Integrative Zoology 2009; 4: 172–178 doi: 10.1111/j.1749-4877.2009.00147.x

ORIGINAL ARTICLE

Testing a passive tracking index for monitoring the endangered Ethiopian wolf

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Abstract

The endangered Ethiopian wolf is considered the rarest canid in Africa. The species faces many threats and is particularly vulnerable to diseases such as rabies. A simple, low-technology means to monitor populations would greatly facilitate conservation efforts, through early detection of population changes and behavior, and signaling a need for intervention. We tested a passive tracking index methodology, which has been a valuable tool for indexing canids and other species around the world. The method uses counts of track intrusions into plots placed in the animals' routes of travel as the basis for calculating an index. Unlike for other species, for which the placement of tracking plots on dirt roads has been extremely successful, we found in our first trial that this approach did not adequately intersect the wolves' activity patterns. The low vegetation associated with Afro-alpine habitats offered little benefit for the wolves to travel roads. However, in our second trial among molerat colonies, a focus of wolf foraging activity, we found plot placement on molerat mounds was efficient for collecting Ethiopian wolf plot intrusions for index calculations. This plot placement method coupled with the passive tracking index calculations might offer resource managers a cost efficient tool that requires minimal equipment to monitor Ethiopian wolf populations on the Sanetti Plateau and other Afro-alpine habitats. Plot placement on roads in other Ethiopian wolf habitats where cross-country travel is more difficult might still be a viable means to collect track data, but would require further testing.

Key words: endangered species, population abundance, population monitoring, Simien fox, Simien jackal.

INTRODUCTION

The Ethiopian wolf (*Canis simensis* Rüppell, 1840) is classified on The World Conservation Union (IUCN) Red List as endangered and is considered by many scientists to be the rarest canid in Africa (IUCN 1997; Sillero-Zubiri & Marino 2008). Fewer than 500 Ethiopian wolves persist, patchily distributed among seven fragmented regions from the northern highlands of the Simien Mountains to the south-central highlands of the Bale Mountains (Marino 2003a). Threats to the Ethiopian wolf are largely from anthropogenic activities, such as livestock grazing, illegal killing, disease, and hybridization with domestic dogs (Stephens 2001; IUCN 2004).

Endemic to the Ethiopian highlands, the species generally inhabits altitudes of 3000 to 4500 m (Gottelli & Sillero-Zubiri 1992), preferring open grasslands, fens, and heathlands associated with Afro-alpine habitats (Morris & Malcolm 1977; Yalden & Largen 1992). Ethiopian wolves

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live in packs of 2–13 adults and subadults (1–2 years), congregating mostly in the evening, night and early morning (Sillero-Zubiri & Gottelli 1995; IUCN 1997). During the late mornings and early afternoon, the pack normally disbands to hunt and forage for rodents independently (IUCN 1997). The territories of wolf packs vary from 6 to 13 km^2, depending on prey density (Sillero-Zubiri & Gottelli 1995b; Marino 2003b).

Afro-alpine habitats are well suited for a variety of rodent species that are the Ethiopian wolf's primary prey (Sillero-Zubiri *et al.* 1995a,b). In the Bale Mountains, where approximately half of the global population is found, wolves rely heavily on the endemic giant molerat (*Tachyoryctes macrocephalus* Rüppell, 1842) for food, which is believed to be found exclusively in these mountains above 3200 m (Yalden 1985). The giant molerat weighs between 300 and 1000 g, and is between 51 and 70 mm in length. It spends most of its life burrowing throughout an elaborate tunnel system 10–15 cm below the soil surface, and feeding on vegetation around different tunnel entrances (Yalden 1985). Giant molerats can often be found in high densities, where their mounds might cover an area over several hectares. These colonies provide optimal hunting opportunities for the Ethiopian wolf, regularly listening and watching for surface activity by molerats. Wolves will stalk individuals as they come above ground to gather fodder, and sometimes dig them out if they don't capture them with the first pounce. Sillero-Zubiri *et al.* (1995b) suggest that wolves synchronize hunting activities with surface activities of giant molerats.

