conservation Biology **11**, 1397-1406.

Mills, M.G.L. & Hofer, H. (1998). Hyenas: status survey and conservation action plan. IUCN/SSC Hyena Specialist Group, International Union for the Conservation of Nature (IUCN), Gland, Switzerland, and Cambridge, United Kingdom.

Mills, M.G.L. (1985). Hyena survey of Kruger National Park, August-October, 1984 IUCN-SSC Hyena Specialist Group, Newsletter **2**, 15-25.

Mills, M.G.L. (1990). Kalahari hyenas: the comparative behavioral ecology of two species. London: Unwin Hyman.

Mills, M.G.L. (1992). A comparison of methods used to study food habits of large African carnivores. In: Barrett, R.H. ed. Wildlife 2001: populations (pp. 1112-1124). Elsevier Applied Science: London, United Kingdom.

Mills, M.G.L. (1996). Methodological advances in capture, census, and food habits studies on large African carnivores. In: Gittleman, J.L. ed. Carnivore behavior, ecology, and evolution (pp. 223-242). Comstock Publishing Associates: London, United Kingdom.

Mills, M.G.L., Juritz, J.M. & Zuccini, W. (2001). Estimating the size of spotted hyena (*Crocuta crocuta*) populations through playback recordings allowing for nonresponse. Animal Conservation **4**, 335-343.

Mitchell, B.R. (2003). International Historical Statistics: Africa, Asia and Oceania 1705-2000. 4th ed. New York: Palgrave Macmillan.

Ogada, M.O., Woodroffe, R., Oguge, N.O. & Frank, L.G. (2003). Limiting depredation by African carnivores: the role of livestock husbandry. Conservation Biology **17**, 1521-1530.

Ogutu, J.O. & Dublin, H.T. (1998). The response of lions and spotted hyenas to sound playbacks as a technique for estimating population size. African Journal of Ecology **36**, 83-95.

Ogutu, J.O., Bhola, N. & Reid, R. (2005). The effects of pastoralism and protection on the density and distribution of carnivores and their prey in the Mara ecosystem of Kenya. Journal of Zoology (London) **265**, 281-293.

Olson, T.L.G.B.K. (1994). Variable impacts of people on brown bear use of an Alaskan river. International Conference on Bear Research and Management **9**, 97-106.

Parks, S. & Harcourt, A. (2002). Reserve size, local human density, and mammalian extinctions in US protected areas. Conservation Biology **16**, 800-808.

Polisar, J., Maxit, I., Scognamillo, D., Farrell, L., Sunquist, M.E. & Eisenberg, J.F. (2003). Jaguars, pumas, their prey base, and cattle ranching: ecological interpretations of a management problem. Biological Conservation **109**, 297-310.

Reinhart, D.P.M.D.J. (1990). Bear use of cutthroat trout spawning streams in Yellowstone National Park. International Conference on Bear Research and Management **8,** 343-350.

Reynolds, J.C. & Aebischer, N.J. (1991). Comparison and quantification of carnivore diet by faecal analysis: a critique, with recommendations, based on a study of the fox *Vulpes vulpes*. Mammal Review **21**, 97-122.

Schulenburg, H., Kurtz, J., Moret, Y. & Siva-Jothy, M.T. (2009). Introduction. Ecological immunology. Philosophical Transactions of the Royal Society B: Biological Sciences **364**, 3-14.

Sheppard, C.R.C. (1999). How large should my sample be? Some quick guides to sample size and the power of test. Marine Pollution Bulletin **38**, 439-447.

Shochat, E., Lerman, S.B., Katti, M. & Lewis, D.B. (2004). Linking optimal foraging behavior to bird community structure in an urban desert landscape: field experiments with artificial food patches. The American Naturalist **164**, 232-243.

Sillero-Zubiri, C. & Gottelli, D. (1992). Feeding ecology of spotted hyena (Mammalia: *Crocuta crocuta*) in a mountain forest habitat. Journal of African Zoology **106**, 169-176.

Sillero-Zubiri, C. & Laurenson, M.K. (2001). Interactions between carnivores and local communities: conflict or coexistence? In: Gittleman, J.L., Funk, S.M., Macdonald, D.W. & Wayne, R.K. eds. Carnivore Conservation (pp. 282-312). Cambridge University Press: Cambridge.

