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HIROLA (*BEATRAGUS HUNTERI)* POPULATION STATUS AND DEPREDATION IMPACTS IN TSAVO EAST NATIONAL PARK, KENYA.

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L|IST OF ACRONYMS

IBCWC	Ishaq Bini Community Wildlife Conservancy
KWS	Kenya Wildlife Service
LWC	Lewa Wildlife Conservancy
NRT	Northern Rangelands Trust
ZSL	Zoological Society London

ABSTRACT

Hirola are the most critically endangered wild living ungulate in the world and are found in two populations in Kenya. Hirola are the last remaining survivor of the genus *Beatragus* and if they were to go extinct they would be the first mammalian genus extinction in Africa in modern human history.

Hirola natural range spreads from the east of Garissa to just west of the Kenyan coast and extends north into Somalia, although these populations are currently unstudied and there has been no reports of hirola in Somalia since the 1950's. In the past 40 years hirola have undergone massive population declines from over 14,000 to less than 300 individuals in the entire natural range. This has happened in conjunction with massive habitat loss, which may be the driving force behind recent population declines. Massive population declines occurred during the early 1980's after a rinderpest outbreak in the natural range. 1963 saw a small population of roughly 30 individuals translocated to an ex-situ site in Tsavo East National Park. This population was then added to in 1996 with a further 29 individuals, although since the second introduction the population in Tsavo East has not grown. There have been very few studies on hirola in Tsavo East and theories suggest that the lack of population growth stems from the high number of predators found within Tsavo East.

In order to understand the limiting factors preventing growth it was decided that this study should focus on predator selectivity in Tsavo East. Together with a population status survey to establish the Tsavo East population. By looking at selectivity one would be able to identify whether there is excessive pressure being exerted on hirola. It was decided that the best means of identifying predator preference would be through a scat analysis.

The population survey produced a minimum population estimate of 67 hirola in Tsavo East. This is an extremely low population and runs the risk of becoming close to localised extinction. The population demography also showed future population growth is under pressure, as there appears to be a shortage of sub-adult females, which will have negative impacts on recruitment rates.

Predator selectivity was not significantly shown although there appeared to be a preference for both lion and hyena to prey on warthog. This suggests that there is a crossover between these two in terms of prey species and could therefore, if they are preying on hirola at a higher rate at different times of the year, have significant impacts on the hirola population. The scat samples only produced one hirola kill which indicates that predation is taking place but does not demonstrate any selectivity.

Further protection in the form of a predator proof sanctuary with a breeding group is recommended as being the most advisable means of protecting the hirola population in Tsavo East.

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1. INTRODUCTION

1.1 Introduction to hirola

Hunter's antelope, or as it is more recently known hirola, (*Beatragus hunteri*) is a member of the family *Bovidae* and subfamily *Alcelachinae*. Hirola was first described in 1889 by Sclater as Hunter's hartebeest (*Damaliscus hunteri*) suggesting that it was a congener of topi and a member of the genus *Damalis* (Sclater, 1889). More recent studies, however, have shown that the hirola belongs to a genus of its own, which was given the name *Beatragus* (Kumamoto *et al*., 1996; Kingdon, 1997; Pitra *et al*., 1997; Estes, 1999). The name hirola is thought to have derived from the variously spelt Somali Galla tribal word "aroli", "arrola", "arawale" "herola", "arawla" and "carowla" and means "tawny" in reference to the general colour of hirola. H. Hunter first encountered the name when he came across the hirola on a hunting excursion along the Tana River (Sclater, 1889).

Historically hirola are known to have had a range that covered large areas of East Africa (Andanje, 2002) and probably extended from the Cape to the Horn of Africa (Bunderson, 1985) This range has decreased considerably over the millennia to the point where the species now occurs in just two small administrative districts in far eastern Kenya - restricted to a natural range that runs from South of Garissa town in Kenya to 30-50 km inland from the Kenyan coast, east of the Tana river to a northern limit just north of Kismayu west of the Juba river in Somalia. The entire range is about 20,000 square kilometres (Butynski 2000; Andanje 2002). This is assuming that hirola are still present in Somalia, which was noted to have declining population as early as the 1950's (Ward and Sorrell, 1950). Due to poor security in the area there have been very few studies conducted within the Somali range of the hirola since the report by Ward and Sorrell (1950). Insecurity has also limited the exposure of the Kenyan population to scientific studies. Hirola range appeared not to change in first 80 years since first described (Figure 1), although there has been reported range contraction starting approximately 40 years ago (Figure 2) due to increased human pressures through livestock and changing farming practises (Stewart and Stewart, 1963; Kingdon, 1982; Bunderson, 1985). The natural range prior to the 1960's was estimated at roughly 38,400km^2 in both Kenya and Somalia, with roughly 17,900km^2 of that being in Kenya. The Kenyan range has since decreased to an estimated 7,600km^2 in 1996 (Butynski, 2000).

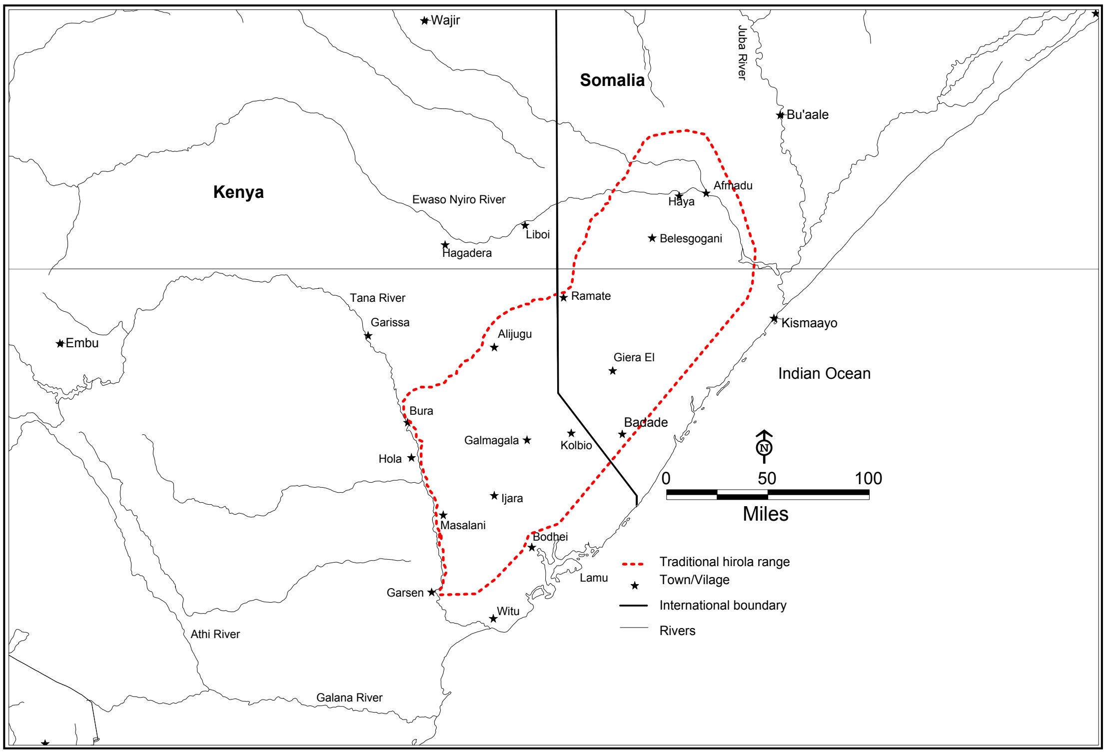


Figure 1. Map showing the range of hirola prior to the range constriction 40 years ago (adapted from Andanje, 2002).

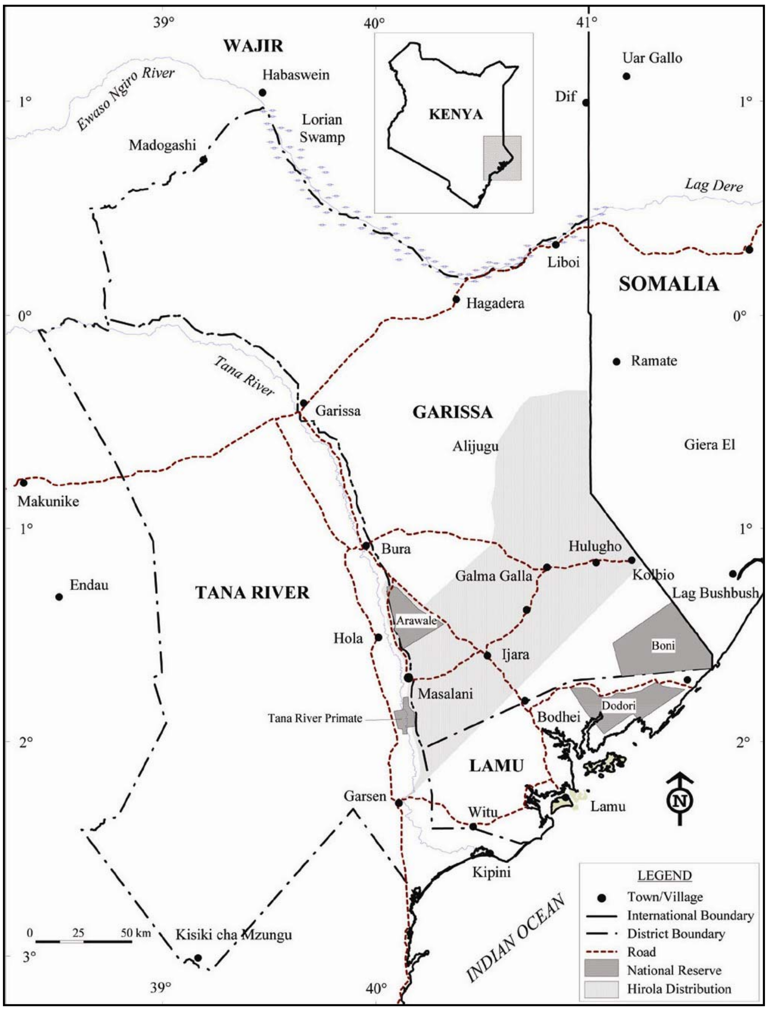


Figure 2. Map illustrating current natural hirola range. Note that no information is available on the Somali population range (Butynski, 2000).

Hirola range constriction has occurred alongside massive population declines, with the estimated population decreasing from roughly 14,000 in 1976 (Bunderson, 1976), to 2,500 in 1989 (Grunblatt *et a*l., 1989), to an estimated 300 in 1995 (Ottichilo *et al*., 1995) and the most recent count conducted within the natural range in Kenya found there to be 245 individuals (Northern Rangelands Trust). This combined with the estimated population within Tsavo East National park of 67 (KWS report and pers. obs.) brings the total numbers remaining in Kenya to be estimated as ~300 individuals. It is important to note that these estimates are extremely rough and the reliability is questionable due to detectability and therefore the need to clarify the status of these populations; this is especially true for the Tsavo East population and is an important objective of this study. According to these estimates hirola are the most endangered antelope in the world after the scimitar horned oryx, which is assumed to be extinct in the wild and in being the only surviving member of its genus the loss of hirola would represent the first mammalian genus extinction in Africa in modern human history (IUCN, 2008).