Ethiopian wolf populations also rely heavily on various diurnal rodents for prey. Sillero-Zubiri *et al.* (1995b, c) report a positive correlation between wolf density and rodent biomass. In addition to the giant molerat, wolves regularly forage for *Arvicanthis blicki* Frick, 1914, *Lophuromys melanonyx* Petter, 1972, *Otomys typus* Heuglin, 1877, and other species of rats that are found concentrated around specific vegetation types (Sillero-Zubiri *et al.* 1995d; IUCN 1997; Walia 1998). Localized areas that have high rodent densities are important to the wolf's dietary needs and an integral component of territorial boundaries (Sillero-Zubiri *et al.* 1995a). As with molerat colonies, wolves will regularly inspect these areas when foraging.

Perhaps the most immediate threat to Ethiopian wolf is from diseases, which are known to devastate populations of rare and endangered species (Thorne & Williams 1988; Alexander & Appel 1994). Of particular concern for Ethiopian wolf populations are the rabies virus, the canine distemper virus and the canine parvovirus (Sillero-Zubiri *et al.* 1996; IUCN 1997; Whitby *et al.* 1997; Randall *et al.* 2004). Since intensive scrutiny of Ethiopian wolves began in the 1980s, the impacts from rabies have been well-documented in the Bale Mountains National Park (BMNP). The first significant outbreak recorded occurred in 1990 on the Sanetti Plateau (Sillero-Zubiri *et al*. 1996), killing 54% of the wolf population. In 1992, a second rabies epidemic swept through the Web Valley, killing 77% of the wolves. The cumulative effect reduced wolf numbers in Web and Sanetti from 76 to 23 individuals, in comparison with an estimated population size for the whole of the Bale Mountains of 120–160 animals at that time (Sillero-Zubiri *et al.* 1996). In 2003 and 2004, another rabies outbreak occurred in BMNP, where over two-thirds of the 95 wolves in the Web Valley were found dead or disappeared (EWCP 2004; Randall *et al.* 2004). The devastating impacts of infectious diseases, and the rapid rate of spread among gregarious species, continue to threaten the survival of Ethiopian wolves. Although wildlife managers are better equipped today to intervene with vaccination strategies (Randall *et al.* 2004), intervention relies heavily on early detection of new outbreaks, especially with more remote populations of wolves (Haydon *et al.* 2006).

Although the wolf's rarity and vulnerability make monitoring a conservation imperative, its distribution across remote Afro-alpine habitats also presents many logistical challenges. Most monitoring activities for the Ethiopian wolf are conducted by the Ethiopian Wolf Conservation Programme (EWCP) with support from international conservation organizations and academic institutions outside Ethiopia (IUCN 1997). The EWCP and regional wildlife managers lack the economic resources and personnel to implement long-term or in-depth monitoring strategies of their own, especially when costly equipment and new technologies are required. Most wildlife species are monitored through periodic survey transects and direct counts. Although these methods are commonly used and produce valuable results, they often lack the sensitivity to detect subtle changes in wildlife movements and populations when surveys are conducted on an irregular basis. There exists a need in Ethiopia and other developing countries to identify methods that effectively monitor rare and endangered wildlife species and that can be easily applied by resource managers. Field techniques need to be easy to implement, requiring minimal equipment, and involve simple statistical analysis that can produce comprehensive results and detect changes within a population. We tested the application of a passive tracking index (PTI) on the Ethiopian wolf, which could provide a rapid cost-effective assessment of wolf populations and pack movement. Passive tracking indices have been highly successful for monitoring wild canids in Australia and North America (Allen *et al.* 1996; Engeman *et al.* 2000, 2002), and have been shown to work well with other Ethiopian wildlife (Engeman & Evangelista 2006), such as hyaena (*Hyaena hyaena* Linnaeus, 1758, or *Cocuta crocuta* Erxleben, 1777), baboons (*Papio Anubis* Lesson, 1827) Guenther's dikdik (*Madoqua guentheri* Thomas, 1894) and lesser kudu (*Tragelaphus imberbis* Blyth, 1869). The PTI offers several statistical and logistical characteristics that would be favorable for monitoring Ethiopian wolf populations. First, it is non-invasive and can be conducted without any direct contact with animals. Second, it is easily and quickly applied, and is readily understood in the field, requiring no expensive equipment or complicated technologies. Its effectiveness has also been proven with many species and it has been especially useful for monitoring canids. Finally, the index is easily calculated and has a closed-form variance estimate (Engeman 2005), enabling valid statistical comparisons among index values. An indexing method successfully applied to a particular species should not be assumed appropriate for even similar species without prior field testing (Engeman 2005), hence the trials we report here.

