UNDERSTANDING HUMAN-LARGE CARNIVORE CONFLICT IN CHOBE, BOTSWANA.

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ABSTRACT

Large carnivores most often get in conflicts with people because they compete for resources that humans require—space and food. Throughout Africa, large carnivores have been eliminated or significantly reduced because of livestock predation. This study is part of the Large Carnivore Research Project initiated by African Wildlife Foundation (AWF) in the Chobe-Caprivi area of Botswana and Namibia respectively. Using GPS collars (a male and a female lion) and spoor counts, data are being gathered on population size, distribution, movement patterns and habitat use of large carnivores. Human impacts are also being examined through mapping of settlements and community interviews. Preliminary results confirm that areas of high carnivore activity correlate positively with protected areas and water availability, and negatively with human presence. Analysis of GPS data (Nov 2004–Oct 2005) from the collared lions has indicated a clear preference for grassland however, male prefers woodland and shrubby savannah more than the female. Additionally, enormous difference in space usage was observed between male and female lion, which is likely to bring males closer to humans and exacerbate conflicts. Male lion was closest to the human settlements in the dry season (April-September) during dawn and dusk. Results from this project will be incorporated into the current Chobe Land Use and Management Plan in order to effectively manage land and mitigate existing conflict between people and carnivores and ensure the survival of large carnivores in the region.
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Introduction

People and Carnivores

Africa and Asia have a lot in common. These regions cradle diverse cultures and natural wealth and are also where poverty and biodiversity are found very close to each other, with the fate of the latter being strongly influenced by the former. With more people living closer to protected areas, more conflicts between wildlife and people are inevitable. Moreover, the extremely poor of the world have little incentive to invest in the protection of natural resources whose returns are beyond their grasp.

Large mammals most often conflict with people because they consume resources that people require—space and food. Large carnivores such as lions and tigers utilize huge areas and compete for food resources that are crucial for human survival. Historically, large carnivores have been perceived as a threat to human survival because of danger to human life and to livestock. In Gir Forest Sanctuary, India, the last stronghold of Asiatic lions in the world, approximately 1,900-2,000 domestic animals have been killed annually by lions in recent years (Singh & Kamboj 1996). In Nepal, Mishra (1997) found losses of 18% of the stock holding in an 18 month period, attributed (rightly or wrongly) to wolves and snow leopards, amounting to a loss of half the average annual per capita income. Due to such threats, carnivores have been long exterminated, which has led to extinction of many species and significant reductions in carnivore populations wherever they are found. World population of cheetahs has been reduced by 50% in the last 25 years, and about 20% of the remaining survivors are found on the commercial livestock and game farmland in north-central Namibia (MacDonald et al., 2002). A survey conducted by Marker et al. (2003b) revealed
that in the 1990s 22% of Namibian farmers confirmed that they had a cheetah problem, and 84% of them said they removed cheetahs. This similar trend of carnivore removal has been seen all across the world ranging from wolves in North America to jaguars in Neotropical and South America. Being on the top trophic level, carnivores usually occur in low densities, need large areas to thrive and generally have low reproduction rates. This makes them even more vulnerable to pressures from commercial hunting, habitat reduction and extermination by humans.

Historically, fences enclosed majority of the protected areas in Africa, but some years ago such fences were removed in several areas to restore natural migrations of animals. Although it has helped large carnivores by allowing them to utilize newer areas, this has also brought settlers and carnivores into close proximity, thereby increasing human-wildlife conflict.

Dwindling wild prey population has further intensified attacks on domestic livestock by carnivores. Retaliation in the form of elimination by the local people is the major contributor to diminishing population of the large carnivores. In many places the true reasons for the conflict are unknown; hence appropriate actions cannot be taken to alleviate it. Even within the relatively narrow field of lion-human conflict, mitigation strategies that may work for large ranches in Kenya may not be applicable to the Fulbé and Arab Choa people around Waza national park in Cameroon, the Ju/Hoan communities in Namibia or stock owners in the Southern Kalahari (Hemson, 2003). The economic, ecological and socio-political profile of each area ultimately determines the potential for mitigations to succeed. To win the support of local communities and lessen the intensity of human-carnivore conflicts, we need to foster peaceful coexistence and find appropriate ways for people to be rewarded for their tolerance towards the animals. This would ultimately lead to increased community participation in the protection of wildlife.
Botswana: A Unique Case Study

Botswana is a land-locked country located just north of South Africa. It is roughly the size of Texas (USA). Botswana presents an interesting opportunity to study human-carnivore conflict because it still has vast tracts of uninhabited land that holds significant carnivore numbers but that is rapidly coming under development pressure due to expansion of industry and human population. Agriculture is extremely difficult to practice in most of Botswana owing to arid climate, water scarcity and inhospitable soil composition. Cattle farming is the most popular source of livelihood for rural Botswana because cattle are relatively hardy and can live off of dry grass and drinking water. In 1997, there were 180 commercial cattle operations and 64,707 traditional cattle farms in operation; between them they hosted 2.2 million head of cattle, more than the 1.6 million human population of Botswana (Botswana Central Statistics Office, 2002). Human-carnivore conflict is on the rise with ever expanding cattle farms and development shrinking carnivore habitat. Almost 50% of Northern Botswana, most of which is in Chobe district, is legally protected via a network of national parks, wildlife reserves and community lands. Carnivores are extremely important for the eco-tourism driven economy of Chobe district. In Botswana, a 14-day lion hunt could gross US$23,200 (ULG, 2001). Large carnivores also accrue substantial revenues to both communities and governments from television crews, journalists, photographers and writers wishing to record the behavior of these animals for the wider public. Carnivores are relatively safe in protected areas; it is outside the boundaries where substantial conflict happens. It is difficult to restrict carnivores within the bounds of protected areas as they require large spaces. Hence, it is imperative to devise land use policies such that development does not encroach on carnivore-rich habitats. Such policies should partition resources between people and carnivores so that it reduces clashes. Any sound policy should
be rooted in science and based on thorough research while incorporating social sentiment and community attitude.