These decreases could have happened as a result of a number of drivers, although the exact driver is not fully understood. Population declines could be due to decreasing and degrading habitat, increased human-animal conflict through livestock and farming, disease, depredation and poaching (Ottichilo, 1995; Andanje and Ottichilo, 1999; Butynski, 2000; Andanje, 2002). Disease has been identified as being the biggest driver for the 1976-1989 population collapse as a rinderpest outbreak was documented in the area between 1983 and 1985 resulting in an 80% decrease in hirola (Butynski, 2000; Andanje, 2002; Kock *et al*, 2010) with a further outbreak occurring between 1993-1994 resulting in populations crashing by a further 80% from ~1,750 in 1993 to ~300 in 1995 (Kock *et al.,* 2010). It must also be noted that population estimates have varied considerably between studies and that reliability is an issue as a result of low detectability with hirola (Butynski, 2000; Andanje 2002). Estimates may also vary as a result of a number of factors including time of survey i.e. dry/wet season and before/after calving or survey methods (Butynski 2000; Andanje 2002). Regardless of these variations the overall trend has remained the same and shows dramatic decreases in population over the last 30 years. As a result hirola are currently listed as Critically Endangered (CR) on the IUCN Red List according to the criteria A2 (2011), and as a result of decreasing area of occupancy and habitat quality.

1.1.1 Tsavo East Sub-population

In 1963, it was noted that increasing pressures were being exerted on the natural hirola population, and although the population had not undergone the massive crash yet habitat restriction and human pressures forced scientists and the government to consider alternative measures (Grimwood, 1964). To mitigate for this an ex-situ sub-population was established in Tsavo East National Park using individuals from the lower Tana River region of the natural range (Grimwood, 1963, 1964; Andanje and Ottichilo, 1999; Andanje, 2002). The actual number of hirola translocated varies according to different sources, for example Andanje and Ottichilo (1999) suggest that less than 20 individuals were released, this estimate comes from the authors' conversations with P. Jenkins. Whilst Butynski (2000) has the number released as 30 and East (1998) suggests that a total of 14 were released. Irrespective of the actual numbers, a large proportion of those moved died due to muscle atrophy related to stress caused by transportation and capture, 29% (~15) of the animals captured died prior to release (Butynski 2000).

In 1996 following an aerial count on the natural range population showed a massive decline in numbers, a further 35 individuals were captured of which 6 died leaving a group of 29 that were transported to Tsavo East to supplement the individuals that survived the initial translocation (East, 1998; Andanje and Ottichilo, 1999; Butynski, 2000; Andanje, 2002). From those transported 12 died or were suspected to have died after the release (East, 1998). An intensive ground survey in 1995 by Andanje and Ottichilo (1999) found there to be at least 76 hirola in Tsavo East prior to the second release, this is a growth rate of 1.8 individuals per year (Andanje and Ottichilo, 1999). East (1998) has a similar population estimate, between 56-76, before the second translocation. East (1998) also proposes that the population increased to 93 immediately after the translocation and 100 individuals 2 years later in April 1998 (East, 1998). It is suggested by Andanje and Ottichilo (1999), and Andanje (2002) the ex-situ population again dropped to roughly 76 individuals.

Since translocation very little research has been conducted on the Tsavo East so there is very little known about the limiting factors that appear to be preventing population growth in this population. The frequency of sightings indicates that the population is low and the recent drought must have had an impact considering the impact on the other wildlife. It is predicted the hirola numbers in Tsavo could be as low as 50. This indicates the population has not grown to any degree since the mid 1990s despite the translocation and most likely declined. The reinforcement should have reduced the likelihood of inbreeding depression of the small founder population so the main reason for the lack of growth appears to be a combination of meat poaching and predation, especially by the robust lion population in Tsavo East National Park. It is therefore crucial to closely monitor the population and to identify the factors limiting the Tsavo population allowing protective and management programs to be put in place to mitigate against these threats particularly the establishment of a predator-proof fenced sanctuary.

1.2 Threats

1.2.1 Disease

There was a drastic decline in 1984-85 as a result of a major rinderpest outbreak which could well have been the single most important factor behind the hirola's decline against a backdrop of simultaneously falling livestock numbers (Woodford, 1984; Kock, 1995, 1996, 1997; Kock *et al.,* 1999). Coupled with a further but lesser outbreak in Tsavo East 1994-1995 (East, 1998), it is clear that disease will have played a major pressure preventing growth and actively causing declines

1.2.2 Habitat Change

The disappearance of elephants from the area was potentially another contributing factor. In the absence of dispersing elephants, which are major ecological drivers for grassland, bush encroachment on the hirola's natural habitat became widely spread (Wijngaarden, 1985). Habitat restrictions may also increase the risk of predation as hirola have a preference for short grasses and were often observed to be grazing in the same area on different occasions and are therefore predictable in their behaviour (Andanje, 2002).

1.2.3 Poaching

In addition, during the 1990s, there was an influx into the natural range of refugees fleeing civil conflict and persecution across the border in Somalia. This resulted in increased poaching of wild animals (hirola included) by armed fugitives and other groups (Butynski, 1999; East, 1999). There is also worrying reports by Andanje (1998, 1999, 2000) suggesting that high levels of poaching are taking place on by members of the Kenyan army, Kenyan administration police, armed home guard members and bandits (Butynski, 2000).

1.2.4 Drought

Periods of drought including the devastating one in 2008-2009 have caused significant declines of wildlife including hirola.

1.2.5 Predation

It is also likely that predation rates may be sufficient to suppress population growth in these remaining small populations.

1.3 Introduction to this study

Hirola although Kenya's most endangered ungulate and potentially the most endangered antelope in the world, is little known, both scientifically and to the general public. This is partly due to the hirola natural range lying within areas that are prone to civil unrest and insecurity, making it difficult to conduct long-term studies. A planned 3-year study by A. D. Graham in 1962 was cancelled due to civil unrest in the area (Grimwood 1963, 1964; Butynski, 2000). There was also further disruption to hirola conservation efforts in 1996 during the second translocation from Ijara when local community members were incited by local politicians into believing that the Hirola Task Force were spraying the communities with poisons and that they were stealing the hirola (Butynski, 2000). This was eventually overcome and the translocation went ahead but there were delays and changes in methods, which had negative effects on the number of translocated surviving (Andanje and Ottichilo, 1999; Butynski, 2000; Andanje, 2002; Kock *et al.*, 2010).

1.3.1 Predation

There is sufficient evidence to suggest that the hirola are very selective of their microhabitat (Andanje, 2002), preferring habitat consisting of shrubby grassland during dry periods and shifting to open grassland during wetter periods (Magin, 1996). Andanje (2002) found that hirola preferred short diverse grass in areas with plenty of shade, raised red soil patches with a large number of waterholes. Although this is not likely to be for the water as it appears hirola are capable of surviving drought periods by laying down fat avoiding energetic activity, and by resting during the heat of the day (Bunderson, 1985; Butynski 2000). It has also been suggested that hirola may be ecologically limited by habitat availability (Andanje, 2002). Habitat selectivity in hirola may inadvertently make them more vulnerable to predation as they appear to have core-feeding sites that they return to when conditions are preferential allowing ambush by predators such as lions who take advantage of the prey predictability (Estes. 1992; Andanje, 2002). This is especially true during dry seasons when other prey species may move away from the area to their dry season ranges (Andanje, 2002). The in-situ population is at risk from a number of predators including lion, spotted hyena, leopard, cheetah and more recently it is becoming apparent that hirola are being predated on by the growing number of wild dog in the area (Andanje, 2002; Gibbon, 2010). There are the same main predators, in Tsavo East affecting the ex-situ population, excluding wild dog, which are found further north in Tsavo East and are rarely spotted in the hirola range. The relatively large population of lion in Tsavo East are likely to be the biggest predation threat.

The proposition by Estes (1992) and Andanje (2002) about habitat selectivity and predation goes a long way to suggest that predation and habitat availability are together exerting significant pressures on a struggling species with a such a low number. Until recently there have been no studies of depredation impacts on the natural hirola population and no depredation study has been conducted in Tsavo East NP.

1.3.2 Monitoring

Hirola are extremely difficult to find due to their habits and the scrubland habitat in which they live in. The animals live in groups of females with their offspring, each accompanied by an adult male. These groups move over large ranges, sometimes up to 20 km^2. After spending a few days in one part of this range groups may suddenly move to another area. Young animals and bachelors, which live alone, are also difficult to locate due to their behaviour.

1.4 Aims and Objectives

This study aimed to test the primary null hypothesis that depredation within Tsavo East NP is non-selective, by testing whether predators preferentially prey on certain prey species over other prey species with particular interest being paid to hirola depredation. The output from this knowledge was ultimately to allow a better understanding of predator behaviour in Tsavo East and from that to understand what is restricting hirola within an environment that initially appeared to be a suitable. If there is evidence of high depredation on hirola as an important limiting factor, then a management option is to place a few groups of the population into a predator proof sanctuary to be used as a harvesting population to boost the free ranging population.
A secondary objective will be to establish a baseline on hirola status and group demographics of the Tsavo East population using a standardised approach for longer term monitoring.

2. BACKGROUND

2.1 Hirola

Following the release in 1963 there were no studies conducted on the Tsavo sub-population and as a result there is no record of how big the population was pre-1995

(Andanje and Ottichilo, 1999). The estimates for the founder population range between 11 and 20, it should also be noted that the literature suggests all those released into Tsavo were juveniles as it was noted that they had a better survival rate after capture (Grimwood 1964; Butynski 2000). It took another 30 years and a population crash from 14,000 to 300 individuals (Andanje and Ottichilo, 1999) in the natural population to bring about further scientific interest in the ex-situ sub-population.

Some studies have been conducted on the natural range population, but very few of these have been published. Ottichilo *et al*. (1995) and Ottichilo and Andanje (1997) are both unpublished Kenya Wildlife Service (KWS) reports that have contributed to the Hirola Evaluation Report (Butynski 2000). This report collated all the unpublished KWS reports and other less accessible magazine reports with published studies by Andanje and Ottichilo (1999) and other scientists. Butynski (2000) states that "the hirola have never been the subject of detailed study" and this lack of scientific knowledge has prevented accurate population estimates. The most detailed study has been by Andanje (2002), which was a PhD thesis looking at the limiting factors for hirola abundance and distribution. The thesis produced found that with regard to abundance, the in-situ population was found to be declining, whilst the ex-situ Tsavo population was found to be static during the study period. The implications of this are that the overall hirola population was in decline. Reasons for this decline were linked with habitat loss and encroachment in the for the in-situ population, whereas the main limiting factors for the Tsavo population are more complex and were found to be predation, food, amount of cover available for shade and the cover this would provide to avoid predation. These findings further indicate the potential importance of predation as a limiting factor for the ex-situ population.

Magin (1996) did a Population Viability Analysis (PVA), in which it was found that that the minimum viable founder population is 30 individuals, with a demographic bias towards females. Magin (1996) also proposes that the best option for the survival of the hirola is to reduce the high rate of juvenile mortality. Andanje (1997, 1997a) and Butynski (2000) provide evidence of high calf mortality as it was found that there was to be 40-50% calf mortality during the first 6 months of their life with this rate being especially high during the first month. Although high this mortality rate is not unique to hirola. Mortality for wild African antelopes observed under natural living conditions in open habitats have a calf mortality rate in the first year of 50% or more (Kingdon, 1982), when considering such a low ex-situ population this would be a significant limiting factor and therefore reducing mortality would be the most effective way to increase the population growth rate, particularly calf mortality. It is assumed by Butynski (2000) that these high mortality rates are down to depredation, and suggest that the number of calves killed by predators would be reduced by about 3-5 individuals per year if there were 30 hirola kept within a predator proof sanctuary (Butynski, 2000). Since Magin (1996) first proposed a predator proof sanctuary there has been no progress in Tsavo East. Plans have since been put in place and an environmental impact assessment has been conducted in order to build a predator proof sanctuary in its natural range (Ishaq Bini Community Wildlife Conservancy - IBCWC) (Craig; Ngene; Kock Pers. Coms.). The question as to why progress has been so slow in building a predator proof sanctuary is difficult to answer, although it is probably down to the high cost of building and maintaining a fenced sanctuary together with difficulties finding a location to fence off and restrict access to a site (Magin, 1996; Butynski, 2000).