METHODS

Study site

Our study was conducted on the Sanetti Plateau within the boundaries of the BMNP in South-central Ethiopia. Elevations range from 3800 to 4000 m on the Sanetti Plateau, which has the distinction of being the largest extent of Afro-alpine habitat in Africa. Heathlands (*Erica arborea* Linneaus, 1753 and *Erica trimera* Engler) form a dense belt around the lower perimeter, while upper elevations are dominated by short herbs and grasses, moorlands and rocky outcrops (Miehe & Miehe 1993). BMNP was created in 1974 primarily to protect a rich array of rare and endemic species, with special concern for the Ethiopian wolf and mountain nyala (*Tragelaphus buxtoni* Lydekker, 1910) (Waltermire 1974). During the time of the study, the Park held approximately 300 wolves, the largest concentration worldwide (EWCP 2004). The PTI was tested within the territory of the Quarry Pack (6°51'N, 39°51'E), named and intensively monitored by researchers from the EWCP. At the time of sampling, the Quarry Pack had 10 members: 1 adult female, 4 adult males, 1 subadult female and 4 pups (EWCP 2004). Their territory size was estimated to be 10.7 km^2. Observations by the EWCP team following our field sampling suggested that the pack might have been in the process of splitting into two packs of five.

Track data collection

The procedure entails placing tracking stations randomly throughout the area of interest along projected routes of travel of the target species. Using transects of tracking stations on dirt roads and tracks is an efficient sampling method (Pearson & Ruggiero 2003; Engeman & Evangelista 2006), and an effective means to intersect the daily activities of many canid species because of their usage of roads and tracks as travel routes. For our initial evaluation we felt it important to assess the PTI on dirt roads due to widespread success from using this placement for canids elsewhere. In January 2005 we placed tracking stations (n = 10) along a dirt two-track road at 0.5 km intervals. Plots were 1.5 m long, spanning the width of the tracks (approximately 3 m), and were raked and smoothed to produce a good tracking base. After 24 h, each station was examined for spoors, and resurfaced (tracks erased and soil smoothed) for the next day's observations. At each station, the number of intrusions (track sets) was recorded for each species observed. Each station was observed for 3 consecutive days.

Often, potentially continuous measures have been neglected in favor of binary observations (i.e. presence–absence measures at each station). Reduction of potentially continuous data to binary observations is easily demonstrated to have less descriptive ability and to result in a greater opportunity for erroneous inferences (Engeman *et al*. 1989). This principle has been well-demonstrated for tracking plot data (e.g. Allen *et al*. 1996, Engeman *et al*. 2000, Engeman *et al*. 2002, Blaum *et al*. 2008), whereby the number of intrusions into the plots is a much more sensitive measure of population than a binary measure.

