

**THE IMPACT OF PREDATION ON GREVY'S ZEBRA (*Equus grevyi*)  
POPULATION ON LEWA WILDLIFE CONSERVANCY**



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**A thesis submitted in partial fulfillment of the requirements for the award of the  
degree of Master of Science in Biology of Conservation.**

## DECLARATION

This thesis is my original work and has not been presented for award of a degree in any other university

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## **DEDICATION**

I dedicate this thesis to my parents, my brothers, my husband and my lovely daughter Alcina Richelle. God bless you all.

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## **LIST OF ABBREVIATIONS**

**IUCN** – International Union for Conservation of Nature and Natural Resources

**LWC** - Lewa Wildlife Conservancy

**GIS** - Geographic Information System

**GPS** - Global Positioning System

**GZ** - Grevy's zebra

**RHC** –Reference Hair Collection

**LMD** –Livestock Management Department

## ABSTRACT

Lewa Wildlife Conservancy (LWC) is home to a large number of herbivores that form the prey base of a growing predator population. Similarly, LWC is home to at least 20% of the world's remaining wild population of Grevy's zebra. This is a significant breeding population with the potential for restocking former range lands of the species. Research and monitoring of this population is thus of paramount importance to understand and subsequently implement management interventions to ameliorate factors that constrain the growth of this population.

This research focused on explaining one factor limiting the growth of Grevy's population: predation by lions and hyenas and the availability of suitable resources. These issues required information on births, foal survival, mortality resulting from predation and proportion of Grevy's zebra hairs found in scat samples. This data was collected for a period of six months from October 2008 to April 2009. Five foals were born during the study period and three confirmed dead.

Vegetation study was carried out to determine the distribution and abundance of food available to the Grevy's zebra in the study area. Vegetation transects were set on different vegetation types and data gathered using a pin frame. Species diversity was found to be low (Simpson Diversity index (D) = 0.8) with *Pennisetum stramenium* being the dominant grass species. Green grass attracted more Grevy's zebra for both dry and wet season than areas dominated by brown grass but this was not statistically significant ( $F(1, 33) = 0.98$   $P > 0.05$ ). Grevy's also preferred areas with high grass biomass (11,095kg/ha,  $SE \pm 419$  kg/ha) as opposed to low grass biomass (9,964 kg/ha,  $SE \pm 647$ kg/ha),  $t = -3.53$ ,  $P < 0.05$ ,  $DF = 248$ . Tree density as a measure of cover was high at the core home ranges of both Grevy's zebra and lions (68 trees/ha).

Wildlife mortality data was collected based on daily field reports. The dead species was identified and cause of death as observed from the carcass recorded. Mortality data was analyzed using Jacobs Index to determine prey preference. Scat analysis results indicate that both species of zebras found on LWC, formed basic diet for the lion population.

Based on the findings of this research work, practical and relevant adaptive management interventions have been mentioned: Habitat manipulation to open up closed areas thus increasing the visibility of Grevy's zebra and also translocation of lions.



## CHAPTER ONE

### 1.0 INTRODUCTION AND LITERATURE REVIEW

#### 1.1 Introduction

Grevy's zebra numbers are declining in their ranging areas (William, 2002). In the 1970's, approximately 15,000 animals roamed the semi-arid areas of Kenya whereas today the population stands at 2,623 animals (KWS, 2008). This decline was attributed to poaching and competition with livestock for water and grazing resources especially for the populations outside protected areas in Northern Kenya.

In the protected areas where wildlife is encouraged and livestock has been withdrawn completely, numbers are also not increasing (Rubenstein, 2004). In Lewa Wildlife Conservancy for example, the numbers have been decreasing from a peak population of 500 animals in 1999 to 450 animals in 2000, 400 in 2008 and currently 370 animals (Lewa wildlife Conservancy, 2008). Three factors are likely to be responsible for limiting the growth of Grevy's zebra in such protected areas: Competition with other wildlife especially the Plains zebra (*Equus burchelli*), diseases and high parasite load and predation.

Preliminary study have revealed that diseases and parasite load are not likely to cause Grevy's zebra population decline on LWC since overall parasite loads of Grevy's zebras are much lower than that of Plains zebra (Njonjo, 2005). Competition with Plains zebras has a significant contribution to the decline of Grevy's population (Rubenstein *et al*, 2004) as the plains zebra reduces foraging success of Grevy's zebra.

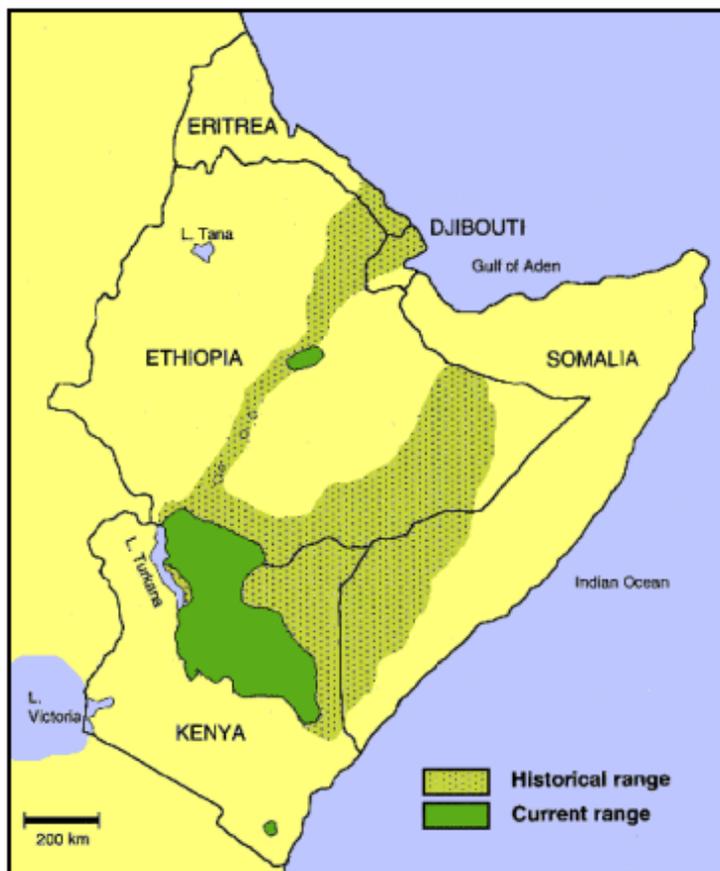
Research on Grevy's zebra predation has not been fully exploited and therefore, understanding patterns associated with Grevy's zebra predation can be key in explaining its impacts on the population and mitigate its effects and thus enhancing population growth. This study examined lion numbers and their distribution through daily tracking, and determined both lion and hyena diet through hair analysis from their scat.

Grevy's zebra distribution and habitat use was also assessed and foal census carried out to determine survival and recruitment rates.

## 1.2 Literature review

### 1.2.1 Numbers and distribution

Grevy's zebras have undergone one of the most drastic reductions in range and numbers since 1970's when the population was estimated at 15,000 animals (Klingel, 1980). Historically, they ranged in Kenya, Ethiopia and Somalia. The population is already extinct in Somalia (Figure 1).



**Figure 1:** Historic and present distribution of Grevy's zebra in the horn of Africa (data from Kingdon, 1979; Yalden et al, 1986)

According to surveys conducted in Kenya and Ethiopia, where the population lives sympatrically with pastoralists and their livestock, the population of Grevy's zebra now stand at 2,623 individuals up from rough estimates of between 2,000 to 2,300 (KWS 2008, Mwasi & Mwangi, 2007), indicating a positive response to Grevy's zebra conservation efforts. More than 80 per cent of this population is in the community areas with only 0.5 per cent of this falling within formally protected areas (Samburu and Buffalo springs G. Reserves) and private ranches such as Lewa. In Ethiopia, the most

recent update estimated 126 Grevy's zebra remaining (Kabede *et al*, 2003). In Kenya, the rate of decline has been slower than that of Ethiopia.

### **1.2.2 Conservation status**

With sharp population declines, Grevy's zebra have been placed on CITES Appendix I which offers them the highest protection against illegal trading and they are also listed as Endangered in schedule A1a, 2c by the IUCN Equid Specialist Group (IUCN, 2003). In Ethiopia, they are legally protected while in Kenya, they have been protected by a hunting ban since 1977 (KWS, 2008). The Kenyan Government is currently revising their conservation status from 'Game Animal' under the first schedule, Part II in CAP 376 of the Wildlife Management Act to 'Protected Animal' (KWS, 2008)

### **1.2.3 Ecology and behavior**

Grevy's zebra live in arid and semi-arid grass/shrub land where there is permanent water. They are predominantly grazers but in stressed conditions such as drought, they can browse for up to thirty percent of their diet (Rowen & Ginsberg, 1992). They require free standing water as part of their diet but bachelor males and non-lactating females can go for a maximum of five days without water; unlike lactating females which can only go for one to two days (Becker & Ginsberg, 1990).

The social organization has been described by Klingel (1974), Rubenstein (1986) and Ginsberg (1989). Breeding males defend large resource territories and behavior and reproductive success is dependent on females that are attracted to their territory. In contrast, a female's reproductive condition determines the priority that she places upon different resources (Williams, 2002). For example, lactating females are found in close proximity to water than other classes of females, thus they only mate with territorial males whose territories are close to water. Non- lactating females mate with males whose territories contain resources that attract them. Breeding is also dependent on conditions that facilitate oestrus among females (Williams, 1998). When resource availability is low, the body condition becomes poor and they do not go into oestrus. A peak in oestrus follows the onset of high resource availability which in turn results in a peak in births (Williams, 1998). Breeding is thus dependent on variations in climatic patterns specifically rainfall.

Lactating females with young foals are more predictable in association as they form stable groups and only separate after the lactation period while non-lactating females are less predictable. Their associations are fluid and their movement is determined by resource availability (Williams, 2002).

#### **1.2.4 Threats**

##### *Reduction of water sources*

The unregulated extraction of perennial rivers for irrigation in highland areas has resulted in a reduction of water available to Grevy's zebra (Rubenstein, 2004) specifically from Ewaso Ng'iro River. As water levels go down and eventually dry up, the range of all animals is restricted because they depend on permanent water sources. People and livestock on the other hand are more water dependent and hence settle around water sources especially during dry season thus excluding Grevy's zebra. This has adverse effects especially on lactating females as they are forced to drink during the night and exposing them to predation risks. To protect the water resources, pastoral people build thorn enclosures around the water points thereby blocking access by Grevy's zebra.

##### *Habitat degradation and loss*

National parks provide the best remaining habitat for many wildlife species but the parks are not enough to support all the wildlife populations. More than 70 per cent (Pratt *et al*, 1977) of the wildlife population in Kenya is found in unprotected areas that are mainly occupied by pastoralist communities. In these areas, wildlife coexists with livestock utilizing same resources. Pastoralists keep large numbers of livestock leading to overgrazing that changes vegetation communities induces soil erosion and lead to degradation of vegetation near water sources. This is severe especially during dry season when large numbers of livestock congregate around water sources in search of greener pastures in Northern Kenya.

In the recent years, pastoralists have started to live a sedentary life reducing the natural habitats into patches, some too small to meet the ecological requirements of the animals (Williams *et al*, 2004) especially those that require large tracts of uninterrupted habitat. Animals in these patches are becoming increasingly isolated by adjacent environments which are inhabitable or dangerous to cross.

### *Competition for resources*

Use of forage by large numbers of livestock leads to competition and this limits food availability to Grevy's zebra. This situation is worse in the dry season especially around water sources and lactating females are forced to travel far and wide between water and food sources. As long as pastoral people maintain high grazing pressure through livestock, Grevy's zebra will become increasingly mobile in search of food and water and overall, recruitment rates are likely to remain low (William, 2002).

In protected areas, Grevy's zebra may compete for resources with other wild animals. In particular, this happens where a higher population of plains zebra (*Equus burchelli*) are in higher density than Grevy's zebra (Rubenstein, 2004).

### *Hunting*

Although agriculture and animal husbandry has become more prevalent in arid areas, hunting has often remained as a part of human culture where the environment and social conditions allow. The drastic decline of Grevy's zebra population has been attributed to hunting for meat and medicinal purposes; where the fat is used to cure diseases. This has been reported in Sibiloi, El Barta, North Horr and South Horr (William, 2002).

### *Diseases*

Threat by diseases is very common to the populations in areas where there is a diffuse wildlife/livestock interface. The continued globalization of society, human population growth, and associated landscape changes further enhances the interface between wildlife, domestic animals, and humans, thereby facilitating additional infectious disease emergence. Further, habitat loss and other factors associated with human-induced landscape changes have reduced past ability for many wildlife populations to overcome losses due to various causes. The emergence and resurgence of diseases has reached unprecedented levels for the sustainability of viable population sizes for many wildlife populations and threatens the long-term survival of some species.

Anthrax is endemic to the Grevy's environment and this makes them susceptible to the disease (William, 2002). An outbreak of anthrax that was confirmed in Wamba area of Northern Kenya in 2005 lead to deaths estimated of over 100 Grevy's zebra (Manyibe *et al*, 2006).

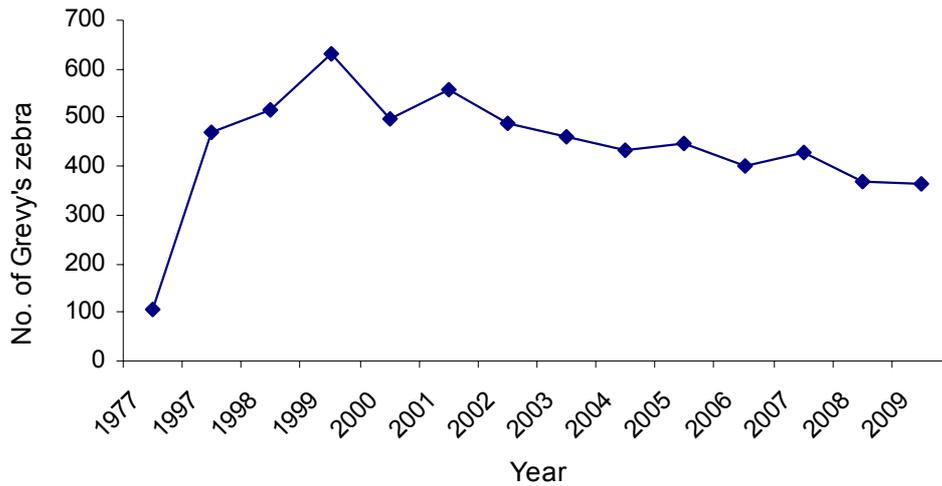
### *Predation*

Predation is important in influencing the distribution, abundance, and diversity of species in ecological communities. Generally, successful predation leads to an increase in the population size of the predator and a decrease in population size of the prey. These effects on the prey population may then ripple out through the ecological community, indirectly changing the abundances of other species.