2.2 Depredation

Although predation has been sighted as a limiting factor to population growth outside of disease periods (Andanje and Ottichilo, 1999; Butynski, 2000; Andanje, 2002) there have been no direct hirola predation studies or predator preferences studies undertaken in Tsavo East NP and only one unpublished study conducted in IBCWC (Gibbon, 2010). As a result there is a gap in scientific knowledge of predator impacts within Tsavo East NP. It could be that predators especially the robust lion population, are having a massive impact on the population of hirola and are preferentially targeting hirola. If this is the case then informed and targeted management action can be put in place.

An unpublished hirola depredation study was conducted on the natural range population, midway through 2010 by Northern Rangelands Trust (NRT). This study looked at scats collected by rangers within the Ishaq Bini Community Wildlife Conservancy, north of the Tana River. A total of 44 predator scats were collected and 12 community members interviewed (Gibbon, 2010). The study was conducted for 14 days during May 2010; this is at the end of the long rains in Kenya.

The study found 29 spotted hyena, 11 lion and 3 leopard scats, from which it was found that hirola made up 9.8%, 20% and 3.9% of the hairs removed from the scats respectively (Gibbon, 2010). The study suggests that hirola make up a fairly high proportion of predators diet in this area, however, this is not entirely accurate. Firstly as the study was only conducted over a 14-day period this is a snapshot look at depredation on hirola and will have temporal variability. Secondly the study has not taken into account the available prey density and biomass representation of hirola or that of the other prey species, this means that hirola could be over/under represented in the scats. What the study does prove is that hirola in Ishaq Bini are subject to depredation, the rate at which this is happening is not conclusive. It might also be significant to mention that this study followed a period of livestock grazing restrictions in the area put in place to for habitat recovery, which may be a contributing factor to the level of predation, as pastoralists are known to keep large predators away.

2.3 Prey preference

In order to understand the threat posed to hirola and other prey species by depredation, a basic understanding of predator behaviour is necessary. Predators appear to follow the optimal diet theory, which states that diet depends on encounter rates, profitability and variance of profitability of more profitable prey (Scheel, 1993). Scheel (1993) conducted a study on lions in the Serengeti national park in Tanzania, in which it was found that lions (*Pathera leo)* have a prey preference that is linked with encounter rates. It was also found that preference appears to change with seasons (Scheel, 1993), as animals migrate with the rain leaving different and potentially less abundant prey species within the lions' home range.

African lions have been found to prefer prey species that weigh between 190-550kg with the mode being 350kg and species outside this weight range are generally avoided (Hayward and Kerley, 2005). It appears that some species are taken because they are found in close proximity to lions although they are outside the weight range; warthog is a prime example of this having an average weight of about 72kg (Hayward and Kerley, 2005).

The spotted hyena (*Crocuta crocuta)* has previously been considered as a scavenger relying mostly on other predators to provide kills; this however is not the case. Hayward (2006) states that they are extremely efficient predators and have a prey size preference between 56-182kg with a mode of 102kg (Hayward, 2006). They are also said to hunt the most abundant prey species (Holekamp *et al*, 1997).

The same can be said for cheetah, although their prey size preference is considerably smaller, between 23-56kg (Hayward *et al*., 2006). It is also proposed by Hayward *et al.* (2006) that preference is defined by the frequency of a particular species killed being higher than the relative abundance and availability of that species, therefore by predating a relatively low abundance species more frequently than a species with a high relative abundance that predator is showing positive preference for the less abundant species.

Leopards (*Panthera pardus*) have the smallest prey size preference of the predator species found in Tsavo East, 10-40kg (Hayward *et al*., 2006a). Leopards also prefer to hunt in dense habitats where they can ambush their prey and thus reducing the risk of injury (Hayward *et al*., 2006a). They are therefore limited in the species that they can prey on as a number of antelope species, including hirola, and other herbivores prefer open grassland where they can be vigilant for predators (Estes, 1991).

Prey vulnerability to predation depends on a number of factors: its abundance, size, temporal and spatial distribution, defences and anti-predatory behaviour (Hayward and Kerley, 2005; Hayward, 2006). Success in hunting is also heavily dependant on environmental factors including bush cover, terrain, lunar activity and time of the day (Hayward and Kerley, 2005).

2.4 Predator diet

All the studies that were reviewed with regard to prey preference in African carnivores were built up from data collected by observing and following the predators while they hunted. This is both time consuming and potentially disruptive to the predator's behaviour, it is also very dependent on vegetation cover allowing clear observation of the kill (Klare *et al*., 2011). To counter these difficulties a different, non-disruptive technique has been developed. By extracting hairs from predator scat samples one is able to decipher what the predator has been consuming. The hairs are compared to known hairs taken from prey species within that area using a compound microscope (Mukherjee *et al*., 1994, 1994a; Melville *et al*., 2004; Klare *et al*., 2011).

2.5 Scat analysis

Klare *et al*. (2011) conducted a study looking at the best method to interpret data collected from scat analyses. The authors compared 50 papers, which used various interpretation methods in conjunction with trying out different methods on a large data set that they had collected themselves. It was found that the vast majority of papers used frequency of occurrence methods (94%), although it was concluded that these methods had the least ecological value and are only considered to have value with studying animals with a uniform diet e.g. carnivores (Klare *et al*., 2011). The method that the authors propose as having the best ecological value uses biomass calculations, however, of the papers they looked only 23% used these methods. The authors propose that frequency of occurrence methods cannot be used as the sole technique for establishing predator diet, especially when trying to estimate depredation impacts on an endangered prey species (Klare *et al*., 2011). The authors also propose scat composition analysis using quantitative methods, which can be used to find importance of different food components. This method takes mass and volume of the scat into consideration resulting in and estimate for biomass intake (Klare *et al*., 2011).

The methods proposed by Klare *et al*. (2011) as being the most valuable involve biomass calculations. One method that was studied is based on the number of prey individuals detected in the scat samples by removing bits of bone and teeth multiplied by the weight of the species (Klare *et al*., 2011). Although the actual method and reliability of this are questionable as it is difficult to accurately estimate how many individuals have been consumed by counting the number of bones or teeth extracted from the predator's scats. The authors propose that this method also tends to show a bias towards large prey species that will tend to have more body parts and their remains will often be found in multiple scats as they take longer to digest (Klare *et al*., 2011).

Floyd *et al*. (1978) and Ackermann *et al*. (1984) by contrast propose that larger prey is underrepresented in the faecal matter when using hair remains, as a greater proportion of the collectable scats were made up of the smaller prey species (Floyd *et al*., 1978; Ackermann *et al.*, 1984). This is because smaller prey species have a more hair per body unit weight than larger animals and therefore produce more scats per unit prey weight consumed. Biomass calculations based on feeding trials like the one conducted by Floyd *et al*. (1978) using linear regressions models tend to work better with medium and large prey species although when looking at omnivores or smaller carnivores with a more varied diet a correction factor must be included (Klare *et al*., 2011). Thus calculated frequency of occurrence does not adequately represent the proportion of different prey species consumed. To overcome this a regression equation developed by Ackerman *et al. (*1984) is used to relate the average live weight of prey animal consumed to the weight of that prey represented in one field collectable scat.

$$Y=1.980+00.35X$$

Where "Y"= prey biomass and "X"= the average live weight of prey species (Ackermann *et al*., 1984). Further to this feeding in the wild and feeding in captivity are often very different, there are more variables involved in wild feeding and it is often harder to establish predator sex and age (Klare *et al.,* 2011). Klare *et al*. (2011) also suggest that predator age and sex may have an impact on the digestive capabilities, they also propose that there may be a difference in the digestive tract of captive and wild animals.

When analysing wild predator scats a number of assumptions must be made both with regard to the prey and the predator species. By using the correction factor to estimate relative prey contribution the prey is assumed to be adult as the average adult weight is used in the calculation. Unless the prey individual was known to be juvenile in which case a corrected mass could be used. Predator age will also be assumed as it is difficult to ascertain the age of a predator from the scat size unless that particular individual was seen defecating, Klare *et al*. (2011) propose that if the age of the predator is unknown mistakes in the calculation can occur, as the size of the predator, which is linked with age, would effect the amount of food that the predator is capable of consuming and therefore the relative amount of the prey species found within the predator's scats.

Biomass calculation models are considered when using the computer program Scatman (Hines and Link, 1994) to establish the proportion of scat represented by each prey species present (Bagchi *et al*., 2003). Scatman tests prey selectivity based on random samples of predator scats by comparing prey availability to frequency in scat. The program runs a chi-squared goodness of fit test if population density and number of scats per kill are known, however this is generally not the case as population density is estimated and the number of scats per kill are variable causing an inflation in Type 1 error (registering a difference when in fact there is none), this is mitigated for by implementing a non-parametric bootstrap as suggested by Link and Karanth (1994). Scatman uses a list of prey species, list of estimated densities, standard error of estimate densities, scat production rates and scat production variability, it also allows the user to specify the number of bootstraps that should be run, Bagchi *et al*. (2003) chose to do 1000 iterations and Grey (2009) chose to do 200.

2.6 Study Area

The study was conducted in Tsavo East National Park in South East Kenya. Tsavo East NP covers an area of 13,000 km^2, between $2^o00'-3^o45'$S and $38^o30'-39^o15'$E. It is bordered by Tsavo West National Park to the west, Taita ranches and settlements to the south and southwest, Galana and Kulalu ranches to the east and Kitui to the north. Several areas along the park border are quite heavily populated by settlements (Kitui and Taita) and some stretches of the borders here are fenced to reduce human-animal conflict, whilst other parts are not fenced and allow free flowing movement of animals between ranches and the park.

Tsavo East NP has three main rivers flowing through it, the Tiva in the north, the Voi in the south and the Galana. The Tiva and Voi rivers are seasonal and rely on rains, whereas the Galana receives between 200-700mm of rain per year and is fed by the Tsavo and Athi, and is therefore permanent. For this reason the Galana functions as a reliable water source, particularly during the dry seasons when the other rivers and waterholes scattered around the park are dry. Tsavo East NP experiences two rainy seasons, the long rains between March/April to May and the short rains between November and December. Temperatures range from between maxima of 30^oC and minima of 20^oC. The park lies between 200 and 1000m above mean sea level, with open arid bush land being the predominant vegetation. This is made up of three communities: *Commiphora-Lannea*, found on well drained acid soil this is mostly found within the study area; *Commiphora-Acacia*, found on well to poorly drained soils that are non-saline and non-acidic; finally *Acacia-Schoenefeldia* on poorly drain alkaline and saline soils.