A second plot placement tested in December 2005 was based on the observation that wolves use molerat mounds as primary places for hunting and lookout, making the mounds projected places for daily wolf activity. Therefore, we placed tracking stations on molerat mounds to intersect wolf activity. The molerat colony we selected had approximately 25 mounds distributed over a 0.75 km^2 area, and wolves were known to forage in the area on a regular basis. We randomly selected 5 molerat mounds as stations. Because molerat mounds can be fairly large (up to 25 m^2), we placed five 1 m^2 tracking plots around five randomly selected mounds, with each raked and smoothed to produce a good tracking base. After 24 h, all plots at each station (molerat mound) were examined for spoors and resurfaced for the next day's observations. At each plot on each mound, the number of intrusions was recorded for 3 consecutive days. We considered the molerat mound to be the experimental unit, and the total number of track intrusions each day into all plots on a mound to be the measurement for index calculations. However, having five plots/station also allowed us to analyze variance components to evaluate the relative importance of numbers of stations and numbers of plots within molerat mound stations.

Index calculations

The PTI and associated variance were calculated according to a general paradigm described by Engeman (2005). A linear model incorporating random effects (McLean *et al.* 1991; Wolfinger *et al.* 1991) described measurements at each station (mound) each day, with no assumptions of independence among stations (mounds) or days. The mean measurement across stations (mounds) was calculated for each day. The index values were the means of the daily means:

$$PTI = \frac{1}{d}\sum_{j=1}^{d}\frac{1}{s_j}\sum_{i=1}^{s_j} x_{ij},$$

where x_{ij} represents the number of track intrusions at the i^{th} station (mound) on the j^{th} day, d is the number of days of observation, and s_j is the number of stations (mounds) contributing data on the j^{th} day. SAS PROC VARCOMP, with restricted maximum likelihood estimation (SAS Institute 2004), was used to calculate the variance components (Searle *et al.* 1992) needed in the variance estimation formula (Engeman *et al.*; 1998 Engeman 2005):

$$\mathrm{var}(PTI) = \frac{\sigma_s^2}{d}\sum_{j=1}^{d}\frac{1}{s_j} + \frac{\sigma_d^2}{d} + \frac{\sigma_e^2}{d^2}\sum_{j=1}^{d}\frac{1}{s_j},$$

where the σ_s^2, σ_d^2 and σ_e^2 are, respectively, the components for station-to-station (mound-to-mound) variability, daily variability and random observational variability associated with each station (mound) each day.

RESULTS

Although we regularly observed wolves in the vicinity, we only recorded 4 Ethiopian wolf intrusions during 30 plot-days of observations on the dirt road, resulting in a PTI = 0.17 (standard error [SE = 0.09]). It is important to note that the 4 intrusions were in a direction that was perpendicular or diagonal to the dirt road. This indicated that the wolves were not typically using the roads as routes of travel, but were intersecting them incidentally in their travels. We also noted that the vegetation in the area was extremely low (<10 cm), implying there was little difference in effort required to travel cross-country or on the roads; therefore, cross-country travel might be preferred as it offers the most direct routes to foraging grounds, water and other daily destinations.

In contrast, when using molerat mounds for tracking station placement, 77 intrusions were recorded in 15 mound-days (Table 1) resulting in a PTI = 5.13 (SE = 0.99). Plot placement on molerat mounds appeared to well-intersect the activity patterns of Ethiopian wolves in the habitat typical of the Sanetti Plateau. We note that the index based on plot placement on molerat mounds is not comparable to the one based on road placement, because they were not sampling the same usage or activities, nor were they physically the same in design (Engeman 2005).