This is a potential limiting factor in the growth of the population of Grevy's zebra, because the number of lions has greatly increased as a result of improved conservation efforts aimed at promoting tourism (Rubenstein, 2004) within the range of Grevy's zebra especially in protected areas. Lions and possibly hyenas are a major threat to the growth of the Grevy's population on Lewa Wildlife Conservancy (Mwololo, 2006) and in community areas within the larger Samburu landscape (King & Malleret-King, 2006).

### **1.3 Grevy's zebra on Lewa Wildlife Conservancy**

LWC is currently home to 370 Grevy's zebra, from 106 animals that were in Lewa in 1977, representing 14 per cent of the world's remaining population. The increase in the conservancy has mainly been through births. This sub-population is critical in the global context as it is one of the populations surviving inside a protected area. It is not faced with negative anthropogenic factors that threaten other population that survive outside protected areas in Northern Kenya. Due to this, it is expected to have optimum population growth rates and such can be used as benchmarks to compare reproductive rates of other sub-populations faced with livestock and human threats. One of the visions of LWC is to use its population of Grevy's to repopulate and re-stock areas that were once part of historic range.



**Figure 2:** Grevy’s zebra population trends in Lewa, 1977 – 2009. (Data source: Lewa Research Department, 2009)

Diseases and competition for resources are low on LWC, but predators are present thus providing an opportunity to study predator-prey relationships.

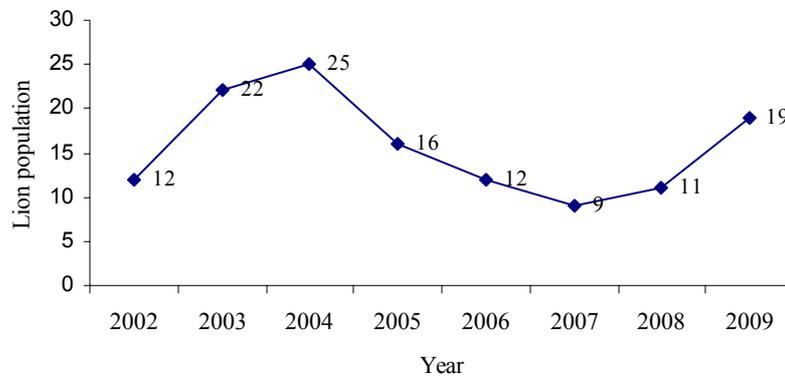
The distribution of Grevy’s zebra within LWC has been found to vary with season (Cornwall, 2000). During the wet season, these animals are distributed in open grasslands while during the dry period, large herds are normally found near permanent water sources. Lactating females have been found to use only some specific areas for the first 9 months of the foals' life thereafter dispersing out from their birth places and inhabiting all the ranges of the Conservancy. These areas are characterized with availability of water and grass that is almost ever green and nutritious almost all year round (Rubenstein *et al*, 2004).

Territorial stallions defend their territories retaining exclusive breeding rights within their territories. Non-lactating females and bachelor groups do not to have any fixed area of habitation as they crisscross the entire Lewa wildlife conservancy.

#### **I.4 Lions on Lewa Wildlife Conservancy**

Tourism has flourished on LWC in the past few years and the management has adopted measures aimed at increasing lion population to boost and support tourism such as offering maximum protection to wildlife through enhanced security (Rubenstein, 2004). In October 2004, the population stood at 25 resident lions up from an estimated population of 12 in 2002 mainly through immigration from Borana Ranch – Lewa’s

neighbour to the west. There was a significant reduction in the following years to a minimum of 9 resident lions (figure 3) following emigration to Borana ranch and Samburu National Reserve.



**Figure 3:** Lion population trends in Lewa, 2002 - 2009 (Data source: Lewa Wildlife conservancy)

### 1.5 Justification

Grevy's zebra numbers on Lewa appear to fluctuate from 360 to 400 individuals. Predation resulting from an increasing lion population and changes in the survival rates for the Grevy's zebra foals may be changing affecting the entire population size. In order to reverse the trend in the decline of Grevy's zebra it is important to study the impact predation has on this population. Understanding the predator-prey dynamics within LWC will help to obtain accurate information on the contribution of lions and hyenas to the decline of the Grevy's zebra population.

With this understanding, LWC managers will be able to implement effective control strategies ensuring that the Lewa Grevy's zebra population remains large and even expands in size.

### 1.6 Objectives

The primary objective of this study was to investigate the impact of predation of prey species by lions and hyenas with particular emphasis on the endangered Grevy's zebra on Lewa Wildlife Conservancy (LWC).

The specific objectives of this study were to:

1. Investigate the impact of predation of prey species by lions and hyenas with key emphasis on Grevy's zebra.
2. Assess the survival and recruitment rate of Grevy's zebra foals

3. Monitor Grevy's zebra population and movements on a spatial-temporal base to determine habitat use.
4. Determine the status of the current LWC lion population.

### **1.7 Hypothesis**

The hypotheses of this study were:

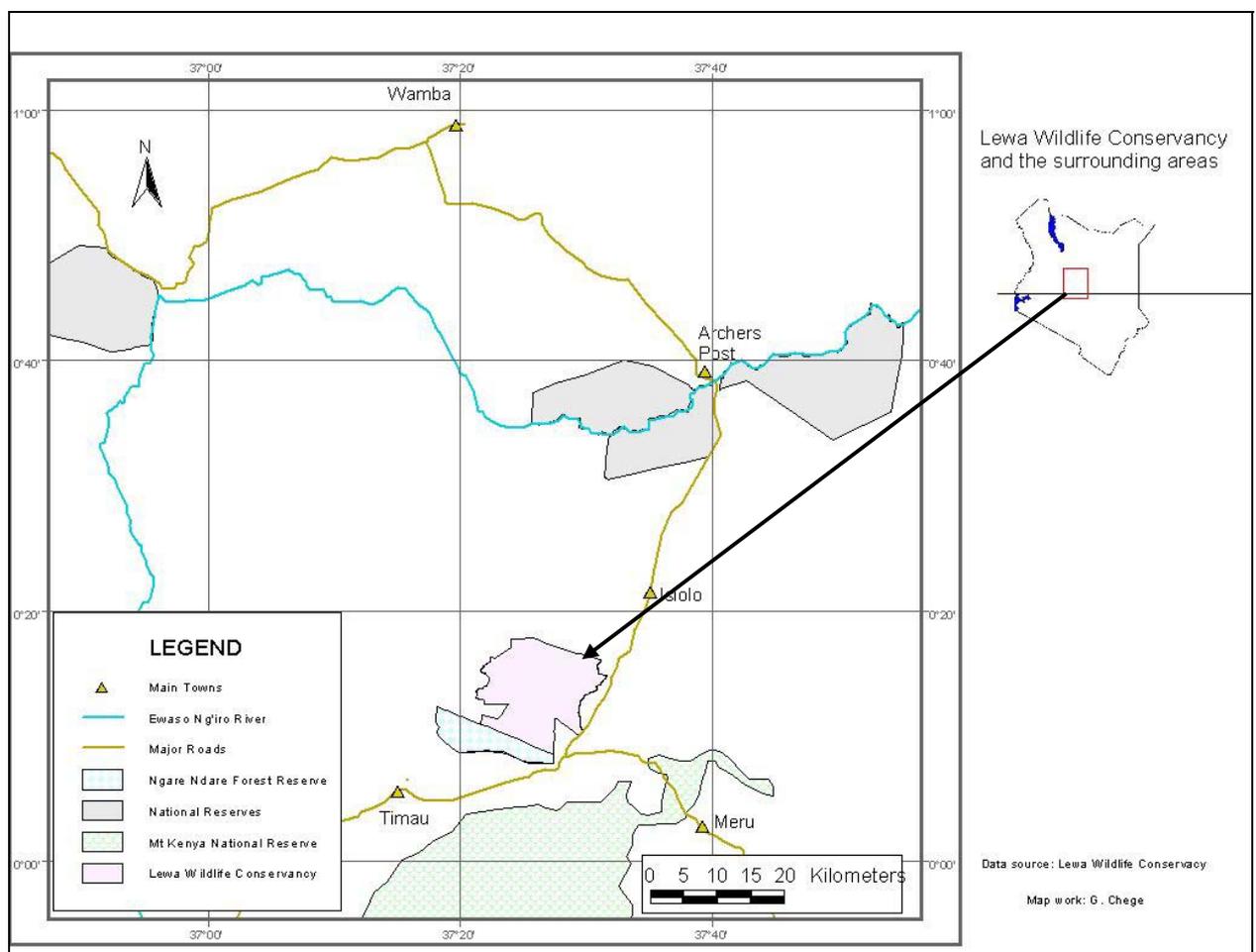
1. Predation has an impact on Grevy's zebra movement within LWC, related to resource availability.
2. Grevy's zebra maybe the most preferred prey species by both hyenas and lions.

## CHAPTER TWO

### 2.0 STUDY AREA, MATERIALS AND METHODS

#### 2.1 Study area

The Lewa Wildlife Conservancy lies between latitudes  $0^{\circ} 06'$  and  $0^{\circ} 17'$  North and longitudes  $37^{\circ} 21'$  and  $37^{\circ} 32'$  East in the Northern foothills of Mount Kenya, about 65km north east of Nanyuki town and it is approximately  $267 \text{ km}^2$  in size. There is an elephant access route on the Northern boundary that allows for migration of all the animals with an exception of the rhinos (Botha, 1999). A one meter wall of stones has been piled on this gap limiting exit by rhinos.



**Figure 4:** Map of Lewa Wildlife Conservancy in relation to its position in Kenya

### **2.1.1 Topography**

Lewa is located on an altitudinal gradient, varying from 1450m above sea level in the North, to 2300m above sea level in the south. As a result, the area contains many different topographical and geomorphological units (Botha, 1999). The topography can be described as broken, with steep valleys in the south, gradual slopes tending to flatter volcanic plains in the central part and undulating hills with occasional steep river valleys in the North.

### **2.1.2 Drainage**

Lewa's drainage network forms part of the Ewaso Ngiro river basin situated north of the study area. They are Ngare Ndare river, Ngare Sergoi river and the Lewa river. The latter river originates as a spring and flows through the Lewa swamp. The seasonal Marania river has its source, the Lolmutunyi spring, in the northeastern corner of Lewa. The Marania river and Lewa river join at Isiolo town to form the Keromet River, which in turn flows into the Ewaso Ngiro river. There is a dam on the Western side of the conservancy.

### **2.1.3 Geology and soils**

Two distinct geological rock formations occur on Lewa (Botha, 1999), namely basement rocks and volcanic rocks. Basement system rocks are sedimentary deposits that form the floor upon which the remaining rocks of the area rest. The system consists of schists, granulites and heterogeneous gneisses (Linsen & Giesen, 1983) volcanic rocks and subordinate sediments of the Mount Kenya volcanic series. The volcanic rocks consist of upper basalts, overlying lower basalts of the Mount Kenya volcanic series. Some areas are covered by superficial Pleistocene deposits which are mainly volcanic ash or basement system gneisses.

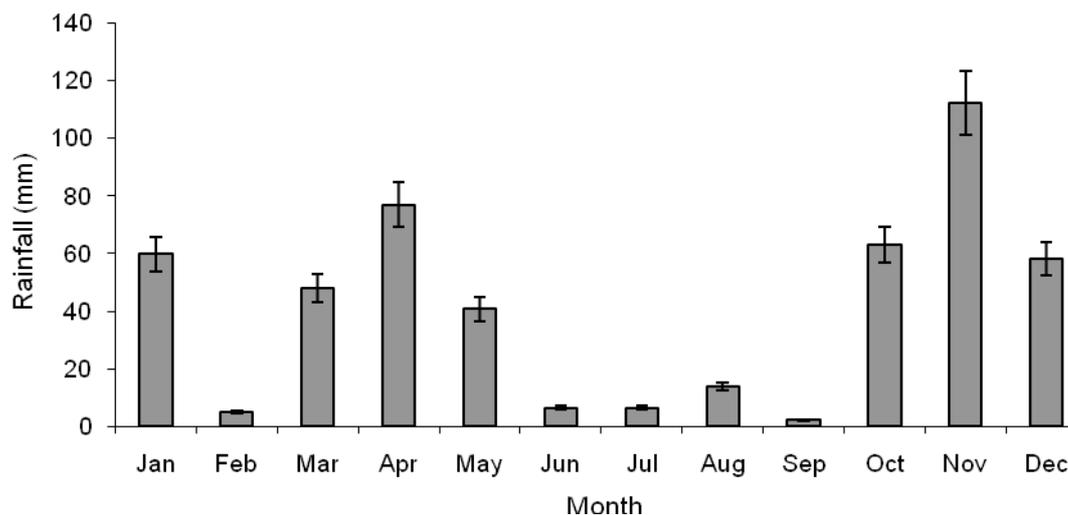
Five dominant soil types are found on Lewa, namely; nitisols, vertisols, solonetz, fluvisols and gleysols and are mainly derived from the erosion of geological formations. Much of Lewa is underlain with black cotton type of vertisol which is a characteristic of impeded drainage. Solonez soils are deep, red soils and are characterized by extreme erodibility, low resilience and poor recovery potential

### 2.1.4 Climate

Linsen and Giesen (1983) describe the climate of Lewa as transitional between that of the eastern Kenya Highlands and Northern Kenyan Lowlands.

The daily maximum temperatures on Lewa range from 24°C to 32°C and the daily minimum temperature from 8°C to 16 °C (Linsen & Giesen, 1983). According to Botha (1999) the daily maximum temperatures during the wet season are lower than during the dry season. Conversely, the daily minimum temperatures during the wet season are higher than during the dry season. There is a marked temperature difference along an altitudinal gradient, being warmer in the north than in the south.

There are two main rainy seasons: the long rains which fall in March to May and short rains from October to December. The mean annual rainfall is 666mm, ranging between 250mm to 700 mm per annum. Periods of prolonged drought are relatively common.



**Figure 5:** Mean monthly rainfall ( $\pm$ SE) recorded at LWC, 1995 to 2008. (Data source: Lewa Wildlife conservancy, 2008)

### 2.1.5 Vegetation

The vegetation of Lewa forms a transition from a semi arid highland to arid lowland.

Most of the area can be physiognomically described as savanna or, more precisely, grassland with a tree and a shrub cover of more than 20 per cent (Pratt & Gwynne, 1997).

