SPATIAL AND TEMPORAL VARIATION OF LIVESTOCK PREDATION BY LARGE CARNIVORES AROUND AMBOSELI NATIONAL PARK - KENYA

BY

TUQA JIRMO HUQA

RE: I56/69196/2011

A THESIS SUBMITTED TO THE SCHOOL OF BIOLOGICAL SCIENCES IN PARTIAL FULFILMENT FOR THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTERS OF SCIENCES IN BIOLOGY OF CONSERVATION

UNIVERSITY OF NAIROBI

2016

DECLARATION

I hereby declare that this is my original work and has not been presented for an a' degree in any other university.

SIGNATURE .... DATE 05/08/16

TUQA JIRMO HUQA

This thesis has been submitted for examination with our approval as University supe

SIGNATURE .... DATE 05/08/2016

DR. JOHN M. GITHAIGA

UNIVERSITY OF NAIROBI

SIGNATURE .... DATE 05/08/16

DR R.M. CHIRA

UNIVERSITY OF NAIROBI

DEDICATION

This thesis is dedicated to my mother Tato Jirmo who played a great role in my going to school in what would have been impossible.

ACKNOWLEDGEMENT

I would like to sincerely thank my children Machii, Tato and Bilacha for moral support and patience during my long absences from home while in the field doing research. I would also like to thank Kenya Wildlife Service Director for giving me study leave that enabled me to pursue my esteemed career and accomplish this research project. I would like to extend my appreciation to Peter Hongo of GIS department for assisting with preparation of GIS spatial maps. I thank Kenya Wildlife Service staff at Amboseli National park for their overwhelming support during my stay at Amboseli National Park. I am particularly grateful for the use of research facilities, accommodation and occasionally vehicles that greatly facilitated my data collection. The field staff developed unlimited enthusiasm in carnivore research and human wildlife conflict resolution. For the cooperation so enjoyed, I hereby record my gratitude to the following; Richard Chepkwony- senior warden, Steven Ndambuki – research scientist, Corporal James Saoli in charge of problem animal control among others.

I wish to record my utmost gratitude to my supervisors Dr John Githaiga and Dr Evans Mwangi. I sincerely appreciate their encouragement and guidance that has seen me through successful research and development of this thesis. I thank Professor Nathan Gichuki of school of biological sciences for always providing unlimited guidance and mentorship, thesis structure, and making a number of useful comments.

My appreciation is also extended to the staff of Olgulului predator consolation scheme for their dedication and consistent collection of human carnivore conflict data. The Olgulului predator consolation scheme coordinator Partric Seyyelle was very instrumental in support of my research and passionate on conservation of large carnivores in Amboseli ecosystem.

Finally, the task of preparing this thesis was greatly facilitated by discussion and peer review and some of the data analysis was suggested by Mumbi. I thank her very much for assistance and interest.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANP: Amboseli National Park

ACC: African Conservation Centre

IUCN: International Union for Conservation of Nature

KWS: Kenya Wild Life Service

NDVI: Normalized Difference Vegetation Index

NP: National Park

Pas: Protected areas

WCU: World Conservation Union

Operational Definition of Key Terms

Boma: An enclosure where livestock are kept overnight

Conflict: A disagreement or clash between ideas, principles, people or livestock

Controlled herds: Livestock that are kept in a boma (livestock shed)

Controlled livestock: Livestock that are kept in a boma (livestock shed)

Depredation: Wildlife causing damage to property and people

Dispersal systems: Wet season dispersal and dry season concentration of animals in a range.

Environmental change: Natural climatic fluctuations that affect the surroundings

Grazing herds: Herbivorous animals, wild or domestic, that primarily feed on grass as a group

Human settlement: Place occupied by humans

Hunting: The practice of killing or trapping any living organism, or pursuing it with the intent of doing so.

Keystone species: An organism whose characteristics (presence or absence, population density, dispersion, reproductive success) are used as an index of attributes that are too difficult, inconvenient or expensive to measure for other species or environmental conditions of interest

