EVALUATING ANTI-PREDATOR DETERRENT AGAINST LIONS IN GROUP RANCHES SURROUNDING AMBOSELI NATIONAL PARK, KENYA

By

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(BSc Hon., UoN)

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DECLARATION

This Thesis is my original work and has not been submitted as part of the requirement for award of a degree to any other university.

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To my son, Keith Orenge.

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ACRONYMS

ANOVA	Analysis of Variance
ASALs	Arid and Semi-Arid Lands
AWF	Africa Wildlife Foundation
HWC	Human Wildlife Conflict
IUCN	International Union for the Conservation of Nature Red List
KWS	Kenya Wildlife Service
LCU	Lion Conservation Unit
LED	Lion Entry Deterrent
NP	National Park
NR	National Reserve
PAC	Problem Animal Control
PAs	Protected Areas
Pre-LED	Before Installation of LED System
Post-LED	After Installing the LED System
SPSS	Statistical Package for Social Sciences
Shoats	Sheep and Goats
WWF	Worldwide Fund for Nature

ABSTRACT

World over, human-carnivore conflicts is among the leading causes in the decline of large carnivores populations. In Kenya, lions are widely killed by some members of the pastoralist community due to conflict over livestock. It is therefore necessary to develop mechanisms of minimizing the conflict. The main objective of this study was to develop an effective lion entry deterrent system and anti-predator strategy to minimize livestock depredation and reduce lion mortality arising from retaliatory attacks. The specific objectives were to determine the densities of available lion prey in the study area, establish the livestock depredation patterns in the last one year and determine the efficiency of lion entry deterrent system. The study was carried out in Olgulului and Kimana Group Ranches surrounding Amboseli National Park. Forty homesteads were selected for the study, twenty from each ranch. Then, ten homesteads from the ranches were installed with lion entry deterrent system while the remaining ten were not. Data were collected daily from all the forty homesteads to determine depredation frequency. A potential prey survey was carried out to determine the prevalence of lions/preys in the ranches. A binary logistic regression model was used to assess the efficiency of the LED system. Chi-square and correlation tests were carried out to determine the association between abundance of predator and prey density in the study areas. A two-sample t-test was used to assess the difference in the frequency of attacks and livestock killed in homesteads during the Pre and Post LED period. Results showed that cattle were the most abundant potential prey, (Mean=64 ±5.4), zebra ranked second (Mean=56 ±8.5), while the other prey types comprised of smaller groups of individuals. Further, the results indicated that hyenas caused over 50% of predatory incidences in both sites (Kimana; 57%, Olgulului; 51%) while the lions were responsible for an average of 25% of the incidences (Kimana; 24%, Olgulului; 29%). More predatory incidences were recorded during the wet season than during the dry season. Lastly, homes with LED systems registered low mean livestock loss which was consistent with high (90%) LED efficiency levels compared homes without LED systems with low (20%) efficiency level. Thus, once the LED system was installed, homesteads neighboring wildlife conservation areas experienced fewer predatory incidences and reduced subsequent retaliatory attacks on large carnivores. Therefore, if non-lethal methods like lion entry deterrent systems are adopted; poisoning, snaring and spearing of large carnivores can be minimized. Subsequently, co-existence between people and carnivores in areas bordering protected conservation areas such as Amboseli and Nairobi NP can be achieved.

Key Words: Efficiency, Lions, Livestock depredation, Lion entry deterrent system, Human wildlife conflict

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Over the past five decades, human population has rapidly grown and expanded in space from densely populated areas to Kenya's rangelands to practice subsistence agriculture, where they overlap with the majority of the country's wildlife (Ottichilo *et al*., 2000). This population surge has led to habitat conversion in rangelands to subsistence agriculture, horticulture and settlements thereby increasing conflict between people and wildlife (Awere, 1996).

Usually, human wildlife conflicts (HWC) occur when wildlife requirements overlap with those of human populations, therefore, bearing a cost to both wild animals and residents (World Park Congress, 2003). These conflicts are due to spatial proximity of people to the wildlife habitats (Knight, 2000). Generally, HWC occurs commonly in and around wildlife protected areas (PAs). This poses a huge management challenge of PAs in the conservation of large carnivores. This is because conflicts fuel opposition from local community thus undermining support that is much needed for biodiversity conservation efforts (Madden, 2004; Treves, 2009).

Over a long period of time, humans and wildlife have co-existed. However, over the past few decades studies have indicated an increased frequency in occurrence of human wildlife conflict (Graham *et al.,* 2005; Wang and Macdonald 2006). This is mainly due to; ineffectiveness of the conflict mediating institutions (Anthony *et al.*, 2010), and reduced prey due to reduced habitats (Woodroffe *et al.,* 2005). Lastly, high distribution of wildlife in protected areas and their surrounding areas (Stahl *et al.*, 2001).

Human wildlife conflicts occur in different ways ranging from human induced wildlife mortality, diseases, raiding of crops, forage and prey resource competition, general biodiversity threat, attacking of livestock and destruction of infrastructure (Knight, 2000; Thirgood *et al.,* 2005). According to Boer and Baquet (1998), human wildlife conflicts are more common in developing countries where agriculture and livestock farming are the main sources of livelihood.

1.2 Problem Statement

More often, lions wander off protected areas into community settlement areas making them some of the most difficult animals to conserve. When lions attack and kill livestock, they cause financial losses and hence becoming a nuisance to land owners. For instance, in Kenya, lions are widely killed by some members of the Maasai community due to conflict over livestock (Woodroffe and Frank, 2005). Conflict between people and lions is very detrimental to the viability of the highly vulnerable lion population.

According to Woodroffe and Ginsberg (1998), carnivore mortality in and around wildlife protected areas is human induced either intentionally or unintentionally. The causes of mortality are usually poisoning, shooting, snaring, capturing and road accidents (Harcourt *et al.,* 2001). These deaths cause population 'sinks' around protected areas and are likely to lead to local extinction (Graham *et al.,* 2005). Therefore, animal species like lions that are exposed to human wildlife conflicts are said to be more vulnerable to extinction (Ogada *et al.*, 2003) than those living without coversine conflict with humans.

Lions therefore are vulnerable to extinction if appropriate measures are not put in place to mitigate human wildlife conflict. However, it has been difficult to keep lions within protected areas and away from conflict with human (Woodroffe 2001). This is partly because of the distribution or outward dispersal of their prey and human encroachment in to wildlife protected areas (Ogutu and Dublin, 2002).

In Kenya, lion human conflict affects all areas around protected areas with resident lions (Ogada *et al.,* 2003). Conflict between lions and people has gradually increased in the community lands bordering Amboseli National Park, Tsavo West and East National Parks, Nairobi national Park and the Maasai Mara Game Reserve. The conflict centers on livestock depredation by lions and a threat to human life (Graham *et al.*, 2005)

In order to deter predators including lions from attacking their livestock, land owners have traditionally practiced active herding of livestock, erecting barriers around livestock bomas and homesteads, scaring and sometimes killing the invading lions (Ogada *et al.,* 2003). These methods of deterring lions from attacking livestock have had varied successes and have mitigated the conflicts (Ogada, 2004; Wang and Macdonald 2006).

The purpose of this study was therefore to determine the factors that predispose livestock to lion predation and test the effectiveness of a new visual lion entry deterrent system (LED) in community group ranches surrounding Amboseli National Park in Southern Kenya.

1.3 Rationale of the Study

To date, intense persecution of lions has been one of the leading threats to their survival. More than other factors, persecution has led to high predator species reduction in both population distribution and sizes (Woodroffe and Ginsberg, 1998). Currently, very few protected areas in Africa are able to maintain viable carnivore populations mainly because of strong edge effect of the protected areas (Loveridge *et al.*, 2001), leading to population sinks. For effective conservation practice that can stand the test of time, there is an urgent need to curb, reduce and minimize human-induced mortality of carnivores in and around protected areas.

Finding adaptive measures to achieve harmonious co-existence between pastoralists and carnivores is very critical to the long term survival of lions (Hackel, 1999; Woodroffe, 2000). Thus, to conserve lion population, livestock predation should be minimized. Lion entry deterrent systems can play a vital role in resolving human wildlife conflicts. This can lead to existence of viable populations in and outside wildlife protected areas. This is because LEDs will lead to reduced predation on livestock. In turn, there will be reduced mortality of lions that result from retaliatory attacks. This study therefore seeks to address the efficiency of LEDs and lion-proof fences as a conservation mitigation measure of human/lion conflict.

1.4 Research Questions

The research study aimed to answer the following key questions**:-**

1. What were the available lion prey species in Kimana and Olgulului GRs?
2. What were the livestock depredation patterns in the study area?
3. How effective are the lion entry deterrent systems compared to traditional barriers?

1.5 Objectives of the Study

1.5.1 Main Objective

The main objective of the study was to develop an effective lion entry deterrent system and anti-predator strategy to minimize livestock depredation and reduce lion mortality arising from retaliatory attacks by the Maasai pastoralists in the group ranches surrounding Amboseli National Park in Southern Kenya.

1.5.2 Specific Objectives

The specific objectives of the study were:-

1. To determine densities of available lion prey in Kimana and Olgulului GRs.
2. To establish the livestock depredation patterns in the study area.
3. To determine the efficiency of visual lion entry deterrent system against traditional barriers.

1.5 Hypothesis

The hypotheses of the study were:

1. Lion prey density has no influence on livestock depredation events
2. Livestock depredation patterns by lions are independent of season
3. The lion entry deterrent system is not more effective than traditional barrier systems

CHAPTER TWO

LITERATURE REVIEW

2.1 Large Carnivores of Africa

As a continent, Africa has a huge number of larger predator species including the leopard (*Panthera pardus*), lion (*Panthera leo*), cheetah (*Acinonyx jubatus*), caracal (*Caracal caracal*) spotted hyena (*Crocuta crocuta*), African wild dog (*Lycaon pictus*), and black-backed jackal (*Canis mesomelas*) (Patterson *et al.,* 2004; Holmern *et al.,*2007) among others.