Eleven vegetation types have been recognized as: *Stipa dregeana* – *Juniperus procera* tall forest; *Acacia drepanolobium* – *Themeda triandra* low thicket; *Commiphora africana* – *Lanea rivae* low thicket; *Acacia tortilis* – *Chrysopogon plumulosus* low thicket; *Acacia nilotica* – *Pennisetum stramenium* low open woodland; *Acacia mellifera* –

*Sorghum versicolor* tall sparse shrubland; *Pennisetum stramenium* – *Becium hildebrandtii* short closed grassland; *Acacia drepanolobium*-*Acacia seyal* low open woodland; *Acacia xanthophloea* – *Achyranthes aspera* tall closed woodland; and, *Typha domingensis*- *Echinochloa colona* swamp.

These plant communities have been placed into four main habitat types, based on dominant plant species; that form the basis for management of Lewa Wildlife Conservancy; these four types are: Forest habitat, Plain habitat, Hill and rocky outcrop habitat and Riverine habitat.

### **Forest Habitat**

The Ngare Ndare forest consists of about 7,300 ha of *Juniperus-Olea* forest. It extends in altitude from about 2000 m to the upper limit of LWC at 2400 m – above this level forested areas give way to extensive wheat fields. This forest has recovered spectacularly since its incorporation into LWC where tree and shrub cover was about 35 per cent in 1962, but now is more than 80 per cent. Characteristic species are ‘Cedar’ *Juniperus procera*, Brown Olive *Olea africana* and a wide range of broadleaf species such as *Dodonea*, *Euclea*, *Lannea*, *Myrsine*, *Rhus* and *Scolopia*

### **Plain habitat**

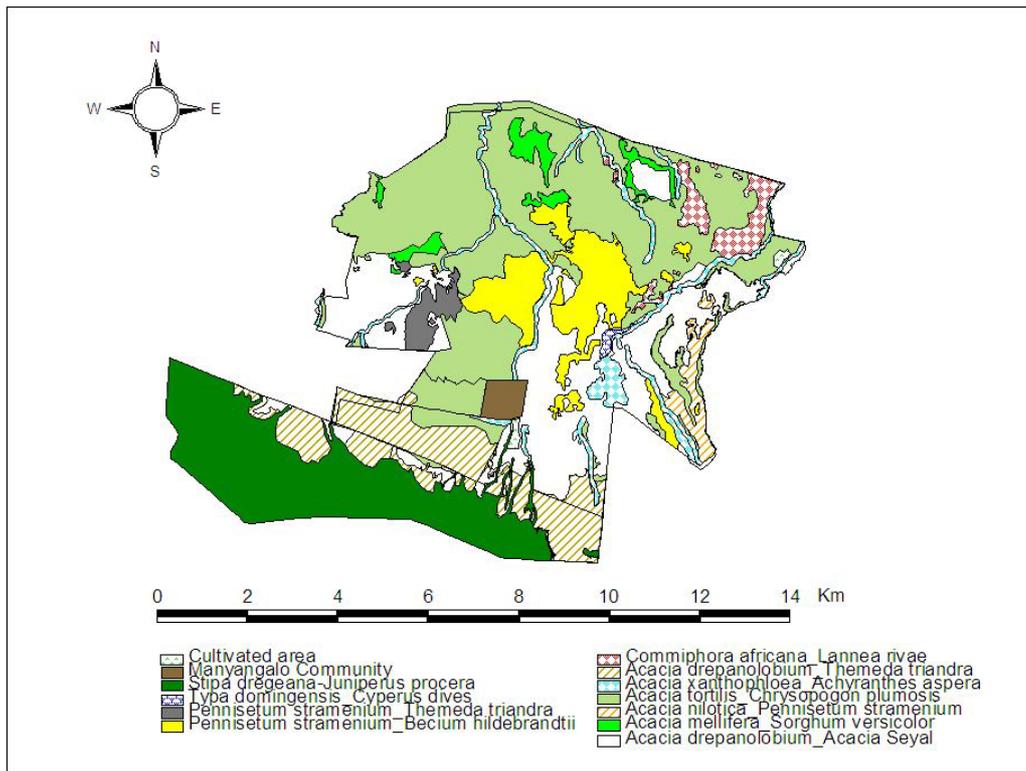
This is the most extensive habitat in LWC, covering about 7000 ha. It is dominant by *Pennisetum* grasses mainly *Pennisetum mezianum* and *Pennisetum stramenium*. Both species are tough and wiry, and fairly unpalatable to stock and wildlife when mature, but form good grazing when freshly sprouting. Several herbs are found in this habitat type especially after the rains: *Aerva lanata*, *Helichrysum glumaceum*, *Heliotropium steudneri*, *Indigofera volkensii*, *Ocimum filamentosum* and *Vigna frutescens*, but also succulents such as *Ammocharis tinneana* and *Crinum macowanii* . This habitat type is dominated by acacia tree species mainly *Acacia drepanolobium* and *Acacia seyal*, and these may dominate along with the two *Pennisetum* grasses mentioned above. Other common shrubs and shrublets in the plains include *Boscia mossambicus*, *Hibiscus flavifolius* and *Lycium shawii*.

### **Hill & rocky outcrop habitat**

This is the most varied habitat in Lewa, occurring on a range of soils (clays derived from basalts or volcanic ash, and sandy soils formed from Basement Complex gneiss) and with a wide range of species. In some areas, the 'hill' aspect may not be apparent, but where rocks are at the surface, characteristic species are usually found. A range of tree and shrub species dominate this habitat, including various acacias (*Acacia brevispica*, *A. mellifera*, *A. nilotica*, *A. senegal*, *A. tortilis*), *Commiphora* and *Grewia* species (*Grewia holstii*, *G. similis*, *G. tembensis*), and a wide range of herbs species mainly *Justicia*, *Kalanchoe*, *Pellaea* and *Commelina*.), grasses (*Aristida*, *Chrysopogon*, *Heteropogon*, *Hyparrhenia*, *Microchloa*, *Rhynchelytrum repens*, *Themeda triandra*, *Tragus berteronianus*) and climbers (*Cissus rotundifolia*, *Gloriosa simplex*, *Sarcostemma viminale*).

### **Riverine habitat**

This habitat covers a small area ranging from areas around rivers and the swamp. It is highly important as it provides drinking water and green vegetation for wildlife during periods of drought, and for certain species such as waterfowl, amphibians and sitatunga, it forms the only available habitat. These perennial streams are characterized by the presence of *Acacia xanthophloea*, along with a host of sedges (mainly *Cyperus* spp.), grasses (*Digitaria* spp, *Leersia hexandra*), and cattail (*Typha domingensis*) and semi-aquatic herbs such as *Berula erecta*, *Lythrum rotundifolium*, *Mentha longifolia*, *Polygonum strigosum* and *Ranunculus multifidus*. In deeper valleys the wild date palm *Phoenix reclinata* is also characteristic, along with the sycamore fig (*Ficus sycomorus*) although the latter is less widespread. Other streams are ephemeral, and fever trees may be absent if groundwater levels are drawn down too much in the dry months. Lewa swamp, which extends over about 60 ha is dominated by *Cyperus dives*, along with *Cyperus assimilis*, *C. esculentus*, *C. involucata*, *C. sphacelata* and *Scirpus brachyceras* and a range of herbs and grasses, including *Eragrostis paniciformis*, *Eriochloa meyerana*, *Leersia hexandra*, *Sporobolus pyramidalis* (grasses), *Alisma plantago-aquatica*, the uncommon *Berula erecta*, *Lythrum rotundifolium*, *Mentha longifolia*, *Ranunculus multifidus*, *Sphaeranthus gomphrenoides* and *Veronica anagallis-aquatica*



**Figure 6:** Map of Lewa showing different vegetation types (Map source: Lewa Wildlife Conservancy)

### 2.1.6 Fauna

The conservancy's diverse area vegetation communities and water availability attracts many wildlife species. Because of a reduction in the natural habitat for the wildlife species in Northern Kenya, the remaining populations have sought refuge in protected areas such as LWC. Wildlife has always had access to Lewa through the game gap that connects LWC and community conservancies and National reserves in Northern Kenya. Lewa also forms part of an old migration route for elephants into the Ngare Ndare Forest and Mt. Kenya complex. It also provides refuge and effective protection for both the black and white rhinoceros population. All species have benefited from the enhanced level of security afforded by Lewa, particularly the Grevy's zebra *Equus grevyi* and Sitatunga *Tragelaphus spekii*. On rare occasions, wilddog *Lycaon pictus* enter Lewa from neighbouring ranches and community areas. Sightings of Lesser kudu *Tragelaphus imberbis* have also been documented even though they are found in low numbers. Reticulated giraffe *Girrafa camelopardalis*, is found in the conservancy and throughout

northern Kenya. Plains zebra *Equus burchelli*, are quite common. Cape buffaloes (*Syncerus caffer*), impalas (*Aepycerios melampus*) and defassa waterbuck (*Kobus defassa*) favor heavily bushed areas. Other large ungulate species found in the conservancy are the beisa oryx (*Oryx beisa*), Jackson's hartebeest *Alcelaphus buselaphus*, the eland (*Taurotragus oryx*) and the gerenuk (*Litocranius walleri*). Small ungulates include Klipspringer (*Oreotragus oreotragus*), common duiker (*Sylvicapra grimmia*), Kirk's dikdik (*Madokua kirkii*) African hare (*Lepus capensis*) and warthog (*Phacochoerus aethiopicus*).

The predators present in the conservancy include lion (*Panthera leo*), leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), caracal (*Caracal caracal*), African civet (*Civettictis civetta*), wild cat (*Felis silvestris*), wild dog (*Lycaon pictus*), spotted hyena (*Crocuta crocuta*) and striped hyena (*Hyaena hyena*). The smaller predators include the bat eared fox (*Otocyon megalotis*), golden-backed jackal (*Canis aureus*), black-backed jackal (*Canis mesomelas*), serval cat (*Felis serval*), aardvark (*Orycteropus afer*) and dwarf mongoose (*Helogale parvula*)

Primates found in the reserve are the vervet monkey (*Cercopithecus aethiops*), olive baboon (*Papio anubis*) and colobus monkey *Colobus guereza* found in Ngare Ndare Forest.

Almost 400 species of birds have been recorded in the conservancy. Birds of prey abound in the conservancy notably the martial eagle (*Polemaetus bellicosus*), bat-eared eagle (*Terathopius ecaudatus*), eastern pale chanting goshawk (*Melierax poliopterus*) and augur buzzard (*Buteo augur*).

## **2.2 Materials and Methods**

### **2.2.1 Grevy's zebra monitoring**

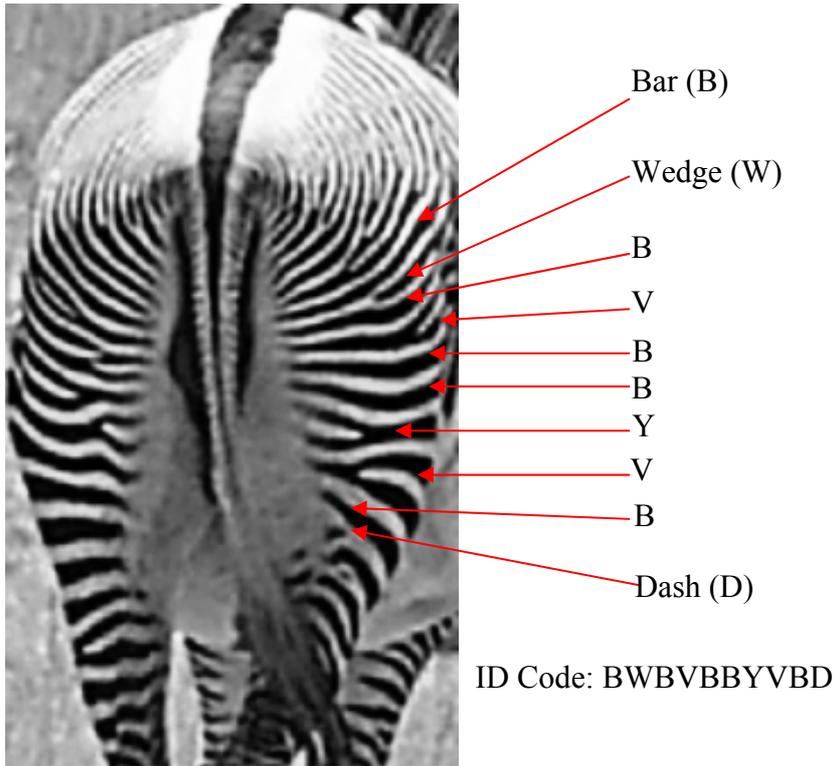
#### ***Grevy's zebra distribution***

Data on zebra distribution was collected within the different habitat types (Low thicket, low open woodland, tall sparse woodland and short closed grassland) and this gave an indication on the level of habitat use. Within these habitat types, they were further classified into two categories: utilized and less utilized areas. These distributions provide data for calculating habitat use and range overlap between Grevy's zebra and lions. Study groups were identified while driving along these areas. Driving speed was maintained at 20 kilometres per hour to avoid disturbing the animals.

Only Grevy's zebra that were within a range of 200m from the road were sampled. Distance here was estimated using a range finder. On sighting GZ groups the following point sample information was recorded: group size, age and sex structure, GPS location, time, grass species, distance to water: estimated on a straight line and other wildlife species present. Grass species was identified from the ground and this was the last to be recorded to avoid disrupting the focal group. A group here was defined as all animals occurring within 50m of another individual.

#### ***Foal census***

All lactating females were identified and these monitored on a monthly basis. Any female sighted with a new foal were subsequently added to database. Digital photos were taken on the right rump for each individual female for identification purpose. Identification was done using a customized database that relies on the unique bar code on the right rump of Grevy's zebra. These stripes are unique to each individual just like the human finger prints. The barcode begins below the tail base and ends at the hind leg where the black stripe goes round the leg. This identification system falls into several categories depending on their connections and their endings in the un-striped area near the tail as shown in figure 7 below.



