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Conservation in the Bale Mountains National Park: A Statistical Analysis of Population Trends of Ethiopian Wolves (Canis simensis) and Human Influences (2001-2007)

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Abstract

The Ethiopian wolf, *Canis simensis*, is a large endangered carnivore endemic to the Ethiopian highlands. Over half of the remaining population lives in the Bale Mountains National Park and this population has been monitored since 1983. The present study analyzes the monthly line transect counts in the Sanetti Plateau region of the Park from September 2001-January 2007. As a continuation of the investigation completed by Marino et al. (2006), these data were analyzed on a yearly basis using index of wolf abundance and encounter rates (divided into three habitat regions) and on a seasonal basis, along with a population density analysis using the Distance 5.0 Release 2 program. Data from the domestic species were also analyzed to determine trends within species and possible relationships between livestock presence and wolf abundance. The present study determined a population density of 0.814 wolves per square kilometer in the transect area. It also found a marked increase in livestock (cattle and sheep/goats) presence since the Marino et al. (2006) study. There was also a more consistent presence of livestock than previously, as there was no seasonal variation among the study years. Further population density analysis should be done to look for population increase since the 2006 canine distemper epidemic. The recent increase in livestock abundance should also continue to be monitored, especially to see if the wolf populations within optimal habitat regions become affected by the number of livestock.

1.0 **Introduction**

1.1 Study Overview

The Ethiopian wolf, *Canis simensis*, is the most endangered canid on the planet, and a species endemic to the Ethiopian highlands. The species was listed as "critically endangered" in 1996; it has since been downlisted to "endangered" by the International Union for the Conservation of Nature Red List (Sillero-Zubiri and Marino 2004). There are an estimated 500 individuals of this species remaining living in discrete packs (Sillero-Zubiri 1994). The goal of this work is to monitor the wolf population, as monitoring is an important factor behind conserving the species. In this paper I will report on analyses of monitoring efforts for the Ethiopian wolf and domestic animals in the Bale Mountains National Park.

1.2 Ethiopian Wolf General Information

The Ethiopian wolf has previously been known as *C. semiensis* and *Simenia simensis*, while additional common names include Abyssinian wolf, Simien fox, Simenian fox, Simien jackal, Simenian jackal, Ethiopian jackal and red jackal (Sillero-Zubiri and Macdonald 1997). They are carnivores, with a diet consisting largely of rodents (Sillero-Zubiri 1994).

Canis simensis is made up of two subspecies: *C. s. simensis* and *C. s. citernii*, based on the morphological characteristic of skull bone structure (Sillero-Zubiri and Gottelli 1994) and divided between the northern and southern populations (*pers. comm.* J. Malcolm). Males of the species are over 20 percent heavier than the females. Adult males weigh an average of 16.2 kilograms (kg), whereas females weigh 12.8 kg on average (Sillero-Zubiri 1994). Ethiopian wolves are restricted to Afroalpine grasslands and heathlands (Yalden and Largen 1992 in Sillero-Zubiri 1994). The species is divided into seven distinct populations (Marino 2003b in

Tallents 2007; Sillero-Zubiri 1994). The largest population is in the Bale Mountains National Park (BMNP) in Southern Ethiopia.

1.3 Bale Mountains National Park

The Bale Mountains National Park, established in 1969, encompasses about 2,200 square kilometers (km^2), including mountains and forest. It lies in southern Ethiopia between 6°29'-7°10'N and 39°28'-39°57'E and includes the largest area of land over 3,000 meters above sea level (m asl) in all of Africa. The Bale Mountains are home to many endemic species, including various mammals, amphibians, birds and plants, a number of which are threatened. While the region is especially important to these species, it is also an important region for Ethiopians as the origin of major rivers and home to many communities (GMP 2007-2017).

1.4 Wolf Range and Habitat

Around 1,000 km^2 of the park consists of Afroalpine habitat, over 3,500 m asl, and many of the endemic species of the region are limited to this habitat. BMNP is home to over half of the population of Ethiopian wolves (GMP 2007-2017), which live over 3,000 m in altitude, and have not been seen below 3,000 m since the early twentieth century (Sillero-Zubiri 1994). Within the altitude range of 3,000-4,400 m, the habitat is divided into subalpine (3,000-3,700 m) and Afroalpine (3,700-4,400 m) (Malcolm and Sillero-Zubiri 1997).

Afroalpine area consists of open space above the treeline, which occurs in ten parts of Ethiopia. Vegetation of this zone includes mainly grass and shrubs. Four of the five major Afroalpine vegetation communities occur in Ethiopia: *Helichrysum* scrub, *Alchemilla* scrub, Tussock grassland, and bogs. There is little human cultivation or settlement in the Afroalpine zone, although the area is still used for livestock grazing. The subalpine zone supports two main vegetation types, grasslands and heathlands. The heathlands include species of the genera *Erica* and *Phillipia*, forming woodlands with a height of 5-15 m. Grasslands occur in the valleys of the subalpine zone (Malcolm and Sillero-Zubiri 1997).

Habitat types for the Ethiopian wolf have been divided into groups of optimal, good and marginal habitats based on the estimated population densities of wolves in the areas. Other important characteristics in this partitioning include vegetation type and rodent biomass. Optimal habitat is described as Afroalpine grasslands with a rodent biomass of approximately 27-29 kilograms per hectare (kg/ha) and approximate wolf density of 1.2 km^{-2}. This is mostly found in the Web Valley and Central Sanetti regions of BMNP (Figure 1). Good habitat has *Helichrysum* dwarf-scrub predominating, with one-fifth of the rodent biomass as the optimal habitat and wolf density of around 0.25 km^{-2}. Good habitat also consists of northern grasslands, with a rodent biomass of one-half that of optimal habitat. In Bale, good habitat is in the Western Sanetti (Tullu Demtu). Marginal habitat has an Ericaceous belt, with a rodent biomass of one-tenth of optimal habitat with very few wolves, and is located in the Eastern Sanetti (Marino et al. 2006; Malcolm and Sillero-Zubiri 1997).

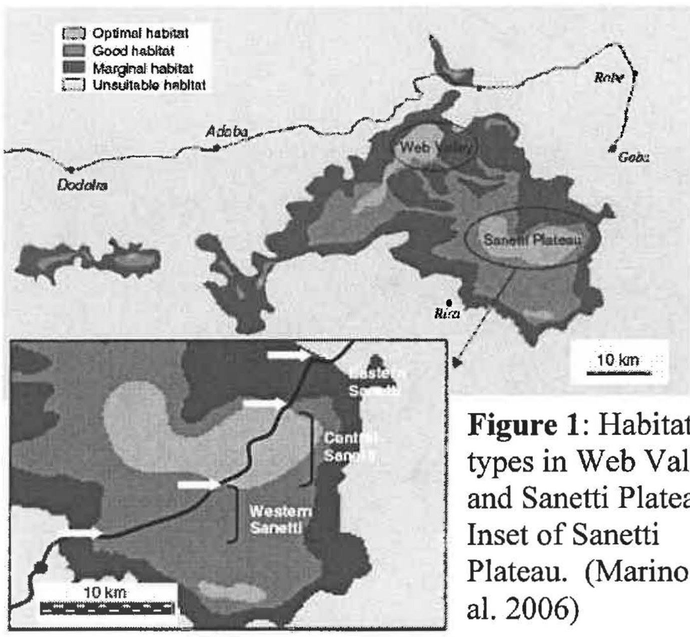


Figure 1: Habitat types in Web Valley and Sanetti Plateau. Inset of Sanetti Plateau. (Marino et al. 2006)

1.5 Behavioral Ecology

Ethiopian wolves are socially organized into packs with an average of six adults and subadults with three to eight adult males, one to three adult females and one to six juveniles. Pack size is smaller in areas of lower prey productivity (Sillero-Zubiri and Gottelli 1995 in Sillero-Zubiri and Macdonald 1997) and smaller packs take up a smaller area of habitat per wolf than larger packs (Marino 2003a in Tallents 2007). Two-thirds of females become floaters at two years of age, and besides these females the packs are discrete with exclusive territory. Floater females are those females who left the packs they were born into and live on their own until a position for a breeding female in a pack is available. Packs have well-established hierarchies, which can be altered among the males, but are unchangeable in females of the group (Sillero-Zubiri and Macdonald 1997).