Conflict with large carnivores in Chobe is chiefly in the form of predation of domestic livestock. Even though the number of livestock kills per year by carnivores in Chobe is not as high as in the other similar regions in Africa, the impact of this predation is extremely serious as most of the cattle farmers in the region have very small herd size, which is most often their only source of income. People retaliate to predation by poisoning carnivores or setting forests on fire, threatening the survival of predators in the region. To increase people’s tolerance towards wildlife, a compensation system has been instituted. Botswana is the only member of the Southern African Development Community (SADC) to employ a state funded compensation system for losses due to wild animals.

I worked with African Wildlife Foundation’s Large Carnivore Research Project located in Chobe, Botswana and Caprivi area (Namibia). African Wildlife Foundation (AWF) is a non governmental organization dedicated to the conservation of wildlife and landscapes in the African continent. The AWF’s Large Carnivore Research Project (LCR) was established in late 2002 and has been involved in collecting carnivore data for almost four years now in order to generate a comprehensive carnivore database which will be used for monitoring conflict. Absolutely none to sparse records of the population, distribution and habitat use of large carnivore species in the region have been documented to date. Any policy intervention in the future would be contingent on the baseline data which is absent for this region. This research is a step towards bridging the gap between research and policy-making by conducting science that directly leads to enhanced welfare of the environment and the people linked to it. Through ecological research on carnivores and community based participatory approaches, we are trying to come up with solutions to mitigate existing
conflict and to avoid potential conflicts ahead of time. The results of this program would be used to forward the existing Chobe Enclave Land Use and Management Plan to effectively manage the land for people and carnivores.
Objectives

The overarching objective of LCR is to gain the ecological and socio-economic understanding necessary for effective conservation activities aimed at ensuring the survival of large carnivores in Chobe region of Botswana. This is a long-term project conceptualized by African Wildlife Foundation (AWF) in 2002 and is in its introductory stage and there is still a long way to go before any conclusive results can be reached. In this project ‘large carnivores’ refers to all carnivorous species larger than jackals (Canis spp) by body size/weight. In the study area such species are African lion (Panthera leo), leopard (Panthera pardus), spotted hyena (Crocuta crocuta), African wild dog (Lycaon pictus), black backed jackal (Canis mesomelas) and side-striped jackal (Canis adustus). LCR principally focuses on African Lion and Spotted hyena because they are the most abundant predators in Chobe-Caprivi and the most important species in human-carnivore conflict. Lions have been identified as major livestock predators in several studies in Africa and India (Butler, 2000; Frank, 1998; Funston, 2001; Karani et al., 1995; Kruuk, 1980; Mills, 1991; Saberwal et al., 1994).

To achieve the overall objective, the project was sectioned into three stages with specific goals for each stage. Below are the objectives for each stage of the project:

Stage I: Determine the status (population size, distribution and structure) and various factors influencing movement of large carnivores. [Research] {Started in 2002, still ongoing}

- Collect carnivore distribution, habitat use and population data in Chobe and Caprivi.
- Analyze the incoming carnivore data to explore the habitat trends to guide following research initiatives.

Stage II: Participatory community-based approach to document economic impacts of large
- Conduct community surveys and interviews to understand people’s perspectives on carnivores and to initiate community-based conservation methods.

Stage III: Test and apply innovative solutions to ameliorate human-carnivore conflict. [Policy implementation] {Final stage}

Research Questions

I joined this project in May 2007 with the aim to address specific research questions related to carnivore ecology, movement and conflict with humans. I collected data on carnivore ecology with AWF from June to August 2007. I analyzed all the data gathered to date by LCR so far in order to answer the questions outlined below. My focal carnivore species for the purpose of this project was African lion. The questions have been divided into two broad areas: ecology of carnivores and interaction with humans:

Ecology of Carnivores: Habitat and space use analysis

All Large Carnivores:

1. What is the habitat preference of large carnivores of Chobe-Caprivi region? Are there any habitat hotspots that are favored by most of the large carnivores?

African Lion:

2. What is the habitat preference of lions? Does it vary with seasons and time of day?

3. Do male lions prefer different habitat types as compared to females? Is seasonality
4. How do lions move in their range and what factors influence the selection of their territories at a temporal scale? Is seasonality associated with the movement?

5. Do male lions move differently from female lions?

**Interaction with Humans:**

1. Is there a habitat that humans prefer to locate their settlements in?

2. What is the status of the conflict in the region? Which carnivores are responsible for most interactions with people?

3. How do lions interact with people? How close are they to human settlement?

4. Does proximity to human settlements vary with season and time of day? Is there a particular time of day when collared animals are nearest to human settlements?

5. What are people’s perspectives on large carnivores? What are some mitigation strategies used by them?
Study Area

Large Carnivore Project is based in ‘Kazungula Heartland’ which is a wildlife-rich transboundary landscape where Botswana, Namibia, Zambia, and Zimbabwe come together (Figure 1). Our study area in ‘Chobe –Caprivi’ (outlines in red in Figure 1) is a part of the heartland centered on two river systems, the Zambezi and the Linyanti-Kwando River which also marks the international boundary between Botswana and Namibia. It is composed of 11,000 km² of Chobe National Park, CH/1 and Chobe forest reserve which are community lands or extractive forest reserves jointly referred as Chobe Enclave, Kasane forest reserve and Salambala in Namibia. Chobe National Park is free from human habitation however other areas allow restrictive human activities and harbor human settlements.

The area’s vegetation is zoned depending upon the proximity to rivers changing with soil type and impact of herbivores (Makhabu 2005). The area lies over Kalahari sands, and fluvisols exist where floodplains of the two river systems occur. Predominant vegetation type is deciduous forest stands of Rhodesian teak (Baikaiea plurijuga) and Mopane (Cholospermum mopane), while riparian tree species like African mahogany (Khaya ivorensis), Leadwood (Combretum emberbe), Garcinia livinstonii and Fever berry (Croton megalobotris) occur along the river systems (Mosugelo et al., 2002; Skarpe et al., 2004). Over the past decades woodland has gradually moved back away from the Chobe riverfront due to a number of reasons including increased damage by elephants (Mosugelo et al., 2002). The area has changed dramatically both topographically and ecologically for example, what is now shrubland on the alluvial soils earlier had large Acacia and Combretum trees, and before that it was open flats (Skarpe et al., 2004).
The region has a marked dry and a wet season. The October-March rainy season is highly variable (Bhalotra, 1987; Bekker & DeWit, 1991). Annual average rainfall is about 640mm (Botswana Meteorological Service Department, *unpubl. data*) most of which falls in the rainy season. The period from April to September is the dry season. Mean maximum and mean minimum monthly temperatures during October (hottest month) are 39 °C and 14 °C, respectively and in July (coldest month) 30 °C and 4 °C, respectively (Botswana Meteorological Service Department, *unpubl. data*).