Variance component analyses indicate that variability among stations within mounds is low compared to random error. Therefore, fewer than 5 stations per mound would likely still be effective, while reducing labor for indexing wolves. Based on a variety of previous variance

Table 1 Track counts from Test 2 with passive tracking index stations placed on giant molerat mounds, where five 1-m^2 plots (a–e) were placed around each molerat mound

Molerat mound	Plot number	Day 1	Day 2	Day 3
1	1a	4	8	
	1b	2		
	1c			
	1d			
	1e			
2	2a	2	6	5
	2b			
	2c			
	2d			
	2e	3		
3	3a			2
	3b			
	3c			2
	3d			
	3e	3		
4	4a		2	
	4b			
	4c			
	4d		11	1
	4e	2		
5	5a			4
	5b	2		
	5c	2		3
	5d	4		
	5e	4	5	

component results (e.g. Engeman 2005; Engeman & Evangelista 2006; Engeman *et al*. 2000, 2002), we recommend using 2 stations per mound on opposite sides of the mound. Again, it should be noted that different design procedures produce different indices (Engeman 2005), making an index calculated using 5 stations per mound different from an index calculated using 2 stations per mound.

DISCUSSION

The PTI appears to have promise as a practical means for monitoring Ethiopian wolves, especially in populations where favored prey are concentrated in prime foraging patches. Species this rare, with fragmented populations vulnerable to acute and severe impacts from disease, require constant vigilance to determine if human intervention is necessary. It is important to note that the PTI is a tool that can be used for monitoring and detecting changes in wolf densities and movement patterns, and not for estimating total populations.

Results from the PTI test conducted on the dirt road were unable to adequately detect daily movement of Ethiopian wolves. The 4 intrusions recorded can be considered incidental because individuals were moving across the stations and not using the road as a route. While conducting this first test, we also observed one set of wolf tracks on day one and three sets on day 2 that crossed the road at different points between the established stations. We speculate that roads offer little, if any, in travel efficiency to Ethiopian wolves on the Sanetti Plateau, where vegetation height is generally low. Therefore, roads and tracks might not be opportune settings for intersecting animal activity in Afro-alpine environments.

As with monitoring canids with the PTI on other continents, the ability to predict routes of travel, or other areas of activity, results in efficient collection of data suitable for indexing particular species. On the Sanetti Plateau, placement of tracking stations on molerat mounds appears to be a practical choice for collection of tracking data. Areas with high densities of other rodent species are likely to provide additional opportunities for monitoring Ethiopian wolves. However, the ineffectiveness of road placement for tracking plots in this environment should not dissuade their placement on roads and trails in other environments. Other landscapes, such as the ericaceous belt found at lower elevations, are more difficult to travel, and wolves would be more likely to rely on roads, and delineated wildlife and livestock trails. For example, in the Galama Mountains, where *Erica* spp. cover nearly 90% of the massif, travel by Ethiopian wolves could be greatly facilitated by the use of roads and tracks, probably making them ideal for tracking plot placement. Of course, this placement design should be tested prior to operational implementation of an indexing/monitoring program (Engeman 2005).

Another advantage the PTI offers is that it can be easily used by wildlife managers and requires little expertise or equipment. This is especially important for wildlife management agencies that have few resources and limited budgets. For example, EWCP has fewer than 10 trained biologists responsible for all of Ethiopia's wildlife resources. Additional support in the field is available at local levels; however, these personnel generally lack adequate training to conduct in-depth surveys or analyses. Like most of Ethiopia's wildlife populations, the Ethiopian wolf is found in remote areas that are not easily accessible. As a result, most populations are not regularly monitored and wildlife managers must often rely on international research for support and information gathering. The PTI could potentially be applied by local field technicians for continual monitoring of the Ethiopian wolf and early warning of changes in population or behavior. An event such as a rabies outbreak could be detected in its early stages and wildlife biologists could be dispatched for intervention. This approach would not only enhance monitoring of Ethiopian wolf populations, but also provide a more efficient management strategy without the need for additional resources.

ACKNOWLEDGMENTS

The authors thank the Ethiopian Conservation Organization and Oromia Regional State for their guidance and support with this research. Additionally, we thank Jason Roussos and Ethiopian Rift Valley Safaris for logistical support; the staff of BMNP and EWCP for direction and advisement; and the Murelle Foundation and M. and R. Cabella for funding field expeditions. We also thank Dr Niels Blaum and an anonymous referee for helpful reviews and comments.

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