Extra-pack copulations are mating occurrences between two individuals associated with different packs and do not include female floaters (as they do not mate). Female floaters and extra-pack copulations allow for genetic diversity among a subpopulation. Extra-pack copulations contribute up to 70 percent of mating (Randall 2006 in Tallents 2007; Sillero-Zubiri et al. 1996 in Sillero-Zubiri and Macdonald 1997). Within a pack, mating occurs between the single most-dominant male and female. Pups emerge from the den at three weeks (Sillero-Zubiri et al. 2004 in Tallents 2007; Sillero-Zubiri and Macdonald 1997) while juveniles join the territorial patrols at six months of age. Mating occurs mostly between August and November with birth occurring between October and December (Sillero-Zubiri and Macdonald 1997). The reproductive cycle of the wolves is taken into consideration when the yearly total counts are performed as more of the individuals are in groups than alone during this time, which eases the data collection process. During the breeding season, the packs are more cohesive, so the annual total counts are taken at this time. (Marino et al. 2006).

While Ethiopian wolves reside in packs, foraging usually occurs on a solitary basis, preying on rodent species such as: giant molerats (*Tacyoryctes macrocephalus*), and grass rats (*Arvicanthus blicki*). The wolves will occasionally cooperate for the purpose of hunting larger species, e.g. Stark's hare (*Lepus starcki*), reed buck (*Redunca redunca*), mountain nyala calves (*Tragelaphus buxtoni)* and small domestic animals (Tallents 2007; Sillero-Zubiri and Macdonald 1997).

1.6 Population Monitoring

The following overview on monitoring of the wolves is summarized from Randall et al. 2005 unless otherwise noted:

The population of Ethiopian wolves in the Bale Mountains National Park is divided into eight subpopulations (Figure 2): Sanetti Plateau, Chafa Delacha, Raffu, Tullu Deemtu, Web

Valley, Morebawa, Gaysay Valley and Central Peaks. Regular surveys of the wolves in this region began in 1983 (monitoring efforts since 1985 in Table 1) by the Bale Mountains Research Project in four of the eight subpopulations, including the Sanetti Plateau, the main topic of this study. Since 1996, the Ethiopian Wolf Conservation Programme (EWCP) has controlled the wolf monitoring, and has expanded monitoring to additional populations in Ethiopia (Marino et al. 2006).

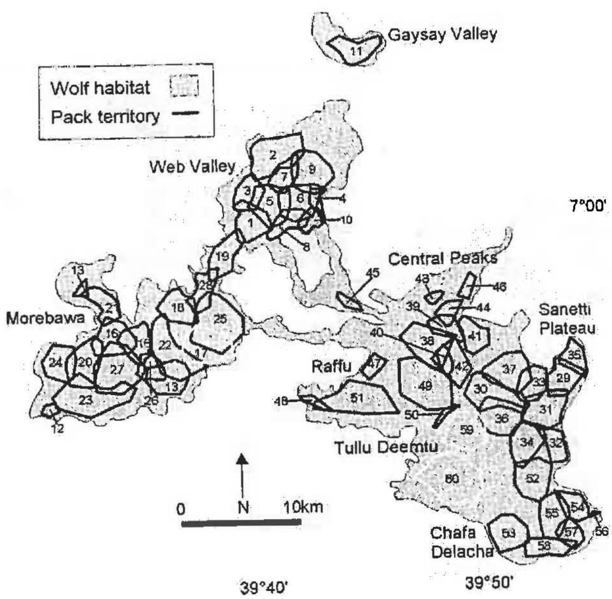


Figure 2: Subpopulations and pack territories in the BMNP metapopulation. Pack ID numbers are as identified in Table 2. (Randall et al. 2005)

Since surveys have begun, researchers have been able to estimate the total population of Ethiopian wolves in Bale. In 2000, Sillero-Zubiri and colleagues estimated the population size at 250 (Sillero-Zubiri et al. 2000). These estimations were made by known wolf densities during the Ethiopian Wolf Conservation Strategy Workshop. A more recent population estimation for BMNP was calculated by Randall et al. (2005). This estimation included a total of 60 packs, nine of which were in the Sanetti Plateau, and floater females, totaling 351 wolves over one year old (Table 2).

Table 1: Sanetti Plateau Wolf Monitoring History
Line transect counts in total number of counts per year. Total count data of central Sanetti packs measured in years indicated with "X." Data from 1985-2000 from Marino et al. 2006.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Line-transect counts:												
Sanetti Plateau	19	22	23	28	23	5	8	3	0	8	8	3
Total counts:												
Central Sanetti			X	X	X	X	X					

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Line-transect counts:										
Sanetti Plateau	7	10	10	11	4	13	5	8	5	4
Total counts:										
Central Sanetti	X	X	X	X	X	X	X	X	X	X

Table 2: Sanetti Pack Counts from 2003-2004 breeding season. Data from Randall et al. (2005)

Study Area	ID	Pack Name	Pack Size
Sanetti	29	Badagasa	10
	30	Batu	8
	31	BBC	9
	32	Bilisa	6
	33	Garba Guracha	11
	34	Lencha	6
	35	Nyala	6
	36	Quarry	6
	37	Sulula	5
		Floaters	5
Total Sanetti:			72
Other area packs:			261
Other area floaters:			18
Grand Total:			351

1.7 Census Techniques

There are two types of census data collected on the Ethiopian wolves in the Sanetti Plateau of BMNP: total counts and line transects. Total count data is collected in optimal habitat (Central Sanetti) once a year. The data are collected on horseback or on foot with binoculars between November and March. Since 1996, records have been kept of all individuals seen, allowing for a complete list of all adults and subadults. Total counts include individuals in packs over one year of age, and floater females (Marino et al. 2006).

The second type of census technique is the utilization of a line transect. This technique uses perpendicular distance of the animal to a transecting road to model the population and population density. Once a month, a car with observers is driven down the road from Goba, Ethiopia southwest into the Sanetti. The road transects through optimal and suboptimal habitats. While driving approximately 20 kilometers per hour (km/h), every mammal over 10 kg is recorded, along with direction to the animal and distance to the animal. (See Appendix 1 for a blank sample spreadsheet with a list of all data categories collected.) These data include mammals other than wolves as 90 percent of all observations are of domestic animals (*pers. comm.* J. Malcolm). Therefore, the data can be used to search for correlations between wolf populations and populations of other species in the region.

The road from Goba is 31 km long, traversing marginal (Eastern Sanetti), optimal (Central Sanetti) and good (Western Sanetti) wolf habitats, and is divided into these three sections as A, B and C consecutively (Figures 1 and 3). Section A is 6.7 km long, B is 10 km long, and C is 14.3 km long (Marino et al. 2006). Originally, line transect counts of the Ethiopian wolf did not directly record perpendicular distance. Direction of the road and direction to the animal were used, along with distance to the animal, in order to calculate perpendicular distance. More recently, observers began to measure distance to the animal only when perpendicular to the road (*pers. comm.* J. Malcolm). Observers record animals on both sides of the road in clusters (a group of wolves at one location is marked as one entry of multiple individuals) for these censuses. Further information on line transects can be found in Greenwood (2006).