Common large herbivores in the area are African elephant (*Loxodonta africana*), Cape buffalo (*Syncerus caffer* (Sparrman)), greater kudu (*Tragelaphus strepsiceros* (Pallas)) and impala (*Aepyceros melampus* (Lichtenstein)). Chobe National Park alone holds an elephant density averaging 7.6 animals km² (Gibson et al., 1998). Elephants are by far the most important browsers in this system owing to their large body size, impact on the vegetation and high population density. Gibson et al. (1998) have documented an annual increase of 6% in the elephant population of northern Botswana since the early 1980s. The area is a hub of eco-tourism and wildlife safaris owning to high densities of various wild animals and their easy visibility during the dry season when all of the animals are concentrated near river systems.

The study area composed of Chobe in Botswana and Caprivi in Namibia is an interesting setting because of the contrasts and similarities between these two regions. More than half of Chobe is protected while Caprivi is heavily settled (subsistence farming and livestock) with three small protected areas. An advantage of such a selection is the possibility of comparison of different land use patterns on carnivore ecology and conflict with humans.
Figure 1: Study Area

Human-Large Carnivore Conflict - STUDY AREA

Study Area
National Park
Kazungula Heartland
Other Protected Areas (Conservancy, Wildlife Management, Safari Area, Sanctuary, Forest Reserve)
Country Boundary
Methods

A wide variety of data were required to answer the research questions. This included field
data on carnivore ecology, satellite data and community surveys. The flow chart in Figure 2
shows the relationship between different kinds of data and the top-down sequential
approach used to analyze the available data.
Carnivore Data:

LCR has been collecting ecological data on carnivores in Chobe since its inception in late 2002. LCR hopes to collect more data in the coming years to generate a comprehensive carnivore database which will be used for monitoring conflict. Data\(^1\) for this project was collected through following approaches:

1. **Satellite Telemetry (GPS radio collar):** Two lions, a male and a female, were collared in the Chobe riverfront of Chobe National Park in February 2004. GPS frequencies 151.807 MHz and 151.817 MHz were deployed on the male and the female respectively. The GPS was programmed to collect more frequent fixtures from dusk through dawn when carnivores are most active. Data was retrieved after a year and the collars were put back on the animals. A total of just above 8,500 position fixes were collected by the two collars (3,238 and 5,297 by collars 151.807 and 151.817 respectively). The male’s radio collar became dysfunctional after a year however, the female’s collar worked for a longer time. Satellite telemetry data for the female that overlapped with the functional time zone of the male’s collar was selected for comparative analysis. This was a 12 month period from November 2004 to October 2005. In 2005 two hyenas (male and female) were also collared.

2. **Carnivore Spoor Counts:** Carnivore tracks are referred to as spoors. Existing dirt roads such as fire lines and tracks for forest department and tourist vehicles that were relatively free of vegetation were identified as transects. Animal tracks are only impressionable on dirt or loose sand so these existing roads presented an opportunity to act as custom made transects. Additionally, it was difficult to cut new transects due to logistical and terrain constraints. The

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\(^1\) All the data used in this master’s thesis is a legal property of African Wildlife Foundation. Use of this data or the results in any form without AWF’s permission will be a violation of copyright laws.
transects were traversed on a land rover during sunrise/early morning and sunset/evening. We choose those two time windows due to three main reasons: the sun’s angle during the said times windows aided in identifying the tracks, the tracks were not obliterated by tourist vehicles, and carnivores are most active during dusk and dawn so there were higher chances of direct observation. GPS location, carnivore species and gender of the animal were determined for each distinct spoor located on the transects. The transects were repeated several times during the data collection period. Surveys were conducted for two months during wet (October-November) and dry (June-July) season. Data is present since the 2005 dry season. Figure 3 shows some of the transects already visited and Figure 4 (a, b) shows how we traveled the transects and an example of a carnivore spoor.

Figure 3: Transect locations: gray represents all roads in the area and green are the transects already traveled.
3. **Direct observations, indirect signs of carnivore and human-carnivore incidents:**

Direct observations involved opportunistic sightings of carnivores. GPS location, carnivore species and number of individuals were determined for each sighting. Indirect signs such as carnivore kills, claw marks on the trees and carnivore corpses were also recorded.

4. **Mapping location of permanent water holes and rivers.**

5. **Mapping human presence:** All the human settlements, cattle posts, villages and crop fields in the study area were mapped using a hand-held GPS.

6. **Community Surveys:** We also conducted surveys while mapping the settlements in the study area to determine the status of human-large carnivore conflict. Home and cattle owners were asked questions about the frequency of livestock predation, predominant problem animals and date of their latest livestock predation. Data was also collected on each family’s livestock for monitoring cattle population in the future.
Satellite Images

Three Landsat images, two from 2001 and one from 2002 were acquired from the Global Land Cover Facility\(^2\) (Table 1). Each image was radiometrically corrected to at-satellite reflectance using parameters specified by Chander et al. (2007) and atmospherically corrected to surface reflectance using Dark-Object Subtraction (Chavez 1988; qtd. in Conghe et al., 2001). This was done to account for temporal variation in the images.

\textit{Table 1: Attributes of LANDSAT images for the study area}

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Path</th>
<th>Row</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 ETM+</td>
<td>173</td>
<td>73</td>
<td>06/18/2001</td>
</tr>
<tr>
<td>7 ETM+</td>
<td>174</td>
<td>72</td>
<td>04/09/2002</td>
</tr>
<tr>
<td>7 ETM+</td>
<td>174</td>
<td>73</td>
<td>01/03/2002</td>
</tr>
</tbody>
</table>

Landcover Classification

Landcover was mapped using fuzzy logic, which is a special type of supervised classification. Fuzzy set theory recognizes that landscapes are not homogeneous and that heterogeneity at finer scales is usually not effectively captured by image pixels. A hard classification will assign this pixel to one of the landcover classes; however, fuzzy theory indicates that a pixel may have partial membership in several classes. For instance, a 30 meter LANDSAT pixel may contain 30% dense forest, 20% water and 50% grassland.