The lion (*Panthera leo*) is the second largest cat after the tiger (KWS, 2007). Previously, it inhabited Europe, Asia and Africa. Currently, it only survives in Africa and Asia. Its diet mainly includes livestock, buffalo, zebra, wildebeest, impala, giraffe, and reptiles. Lions are the only cats which live in prides consisting of about fifteen lions (IUCN, 2006b). They are nocturnal and territorial. According to the International Union for the Conservation of Nature **(**IUCN) Red List, lion is listed as 'vulnerable' by WWF. The current lion population in Kenya is estimated to be around 1,600 down from 10,000 a few decades ago (WWF, 2012).

Lions live in most parts of Africa. They are mainly found in the West, Central, Southern and Eastern parts of Africa (IUCN, 2006a). The areas are mapped into habitat patches, lion conservation areas (LCUs) and PAs known to contain resident lion populations as well as those with possible, temporary or recently extirpated lion populations.

2.2 Large Carnivore Conservation Challenges

In today's overpopulated world that is growing towards modernization, large carnivores are some of the most difficult category of animals to conserve (Graham *et al.,* 2005) as compared to other taxonomic groups. Because of this, their populations have dramatically reduced world over. Over the last few decades, humans and their activities have directly contributed to a massive reduction and distribution of carnivore species (Johnson, 2010). Indeed jaguars, wolves, lions, leopards among other carnivores have significantly reduced (Woodroffe, 2000) world over.

Due to growing demand for agricultural land and agricultural products, separation of human population from large carnivore communities and habitats may ultimately be difficult (Ogada *et al.*, 2004). In the last century, loss of wild life habitats has greatly contributed to the loss of over half of large carnivore population (Riggio *et al.*, 2012). According to Woodroffe and Frank (2005) human wildlife conflicts have increased in frequency and occurrence negatively impacting on the conservation of large carnivores.

Finally, Parker (2011a) clearly reports that poorly controlled and un-coordinated game hunting has resulted into unsustainable harvesting of large predators in many countries. Among large carnivores, many populations have been noted to be genetically isolated (Slotow and Hunter, 2009). This has resulted into cases of in breeding which is associated with low rates of reproduction (Trinkel *et al*., 2008). Several small populations then come up and have been noted to have reduced disease resistance (Johnson *et al.*, 2010) which may affect their survival. If not addressed, anthropogenic driven mortality has been and will be a persistent threat (Kissui and Packer, 2004) to many carnivores.

2.3 Trends in Human Carnivore Interactions

Interaction between humans and wildlife is inevitable. A result is human wildlife conflict globally (Thirgood *et al.*, 2005) involving carnivore species in diverse ways. World over, livestock predation is the most common and cited issue causing human wildlife conflict (Laurenson and Sillero-Zubiri 2001). Worldwide, studies have shown the conflict problem i.e. golden jackals in Israel (Yom-Tov *et al.,* 1995), brown bears in Norway (Sagor *et al.,* 1997), tigers in India (Sekhar 1998), lynx in France (Stahl *et al.,* 2001b), pumas in Brazil (Mazzolli *et al.,* 2002), hyenas and lions in Kenya (Ogada *et al.,* 2003) among others.

Livestock kills due to predatory attacks cause huge financial losses of up to 20% per capita income to the pastoralist. There is therefore intense hostility towards carnivores (Jackson 2000). In cases where the livestock is the main source of livelihood and has cultural significance, conflicts become a major hurdle towards carnivore conservation (Anon, 2003).

Carnivores attacking humans is another form of interaction. Though not common as livestock depredation, it has potentially fueled human wildlife conflict (Quigley and Herrero 2005). Known and recorded in world history are the man-eating lions in Tsavo where 28 people perished in 1898-1899 (Baldus 2004). Annually, over 200 people are said to be killed in Tanzania and the frequency of attacks are reported to be increasing in the recent past (Packer *et al.,* 2005). Human attacks generate intense conflicts that significantly impede conservation of potentially dangerous carnivores due to growing hostility and negative attitude from local communities (Thirgood *et al.,* 2005).

Provoked attacks are also common, whereby a person approaches an animal too closely, tries to touch, injure or kill it, or in which food attracts the animal brings it and the person into close proximity (Quigley and Herrero, 2005) thus provoking an attack. It takes the form of poaching, the use of snares (Viljoen, 2009) and trophy hunting whereby wounded carnivores like lions are extremely dangerous. Unprovoked attacks are also known whereby victims cannot be held responsible for the encounter with a carnivore or its aggressive reaction like lions might attack when surprised, particularly at night, or when encountered with young cubs or driven off a kill (La Grange, 2005).

2.4 Escalating Conflicts between Lions and Pastoralists

The proximity of human population, settlements and their activities to lion home ranges in and outside wildlife protected areas suggests occasional cases of HWC (Treves and Karanth 2003). Woodroffe (2000) has clearly studied and examined the relationship between increasing human population and extinction of large carnivores and found out that there is a positive relationship between human density and predator extinction probability. This extinction is further exacerbated by HWC (Thirgood *et al.*, 2005).

Just like other large carnivores, one key threat causing the decline of lions is human wildlife conflict mainly because of its depredation on livestock (Treves and Karanth, 2003) and attacks on humans (Packer *et al.*, 2005). This leads to retaliatory killing of predators (Ogada *et al.*, 2003) hence a threat to both human livelihoods and wildlife (Hussain, 2003).

According to IUCN (2003), the factors driving human-wildlife conflicts are grouped into three. First, land use transformation whereby rangelands, forests and other natural ecosystems are transformed into urban or agrarian ecosystems (KWS, 1994). Secondly, wildlife habitat loss, degradation, fragmentation and population increase hence encroachment into wildlife habitats (Siex *et al.*, 1999). Lastly, unregulated public access and large-scale use of protected areas is also a driving factor.

Other driving forces include but not limited to; Increasing livestock populations and competitive exclusion of wild herbivores (Mishra *et al.,* 2003). This creates an overlap of diets hence leading to decline in wild herbivore populations whereby livestock becomes a main prey for predators (Mishra *et al.,* 2003). Re-colonization of wildlife into their original habitats resulting from increased conservation programmes (Musiani *et al.,* 2003). Climatic factors which can't be controlled like unpredictable rainfall pattern, is directly related to predation intensity in Kenya (Patterson *et al.,* 2004). Lastly, stochastic events like fires that are difficult to forecast and prevent largely can increase human wildlife conflicts (Nyhus and Tilson, 2004a).

2.5 Strategies of Mitigating Human Lion Conflict

In Kenya, KWS is mandated through their conflict resolution office to mitigate HWCs (KWS, 1996). Therefore, KWS has employed several predator entry deterrent methods like guarding, brush fencing, controlled shooting and problem animal control (KWS, 2007). Further, stone walls, high tensile steel walls, wildlife drives, capture and translocation and electric fences have been employed as conflict resolution strategies and options (KWS, 2004).

At the same time on the affected areas, the local communities may have their own mitigation measures. For instance, the WWF (2005) suggests subventions and local employment whereby the local community and existing relevant authority are eligible to benefits from wildlife. The common form of benefit is employment as an incentive for conservation. Livestock management like preventive measures by protecting livestock thus deterring predators and effective herding can also mitigate depredation (Frank and Woodroffe, 2002).

However expensive and laborious it is to put up strong and lasting fences by pastoralists; this approach mitigates and reduces livestock predation by lions (Kruuk, 2002).

The Maasai community routinely guards their livestock by intensifying human vigilance diversifying herding techniques (Ogada *et al.*, 2003). Additional deterrents like domestic dogs and weapons like spears and swords are used to reinforce guarding (Breitenmoser *et al.,* 2005). On the same, livestock guarding animals have also been used and they warn livestock owners of the approaching carnivores. The barking of dogs for instance helps to interrupt and abort predator attacks on livestock (WWF, 2005).

Livestock owners have the sole responsibility to protect their livestock from lion attacks. Therefore, they have built livestock enclosures *"bomas"* that are strong enough to keep lions and other predators away (Mills, 2000). Through time, these fences have been improved to "lion-proof" fences because they are able to contain the stampeding effect of cattle caused by lions thus not breaking out of the enclosure (Skuja, 2002).

Non-lethal methods have also been used to keep predators away. The livestock owners usually shout and use gestures to scare and keep lions away (Oulare, 2008). Also, lighting devices and night fires is a mitigation measure that can scare and keep lions and other predators away (Breitenmoser *et al.,* 2005).

Finding adaptive and realistic measures to conserve Kenya's predator populations while at the same time reducing livestock depredation is critical for the long-term survival of Kenya's lions. In an endeavor to realize this; lion entry deterrent (LED) system was introduced for trials. Four years ago an 11 year-old boy, Richard Turere invented a simple device in an attempt to protect their family cattle in their enclosure from lion attacks in Kitengela area, Kenya. Richard's innovation of torches that flash has now been refined into solar powered prototypes. The LED system is an automated solar lighting system that deters large predators like lions, leopards and cheetahs from killing livestock held in enclosures in rural Africa.

The LED lighting system deters predators from entering livestock enclosures or getting close enough to cause a stampede by the livestock. The lights clearly define the boundary of the enclosure and by virtue of illuminating the entire outer perimeter of the enclosure without shedding light on the inside, enhancing security of the livestock. The LED units come at a relatively low cost and speedy installation. The method is proving to be very effective to predators like lions and leopards that cannot be prevented by ordinary fences when they are searching for prey.

2.6 Research Gaps

In and around wildlife conservation areas, Muruthi (2005) states two main ways of managing HWC: Prevention and Mitigation approaches. The prevention approach involves measures of preventing or minimizing the occurrence of conflict while mitigation involves reactive approaches after human-wildlife conflicts have occurred. The preventive measures consist of lethal problem animal control (PAC), translocation, winning hearts and minds of affected communities, compensation and benefit sharing (AWF 2005). On the other hand, mitigation approaches include eradication, regulated harvesting, exclusion by use of physical barriers which involves fences, stone walls and trenches (Ogada *et al.* 2003)

In lethal control, the problematic animal is identified and killed usually by wildlife officials in cases of loss of human life and severe livestock depredation (Muruthi, 2005). Lethal PAC is a serious problem if the animal in question is an endangered species that might be easily driven into extinction (Mackinnon, 2001).