The process of data collection via a line transect count simplifies a census process as it requires less energy than a total count; therefore, it can be performed more often than total counts. There is a correlation between these counts and the total population, which was depicted in Marino et al. 2006 and has been added to with the data from this study. Marino's study corrected for sampling variance by calculating the index of wolf abundance (see sections 2.3 and 3.3) for each year and concluded a positive correlation between the index of wolf abundance and total counts (Marino et al. 2006).

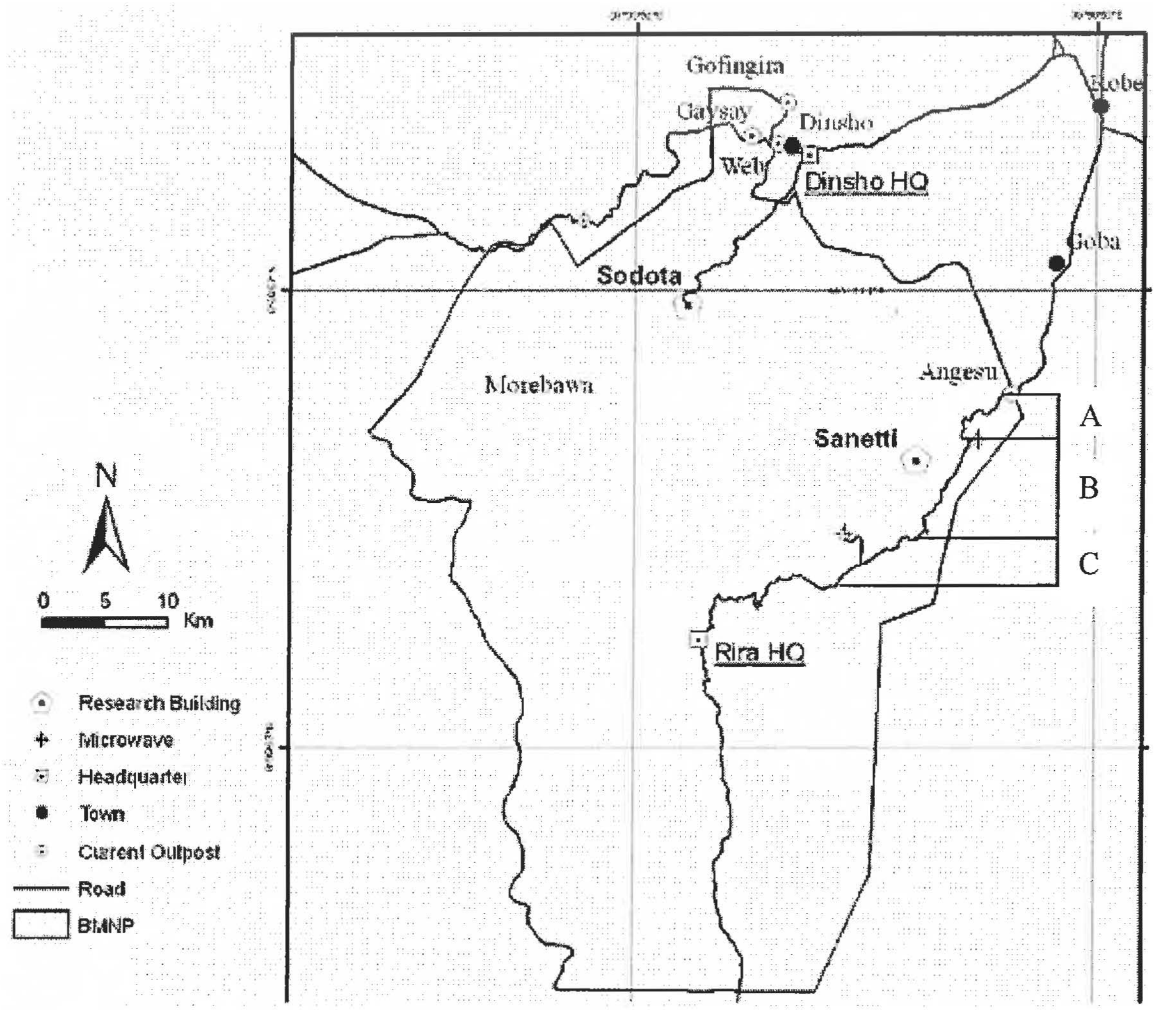


Figure 3: Map of the line transect road through Sanetti. Delineations (A, B, C) are by habitat type: A = marginal habitat; B = optimal habitat; C = good habitat. Adapted from GMP 2007-2017.

1.8 Human Influences

The Bale Mountains are also home to Oromo people. The Oromo society is largely pastoralist, bringing cattle, sheep/goats, transport animals (such as horses, donkeys, mules) and domestic dogs to the region. These domestic species can pose great threats to the Ethiopian wolf population both directly and indirectly. A growing human population enhances these threats. One direct threat posed by people is the presence of firearms with occasional shooting of wolves due to personal frustrations, often stemming from national warfare (Stephens et al. 2001).

Threats by domestic dogs on the wolf population stem from spread of diseases and interbreeding between the two species, posing a risk for the genetic conservation of the wolves (Laurenson et al. 1997).

Other species, such as cattle, sheep and goats, may have both positive and negative effects on the wolf population. It is possible that the wolves can use these large mammals as means of hiding while hunting larger prey (Ashenafi et al. 2005). However, overgrazing by livestock can affect the quality of land for the rodents, decreasing rodent abundances and, in turn, wolf abundances. In the Sanetti Plateau, grazing occurs mostly in the good and marginal habitat areas and is avoided in the optimal Sanetti Plateau due to climatic conditions.

1.9 Disease Outbreaks

The major contributor to the decline of the Ethiopian wolf in recent times is anthropogenic. Humans do not often directly impact the wolves, but indirect factors such as livestock grazing and the presence of domestic dogs potentially pose great threats to the population. As stated previously, domestic dogs introduce a variety of problems into the wolf population, the main contribution being disease. Ethiopian wolves are most susceptible to the rabies virus, canine distemper virus (CDV) and canine parvovirus (Laurenson et al. 1997). Disease has been identified as the most immediate threat in the conservation of this endangered species (Haydon et al. 2002; Laurenson et al. 1997).

The rabies virus is transmitted between hosts by biting, with affected saliva spreading the pathogen. Within the subpopulations of *C. simensis* of the Bale Mountains, outbreaks of rabies caused population declines in 1992 and 2003, with an additional suspected outbreak in 1991. In the early 1990s, rabies caused a decline by two-thirds in the largest population of wolves in Bale

(Haydon et al. 2002). During the 2003 outbreak, 76 percent (72 out of 95) of the wolves of the Web Valley died (Haydon et al. 2006).

One possible means of combating the virus involves vaccination. In theory, this could include vaccinating either the domestic dogs or the wolves. As vaccinating domestic dogs can only happen as a slow process (because it is dependent on cooperation of the owners), outbreaks in wolf populations due to unvaccinated dogs still occur. Haydon et al. (2006) tested this approach by implementing a vaccination strategy for the outbreak in the Web Valley in 2003. While the purpose of vaccination was to save the subpopulations of wolves, it also allowed for modeling of the outbreak and determining the minimum percentage of individuals that need to be vaccinated in order for the disease not to spread between subpopulations. Within the subpopulations of Web Valley and Morebawa, they discovered that vaccinating less than 40 percent of the Morebawa subpopulation successfully stopped the outbreak spread from the Web Valley. Models predicted that upon notice of two carcasses (due to rabies), the vaccination process could be implemented and be successful. Connecting back to the Sanetti Plateau, the Chafa Delacha and Central Peaks subpopulations are closest to the Plateau and the most important when studying possible spread of rabies to or from this region.

