HIROLA CONSERVATION PROJECT: HIGHLIGHT FROM THE FIRST FIELD SEASON IN 2011

ANNUAL PROGRESS REPORT TO THE HIROLA MANAGEMENT COMMITTEE AND IUCN/SSC ANTELOPE SPECIALIST GROUP

HIROLA CONSERVATION PROJECT
Organizations: University of Wyoming and National Museums of Kenya

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EXECUTIVE SUMMARY

This report covers the first 12 months of our four year (2011-2014) hirola research project in Ijara and Fafi Districts, Kenya. Our research forms the basis of Mr. Ali's PhD dissertation at the University of Wyoming and is focusing on hirola population dynamics, habitat use, and the effects of land-use change in northeastern Kenya for hirola. Additionally, we have worked with individuals in Ishaqbini Community Conservancy, and Arawale, Gababa, and Galmagalla communities to better understand local perceptions. These are knowledge gaps that have been consistently identified as research priorities for future hirola conservation since 2000. Hirola are the least known large mammals in Africa and, although they have never been common, they have dwindled in numbers from roughly 10,000 in 1970 to somewhere between 300-500 today. The reasons for these declines (and those preventing contemporary recovery) are mysterious; formal research in this geographic area has been logistically difficult given political unrest and tribalism. We suspect a combination of habitat degradation, competition with livestock, and disease are responsible for historic declines, with habitat degradation and predation combining to suppress contemporary populations. Through our ongoing work, we hope to quantify the relative importance of predation versus habitat quality in preventing the recovery of hirola populations. Here, we report preliminary findings from the first phase of the project, which will be submitted for publication in 2012. This initial phase of the project was valuable in 1) demonstrating that range contraction of hirola has coincided with an increase in woody cover in Ijara and Fafi Districts, Kenya; and 2) initiating long-term research in the hirola's geographic range to understand resource selection, demography, and distribution.

Additionally, we administered a structured questionnaire in Bura, Galmagalla, Gababa, Qotile, Hara and Masalani to gain better insight on the historical distribution of hirola in the region, attitudes toward hirola, threats to livestock from hirola, threats to hirola from people, and the future of wildlife in these areas.This effort used both field-based data and community meetings to meet its objectives. Preliminary results from this work suggests that communities are responsive and amenable to hirola conservation; increasingly, intensive livestock production is viewed as unsustainable and, already, locals have benefitted from employment associated with conservation efforts (both through this work and through Northern Rangelands Trust). Local scouts in Ishaqbini, Arawale and Gababa received onsite training in distance sampling, vegetation sampling, and wildlife monitoring as well as aspects of environmental education. In so doing, we facilitated community-wide consultation in several parts of the hirola's range.

We made contributed popular publications to several media outlets including Swara, AZA's Connect magazine, The Standard (one of Kenya's leading newspaper) and local FM radio stations in the region. In this regard, we have tried to raise awareness and promote better appreciation for hirola within Kenya and in the international community. Further, we suspect that increasing human/livestock populations, infrastructure development, expanding farmlands and quarry/sand harvesting activities in eastern Masalani are major threats to the persistence of hirola. Although they have been reduced in Ishaqbini, poaching continues to be a major threat in rest of the range especially in Arawale along the riverine farming communities. Outside Ishaqbini, the remaining groups of hirola are at the threshold of being lost if financial and technical support is not found and maintained. To ensure adequate conservation and buffer against future environmental stochasticity, viable, free-ranging populations must be established outside Ishaqbini;we should attempt to duplicate the success of Ishaqbini elsewhere in the native range.

1.0 BACKGROUND AND JUSTIFICATION

Sub-saharan Africa is a region with a staggering diversity of both wildlife and human cultures. This is especially so in arid pastoral systems, where livestock and people coexist with the most diverse array of wild ungulates on earth (Kock et al. 2002). In these ecosystems, ungulates exhibit strong seasonal variation in abundance and distribution as a consequence of variability in the availability of food and water (Sinclair, 1983). Both resources are driven partly by the erratic and unreliable rainfall characteristic of arid lands and, historically, rainfall-mediated changes in the abundance and distribution of resources drove the abundance and distribution of wildlife (Western, 1975). However, with an increase in sedentary pastoral practices, the influence of humans and their livestock often overrides such natural, historical drivers, leaving wildlife and livestock to vie for scarce resources (Colin et al. 2007).

The hirola (*Beatragus hunteri*) is the most endangered antelope in sub-Saharan Africa, and it is one of the most critically-endangered species of mammals worldwide (IUCN, 1996; IUCN, 2008). Indeed, the hirola was recently identified by the EDGE (Evolutionary Distinct and Globally Endangered; Isaac et al. 2007) project as one of the top-10 focal species at risk of imminent extinction, and thus in dire need of intensified conservation efforts in the immediate future. Historically, hirola probably were always rare within a restricted geographic range, being confined between the lower Tana River in eastern Kenya and the River Juba in southwestern Somalia (Bunderson, 1972; Kingdon, 1982). Although hirola have been legally protected in Kenya and Somalia since the 1970s, their numbers have declined by more than 80% since 1976 (Ottichilo et al. 1995; Magin, 1996; Butynski, 2000). Remaining populations occur almost solely on pastoral lands with no formal government protection, while the few conservation areas that do exist within the hirola's native range (e.g., the Arawale National Reserve and the eastern part of the Tana Primate National Reserve) lack adequate protection and attention from the international conservation community. Thus, ironically, the hirola ranks high as one of Africa's greatest conservation concerns, but public knowledge regarding its plight is almost entirely lacking outside of north-eastern Kenya. Through his Ph.D. research, Mr. Ali will quantify the interactions between hirola, humans, and their livestock to inform management and conservation efforts within both pastoral lands and the Ishaqbini Community Conservancy.

Despite chronic security threats, high abundances of wildlife persist in many areas of north-eastern Kenya, particularly arid and semi-arid areas with low human population densities. However, arid and semi-arid rangelands are notoriously sensitive to disturbance, and overgrazing by livestock is implicated in recent declines of wildlife populations. However, the mechanisms through which livestock lead to reduced populations of wildlife are unclear. A number of biologists have argued that food limitation resulting from competation with livestock is the primary factor underlying declines in hirola populations (Wargute & Aligula 1993; Wargute, 1994; Agatsiva, 1995; Margin, 1996; Dahiye, 1999; Andanje, 2002). Hirola populations have exhibited steady declines since the 1970s; these declines have coincided with 1) an increase in livestock numbers stemming from a shift from traditional Somali nomadism to sedentary pastoralism; 2) fire suppression; and 3) a 98% decline in elephant numbers throughout the geographic range of hirola in northeastern Kenya (Butynski, 2000; Fig 1); and 4) range degradation (e.g., tree encroachment) produced by a combination of 1-3 (Ali et al. 2012).

Hirola subsist almost entirely on grasses and understory forbs (Kingdon 1982); therefore, any factors shifting open, grass-dominated savanna to tree-encroached woodland have the potential to negatively impact hirola populations. Through interviews with local communities and aerial surveys conducted by the Kenya Wildlife Service (KWS) and Kenya's Department of Resource Surveys and Remote Sensing (DRSRS), we strongly suspect that tree encroachment throughout Ijara and Fafi has converted historically-open rangeland into dense woodland with little forage available for hirola or other wildlife. Thus, one of our objectives in this research centers on analyses of remotely-sensed imagery to disentangle if and the extent to which each of the above factors have contributed to long-term range degradation through tree encroachment throughout Ijara and Fafi Districts. Identifying the causal mechanism(s) responsible for tree encroachment will enable us to make informed management recommendations to HMC and KWS and Northern Rangelands Trust (NRT).