In translocation, problematic animals are moved to new sites. However, translocation can be controversial since the animals may trace their way back to their original habitat or recreate the same conflicts in the new site (AWF 2005). Sometimes, translocated animals die from stress of capture soon after release (Stander 1990), or destabilize a population through competition and introduction of diseases. According to Conover (2002), translocated animals have shown low reproductive and survival rates.

Winning hearts and minds involves consolation for specific loss, changing the attitude and perceptions of affected communities through education, and sharing of benefits generated from national parks with the local community (KWS, 2004). However, the approach is resource intensive hence expensive (Nyhus *et al.*, 2003).

Eradication of predators such as lions, leopards and other problem animals such as elephants, and buffaloes has been carried out in Africa, mainly Kenya and South Africa (Muruthi, 2005). Predator species are persecuted by shooting, trapping and snaring, roost spraying, hunting with dogs, and poisoning with chemicals. With an intention of containing the predator population, the landowners may end up locally exterminating the species implicated (Treves and Naughton-Treves 1999).

Exclusion of wild animals by use of physical barriers is an effective method in excluding predators from human settlements, cultivated areas and livestock areas around wildlife protected areas, thus combating HWC (Ogada *et al.*, 2003). This is achieved by use of electric fences, stone walls and trenches. However, electric fences and stone walls are expensive to construct, maintain and sometimes cause injuries and possible deaths to animals (KWS, 1995). Trenches also may inflict physical injuries and at times drown animals during floods (KWS, 1992).

Although the above discussed strategies have managed to reduce conflicts on a small scale, they have some challenges in terms of prohibitive cost, accessibility and applicability to different situations. The LED system therefore provides realistic and adaptive measures that can minimize livestock depredation and reduce lion mortality resulting from retaliatory attacks by livestock owners. Thus, it can mitigate HWC with minimal costs and effects on the environment. Nevertheless, no comprehensive studies have been conducted to assess the effectiveness of the LED system against traditionally used barriers. This study therefore sought to address the knowledge gaps through field observations and measurements.

CHAPTER THREE

STUDY AREA, MATERIALS AND METHODS

3.1 Description of Study Area

3.1.1 Location of the Site

The Amboseli National Park is located in southern Kenya, at the foot of Mt. Kilimanjaro. The park covers 392 km^2 is surrounded by six community group ranches (NEMA, 2009a). Group Ranches constitute large parcels of land demarcated under the Land Adjudication Act (Cap 284) of 1968 and legally registered to a Group (clan or family). The group ranches around the park are; Olgulului-Ololorashi, Eselenkei, Mbirikani, Kimana, Rombo and Kuku.

The study was carried out in two group ranches around Amboseli National Park (Figure 3.1). The ranches are Olgulului-Ololorashi group ranch, (Olgulului North) and Kimana group ranch. The Olgulului GR surrounds 90% of Amboseli National Park with a total area of 1232 km^2 (Ntiati, 2002). Kimana Group Ranch is to the southwest of the park and it covers a total area of 25,120 hectares. The ranch was sub-divided into 60-acre parcels which were allocated to individual members of the ranch (KWS, 2007).

Land subdivision has introduced significant landscape changes including erection of fences, buildings, water storage dams and pipe lines, and construction of roads and power lines (Njenga, 2004). The subdivision of the land into smaller parcels and subsequent development of infrastructure has caused habitat fragmentation and hindered free movement of wildlife (Githaiga *et al.*, 2003).

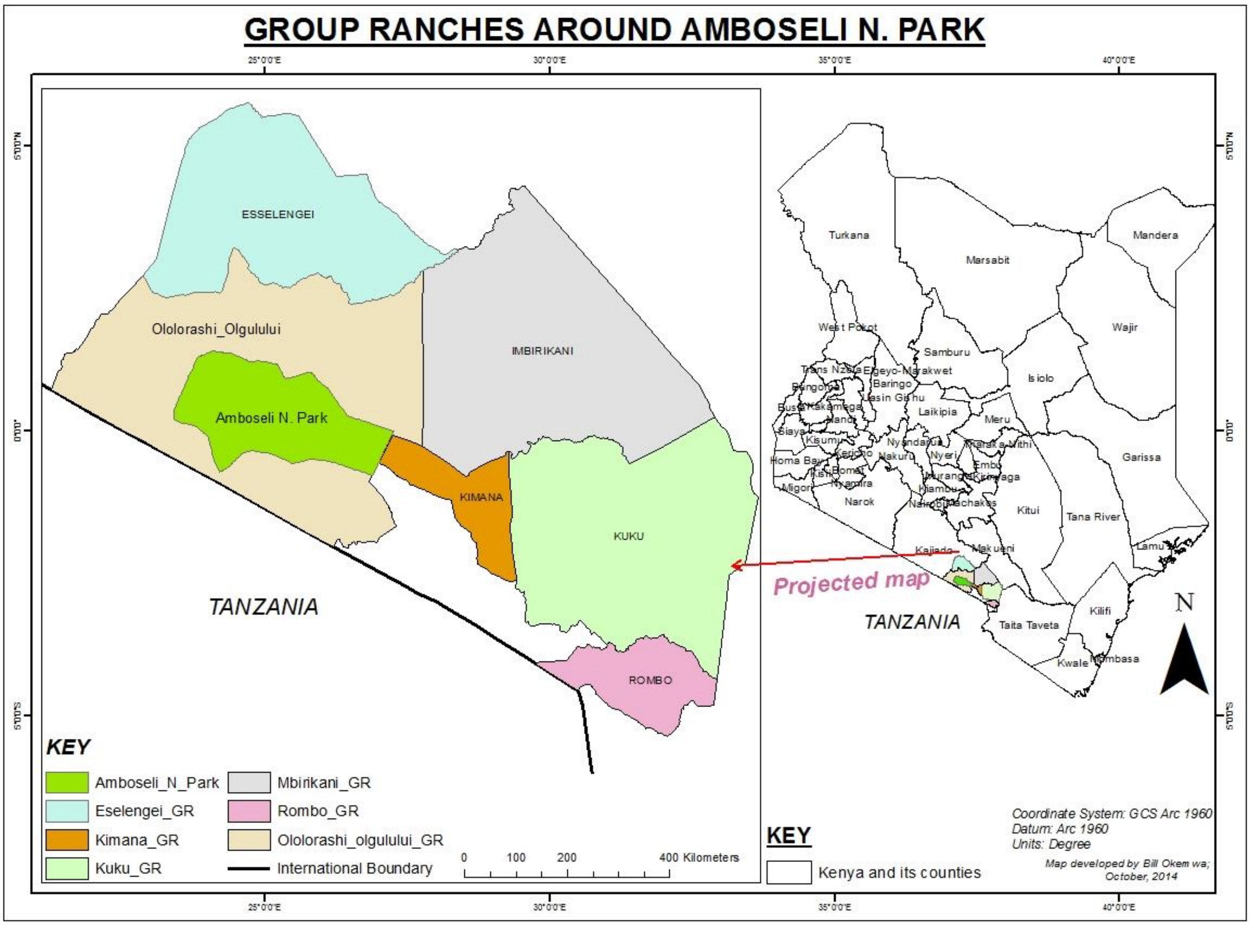

Figure 3.1: Amboseli National Park and the surrounding group ranches

3.1.2 Climatic Conditions

The study area is in semi-arid land falling in agro-climate zone VI (Pratt and Gwynne, 1978). Rainfall is distinctly bi-modal that falls in March to May and October to December with a long dry season from June to early October (KWS, 2007). The annual rainfall has a mean of 430 mm and varies between 132 and 553 mm/yr. The rainfall is often variable and poorly distributed. The temperatures of the area fluctuate between 14ºC and 30ºC (Katampoi *et al.*, 1990).

3.1.3 Soils and Natural Vegetation

The soils in the ranches range from stony cambisols to dark, cracking vertisols to dark clays (KARI, 2009). The soils were young and undeveloped black cotton soils and susceptible to erosion. Black cotton soils dominated the flood plains, while the well-drained higher elevations had calcareous and sandy loams (Katampoi *et al.,* 1990). Further, the soils are classified as volcanic and are generally shallow, highly saline and alkaline (Gachimbi 2002).

The plant communities of the group ranches are mainly bush-land, open grassland and some woodland. *Acacia-Commiphora* dominates throughout the ranches, along with a varying gradient of grassland to open woodland habitat (Githaiga *et al.,* 2003). In the recent past, woodland cover in most of the group ranches has greatly declined due to encroachment for subsistence agriculture (Campbell *et al.,* 2003).

3.1.4 Wildlife Resources

The Amboseli ecosystem supports a variety of wildlife including but not limited to; large diversity of resident ungulates including African elephants (*Loxodonta africana*), African Buffalos (*Syncerus caffer*), Common Hippopotamuses (*Hippopotamus amphibious*), Common waterbuck (*Kobus ellipsiprymnus)* Common zebra (*Equus burchelli*), wildebeest (*Connochaetes taurinus*), gazelles (*Gazella granti*), giraffe (*Giraffa camelopardalis*), impala (*Aepyceros melampus*).

Other dominant predators in the Reserve are spotted hyenas (*Crocuta crocuta*), lions (*Panthera leo*), leopards (*Panthera pardus*) and cheetahs (*Acinonyx jubatus*) (Kioko *et. al.,* 2008). These wildlife resources have made the ecosystem an important tourism hub, and hence generate a lot of revenue for the country and stakeholders in the tourism industry.

3.1.5 Socioeconomic Activities

Because of recent volcanic activity, the top soils in the Amboseli Ecosystem are shallow and unproductive. The land is therefore suited for wildlife conservation, tourism and pastoralism. The ongoing change of nomadic pastoralism to a sedentary lifestyle by the Maasai community has led to severe rangeland degradation (McCabe, 2003). The current land tenure has gradually been changing from group to individual ownership. This transformation has led to conflicting use between pastoralism, agriculture and wildlife conservation (Njenga, 2004).