Land use: The nature of economic activity to which the land is utilized for

Predation: The act of one species of an animal eating on another

ABSTRACT

Most large mammalian carnivores are in global decline, partly due to their involvement in livestock predation. Research that advances our understanding of predator livestock interaction is crucial to conflict mitigation and carnivore conservation and management. The study investigated the influence of environmental and socio-ecological factors on livestock predation by large carnivores in pastoral villages adjacent to the Amboseli National Park in Kenya during a 13-month period (July 2012 – July 2013). A number of factors were identified related to temporal and spatial variation that influences livestock predation rates. Aassessment on how environmental changes affected the distribution and dynamics of vegetation and animal populations. The overall purpose of this study was to determine the intensity of livestock predation by large carnivores in space and time around Amboseli National Park. In the study we investigated livestock predation by large carnivores and factors predisposing in Olgulului and Kimana community group ranches in the southern Kenya during the period between July 2012 and July 2013. In addition if livestock predation rate and intensity varied with season, boma (livestock shed) density and the carnivore species as well. Large carnivore - livestock predation incidences were mapped and a total of 26 herbivore transect counts were conducted in and outside the park during both dry and wet season. The result revealed that there were more prey (herbivores) density inside the park during the dry season as compared with wet season. There was negative correlation between vegetation density, boma density and livestock predation incidences. A total of 1409 predation incidences recorded during the 13 months periods which were attributed to specific predators. Hyenas killed more livestock followed by Jackals, Cheetah and lions respectively. There were a positive correlation ($r = 0.766$, $p = 0.131$, $n=5$) indicating that some carnivores especially hyenas preferred to keep a certain distance from human settlements. More animals were killed while on the grazing fields and lions killed more livestock inside Boma. Conflict was most frequent during evening, late night and mid-morning. The predations by carnivore species were spatially clustered. This conforms to the assumption of non-homogenous distribution of natural resources needed by the animals. Some environmental variables such as human settlement and density of wild prey greatly influenced the observed pattern of carnivore attack distribution.

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.1 Background to the Study

1.1.1 Ecology of large carnivores in Amboseli

Carnivore ecology is a scientific study of how carnivores interact with one another or with other organisms in the ecosystem. This section presents a study of carnivore ecology in terms of diet, social structure, demography, competition among Carnivores, large carnivore biodiversity in Amboseli ecosystem, impacts of human development on carnivores, land use and climate change, impacts of carnivores on human development, global carnivore conservation status, the importance of conserving large carnivore biodiversity and the protected areas systems and their importance for large carnivore conservation

The order Carnivora contains 271 species, 70 of which are found in Africa (Mills et al. 2001). Carnivores are unusual compared to other taxa such as primates because they are found almost in every type of habitat (Gittleman and Gompper, 2001). The relatively low carnivore species richness is due to carnivores occupying higher trophic position than their non-carnivore prey. Species richness tends to be higher at lower tropic levels because at higher trophic levels species tend to occur at relatively small population sizes and are more vulnerable to extinction due to demographic stochasticity and environmental changes (Gittleman and Gompper, 2001). Carnivore species, including leopard, lion, cheetah, and caracal, hyena, and several cat species can be seen easily in the Amboseli Ecosystem. These carnivores rank high as tourist attractions in the protected areas and adjacent areas. They also play a significant role in controlling the herbivore populations.

1.1.1.1 Large carnivore community found in Amboseli

African Lion

Lions (*Panthera leo*) are top-predators and they play an important ecological role in the savannah ecosystem. Lions are the most sociable of all the cats and live in families referred to as prides (Schaller, 1972). Pride members are known to hunt, rear cubs and defend their territories cooperatively (Schaller, 1972). Lionesses usually do most of the hunting in groups, when hunting large mammals, such as zebra and buffalo. When hunting smaller, easier prey such as warthog and wildebeest, they usually hunt alone. As seen in many species, group hunting is most likely when solitary hunters need help (Packer *et al,* 1990). In addition to killing their own prey, lions also scavenge food from other predators and eat animals that have died of diseases and other causes (Funston *et al,* 1998).

In general, lions prefer five prey species (buffalo, wildebeest, giraffe and zebra) Lion Prey preferences do however differ between lion populations in Africa (Hayward *et al,* 2005).

In eastern and southern Africa, 35% of prey is medium size (50-200kg) and 65% is large (>200 kg) whereas in west and central Africa, 49% of prey is medium size and 51% is large .

Lions have no natural enemies, except humans in case of livestock predation. This leads to a conflict with the local people who do not want lions hunting their livestock. Besides humans they fight with hyenas over killed prey and occasionally amongst themselves (Breuer, 2005).

Spotted Hyena

Spotted hyenas (*Crocuta crocuta*) are gregariously living carnivores inhabiting many types of open, dry habitat including semi-desert, savannah, acacia bush, and mountainous forest up to 4,000 m altitude (Mills & Harvey, 2001). They live in clans; the cubs are reared together in communal dens after the first few solitary weeks in a private natal den. Furthermore, food is defended against stealing lions and the territory of the group is defended against other intruding hyenas.

Holekamp and Smale (1992) argue that Hyenas hunt alone, in pairs or in groups, depending on the prey at hand. An adult hyena is capable of bringing down a prey animal weighing up to four times its own body mass. Prey such as wildebeest and gazelle are usually hunted alone or in pairs, whereas larger prey such as zebra or giraffe hunted in larger groups (Holekamp & Smale, 1992). Hyenas habitually dash through a herd, thereby looking for weakest animal to chase (Mills & Harvey, 2001). After one or more hyenas make a kill, nearby clan members will converge on the carcass and feed as well.