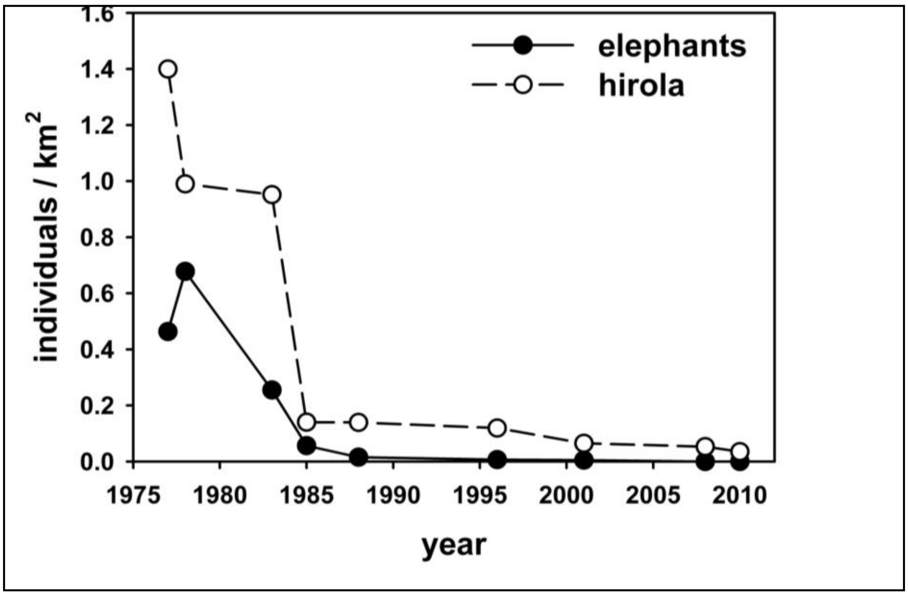

Figure 1: Population declines of hirola and elephants in Ijara District, Kenya.

Our recent analyses with AVHRR data (Fig. 2) demonstrate that the native range of the hirola has contracted with increasing tree cover in Ijara. Both fires and elephants reduce trees, and tree cover is negatively correlated with understory (i.e., hirola and livestock forage). Thus, while fire suppression or reductions in elephant numbers may have been responsible for triggering the declines in hirola populations, food limitation stemming from competition with livestock almost undoubtedly exacerbates this problem and is the most serious contemporary issue facing hirola today (Ali et al. 2012). While information critical to the conservation of hirola has been gathered over the past decade (e.g., Butynski, 2000), the few ecological studies conducted in the region have either targeted hirola in isolation, or have been restricted to opportunistic sample counts through aerial surveys (Dahiye and Aman, 2002; Andanje, 2000; Dahiye, 1999; Department of Resource Survey and Remote Sensing (DRSRS), 1997; Magin, 1996; Ottichilo et al. 1995). This information is key for monitoring long-term population trends (e.g. Ottichilo et al. 2000); however, it is difficult to understand the processes responsible for declines in hirola populations from aerial surveys. This study aims to 1) uncover the mechanisms underlying hirola declines; and 2) formulate conservation and management strategies that integrate local pastoral communities.

1.1 Study objectives

1) Investigate how overgrazing by livestock, fire suppression, and extirpation of the elephant population in Ijara and Fafi relates to hirola declines through tree encroachment.
2) Assess seasonality in hirola resource selection, spatial distribution, and movements.
3) Conduct population viability analyses (PVA) to assess the risk of extinction of hirola populations under various levels of predation and range quality.
4) Foster long-term conservation by involving local communities through education and outreach programs.
5) Make management recommendations to HMC,KWS, NRT and IUCN based on findings from Objectives 1-4

2.0 CAUSES AND CONSEQUENCES OF LANDSCAPE CHANGE

2.1. Hirola historic range collapse and range degradation

From analysis of remotely-sensed imagery and field vegetation surveys, we have been able to show how the hirola's geographic range collapsed over the past 30 years (Fig. 2). More importantly, we have shown hirola persist today only in areas of low tree cover (Fig. 2). Hirola lost much of their suitable habitat because of tree encroachment, and we suspect that this is due to fire suppression, elephant declines and severe range degradation (Fig.3)

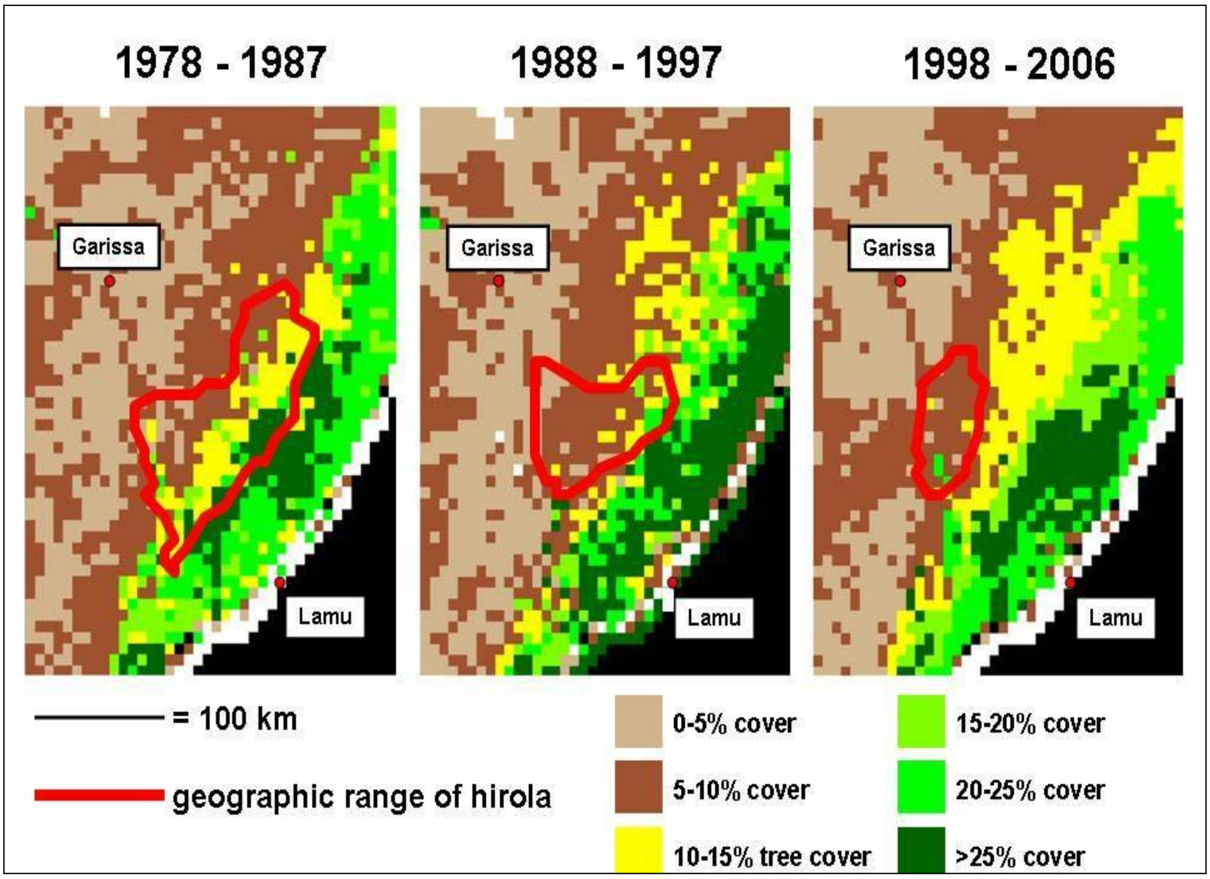

Figure 2: Changes in tree cover and hirola range size between 1978 and 2006.