3.2 Materials and Methods

3.2.1 Sampling Design

A stratified random sampling design was employed in the research study. The study was conducted on two group ranches (Olgulului and Kimana). From the two ranches, strata were selected based on frequency of livestock depredation. The strata were subdivided into two categories; those whose homesteads had lion proof fences, and installed lion entry deterrent systems and with lion-proof fences but no lion entry deterrent system.

Available lion prey count was assessed in the two group ranches. Belt transects with a fixed width and equal lengths (500 m by 200 m) were used to sample available prey in the various strata. This showed the prevalence or frequency of potential prey.

From the Olgulului and Kimana group ranches, forty homesteads with fortified fences were selected, 20 from each ranch. From the twenty homesteads in each ranch, ten were installed with lion entry deterrent systems while the remaining ten were assessed without the use of lion entry deterrent system.

To determine depredation frequency, data were collected daily from all the forty homesteads. These data were intended to reveal the status of livestock depredation before and after installation of lion entry deterrent system.

3.3 Data Collection Methods

3.3.1 Available Prey Count Survey and Carrying Capacity

Prey counts were used to estimate the abundance of the preferred prey species and prey density over time. Prey abundance was estimated with the commonly used strip transects established in various strata. Establishing transects entailed laying a 500m line outside the selected forty homesteads facing the direction of the park. Then animals encountered within 200 m on either side of the 500 m transects were counted. Transects described above were covered five times a month in each strata for a period of six months. A vehicle was driven at a speed of 15–20 km/h with two observers counting animals on the roof of the vehicle. Potential prey animals were sampled in the morning to avoid extreme temperatures that could bias animal distribution.

Monthly numbers of various prey species sampled were calculated to get the common prey species in the study area based on methods described by Hayward and Kerley (2005). The most available prey size of ungulates was assumed to be the most commonly killed prey by lions (Hayward and Kerley 2005). This is because in their studies, Funston *et al.,* (1998) and Loveridge *et al.*, (2006) found that at least five prey species that are abundantly available in a given area contribute to 75% of a lion’s diet. The available preys included buffaloes, zebra, wildebeest, and giraffes among others. These ungulates were readily visible to an observer.

3.3.2 Estimation of Lion Density

Relationships between prey density and lion density can be used to predict the potential number of lions that a given site could support. The Hayward's regression equation was used to estimate lion density from prey density (Hayward *et al.,* 2007):

$$\boldsymbol{D} = \mathbf{10}^{-2.158+0.377*\log x},$$

Where

$\boldsymbol{x}$ = density of the lions' preferred prey species (kg/km^2);

$\boldsymbol{D}$ = Lion density/km^2

This indirect method of estimating lion density was preferred because no counts of lions were made at night when they were most active.

3.3.3 Installation and Testing of Predator Deterrent Devices

To install the LED system in the selected twenty homesteads (10 homesteads from each ranch), first the cattle enclosure "*boma*" was surveyed to know its size. This accurately informed the number of bulbs, bulb stems and connecting wires that were used to install the LED system. Ideally, the bulb stems were spaced at least ten meters apart. This meant that the size of the cattle boma determined the number of bulb stems to be planted. Therefore, the bigger the boma, the more the bulb stems and connecting wires it required.

Once the boma survey was completed, the bulb stems were fixed with bulbs. The bulb stems were strategically planted around the cattle enclosure facing outwards of the boma. The bulb stems were connected to one another and to the main power source (battery) which was powered by a solar panel. This enhanced flickering of the lighting system at night, which uniformly illuminated the outside of the cattle boma. During the day, the lighting system was disconnected from the battery to allow the battery to be charged by the solar panel. For effective flickering of the LED system at night, a maximum of fourteen bulb stems were used. In cases where the cattle boma was large, then more than one LED systems were installed i.e. two batteries and two solar panels (Plates 1a and b).

Photo 1a: Fixing bulbs to a bulb stem **b: Fixing a boma with connecting wires**

Photo 2: A battery system **Photo 3: A solar panel on a roof top**

Once the LED system was fixed in a homestead, data on livestock depredation were collected daily for a period of six months. These data were collected at night. The LED system was switched on at 7 pm and switched off at 7 am. The assessor, usually the cattle owner was alert to record predatory incidences. If there were predatory incidences i.e. predatory attacks or actual livestock killings, they were recorded in a data sheet. The carnivore responsible for the incidence was also recorded. Livestock depredation rates from the enclosures with fortified fences and lion entry deterrent systems were compared with enclosures with fortified fences but no lion entry deterrent system was installed.

Photo 4: Night livestock guarding by men **Photo 5: Flickering LED system at night**

3.4 Data Analysis

3.4.1 Assessment of Efficiency of the Lion Entry Deterrent System

A binary logistic regression model was used to assess efficiency of the lion entry deterrent system. The values of dependent variable (Efficiency of LED system) were computed into categorical binary variables (0 or 1). Efficiency was computed by getting the ratio of post LED success rate to pre LED success rate. A conditional statement '***if***' was used to filter outcomes greater than one in the ratio to determine efficient and non-efficient cases.

The selected study model was employed since it incorporated elements of ecological and human factors influencing the success rate of the LED system. It illustrates relations between the success rate of the LED system and the moderating factors. The model illustrates relationship between the proportions (P) of dependent variable (LED efficiency) to independent variables; weather condition ($x1$), number of livestock killed ($x2$), time of attack ($x3$), and presence or absence of LED system ($x4$). The number of livestock killed as a quantitative variable was checked for multi-collinearity and auto-correlation. The following logistic regression model was used to predict (estimate) favorable outcomes as a measure of LED efficiency (Y).

$$Y = \frac{e^{\alpha+\beta 1x1+\beta 2x2+\beta 3x3+\beta 4x4}}{1+e^{\alpha+\beta 1x1+\beta 2x2+\beta 3x3+\beta 4x4}}$$

Where $x1$ are variables; α is the regression constant; β_i= regression coefficient; i =1, 2, 3, 4…….

Y = Efficiency of LED system (Efficient=1; Not efficient=0)

e= Error term

$x1$ = Weather condition (Dry=0; Wet=1)

$x2$ = Number of livestock killed

$x3$ = Time of attack (Day=0; Night=1)

$x4$ = Presence of LED system (LED homes=1, Non LED homes=0)

The study of LED performance could generate valuable insight into factors that could limit or enhance the success rate of deterring lions and other predators from approaching the livestock bomas.

3.4.2 Interactive Effects among Variables Affecting LED Efficiency

Two-way ANOVA was used to assess the main effects and interactive effects of the underlying factors predicting efficiency of the LED system. Chi-square and correlation tests were also carried out to determine the nature of the association of test and association between predator and prey density in both Kimana and Olgulului Group Ranches

3.4.3 Pre-LED and Post LED Comparisons

A paired sample t-test was used to assess the difference in the frequency of attacks and livestock killed in homesteads during the Pre and Post LED period. Independent samples t-test was used to determine differences in the livestock attack cases in each study site before and after installation of the LED system in the cattle bomas.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents the results and findings of this study. These findings include abundance of available prey and predator densities, livestock depredation patterns, effects of seasonal changes in predatory incidences and efficiency of the LED system. The results have been presented sequentially based on the objectives of the study.

4.2 Abundance of Available Lion Prey

4.2.1 Lion Prey in Olgulului and Kimana Group Ranches

Using transects, animals were identified and head counts were conducted for animals sighted in each study site. The animals sighted included buffaloes, zebra, wildebeests, giraffes, cattle, goats, and sheep among others. Below are photographs of some of the animals seen and counted in different transects of the study areas

Photo 6 & 7: Common zebras occurring in bushed grassland and impalas in woodlands

Photo 8: Cattle in open grassland **Photo 9: Wildebeest in bushed grassland**

Generally, the number of the animals sighted and counted varied slightly in each group ranch. Results indicated that zebras (M=53.7±8.8) and wildebeests (M=43.2±5.0) were the most common type of wild prey in the study area. Similarly, cattle (M=61.2±4.8) were the most common livestock prey identified along the 500m by 200m belt transect established across different habitats in each of the group ranches.

In Kimana GR, results indicated that more wildebeests (M=51.6±4.4) were observed on the stated transect line than zebras (M=50.6±9.8). At the same time, cattle (M=64.1±5.4) were the commonly observed livestock prey. In Olgulului GR, zebras (M=56.7±8.5) consisted of the highest wild preys compared to wildebeests (M=34.8±2.8). Further, cattle (M=58.3±4.3) were noted to be the most common livestock seen in Olgulului Group Ranch.

The number wildebeest differed significantly at 95% confidence, t=3.23, DF=10, $p<0.05$. In other words, wildebeest numbers were higher in Kimana Group Ranch than in Olgulului

Group Ranch. The number of giraffes significantly (P< 0.05) differed in the two ranches with Olgulului GR recording more giraffes (M=23.5±1.6) than in Kimana GR which recorded (M=15.4±1.2) giraffes. However, there was no significant difference (P>0.05) in the number of the other animals in the two group ranches (Table 4.1)

Table 4.1: Animals counted along a 500m by 200m belt transect in the GRs

Prey type	Olgulului & Kimana Mean		Olgulului GR		Kimana GR		Mean difference (*Olgulului-Kimana*)	
	Mean	Std. error	Mean	Std. error	Mean	Std. error	t (2,10)	Sig. (2-tailed)
Wildebeest	43.2	5.0	34.8	2.8	51.6	4.4	-3.23	.01
Zebra	53.7	8.8	56.7	8.5	50.6	9.8	.47	.65
Giraffes	19.4	2.2	23.5	1.6	15.4	1.2	3.98	.003
Buffaloes	9.2	1.3	9.4	1.2	9.0	1.5	.20	.85
Impalas	12.9	1.3	11.3	1.3	14.6	1.0	-2.06	.07
Gazelles	13.9	1.9	16.2	1.5	11.7	1.9	1.84	.10
Warthogs	15.4	2.3	17.8	2.3	13.1	2.0	1.55	.15
Waterbucks	14.4	2.5	16.4	3.0	12.3	1.8	1.18	.27
Cattle	61.2	4.8	58.3	4.3	64.1	5.4	-.85	.42
Sheep	24.3	3.6	26.1	2.6	22.5	4.6	.69	.51
Goats	26.8	4.6	27.8	5.8	25.8	3.6	.31	.76
Donkeys	5.6	1.4	7.1	1.6	4.1	1.0	1.65	.13

4.2.2 Distribution of Prey

Prey density was computed using Hayward's formula ($D = 10^{-2.158+0.377*\log x}$). Results of the study indicated that ungulate distribution at the two study sites were almost similar (Table 4.2). Olgulului GR had the highest wildlife-livestock ratio of 1.29 compared to what was observed in Kimana where wildlife-livestock ratio was 1.24. Cattle density was found to be high in both sites with higher proportion found in Kimana.