1.10 Importance of Monitoring

> "Monitoring is important to many objectives of conservation: to record the success or otherwise in safeguarding sites and species, …and can help to decide on priorities for research, education and interpretation. It can be argued that it is vital to all aspects of nature conservation" (Goldsmith 1993).

For larger predators monitoring is especially vital, as these species have relatively small biomass, and their populations are easily threatened by humans. Large predators around the world besides Ethiopian wolves are monitored, and these efforts have different specific methods and goals with one overarching theme of conservation. In many cases, a rise of human presence has called for an increased monitoring program.

The lions of the Serengeti Park and Ngorongoro Crater in Tanzania have been monitored since the 1960s (Lion Research Center; Kissui and Packer 2004). These lions are watched for indications of threats such as disease and poaching, especially with the rise in exposure to these with the vast increase in human population around park boundaries (Lion Research Center). The growing disease (canine distemper virus) rate in Ngorongoro 25-35 years ago was most likely due to this human increase, and the increase of domestic dog populations in the region (Kissui and Packer 2004).

In addition to the consequences of humans, monitoring is being used to assess the success of population recovery efforts, such as with the tigers in tropical Asia (Karanth et al. 1999) and with the Ethiopian wolves after a rabies vaccination series (Haydon et al. 2006). It can also help to gain an understanding of a population through its prey availability, as has been done with the lions of Ngorongoro Crater (Kissui and Packer 2004) and tigers of Asia (Karanth et al. 1999). While this becomes more difficult with the wolves, due to the size of their prey, there are study periods during which rodent populations are also quantified.

The Ethiopian wolf has been monitored for decades, and now has one of the most extensive monitoring programs seen for large predators. As stated above, disease is one of the greatest reasons for the decline of this species. In order to intervene in a disease outbreak, we must know that the disease is present at all. The presence of human observers to monitor the wolf populations allows for a quick reaction to begin vaccinating if necessary. If people are only temporarily and sporadically in the region to monitor the wolves, a delayed notice of multiple deaths due to disease may be too late to save a subpopulation, and the disease could have already spread to other subpopulations. In 2003, the vaccination process in the Web Valley subpopulation outbreak began after 72 individuals had already died due to rabies (Haydon et al. 2006). In an endangered species with total population of around 500, 72 deaths in multiple subpopulations does not foretell a promising future for this species.

In addition to discovering disease outbreaks, population monitoring can potentially link other species' declining or increasing populations with those of the wolf. The means by which line transect counts can be used to study other mammals in relation to the wolf is further outlined below (sections 2.5 and 3.4).

2.0 **Experimental Objectives**

The formation of the Bale Mountains National Park (BMNP) in 1969, along with the General Management Plans of the park, has allowed for regular monitoring of the Ethiopian wolf, the most endangered canid in the world. The monitoring programs involve both line transect data collection and total counts of the Bale Ethiopian wolf population. Monthly censuses have been carried out on the wolf since 1985 in the Sanetti Plateau of the BMNP, and other species were incorporated into these censuses in more recent years (Marino et al. 2006). The monthly counts in the Sanetti Plateau are conducted along a line transect through optimal, good and marginal habitats. The total population counts are conducted on a yearly basis between November and March and only include the wolf packs in optimal habitat zones. Since 1996, these surveys have been continued by the Ethiopian Wolf Conservation Programme (Marino et al. 2006; Sillero-Zubiri & Macdonald 1997).

The data collected prior to 2001 have been analyzed by Marino et al. (2006) and Stephens et al. (2001). However, monthly census data since 2001 have not been analyzed. This study proposes to analyze these unpublished data from the six years of collection, including a total of 41 line transects. The specific objectives of the study include:

2.1 Merge the data

The status of the data prior to the commencement of this project was disorganized and not in a form that could be analyzed. The files of data needed to be combined and reformatted before being analyzed. Some difficulties with the data stemmed from the fact that multiple observers have been used throughout the years and therefore the method of data keeping has not been consistent. In addition, the transcribing of data from paper to computer files relies on a secretarial position cooperating with the process and a language barrier often must be crossed.

2.2 Distance analysis

Ethiopian wolves populate a range of habitats from marginal to optimal, depending on prey availability. Utilizing the segmentation of the line transect into habitat sections, the data for which there is distance information was analyzed through an analysis program that can ultimately estimate the populations of the packs crossed by the line transect. The program, Distance 5.0 Release 2, uses distance data to calculate the detection radius, or the probability that an animal will be seen if it is a certain distance from the road, assuming there are no large natural barriers blocking the view (in the Sanetti Plateau, some species such as cattle can be seen from kilometers away, as parts of the region are flat). The distance data used by the program is the perpendicular distance of the animal to the road. From this, a population density of the wolves is calculated; if the area of land is known where the line transect is utilized, a population estimate is calculated from the density value.

The transect road through Sanetti does not go in a straight line, so the area accounted for with the transect counts is difficult to quantify. For this study, density was calculated and not translated into a population estimate. See discussion for more information on effects of a non-linear transect.

2.3 Index of wolf abundance

The index of wolf abundance (IWA) was introduced by Marino and colleagues (2006) as a means to reduce the variance caused by different numbers of counts in a year. The IWA relates to the total count data in a positive linear correlation. As a continuation of the work done by Marino et al., this study will calculate the IWA for the years 2001-2006, and the data can then be used to detect whether the correlation between the line transect data and the actual population size is further supported by recent years, or if the relationship is not as strong as initially believed. If so, then a better method should be considered.

2.4 Population Trends and Growth

The wolf abundance data (IWA), along with the total counts, enables trends in the wolf population to be studied. While the total counts are only available for areas of optimal habitat in the Central Sanetti, IWA can be used to visualize trends in population in good and marginal habitats in addition to the optimal habitat. This part of the study will expand upon the data from

Marino and colleagues (2006), and is especially useful in determining trends after epidemics (such as the distemper epidemic of 2006) in order to monitor the population size recovery.

2.5 Analyses of wolf abundance and other species

The monthly censuses measure numbers of other large mammal species in addition to the wolves, such as dogs, cattle, sheep, goats, humans, horses, mules, donkeys, and any other species over 10 kg in weight. Utilizing the line transect data for other species, relationships can be measured between population changes in wolves with changes in other species. Any correlations between population changes in domestic species and the Ethiopian wolves could hint towards anthropogenic causes of wolf population decline. In addition, the population trends of the other species were analyzed for each of the three habitats. This can point towards specific changes that have been occurring in the human population such as a change of lifestyle and modified usage of the park over the decades.

3.0 **Methods**

3.1 Data cleanup and compilation

This study utilizes data from three separate files of line transect counts collected along the road from Goba, Ethiopia into the Sanetti Plateau region of BMNP. The three Microsoft Excel files include data from 2001-2004, 2005-2006, and December 2006-January 2007. While the observers collected data according to the outlined spreadsheet in accordance with Newey and Sillero-Zubiri (2002), slight differences in organization and the language barrier have caused need for some necessary reformatting. The cumulative data are currently in a new, comprehensive format in a combined Excel spreadsheet.