Smuts, G.L. (1979). Diet of lions and spotted hyenas assessed from stomach contents. South African Journal of Wildlife Research **9**, 19-25.

Sogbohossou, E.A. (2011). Lions of West Africa: Ecology of lion (*Panthera leo* Linnaeus 1975) populations and human lion conflicts in Pendjari Reserve, North Benin, PhD Thesis, University of Leiden, The Netherlands.

Sunquist, M.E. & Sunquist, F. (2001). Changing Landscapes. In: Gittleman, J.L., Funk, S.M., Macdonald, D. & Wayne, R.K. eds. Carnivore Conservation (pp. 399-418). 1st ed. London: Cambridge University Press.

Susan, M.C., Holekamp, K.E. & Laura, S. (1999). A seasonal feast: long-term analysis of feeding behavior in the spotted hyena (*Crocuta crocuta*). African Journal of Ecology **37**, 149-160.

Sutcliffe, A.J. (1970). Spotted hyena: crusher, gnawer, digester and collector of bones. Nature **227**, 1110-1113.

Tadesse, T., Ruijs, A. & Hagos, F. (2008). Household waste disposal in Mekelle city, Northern Ethiopia. Waste management **10**, 2003-2012.

Thurber, J.M., Peterson, R.O., Drummer, T.D. & Thomasma, S.A. (1994). Gray wolf response to refuge boundaries and roads in Alaska. Wildlife Society Bulletin **22**, 61-67

Tilson, R.L., Von Blottnitz, F. & Henschel, J. (1980). Prey selection by spotted hyenas (*Crocuta crocuta*) in the Namib Desert. Madoqua **12**, 41-49.

Treves, A., Naughton-Treves, L., Harper, E.K., Mladenoff, D.J., Rose, R.A., Sickley, T.A. & Wydeven, A.P. (2004). Predicting human carnivore conflict: a spatial model derived from 25 years of data on wolf predation on livestock. Conservation Biology **18**, 114-125.

Trinkel, M. (2009). A keystone predator at risk? Density and distribution of the spotted hyena *Crocuta crocuta* in the Etosha National Park, Namibia. Canadian Journal of Zoology **87**, 928-935.

Tumenta, P.N. (2012). A lion population under threat: understanding lion (*Panthera leo* Linnaeus, 1758) ecology and human-lion interactions related to livestock predation in Waza National Park, PhD Thesis, University of Leiden, The Netherlands.

United Nations, Department of Economic and Social Affairs, Population Division (2010). World Population Prospects: The 2010 Revision (United Nations, NY).

Van Dyke, F.G., Brocke, R.H., Shaw, H.G., Ackerman, B.B., Hemker, T.P. & Lindzey, F.G. (1986). Reactions of mountain lions to logging and human activity. Journal of Wildlife Management **50,** 95-102.

Watts, H.E. & Holekamp, K.E. (2009). Ecological Determinants of Survival and Reproduction in the Spotted Hyena. Journal of Mammalogy **90**, 461-471.

Werdelin, L. (1989). Constraint and adaptation in the bone-cracking canid Osteoborus (Mammalia: Canidae). Paleobiology **15**, 387-401.

Western, D., Russell, S. & Cuthill, I. (2009). The status of wildlife in protected areas compared to non-protected areas of Kenya. PLoS One 4:e6140.

Western, D., Strum, S.C. & Wright, R.M. (1994). Natural Connections: Perspectives in Community- Based Conservation (Island Press, Washington, DC).

Woodroffe, R. & Ginsberg, J.R. (1998). Edge effects and the extinction of populations inside protected areas. Science **280**, 2126-2128.

Woodroffe, R. & Ginsberg, J.R. (2000). Ranging behavior and vulnerability to extinction in carnivores. In: Gosling, L.M. & Sutherland, W.J. eds. Behavior and conservation (pp. 125-140). Cambridge University Press: Cambridge.

Woodroffe, R. (2000). Predators and people: using human densities to interpret declines of large carnivores. Animal Conservation **3**, 165-173.

Woodroffe, R., Thirgood, S. & Rabinowitz, A. (eds.). (2005). People and wildlife: conflict or coexistence? Cambridge University Press: New York.