**Figure 7:** Digital identification of Grevy's zebra

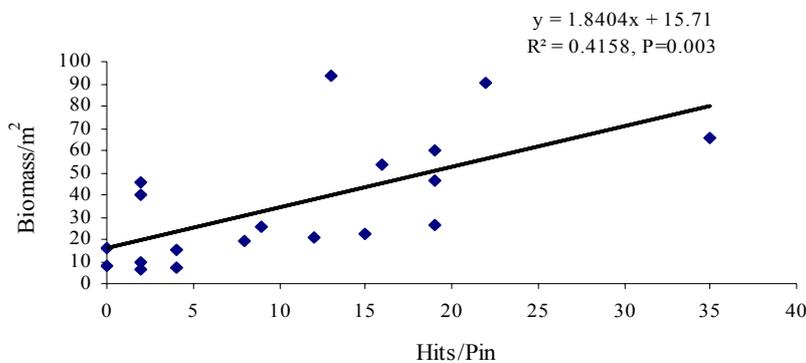
Wedges (W) are shorter than their adjacent stripes and do not reach the un-striped area. Bars (B) start at the un-striped area and round the leg without any distinguishing features. Dashes (D) begin at the edge of the un-striped area but only extend partially around the leg. A V begins at the edge of the un-striped area but then splits into two or more stripes as it rounds the leg. A Y begins as 2 stripes that then merge as they round the leg.

Data on group composition, location, habitat type and distance to water were recorded. The location data was recorded using a GPS and this information used to determine the home ranges for the lactating females and how these change over time. This data also gave an insight on extent of overlap with the lion home range. All the data was collected during the day.

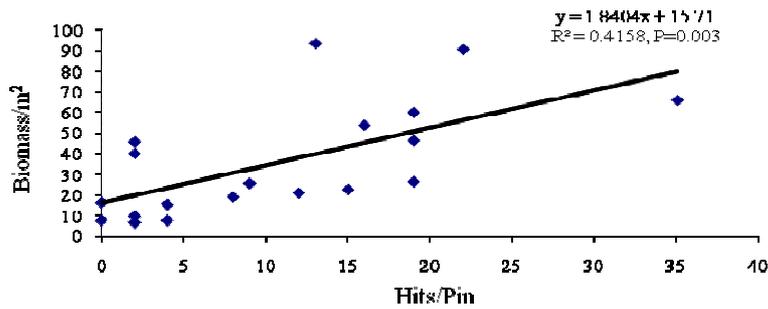
### 2.2.2 Vegetation Measures

The objective of studying vegetation was to determine the distribution and abundance of food available to the Grevy's in the study area. Grasses were the dominant food type for the zebras; a zebra's perception of the food in its environment can be described by its composition and abundance of grass species in a particular habitat.

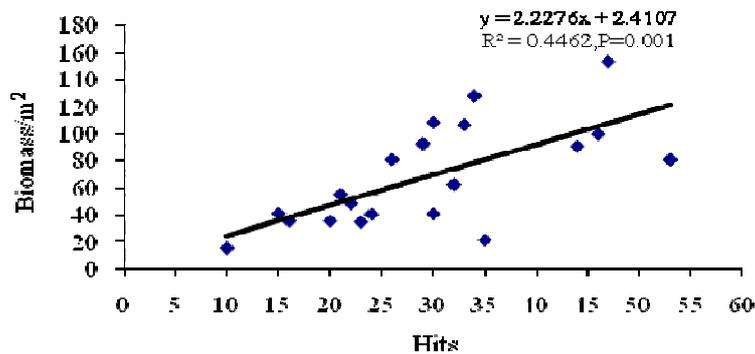
The study area was divided into 9 transect loops based on habitat type and a total of 44 transects were set and these were sampled at two weeks interval. Grass biomass and cover was estimated using point intercept method. The pin was first dropped 50m from the vehicle and successive pins dropped at 1m interval following a straight line to a 30m transect. If a blade of grass touched a pin, grass part (stem, leaves), species, colour (green/brown) and dominant grass species were recorded. Grass height was recorded in centimetres. A 0.5m by 0.5m quadrant was placed randomly within a transect and all the above-ground grass biomass within the quadrant was harvested, dried and weighed. The objective of harvesting grass was to derive an equation (regression) which relates the number of hits on each pin to dry weight biomass of the grass. The regression was calculated for both wet and dry season in both utilized and less utilized areas and tested at  $P= 0.05$  as shown in figures 8a to 8d. Utilized and less utilized areas were delineated using Kernel densities.



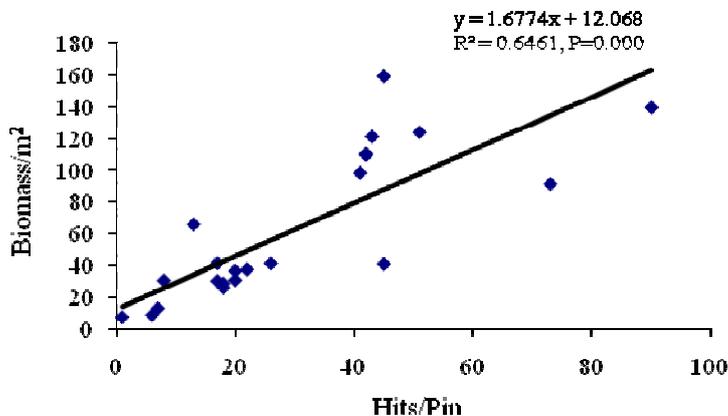
**Figure 8a:** Dry season; less utilized areas



**Figure 8b:** Dry season; utilized areas



**Figure 8c:** Wet season; utilized areas

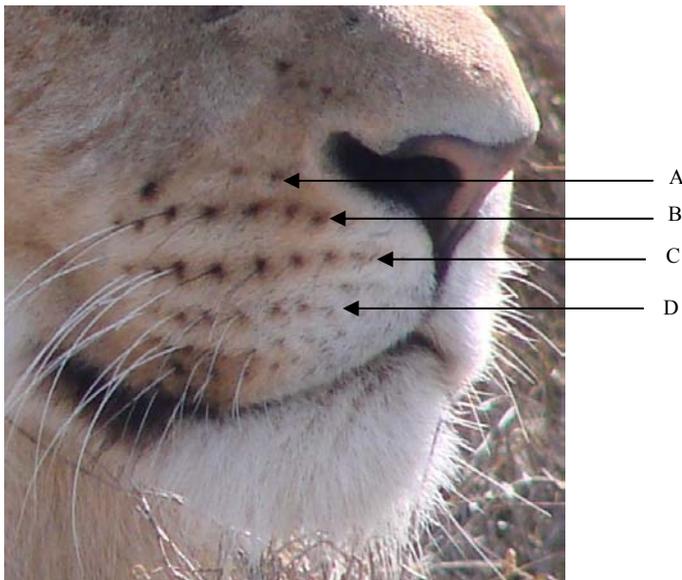


**Figure 8d:** Wet season; less utilized areas

Tree density was estimated in lion home ranges to determine percentage cover. Cover is very important in providing resting place for lions and also in hunting. A total of 20 belt transects measuring 20m by 100m were set. All trees species within a transect were identified and measurements of crown diameter, depth at breast height (DBH) and trunk diameter for each species were taken.

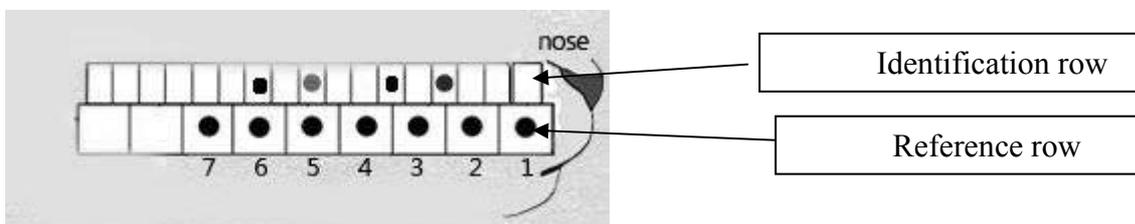
### 2.2.3 Identification, collaring and monitoring of lions

To establish the size of the lion population on LWC, it was necessary to identify individual lions using Pennycuick and Rudnai's method (1970). This method relies on the unique facial whisker spots patterns figure 9, which are as unique as fingerprints are for humans; these are normally different on both sides of the face. Other identifying characteristics such as spots on the nose or cuts and notches on the ears are less effective as these can change throughout the lions' life.



**Figure 9:** Whisker spot patterns

Two rows are used; the identification spots (A) the reference row (B) (Figure 9). The identification spots form an incomplete row above the reference row. There may be up to 5 spots and it is the position of these spots in relation to row B that gives the identification of the lion (figure 10).



**Figure 10:** Spot diagram and position of spots on row A relative to those on row B

In relation to row B, the first spot is in between spots 2 and 3, while the second spot is between spots 3 and 4, the third spot is directly above spot 6. This lion is therefore given the first code as R3: indicating the three spots on right side. We can therefore build on

that code, by indicating the location of the two spots: R2: 21/2,31/2, 6. It is important to give codes for both left and right sides so as to give precise ID codes. Over time, by identifying and re-sighting lions and also identifying new lions, an accurate estimate of the lion numbers was obtained.

Two lions were fitted with VHF collars which transmit a radio signal that can be picked up with a hand-held receiver connected to a directional antenna (Telonics USA). These lions were tracked on a daily basis and this acted as a reference point for locating other lions that may be present in that group. Data on GPS location, group size and sex of each individual was recorded.

Distribution data for both Grevy's and lions were imported into Arc view 3.2 for home range analyses and the delineation of animal movement paths using the extension Animal Movement. Home range is the area traversed by the individual in its normal activities of food gathering, mating, and caring for young. Occasional sallies outside the area, perhaps exploratory in nature, were not considered part of the home range. Most animals do not utilize their entire home range with equal intensity. Certain areas tend to be utilized more heavily than other areas. The center of activity is defined as the geographical location within the home range of the point of greatest activity. Kernels present quantitatively such activity densities within the ranges. The method mathematically converts the position coordinates into lines or areas with varying probabilities of use and presents these graphically. The width of the kernel is based on the smoothing parameter (h), which can be determined by reference (which is based on assumptions of bivariate normality) and least-squares cross validation (which is based on properties of the data) (Kernohan *et al* 2001). Home ranges were delineated using 95% kernel home ranges for point distributions, and 50% kernels to delineate core areas. For purposes of this study areas that were defined by the 95% kernel that fell outside the reserve boundary were clipped as these could not contribute to the home range.

#### **2.2.4 Wildlife mortality**

All species deaths were recorded, at the same time taking notes on the cause of death. This was done through a total count. For the purpose of this study, only predator related deaths were taken into account. Carnivore species responsible for any death was

identified based on mode of killing that could be indicated on marks on the carcass, mode of feeding and tracks around the kill.

### **2.2.5 Scat collection and analysis**

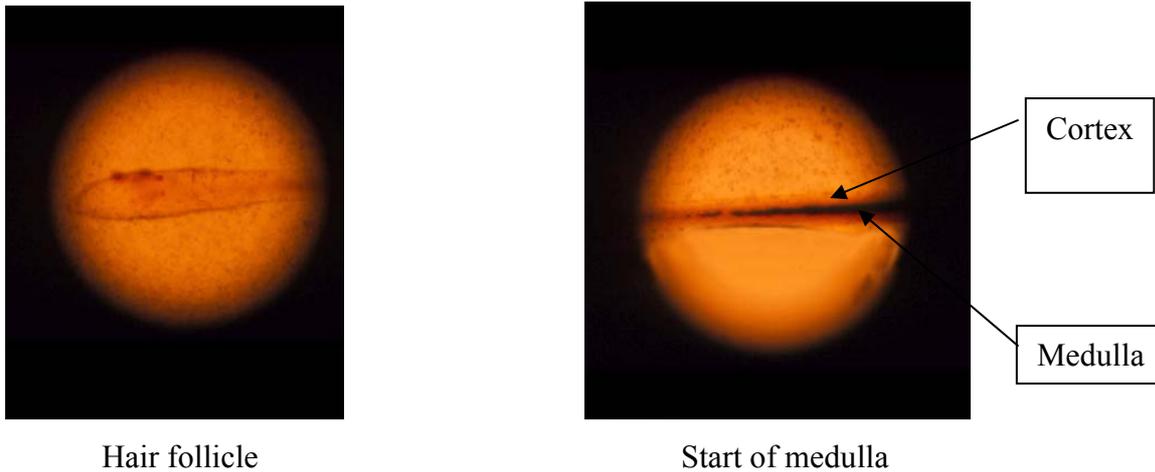
Lion and hyena scat was collected within the conservancy: around kills, dens, resting sites and opportunistically on roads. Hyena scat is white in color from the high calcium content associated with consuming bones while lion scat is black in color.

Hair analysis (Njonjo, 2005) was carried out on LWC laboratory aimed at determining different prey species that were fed on by the lions and hyenas.

Fresh scats and those one or two days old were collected, then dried in open air for 1 to 2 days, during the dry season and for 3 to 4 days during the wet season. The process of drying did not affect the quality of sampling hairs. The samples were placed underneath square wooden wire mesh covers to ensure that they were not tampered with by monkeys and other wild animals.

Once dried, the scats were soaked and cleaned in ethanol (70% alcohol) mixed with hot water in equal proportions. This method allows extraction of the hairs without breaking them. The extracted hairs were then placed in a Petri dish containing pure ethanol and for a period of one hour. This allows further cleaning of the hairs by removing any fatty emulsions and bacteria that may contaminate the hairs while in storage. The hairs were then removed from the Petri dish using forceps, dried and placed in safe plastic bags, which were then labeled accordingly.

20 hairs from each sample were selected for mounting, however only hairs with the follicle (root) intact were mounted. This is very critical for identification as the medulla (middle part) and the cortex (outer layers) are clearly visible (figure 11), and distinct away from the root but become fused on approaching the tip.



**Figure 11:** Image showing hair follicle and medulla

The hairs are mounted on microscope slides using a DPX mountant, and then a glass cover placed on top. All the examinations were done at a magnification of 10.

A Reference Hair Collection (RHC) was established during the period of study. This was made up of hairs collected from all the possible prey species within LWC. These were then permanently mounted. The hairs were always plucked from the skin, never cut, to ensure the presence of the follicle.

### 2.2.6. Statistical analysis

Data was analyzed in PAST and MINITAB programs. The laboratory analysis data were normalized by log transformation [ $X' = \log(X+1)$ ] before applying parametric analysis tests because some of the values were very small or even zero. All hypotheses were tested at  $\alpha = 0.05$ .

Simpsons index (D) was calculated and used as a measure of species diversity for all sampled sites.

To determine a predator preferences, Jacobs' Index (D), was used (Krebs, 1989).

$$D = \frac{r - p}{r + p - 2rp}$$

where  $r$  = the proportion of the total kills at a site made up by a species

$p$  = the proportional availability of the prey species (Jacobs, 1974).

The resulting value ranges from +1 to -1 where +1 indicates maximum preference and -1 indicates maximum avoidance (Jacobs, 1974). The mean Jacobs' index for each prey species across studies was calculated and these values were tested for significant preference or avoidance using  $t$ -tests against a mean of 0 if they conformed to the assumptions of normality (Kolmogorov-Smirnov test).