Cleaning up the data and separating the species into their own Excel worksheets involved some shifting of numbers, as there were large amounts of numbers that were clearly in incorrect columns. To separate the species from each other to determine numbers of animals seen, some data points needed to be discarded that were incorrect. For example, only sheep/goats and cattle could be seen in large groups. No amount of dogs, donkeys or mules over three are seen at a time. Horse numbers were cut off at six individuals (*pers. comm.* J. Malcolm). In some cases, the method of correcting for this was that any extremely high number was a cause for deletion of that animal sighting (as it is more probable that 123 cattle were seen than one dog accidentally marked down as 123 individuals). In addition, if a wolf pack was given in a row that did not include a species name, Ethiopian wolf was assumed to be the species. For any blank values in the column for number of animals seen, the average amount of that species seen in one sighting (from the study years) replaced the blank value. If the age and sex of wolf individuals was collected, but no group size recorded, a sum of the age/sex information was used to gain the missing data.

3.2 Distance analysis

The line transect data includes columns for angle of the transect, angle to the individual/group and distance to individual/group in meters. Utilizing these three pieces of information, simple trigonometry can calculate the desired perpendicular distance (Figure 4) from the animal to the road, where the desired distance is:

x = absolute value [(distance to animal) * sin(angle of transect-angle to animal)].

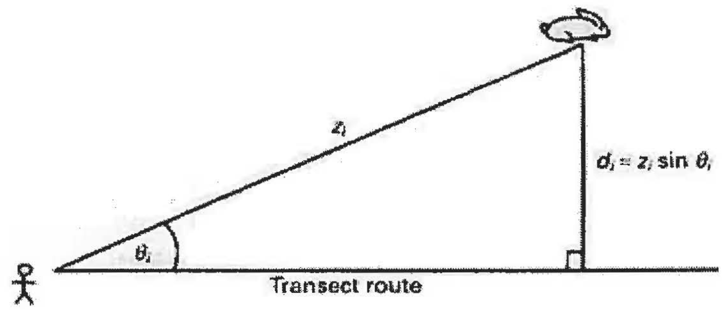


Figure 4: Line transect technique to calculate perpendicular distance (Greenwood 1996). θ_i = angle between transect and animal, z_i = distance to animal (m), d_i = perpendicular distance.

The sightings with this information available were plotted on a map. The UTM coordinates were converted to longitude and latitude using an Excel spreadsheet (Dutch 2005) in order to assign the points according to habitat, delineated through personal communication with James Malcolm. Some data points gave section information, which was only used when the GPS data were not available. If neither UTM nor section information was provided for a data point, the sighting was not used for the distance analysis.

Upon mapping the data points, it was seen that many of the sightings were given improper location information, causing the locations not to fall on the transect road. Of these, any point that could be placed in either of two sections (if either Easting or Northing was incorrect) was deleted, as no section could be identified. If the sighting did not lie on the road but could only be in one of the three sections, that section was recorded and the observation was included. This process relied on the assumption that of the two cells of location information, Easting and Northing, only one was incorrectly recorded.

Once distance quantities were calculated, the Distance 5.0 Release 2 program (Thomas et al. 2006) was used to analyze the data for population size and density. This program takes into consideration: Stratum (habitat type A/B/C), transect (number of transect in a list of censuses), length of transect (of the stratum), distance and cluster size (number of wolves seen during a sighting). The output of the analysis includes effective strip width/detection radius, density, upper and lower 95 percent confidence levels for density and coefficient of variation for the population density.

3.3 Index of Wolf Abundance, Population Trends and Growth

To calculate: IWA = Σwolves sighted/number of counts in the year

IWA was calculated for each of the three sections for each year studied. The same observation deletions were carried out for this sectioning as performed for the Distance analysis. For these yearly calculations, the one transect count from January 2007 was not included, as this is the only count available to this study from that year.

Once IWA was calculated for each of the three habitat sections, it was first used to verify the relationship between IWA and the total counts. Values for IWA and total counts from before 2001 were received from Dr. Marino through personal communication, as were the total count values for the years of this study. A linear regression analysis was performed on this relationship. IWA was also utilized to study fluctuations in population size, following similar methods to Marino and colleagues (2006). The most often used statistical analysis to study differences in population between the years is ANOVA, utilizing the total count data. IWA helps to study trends in non-optimal areas, where total count information is not available. Pearson's parametric correlations coefficient was calculated to analyze any similar variations between optimal and good habitats to determine if fluctuations in populations in these habitats were related.

3.4 Analyses of wolf abundance and other species

One of the purposes of this project was to identify population fluctuations of not only Ethiopian wolves, but also of livestock, domestic dogs, transport animals and sheep and goats (which are clumped into one category of sheep/goats), as an indication of possible causes of wolf fluctuations.

To relate the data with those of Marino et al. (2006), the livestock, people and dog counts were standardized as number of individuals sighted per unit distance (km) and averaged by season blocks: dry season (January-March); early wet season (April-June); mid wet season (July-September); and late wet season (October-December). The January 2007 count was included in these analyses. The seasonal data was tested to determine if there was a seasonal variation for the years of 2001-2006 with two-sample two-way t-tests assuming equal variances.

The yearly encounter rates were graphed versus time for each of the species of cattle, sheep/goats, transport animals, domestic dogs and Ethiopian wolves. A linear regression analysis was completed for each of these sets of data and analysis of variance was used to determine significance. Pearson's parametric test was used to test livestock abundance relationships with the abundance of wolves.

4.0 **Results**

4.1 Population Density

The Distance 5.0 Release 2 program was used to analyze the calculated perpendicular distance of the transect data to determine the density of wolves along the transect. The resulting density was an average over the years analyzed (2001-2006) and includes all three habitats along the transect of the Sanetti Plateau. From the 111 usable wolf sightings from the 40 transects, a density of 0.814 (confidence limits 0.639-1.036) wolves per square kilometer was determined, with an effective detection radius of 125.89 meters in either direction off the line transect road. The coefficient of variation for this data set was 0.122, meaning that there is low variation from these results. This value is valid for the packs whose territories the road transects, within the 31 km of transect area.

This value of density is lower than what has been generally found in previous years, though a fairly similar density of around 0.9 wolves per square kilometers was reported for a three-year period of the 1990s (*pers. comm.* J. Marino). The decreased value of population density for these six years from 2001-2006 could have been due to a canine distemper epidemic that took place in 2006. However, the outbreak mainly affected packs along the road (*pers. comm.* J. Malcolm) and the density in the rest of the Sanetti Plateau could actually be higher in other areas further from these packs.

4.2 Index of Wolf Abundance

The IWA was calculated for each calendar year from 1985 to 2006. It was then verified against the total count data from optimal habitats, including available Web Valley data from 1988-2000 and Sanetti Plateau data since 1988 (Figure 5). The regression had an equation of $y = 2.3359x + 9.92$ ($R^2 = 0.7625$, ANOVA $F = 36.64569$, $p<0.001$).