Yirga, G., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Deckers, J. & Bauer, H. (2012). Adaptability of large carnivores to changing anthropogenic food sources: diet change of spotted hyena (*Crocuta crocuta*) during Christian fasting period in northern Ethiopia. Journal of Animal Ecology **81**, 1052-1055.

Yirga, G., De Iongh, H.H., Leirs, H., Kiros, S., G/ Yohannes, T. Teferi, M. & Bauer, H. (subm.). Spotted hyenas (*Crocuta crocuta*) prefer anthropogenic over natural environment in northern Ethiopia.

Summary

Ecology and Conservation of Spotted Hyena (*Crocuta crocuta* Erxleben 1777) in a Human Dominated Landscape in Northern Ethiopia

Key words

Adaptability, coexistence, Ethiopia, hyena diet, hyena human interaction, spotted hyena (*Crocuta crocuta*)

Hyena was historically one of the most widely distributed predators across the world. Hyena may have originated in Asia, and ranged throughout Europe until the end of the late Pleistocene era. Currently, hyena exists only in Africa, and is the most abundant large carnivore in the continent. A tentative estimate of the total population of hyena in Africa is between 27,000 and 47,000, which is more likely to be an underestimate of the hyena population across Africa. The largest known populations occur in the Serengeti ecosystem, Tanzania and the Kruger national Park, South Africa with estimates of 8,700 and 3,900 hyena, respectively.

Most scientific literature on hyena-human interrelationships in Africa suggests conflict situations, often resulting in the killing of hyenas. Hyenas survive with difficulty in human-altered habitats and coexistence between hyenas and local communities is problematic. This is because hyenas need extensive areas, usually with few people and sufficient prey. In contrast to this, the present dissertation presents an exceptional case of peaceful coexistence between hyenas and humans. Based on regular observations of hyenas and anecdotal reports, I hypothesized that hyenas in the Tigray region, northern Ethiopia, survive in human-dominated landscapes because of a unique combination of adaptation to anthropogenic food and cultural tolerance towards hyenas. My research aimed to investigate hyena ecology and behavior in human-dominated and prey-depleted landscapes in Tigray.

Hyenas are common in many parts of Ethiopia, and in most of those areas, prey populations have been depleted. In northern Ethiopia, the natural prey base is depleted due to agricultural expansion, deforestation, human settlement, and habitat fragmentation and degradation. Hyenas depend entirely on domestic prey species, partly through depredation but more important-

ly 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. In the scat analyses, we found mainly prey items from livestock species. It is likely that most human hairs found came from scavenging at garbage dumps and cemeteries, as we do not have reports of people killed by hyenas at the time of study.

My study showed a remarkable change hyena diet during the fasting period, from predominantly scavenging on waste to active predation on donkeys. During this period, a vast majority of people in northern Ethiopia do not consume animal products, leading to a sharp decline in demand for meat. Hyenas mainly scavenge on waste of butchers and households but during fasting, donkeys provided an alternative food source. The reduced availability of waste from slaughtering forced hyenas to supplement their diet with alternative food sources during the fasting period.

In my study area, a population of 535 hyena lives close to communities without any reports of retaliatory killing. This demonstrates a rare case of coexistence, where hyenas benefit from waste disposal and human communities benefit from the waste clearing service provided by hyenas. It also demonstrates the high adaptability of hyenas, which in this case specialize entirely in waste consumption. This confirms that a moderately high density of hyenas can persist in human-dominated landscapes, outside of conservation areas. Cultural-religious conditions allow coexistence between hyenas and humans. The Orthodox Tewahedo Church celebrates Enkutatash (New Year), Meskel (Finding of the True Cross), Ledet (Christmas), Timket (Epiphany) and Fasika (Easter) every year. Similarly, Islamic tradition also celebrates religious festivals such as Muharram, Ramadan, and Eid-ul-Fitr. During these and other religious festivals, livestock are slaughtered across the country. Solid waste management is generally poor and waste is dumped along roadsides and in open areas. Butchers' and household waste appears to be a key ecological factor influencing abundance and distribution of spotted hyenas within close proximity of human settlements. My findings confirmed 'commuting' movements and raised questions about local hyena social structure. The relative abundance of spotted hyenas at garbage dumping sites reflects their dependence on anthropogenic food sources rather than natural prey.