\footnote{\textsuperscript{2} The Global Land Cover Facility (GLCF) is a center for land cover science with a focus on research using remotely sensed satellite data and products to assess land cover change for local to global systems and is run by the University of Maryland.}
Fuzzy algorithm was used because a sub-pixel classification was important to capture the true landscape heterogeneity which was imperative for further analysis. Classification using fuzzy logic produces $n$ number of classified layers, where $n$ is the number of “pure” landcover classes identified by a user. “Pure” classes are homogeneous classes such as dense forest/woodland, water, grassland and bare earth. “Impure” or mixed classes are generated by a combination of “pure” classes. An example of a mixed class is savanna which is a combination of woodland and grassland. In the first classified layer produced by the algorithm, each pixel is assigned to the class that is most represented in it. Second classified layer classifies the pixels to the second most represented class and so on. Hence, a “pure” pixel will be assigned to the same class in all the layers but a confused pixel will belong to different classes in different layers. Because of radiometric differences between different images, they were classified independently. More than 200 spectral signatures representing four “pure” classes- namely forest, grassland, permanent water and bare earth were captured manually per image. Fuzzy classification algorithm was implemented in ERDAS IMAGINE 9.2. Mixed classes were obtained by linear combination of different layers and various combinations were reclassified to generate meaningful landcover types. Only the first three layers were combined because the fourth layer introduced unwarranted noise. An example of mixed classes produced through different linear combinations of first and second layers is given in Table 2.

The finally classified images were then composited into a 3-image mosaic and clipped to the extent of the study area demarcated in red in Figure 1. Kasane Township located at the northeastern tip of the study area in Kasane district was hand digitized in the classified image so that the proximity of the carnivores to the city could be analyzed. Google Earth was used as a reference to outline the boundaries of the township.
Table 2: An example of mixed landcover classes generated by linear combination of ‘pure classes’.

<table>
<thead>
<tr>
<th>Layer 1</th>
<th>Layer 2</th>
<th>Mixed Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woodland</td>
<td>Grassland</td>
<td>Savanna</td>
</tr>
<tr>
<td>Woodland</td>
<td>Permanent Water</td>
<td>Wetlands/Marshes</td>
</tr>
<tr>
<td>Woodland</td>
<td>Bare Earth</td>
<td>Savanna</td>
</tr>
<tr>
<td>Grassland</td>
<td>Bare Earth</td>
<td>Grassland</td>
</tr>
<tr>
<td>Grassland</td>
<td>Permanent Water</td>
<td>Floodplains/Seasonal Wetlands</td>
</tr>
<tr>
<td>Bare Earth</td>
<td>Permanent Water</td>
<td>Floodplains/Seasonal Wetlands</td>
</tr>
</tbody>
</table>

Spatial Analysis of GPS and Spoor Count Data

Monthly telemetry data from the lions was plotted on the map of the study area in ESRI’s ArcGIS 9.2 to study movement trends. Point locations were converted into movement paths using Hawth Tool’s Animal Movement toolset. Home ranges were calculated by joining the outermost GPS locations. Minimum convex polygon was not used because some portions of the polygons created by Hawth’s Tools were located in areas where lions could not have been able to go, such as the eastern Caprivi. Eastern Caprivi can only be reached from Botswana by swimming across the Chobe River; however, lions do not cross over to Caprivi via Chobe River because it is too deep for them to swim.

To study habitat preference of lions, each GPS location was sampled for the habitat type generated by the landcover classification. These sampled locations were stratified by seasons and time of day to analyze seasonal patterns. Proportional representation of different habitat types in the sampled locations for male and female lions were statistically analyzed to explore the possibility of preference for a particular habitat type. This was done using the ‘test of proportions’ (prop.test) in R Statistical Package. Carnivore spoor counts were overlaid on the
landcover map and habitat was sampled within a 200 meter buffer of each spoor location.

**Analysis of Human-Conflict Data**

Human settlements and cattle kraals were projected on the landcover map and dominant habitat type within a 2 km buffer of each settlement was sampled using zonal statistics tools. A 2 km buffer was chosen because it has been observed that habitat within 2-3 km radius of a settlement influences the probability of its location in a particular area (Neo-Mahupeleleng, *observation*). Two to four km is also the mean distance that cattle travel away from their kraals in search of fodder. Euclidean distance to the nearest settlement was calculated for every GPS location for the male lion to analyze the movement of the male as a function of distance to people. The female was excluded from this analysis because she stayed close to the riverfront and unlike the male did not venture near the settlements.
Results

The results have been divided into three sections: 1) Ecology of the carnivores, which includes movement patterns of the lions, habitat preference of male and female lions, home range analysis of lions and habitat preference of large carnivores; 2) Interaction with humans, which includes habitat preference by humans as well as seasonal and diurnal proximity of lions to human settlements; 3) Status of conflict including a synthesis of community interviews. The broad carnivore surveys conducted by the project in 2003-2004 to gain an overall understanding of the distribution of carnivores in the region confirmed that areas of high carnivore activity correlated positively with the existence of protected areas and availability of water, and negatively with the areas of human population. Availability of surface water operates in two folds: surface water determines concentrations prey populations and provides drinking water to large carnivore populations.

