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The Ecology of Domestic Dog (*Canis familiaris*) and Its Effect on the Survival of the Ethiopian Wolf (*Canis simensis*) in the Web Valley of the Bale Mountains National Park, Ethiopia.

By

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DEDICATION

I would like to dedicate this thesis to my advisor, Prof. Dr. Afework Bekele who recommended me to work in the Ethiopian Wolf Conservation Programme.

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Abstract

The study was carried out in the Web Valley of the Bale Mountains National Park, Ethiopia from November 2001 to October 2002. The study focused on the ecology of domestic dog (Canis familiaris) to determine the potential effects of the domestic dog on the endemic and endangered Ethiopian wolf (Canis simensis) by exploitative and interference competition, disease transmition and hybridization. An examination of the functional significance of the dogs was also carried out. The density of dogs reached 10 dogs/km^2 in wet season and decreased to 4 dogs/km^2 in the dry season. All dogs were owned and no feral dog population was assessed. Nocturnal observation of behaviour of dogs and questionnaire survey revealed that dogs help the local people in defending their livestock from wild carnivores. Dogs also gave service by cleaning the area from human faeces and carcass. The pastoral people of the study area are in conflict with wild carnivores that depredated on their livestock. Spotted hyaena (Crocuta crocuta) was the most serious predator that did 57% of the 704 livestock depredated by wild carnivores in the last three years. Leopard (Felis pardus), Common jackal (Canis aureus) and Serval cat (Felis serval) contributed 18%, 17% and 9% of the kills, respectively. From a loss of potential revenue due to wild carnivores' depredation on livestock over the past three years, hyena caused 83.5% of the total loss amounting to US$ 13,102. Common jackal, leopard and Serval cat contributed, 7.7%, 6.3% and 2.5% of the loss, respectively. In the study of diets of dogs during the focal watch, barely husks and human faeces cover larger proportion of their food by contributing 45.03% and 20.68% of the total 382 recorded meals respectively. Rock hyrax, rodent and starks hare contributed 4.97%, 4.19% and 0.26% of the meals, respectively. Cheese and milk, Kniphofia, carcass and potato contributed 8.12%, 6.54%, 5.25% and 3.93%, respectively. From domestic dog faecal analysis, barely husks, human faeces and carcass occurred in 86.83%, 21.42% and 19.42% of the total 1200 faecals. Next to carcass, potato was the most frequently occurred food item, 5.25% of the feacals. Remains of grass, rodent and rock hyrax follow potato by contributing 3.07%, 2.75% and 1.75% of the feacals. Both faecal analyses and focal watch reveal that rodents contribute only a very small proportion of the diet of dogs. As Ethiopian wolves fed almost exclusively on rodent year round, no significant exploitative competition between dogs and wolves were assessed by during this study. From line transect and field observation, only a small proportion of dogs were found to roam out of settlements and most of them roam on mountain tops to hunt on rock hyrax rather than Ethiopian wolf range. Only 3% of a total dog population were seen roaming in the Ethiopian wolf range, which are familiar with wolf; greet and hunt side by side without showing any aggressive behaviour. In such a case, there is little interference competition between Ethiopian wolf and domestic dogs. However, such close contact has a risk of hybridization. At present, the more likely threat that dogs pose on Ethiopian wolf is disease transmition. In the 33 dog--wolf interactions observed among non "roaming dogs" and wolves that are not familiar to each other, to dominate the interaction depends upon the number of participants. The numbers of seasonal dogs increased by 37% at the end of the year and settlements were continuously pushing the Ethiopian wolf range. These two factors are likely to cause serious threat to the survival of the Ethiopian wolves by interference competition in the near future. Settlement in the 'park' should be minimised.

1. Introduction

1.1. Impacts of introduced or invasive species on native fauna

Species have sometimes invaded new habitats naturally but the arrival of humans on remote islands has generated pronounced peaks in the extinction of native fauna due to introduced exotic species (Rosenzweig, 2000). In many cases, recorded extinctions in historic times have been of endemic, specialized species with small population sizes (Chapman and Reiss, 1999), such as is typical of island species (Mace *et al.,* 1998). Native fauna, particularly in island situations, may not have evolved mechanisms conferring resistance to introduced diseases (Simberloff, 1996); they may be less competitive than the invading generalist species (Macdonald, 2002); and/or they are naïve of predators. These factors may work independently or in tandem to drive species to extinction (Chapman and Reiss, 1999; Roemer *et al.*, 2002).

1.1.1. Competition

Competition between individuals of different species is thought to be important for determining the abundance, health, reproductive capacity and distribution of species within a community (Cornell and Lawton, 1992). Competition operates through different mechanisms, most notably exploitation or interference (Macdonald, 2002). Exploitative competition occurs when a number of organisms utilize common resources with limited supply; in contrast, interference competition occurs when the organisms seeking limited resources physically displace or alter the access of other organisms to the resources (Schooner, 1983).

On islands or in landscapes which include isolated habitats (e.g. relict mountain tops), the restricted resource base and small population sizes often have led to specialized species that are vulnerable to extinction through interspecific, exploitative competition

(Rosenzweig, 2000). While competition between sympatric, co-existing species may be negligible because of niche shifts that have already occurred (Cornell and Lawton, 1992), the introduction of species may cause peaks in competition. There are a number of examples of introduced species out-competing indigenous species and driving them to extinction or local extirpation. The dingo (*Canis familiaris dingo*), introduced to the Australian mainland continent 3500-11000 years ago, may have displaced by exploitative competition both the thylacine (*Thylacinus cynoece phalus*) and the Tasmanian devil (*Sarcophilus harrisi*) (Lever, 1994). The decline in wolf numbers in Italy is thought to be partially due to competition with stray dogs (Boitani, 1992). The native birds of Hawaii compete for food and nesting sites with the alien mynah (*Acridotheres tristis*) and Japanese white-eye (*Zosterops japonica*) (Macdonald, 2002).

In contrast to exploitative competition, interference competition typically occurs when one organism excludes competitors from access to limited resources (Johanson, 1993). On the Japanese island of Oshima, interference competition has been observed between the introduced grey-bellied squirrel and the oriental white-eye bird. The squirrel chases the bird away from the flowers of *Camellia*, which not only affects the birds but also the plant because it is pollinated by the white-eyes (Stiling, 1996). The mechanisms of suppression or displacement are likely to involve a combination of exclusion by the dominant species and avoidance by the subordinate depending on the ecological circumstances in the area of potential overlap (Gittleman *et al.*, 2001).

The outcome of interspecific competition is determined by complex interactions between utilization rates, population structure and degree of specialization (Gatto, 1990). At least three outcomes are possible: first, coexistence may result from either or both competitors undergoing a niche-shift and ultimately character displacement (but this occurs over ecological time frames); second, the loser may alter its spatial or temporal behaviour to avoid the other species; and third, the loser may be forced out of part of its geographic range, suffers a decline in abundance, or becomes extinct (Gittleman *et al.*, 2001).

1.1.2. Pathogens

Pathogenic organisms affecting both wild and domestic species are an increasing conservation problem, exacerbated by the expansion of human populations and the escalating contact between wildlife and domestic animals (Mcallum and Dobson, 1995). Canid species are of particular importance because of their worldwide distribution and are affected by the rabies virus, canine distemper virus (CDV) and canine parvovirns (Thorne and Williams, 1988). The rabies virus is secreted in the saliva of infected hosts and is, thus, most successfully transmitted by biting or mouth-to-mouth greeting behaviour characteristic of canids (Macdonald, 1993). Canine parvovirus (CPV) is a contagious epizootic pathogen that kills wild canids. The virus is transmitted from the faeces of infected animal and susceptible animals become infected by ingesting the virus (Apple and Parrish, 1987). Canine distemper virus (CDV) is a highly contagious and potentially fatal disease of domestic dogs and some wild carnivores. It is typically transmitted by aerially and droplets containing the virus that are expelled from the infected animal's breath and nasal secretions (Apple, 1987).

Domestic dogs and cats are among the primary vectors of wildlife disease, largely because of the greater mobility that people confer on domestic animals, and the high relative densities at which they often occur (Pain, 1997). Dogs are considered the main host and vector for virulent pathogens for wildlife and have been implicated in the decline of lions in the Serengeti through canine parvovirus (Roelke-Parker *et al.*, 1996), wild dog due to rabies in many East African countries (Ginsberg and Macdonald, 1990) and Ethiopian wolves due to rabies in Ethiopia (Sillero- Zubiri *et al.*, 1996).

Understanding the spread of disease from domestic dogs to wildlife requires knowledge of interspecific contact rates (Courtenay *et al.*, 2001), while plans for successful management programmes depend upon knowledge of both species' population ecology (Wandeler *et al.*, 1993). Control measures that may prevent the spread of pathogens from dogs include vaccination (Cleaveland *et al.*, 2000) and limiting physical contact with wildlife (Anonymous, 1994).

Traditionally, the European approach to preventing the incidence and transmission of disease hinged on the principle that the disease would die out if the most abundant wild canids were killed. The failure of this policy to eradicate the disease was attributed to the insufficient reduction of contact rates (Macdonald, 1987). However, although selective population reduction might be useful in some situations, vaccination is more likely to succeed (Backone, 1985; Bogel and Meslin, 1990). For effective control of rabies and other canid diseases, 70% vaccination coverage level of a given population is recommended by the World Health Organization (WHO, 1980).

1.1.3. Hybridization

Hybridization greatly complicates plans to conserve the genetic integrity of wildlife species (Dudash and Fenster, 2000). Interspecific hybridization is likely to be maladaptive because of the partial variety of post-zygotic reproductive isolating mechanisms that usually exist between species (Frankham *et al.*, 2002). Typically, hybridizations occur when humans introduce a closely related exotic species into the range of rare species (Ellstrand *et al.*, 1999). For example, mallard ducks introduced to the Hawaiian islands for hunting have hybridized extensively with the native, endangered Hawaiian duck, greatly complicating recovery plans for the latter species (Simberloff, 1996). On the Seychelles islands, the local subspecies of the Madagascar turtledove has been destroyed through hybridisation with introduced doves. In Japan, the native subspecies of the Siberian white weasel has been extirpated because of introduced Korean subspecies (Stiling, 1996).