Even in two national parks, Awash and Chebera Churchura, prey remains of domestic species were dominant. This presents a new finding on hyena diets in national parks, as previous studies showed their diet to consist of a va-

riety of prey, predominantly wild. This is probably due to very low densities of natural prey in these national parks, and or due to scavenging around the houses of park rangers and near villages and/or extensive illegal grazing and livestock encroachment, which is evident in almost all Ethiopian national parks. Domestic animals remain the predominant food for hyenas even in national parks. I postulate that depletion of natural prey species forces hyena to depend on anthropogenic food sources. Hyenas commonly occur in suburban and urban areas across Ethiopia.

Livestock depredation is not a serious problem in my study area compared to studies across Africa. A range of technical measures including construction of enclosures and the use of guards and dogs are used to mitigate depredation. In my study, domestic dogs were not effective in protecting villages from hyena attacks. Hyena, leopard and jackal showed divergent predatory behavior towards livestock, with regard to the type of prey they attacked, time of day and location of livestock attacks. More livestock predation was observed during the nighttime for hyena and leopard and daytime for jackal.

Survival of hyenas is largely and widely dependent on waste management. Hyena population persistence is secure under present conditions, as waste is dumped along roadsides and into open areas. A change in waste management from open to closed systems would immediately impact on viability of the hyena population. Mekelle city is considering an improvement in solid waste management from an open to a closed system. For long term conservation, I recommend that dumps should have permit hyena entrance.

Acknowledgements

I could say that the road to this PhD thesis started back in 2008 when Dr. Hans Bauer was appointed as research coordinator for the framework of the VLIR IUC scientific cooperation programme between several Flemish universities (Belgium) and Mekelle University (Ethiopia). I am very grateful to Mekelle University for providing a laboratory and VLIR-UOS and Norad III for financial assistance. I am grateful to the MU-IUC and MU-UMB programmes and the coordination offices, particularly Dr. Tsehaye Asmelash, Dr. Kindeya Gebrihiwot, Prof Dr. Seppe Deckers, and Dr. Kasa Amare.

Many people helped us with the field work. My special thanks go to Solomon Amare, Solomon Tesfay and Meheret Hadgu for their support and encouragement during the fieldwork. I acknowledge the assistance of the local community and for sharing their knowledge and cooperation. For all

those who were not cited and who contributed directly or indirectly to this work, please find here the expression of my gratitude.

I thank all my friends and colleagues at Mekelle University for their friendship and encouragement. I would like to express my deepest gratitude to my colleague Dr. Mekonen Teferi for his encouragement at all times of the study.

Samenvatting

Ecologie en bescherming van de gevlekte hyena (*Crocuta crocuta* Erxleben 1777) in door mensen gedomineerde landschappen in Noord Ethiopië

Trefwoorden

Gedragsaanpassing, samenleving, Ethiopië, hyena-dieet, hyena-mens interactie, gevlekte hyena (*Crocuta crocuta*)

De gevlekte hyena (*Crocuta crocuta*) was in de historie één van de predatoren met het grootste verspreidingsgebied wereldwijd. De gevlekte hyena komt oorspronkelijk uit Azië en werd gevonden in geheel Europa tot het einde van het late Pleistoceen. Momenteel wordt de gevlekte hyena alleen in Afrika aangetroffen en is deze soort een van de meest algemene grote predatoren. Een voorlopige schatting van de wereldpopulatie komt op 27.000 tot 47.000 gevlekte hyena's, hetgeen vermoedelijk een onderschatting betreft van de reële populatie in Afrika. De grootste populaties worden gevonden in het Serengeti-ecosysteem, Tanzania en in het Krüger nationaal park, Zuid Afrika, met naar schatting respectievelijk 8.700 en 3.900 hyena's.