Ecology of the Carnivores

i) Movement patterns of collared lions

Figure 5 shows the monthly movement patterns of the male and the female lion. It is clear from the graph that movement of the lions is influenced by Chobe River which is a perennial source of water. The female stayed within Chobe National Park; however, the male ranged into communal areas of Chobe Enclave and Chobe forest reserve. The lioness did not cross the river from Botswana to the Caprivi Strip during 2004 or 2005. The female's movement patterns were predictable: she stayed close to the water during the dry months but traveled widely during the wet months when prey was diffused into inner areas of the park. She covered about half of the Chobe River waterfront and stayed north of the
Figure 5: Monthly movement pattern of the male and the female lion (Nov 2004- Oct 2005). Female is blue, male is green and human settlements are purple. October-March is wet season and April to September is dry season.
Ngoma-Kasane highway (Figure 6). During the dry season, her range was restricted to within a 2 km-wide band parallel to the Chobe River. Within the area immediately adjacent to the river, there was not a great deal of variance in movement pattern depending on the season, except that the lioness did spend more time during the dry season near a water source located near Kasane. During the wet season, she ventured frequently down to another water source near the Ngoma-Kasane highway.

Figure 6: Dry and wet season distribution of the collared female lion. (Source: Neo-Mahupeleng, LCR report 2007)

Legend
- Wet season distribution
- Dry season distribution
- Known incidences of lions in the Namibian conservancies. (Note: These are general lion incidents, not of the collared lioness).
- Water
The male crossed over into Caprivi of Namibia which confirmed the existence of transboundary movements of animals. However, contrary to the previously conceived notion that transboundary passages into Caprivi happen along the Chobe Riverfront, in this case such passages happened outside the Chobe Riverfront in the west of the settled areas of the Chobe Enclave. The male's movement trend suggests clear avoidance of the communal area of Chobe Enclave, showing a possible preference to avoid conflict with humans although contact with human activities such as cattle kraals is very likely especially along the margins of the settled areas (see Figure 7, note the male's range as it ‘rubs’ with the settlements in purple triangles). Both the male’s and the female’s range extended into the Kasane Township Planning area (Kasane Airport area) in the east.

![Figure 7: Movement pattern of lions for the month of August. Male is green; female is blue; human settlements are purple.](image)

The male’s seasonal movement patterns directly contrasted with the female’s movement patterns. He traveled away from water during the dry months to areas where wild prey was
possibly scarce and restricted himself close to Chobe riverfront during the wet months. He also strayed close to the settlements in the dry season.

**ii) Home Ranges and Habitat Availability**

The female’s home range was calculated at 186.3 km² and male’s home range at 2,151.7 km² which was 12 times as big as the female’s (Figure 8). The female’s range was larger during the wet season than the dry season while male’s dry season range was larger than wet season range. Contrary to the expectations that the male would also have a restricted range (to stay close to the pride), he ranged very far beyond the Chobe riverfront. He went as far south as Nogatshaa area and crossed into Namibia at a point further west than was expected. The LCR was the first research project to record such a large range for a male lion in Chobe area, which is difficult to explain given the high prey density for Chobe National Park. The data clearly confirm that crossing of lions from Chobe to Caprivi is a real phenomenon, but further observation is necessary to determine the prevalence of such movement.

Availability of different habitat types in the home ranges of male and female lions is shown in Figure 9. Shrubby savanna in the male’s home range is significantly over-represented (Z-test of proportions; p-value < 0.0007) compared to the female’s range. Another observation was the high presence of permanent water in the female’s home range (Z-test of proportions; p-value < 0.0001) as compared to the male’s range. The explanation for these observations will be discussed in the following sections.
Male's homorange (2151.7 sq km) is 12 times as big as female's (183.6 sq km).

Figure 8: Home range of the collared lions. Male is orange; female is blue.
iii) Habitat preference of male and female lions

GPS locations of lions were overlaid on the classified habitat map and each location was sampled for the habitat (Figure 10). Overall, both the genders showed clear preference for grassland/shrubland followed by shrubby savanna. The remaining habitat types were poorly represented. Table 3 presents the proportional representation of each habitat type for male and female lions. A one-tailed test of proportions was conducted to find out if the difference between habitat use by the male was statistically different from the corresponding habitat use by the female. The male utilized woodland and savanna more than the female (p-value < 0.0001) whereas the female showed a clear preference for grasslands (p-value > 0.95).

The data also indicated that both the lions preferred being close to water sources such as rivers, permanent water holes and marshes during the night as opposed to the day (Z-test of
proportions; male: $X^2 = 47.8687$, $df = 1$, p-value < 0.001 and female: $X^2 = 4.4864$, $df = 1$, p-value = 0.01708).

The male used open areas such as grasslands and bare earth more extensively during the wet season than the dry season (Z-test of proportions; p-value ≈ 1, Figure 11). However, dry season utilization of woodland (Z-test of proportions; p-value < 0.001) and savanna (Z-test of proportions; p-value < 0.001) was greater than wet season. I will use the concept of hunting advantages associated with thicker vegetation cover to explain such a preference, or what I refer to as the ‘visibility theory’ in the following text. This is discussed in detail in the discussion section. The female preferred savanna more in the dry season than the wet season (Z-test of proportions; p-value < 0.001). Male lion’s preference for habitat also depended on the time of the day, for instance he was more likely to prefer open areas during the night as opposed to the day (Z-test of proportions; p-value < 0.001). (See Appendix for more results on seasonal and diurnal habitat preference of lions)

![Figure 10: Habitat preferences for the collared lions. (All location)](image-url)
Table 3: Proportional representation of habitat type for the collared lions (Highlighted habitats were used more by the male than the female.)

<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Number of male locations</th>
<th>Number of female locations</th>
<th>Proportional representation male</th>
<th>Proportional representation female</th>
<th>Test of proportions (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Namibia</td>
<td>5</td>
<td>5</td>
<td>0.0015</td>
<td>0.0016</td>
<td>0.5</td>
</tr>
<tr>
<td>Woodland</td>
<td>361</td>
<td>206</td>
<td>0.1115</td>
<td>0.0661</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Shrubby Savanna</td>
<td>666</td>
<td>478</td>
<td>0.2057</td>
<td>0.1533</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Grassland</td>
<td>1708</td>
<td>1840</td>
<td>0.5276</td>
<td>0.5901</td>
<td>0.99</td>
</tr>
<tr>
<td>Marshes</td>
<td>50</td>
<td>77</td>
<td>0.0155</td>
<td>0.0247</td>
<td>0.99</td>
</tr>
<tr>
<td>Seasonal Floodplains</td>
<td>91</td>
<td>65</td>
<td>0.0281</td>
<td>0.0209</td>
<td>0.03</td>
</tr>
<tr>
<td>Bare Earth</td>
<td>212</td>
<td>191</td>
<td>0.0655</td>
<td>0.0613</td>
<td>0.26</td>
</tr>
<tr>
<td>Permanent Water</td>
<td>142</td>
<td>256</td>
<td>0.0439</td>
<td>0.0821</td>
<td>&gt;0.95</td>
</tr>
<tr>
<td>Kasane Township</td>
<td>2</td>
<td>0</td>
<td>0.0006</td>
<td>0</td>
<td>0.24</td>
</tr>
<tr>
<td>Total GPS locations</td>
<td>3237</td>
<td>3118</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 11: Seasonal habitat preference of the male lion.

iv) Habitat Preference of Large Carnivores

Habitat sampling of spoor locations revealed habitat preferences for all large carnivores.