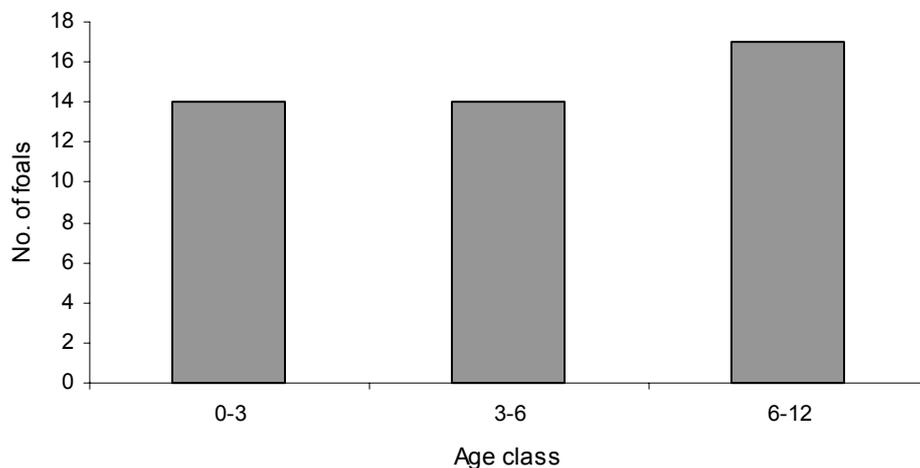
## CHAPTER THREE

### 3.0 RESULTS

#### 3.1 Foal census and survival

A total of 45 foals were counted during the period of study. The sex ratio was compared of the observed number of male foals (16) to female foals (29) with the number of each sex expected under the sex ratio equality (45/2, 23 individuals of each sex) using a chi square test, ( $\chi^2=5.8$ , DF=1,  $P<0.05$ ), indicating that the sex ratio was biased towards the females.

55 per cent of the total foals counted were within 6-12 months age bracket compared to 21 per cent of foals aged 0-3 months and 24 per cent foals aged 3-6 months, (figure 12).



**Figure 12:** Number of foals in different age categories.

Foals were encountered on specific vegetation types: along riverine areas dominated with *Acacia xanthophloea-Cynadon dactylon*, south of Lewa dominated with *Acacia drepanolobeum-Themeda triandra* and a small group to the north with *Acacia mellifera-Sorghum versicolor*.

Five foals were born during period of study, two foals were confirmed dead and four suspected to be dead. Foals were suspected to be dead if the mother was sighted without a foal for two consecutive months. The survival rate was calculated as 86%.

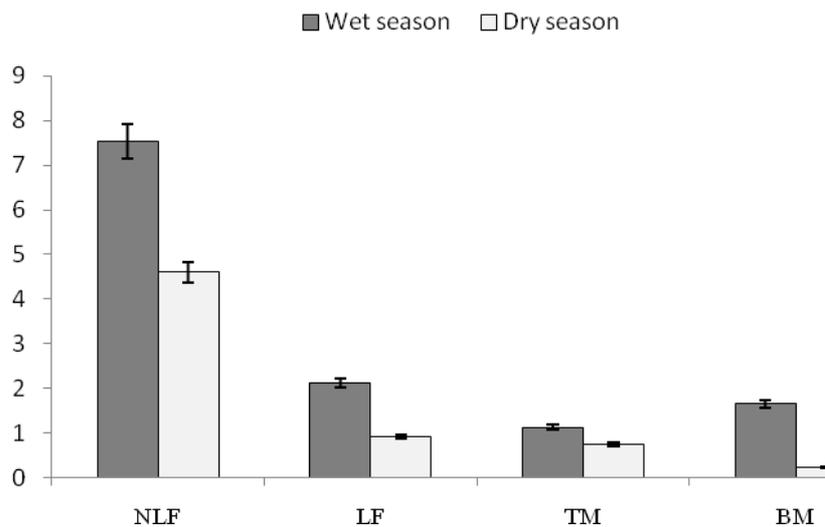
#### 3.2 Inter-birth interval

Out of the 45 lactating females, 38 were found on the Lewa Grevy's zebra database. 7 females were new entries into the database. 17 of these lactating females had already

produced foals in the past three years and a further six may have had foals and were pregnant. Average inter-birth interval calculated was 17 months.

### 3.3 Distribution of Grevy's zebra reproductive classes.

Figure 13 shows the general breakdown of different reproductive classes of the Grevy's zebra encountered in different seasons.

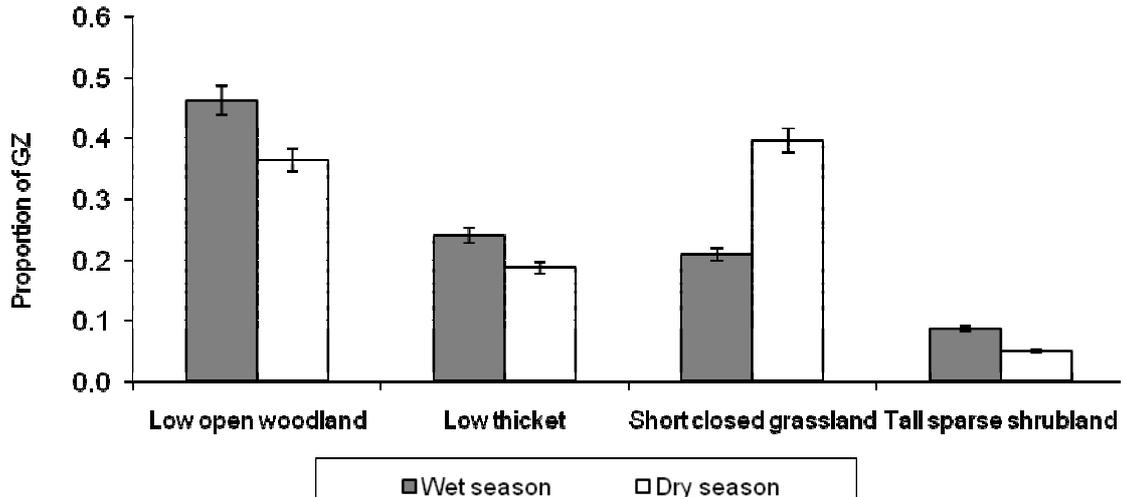


(NLF-Non lactating female, LF- Lactating female, TM- Territorial males, BM- Bachelor males)

**Figure 13:** Mean number of Grevy's zebra reproductive classes encountered in wet season and dry season.

Non lactating females were encountered more than any other reproductive class ( $F_{(3,348)} = 26.02$ ,  $p < 0.05$ ) in both seasons. Comparison was made between the distribution numbers for the two seasons. The two seasons were not significantly different with reference to the numbers encountered ( $t_{(1, 34)} = 1.78$ ,  $p > 0.05$ ).

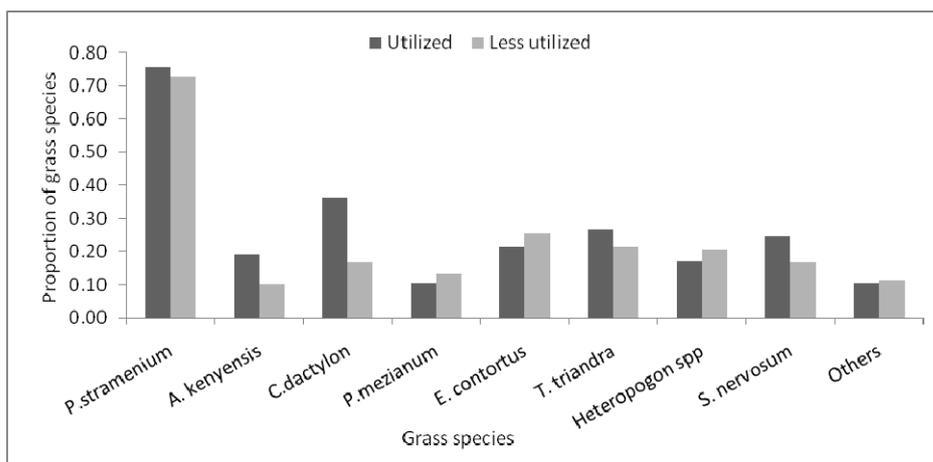
There was no significant difference ( $F_{(1, 7)} = 2.84$ ,  $p > 0.05$ ) in the distribution of Grevy's zebra in the low open woodlands ( $21 \pm 8.6SE$ ) and the short closed grasslands ( $10 \pm 3.8SE$ ) during the wet season. The least proportion was found in tall sparse shrub land ( $6 \pm 1.7SE$ ) in both dry ( $5 \pm 2.1SE$ ) and wet ( $10 \pm 2SE$ ) season. There was no significant difference in zebra abundance in both tall sparse shrub land ( $F_{(1, 9)} = 4.19$ ,  $p > 0.05$ ) and low thicket ( $F_{(1, 10)} = 1.78$ ,  $p > 0.05$ ) vegetation types for both seasons as well.



**Figure 14:** Proportion of Grevy's zebra distribution during Wet and Dry season.

The variation in the distribution was determined by habitat parameters such as food quantity as measured by grass cover and grass biomass and species diversity. There was no significant difference in species diversity in both areas utilized and less utilized by Grevy's zebra ( $F_{1, 262} = 1.4$   $P=0.05$ ). Diversity was calculated as  $0.8 \pm 0.3SE$ .

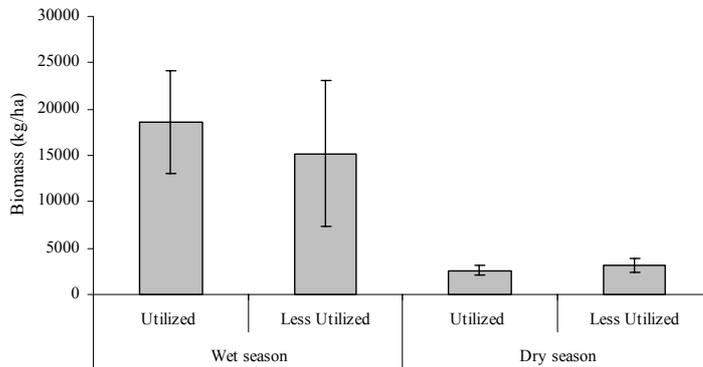
*Pennisetum stramenium* was the most dominant grass species in all the sampled areas accounting for 76 per cent  $F(1, 8) = 22.85$ ,  $p < 0.05$ . The other species did not vary greatly from each other.



**Figure 15:** Proportion of grass species encountered on all study sites.

Grevy's zebra spread themselves in areas of high leaf percentage ( $t = 3.13$ ,  $DF = 262$   $P < 0.05$ ) corresponding to a high biomass  $t = 1.79$ ,  $DF = 262$   $P < 0.05$  on both utilized and less utilized areas though this was not significant. Differences in biomass came with

season with high biomass during wet season( $15225 \pm 7829$  SE) compared to dry season ( $3129 \pm 748$  SE) .



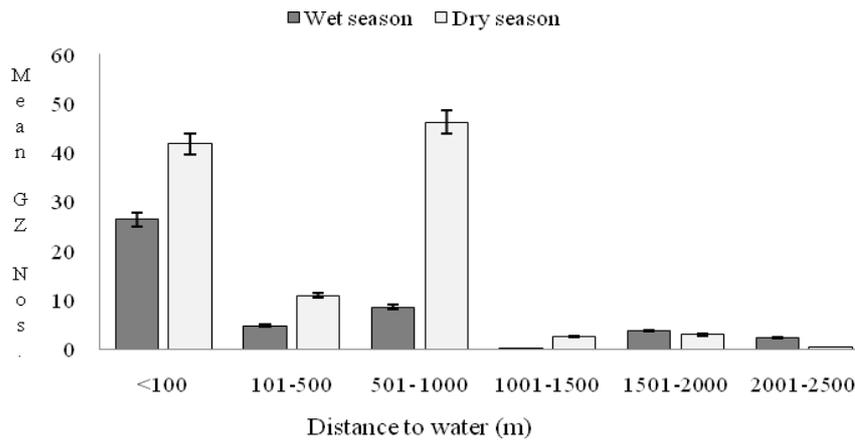
**Figure 16:** Differences in grass biomass during wet and dry season

There was no significant difference in percentage grass cover ( $F_{(1,262)} = 1.46, P > 0.05$ ) (figure 17) for the Grevy’s zebra grazing areas ( $90.8 \pm 0.77$  SE) and the less utilized areas ( $92.2 \pm 0.64$  SE). There was a significant difference in grass cover ( $F_{(1,262)} = 1.33, P < 0.05$ ) during the wet season ( $93.3 \pm 1.1$  SE) and the dry season ( $87.8 \pm 1.3$  SE).



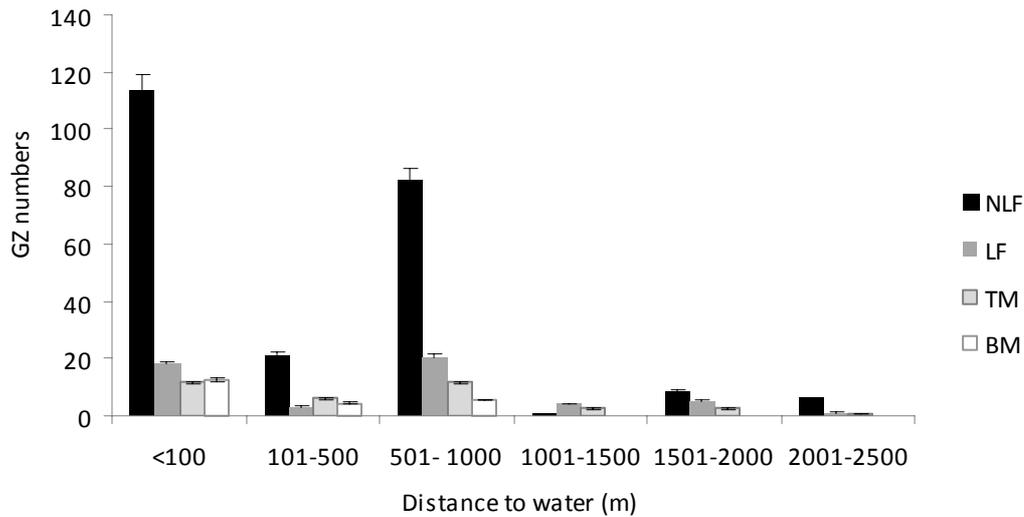
**Figure 17:** Differences in grass cover for utilized and less utilized areas

Water availability also affected Grevy’s zebra distribution. 92 per cent of Grevy’s were found close to water for both dry and wet season to a distance up to 1000m. Beyond 1000m, the numbers significantly drop exhibiting the least mean numbers ( $t = 2.88, DF = 5, P < 0.05$ ) as indicated in figure 18.