Among the 34 canid species, grey wolves and coyotes are known to hybridize, both with each other and with their close relative, the domestic dog (Gottelli *et al.*, 1994). Dogs are known to breed freely with grey wolves threatening the genetic integrity of the animals. In Italy, interbreeding between dogs and wolves is considered to be the major threat to the survival of wolf (Boitani, 1992). In Australia, dingos are known to interbreed with domestic dogs (Newsome and Corbett, 1982). A detailed analysis of interspecific hybridization and genetic variability indicated that hybridization of Ethiopian wolf and their domestic relatives had occurred (Gottelli *et al.*, 1994).

1.2. Justification and aims of the study

Cats and dogs are among the 10 mammalian species with the highest number of reported introductions (Lever, 1994); and, at present, all continents and most islands in the world have been colonised by dogs (Wandeler, *et al.*, 1993). This study will determine the potential threat of the domestic dog on the endemic and endangered Ethiopian wolf (*Canis simensis*). While the domestic dog has probably been present in the landscape for many years, human and, by extension, dog populations have rapidly increased over the past few decades. They have also been increasingly moving into areas such as the Afroalpine ecosystem as people seek agricultural land or pastures for their domestic livestock. While previous work has shown that the domestic dog has a profound effect on the Ethiopian wolf through disease transmission and hybridisation (Gottelli and

Sillero-Zubiri, 1992), no study to date has examined the ecology of the domestic dog to seek solutions that will enable managers to target their efforts in conserving the wolf against the threats that domestic dogs present. In addition, despite the fact that no study has examined the potential for interspecific, whether exploitative or interference, between dogs and wolves, it has been suggested that this may be important to the survival of the Ethiopian wolf. Such work is of importance because with less than 500 surviving individuals, the Ethiopian wolf is the rarest canid in the world (Sillero-Zubiri and Macdonald, 1997; IUCN, 1994).

Finally, as part of the consideration of management solutions, an examination of the functional significance of the dogs is necessary. Dogs have been the universal companion of humans worldwide for the last 10,000 years (Gittleman, 1996). All the present races of dogs originate from the wolf and more precisely from a small-sized wolf (*Canis lupus pallipes*) (Scott, 1968). It has been suggested that these early canids lived on the fringes of human society scavenging on carcasses and other waste food (Budiansky, 2000).

The origin of livestock guarding dogs can be traced back nearly 6000 years, possibly to the upland region of present-day Turkey, Iraq and Syria (de la Cruz, 1995). In Europe, after wolves and bears were eradicated from alpine regions, the use of livestock guarding dogs has generally declined in many regions. More recently, with the success of various conservation programmes or increasing conflict between wildlife and domestic livestock as humans increase their range, the use of livestock guarding dogs for protecting flocks from wild predators is expanding again (Rigg, 2001). At present, the process of rearing and training livestock guarding dogs has been refined, standardized and formally described in more detail in the USA than perhaps anywhere in the world (Andelt, 1999).

Human-carnivore conflict through depredation of domestic livestock is an issue in which there is increasing focus in conservation biology. Over the past 200 years, livestock husbandry has generally been considered to be incompatible with larger predators; coexistence between wild predators and domestic livestock was though to be unattainable (Anderson, 1980). Indeed, this problem continues and is increasingly highlighted from different parts of the world (Andelt, 1992; Blanco, 2001; Civcci and Boitani, 2000; Gilady, 2000; Kaczensky, 1996; Kumar, 2001; Landry, 1996; Marker, 2000; Okarma, 1993; Rigg, 2001 and Tapscott, 1997).

Ginsberg and Macdonald (1990) believe that livestock guarding dogs continue to represent the most cost effective method of non-lethal-predator control. Many American farmers admit that, without guard dogs they could not continue their work (Coppinger and Coppinger, 1993). It was estimated in Colorado, USA, that individual dogs annually save an average of $3,216 (Andelt, 1992). In the United States, predation on sheep flocks with which guard dogs have been placed has diminished by 64-100% (Coppinger *et al.*, 1988). In one case study in western Montana, of a number of tested methods, only the dogs stopped coyote predation on domestic sheep (O'Gara *et al.*, 1983). Two completely different types of dogs, guard dogs and herd dogs, assist livestock producers all over the world (Rigg, 2001). Livestock guarding dogs work by being attentive to livestock and driving away intruders. They are trained to treat livestock as conspecifics, never leaving them and protecting them from wild predators (McGrew and Blakesley, 1982). In contrast to guard dogs, herd dogs do not live permanently with livestock but are specialists at moving stock from place to place (Andelt, 1992).

One objective of the present study is, therefore, to examine the functional significance of dog husbandry and whether the dogs play roles comparable to those elsewhere in the world, particularly where wild carnivores are present. This has the potential to influence management plans that may be suggested and implemented for the conservation of the Ethiopian wolf.

In conclusion, this study was undertaken to study domestic dog ecology to determine the extent to which dogs pose a conservation problem for the Ethiopian wolf by exploitative and interference competition. The study also aimed to evaluate potential of dogs to transmit disease to and hybridise with the Ethiopian wolf through interspecific interaction. Finally, the functional significance of dog husbandry for the local people was studied to examine the reason why people own dogs given that this was expected to influence management strategies. As such, the objectives of the study are as follows:

1. To determine the functional significance of dog husbandry to the pastoral people in the BMNP by conducting a questionnaire survey and by collecting behavioural data on dogs.
2. To examine the threat dogs pose to the Ethiopian wolf, as a result of competition, potential for disease transmission and hybridization through direct interactions. This included:
    a. to ascertain whether there is a potential for exploitative food competition by quantifying diet, foraging behaviour and predation rates of domestic dogs,
    b. to determine the temporal and spatial variation of domestic dogs (feral to domesticated) in relation to wolf range by conducting questionnaire survey and focal watches in the field,

c. to determine the rate and nature of interactions between dogs and wolves from focal watches as part of the examination of interference competition, potential for disease transmission and hybridization.

2. The Study Area and Methods

2.1. The Study Area

The study was carried out at high altitude (*c.* > 3,500m asl) flat and open areas in the Web Valley of the Bale Mountains National Park, Ethiopia. The area covered by the present study was about 70 km^2. The Bale Mountains National Park (BMNP) encompasses the greater part of the high altitude plateau of the Bale massif (Hillman, 1986) (Fig. 1). The BMNP covers 2, 200 km^2, encompassed by the coordinates N6^0 29'- N7^0 10' and E39^0 28' – E 39^0 57' (Hillman, 1993). The study area harbours the highest density of the critically endangered Ethiopian wolf (Sillero-Zubiri, 1994).

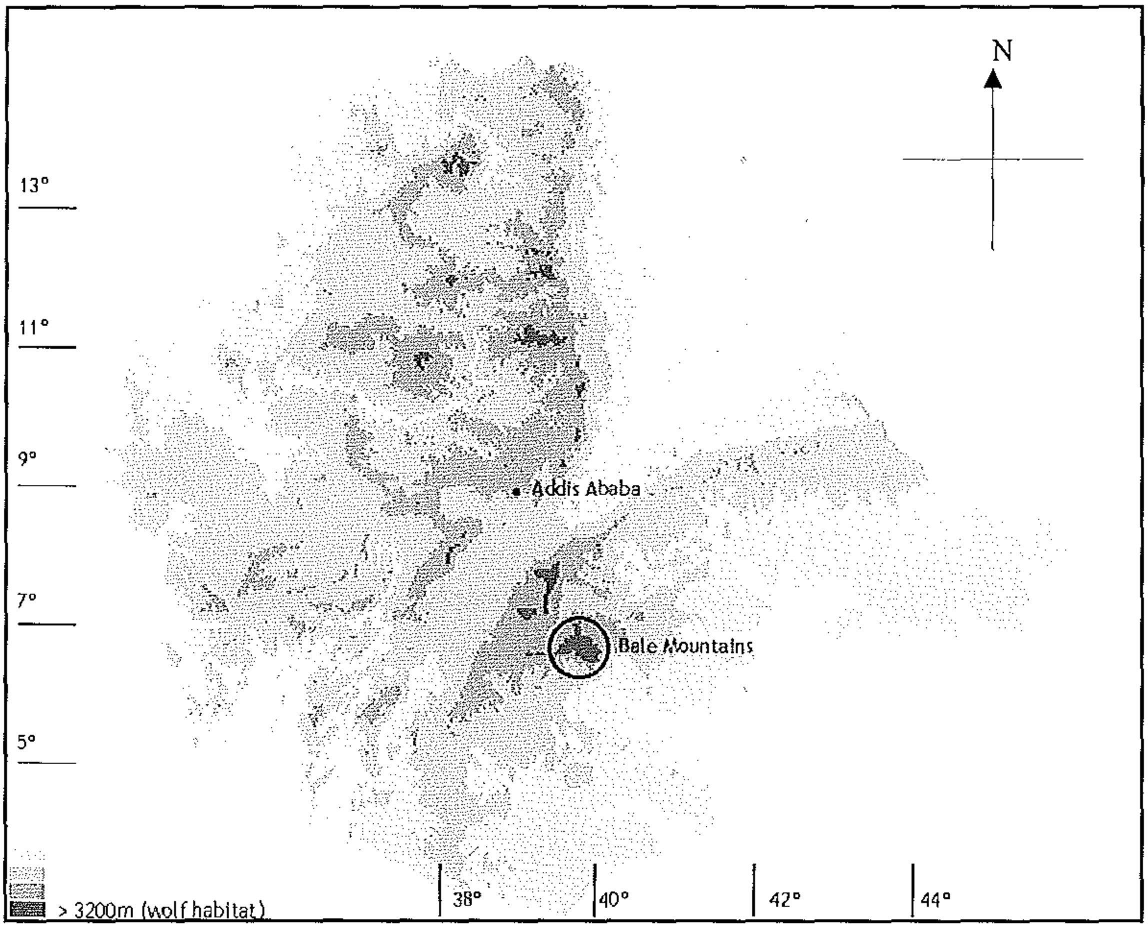

Figure 1. The location of the Bale Mountains National Park in Ethiopia.