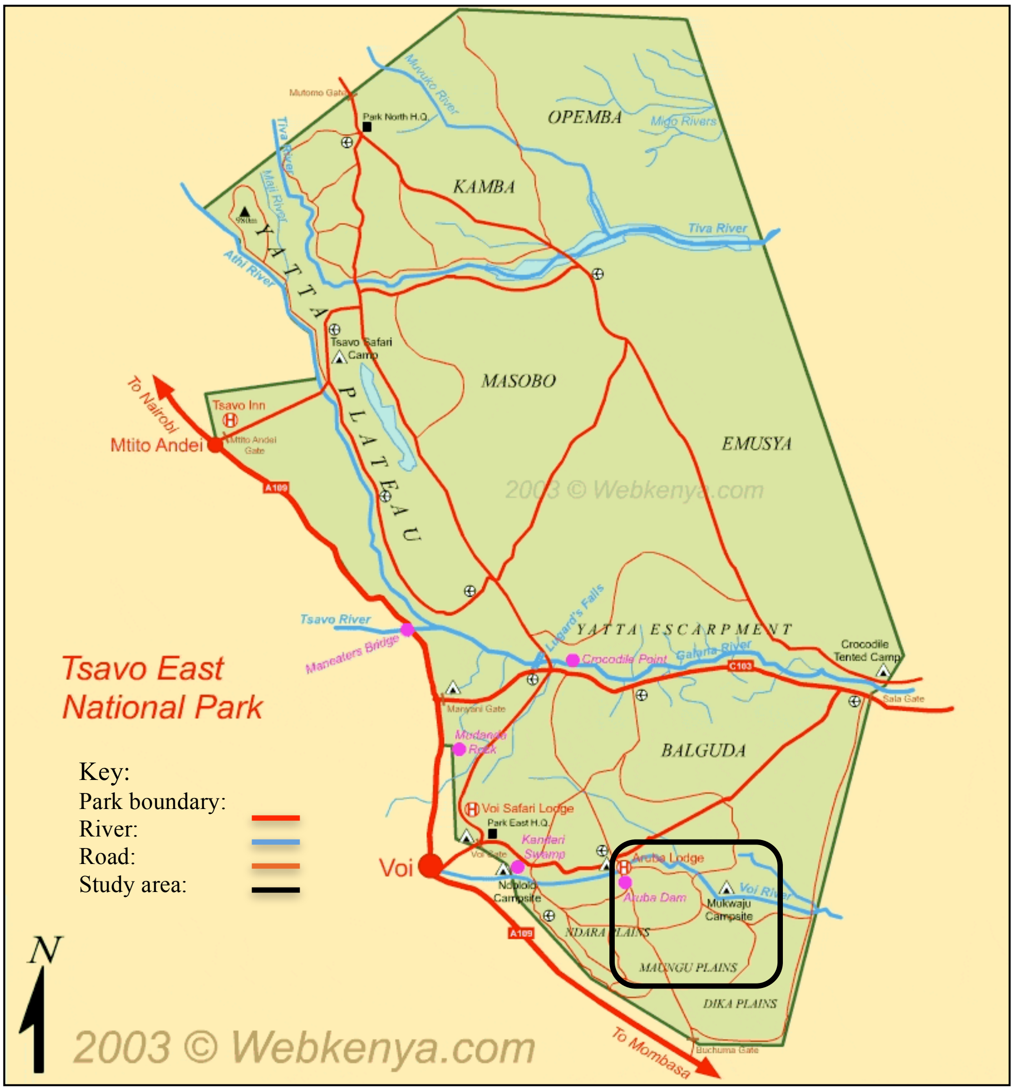


Figure 3. Map showing Tsavo East National Park with the study area highlighted in black. (Webkenya.com, 2003)

The study was conducted within a ~1,250km^2 area that straddled the Voi river, with the borders being 10km north of the river, 3km west of Aruba dam, 15km east of Satao camp and 20km south of Satao and Aruba. The vegetation in this area is predominantly from the community *Commiphora-Lannea*, and varies between open grassland and thick bush.

During dry seasons the Voi River does not flow and only contains water below the surface, some animals are able to access this by digging. There are natural waterholes at a density of ~ one per 10km2 (Wijngaarden, 1985) which hold water for several months into the dry season, and man-made boreholes that have been dug in the area to

provide water throughout the dry season. As a result the waterholes, dams and boreholes become a focal point for wildlife, for water and grazing (Andanje, 2002).
The most common wildlife species in the study area are African elephant (*Loxodonta Africana*) buffalo (*Syncerus caffer*), plains zebra (*Equus burchellii*), Kongoni or Coke's hartebeest (*Alcelaphus buselaphus*), Grant's gazelle (*Gazella grantii*), waterbuck (*Kobus ellipsiprimnus*), impala (*Aepyceros melampus*), hippopotamus (*Hippopotamus amphibius*), giraffe (*Giraffe camelopardalis*), lesser kudu (*Tragelaphus imberbis*), gerenuk (*Litocranius walleri*), warthog (*Phacochoerus aethiopicus*), fringe-eared oryx (*Oryx beisa callotis*) and eland (*Taurotragus oryx*). Carnivores include African lion (*Panthera leo*), spotted hyena (*Crocuta crocuta*), cheetah (*Acinonyx jubatus*), leopard (*Panthera pardus*) and black-backed jackal (*Canis mesomelas*).

3. METHODS

3.1 Hirola Survey

Ground and aerial surveys were conducted in order to locate and establish the Tsavo East hirola population status, population demography and distribution. Ideally the technique used would have followed that used by Andanje and Ottichilo (1999) and Andanje (2000), which involved an aerial survey followed by ground surveys to confirm the aerial sightings. However due to various circumstances, mentioned in the discussion, the aerial survey was delayed till the ground surveys and scat collection had been completed.

3.1.1 Hirola location

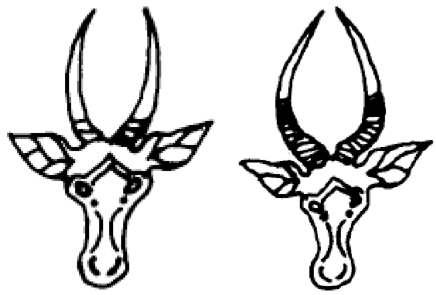
The ground surveys were conducted without the aid of an aerial survey, and following the technique used by Andanje (2000) for ground monitoring of hirola. This involved vehicle transects observing the area as far as one could see either side of the road. The vehicle used was a 2007 Toyota Landcruiser pickup. Existing road network within the known hirola range was used for the transects. Range data was established from previous hirola monitoring conducted by the Kenya Wildlife Service (KWS) research team. Transects were driven with 3 spotters and a driver, if a group of hirola were spotted the car would be driven closer for detailed observation and data recording. It was noticed during this surveying that large parts of the hirola range were not being covered To reduce the amount of area missed random transects were driven in straight lines between the roads, observing any wildlife activity which may be associated with hirola. If a group of animals were spotted that were potentially hirola a closer observation would be conducted before returning to the transect track and continuing. The information gained from this provided the knowledge about general hirola range, this therefore allowed identification of waterholes that would be surveyed during scat collection.

3.1.2 Data collection

On spotting a group closer observation was necessary to establish: group size, demographic, associated species and location was noted and the sighting marked in a Garmin 60CS Global Position System (GPS). The groups were named on the GPS according to the number of individuals in the group or by a distinguishing feature or location of the group. This information was acquired by observing the group closely for a period of time using Carl Zeiss 8x10 binoculars, this allowed accurate identification of sex and age from a distance without disturbing the group hence allowing sufficient time to observe and record the information. It was possible to identify the sex by noting genitalia, whilst age grouping was done by horn size and shape using an abbreviated classification of that put forward by Andanje (2002). A standardised four age class system was established: calf, juvenile, sub-adult and mature adult. Calves ranged from newborn up to three months and were identified by horn sizing up-to just protruding. Juveniles ranged from three-six months and had straight horns up to or just exceeding ear-length. Sub-adults ranged from 7 months to 2 years with horns were showing evidence of diverging and a distinct base angle beginning to show. Adults were anything above 2 years that showed a wide base and straight or nearly straight tips (Figure 4).

Calf (0-3 months)
Individual without horns or with horns just protruding.

Juvenile (4-6 months)
Individual with straight horns, up-to or just exceeding ear-length.



Sub-adult (7 months to 2 years)
Individual whose horn tips have started pointing inwards and widening from the centre and growing to form a clear oval (rugby ball) shape.

Mature adult (2 years +)
Individual with spread out mature shaped horns.

Figure 4. Drawings showing the age class used to distinguish individuals during this study.

As no hirola monitoring had happened for three months prior to our arrival in Tsavo East a random search was undertaken by following the road network transects at a random intensity. Once we had started spotting and identifying herds it became easier to relocate those groups by returning to and systematically searching those areas to obtain better quality sightings and data and also for understanding group ranging patterns.

3.2 Aerial survey

An aerial survey was conducted following the KWS protocol. The survey area was split into 5 blocks to allow for the most efficient flight pattern. The plane used was a two-seater Piper super-cub, allowing for a pilot and 1 spotter. The blocks were split into 500 metre transects which were either flown north to south or east-west depending on the shape of the block (Figure 5). The spotter was responsible for both spotting and recording hirola groups, whilst also marking the sighting on a GPS. These co-ordinates were transferred to a ground-based team who would go to the location to confirm sightings and corroborate numbers. Flights were conducted between 0600 and 1000 in the morning and 1530 till 1800 in the afternoon to allow for refuelling and during the hotter times of the day hirola are harder to spot as they seek shade. The survey was conducted over a four-day period from the 2nd till the 5 of July for a total of 20 hours covering 5 blocks totalling a combined area of ~3,000km^2. During the survey the following data were recorded: hirola numbers and associated species.

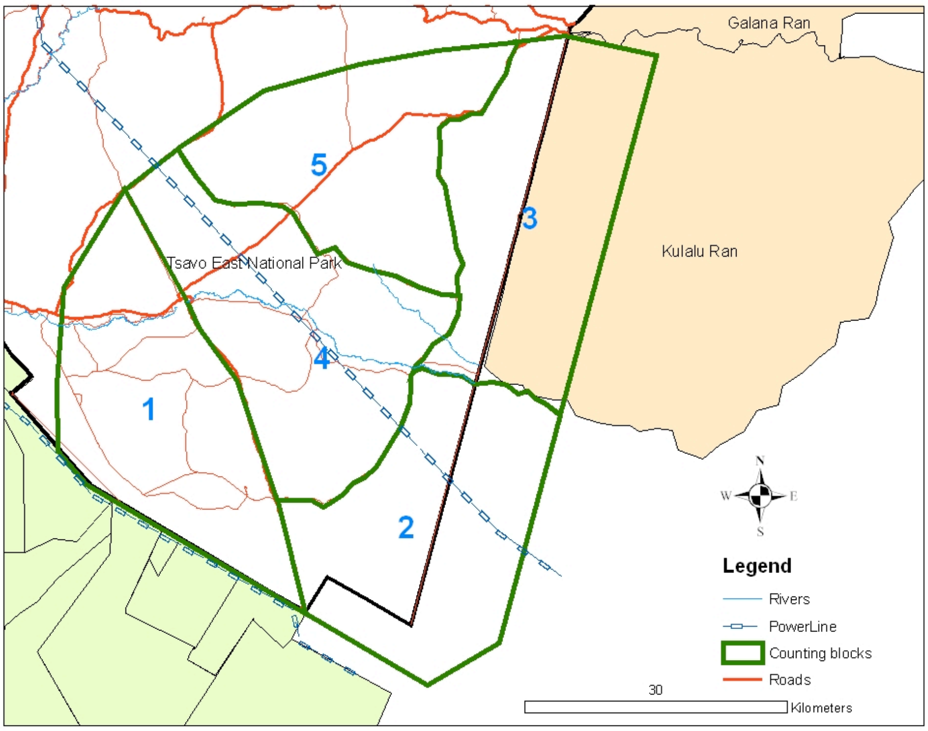


Figure 5. Map of Tsavo East showing the 5 aerial count blocks, the count covered roughly 3,000km^2 (KWS).