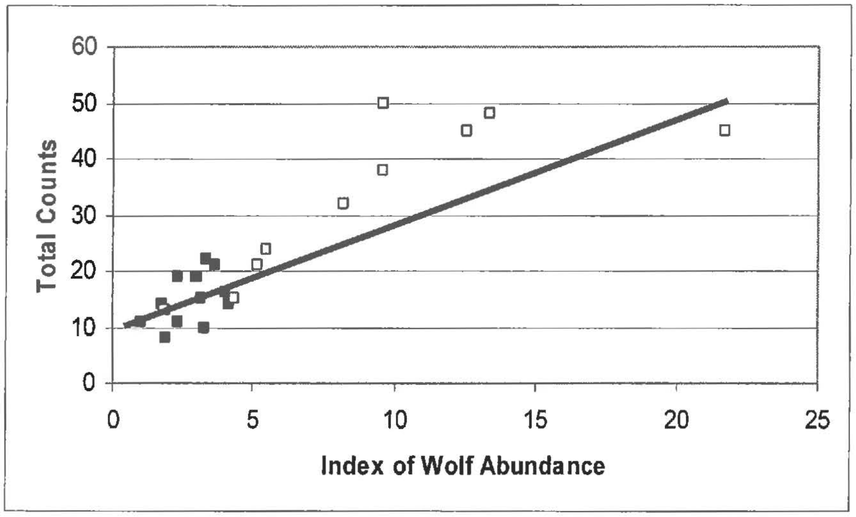
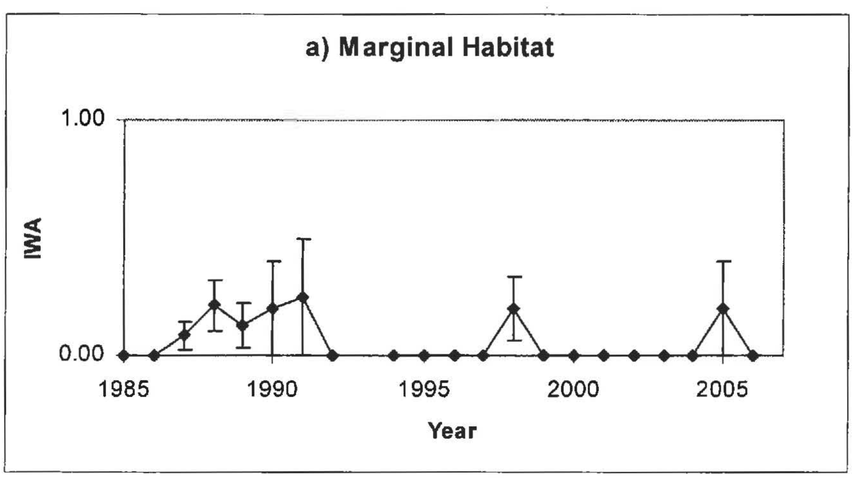
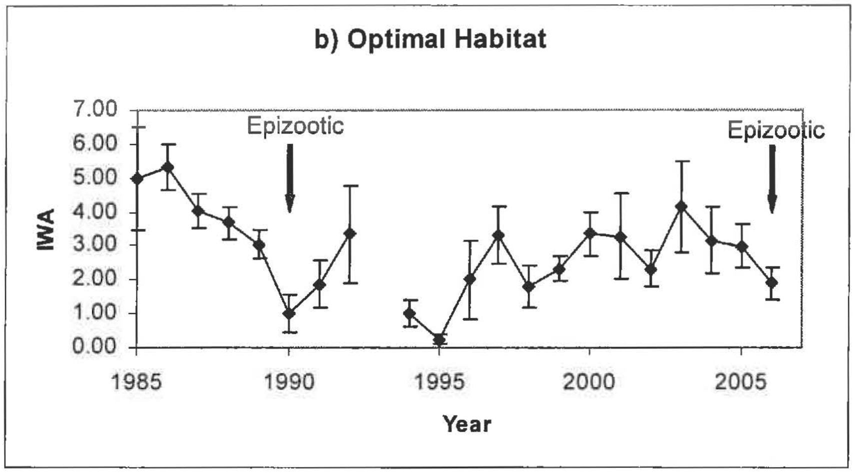


Figure 2: Linear regression of population size versus IWA. Open squares represent Web Valley data 1988-2000. Filled squares represent Central Sanetti data 1987-2006. Data before 2001 from J. Marino (*pers. comm.*)

In the eastern Sanetti (Figure 6a), zero wolves have been seen in the area since 1992, excluding two sightings of a solitary wolf in 1998 and one solitary wolf seen in 2005. Those wolves seen before 1992 were most likely in the same pack, which had a territory that the road transected. An extinction of this pack is most likely the cause of the lack of wolves seen, as field observations agree with the zero count of wolves in the area. The wolves seen in 1998 and 2005 could have been floater females, or individuals journeying away from packs in the neighboring optimal habitat (Marino et al. 2006).





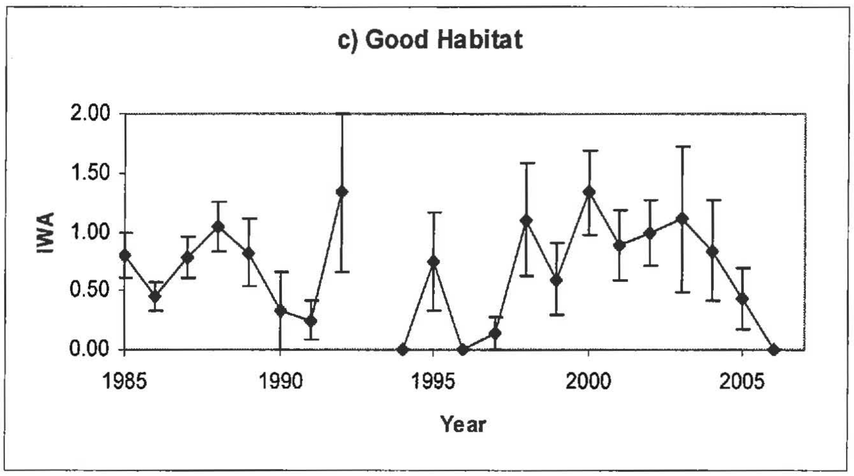


Figure 6: Time series of index of wolf abundance in a) Eastern Sanetti, b) Central Sanetti, and c) Western Sanetti. Error bars are standard error of sample. Data before 2001 from *pers. comm.* J. Marino.

In the optimal habitat (Central Sanetti, Figure 6b), the decline of IWA in 2006 was most likely due to the canine distemper epidemic that occurred that year. In the good habitat of Western Sanetti (Figure 6c), IWA did not vary as widely as for the optimal habitat, yet in 2006 there were no sightings of wolves along the transect.

The IWA values from 1985-2006 were analyzed between the optimal and good habitats using the Pearson product-moment correlation coefficient, resulting in an r-value of 0.36 between these two samples of population. This value is not significant

($p>0.05$), indicating that population variations within each of the two habitats are not related to each other.

4.3 Population Trends

The trends seen here, in both figure and table, are of the entire dataset from 1987-2006, so the old data may still impact the ongoing slopes. It is important to note, however, that the previous study used four values per year, one for each season, and adjusted the values for seasonality. While the current study shows no seasonality for either cattle or sheep/goats in the years evaluated (Figure 7, t-tests $p>0.05$), the previous presence of seasonality was not accounted for in this analysis. The lack of seasonality in livestock trends is evidence of more continual usage of the land than in the past. Not only is the usage more continual throughout the year, but it is becoming more widespread throughout the Plateau. In the past, there was only one or two cattle sighted per kilometer of transect in the Central Sanetti, whereas the encounter rate for 2003 was 16.5 cattle/km. In addition, sheep/goats never used to be seen in Central Sanetti, yet they now have encounter rates up to five or six.