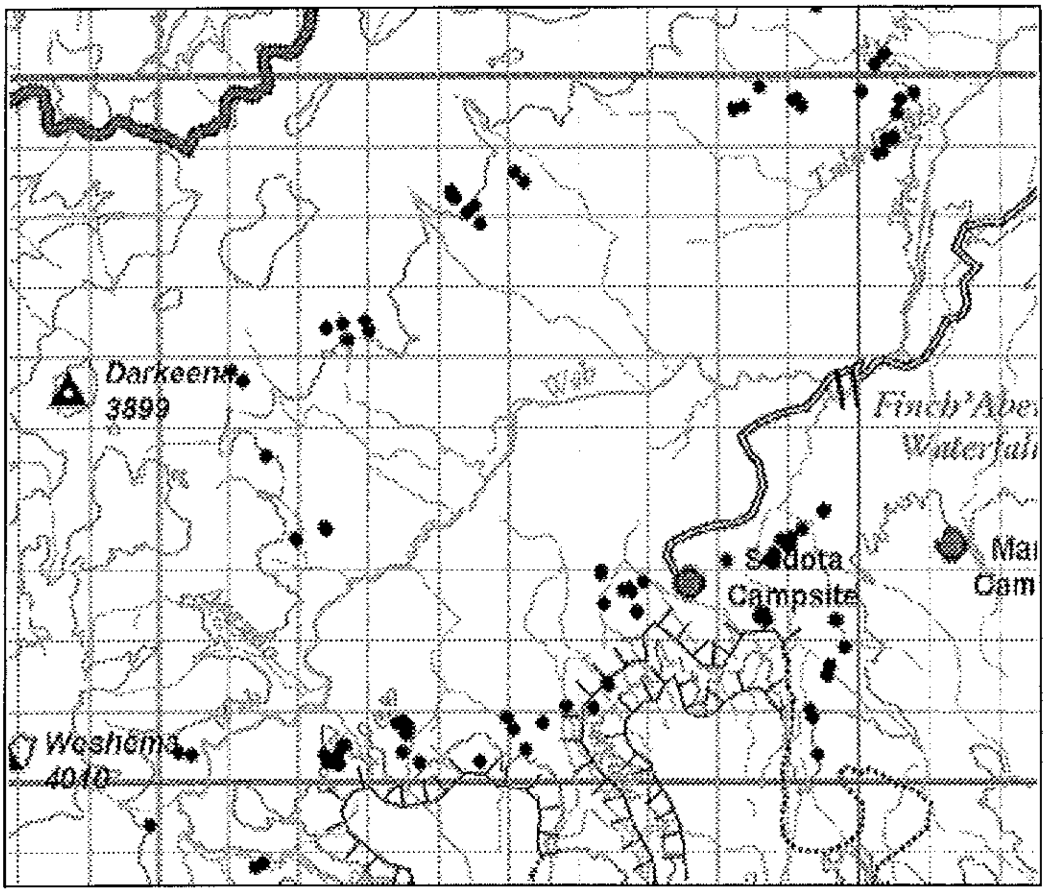

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Figure 2. The study area – the Web Valley of the Bale Mountains National Park, showing the distribution of the households within the area (Black spots indicate location of human settlements).

The annual climate cycle can be described as having a four month dry season, from November to February, with low rainfall, low night and high day temperatures and an eight month wet season, from March to October, with high rainfall, higher night, lower day temperatures than in the dry season (Hillman, 1986). In the present study, March and April are considered as early wet season.

In the Web Valley, human settlements encircled the narrow range of the Ethiopian wolf (Fig. 2). Observing wolves while roaming only 50 m away from all settlements was not uncommon. There were 10 settlements in the area, and the tukuls of each settlement were in close proximity, without fences and were generally aligned along cliffs that bounded the valley. There were no deliberately constructed shelters for the domestic dogs within the settlements. Because of the open habitat and the absence of shelters for the dogs, all activities of the dogs were easily observed.

2.2. Methods

The study of domestic dog ecology was carried out from November, 2001 to October, 2002. This comprises the dry season (from November, 2001 to February, 2002), beginning of wet season (March and April, 2002) and wet season (from May to October, 2002). The following methods were used during the study period:

2.2.1. Questionnaire survey

At the beginning of the study, a survey of households by questionnaire was conducted to provide baseline data on the human population and density of domestic dog population. The questionnaires were directed either to the male household head, or to another adult relative in the household. The human population survey focus on the number of each family and whether they are seasonal or permanent (Appendix 1). The latter Questionnaire focussed on quantifying the number of dogs kept within the household and whether the families were seasonal or permanent residents in the study area (Appendix 2). At the end of the study period (in October, 2002), the questionnaire survey was repeated to assess changes in the dog population over the course of the year at the end of the study period.

A third questionnaire was conducted to collect information about the presence of feral domestic dogs (Appendix 3). According to the WHO (1984) classification, feral dogs are those who do not intentionally receive their essential needs from people.

The fourth questionnaire was conducted to assess why people keep dogs (Appendix 4); thus, to determine the functional significance of dog husbandry. Because the majority of the people responded that they keep dogs to protect their livestock from depredation, the questionnaire was also aimed to determine the number of livestock killed by which predator(s) in the two years preceding the study.

Finally, over the course of the study, the people living in the study area were asked to report, ad hoc, all kills of livestock and dogs by wild predators. From this, the frequency of depredation and its cost, using local market price, were calculated.

The local people identify the predator responsible for individual livestock kills in a number of ways. At night, only spotted hyaenas and leopards attack livestock in the settlements. Their means of killing livestock were characteristic and easily distinguished. Leopards kill their prey with a bite to the throat; in contrast, spotted hyaenas usually attack the base of stomach. When the predators kill sheep and goat within enclosures in the villages, their means of accessing the enclosures was also characteristic. Leopards jump over the enclosure, while spotted hyaenas penetrate by digging and leaving large holes. The people also often observed the predators because the owners were alerted by the warning barks of their dogs. During the day, spotted hyaena predation was very rare. Other diurnal kills were reported by herdsman. When the predators catch one of the livestock grazing away from the settlement, the herd generally run away – enabling the herdsman to recognise the predator.

2.2.2. Nocturnal observation on behavioural response of dogs to predators

Nocturnal interactions between dogs and other species, particularly spotted hyaena: were carried out to assess whether dogs were fulfilling the roles claimed by the owners. When hyaenas approached a village or hamlet in which dogs lived and/or whe it attacked livestock in the settlement, the dogs barked in alarm. Observation commenced from the alarm call, and continued until the interactions were complete an the dog returned to its resting place. The responses of the local people to the alarm o dogs were also observed. Finally, observed kills of livestock by wild carnivores wer also recorded. An average of 25 out of a total of 250 nights were spent in eac settlement of the Web Valley to collect the data.

2.2.3. Line transects

Line transects were carried out in the study area to establish the proportion of the do population that roamed outside of the settlements in and around the wolf rang (Appendix 5). When sighted, 'roaming' dogs, as defined above, were identifie individually by natural markings and later used as focal animals.

Sixteen line transects, totalling 134.89 km, were walked or ridden on horseback. T transects started from a random point (the location of which was generated by random number generator of Microsoft Excel™) along one side of the study area. start points were then located using a GPS and the transects were walked or ridd east direction (90°); thus, perpendicular to the long axis of the study area. Each tra was carried out twice in a single day, once in the morning and again in the afternoo

2.2.4. Focal watches for foraging behaviour, interspecific interactions and home range analysis

Focal watches of individual dogs were carried out for a total of 182 days between December 2001 and October 2002, thus incorporating the dry (58 days), early wet (52 days) and wet seasons (72 days). The watches focussed primarily on foraging behaviour, including food acquisition and interspecific interactions (after Altman, 1974) (Appendices 6 and 7). This was to determine whether there was the potential for interspecific competition, both exploitative and interference, between dogs and Ethiopian wolves, and for disease transmission and hybridisation. All focal watches were carried out on foot using binoculars.

All dogs seen roaming in the study area, both during the initial line transects and later opportunistically when following other focal animals, were identified and used as focal animals. 'Roaming' dogs were those individuals that would be expected to be hunting on rodents and/or interfering with Ethiopian wolves. Further, as no dog ever left a settlement for more than 3 hours, opportunistic observations of the diet and interspecific interactions of all dogs in a settlement were recorded in addition to those of the focal animals.

During the dry and early wet seasons, twenty animals (3 females – all adult, and 17 males – 16 adults and one sub-adult) were followed as focal animals. These were all the dogs that roamed in the study area. Twelve of these were selected during the transects and eight others were identified opportunistically in the field. In the wet season, all except two focal animals stopped roaming (indeed, there was a reduction in the range of all animals during the wet season; see home range results). These two individuals and a further 10 animals (all adult males) that had previously roamed bnt had now stopped were followed as focal animals.

Focal watches were carried out from 06:00-18:00 hrs each day. Focal animals were observed for a total of 2, 064 hours of observation during the study period.

The position of the focal animal was recorded using GPS every 15 minutes. These data were used to determine the home ranges of individual dogs (Appendix 8). The home range of an individual is that area covered during normal daily activities (Blair, 1953). For secretive wild canids, radio telemetry is commonly used to obtain home range and activity data (Cocohran, 1980). However, the activities of urban dogs and of owned dogs in rural areas can be followed by direct observation, with the aid of binoculars and night-viewing devices if needed (Daniels, 1980). Home range analysis was carried out using the Animal Movement add-in (Hooge *et al.*, 1999) for ArcView GIS 3.2a, using the Minimum Convex Polygon (MCP) and Kernel Density Estimators Methods (Powell, 2000). Minimnm convex polygon method simply draws a line around all the location fixes obtained within for each animal during tracking and the area contained within this polygon is calculated. Because all points, including outliers, are included in the polygon, this method tends to overestimate areas used by animals. In contrast, kernel density estimators produce an unbiased density estimate directly from the data (Powell, 2000).