Proportional representation of each habitat type in the spoor locations for all large...
carnivores was calculated and compared within each species to find out if a species was a generalist or a specialist (Figure 12). If the proportions were found to be statistically the same (p-value > 0.05) then the species was rendered a generalist that is without a clear habitat preference. Otherwise, the species was called a specialist, preferring the most represented habitat over other habitats (Table 4).

Table 4: Results of test of proportions (specialists highlighted in blue).

<table>
<thead>
<tr>
<th>Carnivore Species</th>
<th>Most Preferred Habitat</th>
<th>Z-test of proportion (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Backed Jackal</td>
<td>Generalist</td>
<td>0.2837</td>
</tr>
<tr>
<td>Side Striped Jackal</td>
<td>Grassland</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Spotted Hyena</td>
<td>Grassland</td>
<td>0.019</td>
</tr>
<tr>
<td>Leopard</td>
<td>Woodland</td>
<td>0.035</td>
</tr>
<tr>
<td>African Lion</td>
<td>Generalist</td>
<td>0.0749</td>
</tr>
<tr>
<td>Wild Dog</td>
<td>Insufficient Data</td>
<td>0.5488</td>
</tr>
</tbody>
</table>

Figure 12: Large carnivore habitat preference
Interaction with Humans

i) Habitat Preference by Humans

Analysis of habitat preference for human settlements (Figure 13) indicated that people preferred to locate their settlements/cattle kraals in grassland and savanna. These habitats provide fodder for their cattle, which is the main driver for selecting a suitable location for a cattle kraal.

![Habitat Types within 2 Km of Human Settlements](image)

*Figure 13: Habitat preference by humans.*

ii) Proximity to Human Settlements (male lion only)

The lion was closest to the settlements in the dry season and during the night (Figure 14). Lions are nocturnal, hence being close to the settlements during the night seemed logical; however, dry season proximity to settlements was unusual given high wild prey density near Chobe Riverfront. The frequency of lion locations within 3 km of the settlements peaks
between 4 am and 8 am and between 6 pm and 9 pm (Figure 15). Hence, the lion was closest to the settlements during dawn and dusk.

![Graph showing the density plot of lion location vs. distance to human habitat.](image)

*Figure 14: Density plot of lion location vs. distance to human habitat. The frequency graph has been cut off at 2000 meters because we were interested in lion activity in close proximity to human establishments.*

iii) Status of Conflict-Community Surveys

Landholders and cattle owners were interviewed while human settlements were being mapped. They were asked about the intensity and frequency of their interaction with wild animals and their modes of dealing with crop/cattle predation. 10% landowners interviewed claimed that the lion was their predominant problem animal while 34% reported the lion to be their second most problematic animal (n=185) (Figure 16 a & b).
Figure 15: The percentage of GPS-collar fixes at different hours of the day within 3 km of human habitation.

a) First most problematic animal, b) second most problematic animal

Figure 16(a & b): Commonly reported problem animals
The hyena appeared as the most problematic animal for the maximum number of farmers (70%, n=185). Other animals responsible for conflict were leopard, jackal, elephant, crocodile, buffalo, and in few cases honey badger.

36% of the farmers located within a 3 km radius of the male lion’s GPS locations reported that their last incidence of cattle predation was by a lion. This indicates that the collared male could have been responsible for the stock raiding in those settlements. When people were asked about their latest interaction with a large carnivore (Figure 17), 61% reported attacks by hyenas while 23% blamed lions for livestock predation. Interviews also revealed that jackal and leopard usually attacked goats and other smaller animals whereas lions targeted cows and bigger bulls. Lions have been identified as major livestock predators in several studies, often killing both more and larger, more valuable livestock than other large carnivores (Butler, 2000; Frank, 1998; Funston, 2001; Karani et al., 1995; Kruuk, 1980; Mills, 1991; Saberwal et al., 1994).

**Figure 17: Carnivore responsible for the latest incidence of livestock predation**

Hyenas were nonspecific and attacked livestock of all sizes, however cows were favored over smaller animals. Cattle owners also expressed that hyenas caused more overall damage and injured more animals than lions. Hyenas also specifically preyed on spot targets such as weak animals and lactating mothers and their calves.


**Discussion**

The results highlighted some interesting aspects of carnivore ecology and interaction with humans. The illustrated trends in the movement of lions especially the male suggest a potential correlation with human activities. These indicators are useful for understanding the origins of conflict and the mechanisms that will be most effective in conflict mitigation. The following sections discuss carnivore behavior that might be potentially responsible for the observed patterns of habitat preference and livestock predation.