De meeste wetenschappelijke literatuur over hyena-mens interacties in Afrika suggereert conflictsituaties, die vaak resulteren in de dood van hyena's. Hyena's hebben daarom vaak problemen om te overleven in door mensen gedomineerde landschappen en het samenleven van mensen en hyena's is vaak problematisch. Een belangrijke reden hiervoor is dat hyena's grote leefgebieden nodig hebben met weinig verstoring door mensen en voldoende prooidieren. In contrast met deze situatie beschrijft deze dissertatie een bijzonder voorbeeld van vreedzame samenleving tussen mensen en hyena's. Gebaseerd op regelmatige veldobservaties en literatuur heb ik de hypothese ontwikkeld dat hyena's in het Tigray gebied, Noord Ethiopië, overleven in door mensen gedomineerde landschappen dankzij een unieke combinatie van een voedselspecialisatie gericht op menselijk afval en culturele tolerantie voor hyena's. Mijn onderzoek heeft als doel de ecologie en het gedrag van de gevlekte hyena te onderzoeken in een door mensen gedomineerd en prooiarm landschap in het Tigray gebied.

Gevlekte hyena's zijn algemeen in grote delen van Ethiopië en in de meeste gebieden zijn de natuurlijke prooidierpopulaties sterk gereduceerd. In Noord-Ethiopië zijn de prooidier populaties verdwenen als gevolg van landbouwontwikkeling, ontbossing, urbane ontwikkeling en habitatfragmentatie en degradatie. Hyena's zijn volledig afhankelijk van natuurlijke prooidierpopulaties, gedeeltelijk door directe predatie maar ook in belangrijke mate door gebruik van (peri-urbaan) afval.

Het exclusief foerageren op afval is waarschijnlijk voldoende om hyenapopulaties in stand te houden, het prederen op levende prooi is niet noodzakelijk. In hyena-uitwerpselen werden regelmatig resten gevonden van vee. Er werden ook menselijke haren aangetroffen, maar deze zijn waarschijnlijk afkomstig van afvalhopen en kerkhoven, omdat er geen gevallen bekend zijn van hyena's die mensen aanvallen en doden in mijn onderzoek.

Mijn onderzoek toont een opvallende verandering in het dieet van hyena's gedurende de vastenperiode, van primair consumptie van afval naar een actieve predatie van ezels. Gedurende deze periode consumeert de meerderheid van de lokale bevolking in Noord-Ethiopië geen dierlijke producten, hetgeen resulteert in een sterke daling van de vraag naar vlees. Hyena's blijken zich vooral tegoed te doen aan vleesafval van slachters en huishoudens, maar gedurende de vastenperiode vormen ezels een alternatieve bron van voedsel. De sterke reductie van het aanbod van slachtafval dwingt hyena's gedurende de vastenperiode tot deze verandering in dieet.

In mijn onderzoek leeft een populatie van 535 gevlekte hyena's in de nabijheid van menselijke nederzettingen, zonder dat er sprake is van achtervolging of het doden van hyena's. Dit geeft aan dat hier sprake is van een bijzonder voorbeeld, waar gevlekte hyena's voordeel hebben van de aanwezigheid van menselijk afval en waarbij de lokale bevolking profiteert van de schoonmaakfunctie van hyena's. Het toont ook aan dat gevlekte hyena's een groot aanpassingsvermogen hebben en zich, in dit geval, volledig gespecialiseerd hebben op de consumptie van afval. Mijn onderzoek toont ook aan dat er een vrij hoge dichtheid aan hyena's aanwezig is in een door mensen gedomineerd landschap in Noord-Ethiopië, buiten de bestaande beschermde gebieden. De cultureel-religieuze situatie draagt bij aan de vreedzame samenleving tussen mens en hyena. De Orthodoxe Tewahedo-kerk viert het Nieuwe Jaar (Enkutatash), het feest van het Heilige Kruis (Meskel), Kerstmis (Ledet), Sint Martinus (Timket) en Pasen (Fasika) ieder jaar. Ook de Islamitische traditie heeft religieuze feesten, zoals Muharram, Ramadan, en Eid-ul-Fitr. Gedurende deze en andere feesten wordt vee geslacht in het hele

land. Afvalverwerking is meestal beperkt en afval wordt vaak gestort langs de weg en op open plekken. Slachtafval en het afval van huishoudens blijkt een ecologische sleutelfactor te zijn die de aanwezigheid en de verspreiding van de gevlekte hyena beïnvloed in de nabijheid van menselijke nederzettingen. Mijn onderzoek bevestigt regelmatige verplaatsingen van hyena's tussen hun holen en afvalhopen en roept vragen op over de sociale structuur van de hyenapopulaties. Het algemeen voorkomen van de hyena's bij afvalhopen is een afspiegeling van de afhankelijkheid van afval als voedsel.