2.2.5. Scat analysis

Dogs that stay in the settlements, thus, those that did not 'roam' in wolf ranges, were not selected as focal animals as they are not expected to hunt on rodents. Indeed, analysis of their scats indicated that such animals did not feed on rodents. In addition, it was possible that when focal animals were out of sight for some minutes during focal watches, it is possible that they fed upon food items that may not have been recorded. Hence an indirect method, faecal analysis, was used to compare observations from focal watches. Faeces were collected from all animals, whenever they were observed defecating, to avoid the potential bias of collecting scats from other carnivores (Appendix 9).

The scats were air-dried and then were broken carefully by hand. Thereafter, the scat contents were analysed using a hand-held lens and binocular microscope (after Brunner and Comman, 1974). In particular, the bones, teeth, hair and other animal-derived matter were identified against a reference collection held at the BMNP Museum. Hair samples collected during this study from sheep, goats, horses and cattle were added to the reference collection. Since any one sample could contain multiple prey items, the frequency of a particular prey item that occurred in all samples was calculated (after Civcci *et al.,* 1996). One of the principal stable foods for the local people was roasted barley (*kollo*). During the focal watches, no dogs were observed feeding directly on *kollo*. Thus, when found in the dog scats, *kollo* was assumed to be indicative of the consumption of human faeces. This assumption was further tested by collecting and analysing 39 human faeces, 13 in each season (dry, early wet and wet season).

3. Results

3.1. Spatial and temporal variation of dogs

In the study area, dog densities varied with season. In the wet season, the density of dogs reached as high as 10 dogs/km^2 (697 dogs within the 70km^2 study area) while in the dry season the density decreased to 4 dogs/km^2. Households had an average of 2.1 dogs and no household was without a dog. Over the course of the study, there was a 37% increase in the number of seasonal dogs using the area.

The density of dogs is varied due to variations of human population. The results of the questionnaire survey showed that there were a total of 2,158 people (36.7% permanent and 63.3% seasonal) living in 362 tukuls. The seasonal people stayed in the area over the wet season from mid-June to mid-November, when grazing was relatively abundant. All inhabitants of the study area were dependent in part on livestock. However, they also cultivate barely.at lower altitudes away from the study area. In the dry season, after mid-November, the seasonal people leave the area to harvest their crops. This also coincides with a reduction in grass abundance in the Web Valley.

The study showed that all the dogs were owned and there were no reports of the presence (n=120 questionnaires) or observations of feral dogs in the study area. However, no dog was observed to be tied up by its owner and no other mechanism was observed of the local people to restrict the movement of dogs. Despite this, only a small proportion of dogs (3% of a total of 697 dogs) were found to 'roam' out of settlements. Most of them roam on the cliffs hunting on rock hyraxes, which is an area in which Ethiopian wolves were not observed during this study. Only very few of the dogs (0.4% of a total of 697 dogs) were found to roam in the wolf range to hunt on rodents.

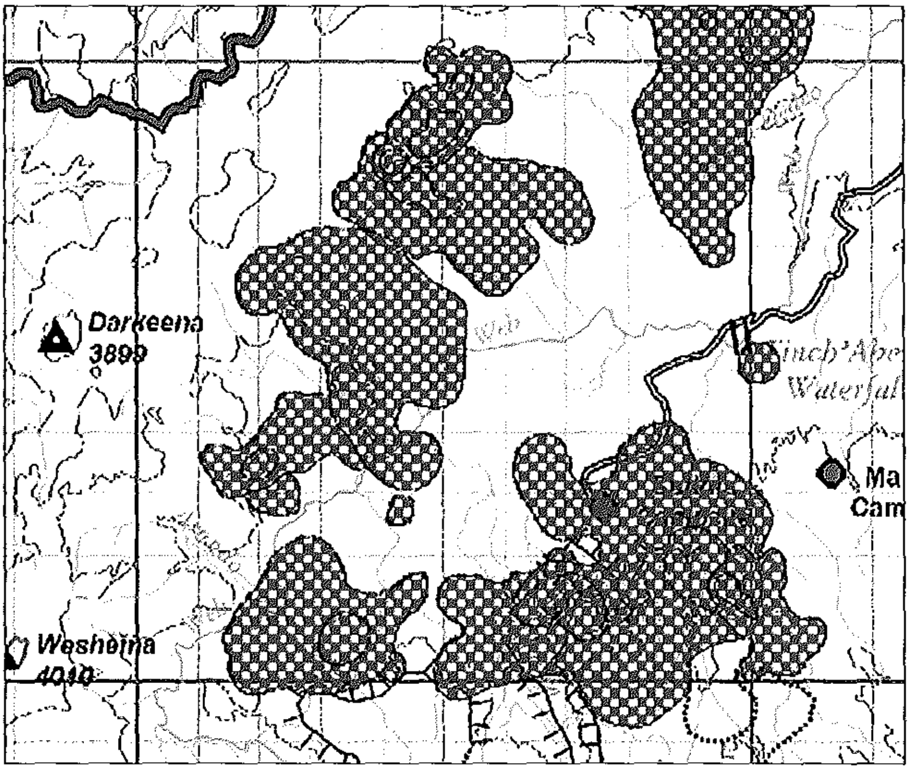


Figure 3. Home range coverage of dogs in the dry season.

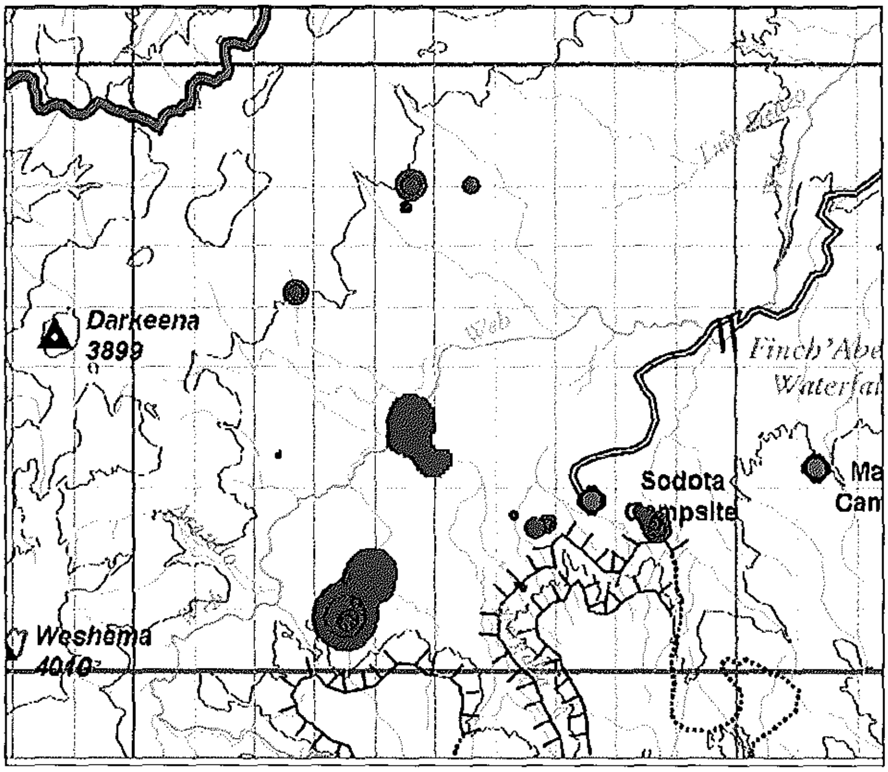


Figure 4. Home range coverage of dogs in the wet season.

Over the course of the study, very few of the dogs moved out of the villages. A total of 3, 884 fixes were obtained from the focal animals for home range analysis. The maximum home range recorded for an individual focal animal in any given season was 20.6 km^2 (thus, 29.5% of the study area but using the minimum convex polygon method of home range estimation, which tends to overestimate home ranges because it includes outliers). Thus, the 95% probability kernel estimator for the same dog during the same season was 2.44 km^2. There was also seasonal variation in home range of the focal animals (Figs. 3 and 4). During the dry season, home ranges were significantly larger than during the wet season (Wilcoxon-test, $p= 0.875$; $mean_{dry}= 5.9$ km^2, standard $error_{dry}= 1.1$, $n_{dry}= 14$ focal animals with a mean of 44.5 location fixes per animal; $mean_{wet}= 0.3km^2$, standard $error_{wet}= 0.2$, $n_{wet}= 12$ focal animals with a mean of 272 location fixes per animal; analyses using 95% probability kernel estimators).

3.2. Functional role of dogs and livestock depredation

All respondents from 362 households gave one reason for keeping dogs: to protect their livestock from wild carnivores, particularly from spotted hyaena. The people rely on dogs as their principal method of livestock protection and did not invest in enclosures for their livestock. Only 2% of the 362 households had stonewalls to protect their cattle, horses, donkeys and mules. The rest of the households left livestock in the open air at night. Sheep and goats were kept in shabbily built enclosures made of wood, which did not provide adequate protection against predators. Stone is the most available material for constructions in the area. However, the people did not make use of the available resources. The preferred way of guarding their livestock was dog husbandry.

Spotted hyaenas were the most significant threat to livestock. Spotted hyaenas visit each village for an average of 5.4 days (n = 100, s.d = 1.7, ranges from 3 to 8) out of every 10 days. A total of 80 dog-spotted hyaena interactions were recorded over the course of the study. In general, the dogs barked at the approaching spotted hyaenas but retreated submissively when the hyaenas approached them (n= 78). When the dogs were accompanied by people, however, the hyaenas retreated. From the observed 80 dog-hyaena interactions, 62 interactions were between two or more hyenas with two or more dogs. In the remaining 18 occasions, the interactions were between one hyaena and two or more dogs. On all occasions, in the absence of humans, hyaenas dominate dogs irrespective of the number of dogs involved in the interaction. Two dogs were observed while being killed by spotted hyaenas. The people reported that a further 20 dogs were killed by hyaenas in the three years preceding the study. On all occasions when hyaenas came to the villages to attempt to kill livestock (n= 80), the people were alerted by their dogs barking in alarm (n= 80).