Zebra and wildebeest were prevalent in the two GRs. In Olgulului, 29.4% of the entire ungulate populations at the site were zebras while 11.1% were wildebeest. The results were different from what was observed in Kimana, where 23.1% and 22.2 % by proportion were wildebeest and zebras respectively.

Table 4.2: Composition and proportion of ungulates in the study sites

Prey Type	Olgulului		Kimana	
	Prey Density	Proportion by Density (%)	Prey Density	Proportion by Density (%)
Wildebeest	30.5	11.4	60.94	22.3
Zebra	71.9	27.0	58.88	21.5
Giraffes	15.2	5.7	7.33	2.7
Buffaloes	3.1	1.1	2.84	1.0
Impalas	4.2	1.6	6.65	2.4
Gazelles	7.9	3.0	4.51	1.7
Warthogs	9.4	3.5	5.45	2.0
Waterbucks	8.1	3.0	4.93	1.8
Cattle	75.4	28.3	89.19	32.6
Sheep	18.4	6.9	14.18	5.2
Goats	20.6	7.7	17.94	6.6
Donkeys	1.9	0.7	0.70	0.3

4.2.3 Estimation of Lion Densities

Using Hayward and O'Brien (2007) methodology, lion densities were estimated. Results from the study found that zebra and wildebeest had the greatest prey densities in the two group ranches. In Olgulului GR, wildebeest had prey density of 0.30 per 100 km^2 while zebra had a prey density of 0.72 per 100 km$^{2.}$ On the other hand, in Kimana GR, the prey density for wildebeest was 0.61 per 100 km^2 while that for zebra was 0.59 per km^2. Using the above stated method, it was found that high zebra and wildebeest numbers would attract many lions in both the group ranches. Small sized preys like gazelles and warthogs attract minimal lion predatory incidences in either of the study areas.

Table 4.3: Predicted lion density from the density of different prey species at Olgulului and Kimana GRs

Wildlife	Prey density (100 Km^{-2})	Predicted lion density (100 Km^{-2})	Study site
Wildebeest	30.47	0.35	Olgulului
Zebra	71.93	0.75	Olgulului
Giraffes	15.25	0.19	Olgulului
Buffaloes	3.06	0.05	Olgulului
Impalas	4.22	0.06	Olgulului
Gazelles	7.94	0.11	Olgulului
Warthogs	9.38	0.13	Olgulului
Waterbucks	8.13	0.11	Olgulului
Wildebeest	60.94	0.65	Kimana
Zebra	58.88	0.63	Kimana
Giraffes	7.33	0.10	Kimana
Buffaloes	2.84	0.04	Kimana
Impalas	6.65	0.09	Kimana
Gazelles	4.51	0.07	Kimana
Warthogs	5.45	0.08	Kimana
Waterbucks	4.93	0.07	Kimana

A scatter diagram below was used to visualize the lion-prey relationship. There was a strong relationship between predicted lion density and prey density in 100 sq. km (R>0.99, P<0.001) (Fig 4.1). The linear relationship formula indicates that in 100 sq. km area, at 95% confidence, about 500 prey would attract 5 lions.

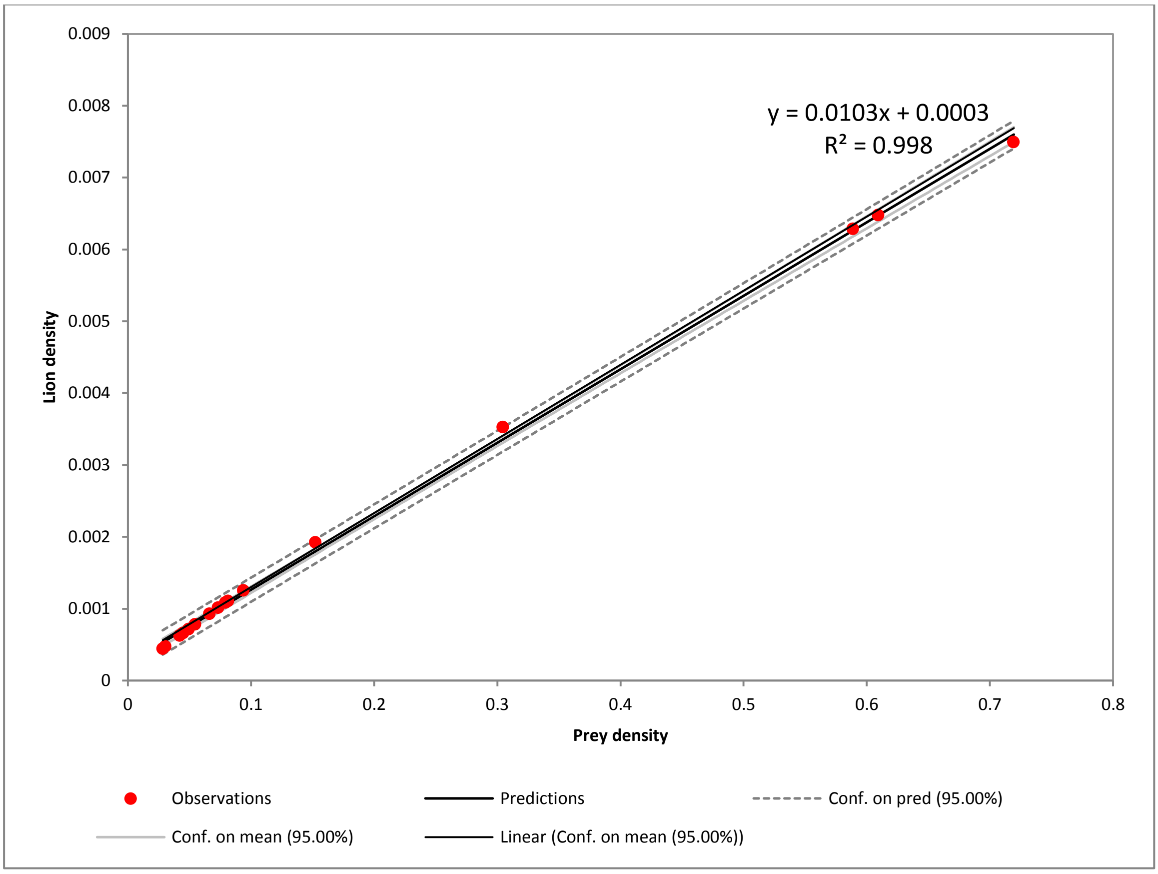

Figure 4.1: Correlation between Lion density and prey density in 100 km^2 area

95% confidence limits of the mean predator density produced a line parallel to the predicted trend. Similarly, 95% confidence limits of the mean lion density were very small especially at high and low density extremes. This reflects existence of tight mixed species groups at low and high prey density regions. However what was important to the lion was the size rather than the diversity of prey.

4.3 Livestock Predation Patterns

4.3.1 Situational Analysis of Predation Patterns before the LED

The situational analysis was performed to obtain history of predatory attacks in the study sites. Reports from KWS and local administration (chief and village elders) provided a platform for understanding the predatory trends one year before the study commenced. During the study period, it was observed that hyenas were involved in more predatory incidences than lions. This was contrary to the hypothesis that lions cause more depredation incidences since they were the target predators. Other predators like jackals, leopards and cheetahs were also responsible for livestock depredation.

The number of predatory incidences reported in both Kimana and Olgulului Group Ranches varied slightly. In both sites, hyenas caused more than 50% of livestock killings while the lions contributed to 25% of the predatory incidences. Below is a breakdown of predatory incidences in both study sites (Fig 4.2).

Incidences of predation by different predators in Kimana Group Ranch indicated that hyenas recorded the highest predatory incidences (57%), followed by lions (24%), jackals (11%), leopards (7%) and cheetahs (2%). In Olgulului GR, similar results were observed where hyenas recorded the highest predatory incidences (51%), followed by lions (29%), jackals (9%), leopards (8%) and cheetahs (2%). Whilst most incidences involved hyenas, they were less conspicuous than those of lions. This is because they fed on small livestock while lions attacked large livestock, particularly cattle.

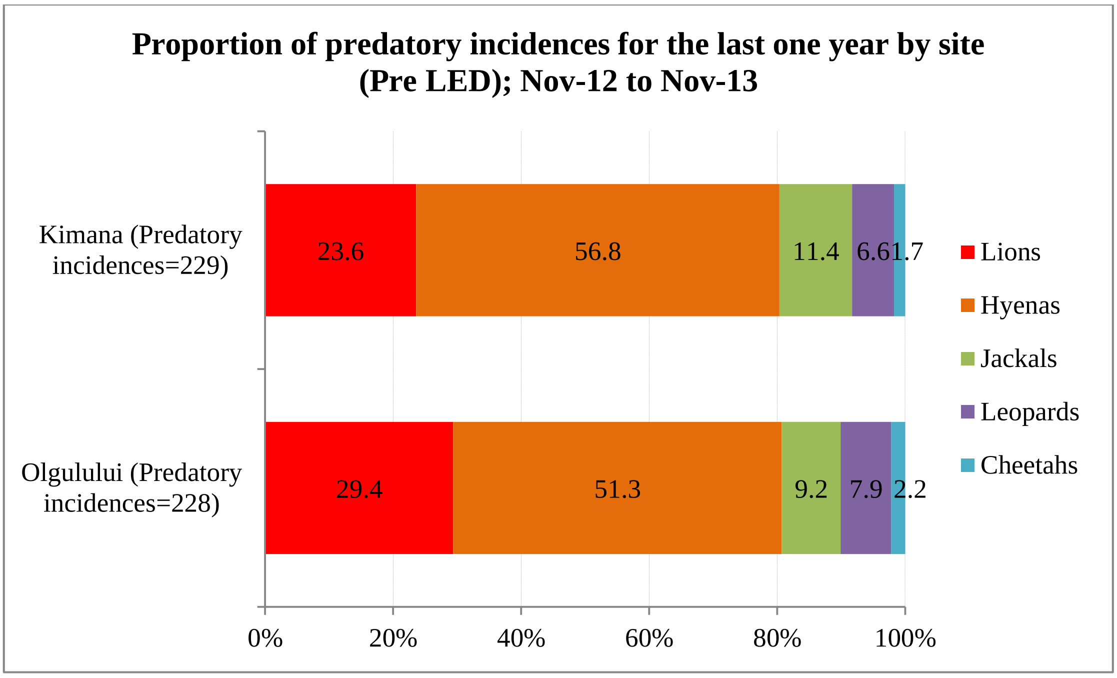

Figure 4.2: Predatory incidences arising the year preceding this studies by site and predators involved.