**Figure 18:** Mean number of Grevy's zebra population ( $\pm$ SE) at different distances from water.

The distribution of different Grevy's zebra reproductive classes was skewed towards water sources (Figure 19). The reproductive class of the Grevy's zebra does affect the distribution of the zebras as they are distributed within water reach.



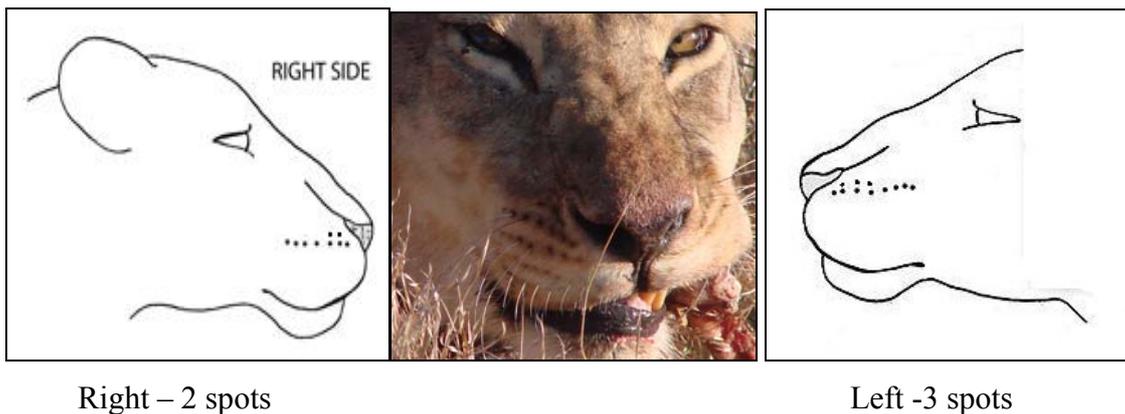
**Figure 19:** Grevy's zebra distribution for different reproductive classes (STDEV) with reference to distance to water sources.

### 3.4 Lion population

All the lions studied were residents within LWC, meaning that they spend all their time within the conservancy. A total of 19 lions were counted and confirmed as resident lions during the period of study. This population comprised of four males, five females and ten cubs. Two individual lions were fitted with operational VHF radio collars of frequencies 172.241 MHz and 172.330(9) MHz. There was no single pride observed but lions formed small groups that merged and split quite often. An average, group size was 4 animals (N=464). A group could consist of all males, females and their cubs, female and males or females only.

#### 3.4.1 Lion Identification

A total of 13 lions were identified using the whisker spot patterns as shown in figure 20, five of these were females, four males and two cubs.



**Figure 20:** Whisker spot patterns of an identified lioness

The identification row on the right side has two spots giving the animal the first code as R2. In relation to the reference row, the first spot on this side lies directly above the spot 2 while the second spot is directly above spot 3. We can therefore build on that code, by indicating the location of the two spots: R2: 2; 3. On the left side, there are three spots on the identification row giving the first code as L3. In relation to the reference row, the first spot is directly above the second spot, the second spot is directly above the third spot and the third spot directly above the fourth spot. Therefore, the Identification code is:

**R2:** 2; 3

**L3:** 2; 3; 4

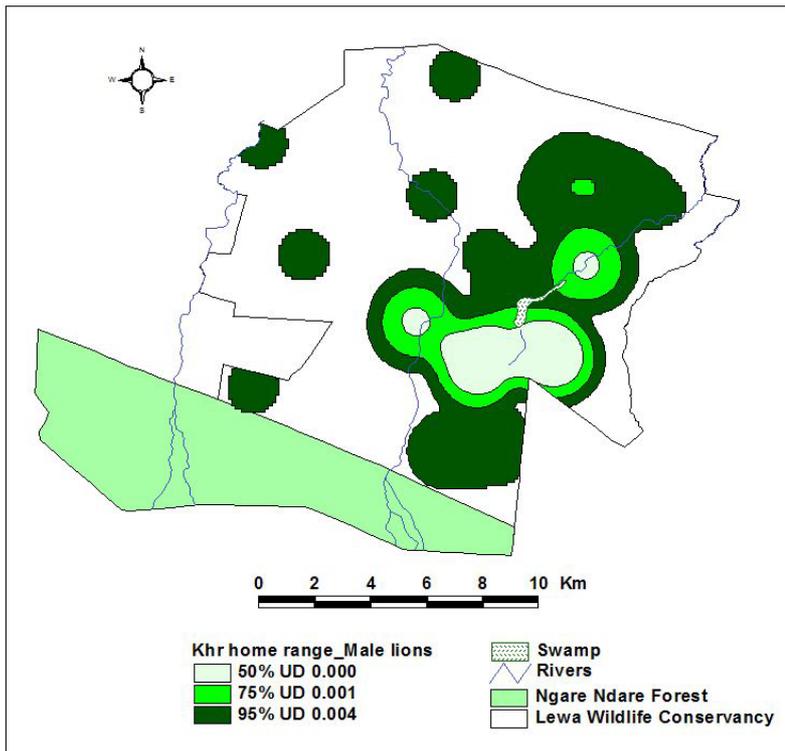
The table below shows the identification codes of the identified lion individuals. The remaining eight cubs were still very young to guarantee clear whisker spots.

Lion ID	Age	Sex	Whisker spot patterns	
			Right side	Left side
LF 001	A	F	R2:2,3	L3:2,3,4
LF 002	A	F	R2: 4,51/2	L3:31/2,41/2,6
LF 003	A	F	R3:2,4,51/2	L3:1,3,4
LF 004	A	F		
BM 001	A	M	R2:31/2,8	L1:3
BM 002	A	M	R2:3,41/2	L1:3
LF001/01	C	F	R3:2,3,5	L3:3,4,41/2
LF 001/02	C	F	R3:31/2,4,6	R3:31/2,4,6
LM001 /03	C	M	R2:2,51/2	L3:31/2,41/2,61/2
LF002/01	SA	F	R3: 3,5,61/2	
LM002/02	SA	M	R1:3	
LM002/03	SA	M	R2:2,51/2	
LF002/04	SA	F	R3:2,31/2,5	

**Table 1:** Identification codes of the identified lion individuals

### 3.4.2: Lion home range

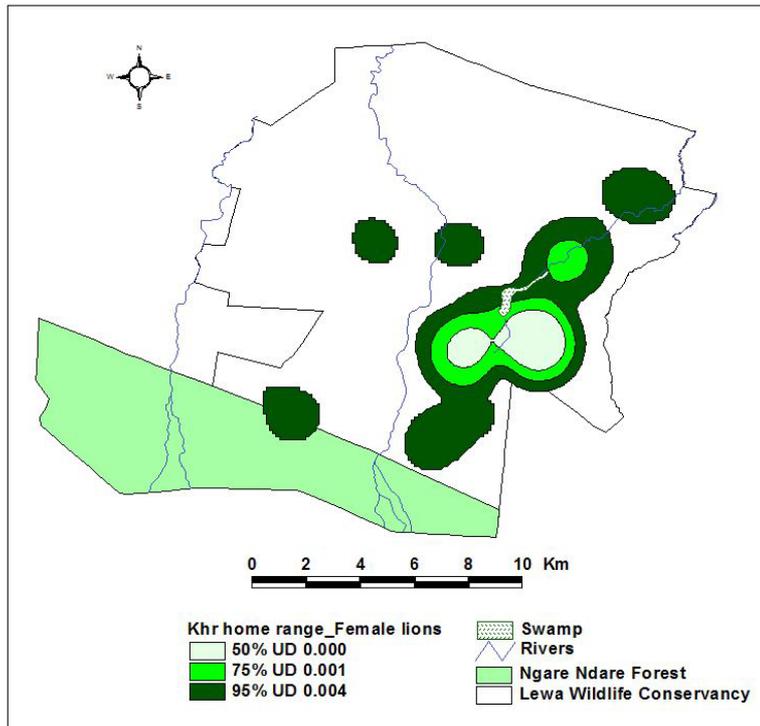
Lions would respond towards resources such as prey, water and cover in all directions and this influences the size of their home range. Male lions were found to have larger home ranges than the females as shown in Figures 21 and 22.



**Figure 21:** Kernel home range showing areas of probability contours for male lions.

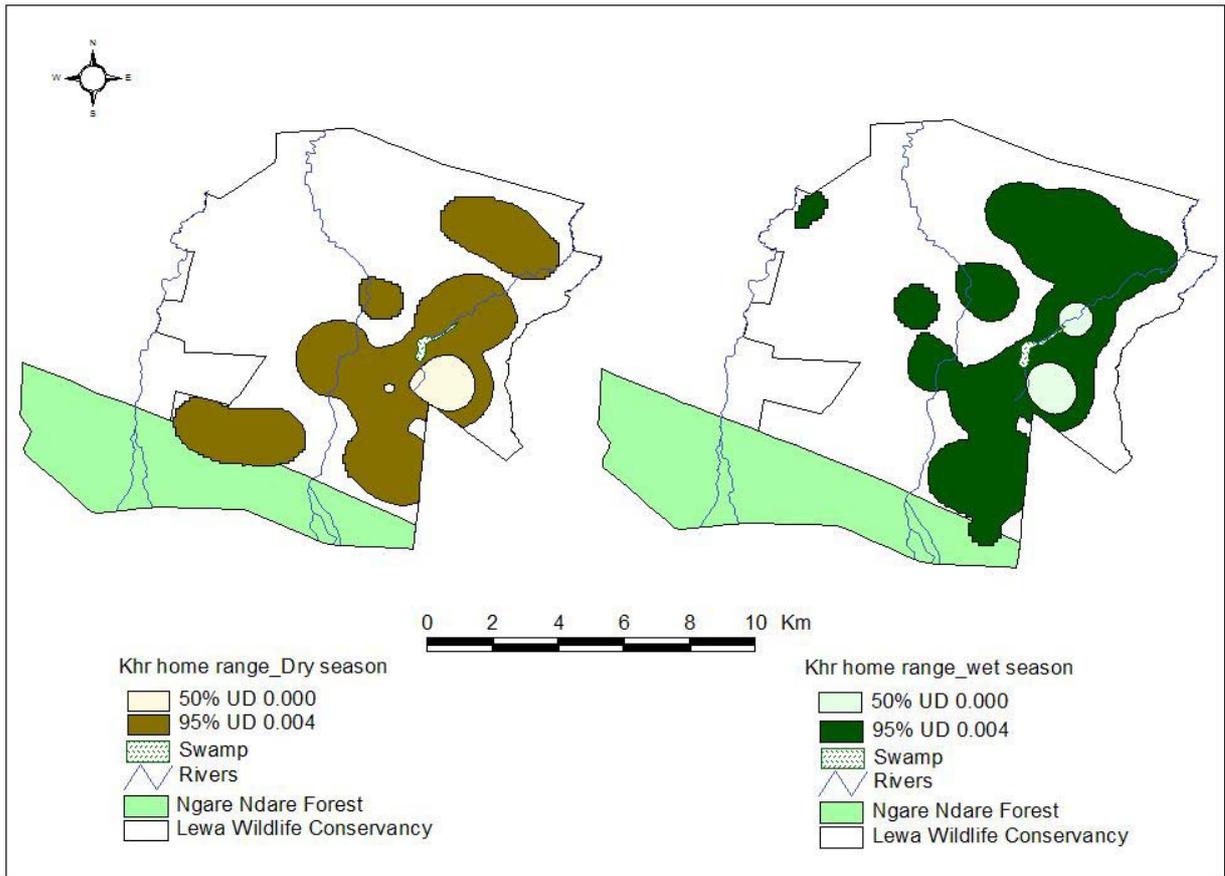
The males' core home ranges were concentrated along the rivers and swamp areas. At 95% kernel home range, they covered 83.3 square kilometers and at 50% kernel home range they covered 17 square kilometers. Females covered 47.04 square kilometers at 95% kernel home range and 11.75 square kilometers at 50% kernel home range.

Two females with a total of 5 cubs aged 8 months had the smallest home range; at 95% kernel home range they covered 23.74 square kilometers and 2.32 square kilometers at 50% kernel home range.



**Figure 22:** Kernel home range showing areas of probability contours for female lions.

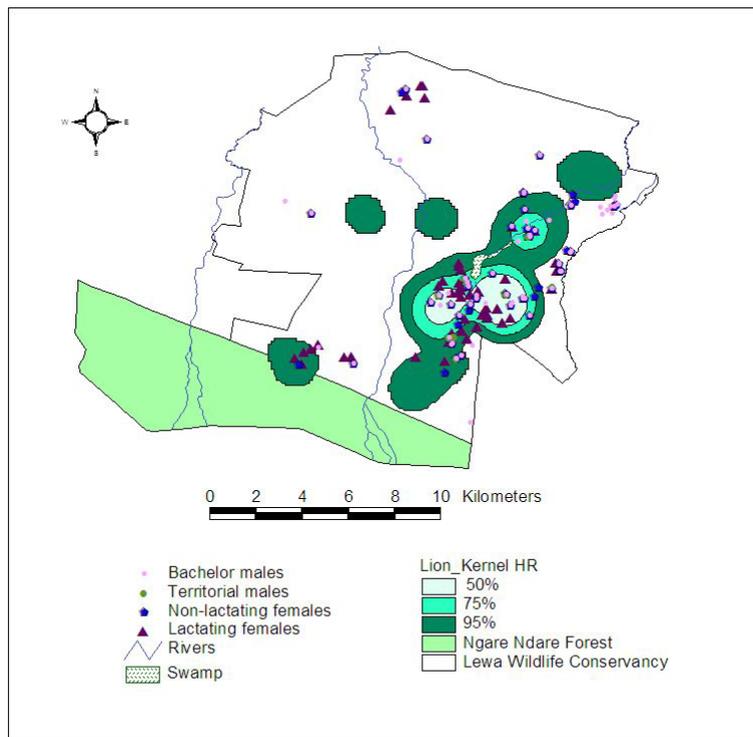
It is evident that there is great overlap between all the lions as they utilize same areas; the core area of utilization encompasses central part of the conservancy. There was no significant difference ( $\chi^2 = 0.008$ ,  $p > 0.05$ ,  $DF=1$ ) in lions home range (both males and females) during the wet season (95% kernel home range,  $75.3 \text{ km}^2$  and 50% core home range,  $5.19 \text{ km}^2$ ) and the dry season (95% kernel home range of  $73.9 \text{ km}^2$  and a 50% core home range of  $4.8 \text{ km}^2$ ) as shown in figure 23. The home range difference was compared of the calculated size ( $75.3 \text{ km}^2$  and  $73.9 \text{ km}^2$ ) with the expected sizes ( $159.2 \text{ km}^2/2$ ,  $79.6 \text{ km}^2$  home range size) using a chi square test.