This study and the questionnaire data revealed that over the period of this study and the two preceding years, 704 livestock were killed by wild predators including spotted hyaena (*Crocuta crocuta*), leopard (*Felis pardus*), common jackal (*Canis aureus*) and serval cat (*Felis serval*) (Fig. 5). Of these, 150 (149 hyaena and 1 serval cat kills) were observed while the carnivores attacked or in the next morning after killing livestock. The remainder were reported or collected during the questionnaire survey. In terms of number of animals predated, spotted hyaenas were reported to be the most important predator as it was responsible for 57% of the total kills. This was significantly more than the livestock killed by leopards (18%; χ^2 = 142.19, d.f = 1, $p < 0.001$) and common jackals (17%; χ^2 = 157.11, d.f = 1, $p < 0.001$). Serval cat was the least important predator, responsible for only 9% of the livestock killed, which, again was significantly less than the hyaenas (χ^2 = 252, d.f = 1, $p < 0.001$). Common jackal and serval cat killed only in daylight. In contrast, spotted hyaenas carried out 99% of their kills at night; the 1% in daylight occurred when livestock approached the hyaena den. Leopard carried out 73% of its kills in day light, with 27% of its kills at night.

Spotted hyaena killed all the livestock types found in the study area. Of its kills, sheep and cattle contributed 30% and 29% respectively, with no significant difference in the rate of predation (χ^2 = 0.15, d.f = 1, p = 0.696). Following these, horses and goat contributed 22% and 15% respectively, with a significance difference in the rate of predation (χ^2 = 5.3, d.f = 1, p = 0.021). Donkey was the least common prey, contributing 4.24% of the hyaenas' depredation, which was significantly less than goat depredation (χ^2 = 24.01, d.f = 1, $p < 0.001$).

In contrast to hyaenas, leopards kill primarily goats, but rarely sheep and cattle. Of its 127 kills, the majority (83%) were goats, while the minority were sheep (13%) and cattle (4%). Of common jackal kills, sheep (79%) contributed significantly more than goats (21%; χ^2 = 39.86, d.f = 1, $p < 0.001$). Serval cats killed significantly more young sheep (82%) than goats (18%; χ^2 = 39.86, d.f = 1, $p < 0.001$). All dogs that were killed in the area (n= 22) were done so by spotted hyaenas at night.

From the total of 704 kills of livestock by wild carnivores, 34.2% were sheep and 33.8% were goats. Cattle, horse and donkey contributed 17%, 12.5% and 2.4%, respectively. From the total number of available livestock during the period of this study, 1.43% was predated by different wild carnivores (Table 1).

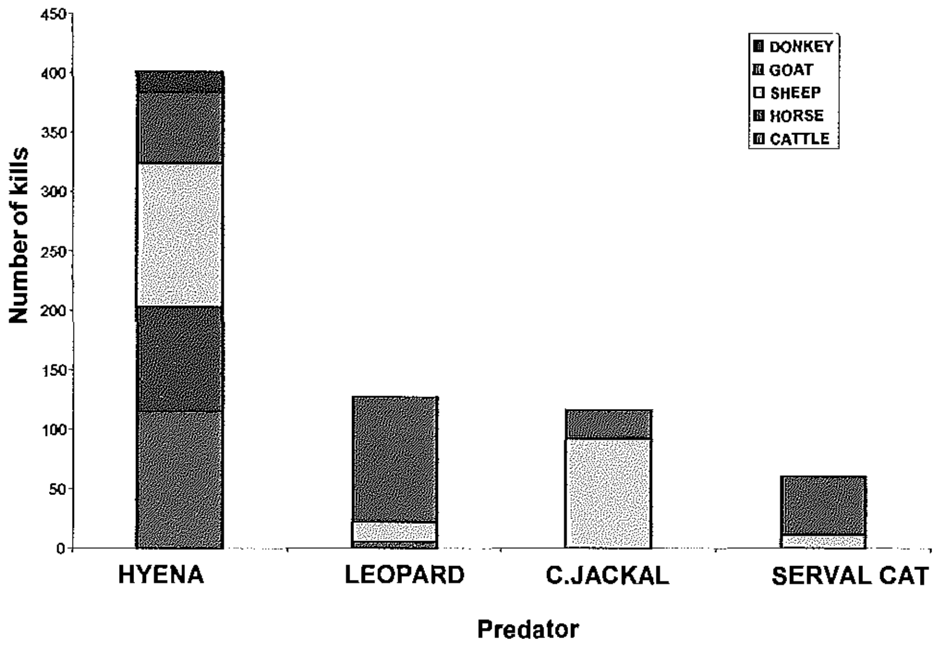


Figure 5. Wild carnivores responsible for the kills of 704 livestock from November, 1999 to October, 2002 in the Web Valley of the BMNP.

Table 1. Livestock depredation by wild carnivores relative to the abundance of livestock over the period from November, 2001 to October, 2002 in the Web Valley of BMNP.

Livestock Type	Livestock number	Predated livestock	% Predated livestock
Goat	3289 (14.8%)	108 (33.9%)	3.28%
Horse	1619 (7.3%)	42 (13.2%)	2.59%
Donkey	444 (2%)	11 (3.4%)	2.48%
Sheep	7241 (32.5%)	99 (31%)	1.37%
Cattle	9655 (43.3%)	59 (18.5%)	0.61%
Mule	50 (0.2%)	-	-
Total	22, 298	319	1.43%

In terms of the value of livestock, predators have caused a loss of potential revenue amounting to US$ 13, 102 over the past three years from total of 362 householders which is equivalent to US$ 12.06 per household per year (see Table 2). Spotted hyaenas were the most important predator, causing 83.5% of this financial loss. Common jackal, leopard and serval cat contributes, 7.7%, 6.3% and 2.5% respectively.

Table 2. Values of livestock loss by wild predators in the Web Valley of the BMNP from November, 1999 to October, 2002. Calculations are based on local 2002 prices for horse (US$ 58), cattle (US$ 35), sheep (US$ 9), goat (US$ 5) and donkey (US$ 23).

	Horse		Cattle		Goat		Sheep		Donkey	
	n	US $	n	US $	n	US $	n	US $	n	US $
S. hyaena	88	5,122	115	4016	60	279	121	1,127	17	396
Leopard	-	-	5	175	105	489	17	158	-	-
C. jackal	-	-	-	-	24	112	92	898	-	-
Serval cat	-	-	-	-	49	228	11	102	-	-

On some occasions, the local people respond to wild carnivore predation by killing the carnivores. Over the course of the study, one spotted hyaena was shot by a man whose horse was killed by spotted hyaenas. In addition, in Gaysay, the area adjacent to the study area in the northern part of the park, wild predators were killed when the people poisoned the carcass of an ox that was killed by hyaenas. The poisoning resulted in the death of at least 9 spotted hyaenas, 2 Ethiopian wolves and 2 common jackals.

3.3. Foraging behaviour and scat analysis

3.3.1. Foraging behaviour

A total of 382 meals were recorded during the study period from focal animals at different seasons. In the dry season, 141 meals were recorded. Thereafter, 86 and 155 meals were recorded at the early wet season and wet seasons respectively. In addition, some other 545 meals (174 in dry, 140 in the early wet and 231 in the wet seasons) were recorded from non-focal animals on an ad hoc basis.

In the dry season, the dogs consumed significantly more barley husks than human faeces (χ^2 = 6.38, d.f = 1, p = 0.012) and human faeces significantly more often than hunted animals (χ^2 = 6.67, d.f = 1, p = 0.01). There was no significant difference in the rates of consumption of rodents, cheese and milk, and carcasses (χ^2 = 9.31, d.f = 2, p = 0.009) (Table 3).

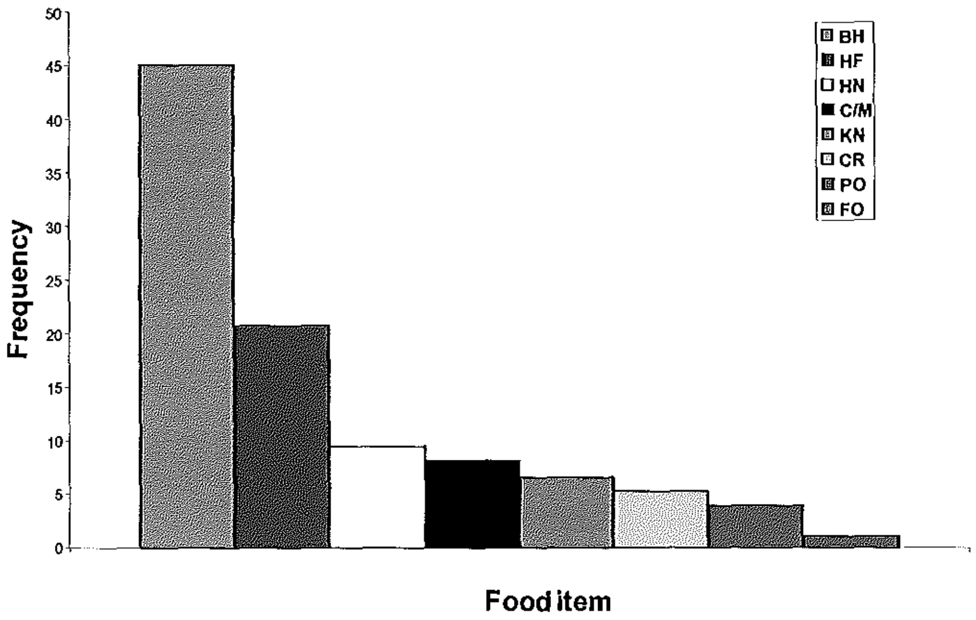
Table 3. The percentage frequency of different food items observed while ingested by focal animals over the course of the study.