3.3 Scat Analysis

In order to know whether depredation is occurring one must see a kill and note down the prey and predator species, encounter an identifiable carcass or observe the remnants of a predators faeces (Grey, 2009). If one was to directly observe the hunting behaviour of predators it would be both time consuming and logistically difficult, this is especially true for areas where the surrounding bush is too thick to follow easily in a vehicle (Grey, 2009) and where one would also risk altering the behaviour of the predator. Carcass identification also requires one to know where the kill has occurred and assumes that there are remains of the carcass visible, which for smaller prey species is unlikely (Grey, 2009). A scat analysis on undigested hairs removed from the faeces is reliable, non-invasive to the predator and cheap, although it also involves locating kills, latrines (in the case of hyena) or dens. By conducting a predator scat analysis this study will be able to establish the prey species that make up the diet from predators within Tsavo East NP. The scat analysis would involve removing hairs from faeces either taken from around kills, dens, latrines and opportunistically. The hairs would then be mounted and compared to a reference library of know hairs (Mukherjee, 1994) from prey species found within Tsavo East NP. These data would be run through the computer program SCATMAN, which was developed by Hines and Link (1994), the program would determine the percentage of hairs present in proportion to the relevant total population of that particular prey species.

Predator prey preference can be determined using a number of techniques including direct depredation observation (Hayward *et al.,* 2006, 2006a), carcass observation (Ruggiero, 1991) and scat analysis (Mukherjee *et al.,* 1994, 1994a; Bagchi, 2003; Melville *et al.,* 2004; Grey, 2009; Klare *et al.,* 2011). Scat analysis was the technique used in this study to identify if predators in Tsavo East NP selectively preyed on certain species and what species those were with a particular focus on Hirola for informed decision making. The information gained from a scat analysis was used to fulfil the primary objective of this study.

3.4 Collection

It was decided that 60 scats per predator would be collected as proposed to be the minimum number of scats for effective scat analysis (Mukherjee *et al.,* 1994; Grey, 2009). Due to the unpredictable nature of animal defecation it is very difficult to know where and when the predators will deposit their faeces. Therefore three methods for scat collection were drawn up. The first involved searching waterholes within and near the historical hirola range. The second method involved locating kills and collecting scat from around the kills. The third method was opportunistic collection and collection from spotted hyena dens and latrines. All methods of collection followed the scat collection and analysis protocol developed by the Zoological Society of London (ZSL) and the Kenya Wildlife Service (KWS) and used by Grey (2009).

3.4.1 Waterhole surveys

This involved surveying waterholes that had been identified from previous studies and opportunistic surveys of those encountered during the hirola survey. These surveyed waterholes were those that contained water during the study period, this included those waterholes that filled up during the study period and dried up before the study had ended. A waterhole survey first involved observing the waterhole and surrounding areas for animals, the reasons for this was twofold, firstly it allowed to observe for hirola presence and secondly to ensure safety once outside the vehicle. Once it was clear there were no animals the waterhole was marked on a GPS using the prefix “WH” followed by a number “01”, “02”, “03” etc. This allowed for later identification of the location of scats found around a waterhole.

The first stage of the survey involved a walk around the immediate circumference of the waterhole, looking for any predator pugmarks and scats. Once this was complete, the paths coming into the waterhole were surveyed to a distance of 100 metres from the waterhole, measured using the GPS. Bushes and tufts of grass along the path were of particular interest. Scats encountered were collected and placed into a brown paper bag, marking the GPS co-ordinates, date, assumed species and distance from waterhole. Scats were kept dry in the bag and also to ensure they were not exposed to anything that may contaminate the samples.

3.4.2 Kills

Scat collection from kills involved a similar survey strategy. The kill itself was marked on the GPS and a number and name given with a naming protocol based on the area in which the kill was found and the species killed. The surrounding area was then carefully studied for predator scat, the base of bushes and tufts of grass again being closely searched. On finding a scat it was placed in a brown paper bag, which was marked with GPS co-ordinates, date, species and kill number. Some kills were visited more than once in case predators had visited the carcass again. Care was taken not to take the same scat sample twice.

3.4.3 Opportunistic collection

Scat samples were collected opportunistically throughout the time surveying for hirola and driving between waterholes. These types of collections were especially important for spotted hyena, which are known for their use of latrine areas, these are often located near their dens to allow them to communicate information (Stuart and Stuart, 1998; Breuer, 2005). Den locations were most often found by chance or from talking to tour drivers and guides. Every scat that was collected singly was placed in a paper bag and marked with the assumed species, GPS location and date.

The collected scats were then dried in the sun. All scats were noted on a scat collection sheet with the same information as on the paper bags: location, species and date collected.

3.4.4 Hair separation and treatment

Following techniques used by Grey (2009) using the same ZSL/KWS scat protocol, dried scats were soaked in warm water containing detergent and washed through fine mesh (1 - 3 mm) sieves. Remains such as bones, hooves and teeth were removed. Hairs were separated from the scats, and cleaned and degreased in tepid water containing detergent. The hairs were then rinsed in distilled water followed by ethanol using a fine-meshed sieve to transport the hairs from one bath to the next. Cross-contamination of samples was avoided by rinsing all equipment thoroughly between each sample.

3.4.5 Medulla and cortex slides

The reference hair library borrowed from Lewa Wildlife Conservancy (LWC) was built using an unknown mounting agent that had bubbled particularly badly in some slides and all reference slides were simple showing the hair intact. Therefore the best comparison was to observe the hairs using temporary slides, without being able to observe the cuticular scales or medulla in too much detail. Twenty hairs were randomly selected from each scat and placed five per slide under a cover slip and kerosene as a mounting agent. The hairs were then observed under a compound microscope at a magnification of 400x. The hairs were compared with the known hairs from the reference hair library by looking at the cortex and medulla patterns, thickness and the proportion of the hair that was made up of each. The reference library contained hairs for the following prey species found in Tsavo East: hirola (*Beatregus hunteri)*, warthog (*Phacochoerus aethiopicus*), giraffe (species was not made clear), lesser kudu (*Tragelaphus imberbis*), gerenuk (*Giraffe camelopardalis)*, waterbuck (*Kobus ellipsiprimnus*), topi (*Damaliscus korrigam jimela)* and dik dik. (*Madoqua sp.*). This means that impala (*Aepyceros melampus*), Grants gazelle (*Gazella grantii*), cokes hartebeest (kongoni) (*Alcelaphus buselaphus*), fringe-eared oryx (*Oryx beisa callotis*), African buffalo (*Syncerus caffer*), plains zebra (*Equus burchellii*) and eland (*Taurotragus oryx*) were not present in the reference library. If a hair was not similar to any of the reference hairs they were separated from the rest of the sample and named unknown 1,2 etc. These were later compared to hairs that were collected from the kills of known species or from the KWS animal orphanage in Nairobi, samples were found in such a way for impala, African buffalo, plains zebra, eland and kongoni. These hairs were prepared in the same way as the scat hairs and compared under the same magnification (400x). Fringe-eared oryx and Grants gazelle were left with no comparable hair samples.

3.4.6 Cuticle slides

For the hairs that were collected during the study period from kills and the animal orphanage cuticle slides were prepared as a reference. A thin layer of gelatin was spread onto a slide, into which 4 hairs were placed side by side. The hairs were then left to set for an hour after which each hair was removed using tweezers. This left an imprint of the hair cuticle in the gelatin, which was unique to each species. The unknown sample hairs were prepared in the same way to allow comparison with the known reference hairs. The cuticle imprints were compared under a microscope to observe similarities with the cuticle patterns.

3.4.7 Computerized hair library

As a result of the LWC hair library only allowing cuticular and limited clarity in a lot of slides, a colleague, Alex Betts, built a computerized hair library based at KWS for future use and to compare those hairs that were harder to identify. The reference library was constructed using hairs collected from the KWS orphanage and the hairs collected from kills, and included photographs of the more discernable parts of the LWC hairs. The hairs were photographed using the same compound microscope with a 400x USB digital microscope. Photographs were taken of the cortex and medulla, the cuticle scales and the root of the hairs wherever possible.

3.5 Statistical Analysis

Frequency of occurrence and percent occurrence were calculated to establish prey preference. Frequency of occurrence represents the proportion of total scats in which each prey species was found, whereas percent occurrence is the number of times a species is found as a percentage of total species items found. Prior to calculating frequency of occurrence those scats containing multiple species were split evenly, for example if a scat contained 2 species it was counted as 0.5, if it contained 3 they were each counted as 0.33.

As mentioned previously prey size can have an impact on frequency of occurrence as smaller prey can be overrepresented as they have a larger number of hairs per unit body weight than larger prey and will therefore be present in more scats per unit of prey weight consumed (Ackermann *et al*., 1984; Bonnin, 2008; Grey, 2009). To overcome this, the corrective regression equation developed by Ackermann *et al.* (1984) was used. The equation relates the average live weight of the prey species (X) and the relative contribution of prey species in one field collectable scat (Y):

$$Y = 1.980 + 0.0035X$$

This equation was originally developed for cougars (*Felis concolor*) so a number of assumptions are made about the digestive system of predators in Africa and although it has never been used on predators in East Africa it has been successfully used in studies on tigers (Karanth and Sunquist, 1995; Bonnin, 2008; Grey, 2009).
For this study the prey species' average weights were taken from Estes (1991) allowing the calculation of each relative contribution. From this the scat production, relative biomass and relative number of individuals killed were calculated.

3.5.1 Prey selectivity

Prey selectivity (preference) was calculated by comparing the observed number scats containing that prey species to the expected number of scat containing that prey species (Ackerman *et al.* 1984; Bagchi, 2003; Bonnin, 2008; Grey; 2009). Assuming no selectivity, the expected proportion of scats containing a particular species was calculated following techniques used by Karanth and Sunquist (1995) and Bagchi (2003) using the equation:

$$\pi_j = d_j \lambda_j / \Sigma d_j \lambda_j$$

Where *j* (prey species) has a population density d_j and λ_j is the average number of field collectable scats produced by the predator from that particular prey species *j* (λ_j

$= X/Y$ as calculated from the regression equation) as used by Ackermann *et al.* (1984), Hines and Link (1994) and Bagchi *et al.,* (2003).

To establish the expected proportions of prey species in the scats and run chi-squared goodness of fit to test the null hypothesis of no selectivity, the computer program SCATMAN (Hines and Link, 1994) was used. SCATMAN compares the prey species availability to frequency of that prey species in the scat; by using population density d_j of that prey species and the estimated number of scats per kill λ_j (Ackermann *et al.,* 1984; Bagchi *et al*., 2003; Grey, 2009). Density estimate standard errors were set at 50% as population estimates were from one single aerial survey with little ground confirmation. Seeing as variability in density estimates and number of scats produced per kill are generally quite high causing an increase in Type 1 error, SCATMAN mitigates this by includes built-in parametric bootstrapping as suggested by Link and Karanth (1994) Bagchi *et al.* (2003) and Grey (2009). Two hundred bootstrap iterations were consequently done on these data with a 40% coefficient of variation in scat production rates.

Prey species population density estimates attained from the actual numbers spotted from the hirola census were combined with other census data held by KWS on Tsavo East NP, to establish estimates for species that were not found in one of the surveys. Detectability is once again an issue here, seeing as there is a difficulty with detecting certain species and variable levels of detectability depending on vegetation cover. There was insufficient information on baboon densities as the surveys had located 44 individuals, this was known not to be true as a number of groups made up of around 30 individuals were seen around the park during the study period (pers. obs.). Baboon were included in the analysis as they are well represented in the scats, however, the results are not referred to as being scientifically relevant.