Note that hirola persist mainly in areas of low tree cover (Fig.2). Advanced Very High Resolution Radiometer (AVHRR) data were acquired from the International Livestock Research Institute GIS database. Range maps were acquired from unpublished data from Department of Resource Surveys and Remote Sensing and the Kenya Wildlife Service.

2.2. Future plans: Causal factors underlying tree encroachment and range degradation

In 2012, we will contract the acquisition of high-resolution (60 cm) Quickbird satellite images (Digital Globe, Fort Collins, CO) across our study sites in Ijara and Fafi Districts. Images will be acquired in February at the peak of the dry season to reliably distinguish tree cover from understory. For each image, we will perform an unsupervised classification through isoclustering and maximum likelihood classification to group pixels with similar spectral reflectance. We will assign pixel groups into the following classes: 1) tree; 2) understory; 3) bareground; 4) recently burned; 5) settlement; and 6) water. We will then ground-truth classifications of pixel groups against each class in the field in 2012 by selecting 50-100 points in each class. In particular, we will ground-truth classifications against tree cover in 2011 by counting and recording every tree withn a series of 0.25 ha plots. We will record trees with a high-resolution global positioning system (GPS; Corvallis Microtechnologies, Corvallis, OR) with sub-meter accuracy. Then, we will correlate numbers of trees from ground surveys with tree cover from Quickbird classifications.

Following ground-truthing, we will train Landsat satellite imagery of Ijara and Fafi Districts against the Quickbird classification. Although Landsat images lack the resolution of Quickbird images, they are freely available from 1972 to present from the U.S. Geological Survey (http://eros.usgs.gov). Resolution of Landsat imagery tends to decline with older imagery; Landsat ETM+ (1999-present) consists of 15-60 m multispectral data, Landsat MSS (1982-present) consists of 30-120 m multispectral data, and Landsat TM (1972-1992) consists of 80 m multispectral data. Our classifications will effectively provide a 39-year time series (1972-2011) of changes in 1) tree cover; 2) understory (forage) abundance; and 3) fire history within Ijara and Fafi Districts. Thus, classifications of Landsat imagery potentially offer unprecedented opportunity to link hirola declines to habitat degradation via tree encroachment and loss of forage.

3.0 HIROLA RESOURCE SELECTION

While predation, disease, and poaching have been implicated in the decline of hirola (Wargute & Aligula, 1993; Wargute, 1994; Agatsiva, 1995; Margin, 1996; Dahiye, 1999; Andanje, 2002), it is difficult to imagine a scenario in which the above factors would initiate and sustain ongoing declines in hirola populations. On the other hand, there is abundant evidence that increasing pressure from humans and their livestock have coincided with, if not driven, hirola declines. For example, in 1976, the biomass density of cattle in southeastern Kenya ranged from about 16-350kg/km2, or 12 times the biomass density for hirola (Bunderson, 1981). Over the next 20 years, biomass density of cattle increased steadily while hirola declined, such that biomass density of cattle was more than 400 times that of hirola in 1996 (Butynski, 2000; Andanje, 2002). Cattle and hirola are both grazers that prefer areas of low woody cover and short grass, and cattle consume large amounts of forage that otherwise would have been available to wild herbivores such as hirola. In particular, competition is expected to be present during droughts when food is especially scarce (Bell, 1970; Sinclair, 1975; Bunderson, 1981; Butynski, 2000; Andanje, 2002).

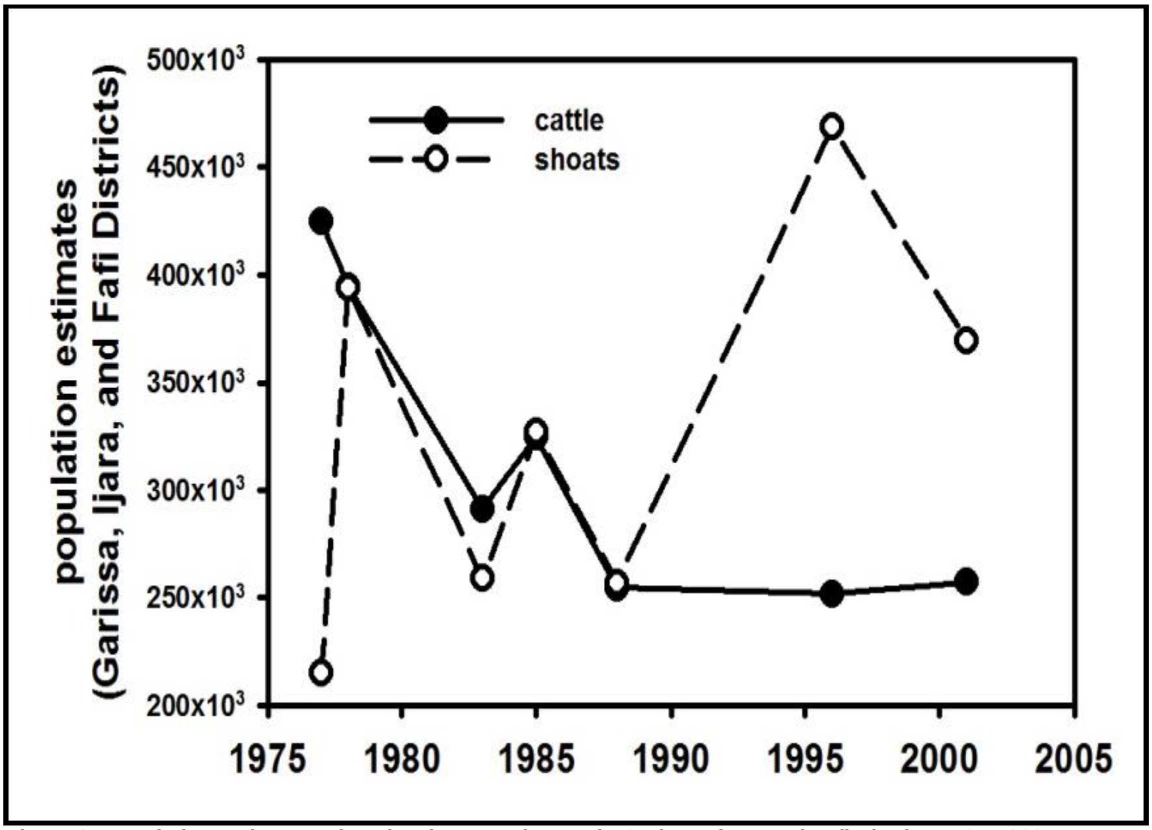

Figure 3: Population estimates of cattle, sheep, and goats in Garissa, Ijara, and Fafi Districts, 1977-2001.

In light of the landscape change we have documented, we suspect that hirola are faced with acute food limitation and habitat loss resulting from a combination of overgrazing, fire suppression, and extirpation of elephants particularly in more inland areas. As a response to these factors, hirola groups are moving southward into the open grasslands of Boni forest. However, prior to recent years, this area was avoided by hirola especially during the wet season. This avoidance may be due to tsetse flies (Plate 1), unpalatable tall tough grasslands as well as the availability of suitable dispersal sites in other areas. Today hirola groups have either been largely displaced from major seasonal dispersal areas such as Galmagala, Dagega, Hulugho and Sangailu; these are areas currently hold a very small and highly fragmented groups. These areas comprise of arid Acacia/Commiphora and Acacia/ Grewia bushlands and grasslands (the Somali Acacia-Commiphora bushlands) and although severly degreded remain the most crucial hirola habitats for longterm survival.