4.3.2 Effects of Seasonal Change on Predatory Incidences

The results of the study indicated that livestock predation by wild animals occurred throughout the year. However, predation incidences were higher during wet season than during dry season. In Olgulului GR, higher incidences of predation were recorded during wet season (69%) compared to low predatory incidences during dry season (31%). Similarly, in Kimana GR, high incidences of predation were encountered during wet season (62%) compared to low incidences during dry season (38%).

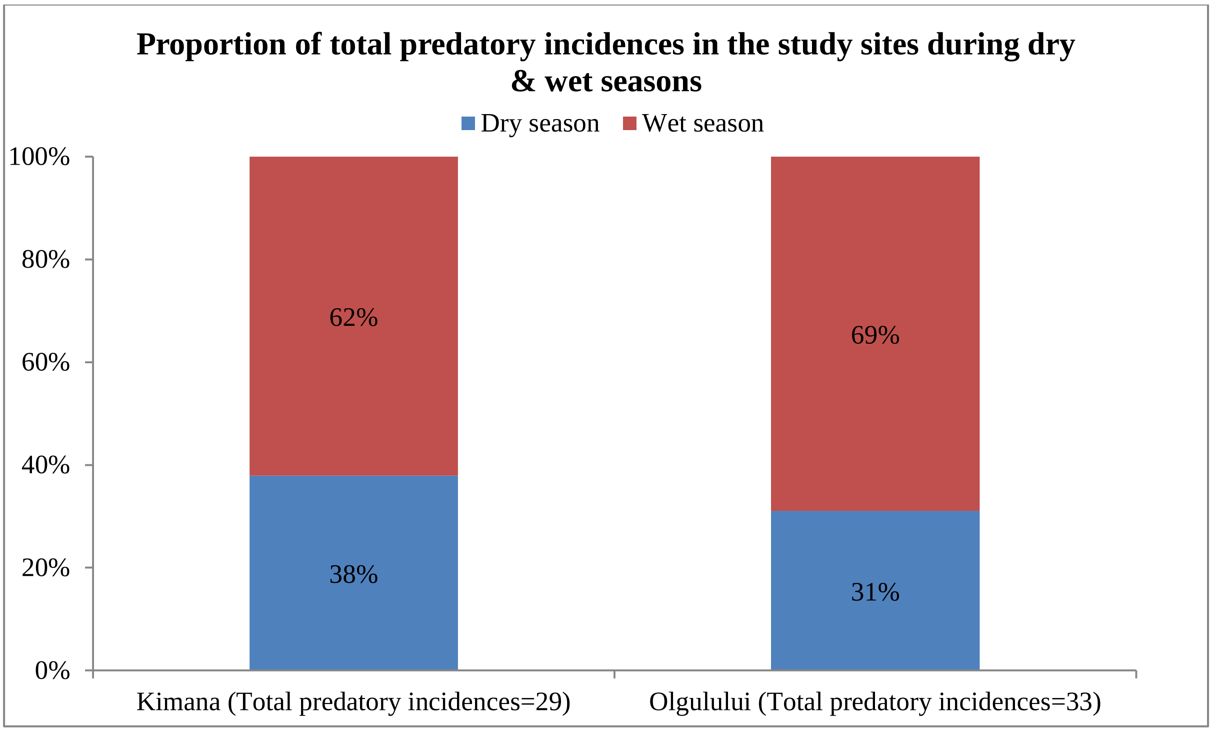

Figure 4.3: Total predatory incidences for both study sites during dry and wet seasons

The total predatory incidences for the two study sites were obtained from the results of the study. Descriptive statistics predatory incidences are as shown (Table 4.4).

Table 4.4: Predatory incidences during wet and dry seasons

	Incidences	
	Dry	**Wet**
Olgulului	11	22
Kimana	9	20

Chi-square was used to determine the nature of the relationship between predatory incidences and seasons (wet and dry). These predatory incidences differed significantly from random expectations at 95% confidence (χ^2 =18.31, p<0.05, DF =1). Thus, predatory incidences were not independent of season with 30 dry season and 42 wet season incidences.

Table 4.4.1: Association between predatory incidences and seasons

Chi-square (critical value)	18.307
DF	1
One-tailed p-value	0.017
Alpha	0.05

There was a significant association between predatory incidences and season (P= 0.02)

4.3.3 Predatory Incidences in Kimana and Olgulului Group Ranches

4.3.3.1 Predatory Incidences during Dry Season

During the dry season between Dec 2013 and Feb 2014, incidences of hyena attacks even in the presence of LED system were recorded. In Kimana, a total of 8 incidences of hyena attacks for the specified period of time were recorded which was followed by 2 incidences of lion attacks over the same period. In Olgulului GR, lower incidences of post LED attacks were observed; a total of five hyena predatory incidences, two leopard incidences, one lion and one jackal attacks were recorded.

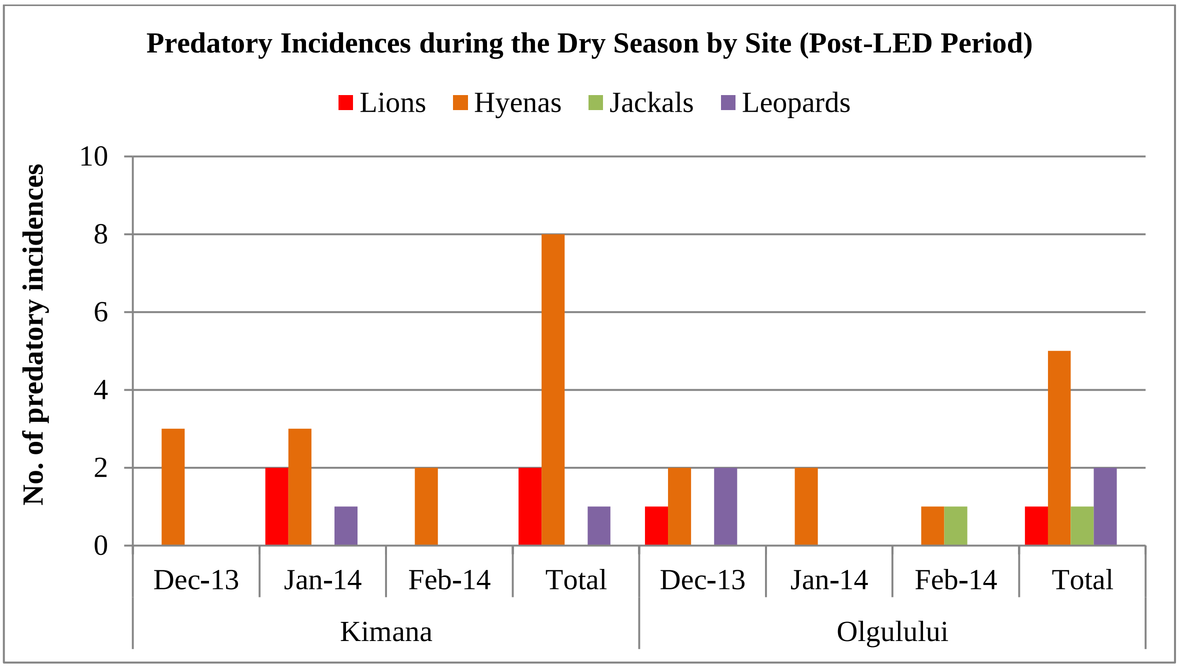

Figure 4.4: Predatory incidences during the Dry season by site

4.3.3.2 Predatory Incidences during Wet Season

Wet season was experienced between March 2014 and May 2014. There was a notable significant increase in the number of predatory attacks. In Kimana GR, 11 incidences of hyena predation, 3 lion incidences, 2 jackal and leopard incidences were recorded. In Olgulului GR, there was a significant increase in the total number of hyenas (9), lions (4) and jackals (6) incidences recorded. However, the number of predatory incidences caused by leopards and cheetahs in both sites remained relatively low. For instance, cheetahs recorded no incidences during both dry and wet seasons.