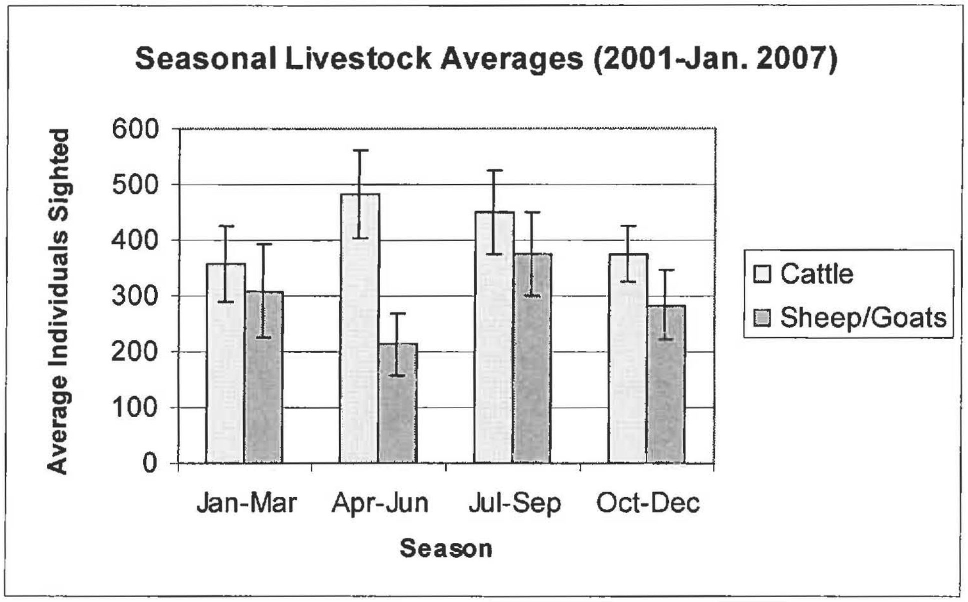


Figure 7: Analysis of seasonality for livestock in years evaluated for current study. No significance shown between seasons using two-way two-sample t-tests.

As seen in Table 3, the livestock trends in each of the three habitat sections have increasing slopes and these trends can be visualized in Figure 8. The Western Sanetti region has the steepest livestock trends as this section is where the herders bring their animals onto the plateau. For this section of good wolf habitat, the average yearly livestock numbers seen per kilometer have increased greatly since Dr. Marino's study of data up to 2000.

Sanetti Plateau Encounter Rate Regression

	Regression slope	R2	p	n
Optimal Habitat: Central Sanetti				
Cattle	**0.7194** *(0.046)*	0.6007	**0.000**	19
Sheep/goats	**0.2619** *(not encountered)*	0.5769	**0.000**	19
Transport	**0.0316** *(0.001)*	0.4372	**0.000**	19
Domestic Dogs	Rarely encountered			18
EW	**-0.0018**	0.0077	**0.000**	19
Good Habitat: Western Sanetti				
Cattle	**0.8108** *(0.193)*	0.4151	**0.000**	19
Sheep/goats	**1.1577** *(0.305)*	0.5934	**0.000**	19
Transport	**0.0038** *(0.023)*	0.0214	**0.000**	19
Domestic Dogs	Rarely encountered			16
EW	**-1.00E-04**	6.00E-04	**0.000**	19
Marginal Habitat: Eastern Sanetti				
Cattle	**0.1317** *(0.200)*	0.0351	**0.000**	19
Sheep/goats	**0.1387** *(0.126)*	0.0916	**0.000**	19
Transport	**0.0193** *(0.009)*	0.1176	**0.000**	19
Domestic Dogs	Rarely encountered			13
EW	Rarely encountered			19

Table 3: Linear regression of encounter rate vs. year for 1985-2006. P-values from ANOVA. Bold values significant ($p<0.05$). Slopes in parentheses are significant for 1985-2000 from Marino et al. 2006.

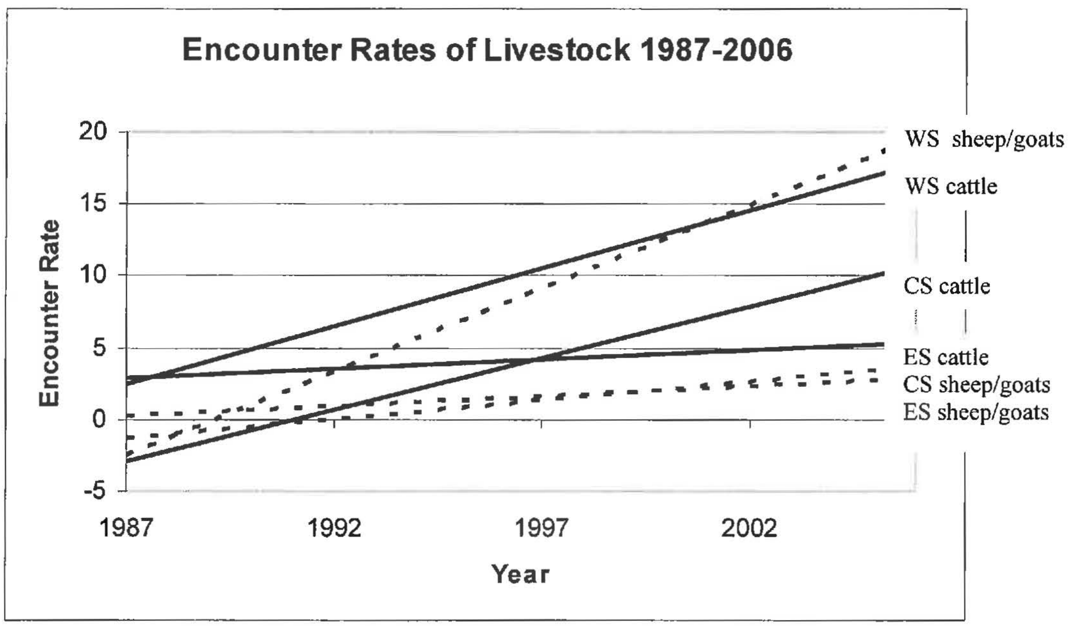


Figure 8: Linear regression time series of encounter rates, separated between cattle and sheep/goats, and by habitats of the line transect. All lines significant by ANOVA ($p<0.05$). ES = Eastern Sanetti, CS = Central Sanetti, WS = Western Sanetti. Solid lines indicate cattle. Dotted lines indicate sheep/goats. Data before 2001 from *pers. comm.* J. Marino.

The Pearson product-moment correlation coefficient was calculated between the Ethiopian wolf encounter rates in each section versus the cattle and sheep/goat encounter rates for that section using data from 1985-2006. The results concluded that there is no significant relationship between the wolf population and either cattle or sheep/goat population within a habitat. With the recent increase of livestock to the area, relationships between wolf and livestock populations should be further monitored in the future, especially as the region is optimal habitat for wolves.

4.4 Transport Species and Domestic Dogs

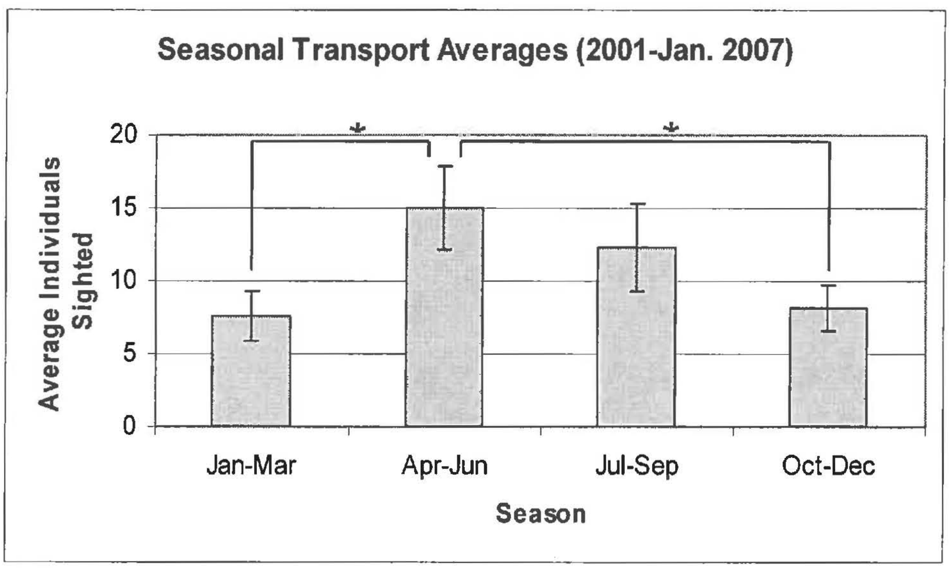


Figure 9: Seasonal averages for sighting transport species (donkeys, horses, mules). Error bars are standard error. * indicates $p < 0.05$ in unpaired two-sample two-tailed t-tests assuming equal variances.