The southern portion of the range including Ishaqbini Community Conservancy and the edges of the Boni forest today hold the highest concentration of groups in the entire range (King et al. 2011). The persistence of these groups could have been facilitated by numbers of factors including the absence of heavy pastoralism (kept away tsetse flies) and availability of pasture throughout the year in these transitional ecotones. Hirola groups are persistently often sighted at the edge of the forest undoubtedly consuming unfavorable tall tough grasslands. The Boni forest and its environs comprise of a mosaic of dense coastal thickets, palm woodlands and edaphic grasslands (corresponding to the northern Zanzibar-Inhambane terrestrial eco-region Burgess & Clarke 2000) and densely inhabited by at least three tsetse species (*Glossina palpalis*, *G. brevipalpis* , *G. austeni*). It will be intresting to document how hirola adjust resource selection between the dry the Somali-Acacia-Commiphora bushlands (where tsetse are almost absent, pasture is more seasonal and influenced by more extreme seasonal variation in climate and the ecotones with high seasonal humidity and moderate to high average temperatures year round.

Plate 1: Common tsetse fly (Glossina spp.) in Ishaqbini Community Conservancy.

Although, it has been in the past suggested that hirola range is limited by trypanosomiasis to the south (Bunderson, 1976), it is most likely that hirola are immune to trypanosomiasis and that it is likely that combination of habitat unsuitability and tsetseflies nuisance limiting the southern boundary of the range. The persistence of hirola groups in these areas despite high level of ticks and tsetse flies coupled with unfavorable habitat could be an indication of further range collapse. Even in an ectone habitats like Ishaqbini and the boundaries of Boni forest, hirola seem to be selecting open bush grassland and lush savanna areas. In particular and especially during the dry season, hirola seem to prefer seasonally flooded lowlands and ditches dominated by tall tough green grasses such *Echinochloa haploclada*, *Oryza punctata*, and *Sporobolus helvolus*.

Plate 2: Seasonally flooded ditches dominated by Echinochloa and Oryza spp. preferred by hirola.

These are uncharacteristic of hirola that are known to prefer to short green grasses (Andanje et al. 1999), thought to be maintained by the combination of grazing by wildlife and domestic livestock and fire (Bunderson 1976). Such a combination of grazing and fire is typical range management employed by Somalis outside Ishaqbini in Qotile (Plate 3). Recently communities have illegally burned some part of Ishaqbini Community Conservancy in anticipation of the approaching rainy season but paid heavy fines as this is not allowed activity within the Conservancy. In the coming years, it will be interesting to see if and how

Ishaqbini landscape responds as both livestock and fire have been removed. Away from these lowland ditches and more inland into the Acacia-Grewia bushlands, hirola prefer grasslands dominated by *Brachiaria leersioides, Chloris roxburgiana, Chloris mossambicensis, Dactyloctenium aegyptium, Schoenefedia transiens, Tetrapogon bidentatus* and *Cenchrus ciliaris.* The spatial and seasonal variation in resource selection of hirola will be detailed in our next progress report in 2013.

Plate 3: Cattle grazing and community control burns in Qotile area near Ishaqbini Community Conservancy

It is important to note that other grasses, such as *Chloris* and *Cenchrus*, are still present in low densities across the native range of hirola. In addition, grasses such as Drake-*brockmania somalensis and Eragrostis aethiopica* (Plate 5) also occur in Ishaqbini, and are largely avoided by hirola, other wildlife, and livestock. Large fields of dead foliage of these grassess (Plate 4) is abundant within the conservancy and even in the rest of the range as clear indication of range degredation.

Plate 4*: Dead foliage of Drake-brockmania somalensis in Ishaqbini Community Conservancy.*

Hirola often are found in close proximity to other wildlife such as plains zebra (*Equus quagga burchellii*), gerenuk (*Litocranius walleri*), topi (*Damaliscus lunatus*), and oryx *(Oryx beisa).* They avoid close association with domestic cattle, perhaps indicating intra/interspecific competition.

Plate 5: ***Hirola grazing with zebra and topi within Ishaqbini Community Conservancy.***

We have sampled herbaceous and woody cover in areas with major concentrations of hirola within Ishaqbini and Arawale. We used a 10-point pin frame (Plate 6) to assess understory composition of herbaceous plants associated with each hirola herd. Frames were placed in the middle of each plot and the number of individual green leaves hitting the pins counted. We are using compositional analysis (Aebischer et al. 1993) to quantify hirola resource selection. A manuscript on hirola resource selection is underway which will be submitted to *Journal of Applied Ecology or Ecological applications* in 2013.

Plate 6: ***Our research team and local scouts sampling the herbaceous vegetation inside Ishaqbini Community Conservancy.***

In conjunction with our work, we collected herbaceous and woody vegetation in these areas and could make available a reference collection within Ishaqbini Community Conservancy in the future (see Appendix 3 and Plate 17).

4.0 HIROLA DEMOGRAPHY, POPULATION VIABILITY ANALYSIS, AND RISK OF EXTINCTION

4.1 Ground surveys

We initially proposed to work across the entire range and cover areas such as Arawale, Gababa, Galmagalla Garaswno,Hulugho and Sangailu. As shown by both the recent NRT/KWS aerial survey and our ground surveys, we found hirola numbers to be extremely low in Arawale, Gababa and Galmagalla; locating herds proved to be extremely difficult, time consuming, and expensive. Therefore, we restricted the collection of demographic data to Ishaqbini Community Conservancy, which houses the greatest concentration of hirola in their remaining range (130-150 individuals). We therefore established 12 lines transects of 2-3km each within Ishaqbini Community Conservancy (Plate 7).

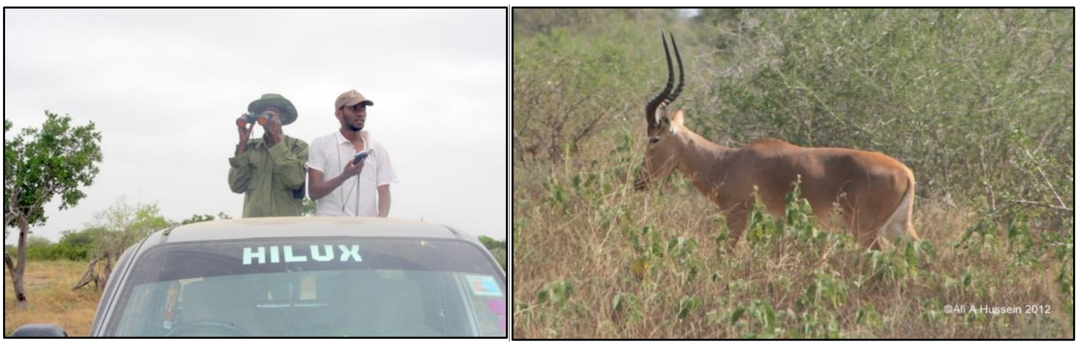

Plate 7: ***Local scout and Mr. Ali on routine distance sampling exercise within Ishaqbini Community Conservancy.***

We are using distance sampling (Buckland et al. 2000) to enumerate population densities of hirola and other large mammals in the area (Plate 9). We are estimating abundances of hirola and other wild ungulates using Program Distance (Buckland et al. 2001). We are using abundance and age-structure data to build projection matrices for hirola. These matrices will be used to perform population viability analyses (PVA) for each population of hirola as a function of predators, livestock, and tree abundance. PVA is a powerful tool to compare among relative risks of extinctions for multiple populations, and for identifying key life stages (i.e., calves, juveniles, or adults) to target in conservation efforts (Morris and Doak, 2002). Our transects are inaccessible by car and are traversed on foot every end of month. A manuscript on population estimates and structure of the Ishaqbini large mammals is underway which will be submitted to *African Journal of Ecology* in 2013.