Food item	Dry	Early wet	Wet	Over all
Barley husks	46.81	44.19	43.87	45.03
Human faeces	28.37	23.26	12.26	20.68
Hunted animals	14.18	10.47	4.52	9.42
Cheese/Milk	6.38	15.12	5.81	8.12
Kniphofia spp. nectar	-	-	16.12	6.54
Carcass	4.26	6.98	5.16	5.25
Potato peelings	-	-	9.68	3.93
Porradge	-	-	2.58	1.05

The wildlife species that were successfully hunted during dry season by dogs (n= 20) included rock hyraces (n= 12), rodents (n= 7) and a Starck's hare (n= 1) (Table 3). Of the rodents, 5 were rat sized rodents while the remaining two were molerats (*Tachyoryctes spp.*) although which of the two species was not distinguished from field observation.

In the early wet season (Table 3), the dogs consumed barely husks significantly more frequently than human faeces ($\chi^2 = 5.59$, d.f = 1, p = 0.018). There was no significant difference between the rates at which dairy products and human faeces were consumed ($\chi^2 = 1.49$, d.f = 1, p = 0.223), or between hunted animals and carcasses ($\chi^2 = 2.64$, d.f = 1, p = 0.267). Of all recorded meals, rodents only contributed 3.49%. The wildlife that was observed to be successfully hunted by the dogs (n= 9) included rock hyraxes (n= 6), rat-sized rodents (n= 2) and an unidentified molerat (*Tachyoryctes spp.*, n= 1).

In the wet season (Table 3), again, barley husks were consumed more frequently than the second-most frequently ingested item, '*Kniphofia* licks' (where a single feeding bout included all iudividual licks of flowers irrespective of the number of licked flowers) ($\chi^2 = 19.88$, d.f = 1, p < 0.001). There was no significant difference between the rate of ingestion of human faeces and *Kniphofia* licks ($\chi^2 = 0.82$, d.f = 1, p = 0.366) and between potato peelings, cheese and milk, carcasses and hunted animals ($\chi^2 = 4.74$, d.f = 3, p = 0.192). Rodents contributed only 3.87% of the recorded meals. Of the 7 hunted animals, 6 were rat sized rodents and one rock hyrax. Only 2.58% of the recorded meals were provided by owners, particularly when dogs could not find barely husks.



(BH= Barley husks, CR= Carcass, KN= *Kniphofia*, PO= Potato, HF= Human faeces, C/M= Cheese/ Milk, HN= Hunted animals, FO= Forage).

Figure 6. Food items observed while ingesting by focal dogs throughout the study period.

Over all, barley husks and human faeces formed the larger proportion of the diet of the domestic dogs (Fig. 6). There was a significance difference between the proportion of the diet made up barley husks in the dry and early wet seasons (χ^2 = 7.54, d.f= 1, p = 0.006) but not dry and wet seasons (χ^2 = 0.03, d.f = 1, p = 0.863). For the second most frequently recorded meal, human faeces, there was a significant difference between dry and early wet seasons (χ^2 = 6.67, d.f= 1, p = 0.006) but no significant difference between early wet and wet season (χ^2 = 0.03, d.f= 1, p = 0.873).

Hunted animals only accounted for 9.42% of all meals recorded from focal animals. The hunted animals include rock hyrax, rodent and Starck's hare each contributed 4.97%, 4.19% and 0.26%, respectively. *Kniphofia* flowers were important only for one month of the wet season (when the flowers were mature). During the three study periods, there was no significance difference in the rate of ingestion of cheese and milk (χ^2 = 1.03, d.f = 2, p = 0.597) and carcasses (χ^2 = 0.4, d.f = 2, p = 0.863) but there was a significance difference between the amount to which hunted animals contributed to the diets of the dogs (χ^2 = 8.97, d.f = 2, p = 0.011).

Dogs were observed when hunting on rodent, rock hyrax and Starck's hare (*Lepus starki*) with different success for their predation rate. Of their attempts, dogs succeeded 55% (n= 55) for rock hyrax, 20% (n= 5) for hare and 17% (n= 96).

Only three dogs were seen to hunt on rodents. Two main techniques were used: of the 16 observed captures of rodents, 75% were carried out by running very fast towards the rodents and capturing animals away from their burrows. The remaining captures (25%) were carried out by digging the burrows and dragging rodents out of the ground. Other dogs that were observed occasionally when crossing the wolf habitat with their owners attempted to capture rodents when they saw them but were not successful (n= 25).

From ad hoc data collected, the most frequently observed food item ingested by "non roaming" dogs were barley husks, human faeces and carcass (Table 4).

Table 4. The percentage frequency of different food items observed while ingested by non focal animals from occasional observation over the course of the study.

Type of food	Dry	Early wet	Wet	Over all
Barley husks	51.15	48.57	45.02	47.89
Human faeces	20.69	18.86	7.79	14.5
Carcass	18.97	14.29	11.69	14.68
Cheese/milk	9.2	19.26	8.23	11.38
Kniphofia spp. nectar	-	-	22.94	9.72
Potato	-	-	4.33	1.83

3.3.2. Scat analysis

A total of 1,200 scats were collected to analyse the diets of the dogs. In the dry season, 400 scats were collected from 210 individual dogs including the focal animals (159 adults, 36 sub-adults and 15 juveniles). A further 400 scats were collected from 170 individual dogs including the focal animals (123 adults, 31 sub-adults and 16 juveniles) in the early wet season. Finally, in the wet season, 400 scats were collected from 124 animals including the focal animals (86 adults, 30 sub-adults and 8 juveniles).

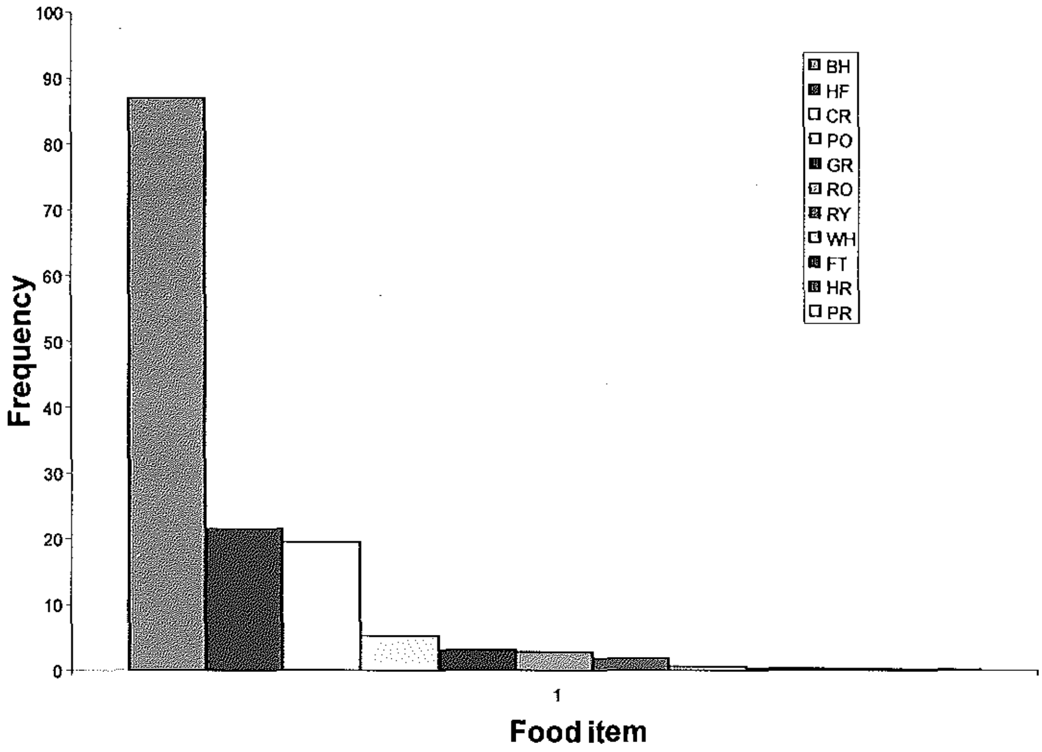
In the dry season, barley husks, human faeces and carcass were the most frequently occurring food items (Table 5). Barley husks were significantly more frequent than human faeces (χ^2 = 156.99, d.f = 1, $p < 0.001$) and carcass remains (χ^2 = 165.08, d.f = 1, $p < 0.001$), but there was no significant difference between the frequency of carcass remains and human faeces (χ^2 = 0.31, d.f = 1, $p = 0.579$). Similarly, there was no significant difference among the frequency of occurrence of rodents, rock hyraxes or potato peelings ($\chi^2 = 0.3$, d.f = 2, $p = 0.093$). Of the 19 rodents identified, 5 were *Arvicanthis blicki*, 7 were *Otomys typus*, 3 were *Tachyoryctes splendens* and 2 were *Tachyoryctes macrocephalos*. The other two were rat-sized rodents but could not be identified.

Table 5. The percentage frequency of occurrence of food items identified in the 400 scats of dogs collected in each of the dry, early wet, wet season and over all seasons (n= 1,200).

Food item	Dry	Early wet	Wet	Overall
Barley husks	85.25	92.5	82.75	86.83
Human faeces	20.5	20.75	22.75	21.33
Bone/skin	12	11.5	18.75	14.08
Goat	5.75	4.75	4.75	5.08
Horse	5.7	8	3.75	5.81
Sheep	5.5	10	5	6.83
Rodents	4.75	1.75	1.75	2.75
Potato peel	3.25	-	12.5	5.25
Rock hyrax	2.5	1.75	1	1.75
Grass	1.75	1.25	6.25	3.08
Cattle	1.5	0.25	2.25	1.33
Wheat husks	0.75	-	1	0.58
Undefined feather	0.25	0.25	0.25	0.25
Porcupine	0.25	-	-	0.08
Hare	-	-	0.5	0.17

In the early wet season, barley husks again occurred significantly more frequently than carcasses ($\chi^2 = 165.72$, d.f = 1, $p < 0.001$) and the third frequently occurring item, human faeces ($\chi^2 = 181.83$ d.f = 1, $p < 0.001$). There was no significant difference between the occurrence of human faeces and carcasses ($\chi^2 = 0.568$ d.f = 1, $p < 0.451$). From the 7 rodents identified, 3 were *Arvicantis blicki*, 1 was *Otomys typus*, 1 was *Ta*chyoryctes spp, and the other two were not identified.