4. RESULTS

4.1 Hirola Survey

During the 27 days of ground surveying in Tsavo East NP a minimum total of 45 individuals in 7 groups were found. The group structure usually remained the same although there were instances where individuals joined a group on one day and left the following day. This made it quite difficult to accurately estimate the population and as a result the maximum population estimate from the ground survey is roughly 50 individuals.

The aerial survey detected 11 groups with a total of 76 individuals, however the ground team only confirmed 6 groups (47 individuals). Of these 6 groups 25 had been seen in the initial ground survey and a further 22 new individuals bringing the minimum population estimate to 67 individuals (Table 1). The age and sex structure of all the groups is summarised in Table 1. From these estimates the maximum density of hirola within the hirola range in Tsavo East is 0.025 hirola/km^2 and the minimum density is 0.022 hirola/km^2. The range for these calculations was based on the survey blocks (3,000km^2) used for the hirola aerial count conducted in July.

Table 1. Hirola group age and sex structure constructed from the confirmed sightings, using ground survey and aerial survey data combined (adapted from Probert, 2011)

Herd	Adults		Sub-adults		Juveniles		Calves	Total
	Males	Females	Males	Females	Males	Females		
3 Bachelors			3					3
Topi Herd	2	7			5			14
Airstrip Herd	1	4			2			7
Baby Herd	1	7			3		1	12
Timid Herd	1	4			1			6
Lone Male	1							1
Lone Females		2						2
Bachelor 2	6							6
Bachelor 3	2							2
Bachelor 4	1		3					4
Nursery 5	1	6			3			10
Total	16	30	6	0	14		1	67
	46		6		14		1	67

The group demographic appears to be heavily weighted towards adults with 69% (49) of the population being adult, 9% (6) sub-adults, 21% (14) juvenile and 1.5% (1) calves. Within the adults and sub-adults 58% (30) were females and 42% (22) were males. The most notable aspect of the hirola demographic is that there are only 5 breeding groups with only one calf.

4.2 Scat Analysis

At total of 63 scats were collected during the time in Tsavo East, of those 30 were from lion (*Panthera leo*) and 33 were from spotted hyena (*Crocuta crocuta*). 67% (22) of the spotted hyena scats contained a limited number of hairs as a result of damaged or old hairs that could not be identified and one of which contained no hairs. Two lion scats were found to contain large amounts of soil, and a number were liquid when first found, however, all these scats contained hairs.

4.2.1 Diet composition

In the lion scats six different prey species were identified from the thirty scats collected, these six species made up 77% (778) of the total hairs found in the scats. This means that a further 23% (237) of the hairs were unidentified. Of those hairs identified the species with the highest frequency of occurrence (proportion of total scats a prey item was found) was zebra (31.56%), followed by warthog (27.01%), buffalo (21.64%), eland (11.71%), baboon (6.29%) and the lowest frequency of occurrence was seen in hirola (1.79%). There was very little difference between percentage occurrence and frequency occurrence in all the prey species.

- African lion

Following calculation of the relative biomass killed by lion during the study period it can be seen that buffalo has the highest biomass killed (43.26%), followed by zebra (26.76%), whilst eland has become more apparent in the results with (17.59%) followed by warthog, and baboon and hirola have the least amount of biomass killed relative to the other prey species found in the scats (1.35% and 0.79% respectively).

Further analysis by comparing the amount of biomass killed with the amount of biomass available per species (X) shows warthog as having the greatest relative number of individuals killed (30.85%), then zebra (25.35%), baboon (17.24%), buffalo (15.26%), eland (8.52%) and again hirola the lowest (1.85%) (Table 2).

Table 2. Results for prey species found in lion scats (n = 30) showing the percentage of occurrence, frequency of occurrence and using the equation $D = ((A \times C)/\Sigma(A \times C)) \times 100$ to calculate the relative biomass killed as a percentage, and $E = ((B/D)/\Sigma(B/D)) \times 100$ to calculate the relative number of individuals killed.

Species	No of prey items	Percentage of occurrence	(A) Frequency occurrence	(B) Average Weight (X)	(C) Correction Factor (Y)	(D) Relative biomass killed (%)	(E) Relative no. of indiv. killed (%)
Baboon	3	7.14	6.29	17.5	2.59	1.35	17.24
Buffalo	9	21.43	21.64	631	24.07	43.26	15.26
Eland	5	11.90	11.71	460	18.08	17.59	8.52
HIROLA	1	2.38	1.79	95	5.31	0.79	1.85
Warthog	12	28.57	27.01	74	4.57	10.25	30.85
Zebra	12	28.57	31.56	235	10.21	26.76	25.35
Total	42	100	100			100	100

- *Spotted hyena*

The 32 spotted hyena scats found, produced more prey species than lion with nine different prey species being identified. These nine species made up 85.09% (428) of the total hairs found (507) with the remaining 14.91% (75) being unidentified. There was however fewer total hairs found than in the lion scats although there were two more scats.

When considered on a frequency of occurrence level (A) warthog appears to be the most popular prey species (28.95%), followed by zebra (20.82%), buffalo (19.11%), eland (10.60%), the remaining five prey species all have frequencies below 10% with the lowest being baboon (2.13%). Frequency of occurrence and percentage occurrence produced the same apparent prey preference, although with slightly lower percentages. This changes when the amount of biomass killed is considered as buffalo become the most prominent prey species (38.07%) followed by zebra (17.59%), Eland

(15.87%) then warthog (10.95%). Again the remaining prey species are below 10%, with the lowest being lesser kudu (1.45%).

Once the relative number of individuals killed is calculated by taking into account the amount of biomass available (X) warthog once again appear to be the favoured prey species (34.74%) followed by zebra (17.57%), buffalo (14.16%) and the lowest number of individuals killed being giraffe (2.55%) (Table 3).

Table 3. Results showing prey species found in spotted hyena scats (n = 32) and their frequency of occurrence, percentage of occurrence and by using the equations: $D=((A\times C)/\Sigma(A\times C))\times 100$ to calculate the relative biomass killed as a percentage, and $E=((B/D)/\Sigma(B/D))\times 100$ to calculate the relative number of individuals killed.

Species	No of scats	Percentage occurrence	(A) Frequency occurrence (%)	(B) Average Weight (X)	(C) Correction Factor (Y)	(D) Relative biomass killed (%)	(E) Relative no. of indiv. killed (%)
Baboon	1	1.67	2.13	17.5	2.59	0.46	6.13
Buffalo	10	16.66	19.11	631	24.07	38.07	14.16
Eland	7	11.67	10.60	460	18.08	15.87	8.10
Gerenuk	3	5.00	6.39	60	4.08	2.16	8.44
Giraffe	3	5.00	3.53	900	33.48	9.78	2.55
L. Kudu	2	3.33	3.53	85	4.96	1.45	4.00
Warthog	19	31.67	28.95	74	4.57	10.95	34.74
Waterbuck	3	5.00	4.94	200	8.98	3.67	4.31
Zebra	12	20.00	20.82	235	10.21	17.59	17.57
Totals	60	100	100			100	100

4.2.2 Prey Selectivity

The scat frequency of the prey species identified in the scats for each predator species and a combined scat frequency are presented in Table 4, together with the scat production estimates and the prey density estimates for each prey species based on the data gained from the hirola aerial survey in July.

Table 4. The scat frequency of each prey species in scats from lion (30), spotted hyena (32) and the two combined, the estimated number of scats produced per prey species calculated using the equation λj = X/Y. The estimated prey density and standard error of 50% due to the estimates coming from only one aerial survey.

Species	Scat frequency lion	Scat frequency spotted hyena	Combined scat frequency	Scat Production (λj = X/Y)	Prey density (individuals/km^2)	SE density
Baboon	1.16	0.5	1.66	6.75	0.02	0.01
Buffalo	3.99	4.49	8.48	26.22	0.25	0.13
Eland	2.16	2.49	4.65	25.44	0.27	0.14
Gerenuk	0	1.5	1.5	14.71	0.02	0.01
Giraffe	0	0.83	0.83	26.88	0.11	0.06
HIROLA	0.33	0	0.33	17.91	0.02	0.01
Lesser Kudu	0	0.83	0.83	17.15	0.01	0.01
Warthog	4.98	6.8	11.78	16.19	0.05	0.02
Waterbuck	0	1.16	1.16	22.27	0.02	0.01
Zebra	5.82	4.89	10.71	23.03	0.46	0.23

- African Lion

Estimates produced by SCATMAN suggest that there is selectivity on an individual basis for a couple of prey species. Lions appear to have significant selection towards warthog (p-values of <0.001) with predation happening at a higher rate than would be expected. Eland is observed significantly less than expected with a p-value of 0.0186, this is also true for zebra that had an observed frequency (5.82) lower than the expected (7.68) and a p-value of 0.0509. Of the other two species (excluding baboon) buffalo were preyed on at a slightly lower rate to that which would be expected of lion, however none of these differences are significant (buffalo p = 0.1194), and hirola have a very slightly lower observed frequency (0.33) compared to the expected frequency (0.67) and this is reflected in the p-value (0.6713) (Table 5).

Table 5. Results of lion prey selectivity using data from Table 3. Variability of scat production rate was set at 40% of the mean and bootstraps were set at 200 iterations.

Species	Observed	Expected	Chi-Squared	Unadjusted p-value	Adjusted p-value	Standard Error
Baboon	1.16	0.17	5.8302	0.016	0.0160	<0.001
Buffalo	3.99	8.22	2.9283	0.087	0.1194	0.0030
Eland	2.16	8.61	6.6156	0.010	0.0186	0.001
Hirola	0.33	0.67	0.1791	0.672	0.6713	0.0034
Warthog	4.98	1.01	15.9988	<0.001	<0.001	<0.001
Zebra	5.82	7.68	4.7425	0.029	0.0509	0.0019

- *Spotted hyena*

From these results spotted hyenas appear to significantly select for warthog (p = <0.001) with their observed scat frequency (6.8) being significantly higher than the expected frequency (0.66). A number of species, including buffalo and zebra were preyed on less than expected, however, these differences were not found to be significant (p= 0.6865 and 0.1365 respectively). Predation on lesser kudu was also found to be occurring at a higher rate than expected, although again the difference between observed (0.83) and expected (0.14) frequency was not significant (p = 0.0584) (Table 6).

Table 6. Results showing prey selectivity in spotted hyenas using data from Table 4. Scat production variability is set at 40% and the tests were run using 200 bootstraps iterations.

Species	Observed	Expected	Chi-Squared	Unadjusted p-value	Adjusted p-value	Standard Error
Baboon	0.5	0.08	2.1169	0.146	0.1454	0.0007
Buffalo	4.49	5.35	0.1803	0.671	0.6865	0.0039
Eland	2.49	5.61	2.2792	0.131	0.1571	0.0026
Gerenuk	1.5	0.24	6.673	0.010	0.0099	0.0001
Giraffe	0.83	2.41	1.1592	0.282	0.2938	0.0019
Lesser kudu	0.83	0.14	3.4246	0.064	0.0663	0.0004
Warthog	6.8	0.66	58.655	<0.001	<0.001	<0.001
Waterbuck	1.16	0.36	1.7704	0.183	0.1844	0.0009
Zebra	4.89	8.65	2.5894	0.108	0.1365	0.0026

When depredation by lion and spotted hyena is looked at as a whole, it is evident that these two predator species have a preference for warthog (p = <0.001) (Table 7). This is reflected in their individual choice as shown in Tables 5 and 6. It appears that there is also level of negative selectivity against zebra, eland and buffalo as their observed frequency was lower than the expected, although the difference was not significant (p = 0.2006, p = 0.0892 and p = 0.7483). It is clear from Table 7 that there is a prey species overlap between lion and spotted hyena of 50% (5), of these overlapping species one of them appear to be preferentially selected for (warthog p = <0.001).