Zelfs in de twee nationale parken, Awash en Chebera Churchura, blijken prooiresten van vee dominant te zijn in de uitwerpselen van hyena's. Dit is een verrassend resultaat, omdat voorgaand onderzoek een grotere variatie aan vooral natuurlijke prooidieren liet zien. Het verschil kan waarschijnlijk worden verklaard uit de extreem lage dichtheden aan natuurlijke prooidieren in de onderzochte nationale parken en het gegeven dat hyena's uit de parken hun voedsel zoeken rond de huizen van de parkwachters en/of zich vergrijpen aan vee dat illegaal graast binnen de grenzen van het park, zoals het geval is in bijna alle nationale parken in Ethiopia. Gedomesticeerde dieren blijken het voornaamste voedsel van hyena's, zelf in nationale parken. Mijn conclusie is dat de lage dichtheden aan natuurlijke prooidieren de hyena's afhankelijk maken van gedomesticeerde dieren en menselijk afval. Inderdaad zijn hyena's algemeen in geheel Ethiopië, ondanks de afwezigheid van natuurlijke prooidieren.

De predatie van vee is niet een groot probleem in mijn onderzoeksgebied in vergelijking tot in andere gebieden in Afrika. Een reeks van technische maatregelen, zoals de constructie van omheiningen, het gebruik van bewaking en van honden kunnen bijdragen aan de bescherming van vee. In mijn onderzoek echter, bleken gedomesticeerde honden niet geschikt voor de bescherming van vee tegen hyena's. Gevlekte hyena, luipaard en jakhals bleken verschillende voorkeuren te hebben bij de predatie van vee met betrekking tot soort van vee, tijdstip van de dag van een aanval en de locatie van de aanval. Het aantal aanvallen op vee nam toe gedurende de nacht voor gevlekte hyena, luipaard en jakhals.

Het overleven van de gevlekte hyena in mijn onderzoek hangt grotendeels af van de beschikbaarheid van afval. De overlevingskans van gevlekte hyena's wordt groter bij het huidige systeem van afvalbehandeling, waarbij afval gestort wordt langs de wegen en op open plekken. Een verandering in het systeem van afvalverwerking van open storting naar een meer gecontroleerde verwerking zal een direct effect hebben op het overleven van

hyenapopulaties. De stad Mekelle overweegt een modernisering van het afvalverwerkingssysteem. Voor de bescherming van hyenapopulaties op de lange termijn adviseer ik dat ook bij gemoderniseerde afvalverwerking er openingen blijven voor de benutting van afval door hyena's.

Curriculum vitae

Gidey Yirga was born on the 24th of May 1983 in Tigray, Ethiopia. He studied Biology in 2001 at Mekelle University in Mekelle, Ethiopia. After graduating with a Bachelor of Science degree in Biology in 2005, he was recruited at Mekelle University as a Graduate Assistant. In 2006, he was admitted to graduate school at Mekelle University and studied and graduated with a master degree in dry land agronomy in 2008.

During his master's study, he participated in a CSS-Rodent Project that investigated rodent ecology in the highlands of northern Ethiopia. His master's research studied rodent abundance and diversity in the highlands of northern Ethiopia.

Since 2009, he has conducted field research on hyenas in human-dominated landscapes in northern Ethiopia along with Dr. Hans Bauer, who is his local supervisor. Prof. Dr. H. Leirs, Prof. Dr. ir. H.H. de Iongh and Prof. Dr. G.R. de Snoo are his promoters and his research has led to this thesis.

Yirga currently works as Associate Professor at the Mekelle University department of Biology in Ethiopia. He was awarded a research grant from the institutional collaboration fund between the Norwegian University of Life Sciences and Mekelle University in 2010 to fund his PhD research.

Selected publications

Yirga, G., Ersino, W., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Deckers, J. & Bauer, H. (2013). Spotted hyena (*Crocuta crocuta*) coexisting at high density with people in Wukro district northern Ethiopia. Mammalian Biology 78, 193-197.