Plate 8: ***Some of the other large mammals in Ishaqbini Community Conservancy***

4.2 Population viability analysis, and risk of extinction

Along with the translocation effort into the predator-proof sanctuary and in conjunction with distance sampling, we will conduct mark-resight and sight-resight analyses on adult female hirola (the demographic class most responsible for driving population change). This work will commence in September 2012. We will target herds under three scenarios:

1) INSIDE SANCTUARY, INSIDE ISHAQBINI characterized by low livestock grazing (equating to high range quality) + low predation
2) OUTSIDE SANCTUARY, INSIDE ISHAQBINI characterized by low livestock grazing (equating to high range quality range quality) + high predation
3) OUTSIDE SANCTUARY, OUTSIDE ISHAQBINI characterized by high livestock grazing (equating to low range quality) + low predation

Scenario 1 involves the translocation of 60-70 hirola from the outskirts of Boni Forest (roughly 30 km to the east) into the predator-proof sanctuary within Ishaqbini. This effort is underway and will occur sometime between June and August 2012. During processing, capture technicians will fix uniquely-numbered ear tags to individuals to aid in future identification. We intend to obtain blood samples to evaluate serum chemistry and pregnancy hormones. Animals within this sanctuary will be protected from predators and will experience high-quality range stemming from the absence of cattle.

Scenario 2 involves the identification of individuals with unique marks and horn shapes (Plate 9). Since initiating our work in Ishaqbini, we have identified eight adult individuals that we use to track eight groups of hirola within Ishaqbini. These groups are faithful to particular areas and rarely stray outside the bounds of Ishaqbini, presumably because of high-quality range and heavy presence of livestock and humans in the surrounding buffer zones. Hirola within Ishaqbini are in the process of being habituated for future tourism ventures and will not be captured and moved into the predator-proof sanctuary. Hirola within Ishaqbini but outside the sanctuary will experience the same high-quality range as animals in Scenario 1, but will be exposed to lions and other predators.

Plate 9: ***One of the groups we are monitoring (note the unique horn shape).***

Scenario 3 involves the capture of hirola from herds at the periphery of this species' geographic range from Arawale, Gababa, Gallmagala, and Sangailu communities. We will fit GPS collars on 10 adult (>3 years old) females from 10 different herds to both estimate survival rates of collared individuals and relocate associated herds. Hirola will be immobilized with Carfentenil Citrate delivered remotely from helicopters by field veterinary staff from the Kenya Wildlife Service and Zoological Society of London. During processing, capture technicians will draw a blood sample (15 ml) from the jugular and fix uniquely-numbered ear tags to individuals to aid in future identification. Blood samples will be screened to evaluate serum chemistry and pregnancy hormones; serologic testing will be conducted for antibodies to relevant diseases and blood will also be used for an ongoing genetic study. It is not feasible to mark and resight (as in Scenario 1) or sight and resight (as in Scenario 2) these animals, as our preliminary data demonstrate that herds at the periphery of the range are extremely dispersed and wide-ranging. GPS radiocollars (Telonics TGW-3600) will record one GPS location every three hours throughout the year. Each collar will be equipped with a VHF (Very High Frequency) signal as well that will emit 50 pulses per minute for monitoring, or 30 pulses per minute to indicate mortality if the individual has not moved for eight hours or more. VHF signals will be used to relocate animals visually twice per week, to note the presence or absence of calves. GPS collars will be scheduled to drop off remotely in January 2014, when they will be collected for downloading of the accumulated data.

We will employ mark-resight and site-resight methods (Johnson et al. 2010) to estimate survival of 10 adult female hirola (the age class most affecting population growth) in each of the above scenarios. We will conduct population viability analyses (PVA) of hirola herds under each of the three scenarios detailed above (Morris and Doak 2002). We will build matrix population models and conduct life table response experiments (LTRE) to attribute differences in the annual rate of population change (λ) to some combination of predation and range quality (Maclean et al. 2011). Specifically, from the LTRE between Scenario 1 and Scenario 2, we will be able to quantify the effect of varying risk of predation on population growth of hirola. Similarly, from the LTRE between Scenario 1 and Scenario 3, we will be able to quantify the effect of varying range quality on population growth of hirola. Thus, PVA will permit us to quantify the relative impacts of predation and range degradation, and will permit us to make informed management decisions to maximize the chances of long-term persistence.

For the radio-collared hirola from outlying herds, we will construct resource selection functions (RSFs; Boyce and McDonald 1999) to quantify the extent to which particular habitat features (distance to water, distance to settlement, percent grass cover, percent forb cover, percent tree cover, etc) are selected or avoided by hirola. Our RSFs will be used to inform future reintroduction efforts of sanctuary-bred animals.

As with many declining species, more than one factor probably underlies the plight of hirola. It is possible (and indeed, likely), that some combination of predation and range degradation is responsible for the apparent inability of hirola to recover in eastern Kenya. Documenting the relative influence of these two factors in the field holds promise as to what steps can and should be taken to maximize the chances of hirola persistence in the future.

For example, if predation (or poaching) is the primary factor suppressing hirola numbers, we anticipate rates of population change to exceed 1.0 within the predator-proof sanctuary, indicating positive population growth. Under this scenario, future management efforts would be well-advised to focus on some combination of 1) community education and outreach in attempt to minimize poaching; 2) training anti-poaching squads; and 3) identifying reintroduction sites where the risk of predation and/or poaching is minimal.

On the other hand, if predation (or poaching) is an important but secondary factor suppressing hirola numbers and range condition drives hirola numbers, we anticipate rates of population change to increase within the sanctuary, but below the expected rate (i.e., with predation removed). If this is the case, we would expect hirola outside Ishaqbini--where *Chloris* and *Cenchrus* are even rarer than within Ishaqbini--to exhibit lower survival and birth rates, regardless of whether they were contained in the predator-proof sanctuary. In the event of these results, future management efforts should focus on range improvement strategies (e.g., holistic management, bush clearing, etc) in outlying areas in attempt to improve habitat and bolster hirola numbers. The massive undertaking of creating and maintaining a predator-proof sanctuary to serve as a source for future reintroductions will only be successful if the major threats outside the sanctuary (i.e., in the reintroduction sites) are identified and mitigated.

Of equal importance to this effort will be the use of RSFs to identify sites suitable for the reintroduction of sanctuary-bred hirola. We anticipate the reintroduction of hirola into outlying areas of Ijara 3-4 years after the translocation into the predator-proof sanctuary (i.e., June 2015 or June 2016). To maximize the chances of successful reintroduction, it is imperative that we understand the landscape (distance to nearest settlement, distance to water) and vegetation (percent shrub cover, percent annual grasses, percent perennial grasses) features that hirola select or avoid so as to target reintroductions in areas that share these attributes.

Our effort represents the first attempt to meld rigorous science into the conservation of hirola, which have been largely neglected because they occur in an area of historic, political unrest.

4.4 Assessing hirola mortality

Throughout our study sites, we are opportunistically recording carcasses of hirola and other ungulates to draw conclusion on mortality rates of hirola in each of these areas. If possible, causes of mortality will be recorded. This data will be used to complement the demographic data described in above.

Plate 10: Mr. Ali recording and inspecting dead hirola carcasses in the field

5.0 HIROLA POPULATION GENETICS

To address whether the current range of hirola reflects range collapse or a range shift, we are collecting fecal samples to amplify DNA that is shed when the animal defecates. This will allow us to demonstrate whether the hirola in Ijara have either 1) persisted in this area while trees have encroached over the past 30-40 years; or 2) been "pushed" into the suitable habitat (low tree cover) that remains following elephant extirpation, overgrazing, and/or fire suppression. Further, we will address if ongoing declines of hirola could be partially due to inbreeding depression, compare effective population size to census size, and develop genetic mark-recapture methods for long-term population monitoring.

We recently collaborated with Dr. Melanie Murphy a landscape ecologist and population geneticist at the Department of Renewable Resources, University of Wyoming. Dr. Murphy has major interests in population genetics. Her involvement is crucial to understanding the demographic and genetic consequences of range collapse in hirola.