**Carnivore Ecology**

i) **Movement of Lions**

The male’s seasonal movement directly contrasts with the female’s movement pattern. Availability of water and the prey that congregate near water sources in the dry season governs the female’s movement whereas the male lion’s seasonal movement does not show a strong relationship with Chobe River. Females also have the added responsibility of rearing the cubs; hence a steady supply of water and food is necessary, which is guaranteed by proximity to the river. Analysis of home range revealed that the male’s home range of 2,151.7 km² was 12 times larger than the female’s. A number of studies have recorded lion home range sizes (calculated with minimum convex polygons) to vary from between 22 km² to over 2,000 km² (Stander, 2001; Stander & Hanssen, 2003; Van Orsdol et al., 1985). Results from some specific studies that recorded home ranges of lions in areas with varying prey densities are: 725 km² in Makgadikgadi Pans National Park, Central Botswana, by Hemson et al. (in prep); 424 km² in Savuti, Central Chobe, recorded by Viljoen (1993), 345 km² in Hwange National Park, North-Western Zimbabwe, by Loveridge et al. (2002) and 69 km² in Khudum, Okavango Delta, Botswana by Winterbach & Winterback (2002). Chobe
riverfront supports an extremely high prey density, especially in dry season. For instance, Sharpe et al. (2004) found impala densities higher than 150 animals per km² in some areas of Chobe riverfront. Consequently, lion home range should be smaller in this area due to extremely high herbivore density since home range size is negatively correlated with prey abundance during periods of prey scarcity, competitor density and strength (Van Orsdol et al., 1985; Adams, 2001). Several questions that remain unanswered are

- Why is the male lion utilizing such a large area given high prey densities in Chobe riverfront?
- What is driving the male to move away from Chobe riverfront during the dry season to areas of potentially low prey abundance? and,
- Why does the male wander close to human settlements during dry season?

Below I discuss several possible explanations for this behavior.

Burt (1943) defines home range as ‘the area transversed by an individual on its day to day activities of obtaining food, mates and caring for young’. I will consider each of these three factors separately. Chobe Riverfront carries the highest prey density in the entire Chobe National Park and Chobe District (Neo-Mahupeleng, field observations and aerial survey data), hence food cannot be the only attribute driving the expansive movement of the male. However, during dry season when grass is shorter and overall vegetation cover is less, predators are more visible, which might reduce the probability of catching wild prey. Lions are ambush hunters and rely on concealing themselves in their surroundings as a hunting tactic. Higher visibility could negatively influence the probability of successfully catching wild prey. Domestic prey is easier to catch as compared to wild prey which might be an incentive for the male to wander close to the settlements. Hemson et al. (2003) observed that stock-raiding lions in Makgadikgadi moved closer to cattle posts when wild prey migrated to
farther areas. Serengeti lions hunted and fed in areas with high prey ‘catchability’ rather than high prey density. These areas of high prey catchability in the Serengeti were identified as erosion embankments and woody vegetation (Hopcraft et al., 2005). Hence, the collared male could be responding to the movements of wild prey by shifting its range closer to human settlements where domestic prey could be substituted for wild prey. This could be a part of the reason for the male lion’s movement, but alone does not seem to substantially explain the huge range.

The last home range factor suggests that mates could be a potential cause of the male lion’s movement away from the river. In this same area there were a number of natural pans with water and thus existence of females at very low densities can not be ruled out. It is likely that the potentially present females in this area could also be significantly contributing to the male’s range expansion. Competition from other males plays a big role in restricting home range, however this doesn’t seem to apply here because the collared male is part of a two male coalition which are the only males in the Chobe riverfront area. No lion signs were found during 2005 dry season large carnivore survey in the area coincident with the males’ home range (Neo-Mahupeleng, 2007, unpib.) It is possible that the area the males’ range expanded into was not held by any tenure males during the time of expansion (July – October 2005). Does that imply that there is a shortage of males in the Chobe-Caprivi landscape? Intensive monitoring in this area, known as Linyanti-Shaile, being carried out now by LCR will contribute towards answering this question. No single factor could alone explain the large male range. In sum, the huge movement might have been undertaken by the male to look for potential mates and sustained due to the availability of easy domestic prey and lack of competition from other males. Although the above mentioned factors seem to explain the range expansion, one should not discredit the possibility that this expansion
might have been just an ordinary increase of range for maximum benefits from resources associated with increase in space. Thus, it is important to add that more field data will be required to substantiate this conclusion.

The project confirms the prevalence of transboundary movement of lions from the area west of Chobe riverfront, Botswana into Caprivi in Namibia. This could mean that the lion population in Caprivi is not a separate population but composed of transient visitors from Chobe riverfront. A genetic analysis across the sub-populations of the region will be the next step needed to address this issue. If the Chobe riverfront population is indeed responsible for conflicts in Caprivi, then it might have deeper implications for conservation as well as the relationship between the two countries.

**ii) Habitat preference of male and female lion**

Male and female lions show very different habitat affinities which change seasonally and diurnally. Telemetry data revealed that the male lion’s utilization of woodland and savanna was significantly greater than the female’s. There could be two possible explanations for such a habitat affinity: firstly, preference for particular prey species. Males when hunting without the females prefer to prey on bigger herbivores like kudu, elephant and giraffe, which are browsers usually found in wooded savannas where tree density is high. Females on the other hand prefer smaller prey species like impala, zebra and wildebeest which are grazers predominantly found in grasslands. Secondly, the male’s preference for woodland and shrubby savanna could reflect the advantage that taller vegetation provides by concealing the lion during the day. This also supports the observation from GPS data that the male seems to prefer open areas (floodplains, grasslands and bare earth/sandy patches) during the night. This is corroborated by Hoecraft et al.’s (2005) study that showed that catchability of prey
was a stronger determinant of habitat preference of lions than prey abundance, with
catchability positively correlated with woody vegetation.

The results also revealed that dry season utilization of woodland and savanna by the male
lion was significantly greater than wet season. I applied visibility theory to explain this
seasonal preference. During the wet season, grasses are taller providing more opportunities
for ambushing and thus increasing catchability of prey. Lack of cover in the dry season is
compensated for by moving to woodland and savanna where trees provide required
concealment for successful hunting. Hence, catchability/visibility theory and prey preference
adequately explain temporal and spatial variation in habitat selection by male and female
lions. The results emphasize the importance of fine-scale landscape and habitat features
when assessing predator–prey theory and conservation.