In a very similar pattern, barley husks were the most frequently occurring food item in the scats analysed from the wet season. Barley husks occurred significantly more frequently than human faeces ($\chi^2 = 136.49$, d.f = 1, $p < 0.001$) and also from the third most frequently recorded food item, carcasses ($\chi^2 = 180.48$, d.f = 1, $p < 0.001$). There was a significance difference between the occurrence of carcasses and human faeces ($\chi^2 = 4.7$, d.f = 1, $p = 0.03$), but not between carcasses and potato peelings ($\chi^2 = 1.72$, d.f = 1, $p = 0.19$). Hunted animals such as rodents, rock hyrax and hare contributed only a small proportion of the dogs' diet, being 1.75%, 1% and 0.5% of the scats respectively. From the 7 rodents identified, 4 were *Arvicantis blicki* and 1 was *Otomys typus*. The remaining two could not be identified to species level as only hair remains were found.



(BH= Barley husks, HF= Human faeces, CR= Carcass, PO= Potato, GR= Grass, RO= Rodent, RH= Rock hyrax, WH= Wheat husks, FT= Feather, HR= hare, CP= Porcupine)

Figure 7. Food items identified from 1, 200 domestic dog scats.

Out of a total of 1200 faecal analysis, there was a very significant difference between the most frequently recorded food type, barley husks and the second most frequently recorded food item, human faeces ($\chi^2 = 474.38$, d.f = 1, $p < 0.001$) (Fig. 7). After human faeces, carçass was the most frequently occurred food item; its occurrence was not significantly different from the occurrence of human faeces ($\chi^2 = 1.61$, d.f = 1, $p = 0.204$). Following carcasses, potato peel was the most frequently observed food item, which was significantly different from the occurrence of carcasses ($\chi^2 = 94.37$, d.f = 1, $p < 0.001$). There was no significant difference between the occurrences of the remains of grass, rodent and rock hyrax that follow potato peel in frequency of occurrence ($\chi^2 = 4.57$, d.f = 2, $p = 0.102$). Hunted animals altogether contributed only 4.67% of all the scats collected. All remains of rodents were found from scats of roaming animals and no scats from 'non-roaming' dogs contained remains of rodents. There was no significance difference detected between frequencies of barley husks ($\chi^2 = 2.36$, d.f = 2, $p = 0.278$), human faeces ($\chi^2 = 1.18$, d.f = 2, $p = 0.307$) and carcass ($\chi^2 = 5.47$, d.f = 2, $p = 0.065$) between dry, early wet and wet seasons.

3.4. Analysis of human faeces

During the dry season, the analysis of 13 human faeces showed that 91% of it had remains of barley seeds (*kollo*). In the early wet and wet season, *kollo* was found in 84% (of a total of 13 samples) of the faeces in each season.

3.5. The rate and nature of dog-wolf interaction

Over the course of the study, a total of 36 dog–wolf interactions were observed. In the interactions, if there was more than one dog, the dogs chase the wolf (n= 21). If there were more wolves than dogs, the wolves dominated the interaction and they chase the dogs away (n= 9) (Table 6). When dogs that were not defined as 'roaming' entered wolf range and met a wolf, they avoided contact and moved apart (n= 3). Rodent hunting dogs were familiar with wolves and were observed greeting and mingling with the Ethiopian wolves (n= 3).

As most settlements were established near to the Ethiopian wolf habitat, 92% (21 interactions) of the time when wolves were chased by dogs happened when a wolf approached the settlements. Dogs that follow their owners were also observed chasing Ethiopian wolves but these seemed to be over shorter distances.

Table 6. Dog-wolf interaction matrix.

Looser \ Winner	2 DD	3 DD	5 DD	7 DD	1EW	2 EW	4 EW
1 DD	-	-	-	-	-	2	5
2 DD	-	-	-	-	-	-	2
3 DD	-	-	-	-	-	-	-
5 DD	-	-	-	-	-	-	-
1 EW	10	7	3	1	-	-	-
2 EW	-	-	-	-	-	-	-
4 EW	-	-	-	-	-	-	-

(DD= Domestic dog, EW= Ethiopian wolf)

4. Discussion

The first principal aspect of the study, an examination of dog husbandry, showed that this practice in the Bale Mountains appears to be a result of human-wildlife conflict. Domestic dogs form the best apparent solution for the local people to minimize depredation of domestic livestock. The people use dogs as an 'early warning' system - relying on the dogs to inform them of the approach of predators, usually hyaenas. However, even in the presence of dogs, the hyaenas frequently visited the villages and despite the presence of the dogs, the depredation rate of livestock by spotted hyaenas was high, both numerically and economically. Whether the dogs had an overall significant effect on reducing livestock depredation was, however, impossible to test. This was because all households owned dogs, and, thus, it was impossible to determine whether depredation increases in the absence of dogs. It was also impossible to remove dogs to test changes in predation in their absence. Yet, the frequency with which the hyaenas visited the villages means that the presence of dogs was probably of significant economic value to the people.

In terms of number but more significantly the potential economic value of the livestock killed, spotted hyaenas were the principal predators of livestock in the study area. Leopards, common jackals and serval cats altogether contributed a lesser proportion of the kills than hyaenas, and most of their kills were less 'expensive' livestock types, mostly goats and sheep. Stopping hyaena predation would, therefore, minimize the loss of wildlife depredation on livestock. The role of hyaenas in livestock depredation varies in other areas of Africa. Predation by spotted hyaena was noticed by Hawkes (1991) in some areas Zimbabwe where it was most common predator of cattle and donkey. In other areas of Zimbabwe, Butler (2000) indicated as they were notably insignificant as predators despite their presence.

According to Andelt, (1987), only in the last few decades have data been collected systematically to assess the extent and costs of livestock losses to carnivores. However, Gittleman, (1996) indicated that, such a study is vital because carnivore depredation can bring serious financial losses to human enterprises, often adjacent to natural habitat, and can provoke a negative human attitude towards carnivores. In some occasions, quantifying this is problematic because it is difficult to estimate the annual income of pastoral people who own many livestock but may not sell any of them – as seemed to be the case in the present study. In other studies, Oli *et al.* (1994) showed the economic loss from livestock depredation has been estimated to represent up to a quarter of the average per capita income in Nepal where snow leopards, *Panthera unica*, killed between 2.6% and 5.1% of total livestock holdings. Similarly, Mertens and Anghel (2000) estimated that in Romania, in 2000, the damage caused by wild carnivores was much less than 0.62% of all sheep, but this was significant given Romania's economic condition. Indeed, the proportion of livestock depredation (3.28% of goats; 1.43% altogether) found in the present study was similar to these other studies. In contrast, Rasmussen (1996) found that African wild dogs (*Lycaon pictus*), spotted hyaena (*Crocuta crocuta*) and leopards (*Panthera pardus*) together accounted for 0.4% of cattle losses on ranches relative to total herd size. Amongst pastoralists in Niger, McShane and Grettenberger (1984) also estimated loses as being minimal, with 2.1% of goats and 0.5% of sheep being lost to jackals. On a ranch in Kenya, Mizutani, (1993) explain that, leopard killed 2% and 0.8% of total sheep and cattle numbers, respectively. According to Kaczensky (1996), in Europe wolves are main predator of livestock mainly sheep.

An alternative to these simplistic economic considerations, what may be considered in future studies is the 'livelihood' and 'cultural' value that people also attribute to their livestock. Therefore, if the use of livestock by the people, either for food, leather, transport or as assets to socio-cultural development as well as for sale could be quantified, then a more accurate cost of depredation could be calculated.

Depredation by wild carnivores on livestock can lead the pastoral people into conflict and could cause reduction of carnivore populations. As described by Norton (1986) and Woodroffe and Ginsberg (1998), for carnivores even in protected areas, conflicts with humans are usually the most important cause of mortality in adults. Hey (1985) state that lions, wild dogs and spotted hyena have been more or less exterminated from all private farmland of South Africa, while cheetahs and leopards also are being very heavily persecuted to minimize depredation of livestock. The study of Linnell *et al.* (1996) showed that dramatic reductions in the distribution and number of large carnivores in Western Europe, almost to the point of extermination, is another clear example of lethal control taken to minimize depredation of carnivores on livestock. In the present study, the killing of wild carnivores by the local people showed that conflict could lead to a reduction of carnivores in the area.

Hummel and Pettigrew (1991) state that, in the past few centuries, carnivore species have declined dramatically in numbers and range through out the world. To avoid further decliue and to restore large caruivores as an integral part of ecosystems and landscapes across the world, human-wildlife conflict has to be changed to co-existence. There is no single approach that alleviates conflict; however, alternative methods have to be derived from detailed research work. To miuimize the conflict, Nowell and Jackson, (1996) suggest modification of livestock management, mechanisms for compensation to allow pastoral people or ranchers to recoup losses caused by depredation and elimination of specific problem individuals responsible for depredation. In addition, Linnell *et al.* (1996) state that, protection of natural prey species of the carnivores is also very important to minimize livestock depredation. For example, Tubbs (1997) indicate that wolf diet in Portugal is almost exclusively based on domestic animals due to the low numbers of wild prey such as red and roe deer. Even though Ginsberg and Macdonald (1990) indicate that, the use of guard dogs is found to be best, non-lethal method to control depredation, it seemed to have limitations in the present study because livestock depredation levels remained high. In addition, Lorenz (1985) has stated that the training requirements of 'guard' dogs, implying the socialization of the puppy with the livestock species, requires capacity, investment and willingness from the livestock owners.