**Figure 23:** Home ranges for all the lions during wet and dry season.

### 3.4.3: Home range overlap

Data from the movement patterns of lions have shown that there is a strong overlap of lion's core home ranges all the reproductive classes of Grevy's (Figure 24).



**Figure 24:** Grevy's zebra and lions range overlap

There was no significant difference in the distribution of all the classes in the different Kernel densities for the lions  $\lambda^2 = 4.86$ ,  $p > 0.05$ ,  $DF=3$ ).

46% the total sightings for Bachelor males were sighted at the lions core area of utilization ( $\pm 0.06$  SE), 5% ( $1 \pm 0.2$  SE) were Territorial males, 21% ( $\pm 0.2$  SE) were lactating females and 27% ( $\pm 5.2$  SE) were non-lactating females.

There was no significant difference in the distribution in wet and dry season,  $F_{3, 50} = 1.73$ ,  $P > 0.05$

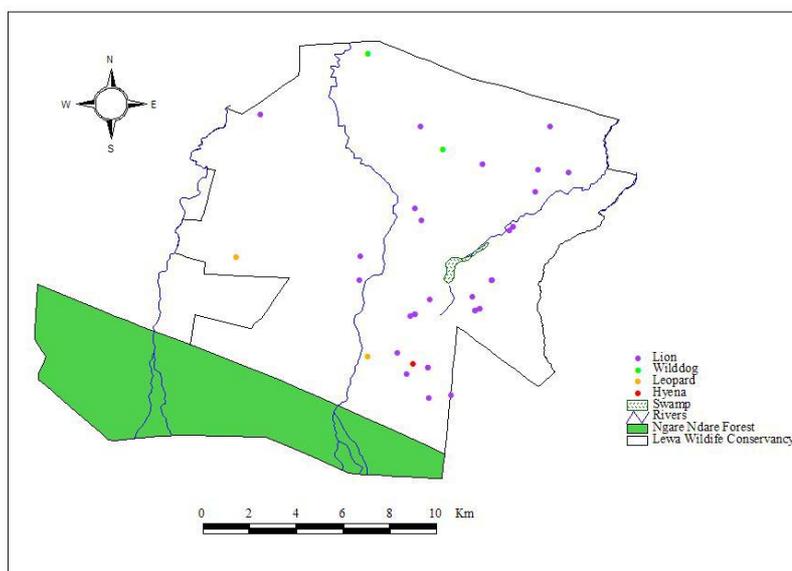
Tree density at the core area was estimated at 68 trees/ha, dominated by *Acacia drepanolobeum-Acacia seyal*, compared to 18 trees/ha on the 75% kernel home range that is mainly open grassland with scattered trees.

### 3.5 Scat results

#### 3.5.1 Wildlife mortality and scat analysis

A total of 56 cases of wildlife mortality were recorded during the period of study. 38 of these were predator related: 76% (were caused by lions, 13% by leopards, 1.8% by cheetahs and 1.8% by hyenas. 34% of the total deaths were zebras of which 53% were plains zebra and 47% were Grevy's zebra.

Majority of the kills were also located on the eastern region extending towards the forest as shown below, and lions did most of the kills as shown. Very few kills were found on the western side of the conservancy. These kills varied in species including Burchell's zebra, Grevy's zebra, Impala, waterbuck, hartebeest, Eland, Oryx, Warthog, Giraffe and Buffalos.



**Figure 25:** Kill locations on LWC by different predators

There was no significant difference in mortality ( $t=-1.44$ ,  $DF=9$ ,  $P>0.05$ ) during wet ( $1\pm 0.3SE$ ) and dry ( $1\pm 0.5SE$ ) seasons.

Mortality data was subjected for analysis using Jacob's Index (D). The analysis of this data looked at prey preference from a population perspective including both males and females. Jacobs' index scores were calculated for 28 kills of 10 different species recorded as prey as shown in Table 2 below.

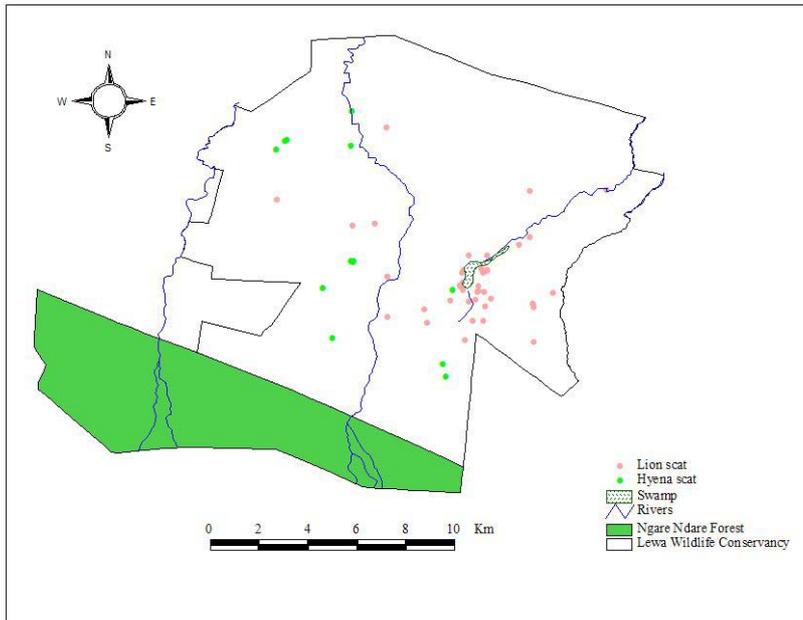
Species	Total population numbers	Jacob's Index value (D)	
		Lion	Hyena
Burchell's zebra	1288	0.14	-1
Grevy's zebra	364	0.08	-1
Impala	1029	1.00	-1
Waterbuck	175	-1.00	-1
Hartebeest	24	0.18	1
Eland	218	0.11	-1
Oryx	65	-1.00	-1
Warthog	160	0.33	-1
Giraffe	293	0.33	-1
Buffalo	402	0.14	-1

**Table 2:** Jacobs' index values, recording prey species

Grevy's zebra were recorded as lion prey in 7 kill sites, Burchell's zebra, 4, Eland 5 and Buffaloes 4. Other prey species included Hartebeest (3), Warthog (2), Impala (1) and Giraffe (2). Only one hartebeest were recorded as hyena kill on site. Grevy's zebras were the most commonly killed prey (25%), followed by elands (17.9%) and then Burchell's and Buffaloes each at 14.3%.

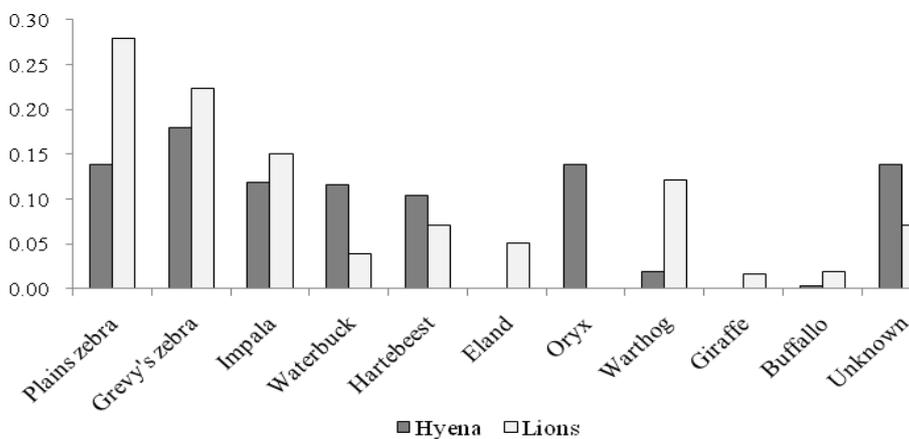
Impalas were taken proportionally taken by lions to what was available. Grevy's zebra and Burchell's zebra were taken in accordance to their abundance. Other prey species mainly hartebeest, eland warthog, giraffe and buffaloes' were taken in accordance to their abundance. Hartebeest (1) was the only species recorded at a kill site as prey species for hyenas. Other species were not recorded for hyena kills hence the negative values.

58 scat samples were collected and analysed for prey species. 77 per cent of these from lions while 23 per cent from hyenas. A large number of lion scat ( $42 \pm 13SE$ ) was collected along the Lewa river and the swamp on the eastern side of LWC, (Figure 26). This area also forms the core home range for the lions as shown in figures 21 and 22.



**Figure 26:** Scat Locations within LWC

Laboratory scat analysis on the other hand indicated that both zebra species found on LWC formed a major part of lion diet, figure 27. Impalas and warthogs, despite the fact that they are small bodied animals, still formed part of lion diet. Other prey species include hartebeest, eland, giraffes and buffaloes. No Oryx hairs were found in lion scat, but they were found in hyena scat. Water bucks ( $10.3 \pm 4.9SE$ ) and hartebeest ( $14 \pm 6 SE$ ) hairs took a higher proportion in hyena scat compared to lion scat.



**Figure 27:** Proportion of hairs found in lion and hyena scat.

There was no correlation between species mortality and species hairs found in lion scat ( $r = 0.041$ ,  $P > 0.05$ ), this was because many kills go unreported because they were either eaten all especially the small prey species or carcasses were not seen due to long grass found on LWC. Similarly, there was no relationship between Jacob's index and species hairs found in lion scat ( $r = 0.004$ ,  $p = 0.993$ ).

## CHAPTER FOUR

### 4.0 DISCUSSION, CONCLUSION AND RECOMMENDATION

#### 4.1 Grevy's zebra distribution and habitat use

Resource availability and abundance was an important determining factor in the use of space by the Grevy's zebra. Rainfall determines water distribution and has been shown to influence patterns of grass abundance and water availability. This was determined during the wet season and dry season. Rainfall patterns were erratic during this study as more rain was recorded on the eastern side of the conservancy than the western side. There was therefore a significant shift in level of grass greenness and water availability on the eastern side forcing the Grevy's zebra population to disperse to such areas, while the western side became progressively drier and these areas were completely avoided.

After the rains, the distribution of water changed quickly, and so was vegetation abundance and quality. Over a period of approximately one month, water was only found on permanent springs and rivers. On Lewa, permanent water sources were found in three main rivers: Serghoi, Lewa and Ngare Ndare. The Lewa river forms the Lewa Swamp, where there is permanent green grass through out the year thus forming a dry season grazing ground for all age classes of Grevy's zebra. This explains why there was high concentration around the swamp. It was observed that the non-lactating females were encountered more than any other reproductive class. This corresponds to the high number of foals aged one year (under the 6-12 months age bracket). Grevy's zebra are known to have no permanent bonds between any two or more adult animals: stallion groups, mare groups and mixed herds. All these groups are variable and their composition change within hours. The only permanent bond was between a mare and her foal. Mares and their foals form aggregations on LWC that split once the foals grow to juvenile class as it was observed.

These were in the last stage of gestation period and they utilized areas close to water sources. These areas contained a high percentage of *Cynadon dactylon*, which reflects the feeding preferences for lactating females (Cornwall, 2000).

Very few lactating females were encountered compared to the non-lactating females and these were found near the swamp close to water sources. However, some lactating females reacted differently to water availability in that they utilized areas far from water sources; more than 1000m. One such group was found South of Lewa near Ngare Ndare Forest an area that is covered with thick *Acacia drepanolobeum*- *Themeda*

*triandra/Pennisetum* species. Such aggregations are triggered by females behavioral adaptation as the foals are thought to be physiologically and energetically (Rubenstein, 1986) constrained and cannot move greater distances between food and water. Availability of highly nutritious grass (MacNaughton, 1984) is also another factor. Continued grazing promotes re growth of highly nutritious grass and by remaining in such areas of regeneration, these zebras increase their grazing success. The absence of predators in this area is also another factor that could influence lactating Grevy's zebra to utilize such areas. This was the only group of lactating females whose area of utilization did not overlap with lion home ranges.

Grass biomass was greater in less utilized areas than in the utilized areas corresponding to high leaf percentage. These results were consistent with estimated vegetation cover on the same areas. However, there was a variation in seasons with more biomass in wet season than the dry season. This explains why movement patterns of Grevy's zebra within the conservancy not dictated by high grass biomass or vegetation cover.

Species diversity was very low on both utilized and less utilized areas in both wet and dry seasons. However, during the wet season, a number of annuals were encountered although the rains were quite erratic as discussed above. During the wet season, rain enables new species to sprout producing soft and green vegetation for grazers. There was one species *Pennisetum stramenium* that was highly encountered on all areas thus lowering the diversity. This species is an increaser I species, (see appendix I) meaning that it increases on selective grazing: it's not palatable to grazers and so it's selectively grazed. There was more *Cynadon dactylon* and *Aristida kenyensis* in utilized areas compared to the less utilized.

## **4.2 Lion population**

All the lions studied were residents, no nomads encountered. None of these individuals came emigrated from another area; they were all born on LWC. There was no pride within this population, rather they formed groups that merged and split quite often. This could be because this population is faced with a lot of emigration especially the males to other neighbouring reserves and conservancies. This is dictated by territory availability. The thirteen individuals that were identified will form a basis for lion database on LWC.

Male lion home range size was larger than that of female lions; two mechanisms can be used to explain this: 1) males are larger than females and have higher food requirements (Gittleman & Harvey, 1982); 2) males configure their home ranges not only to secure food but also to acquire and defend access to females (Schaller 1972; Bygott, Bertram & Hanby 1979). Females significantly affected the size of male home ranges as it is shown with great overlap of their home ranges. Further to this, two females had small cubs and could not move quite a lot thus restraining their home range size. The males as well offered protection to these cubs and so the reason for the overlap.

In this study, lion home range for both, males and females showed strong preference for drainage lines and rivers where prey densities were higher especially during dry season. It has been known that home range size and configuration of large carnivores is influenced by patterns of resource distribution as well as their dispersion and predictability with which they are available and by social effects. It was observed that prey moved closer to riverine areas and other water rich areas during the dry season. Under dry conditions, herbivores aggregate more close to water sources where consequently predators have a greater chance of encountering their prey as indicated by the distribution of kills. Therefore, annual rainfall influenced not only the abundance of herbivores, but also their dispersion and the predictability with which lions encountered them.

Tree density estimates on the lion home ranges were high in the core area than the other areas translating to high vegetation cover. Cover provides protection for cubs particularly as it is manifested by strong preference by the lionesses.