Table 7. Results of the collated results for both lion and spotted hyena (62 scats), showing species that are preyed on by both species in *italics*. Scat production was again set at 40% and 200 bootstrap iterations were used.

Species	Observed	Expected	Chi-Squared	Unadjusted p-value	Adjusted p-value	Standard Error
Baboon	*1.66*	*0.19*	*15.804*	*<0.001*	*<0.001*	*<0.001*
Buffalo	*8.48*	*9.42*	*0.1228*	*0.726*	*0.7483*	*0.0043*
Eland	*4.65*	*9.87*	*3.6205*	*0.057*	*0.0892*	*0.0026*
Gerenuk	1.5	0.42	2.7687	0.096	0.0975	0.0005
Giraffe	0.83	4.25	3.0654	0.08	0.0954	0.0016
Hirola	0.33	0.51	0.0674	0.795	0.7927	0.004
Lesser Kudu	0.83	0.25	1.3878	0.239	0.244	0.0014
Warthog	*11.78*	*1.16*	*99.5625*	*<0.001*	*<0.001*	*<0.001*
Waterbuck	*1.16*	*0.64*	*0.4277*	*0.513*	*0.5147*	*0.0026*
Zebra	*10.71*	*15.22*	*2.1119*	*0.146*	*0.2006*	*0.0048*

5. DISCUSSION

5.1 Hirola Survey

The ground survey found a minimum count of 45 hirola in 6 groups. The group structure varied between herds with 12-14 individuals where there is a dominant male with a harem of females plus either calves of juveniles to individual males or bachelor herds. These herds sometimes changed in number as individuals joined or left. This often made it difficult to decide whether the herd was one previously identified or a completely new herd, which was exacerbated by the fact that the groups were often spotted in different parts of their home range. The topi herd were a good example of this as the group grew from 12 to 14 individuals overnight and remained that way for a couple of days and then two individuals left bringing the numbers back down to 12.

In this case identification was of the group was made by the association of single topi with a broken horn that was always found to be following this group, the demographic of this group was also known so helped identify them throughout.

Ground surveys conducted in Tsavo East are heavily effected by bush cover, a large proportion of the area being surveyed was thick shrub that was difficult to penetrate in a vehicle and difficult to see the proposed 200 metres. It was also noted that during the survey a road could be driven numerous times before any hirola were seen. One group was consistently seen within an 8 km stretch of that road suggesting that the hirola move a significant distance within their range depending on various environmental factors. It was also noted that a peak of hirola sightings occurred when elephant numbers were low in the area, although this may have been due to recent rainfall that resulted in new grass growth in the area and therefore the hirola are less likely to move on to new grazing areas. It is known from Andanje (2002) that hirola like to graze on new grass and will remain in one area if there are no disturbances and the grazing is good. Little is known about the size of hirola ranges and their habitat use within those ranges.

The majority of sightings were made either during the morning or in the evening although this is mostly due to the fact that this was when the surveys were conducted on the evidence provided by Andanje (2002) suggesting that hirola sought shade during the hotter hours of the day and would therefore be hard to spot. In fact the times when surveying was conducted mid-morning or driving during the midday a surprisingly large number of hirola were seen and their shade behaviour appeared to be minimal. The reasons for this could be that the time of year did not demand such shade behaviour, as the temperatures were not too high. Ultimately it was decided that morning and evening drives were the best option in the interests of both spotting hirola and running the vehicle on budget.

5.1.1 Population structure

The aerial survey, although delayed, produced a further 22 individuals on top of the 45 already spotted in ground survey. These were confirmed to be different groups from the ground survey ones by doing ground verification. A total of 11 groups were identified. The population demographic of these groups suggests a large proportion of the Tsavo East hirola are adult. There are 5 breeding groups and only 1 calf present. When considering that the peak birthing period is at the beginning of the short wet season in October and the calf mortality rate of 48.6% (Andanje 2002) the estimated juvenile population 7 months after the peak calving season from 30 adult females should be 14.58. The study located exactly 14 juveniles, as per the age classification in Figure 4, this is the same as the expected population assuming that each female has in fact had a calf. There is still a risk of the current juvenile population declining further as Butynski (2000) found that hirola had a juvenile mortality rate of 32% (4.48 out of 14), therefore the juvenile population in 6 months time could potentially be as low as 9 and the overall minimum population estimated as ~62. The calf population, although low, is not entirely unexpected as it reflects the calving season, which peaked 6 months prior to the study period. The high adult relative population suggests that there is either a high level of predation on juveniles and calves as is proposed by Andanje (1997; 1997a) or that the study was conducted in between breading seasons and therefore there were fewer juveniles and calves.

Another potential conservation concern is the lack of female sub-adults located during the study. It appears that there are no females in the current sub-adult population to replace the adult females that might be nearing the end of their lives. Coupled with a potential predicted future juvenile mortality of 32%. Long-term this is has potential decrease the recruitment rates, and therefore the overall population of the Tsavo East hirola. If this is to be avoided a plan must be put in place to reduce the mortality rate of the current population and any future calves. As Magin (1996) states, the best way to improve the recovery of a population is to reduce juvenile and calf mortality.

5.1.2 Previous monitoring

The aerial survey conducted following the ground survey was only the third population survey conducted on the Tsavo East hirola since their introduction in 1963. The first by Andanje and Ottichilo (1999) in 1996 estimated the population to be 76 individuals, again with a bias towards adults (60.53%). The second a few years later in 2000 was conducted by Andanje (2002) and found 77 individuals and 61.04% of those being adults. By looking at the estimates for the last 15 years one can see that the population estimates appear to have remained between 65 and 80 individuals, and although this is likely to be an undercount it is still an extremely low population.

5.1.3 Carrying capacity

When considering the raw and unverified data, the population estimates have apparently only varied by 1 individual over a 15-year period, this could raise a certain degree of scepticism about the technique involved and whether the estimate of 76±1 is a number that can be trusted. For a population estimate to change that little over a 15-year period, it could suggest that the population is at its carry capacity within Tsavo East. This would mean that Tsavo East can only support hirola at a density of 0.022 hirola/km^2, which is highly unlikely when considering the population density of associated species such as the Coke's hartebeest (Kongoni) of 0.34/km^2, zebra at 0.46/km, Grants gazelle at 0.29/km^2 and impala at 0.12/km^2 (July aerial survey data). This suggests that species similar to the hirola are capable of existing in far greater numbers than the hirola are presently.

Such low population densities suggest that there are limiting factors affecting all species in Tsavo East, these could be environmental, predation or a combination of both. There are a number of factors that would affect the population of ungulates in Tsavo East, most importantly food resources, habitat quality, weather, disease and predation (Gaillard *et al.,* 1998). All of which could be having a more pronounced impact on hirola than the other species as hirola have had an extremely low population in Tsavo East since the initial translocation. A small population is less like to be capable of coping with stochastic events or predation, as a loss of even 1 individual can have a large impact on the current populations and reduces the future population potential especially if it is a female.

5.1.4 Population status

Comparison of the July census population estimate of 67 with the previous estimate of 77 (Andanje 2002) shows a negative population growth rate of -0.9. This suggests that the population is decreasing at 0.9 individuals a year, which for such a small population is of extreme concern and requires correction as quickly as possible.

5.2 Scat analysis

Although it was initially planned to collect 60 scats per predator species as this is suggested as being the minimum sample size for scat analysis (Mukherjee *et al,* 1994; Grey, 2009) it was only possible to locate 30 scats for lion and 33 for hyena. This gives a total predator scat total of 63, which would satisfy this recommendation when looked at all together.

5.2.1 Diet composition

The frequency of occurrence, percentage of occurrence, biomass killed and relative number of individuals killed were calculated on an individual predator basis as it provides information on actual predation by lion and hyena during the study period.
Frequency of occurrence in lion scats suggests that predation is mostly on zebra (31.56%) followed by warthog (27.01%) and for hyena there appeared to be a preference for warthog (28.95%) followed by zebra (20.82%). These data need to be used with caution, as smaller prey species can be overrepresented in the scats due to the high proportion of hairs to biomass (Floyd *et al*., 1978; Ackermann *et al*., 1984). For this reason the correction factor proposed by Ackermann *et al.* (1984) was used .

Calculations using the correction factor and frequency of occurrence produced a more representative measure of biomass killed as a percentage. This appears to demonstrate a bias towards the larger animals as eland also show an increase in both lion and hyena (11.90%-17.59% and 10.60%-15.87% respectively).

Once the relative number of individuals killed as a percentage was calculated, the results gave a more representative view of predator diet, with warthog having the largest number of individuals killed by both lion and hyena (30.85% and 34.74% respectively) and zebra being the second most popular prey species killed by both lion and hyena (25.35% and 17.57% respectively).

5.2.2 Double pressure

These results demonstrate that the predators in Tsavo East apparently preferentially prey on the same two prey species. This is likely to create a large amount of pressure for these species, as there are considerably higher predator populations when two species are considered than there would be for a single predator species. It has been shown that predation can have large impacts on population structures for warthog and zebra (Sinclair, 1985), and although predation evidence is low on hirola the impacts of even a low level of predation might be profound.

Hirola is the lowest represented prey species with a relative number of individuals killed being 1.85% for lion and there were no hirola remains identified in hyena. Although this does not prove that predation on hirola is happening at a high rate and therefore a rate that is potentially limiting population numbers, it does prove scientifically that predation on hirola is occurring.

When considering the actual prey species killed and the number killed it is apparent that both lion and hyena kill more warthog than any other prey species. This is in support of evidence found in previous studies suggesting that lion will prey on warthog even though they are below the preferred prey size due to their sympatry with lions, they are relatively slow and have low levels of vigilance, are often found within the same area so are predictable in behaviour (Hayward and Kerley, 2005) and are more vulnerable to gregarious species as they live in small groups of singly (Støen and Wegge, 1996).

The high number of zebra killed by lion is expected as they are found within the preferred weight range of 190-550kg (Hayward and Kerley, 2005). Spotted hyena depredation on warthog at the levels indicated (34.74%) is more expected as warthog are found within the preferred weight range for hyena prey of 56-182kg (Hayward, 2006). Whereas zebra being the second most popular prey species in hyena diet is less expected. Zebra are well beyond the average prey size of hyena and this could therefore reflect the high level of zebra depredation by lion and be representative of the high level of zebra carrion present. Although there is an argument to suggest that these high results are due to the optimal diet theory, which states that diet depends on encounter rates, profitability and variation in profitability of more profitable prey (Scheel, 1993). Therefore, seeing as zebra have the highest prey density of 0.46/km^2 it would suggest a high encounter rate and consequently a higher predation rate. Zebra also exhibit less anti-predator and warthog than demonstrated by other prey species, antelope have horns or can run faster, whereas buffalo and eland require more effort to kill and due to their size and horns are high risk prey species.

Hirola are shown to have an extremely low number killed suggesting that the predator encounter rate with this species will be very low. Hirola have been described as being susceptible to predation as they are relatively slow compared to other species and have weak anti-predator behaviour (Andanje, 2002) suggesting that high levels of predation would be expected. A low encounter rate explains the lack of presence in the predator scats, although the fact that predation is happening means that it cannot be ruled out as being a limiting factor for the Tsavo East hirola population.

While the sample size for lion and hyena on their own was not sufficient to provide scientific proof of preference, it does prove that selectivity may exist through an apparent preference for warthog.

5.3 Prey selectivity

A further issue develops when dealing with prey selectivity, as it relies on accurate prey species density estimates and a number of the prey species had limited data for density estimates thus resulting in low expected values. As a result most of these species were discounted in the analysis although a couple were included out of interest but have no scientific value.