Plate 11: Hirola feaces within Ishaqbini Community Conservancy

7.0 COMMUNITY KNOWLEDGE, EDUCATION AND OUTREACH

7.1: Indigenous knowledge and attitudes

Increasingly, indigenous knowledge and local participation are key components of conservation efforts. As yet, little documentation of Somali pastoralist's ecological knowledge exists, and even less is known about how this knowledge is, or can be, applied to hirola management and conservation. We will outline the ecological knowledge of Somali nomadic pastoralists and its role in hirola conservation in Ijara and Fafi Districts.

In 2011, we administered a structured questionnaire to gain a better insight on the historical distribution of hirola in the region, attitudes toward hirola, threats to livestock from hirola, threats to hirola from people, and the future of wildlife in these areas. The questionnaires were distributed to homesteads in Arawale, Gababa, Bura, Galmagalla, Hara, Masalani and Qotile. We are analysing survey data using factor analysis (Legendre and Legendre, 1999) to identify linear combinations of predictor variables accounting for community perceptions of hirola. Preliminary analysis of the data shows that the communities are knowledgeable on status of species occurring in the area (Fig.4) and are also well versed with the issues surrounding hirola declines. A manuscript on community knowledge and attitudes regarding hirola conservation is underway which will be submitted to *African Journal of Ecology* in late 2012 in which we will make guidelines for range restoration in the hirola's geographic range.

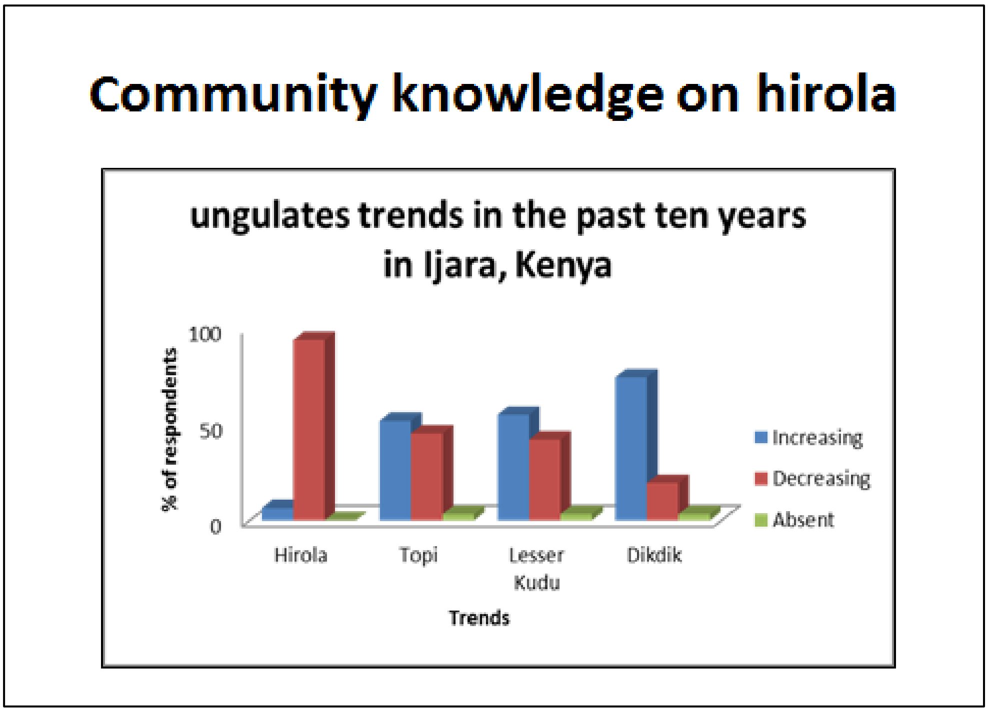

Figure 4: Community perspective of ungulates trends in the hirola range over the past 10 years

7.2 Education and outreach

Because they are large, charismatic, and indicative of high-quality rangeland, hirola can be utilized as both indicator and flagship species for semi-arid ecosystems in the Horn of Africa. However, despite international concerns and government protection through the Wildlife Act (Cap 376), hirola remain poorly understood and virtually unknown outside of northeastern Kenya. Therefore, raising well-informed future generations with strong commitments to sustained management through education is an important activity for hirola conservation in the medium to long-term. Education and outreach efforts stemming from this research will be targeted toward local communities from the main villages in the hirola range. Early efforts suggest that communities are responsive and amenable to hirola conservation; increasingly, intensive livestock production is viewed as unsustainable and, already, locals have benefitted from employment associated with conservation efforts (both through this work and through the NRT).


Plate 12: Scouts assisting in vegetation sampling in Ishaqbini Community Conservancy

Since 2009, we have been holding a series of village-based community meetings in both Ijara and Fafi Districts (Plate 13). In the coming years we will continue with these efforts as locals acclimatize to this research and our findings will be disseminated, through the use of local *barazas* (village meetings) and also through simple materials such as brochures, posters, and leaflets. This way, local leaders and the general public will be exposed to the need for them to betake responsibility in the conservation of natural resources within their own communities through sustainable natural resource management.

Plate 13: Mr. Ali sensitizing community members about the plight of hirola in Fafi District

Further, we will be approaching the media (local dailies, radio and television) to provide time slots or print space on hirola conservation initiatives in the region in order to broaden public awareness. Our work was recently covered in the Kenyan media where Mr. Ali (the Principal investigator of the project) was featured in The Standard, one of Kenya's leading national newspapers: http://www.standardmedia.co.ke/specialreports/InsidePage.php?id=2000035100&cid=259&
As part of our sustained effort to curb the decline of this species, Mr. Ali has also conducted live radio interviews with the Kenya Broadcasting Corporation highlighting the plight of the hirola (see appendix 1). We published an introductory article in the January issue of Swara, a popular publication of the East African Wildlife Society to further highlight the plight of the species to the broader East African and international conservation networks. For the first time in the history of this species, we were able to submit several high resolution field photos to Arkives (a global initiative with the mission of "promoting the conservation of the world's threatened species, through the power of wildlife imagery"), some of which are already uploaded to their site (Plate 14). We have a plan of submitting field videos of hirola to Arkives as part of sustained effort to create a hirola multimedia conservation education tool for public use. We think this will further illuminate and create interest in the conservation of what is arguably the world's most endangered antelope.

Plate 14: One of the images uploaded into Arkive website

8.0 CHALLENGES FACED DURING THE PROJECT

In early 2011, Mr. Ali spent several months trying to identify individual hirola within Ishaqbini to construct demographic models and better understand factors underlying the decline of this species. Initially, we had hoped to identify hirola through horn annuli and unique, naturally-occuring marks (scars, albinism, horn shape). However, this proved slow and difficult because hirola are very skittish, and because we suspect a significant amount of "mixing" of individuals between herds. In addition, hirola are highly mobile, and herds often would disappear and re-emerge over the course of weeks in the communities outlying Ishaqbini. Recently, however, we have made significant progress in constructing reliable demographic models for this species. In the long run, we hope to develop a photographic database of all individuals within Ishaqbini Community Conservancy.

Plate 15: ***Similarity in horn shape and annuli among typical adult hirola***

9.0 CONCLUSIONS AND FUTURE DIRECTIONS

Along with that of our collaborators, our work promises to make the necessary next steps to inform the conditions under which these future reintroductions are most likely to succeed. Thus, with the support of groups like KWS and NRT, it is possible (and indeed likely) that we will make real headway toward the conservation of this unique animal. In our opinion, the most important priority is to address habitat improvement measures within the hirola's native range, particularly in Arawale National Reserve. We have been in discussions with KWS, NRT, and ZSL representatives about this effort.