While domestic dogs are rarely seen within the study area, the transport species of horses, mules and donkeys showed a seasonal variation using two-sample, two-tailed t-tests assuming equal variances (Figure 9). For these species, significant differences were detected in abundances between the early wet season (April-June) and each three-month period of the dry season. Transport species are usually seen with livestock and people. However, since the livestock trends did not show seasonality, these data may be due to a difference in human presence between the periods (human and transport species seen without livestock). This could be further analyzed with the human data.

5.0 **<u>Discussion</u>**

5.1 Study Conclusions

The Sanetti Plateau is home to approximately one-fifth of the world's population of Ethiopian wolves. As this area is so important, the continual monitoring of the wolves is crucial in order to be aware of vaccinating needs to avoid the spread of disease, to keep tabs on the human spread into the park, and to determine the domestic animals' influences on the wolf population. The analyses of this study concluded that the density of the wolf population along the road is approximately 0.814 wolves per square kilometer, a lower value than previously recorded, and indicated greatly increasing numbers of domestic species in the study area. The encounter rates of such species have been on the rise partially due to more people permanently living within the park. The increasing use of the study area by livestock is probably due to people living closer to the transect. There are now more villages both on the plateau and in the surrounding area than before (*pers. comm.* J. Malcolm). Unfortunately, along with humans and livestock come domestic dogs which bring the risks of hybridization and diseases. If the domestic dog vaccination rules do not change with the influx of people, the presence of diseases and hybrid animals may increase. Keeping an eye on these threats is a must, further validating the need for monitoring efforts of this endangered species.

Since 1983, through the formation of EWCP in 1996, and up until today, the process of wolf monitoring has been evolving to make it most effective with least sources of error (see section 5.2 for current sources of error). In the spring of 2008, an improved system of data entry was devised and implemented by Dr. C. Sillero-Zubiri and Dr. J. Marino. This new system gives the person entering data the option of inputting values into blanks, separated from each other (unlike in a spreadsheet), and individually labeled. The sheet also allows inputting the number of each sex/age group of wolves seen and the total wolf number per observation is added automatically by the program. This new process will hopefully help to cross the language barrier, to minimize the number of values seen in incorrect columns, and force the sex/age data on wolves to be recorded. Features of the process that have yet to be perfected include the "bad telephone line" (*pers. comm.* Claudio Sillero-Zubiri) aspects of the data collection system that involves two hand-written copies of a data set that then are passed along to the individual who inputs the data. Hopefully, the changes recently implemented will help to improve the process to the point where further advances could only develop with more financial support.

5.2 Sources of Error

There are many sources of error that stem from the methodology of the line transect counts in Sanetti. The first arises from the transect itself. The transect and the means of data collection go against two of the assumptions that are related to using a line transect: 1. the transect is straight; 2. one observation does not affect the probability of observing something else (Harris and Burnham 2002). With a nonlinear track, animals blocked from view from a perpendicular angle to the road, can be seen from around a curve, and wind up being counted disregarding the topography of the land. Curves of the road also allow for multiple perpendicular distances to one animal, which could affect a Distance analysis of effective strip width.

A line transect is also supposed to go through the habitats in proportion to the abundance in the area. The Sanetti Plateau transect goes through the three habitats of Erica moorland (marginal habitat, Eastern Sanetti), grassland (optimal habitat, Central Sanetti) and Helichrysum heaths (good habitat, Western Sanetti) with relatively good proportions, but other habitat types are not represented in the transect such as lakes and rocky slopes. Roads are generally built to curve with the ridges and to avoid difficult terrain, which in this case impacts the reliability of some data values as representative of the entire subpopulation (*pers. comm.* J. Malcolm).

The second assumption that is broken, along with further errors, comes from the methods of data collection along the line transect. First, one observation should not affect another. While collecting data, many livestock can be seen at far distances, as they stand out due to sheer numbers of individuals. When counting with binoculars, wolves can be seen amongst the cows and these individuals are noted. The data points of these individuals have not been truncated out and may affect the effective strip width. Distances to the animals from the road are also estimated by eye, which also affects the strip width.

Also, the planned monthly counts are actually not always done on a monthly basis. For species that have no seasonal variation, the outcome of analyses involving yearly averages is not influenced. However, those species whose numbers are affected by the season require a correction for this factor. Seasonality has been accounted for in the past but this study did not take it into consideration due to time constraints and program difficulties.

While conducting a line transect, the data collector is not always the same person. Throughout the years, the observation efforts between the better and worse observers hopefully have canceled out but there is no way to test for this.

5.3 Future Work

The wolf monitoring program is a continuous project that must be maintained in order to track the effects of humans on the population. Not only do the data since 2006 need to be analyzed, the monthly count data since 2000 for the Web Valley have to be looked at as well. The Web Valley is an area of optimal habitat, and the trends for wolves and livestock in this area may be even more useful to examine than those for the optimal habitat of the Sanetti Plateau. For the population density, distance analysis should be carried out excluding the 2006 data to determine if the lowered density is due to the distemper epidemic of this one year. In addition, with a reasonable estimate of area within which this density is valid, an estimate of the wolf population in the area can be calculated. For this calculation, the curvature of the road must be considered, which would be aided by a more accurate map.

The index of wolf abundance is used to visualize the line transect count data into trends of wolf population. If the line transects are not a valid means of monitoring the population, this should be acknowledged and remedied. Thus, the IWA values from the Web Valley for the years of this study should be verified against the total count data of the focal packs. These values can be added to the regression line in this report.

Finally, another analysis that can be added with these data is the rate of population increase versus population size. Marino et al. (2006) used the previous data to conclude that within the Central Sanetti there is a negative relationship between the two, indicating a density dependence of population growth. Looking just at those years after an epizootic, it is seen that there is some delayed recovery time of a population. The current data should be added to this analysis; it would also be interesting to keep a close watch during these next few years to look for a delayed recovery from the 2006 epidemic similar to the recovery after the last epidemic.

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Appendix 1: Sample line transect count spreadsheet

DAY	MONTH	YEAR	TIME	NORTH	EAST	DIR TRANS	DIR ANI	DIST	GRP NO	GRP SIZ	SPP	PACK ID	ACT	AD male	SA male	JU male	AD female	SA female	JU female	Tp	Ht	SI	Te	AWARE
30	11	4	13:25	596834	754648	13	312	200	1	1	EW	LEN	FO				1			1	1	2	2	

Columns of the Sample Spreadsheet:

All abbreviations in the data observations are in accordance with the Field Manual (Newey and Sillero-Zubiri 2002)

Day – day of the month
Month – month of the year
Year - year
Time – time in 24-hour clock
North – northing in UTM
East – easting in UTM
Dir Trans – direction of the transect in degrees
Dir Ani – direction to the animal in degrees
Dist – distance to the animal from observer in meters
Grp No – instance of sighting that species (first group seen = 1, second group seen = 2, etc.)
Grp Siz – number of individuals of the species sighted
Spp – species
Pack ID – name of pack if Ethiopian wolf
Act – action
AD male – number of adult males in the sighting
SA male – number of subadult males in the sighting
JU male – number of juvenile males in the sighting
AD female – number of adult females in the sighting
SA female – number of subadult females in the sighting
JU female – number of juvenile females in the sighting
Tp – vegetation type
Ht – vegetation height
Sl – slope
Te – terrain
Aware – was/were the individual/s aware of the observer's presence?