The second principal aspect of the study was to determine the potential ecological interactions between Ethiopian wolves and domestic dogs. As foraging behaviour of animals depends on food availability, and food availability is affected by season (Freeman and Grossman, 1992), the study was carried out in different seasons. In this study, there appeared to be no potential for exploitative competition between dogs and wolves in all seasons. As indicated by Boitani *et al.* (1995); Lantis (1980) and Macdonald and Carr (1995), the basis of many dog populations diet is waste human food due to their close association with people. According to the study of Butler (1998), in the communal lands of Zimbabwe, *sadza* (porriage made from maize) is the most important food item used by the people and as well by their dogs. Similarly, in the present study, the most important food for the dogs was barley husks discarded by the people when preparing their staple food, barley.

As stated by Butler (1998) and Lantis (1980), in many parts of the world dogs have been recorded to feed upon human faeces. In the present study, humans defecated out in the open: there were no latrines in the study area. Human faeces comprised the second most important food item for the dogs, even though it is likely that their occurrence in the scat analysis was underestimated because not all human faeces contained roasted barley (*kollo*) that were used as the indicator of their consumption.

Dogs feed upon carcass opportunistically – particularly when animals were killed by hyaenas or when they died because of disease. It is the third most important food item for the dogs of the study area. In the study of Butler and Dutoit (2001) and Scott and Causey (1973), dogs were known to be one of the most successful scavengers of carcasses.

It is apparent that domestic dogs feed predominately on human refuse – the waste products of human food preparation, human faecal matter and any carcasses near the villages. This has two implications. First, this represents an important functional role that the dogs are playing. Despite the potential sanitary and health implications, none of the respondents to the questionnaires gave this as a function of dog husbandry. In contrast, the people of Bale, as Muslims, have certain behavioural taboos – such as not touching dogs, particularly their mouths – that would be consistent with the role of dogs as living sanitary units. Second, this result has implications for the domestication of wolves. It is generally believed that dog husbandry evolved through wolves following and scavenging off human kills of large mammals. The results of this study suggest that wolves may have been attracted to human waste, including faeces that must have accumulated around human camps or villages.

Other food items such as cheese and milk, and *Kniphofia* nectar could not be assessed through scat analysis; however, the importance of such food items was determined through the observation of foraging behaviour and indicated the limitations of scat analysis alone as a method for diet determination in domestic dogs. The cheese and milk and potato peelings were among the few food items that were provided to the dogs by their human owners, usually when barley husks became scarce.

Interestingly, hunted wildlife contributed only a small proportion of the diets of dogs. This result is in contrast to the allegation by Gottelli and Sillero-Zubiri, (1992), and Sillero-Zubiri and Gottelli (1994, 1995) that dogs compete with the highly endangered Ethiopian wolf for rodents. While Ethiopian wolves feed almost exclusively on rodents (Siller-Zubiri and Gottelli, 1995), only very few dogs hunted rodents and, of those that did, the rodents formed an insignificant proportion of their diet. This means that it is highly unlikely that exploitative competition would be an important interaction between domestic dogs and the Ethiopian wolves.

Dogs showed different success in their predation rate at different seasons. Predation on rock hyrax was highest during the dry season, probably because the hyraxes had to forage further away from the shelter of the rocks than in the wet season when food abundance was higher.

In contrast to Gottelli and Sillero-Zubri (1992) findings of feral dogs that are living off offal and carrion, no feral dogs were observed during this study nor was their presence reported by the local people. However, the home ranges of 'roaming' dogs recorded in this study (mean minimum convex polygon = 4.37 km^2 or 437 ha in the dry, and 4.32 km^2 or 431.5 ha in the wet season) were large when compared to other reported home ranges of owned, urban domestic dogs (e.g., 26 ha. for urban dogs in Baltimore, Maryland, Beck (1975); 52 ha in St. Louis, Missouri, Fox *et al.* (1975); 4 ha in New York, Rubin and Beck (1982); 0.7 ha in New York, New Jersey, Daniels (1980) and 97.2 ha in rural Zimbabwe, Butler (1998). The home range of the present 'roaming' dogs approximated to those of feral dogs in Alabama; USA, reported to be between 444 and 1050 ha by Scott and Causey (1973). Interestingly, the home range of domestic dogs in the dry season is much larger than wet season. The scarcity abundance of rock hyrax in the wet season may be the reason for the 'roaming' dogs to stay around house instead of roaming out in the mountain tops. In addition, as barely husks were relatively very scarce in the wet season, the dogs may have been energetically constrained.

As stated by Macdonald (1993), disease can also be transmitted through close contact between the dogs and wolves. The study of Sillero-Zubiri *et al.* (1996) showed that Ethiopian wolves are known to be susceptible to disease and major epidemics occurred in Bale in the early 1990's when up to two third of the wolf population died of a rabies and canine distemper outbreak. In addition, Laurenson *et al.* (1997) and Laurenson *et al.* (1998) state that, the domestic dogs in the study area have previously been found to harbour and be the vector for both these diseases. It was apparent from the present study that only a small proportion of the domestic dogs have close contact with the wolves; these were those that frequently 'roamed' into wolf ranges. However, neither does this preclude a diseased dog immigrating from outside the study area nor was there an examination of the interactions between local diseased dogs and wolves. This would be expected to change the behaviour of the dog and the results of this study cannot be extrapolated to this.

Finally, during this study, interference competition between wolves and dogs did not seem to be important. This was in contrast to reports by Gottelli and Sillero-Zubiri (1992), where dogs dominated all dog-wolf interactions. In the present study, wolves were observed dominating interactions, particularly when they had the numerical advantage. Other dogs were observed to be 'accepted' by the wolves and were observed greeting and walking together with the Ethiopian wolves. However, there were aspects of the dog-wolf interaction that were not observed. For example, the behaviour of dogs around wolf dens, when there were newly born wolf pups, was not observed. This could have critical implications for the survival of the Ethiopian wolf, if dogs predated wolf pups. However, in the context of the present study, as most dogs stay only in the settlements and roaming dogs did not have escalated aggressive interactions with the wolves, interference competition of dogs did not seem to be a significant threat to the Ethiopia wolf. The number of people in the study area is, however, growing and with it the domestic dog population. Thus, disease transmission, hybridisation and interference competition may become increasingly important. This is a situation that should be monitored in the future and for which conservation solutions will have to be sought.

5. Management recommendations

The present study was carried out to investigate the ecology of the domestic dog in the Bale Mountains of Ethiopia in order to determine how they might affect the conservation of the Ethiopian wolf. This is also taken in the context of the ongoing activities of the Ethiopian Wolf Conservation Programme that has its base in the Bale Mountains. In doing so, the functional significance of domestic dogs was also examined so that the impact of management solutions on the owners of the dogs would be better understood. The results of the present study have led to the following management recommendations:

- With the increase in the human population, so too is the increase in the number of dogs. Their settlement in the 'park' should be minimised. This will:
  - Help to reduce contact rate between wild carnivores and livestock
  - Help the natural prey of the carnivores to survive and reproduce out of the direct and indirect human impacts
- Making the pastoral people take responsibility for their livestock to a greater degree by ensuring that they can effectively enclose them away from wild predators. The people should be trained to construct stone enclosures that can protect their livestock from predators. In this way, the role of the dogs as guards of their livestock may be reduced and ultimately this may help to reduce the population of dogs. This will also provide a solution to the human-wildlife conflict by reducing the loss of livestock due to wild carnivore predation.
- People with 'roaming' dogs should ensure their dogs are tied up (as is provided for in the existing legislation). This would prevent all predation of rodents and reduce dog-wolf contact.

- The EWCP's ongoing dog vaccination campaign which is carried out to control disease transmission from dogs to wolves should be extended to adequately cover areas out of the park from where seasonal dogs come.
- The EWCP has been carrying out a pilot sterilisation campaign which aims to reduce the dog population (to reduce the threat of disease and hybridisation), given that only 100% castration of male dogs would make this successful, this campaign may be impracticable and other solutions may have to be sought.

Given the paucity of information on human-wildlife conflict, particularly in Ethiopia, there is much scope for detailed research. This should focus on quantifying the rate of depredation relative to the availability of wild and domestic prey. Future studies should also quantify the efficacy of dogs as reducers of depredation by examining dependence of depredation rate on variation of domestic dog, human, and domestic livestock numbers.

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Appendix 1. Human population survey

Date: ____________ Page No.____________

Settlement: ________

Family number	Name of all family members	Sex	Age	Per/seas.	Source if seasonal

Per/seas.= permanent or seasonal settlers

Appendix 2. Domestic dog population survey

Date: ______________ Page No.____________

Settlement: __________

Owner name	Number of dogs	Name of the dogs	Per/Seas.	Source if seasonal

Per/seas.= Permanent or seasonal settler

Appendix 3. Feral dog population survey

Date: ________________ Page: ____________

Name	How long do you stay here	Settlement	Have you ever seen feral dog	Have you heard about feral dog

Appendix 4. Functional values of domestic dogs

Date: ______________ Page No.___________

Settlement: _________

Name	Why do you keep dogs?	Loss of LV due to WC in the last 2 years time	If yes, its detail		
			YM	LV type	WC responsible

(LV= LIVESTOCK, WC= WILD CARNIVORES, YM= YEAR AND MONTH)

Appendix 5. Domestic dog line transect

Direction of transect: East

Date: ________________ Page No.________________

Start time: ___________ Start location: _____________

End time: ___________ End location: _____________

Time	Weather	Observed dog identity			Activity of the dog
		Sex	Colour of different body parts of the dog	Notice	

Appendix 6. Domestic dogs foraging bouts

Page No.____________

Date	Time	Loc X	Loc Y	Dog ID	Food item	How acquired

Appendix 7. Domestic dog-wolf interaction

Date: ________________ Page No.________________

Time	Loc X	Loc Y	No. of participants		Out come	ACD
			DD	EW		

ACD= Approximate chasing distance if any

Appendix 8. Domestic dogs movement tracking

Date: ________________ Page No.__________

Dog ID: ______________

Start time	End time	Loc X	Loc Y	Activity

Position of the animal taken in every 15 minutes interval

Appendix 9. Domestic dog faecal sample collection

Page No.__________

Date	Time	Card No.	Loc X	Loc Y	Dog ID.	Sex	Age	Origin