iii) Habitat Preference of Large Carnivores

Grassland appears to be the most important habitat type for all the carnivore species except
the leopard. The results of my analysis conformed to the habitat ecology studies done on
these carnivores in other areas. For example, Loveridge & MacDonald (2002) concluded that
in the absence of intense competition, black backed jackal showed a wide habitat tolerance
whereas side striped jackal chose to use grassland and open areas over other habitat types.
This analysis classifies lion as generalist, however GPS telemetry data confirmed that lions
disproportionately preferred grasslands. This difference in results could be an artifact of
fewer number of spoor locations as compared to telemetry data. In addition, seasonality was
not considered while analyzing spoor-habitat relationship and might have caused this
difference.
Human Conflict and Interaction with Carnivores

i) Habitat preference by Humans

There seems to be an apparent overlap between habitat preference by cattle owners and large carnivores. Both have been shown to prefer grassland and open savanna which might be the root cause of the conflict. Grasslands provide food for both the domestic and the wild prey species, thereby attracting carnivores. It will be a challenge to partition this resource between domestic and wild prey such that the conflict with carnivores is minimized.

ii) Proximity of Lions to Human Settlements

Since the results of this section were only based on the data from the collared male, one might argue against the generalization of these results to the lions of Chobe. I assert that even though the sample size of one adult male restricts our extrapolation of the results to behavior of other lions in the region, it would not be a completely invalid assumption since the Chobe riverfront lion population is composed of a coalition of two adult males and their movement patterns must be correlated. Hence, the results for the male lion are representative of 50% of the total male population. With that said, it would be risky to use these results for lion populations elsewhere in the Chobe National Park (such as Savuti) due to distinct landscape dynamics and circumstances. Lack of human presence and dissimilar vegetation structure make these two areas very different from each other.

The male’s proximity to settlements is crucial in understanding the conflict because adult males have been shown to interact with humans more frequently than adult females. Adult males were three times as likely as adult females to be problem animals in Etosha, Namibia
In the Makgadikgadi, all adult males (n=7 in three coalitions) were stock-raiders and had home ranges that overlapped with cattle-posts (Hemson, 2003). The collared male’s movement close to the settlements during the dry season can be explained using the concepts discussed earlier: easy domestic prey, lack of competition from other males and potential mates. Proximity of the male to the settlements at dawn and dusk can be attributed to time of peak lion activity and herding behavior. Cattle are herded to pastures at dawn and herded back to the kraals at dusk. It is quite possible that the male is specifically looking for strays at this time of high activity. There is a clear indication of avoidance of human settlements by the male because he does not penetrate the core of human habitat even though his trajectory “rubs” the periphery of the settlements. Cattle posts are usually located along the periphery of the villages. Lions have been shown to avoid direct contact with humans as people present a risk to predators, and the demonstrated movement pattern confirms that behavior (Hemson, 2003 and Mazzolli et al., 2002). This avoidance suggests that the lion searched for domestic strays and wild prey at night away from human habitation. As such he seems to be compelled to approach cattle-posts at night when the probability of encountering herders is lowest. There were very few GPS fixtures within 0-100 meters of the cattle posts, which corroborates the hypothesis that he may be searching for stray livestock farther away from cattle kraals, which are fairly common in the study area (Nijhawan, 2007, visual observation). These findings support the prediction that improving static defenses alone may not significantly reduce livestock predation, as most of the predation appears to occur in areas beyond the cattle kraals where these defenses would have no influence. This finding has important implications for conservation and conflict mitigation.
In order to establish strong correlation between livestock and lion movement it will be important to study livestock foraging patterns. The project plans to deploy radio collars on some domestic animals to investigate this behavior. Additionally, monitoring migrations and seasonal abundance of important wild prey species in tandem with domestic prey will lead to important insights into the relationship between frequency of livestock predation and wild prey availability.

iii) Synthesis of community perspective on carnivores.

Data gathered on the modes of retaliation and protection against carnivore predation and on best conflict mitigation strategies shed light on local perspective on carnivore conservation. Two main schools of thought emerged when cattle owners were asked what they would do, if given a choice, to curb livestock predation. First was ‘unite and increase herding practices’ and second was ‘kill the problem animals’. The earlier viewpoint is in harmony with the aims of conservation while the latter shows an extreme stance on the existence of carnivores. The underlying aim of this project is to encourage community participation in carnivore monitoring so the latter thought can be reversed.

Carnivores are very important for the eco-tourism centered economy of the region. Botswana caters to high-end international tourists who pay huge sums of money to view large animals including carnivores in their natural environment. Reduction in carnivore population due to extermination by farmers can lead to decreased revenue from safaris and related activities. AWF is mobilizing its community outreach activities so that local people realize the importance of carnivores for maintaining the regional economy.

An innovative approach of involving communities in conservation has been instituted in Chobe where benefits of tourism are shared with local communities. Seasonal trophy
hunting is allowed in Chobe forest reserve and Chobe Enclave. The trophy belongs to the hunting party but the meat is distributed to the local communities. This policy helps foster the divide between affluent foreign tourists and poor local communities and also underscores the importance maintaining biodiversity. The Botswana government also issues a fixed number of hunting permits to each community on yearly basis. I believe that this strategy is vital in maintaining the relationship between nature and the people and gives people a sense of ownership of the wildlife.

**Concluding Recommendations**

Since the project is still in its preliminary stage, any recommendations would be necessarily inadequate in completely mitigating the conflict, mainly due to the gaps that still exist in our understanding of the situation. However, the analysis so far suggests that implementing basic precautionary measures can go a long way in reducing predation by carnivores. Below are some steps we recommend to herders:

1. Exercise increased vigilance when bringing livestock near water bodies, especially at night.
2. Adapt traditional enclosures by making the walls and stockades higher and thicker. However, lion movement near the kraals and anecdotal accounts suggest that most of the predation happens to stray cattle farther away from the kraals. Therefore, reducing the number of strays at night and developing static defenses simultaneously would appear to be a promising way of reducing livestock losses. Implementing one without the other may not have a significant effect.
3. Improve livestock surveillance, including deployment of more herders especially during dawn and dusk. Community herding needs to be encouraged.
References


Lion Conservation Research. Workshop 2: Modelling Conflict. Wildlife Conservation Research Unit, Oxford University.


Appendix

Habitat preference graphs for collared lions:

Habitat Preference of Male during Day and Night

Habitat Preference of Male and Female during Night
Habitat Preference of Female in Wet and Dry Seasons

Habitat Types

Proportion of GPS Locations

Wet
Dry

Habitat Types

Proportion of GPS Locations

Wet
Dry

Habitat Types

Proportion of GPS Locations

Wet
Dry

Habitat Types