There was a high home range overlap between the lions and all the reproductive classes of Grevy's zebra in both wet and dry seasons. Bachelor males were the most sighted on the core lion home range, followed by non-lactating females and then lactating females. The least sighted were territorial males and this is because, each male protects resources within their territories and with no overlapping between two territories. This means that this area is a key grazing zone for the entire Grevy's zebra population on LWC. This further explains that resource availability: mainly grass and water, dictates habitat use by Grevy's zebra more than presence of predators.

Majority of the wildlife mortality were caused by lions and these varied from large herbivores such as giraffe and buffalo to small ungulates like warthogs. Majority of the small ungulates carcasses could not be sighted because of the high grass biomass on LWC making it difficult to sight such kills. Majority of these small prey species are wholly eaten in that they are never detected. This explains why there were very few kills being reported. There was only one hyena kill that was recorded an indication that hyenas were not actually involved in the killing of prey species.

The study of scats for prey analysis plays a crucial role in determining predator prey preferences. If a Grevy's zebra hair, for instance is found in a lion scat then it is possible to be absolutely confident that it has preyed or possibly scavenged upon that animal. In LWC the main predators of the Grevy's zebra population are mainly lions. Hyenas do not significantly prey on large or medium sized ungulates as indicated by the index values that show a clear indication of maximum avoidance. This explains the scavenging nature of hyenas as manifested in prey species hairs found hyena scat.

Based on the results, lions on LWC preyed on small to large herbivores and ranging from impalas, warthogs, hartebeest, waterbuck, eland, Burchell's zebra, Grevy's zebra, giraffe and buffalo. The capture of prey by a predator involves behaviors relating to searching, stalking, attacking and susceptibility of a prey species to a particular predator (Elliott *et al.*, 1977). The initiation of this series of behaviors depends on the difference between the energy expenditure required during the hunt and that gained in its ingestion (Elliott *et al.*, 1977). This energy differential is also weighted against the risks involved in capturing it. This gives possible reasons behind high preference of impalas and warthogs by lions. Some are opportunistically captured bearing in mind that the height of the grass on LWC is high that provides excellent cover for predators. Their kill reports are quite low

showing an undercounting of the carcass of these small species which in most cases are totally consumed. More likely, warthogs are in common habitats where lions are, and are slower and have less endurance (Estes, 1999).

Giraffe and buffalo are large species that are riskier to hunt but they seem to hold a higher preference by lions than Grevy's zebra. However, the returns in energy investment make the risk rewarding (Funston, *et al.*, 1998). It was observed that, such large prey species were only caught by male coalitions and no solitary lions or females preyed on them. According to Scheel and Packer, buffalo herds are easy to detect through their noise and smell, and this may increase the preference of lion for buffalo especially during droughts when they are energetically weak.

Eland are known for their active defense, vigilance (through large herd size) and their weaponry (Estes, 1991), reduce their likelihood of predation. On the other hand, waterbuck and oryx were significantly killed less frequently than expected based on their abundance. This may be as a result of active avoidance by the lions (Hayward *et al.*, 2008) possibly arising from taste aversion stemming from waterbucks' lack of scent glands that results in greasy, musky smelling coat (Estes, 1999).

### **4.3 Conclusions and recommendations**

In this study, I tested the hypothesis that predation of Grevy's zebra by lions and possibly hyenas is the major limiting factor to the growth of this population. I conclude that lions are the key predators for Grevy's zebra population on LWC. Hyenas do not predate on Grevy's and may only scavenge on what was killed by the lions. The current lion population of 19 individuals has only 9 adults, in this case capable of hunting. The 10 cubs cannot hunt on their own rather they are still depended on their mothers for food. With this kind of age structure, the threat to Grevy's zebra population is minimal: it cannot be equivalent to zero. This means that as long as there is lion population on Lewa, Grevy's zebra predation will still remain, what may change is the rate at which predation of this species occurs, and this is dictated by the number, age and sex structure of the lion population. If the lion population is followed by new births and no emigrations, there will be ecological costs to the growth of the Grevy's zebra population on LWC. Possible reason for this is the overlapping ranges of lion and Grevy's zebra, in particular the lactating females and their foals.

On the other hand, Grevy's zebra habitat use seems to be dictated by resource availability mainly grass and water. I therefore suggest a further study on Grevy's zebra emigration from LWC to the northern region which covers Il-Ngwesi group ranch and LMD area to confirm spatial and temporal movement patterns over time.

The results of this study can be used to predict what lions will eat when reintroduced or what impact will lion predation have on a key species reintroduced in a given area. Understanding of such fundamental issues of predation allows better planning and management rather than simply respond. Consequently, the information presented here will allow us to move beyond descriptive dietary studies to improving our predictive understanding of the mechanisms underlying predator/prey interactions by use of predator/prey models.

## REFERENCES

- Becker, C.D. and Ginsberg, J.R. (1990). Mother infant behaviour of wild Grevy's zebra Adaptations for survival in semi-desert East Africa. *Animal behavior* **40**: 1111-1118
- Botha J.O. (1999). A resource management plan for the Lewa Wildlife Conservancy in the Meru District of the central Kenyan highlands. University of Pretoria, Pretoria.
- Bygott, J. D., Bertram, B. C. R. & Hanby, J. P. (1979). Male coalitions in large coalitions gain reproductive advantages. *Nature* **282**: 839-841.
- Cornwall M. (2000). An Analysis of the Competitive Interaction between Two Sympatric Species of Zebra: *Equus grevyi* and *Equus burchelli*. Department of Ecology and Evolutionary Biology. Princeton University.
- Chesson, J. (1978). Measuring preference in selective predation. *Ecology* **59**: 211-215.
- Elliott, J. P., McTaggart Cowan, I. & Holling, C. S. (1977). Prey capture by the African lion. *Can. J. Zool.* **55**: 1811–1828.
- Estes, R.D (1991). The Behavior Guide to African Mammals. University of California Press. pp 240-241, pp 370
- Estes, R. D. (1999). The safari companion: a guide to watching African mammals. Halfway House: Russel Friedman Books.
- Funston, P. J., Mills, M. G. M., Biggs, H. C. & Richardson, P. R. K. (1998). Hunting by male lions: ecological influences and socio-ecological implications. *Anim. Behav.* **56**: 1333–1345
- Ginsberg, J.R. (1989). The ecology of female behavior and male mating success in the Grevy's zebra (*Equus grevyi*). *Symp. zool. Soc. Lond.* **61**, 89-110.
- Gittleman, J. L. & Harvey, P. H. (1982). Carnivore home-range size, metabolic needs and ecology. *Behavioral Ecology and Sociobiology*, **10**: 57-63.

Hayward, M. W., & G. I. H. Kerley. 2008. Prey preferences and dietary overlap amongst Africa's large predators. *South African Journal of Wildlife Research* 38(2):93-108.  
2008

Hayward, M. W., & G. I. H. Kerley. 2005. Prey preferences of the lion (*Panthera leo*). *Journal of Zoology (London)* 267:309–322.

IUCN (2003). IUCN Red List of Threatened Species. IUCN, Gland, Switzerland.

Jacobs, J. (1974). Quantitative measurement of food selection. *Oecologia (Berl.)* **14**: 413–417.

Kenya Wildlife Service. (2008). Conservation and management strategy for Grevy's zebra (*Equus grevyi*) in Kenya 2007-2011.

Kernohan, B. J., R. A. Gitzen, & J. J. Millspaugh. 2001. Analysis of animal space use and movements. In: Comparison of Programs for Fixed Kernel Home Range Analysis. Academic Press.

King, J & Malleret-King, D (Eds) (2006). The Ewaso Landscape planning workshop: January 25<sup>th</sup>-29<sup>th</sup> 2006. Impala Research Centre, Laikipia Kenya.

Kingdom, J. (1979). East African Mammals: An atlas of Evolution in Africa. Chicago University Press. Chicago.

Klingel, H. (1974). Social organization and behavior of the Grevy's zebra. *Z.Tierpsychol.* 36, 36-70.

Klingel, H. (1980). Survey of African Equids. IUCN Survival Service Commission, Switzerland.

Krebs, C. J. (1989). *Ecological Methodology*. Harper Collins Inc. New York.

- Lehmann M.B, Funston PJ, Owen CR, Slotow R (2008). Home Range Utilisation and Territorial Behaviour of Lions (*Panthera leo*) on Karongwe Game Reserve, South Africa. PLoS ONE 3(12): e3998. doi:10.1371/journal.pone.0003998.
- Lewa Wildlife Conservancy (2008). Research and monitoring annual report. (Unpublished)
- Linsen L. & Giesen, W. (1983). An ecological study of Lewa Downs, seasonally dry, central Kenyan grassland. University of Nijmegen, Nijmegen.
- Manyibe, T., Low B. & Chege G. (2006). Mass Vaccination of Grevy's Zebra against Anthrax in Northern Kenya. Kenya
- MacNaughton S.J. (1984). Grazing lawns: Animals in herds, plant form and coevolution. *American Naturalists* **124**: 863-886.
- Macdonald, D. W. & Carr, G. M. (1989). Food security and the rewards of tolerance. *Comparative socioecology: the behavioural ecology of humans and other mammals*. (eds V. Standen & R. A. Folley), pp. 75-99. Blackwell Scientific Publications, Oxford.
- Mills, M.G.L & Shenk, T.M. (1992). Predator-Prey relationships: The impact of Lion predation on wildebeest and zebra populations. *The Journal of African Ecology*, Vol.61, No.3, 693-702.
- Mwasi, S. & Mwangi, E. (2007). Proceedings of the National Grevy's Zebra Conservation Workshop 11-14<sup>th</sup> April 2007. KWS Training Institute, Naivasha, Kenya
- Mwololo M.N. (2006). Lion monitoring report. *Unpublished report*. Lewa Wildlife Conservancy.
- Njonjo D. (2005). Predator Project Report. Lewa Wildlife Conservancy.

- Ogutu J.O & Dublin H.T. (2004). Spatial dynamics of lions and their prey along an environmental gradient. *African Journal of ecology*, **42**: 8-22.
- Pennycuick C.J. & Rudnai J. (1970). A method of identifying individual lions with an analysis of the variability of identification. *Journal of Zoology, London* 160: 497–508
- Powell, R. A. 2000. Animal home ranges and territories and home range estimators. In: *Research Techniques in Animal Ecology* (Ed. by Boitani, L. & Fuller, T. K.), pp. 65-110: Columbia University Press.
- Pratt, D. J & Gwynne, M.D. (1977). *Rangeland management and ecology in East Africa*. Hodder and Stoughton, London.
- Rowen, M. (1992). Mother- infant behavior and ecology of Grevy's zebra, *Equus grevyi*. Phd Thesis, Yale, New Haven.
- Rowen, M. & Ginsberg, J.R. (1992). Status and action plan for the conservation of Grevy's zebra (*Equus grevyi*) In *Zebras, Asses and Horses*. IUCN, Gland, Switzerland.
- Rubenstein, D. I. (1986). Ecology and sociality in horses and zebras. In *Ecological aspects of social evolution* (Eds D.I. Rubenstein & R.W. Wrangham), pp 282-302. Princeton University Press, Princeton.
- Rubenstein, D. I. (2004). Why are Grevy's zebra numbers not increasing? Potential impacts of interspecific competition and predation. Paper presented at a workshop on "Grevy's zebra Conservation", Mpala Research Centre, Kenya, March 22 – 24, 2004.
- Rubenstein, D.I. & Hack, M. (2004). Natural and sexual selection and the evolution of multi-level societies: insights from zebras with comparisons to primates. In *Proceedings of the Second International Conference on Mobile Systems, Applications and Services*, PP. 266-279.
- Scheel, D. & Packer, C. (1995). Variation in predation by lions: tracking a movable feast. In *Serengeti II: dynamics, management and conservation of an ecosystem*: 299–314. Sinclair, A. R. E. & Arcese, P. (Eds). Chicago: University of Chicago Press.

- Schaller G.B. (1972). *The Serengeti Lions: A study of Predator-Prey Relations*. University of Chicago Press. London.
- Strauss, R.E. (1979). Reliability estimates for Ivlev's electivity index, the forage ratio and proposed linear index of food selection. *Trans. Am. Fish. Soc.* **108**: 344-352.
- Trollope W.S.W & Trollope L.A (1999) Report on the assessment of range condition and the fire ecology of the savanna vegetation on the Lewa Wildlife Conservancy in Kenya -1998.
- Williams, S. & Low, B. eds (2004). *Grevy's zebra conservation*. Proceedings of a workshop on "Grevy's Zebra Conservation". Mpala Research Centre, Kenya, March 22-24.
- Williams, S.D., Nelson, A.P.W. & Kabebe, F. (2003). Grevy's zebra survey: Ethiopia. Interim report. WildCRU/EWCO, Addis Ababa.
- Williams, S.D. (2002). Status and action plan for Grevy's zebra (*Equus grevyi*). In *Zebras, Asses and Horses* (ed P.D. Moehlman). Pp.11-27. IUCN, Gland, Switzerland and Cambridge.
- Williams, S.D. (1998). *Grevy's zebra: Ecology in a heterogeneous environment*. University College London.
- Yalden, D.W., Largen, M.J., & Kock, D. (1986). Catalog of the mammals of Ethiopia. *Perissodactyla, Proboscidea, Hyracoidea, Lagomorpha, Tubulidentata, Sirenia and Cetacea*. Italian Journal of Zoology, **21**: 31-103.

## APPENDICES

**Appendix 1:** The classification of grass species identified within the conservancy into Decreaser (D), Increaser (I & II) species. (Trollope, 1999)

No.	Species	Common Name	Category
1	<i>Pennisetum stramenium</i>	Masaai grass	I
2	<i>Pennisetum mezianum</i>	Bamboo grass	I
3	<i>Pennisetum masaaicum</i>	-	I
4	<i>Aristida kenyensis</i>	Kenya needle grass	II
5	<i>Cynadon dactylon</i>	Common star grass	II
6	<i>Eneopogon shimperanus</i>	Grey head grass	II
7	<i>Heteropogon contortus</i>	Spear grass	D
8	<i>Themeda triandra</i>	Red oat grass	D
9	<i>Sehima nervosum</i>	-	I
10	<i>Setaria pumila</i>	Pale setaria	II
11	<i>Sporobolus africanus</i>	Ratstail dropseed	II
12	<i>Digitaria nuda</i>	-	II

**Note: Decreaser species** –Grass species which decrease when rangeland is under or over utilized

**Increaser I** – Grass species which increase when rangeland is under utilized or selectively grazed.

**Increaser II** – Grass species which increase when rangeland is over utilized