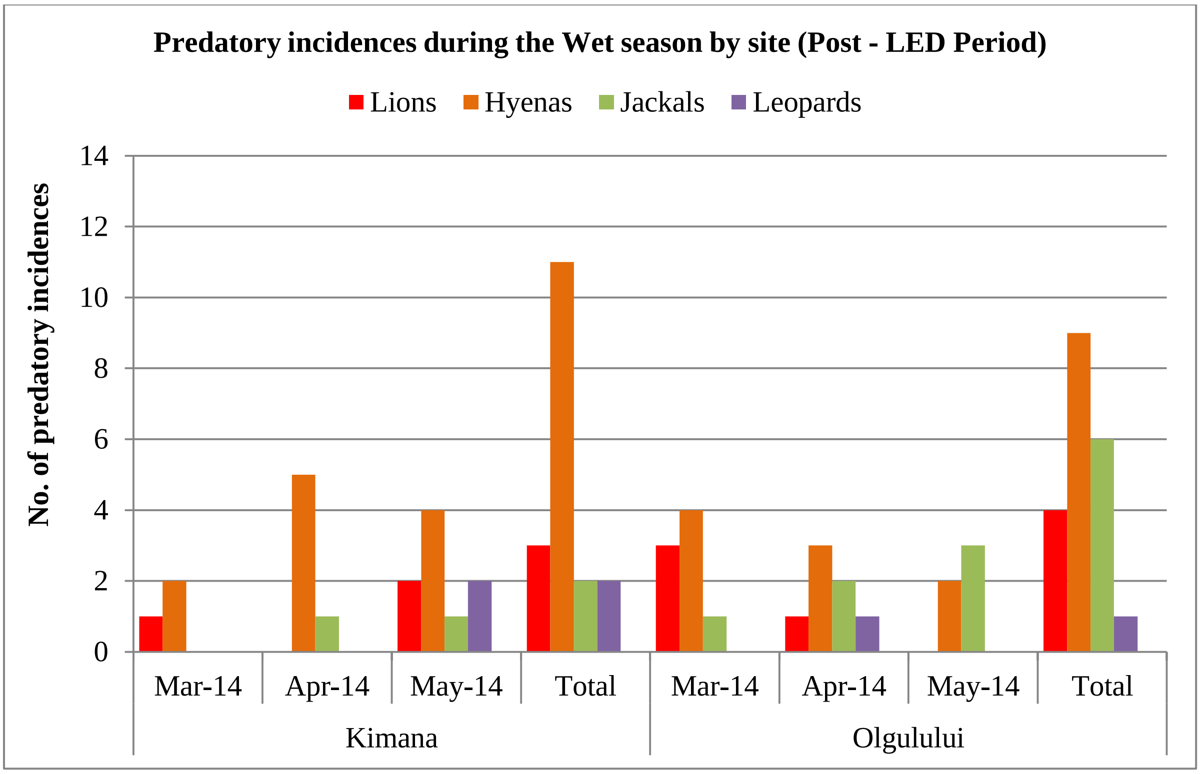

Figure 4.5: Predatory incidences during the Wet season by site

4.4 Efficiency of the LED systems

Homes with LED systems registered low mean (1.8±0.42 in Olgulului and 2±0.49 in Kimana) livestock loss compared with homes without LED system during the study period. Results from the study indicated that more livestock were killed in Kimana GR than in Olgulului GR (Table 4.5). Further, results indicated that homesteads with the LED system had an efficiency level of 90%, whereas homes without LED system only possessed 20% efficiency level (Table 4.6). From the same table, it was also observed that LED system was highly efficient during dry season (65%) as compared to wet season (45%).

Table 4.5: Mean (±SE) of livestock killed in the study sites

	Olgulului	Kimana
With LED only	1.8±0.42	2±0.49
Without LED	10.8±1.09	16±2.05

Table 4.6: Association between 3 test variables and efficiency of LED systems

Predictor Variables		LED Efficient		LED Not efficient		χ^2	P-Value
		n	%	n	%		
Fence type	With LED	18	90.0	2	10.0	19.80	<0.001
	Without LED	4	20.0	16	80.0		
Time of attack	Day	1	14.3	6	85.7	5.68	0.017
	Night	21	63.6	12	36.4		
Season	Dry season	13	65.0	7	35.0	1.62	0.204
	Wet season	9	45.0	11	55.0		

4.4.1 Logistic Regression Model for Efficiency of LED System

A summary of logistic regression result on the test variables is as below (Table 4.7). The odds ratio measures the effect size based on the referenced variable. It therefore means that homesteads with LED systems are more efficient than homes without LED systems though the association is not significant at 95% confidence (OR=9.34, 95% CI: 0.094-924.54, P>0.05). Time of attack and weather conditions were other determining factors of LED efficiency. However, all these factors were not significant by association with LED efficieny at 95% confidence level.

Table 4.7: Logistic regression model for test variables and efficiency of LED systems

Test variables	B	S.E.	Wald	Df	Sig. (p)	Odds Ratio	95% C.I. for EXP(β)	
							Lower	**Upper**
Fence type(With LED only)	**2.234**	2.345	.908	1	.341	9.337	.094	924.538
Time of attack(Night)	**1.588**	1.547	1.053	1	.305	4.893	.236	101.547
Weather condition(Dry)	**1.922**	1.708	1.266	1	.260	6.833	.240	194.212
Post LED livestock killed	**.064**	.146	.190	1	.663	1.066	.800	1.420
Constant	**-1.930**	2.576	.561	1	.454	.145		

Dependent variable: Efficiency of LED system

Overall, there was no significant relationship between fence type, weather condition, time of attack, and Post-LED livestock killed and efficiency of the LED system. Thus, LED system was effective irrespective of fence type used, weather conditions prevailing and time of the night when attacks usually occurred.

Below is an ANOVA indicating both main effects and interactive effects (Table 4.8). Results indicated that interaction between LED presence and time of attack (night) was the only significant predictor of efficiency ($F_{1, 39}$=5.56, P<0.05). The three factors explained 61% of the total variations in the LED efficiency.

Table 4.8: Interaction between test variables and efficiency of LED systems

Dependent Variable: Efficiency

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	6.042[a]	7	.863	7.161	.000	.610
Intercept	.201	1	.201	1.665	.206	.049
Post-LEDs Livestock killed	.053	1	.053	.441	.512	.014
Presence of LED	.345	1	.345	2.865	.100	.082
Time of attack	.455	1	.455	3.774	.061	.105
Weather condition	.005	1	.005	.040	.843	.001
Presence of LED * Time of attack	.673	1	.673	5.579	.024	.148
Presence of LED * Weather condition	.018	1	.018	.147	.704	.005
Time of attack * Weather condition	.194	1	.194	1.609	.214	.048
Error	3.858	32	.121			
Total	22.000	40				
Corrected Total	9.900	39				

R Squared = .610 (Adjusted R Squared = .525)
d≤0.2 (small effect), d=0.5 (medium effect), d=0.8 (Large effect)

Interaction of the three independent variables (presence of the LED system, time of attack, and weather condition) significantly influenced the LED system success (p=0.000). Presence of LED system and time of attack were significantly associated with LED success (p=0.024).

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

5.1.1 Composition of Available Lion Prey

In Africa, lion prey species range in number from as low as 14 species (Breuer, 2005) and sometime exceeds 20 prey species (Hayward and Kerley, 2005; 2009; Lehmann *et al.*, 2008). In Olgulului and Kimana Group Ranches, the available prey species composition observed was slightly lower than the lowest range of 14 species. The sighted prey composition comprised of 8 wild prey types and livestock comprising of 4 prey types. These summed to 12 prey species, two species less the lowest range in a given site according to Breuer (2005), Hayward and Kerley, (2005; 2009) and Lehmann *et al.*, (2008). In both study sites, wild prey means were higher compared to livestock preys.

Past studies by Funston *et al.*, (1998) Druce *et al*., (2004) and Loveridge *et al.*, (2006) found that up to five or more prey species that are commonly available at a given area constitute 75% of a lion's diet. At the study sites, the most common wild preys were wildebeests, and zebras as well as cattle and sheep (livestock). In Olgulului GR, the order of prey abundance was cattle, followed by zebra while giraffes were least abundant. Similarly, in Kimana GR, cattle and wildebeests were most common and finally giraffes were least common.

5.1.2 Prey Size

For a lion to survive and meet its high energy demand, a stable and diverse prey base is very critical (Funston *et al.,* 2001). The encroachment of humans and human activities into and around wildlife protected areas has introduced another variety of prey, the livestock.

Therefore, lions predate on a variety of wildlife and livestock animals ranging from small sized (<50 kg), medium sized (50-200 kg), to large sized preys (>200 kg), (Bauer *et al.*, 2005). The lions' diet and prey preference is determined by distribution and availability of the prey, size of the prey and vulnerability of the prey (Hayward & Kerley, 2005; Carbone *et al*., 1999).

Results from this study indicated a similar trend whereby the available and sighted preys comprised of small, medium and large sized wildlife and livestock lion preys. Medium sized preys of both wildlife and livestock comprised of the major available lion preys. They comprised of zebra, wildebeest, waterbucks, impalas as well as cattle and donkeys making up to 50% of the available lion prey. The high population proportions of medium-sized prey in the study sites can be attributed to the ASALs regions of eastern Africa where these prey sizes predominate (Stander, 1992; Druce *et al.*, 2004). Similarly, Bauer *et al.,* (2008b) found out that medium sized preys dominate most of the lions' diet in many wildlife protected areas in Africa.

Breuer (2005) in his studies found that larger ungulates also form part of lion's diet. Further, the presence of larger ungulates consisting of buffaloes and giraffes confirms the same. Thus, large sized preys accounted for 16.67% of the available prey. Despite the fact that the study site supports a large number of medium sized preys, availability of larger prey also confirms the preference of the lion for large prey species (Hayward and Kerley, 2005). The lions' preference to larger preys can also be attributed to its big size. Similarly, studies by Owen-Smith and Mills (2008) established that lions in East and Southern Africa prefer medium and large sized preys as opposed to small sized prey.

Lions' most preferred prey averagely weighs 350 kg (Hayward & Kerley, 2005). Therefore, any prey sizes falling outside this range may not be preferred. However, lions are known to be opportunistic feeders in their behavior (Schaller, 1972). In this study, the inclusion of small sized preys comprising of gazelles, sheep and goats explains this fact. On the same note, depredation of lions on sheep and goats can be attributed to their availability. Still, their inability to morphologically adapt to defend or escape from predators makes them more vulnerable. Contrary to Hayward and Kerly (2005), results of this study indicated that buffaloes were among the least observed prey. This was because transects were established around homesteads where buffaloes least occur.

5.1.3 Livestock Depredation Patterns

Human wildlife conflict is a common phenomenon around wildlife protected areas (Anthony *et al.*, 2010). Generally in Africa, birds, rodents, insects, hippopotamuses, monkeys, carnivores and large herbivores like elephants and buffaloes among other wild animals are responsible for human wildlife conflict (IUCN, 2006b). In Kenya's wildlife protected areas, carnivores are among the most problematic animals and they are but not limited to the following; spotted hyena (*Crocuta crocuta),* lion (*Panthera leo)*, cheetah (*Acinonyx jubatus),* leopard (*Panthera pardus)* (Treves, 2009).