Yirga, G., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Berhe, G., Asmelash, T., Gebrehiwot, H. & Bauer, H. (2012). The Ecology of large carnivores

in the highlands of northern ethiopia. African Journal of Ecology **51**, 78-86.

Yirga, G., De Iongh, H.H., Leirs, H., Gebrehiwot, K., Deckers, J. & Bauer, H. (2012). Adaptability of large carnivores to changing anthropogenic food sources: diet change of spotted hyena (*Crocuta crocuta*) during Christian fasting period in northern Ethiopia. Journal of Animal Ecology **81**, 1052–1055.

Yirga, G., Bauer, H., Gebrehiwot, K. & Deckers, J. (2011). Peri-urban spotted hyena (*Crocuta crocuta*) in Northern Ethiopia: diet, economic impact, and abundance. European Journal of Wildlife Research **57**, 759-765.

Yirga, G., Bauer, H., Worasi, Y. & Asmelash, S. (2011). Farmers' perspectives of leopard (*Panthera purdus*) conservation in a human dominated landscape in the northern Ethiopia highlands. International Journal of Biodiversity and Conservation **3**, 160-166.

Yirga, G. & Bauer, H. (2010). Diet of the spotted hyena (*Crocuta crocuta*) in southern Tigray, northern Ethiopia. World Journal of Science, Technology and Sustainable Development **7**, 391-397.

Yirga, G. & Bauer, H. (2010). Livestock depredation of the spotted hyena *(Crocuta crocuta)* in southern Tigray, northern Ethiopia. International Journal of Ecology and Environmental Sciences **36**, 67–73.

Yirga, G. & Bauer, H. (2010). Prey of Peri-urban Spotted Hyena (*Crocuta crocuta*) in Southeastern Tigray, Northern Ethiopia. Asian Journal of Agricultural Sciences **2**, 124-127.

Yirga, G., De Iongh, H.H., Leirs, H., Gebrihiwot, K., Deckers, J., Asfaw, A., Acha, A. & Bauer, H. (in reviw). Predator adaptability to prey depleted and human dominated landscapes: Spotted hyenas (*Crocuta crocuta*) depend on anthropogenic food in Ethiopia.

Yirga, G., Imam, E., De Iongh, H.H., Leirs, H., Kiros, S., G/ Yohannes, T. Teferi, M. & Bauer, H. (in reviw). Habitat preference of spotted hyenas (*Crocuta crocuta*) for human dominated landscapes in northern Ethiopia.

Yirga, G., De Iongh, H.H., Leirs, H., Gebrihiwot, K., Deckers, J. & Bauer, H. (in review). Spotted **hyena** (*Crocuta crocuta*) concentrate around urban garbage dumps in northern Ethiopia.

Yirga, G., Gebresenbet, F., Deckers, J. & Bauer, H. (in reviw). Status of lions (*Panthera leo*) and spotted hyenas (*Crocuta crocuta*) in Nechisar National Park, Ethiopia.

Research needs

This first long term study of the spotted hyena in Ethiopia has provided baseline information about diet, abundance and distribution, economic valuation of livestock losses and has contributed to a better knowledge of the species ecology. However, in order to better understand the ecology of the species in Ethiopia several aspects still need to be investigated. To support viable hyena population in the future study on home range, movements, activity patterns, habitat use, local hyena social structure and effect of moon phase on livestock depredation by hyenas should be investigated with telemetry. This would help to understand adaptability of the species to anthropogenic environment and anthropogenic pressure on the species. Research on kinship relations and inbreeding depression through analysis of mitochondrial DNA would be important to understand preference of inbreeding and overall inbreeding strategy of spotted hyenas and to conserve viable hyena population in the future.

I also suggest research on parasites of spotted hyenas, disease, disease resistance, immune function, genetic diversity and genetic structure in spotted hyena populations. This would help to understand how spotted hyenas survive feeding on waste infected with pathogens. Study on how much spotted hyenas get their food from depredation and how much from scavenging would also be important. Socio-economic research on the role of hyenas in religion and religion in hyena persistence will also be important to understand fully human hyena interrelations in the region.