Importantly, and unlike many critically-endangered species, we suspect that a modest amount of funding can actually make a substantive impact with respect to hirola populations, for two reasons. First, the primary factor responsible for hirola declines—range degradation—is reversible, given local support and financial investment. This is because the fate of hirola is linked to the long-term sustainability of livestock production in this region, because both hirola and cattle require open grasslands and, at appropriate densities, cattle and hirola can coexist. Because Somali elders have witnessed range degradation through time, they are now eager to implement improvement measures (Ali et al. 2012). Second, the Somali clans in this region (Abdalla and Abudwaq Somalis) typically do not poach or eat bush meat, and ascribe to hirola a near-mythical status. Thus, locals in this area have both economic and cultural incentives to protect hirola, providing a legitimate chance against extinction for this unique species. It is our goal that the uniqueness of hirola will be continue to recognized by the community leaders and members in the region, thus strengthening long-term conservation efforts. Importantly, we have already built strong collaborative linkages with KWS, HMC, and NRT to manage the project in the long-term, thereby maximizing chances of success of the proposed research.

Finally, in the coming years, we will continue with the resource selection and demographic field studies of hirola within the Ishaqbini Community Conservancy. Through this work, we will continue making management recommendations to the HMC, KWS and other collaborators NRT. We continue to compile data into reports that will be submitted to funding institutions, the KWS, HMC, NRT, Garissa, Ijara and Fafi County Councils, and the NMK. We work to maintain good working relations with these groups, all of whom are regularly updated on our recent findings.

10.0 PLANS FOR RESULTS DISSEMINATION AND COMMUNICATIONS

Our work is still in progress and we have been updating stakeholders and communities through HMC meetings (Plate 20) and other forums such as village meetings (Plates 12-16). At the end of the study, data will be compiled into a comprehensive report that will be submitted to funding institutions, the KWS, HMC, NRT, Ijara-Fafi County Councils, and the National Museums of Kenya (NMK). We maintain excellent working relations with these groups, all of whom are regularly updated on project recent findings. Thus, we are hoping filling these knowledge gaps and raising awareness about the plight of the hirola within Ijara and Fafi Districts would technically constitute “success”.

Plate 16: Stakeholders attending hirola workshop in June 2011, held in Ijara, Kenya

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12.0 APPENDICES

Appendix 1: A sample of unedited text messages from locals in response to KBC Talk

Day	Time	Phone	Concerns/questions by communities
Wednesday, July 07, 2010	8:28 PM	254715254808	Som mohamed Hamd guhad ojogo sangailu carawlaha noloshisa meshe uwangsantahay mamesha qawoba amah mesha kulul Translation: which is the most preferred hirola habitat? By Mohamed from Sangailu.
Wednesday, July 07, 2010	8:26 PM	254716888732	SOM What is da lifespan of da said animal ? From Hassan Golo Moyale ETHIOPIA. Translation: What is the lifespan of hirola in the wild?
Wednesday, July 07, 2010	8:11 PM	254717313696	WHERE DO HIROLLA ORGINATED? WHY ONLY FOUND IN GARISSA .?IS IT BEC OF HOT CLIMATE.?.BY MOHAMED MAHAT.HODAN.WAJIR
Wednesday, July 07, 2010	8:10 PM	254723178698	Som =mudu star dhagahaley carowluhu wamuhiim laakiin dowlada ayaakagaabise in uutarmo waa inloosameeya dhulbaag ah iyo ceelal Translation: the government should establish a national park for hirola for long-term solution.
Wednesday, July 07, 2010	8:03 PM	254726574789	som. Hay k.b.c. Iam maankow of wajir bulla jogoo,idle i want to ask mr Abdullahi what is the benefit that antelop has than other wild animals. Translation: why is hirola important compared to other wild animals?
Wednesday,	8:00	254717313696	WHAT MEASURES ARE TAKEN TO SAFE THE

July 07, 2010	PM		ENDENGERED SPICES FROM HUNTERS.OR LIONS.ETC.TO AVERT DECREASING NUMBER FROM 4000 TO 600.BY MOHAMED MAHAT.HODAN.WAJIR
Wednesday, July 07, 2010	7:54 PM	254717313696	HOW MANY TOURIST VISIT ANNUALLY TO SEE HIROLLA.? IF ANY.HOW MUCH MONEY RECIEVED? BY MOHAMED MAHAT.HODAN.WAJIR
Wednesday, July 07, 2010	7:47 PM	254729662479	Som, is that type of animal exist in Nep,issa bangal pharmacy Translation: Does such an animal so special and critically endangered exist in northern eastern Kenya?

Appendix 3: Checklist of plants in and around Ijara area

Species	Family	Growth form	Local name (Somali)
Elytraria acaulis (L.f.) Lindau	Acanthaceae	herb	
Baleria sp.	Acanthaceae		Qothahtol
Barleria eranthemoides R.Br.	Acanthaceae	Herb	
Barleria acanthoides Vahl	Acanthaceae	Herb	
Ecbolium subcordatum C.B.Clarke	Acanthaceae	Herb	
Mollugo nudicaulis Lam	Aizoaceae	Herb	
Gisekia pharnaceoides L. var. pharnaceoides ceoides L.	Aizoaceae	Herb	
Zaleya pentandra (L.) Jeffrey	Aizoaceae	Herb	
Achyranthes aspera var. perphyristachya Hook F.	Amaranthaceae	Herb	Get Biret
Aerva lanata (L.) Juss	Amaranthaceae	Herb	
Puppalia lappacea(Linn.) Juss	Amaranthaceae	Herb	
Digera muricata (L.) Mart.	Amaranthaceae	Herb	
Amaranthus graecizans L.	Amaranthaceae	Herb	
Alternanthera pungens Kunth	Amaranthaceae	Herb	
Carissa edulis (Forssk.) Vahl	Apocynaceae	Shrub	
Asparagus falcatus L	Asparagaceae	Shrub	
Cordia sinensis Lam.	Boraginaceae	Tree	
Heliotropium longiflorum (A.DC.) Jaub. & Spach ssp. undulatifolium (Turrill) Verdc.	Boraginaceae	Herb	Goreya kaharis
Heliotropium steudneri Vatke	Boraginaceae	Herb	
Bourreria teitensis (Gürke) Thulin	Boraginaceae	Shrub	
Farsetia stenoptera Hochst.	Brassicaceae	Herb	
Erucastrum arabicum Fisch. & C.A.Mey.	Brassicaceae	Herb	
Commiphora campestris Engl.	Burseraceae	Tree	
Commiphora bruceae Chiov.	Burseraceae	Shrub or Tree	
Commiphora africana (A.Rich.) Engl.	Burseraceae	Shrub or Tree	Kura
Maerua denhadtiorum Gilg	Capparaceae	Shrub or Tree	Ohia