At the study sites, the lions, spotted hyena, leopards, jackals and cheetahs were the animals recorded to be responsible for human wildlife conflict. Further, results of the study indicated that in both Kimana and Olgulului Group Ranches, hyenas were the most problematic predators with over 50% of predatory incidences (57%, Kimana GR and 51%, Olgulului GR) while lions had the second highest predatory incidences of 24% in Kimana GR and 29% in Olgulului GR.

According to KWS (1996) and Thirgood *et al.,* (2005), human wildlife conflicts occur in different forms ranging from human induced wildlife mortality, disease transfer, raiding of crops, resource competition, attacking of livestock and destruction of infrastructure. In this study, the main manifestation of conflict was attacks on livestock, leading to injury and loss of livestock from some of the local homesteads. Over the study period, no cases of loss of human life or fatal injuries were reported but the threat to human life was always there.

The high number of hyena predatory incidences in both sites can be attributed to their feeding habits. Hyenas feed on fresh and decaying carcasses thus always searching for more prey hence increasing contact with livestock (Watts *et al.,* 2009). Similar studies by Stiner, (2004) also indicated that Hyenas tend to feed on large mammals of 6-14 times their own body weight, and roughly an order of magnitude larger on average than domestic caprovines. Hyenas are the most abundant large carnivores in many African ecosystems and their populations correlate positively with prey abundance (Watts *et al.*, 2009). Hence, their higher numbers in Kimana and Olgulului GRs can be linked to the high numbers of wild prey and livestock reared by the local Maasai community.

Although lions had the second highest predatory incidences in both sites, lion populations are declining in the study sites and the whole of Africa (Ogada *et al.,* 2003). This problem is acutely urgent in Kenya’s Maasai land, where local residents occasionally spear and poison lions due to livestock depredation. Limited data from the Tsavo-Amboseli Ecosystem and other studies indicated that a minimum of 108 lions, and probably many more, had been killed in the region between 2001 to 2013 (Frank *et al.,* 2006). The reduction in lion populations has been largely due to conflict with humans over livestock. Large carnivores kill livestock and are in turn killed by livestock owners (Frank *et al.,* 2006) and this could be the case in Kimana and Olgulului Group Ranches. These retaliatory attacks may lead to local extinction of lions within very few years.

Studies on human wildlife conflict by Patterson *et al.,* (2004) indicated that the maasai pastoral community has recorded rainy seasons with increased carnivore conflicts over time in Eastern Africa. This is in line with findings of Saberwal *et al.,* (1994) who found out that during the monsoon rains, there were increased cases of human tiger conflicts in India. In the current study, there were increased livestock depredation rates during the rainy season as compared to dry season in both Olgulului GR (69% during wet season and 31% in dry season) and Kimana GR (62% during wet season and 38% in dry season).

We can therefore conclude that livestock depredation trends are driven by seasonal variations which in turn influence the availability of natural prey (Woodroffe and Frank 2005). High depredation can be attributed to regrouping of wild prey back into protected areas, thus making hunting by carnivores difficult (Mishra, 1997). Other studies have indicated that depredation rates have been increasing due to more availability of livestock prey in the vicinity of carnivores as the abundance of natural prey decreases (Stoddart *et al.,* 2001).

On the same note, both wildlife and livestock could be observed roaming freely searching for pastures and water during the dry season. However, this was not the case during the wet season when the most sighted preys were mainly livestock. During the dry season, both livestock and wild prey have almost equal chances of being attacked due to their availability (Personal observation).

During the wet season, the cattle *bomas* were observed to be muddy with large piles of dung and small pools of water. Given the high numbers of livestock, muddy and wet enclosures, livestock could not be contained in the enclosures *"bomas"* at night. Hence, the cattle spent the night outside their enclosures (Personal observation). This situation made livestock vulnerable to attack by predators at night. Further, their inability to morphologically adapt to defend or escape from predators makes them more vulnerable to predators. Further, notable in study sites were the difficulties by the Maasai men to be vigilant at night during the wet season due to the harsh cold weather (Personal observation).

5.1.4 Efficiency of the LED systems

Kimana and Olgulului GRs form migration corridors and dispersal areas for wildlife in the Amboseli Ecosystem (KWS, 2009). However, as these areas are lost to agriculture, pastoralism, human settlements and other economic activities, carnivore–livestock conflict is inevitable and likely to increase (Lamprey and Reid, 2004). Findings of this study indicated that indeed human carnivore conflict is prevalent in the two study sites and therefore the need to mitigate these conflicts.

In determining efficiency of the LED system, homes with LED systems registered low mean livestock loss (Olgulului GR, 1.8 ± 0.42 and Kimana GR 0.2 ± 0.49) compared to the homes without LED systems which registered high rates of livestock loss (Olgulului GR, 10.8 ± 1.09

and Kimana GR, 16 ± 2.05). The differences in livestock loss in homes with and without LED system in both study sites clearly indicated that indeed the LED system was effective in reducing livestock depredation by local carnivores.

Despite the fact that LEDs successfully reduced depredation, predator attacks and livestock killings were still noticed in homesteads installed with LED system. This is because first, change in availability of prey was as a result of human development (Dublin and Ogutu, 1998). When availability of lion's natural prey was reduced due to natural dispersal and anthropogenic activities, lions and other predators turned to livestock reared in areas adjacent to the parks (Stander, 1997). Further, Stander (1997) observed that lions are found in areas inhabited by humans because they have high abundance of prey base comprising of both livestock and wildlife.

Secondly, malfunctioning of the LED system contributed to livestock killings during post LED period. As stated earlier, the LED system is made up of a solar panel, a battery and bulbs connected to one another. Thus, when the system short circuits due to wrong connection of terminals i.e. positive to negative and negative to positive, the LED system ceases to function. The homestead therefore becomes vulnerable to predatory attacks. Inadequate charging of the battery during the day or axillary connections like mobile phone charging or house hold lighting at night makes the bulbs flicker dimly hence rendering the system inefficient. This further makes the homestead vulnerable to predatory attacks hence the minimal depredation cases that were recorded during the study period in homesteads installed with the LED system.

Finally, and ecologically, lions are adapted to semi-arid climatic conditions that may have reduced prey bases (de Waal *et al*., 2001). When humans expand into these areas which form lion habitats for pastoralism, some lions become habitual livestock killers if the available prey is mainly livestock (Frank, 2006).

Generally, results of the study have indicated that the LED system was efficient in reducing livestock predation. This was because homesteads installed with LED systems had very reduced attack frequency and consequently the number of animals killed in the livestock enclosures *"bomas"* in those homesteads were reduced significantly. Further, the means of the frequency of attacks and number of livestock killed between homesteads installed with LEDs and those without LEDs were significantly different in both Olgulului and Kimana GRs.

5.2 Conclusion

Reduction of wildlife habitats has contributed greatly to increase in human wildlife conflicts and consequently reduced the size and population of wild herbivores (KWS 1994; Maclennan *et al*,. 2009). This research study focused on developing an effective anti-predator strategy to minimize livestock depredation and lion mortality arising from retaliatory actions in Kimana and Olgulului group ranches in the neighborhood of the Amboseli National Park.

In determining densities of available lion prey, wildlife comprised the highest number of preys as compared to livestock. Zebras and wildebeests contributed to a greater percentage of wild prey in Kimana and Olgulului group ranches. As well, cattle were the most abundant livestock prey in both Kimana and Olgulului group ranches.

In establishing livestock depredation patterns, hyenas had the highest predatory incidences compared to any other carnivore. Despite the fact that the research study targeted lions, hyenas recorded 50% of the incidences whereas the lions came second with 25% incidences in both Kimana and Olgulului group ranches. High predatory incidences were common in Kimana and Olgulului GRs during the wet season as compared to the dry season.

Mitigation measures including but not limited to establishment of livestock movement corridors, keeping of warning animals like dogs and donkeys, fortified fences around villages, herdsmen, and lion repellents have previously been identified by other researchers but their efficiency is yet to be fully verified (Ogada *et al.*, 2003). Thus in determining the efficiency of lion entry deterrent system, so far a combination of fortified fences and LED system has been tested in this study and has proved to be efficient in mitigating livestock depredation.

With LED systems introduced and adopted in many homesteads/communities around wildlife protected areas, fewer predatory incidences and subsequent retaliatory attacks on large carnivores will be witnessed. Therefore, if non-lethal methods like lion entry deterrent systems are adopted, poisoning, snaring and spearing of large carnivores can be minimized and conservation of large carnivores can be achieved in the Amboseli Ecosystem.

This research has provided important insight in to mitigating human wildlife conflict thus ensuring survival of carnivores and other predators in and around wildlife protected area such as the Amboseli National Park. The KWS management should therefore work together with other research students and organizations through regular follow up of the recommendations of this study.

5.3 Recommendations

5.3.1 Changing Perceptions and Attitudes

It is worth noting that future populations of many large carnivores and predators in general are mainly pegged on the perceptions and thinking of the local communities surrounding wildlife protected areas (Stander, 1997). The irony of this is that to date, these communities have paid dearly for the cost of protected areas being adjacent to them in form of livestock depredation by lions and other predators in general, loss of grazing and arable land, pollution and cultural erosion. Therefore, to afford viable carnivore populations as a continent in future, some conditions mainly targeting the local communities surrounding the protected areas should be met (Frank, 2006). In addition to fortified fences and the LED system, below are further recommendations that will ensure that lions and other carnivores will survive in the long term:

5.3.2 Further Research

i. Further research should be carried out on the impacts of the LED system on the behavior and ecology of carnivores over time.
ii. Further research on realistic and affordable human carnivore mitigation measures should be conducted to ensure minimal livestock depredation and human loss while also protecting predator population.
iii. Further research should be conducted on the economics of adopting the LED system technology and its sustainability

5.3.3 Management Actions

i. The LED system should be adopted by pastoralists experiencing livestock predation by wild predators in other parts of Kenya.

ii. The management should carry out education and awareness programmes to the local communities on the importance of perceiving lions and other predators positively and the need to co-exist more so after encroaching into areas around/adjacent to wildlife protected areas.

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