5.3.1 African lion

When considered with the diet composition data the prey selectivity data appears to support the theory that lion kill more warthog than any other prey species (p-value = <0.001). This reflects the high number of warthog killed as shown in diet composition, and this is likely to reflect the optimized diet theory. Other significant results for lion were eland (p=0.010) and zebra (p=0.29) both of which occurred at lower frequencies than expected. A lower observed frequency reflects selectivity against these two prey species, implying that lion choose not to predate on zebra and eland. This is likely to be due to herd behaviour that these two species exhibit. Both eland and zebra are in the stated preferred prey weight range and therefore are expected to be preferentially depredated. However, eland and zebra are often found in medium sized herds where it is harder for predators to single out an individual (Estes, 1991). Eland also have a remarkable ability to jump up to six feet in the air and are armed with sizeable spiral horns that can cause severe damage to any predator that might attack it (Estes, 1991). Zebra have fewer means of protection, however, they do tend to form herds and associate with other prey species (Estes, 1991), providing them greater protection from predators and a higher level of vigilance.

5.3.2 Spotted hyena

Hyenas are shown to have preferences for prey species between 56-182kg (Hayward 2006); thus implying that the largest species they would prey on through preference would be small antelope, gazelle and warthog. Gerenuks appear to be selectively predated by hyena, although the density estimates for this prey species are inaccurate and therefore this selectivity might have been influenced by these inaccuracies. Warthog show a much larger observed (6.8) frequency to the expected frequency

(0.66), which is shown to be a significant difference (p = <0.001). The population estimate for warthog is llow so may be inaccurate, therefore this result should be considered with caution. Although it does show that predation is happing on warthog at a high frequency in comparison to other prey species, the closest prey species frequency is zebra with an observed frequency of 4.89.

5.3.3 Combined

It has been suggested in the literature that an overlap of 58.6% of hyena prey species with lion prey is expected (Hayward, 2006), this is reflected in this study with an overlap of 66% (6 from 9). Hyena were also found to prey on a wider range of species with the sample being made up of 9 different prey species compared to 6 from the lion scats. The combined scat analysis had a sample size of 62 scats, which is above the recommended sample size for accurate scat analysis (Mukherjee *et al*., 1984). The only prey species that has a significantly higher observed scat frequency (11.78) compared with the expected frequency (1.16) in the combined scats is warthog. This produced a p-value of <0.001 suggesting that this result is highly significant and confirms that a large amount of positive selection occurs from predators in Tsavo East towards warthog. Warthog have less means of protecting themselves from predation, they are small animals that lack speed and are often found in small groups (Støen and Wegge 1996; Hayward and Kerley, 2006).

These results, although showing a certain degree of selectivity towards warthog by both lion and hyena, are not entirely reliable due to the sample size and duration of the study period, they do tenuously prove the primary null hypothesis of this study that predation in Tsavo is non-selective. The implications of this with regards to hirola appear to suggest that there is no selective predation on the hirola in Tsavo East. Even though this may be the case it is not in anyway proof that predation is not a serious danger to the ex-situ hirola population.

5.4 Limitations

As with any studies there were a few difficulties encountered during all stages, some of which it was not possible to overcome and others meant a change in method slightly.

5.4.1 Survey

Difficulties during data collection are often experienced especially when working overseas. The initial plan for this study was to conduct an aerial survey first, but due to various people being on leave and unforeseen absences due to work commitments those responsible for setting up the aerial survey were not in Voi on arrival. The reason for starting with the aerial survey was to allow location of all groups or as many groups as possible in the least amount of time providing a base level population and less time spent driving around searching, as had been done by Andanje and Ottichilo (1999) and Andanje (2002). Consequently the surveying took place in a vehicle.

Surveying from the vehicle is both costly and time consuming, and when coupled with there being no recent data on the whereabouts of hirola groups, without this or the aerial survey the ground surveying was initially conducted blind so took longer than expected. A reason for no hirola monitoring having taken place was to do with the fact that there is no research vehicle assigned to hirola monitoring in Tsavo East.

The study was short of transport around Tsavo East for duration of the study period, consequently a car was borrowed from Rod Evans, and used throughout. With the hirola population in Tsavo East being so low (67 confirmed sightings) there is a high risk that an isolated stochastic event or disease could have catastrophic impacts on the population and the research team in based in Voi would know nothing and therefore be unable to react. If monitoring is being conducted with three-month gaps of no activity, large scale deaths could go undetected long enough to cause irreparable damage to the Tsavo East subpopulation.

The aerial survey was finally conducted once the ground surveys and scat collection had been done. This meant that the results could not be used to access hirola groups.

The aerial survey itself was subject to a number of issues with methodology. It is well documented there is a fairly large amount of bias that results from aerial surveys and has been addressed in the literature (Caughley, 1974; Caughley *et al*., 1976). One bias that repeatedly appears in aerial survey is observer bias; it is not possible for observers to spot every animal that are on a transect so aerial counts are often undercounts (Caughley, 1974). There are also suggested differences noted when the experience levels of observers varies, with less experienced observers spotting 25% more than inexperienced observers (Caughley *et al*., 1976). Observer bias is made worse the fewer observers there are, if there is only one observer as was the case for the hirola census the survey is likely to miss large numbers of animals as one observer can realistically only focus on one side properly. In order to avoid such a high level of bias as would be encountered by one observer, multiple observers should be used. Although this still produces bias it is of a lesser level, which can only be overcome by calculating the exact bias. In order to calculate the exact bias an aerial survey should be done in a known area with a known animal population, this is then compared with the number found in an aerial count to give the bias. Once the bias is known a more accurate estimate of the unknown populations can be made. Such a technique should be adopted in Tsavo, not just for monitoring hirola but also for all aerial surveys conducted within that area. This should also be a technique adopted by the entire KWS airwing but would have to be calibrated for each survey area depending on vegetation cover.

5.4.2 Scat collection

There is little predictability in wild animal defecation and in order to encounter scats a large amount of luck and persistence was required. It became quickly apparent that scat collection from around waterholes was unlikely. Having surveyed 6 waterholes in two days and finding no scats it was decided that there focus should be directed at kill location and waterhole surveys should continue to be conducted opportunistically. Scat collection was a lot more time consuming than originally thought, ultimately this meant that the sample size was smaller than is proposed and desired.

To avoid this it would be better to conduct the study over a longer period of time. The short length of the study period also creates other issues as the results only reflect a snapshot view of predation during a 2-month period. This could easily be affected by rainfall and other environmental factors Variations are likely to occur with the reproductive cycles of prey species, as is suggested by Magin (1996) and Butynski (2000) that there is a high level of depredation on juveniles. This may result in higher predation during birthing seasons than the period between seasons. Hirola peak breeding seasons in Tsavo East are between October and November (Andanje, 2002), therefore during the study period, May-July, there would be fewer juveniles and calves available for predation. The effect of this is that there might appear to be a lower level of visible depredation during that time. Depredation on all prey species varies with seasons and is often related to the breeding success of those prey species (Hayward and Kerley, 2005; Hayward, 2006). This can therefore warp the results into appearing that the predators have a preference for a certain species, whereas the true preference is simply for the most common species during the two months of the study. This can be mitigated for by conducting a long term study that looks at the bigger picture of what the predators eat throughout the year varying with seasons and breeding success. To avoid this a long term depredation study should be conducted that looks continuously at depredation over a two year period, failing that a quarterly study that allows observation of depredation during the two wet seasons and during different periods of hirola reproductive cycles.

5.4.3 Scat analysis

The biggest issue with the scat analysis was the sample size, which at 34 scats for hyena and 30 scats for lion. This is smaller than the recommended sample size of over 60 as suggested in the literature (Mukherjee *et al.,* 1984).

The reference hair library that was borrowed from Lewa Wildlife Conservancy was built using very basic mounting techniques that limited the comparative ability to the scat sample hairs. Seven species found in Tsavo East were not represented in the library, five were located and reference samples built, however, 2 had no representative hairs throughout the study, so a number of hairs could not be identified. There were also a number of unidentified hairs as a result of damage and old age; this was especially true for hyena scats, which also appeared to have fewer total hairs than that found in lion scats.

5.5 Recommendations

5.5.1 Studied to extinction

It has been mentioned that a longer study period would allow for greater understanding of hirola behaviour, home ranges and the impact of predation. This, however, might all become irrelevant if the hirola are not afforded the necessary protection that they require and could run the risk of being studied into extinction, as emphasis might be placed on finding out more about the hirola rather than preventing further loss. The Tsavo East population is currently in a state of decline at a rate of -0.9 individuals a year, although this current decline is relatively slow it might soon reach a critical stage from which it will not be able to recover. More to the point this critical level is not know so may happen sooner than would usually be expected. This would result in the loss of an important population of hirola and the potential loss of ~20% of the global hirola population. In order for this population to be ensured survival it is recommended that conservation actions are put in place for the Tsavo population similar to those that are being initiated in Ishaq Bini CWC.

5.5.2 Monitoring and response

Although it has not been proven that depredation in Tsavo East is having a limiting effect on the population, it is still occurring. This supports evidence in Andanje (2002) who experienced actual predation events during his study. The fact that predation is happening is more relevant at this present time than the rate at which it is happening. The population is so low both in Tsavo and in the natural range that it is essential they be provided with as much protection as possible. It is also essential that monitoring on the Tsavo East population be increased and improved drastically. It is not entirely clear why there are not higher levels of monitoring or resources made available for the worlds most critically endangered antelope. A particular point of interest is the general census in February 2011, which appeared to only find 11 hirola throughout the whole of Tsavo East. Following this discovery there was no monitoring for three months, and this fact did not appear to instigate any investigations or any response.

5.5.3 Interspecific competition

Although there has been no research conducted on this topic in this study, it would be worthwhile considering the impacts of other ungulates on hirola population. Interspecific competition for fresh grasses will be relatively high in Tsavo as there is often limited grazing available especially during the dry seasons and other herbivores are found in greater numbers than hirola. A study looking at potential competition as a limiting factor might advise further conservation responses for a

5.5.4 Awareness

It was also noted that knowledge and awareness of hirola with tourists, park staff and tour drivers was extremely poor. The most recent piece of news on the plight of the hirola was published in the Nation Newspaper on the 1st of September 2011. The article is in reference to the sanctuary in Ishaq Bini WLC and throughout the document hirola are referred to as "hilora". This demonstrates the lack of awareness at every level in Kenya at present and should be something that needs to be addressed.

It is also recommended that an local and countrywide awareness campaign be run through the KWS to build up a public pride for the fact that they have the last living member of the genus *Beatragus*. At the very least it should be a requirement for guides and drivers to have a better understanding of wildlife conservation issues in Kenya. This could be integrated into the Kenya Professional Safari Guides Association (KPSGA) bronze-level membership test.

5.5.5 Sanctuary

For the above reasons it is strongly recommended that a breeding population of hirola be placed within a predator proof sanctuary as has been suggested in studies conducted on hirola over the years (Magin 1996; Andanje and Ottichilo, 1999; Butynski, 2000). In conjunction with and regardless of a predator proof sanctuary, increased and improved monitoring in Tsavo East is essential for the survival of this population. Added to this, the monitoring technique that was in place previously was insufficient and worryingly inconsistent. The most important factor that requires change in the monitoring of the Tsavo East hirola is increased frequency of surveys. Monitoring must be conducted on a weekly, or at the very least monthly basis to allow any potential issues to be spotted and systems be initiated early to mitigate these issues.

6. REFERENCES

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