Maerua angolensis DC.	Capparaceae	Shrub or Tree	
Cadaba farinosa Forssk.	Capparaceae	Shrub	ohia sagar
Cleome gynadra L.	Capparaceae	Herb	
Maerua mungaii Beentje	Capparaceae	Shrub	
Maerua decumbens (Brongn.) De Wolf	Capparaceae	Shrub	
Maytenus undata (Thunb.) Blakelock	Celastraceae	Shrub or Tree	ilimdes
Salsola dendroides Pall.	Chenopodiaceae	Shrub	durte
Chenopodium opulifolium Schrad. ex Koch	Chenopodiaceae	Herb	
Terminalia parvula Pamp.	Combretaceae	Shrub or Tree	Qordaboo
Combretum hereroense Schinz ssp. volkensii (Engl.) Wickens	Combretaceae	Shrub or Tree	
Commelina benghalensis Wall.	Commelinaceae	Herb	Bar
Blepharispermum minus S.Moore	Compositae	Herb	Yumarug
Seddera hirsuta Hallier f.	Convolvulaceae	Herb	
Momordica spinosa (Gilg) Chiov.	Cucurbitaceae	Shrub or Climber	Mathah bubuq
Momordica foetida Schumach.	Cucurbitaceae	Herb	
Coccinia grandis (L.) Voigt	Cucurbitaceae	Herb	
Cyperus prolifer Lam.	Cyperaceae	Herb	
Diospyros consolatae Chiov.	Ebenaceae	Shrub or Tree	
Spirostachys venenifera (Pax) Pax	Euphorbiaceae	Tree	haya
Acalypha volkensii Pax	Euphorbiaceae	Herb	Kashimuda
Tragia hildebrandtii Müll.Arg.	Euphorbiaceae	Herb	
Jatropha prunifolia Pax	Euphorbiaceae	Herb	
Phyllanthus maderaspatensis L.	Euphorbiaceae	Herb	
Phyllanthus somalensis Hutch.	Euphorbiaceae	Shrub	Kamora
Euphorbia hirta L.	Euphorbiaceae	Herb	
Euphorbia prostrata Aiton	Euphorbiaceae	Herb	
Flagellaria guineensis Schumach.	Flagellariaceae	Herb	
Endostemon tereticaulis (Poir.) Ashby	Lamiaceae	Herb	
Strychnos decussata (Pappe) Gilg	Loganiaceae	Shrub or Tree	
Lawsonia inermis L.	Lythraceae	Shrub or Tree	Elan
Hibiscus micranthus L.f.	Malvaceae	Herb	Balambal
Pavonia arabica Hochst. ex steud.	Malvaceae	Herb	Moresa
Pavonia zeylanica Cav.	Malvaceae	Herb	
Senra incana Cav.	Malvaceae	Herb	
Abutilon pannosum (G.Forst.) Webb	Malvaceae	Herb	
Thespesia danis Oliv.	Malvaceae	Shrub or Tree	Kabhan
Abutilon wituense Baker f.	Malvaceae	Herb	
Acacia zanzibarica (S.Moore) Taub.	Mimosaceae	Shrub or Tree	
Acacia elatior Brenan	Mimosaceae	Tree	Bura
Acacia hamulosa Benth.	Mimosaceae	Shrub or Tree	adad
Acacia reficiens Wawra ssp. misera (Vatke) Brenan	Mimosaceae	Shrub or Tree	rig/qansah
Albizia anthelmintica Brongn.	Mimosaceae	Shrub or Tree	Hamasha
Commicarpus helenae (Roem. & Schult.) Meikle	Nyctaginaceae	Herb	
Boerhavia erecta L.	Nyctaginaceae	Herb	

Ochna sp.	Ochnaceae		
Ximenia americana L.	Olacaceae	Shrub or Tree	Mandaru
Tephrosia pumila (Lam.) Pers.	Papilionaceae	Herb	
Indigofera tinctoria L.	Papilionaceae	Herb	
Indigofera schimperi Jaub. & Spach	Papilionaceae	Herb	
Rhynchosia minima (L.) DC.	Papilionaceae	Herb	
Indigofera spicata Forssk.	Papilionaceae	Herb	Darqa
Leptochloa obtusiflora Hochst.	Poaceae	Herb	Bayo
Eleusine indica (L.) Gaertn.	Poaceae	Herb	
Digitaria pennata (Hochst.) T.Cooke	Poaceae	Herb	
Brachiaria leersioides (Hochst.) Stapf	Poaceae	Herb	aws danan/dadii
Dactyloctenium scindicum Boiss.	Poaceae	Herb	
Enteropogon macrostachyus K.Schum. ex Engl.	Poaceae	Herb	
Eragrostis ciliaris (L.) R.Br.	Poaceae	Herb	
Eragrostis cilianensis (All.) Link ex Lutati	Poaceae	Herb	
Setaria verticillata (L.) P.Beauv.	Poaceae	Herb	
Chrysopogon plumulosus Hochst.	Poaceae	Herb	
Aristida adoensis Hochst.	Poaceae	Herb	
Enteropogon barbatus C.E.Hubb.	Poaceae	Herb	
Tragus berteronianus Schult	Poaceae	Herb	
Sporobolus helvolus (Trin.) T.Durand & Schinz	Poaceae	Herb	Jarbi
Chloris roxburghiana Schult.	Poaceae	Herb	
Chloris virgata Sw.	Poaceae	Herb	
Cenchrus ciliaris L.	Poaceae	Herb	Darema
Echinochloa haploclada (Stapf) Stapf	Poaceae	Herb	
Chloris mossambicensis K.Schum.	Poaceae	Herb	
Digitaria abyssinica (A.Rich.) Stapf	Poaceae	Herb	
Eragrostis tenuifolia (A.Rich.) Steud.	Poaceae	Herb	
Schoenefeldia transiens (Pilg.) Chiov.	Poaceae	Herb	
Cynodon dactylon (L.) Pers.	Poaceae	Herb	
Drake-brockmania somalensis Stapf	Poaceae	Herb	
Dinebra retroflexa (Vahl) Panz.	Poaceae	Herb	
Brachiaria serpens (Kunth) C. E. Hubbard	Poaceae	Herb	
Calyptrotheca somalensis Gilg	Portulacaceae	Shrub	Dumey
Portulaca oleracea L.	Portulacaceae	Herb	antalaa
Portulaca kermesina N.E.Br.	Portulacaceae	Herb	
Polysphaeria parvifolia Hiern	Rubiaceae	Shrub or Tree	
Zanthoxylum chalybeum Engl. var. chalybeum	Rutaceae	Tree	Miiya Shabel
Dobera glabra (Forssk.) Poir.	salvadoraceae	Shrub or Tree	Garas
Salvadora persica L.	salvadoraceae	Shrub or Tree	athey
Thesium kilimandscharicum Engl.	Santalaceae	Herb	
Lepisanthes senegalensis (Poir.) Leenh.	Sapindaceae	Tree	
Lecaniodiscus fraxinifolius Baker ssp. scassellatii (Chiov.) Friis	Sapindaceae	Shrub or Tree	
Solanum coagulans Jacq.	Solanaceae	Herb	

solanum incanum L.	Solanaceae	Shrub	
Sterculia stenocarpa H.J.P.Winkl.	Sterculiaceae	Shrub or Tree	Qaranri
Grewia villosa Willd.	Tiliaceae	Shrub	Kamasha
Grewia bicolor Juss.	Tiliaceae	Shrub or Tree	
Corchorus trilocularis L.	Tiliaceae	Herb	
Grewia stuhlmannii K.Schum.	Tiliaceae	Shrub	
Chascanum hildebrandtii (Vatke) Gillett	Verbenaceae	Herb	
Rinorea elliptica (Oliv.) Kuntze	Violaceae	Shrub or Tree	
Rinorea ilicifolia (Oliv.) Kuntze	Violaceae	Shrub	
Tribulus terrestris L.	Zygophyllaceae	Herb	

Elephants slowly returning to parts of the hirola range

Elephants knocking down acacias in Ishaqbini improving the habitat for hirola

Community controls burns in Qotile area, near Ishaqbini

Cattle grazing in the buffer zone of Ishaqbini Community Conservancy

Bush encroachment in Arawale National Reserve

Adult female hirola and two calves inside Ishaqbini Community Conservancy

Quarrying activities in East-Masalani, Dubandesa area (Important hirola dispersal and grazing area).

Silver backed jackal often sighted within Ishaqbini Community Conservancy

Cheetahs are common predators within Ishaqbini community conservancy

Snares are easily found within the hirola range; poaching still a challenge in Arawale

Giraffe killed and eaten by poachers in Arawale National Reserve