Next to hunting for their own prey, they also scavenge upon the prey of other carnivores such as lions, which will occasionally causes wounded or dead animals on both sides (Breuer, 2005). Lions are not the only animals in conflict with hyenas; wild dogs and human are also known to sometimes kill hyenas. The later do so for their meat or for defense because hyenas prey upon their livestock and sometimes even on weaker humans, particularly children.

Leopard

Leopards (*Panthera pardus*) are the most widely distributed wild cats in the world. They are found in a wide range of habitats, from deserts to rainforests and from remote mountain ranges to the edges of urban society (Nowell & Jackson, 1996). Leopards are solitary animals only meets each other when mating. Every individual has territory whereby the relatively large territories of males generally overlap several, and smaller territories of females. Hunting strategies of leopards depends on several environmental factors. In open territory, for instance, they are nocturnal and catch their prey by stalking very close to victim, before making a final sprint. In rainforests on the other hand, leopards hunt diurnally and do so generally by ambushing prey from trees or from the side of game trails. In all environments leopards are hunters with an opportunistic diet (Stuart & Stuart, 1993). Adult leopards weight between 20 and 90 kg (Stuart and Stuart *et al.,* 2000) and require between 1.6 to 4.9 kg of meat per day to maintain body mass.

Leopards are also known to scavenge on the kills of other carnivores such as lions or hyanas. They evade other scavengers on their kills by climbing trees with their prey, thereby keeping it out of reach. Besides humans, leopards also have other enemies.

Cheetah

The cheetah (*Acyinonix jubatus*) is a unique and specialized member of the cat family. While running down its prey, it can reach speeds of 64 miles per hour (103 km per hour, Sharp, 1997), making it the fastest creature on land. However, despite their specialized hunting strategy, cheetah is habitat generalists, ranging across a wide variety of habitats, from desert through grassland savannas to thick bush (Myers, 1975).

Cheetah has a social system unlike that of any other cat species. Cheetah females are tolerant of other females, and do not maintain territories, having large overlapping home ranges instead (Caro, 1994).

The cheetah is predominantly diurnal, although hunting at night is not uncommon (Caro, 1994). They hunt by a stealthy stalk followed by a fast chase. Because of their unrivalled speed and acceleration, cheetah can hunt successfully even if they start a chase at a much greater distance than bulkier and heavier large cats, such as lions and leopards (*Panthera pardus*). They take a wide variety of prey, depending on habitat and geographic location, but they prefer prey of 15-30kg: the size of a Thomson's gazelle (*Gazella thomsonii*) or impala.

Furthermore, the ranging patterns of the species incline it to cluster in areas that become temporarily favorable habitat (due to the absence of competitors and availability of prey), making estimating numbers problematic (Durant *et al.,* 2007).

Jackal

The Jackals belong to Canis family. They are distributed in all continents except Antarctica and Australia, jackals are absent in rainforest. Canids are among the most intelligent, adaptable, and opportunistic carnivore. Jackals main range Saia, near Middle East to Burma. Its Africa distribution extends barely beyond he limits of Sudanese and Somali-Masai arid zones. Black-backed or Silver-backed jackal (*Canis mesomelas*), in Eastern Africa occupies habitats intermediate between the plains such as Serengeti and Amboseli region.

Jackals are generally omnivorous and follow the path of least resistance to acquire food. In fact there are no clear differences in feeding ecology of all the three jackal species. They are monogamous, territorial; some off springs serve as helpers. Black back jackals are efficient predators of young Thomson's gazelle and young goats.

1.1.1.2 Diet

Carnivores are classified into two groups based on their dietary needs: (i) species which depend on meat for a high proportion of their diet; and (ii) species that feed on insects or foliage/fruits (Carbone *et al.,* 1999). For example, some carnivores such as cats and weasels are strictly carnivorous while others e.g. Canids and Mustelids and many Viverrids subsist largely on insects (Estes, 1991). This variation in diet may be because of differences in energy requirements between species. For instance, small carnivores usually have lower energy requirements than large carnivores and hence the latter require larger prey to meet higher energy demands, while for small carnivores invertebrates can provide sufficient energy (Carbone *et al*, 1999).

It has been shown that at around a body mass of 20-25kg, carnivores show a transition from feeding on small prey of less than half the predator's body mass to large prey that is near or above the predator's body mass (Carbone *et al.*, 1999). Some carnivores are also more specialised in the type of prey they take for instance, aardwolves feed strictly on two types of termites, *Trinervitermes* and *Hodortermes,* while some species are more specialised in the size of prey they take, e.g. wild dogs show a clear selection for medium-sized antelopes (Estes, 1991).

1.1.1.3 Social Structure

Carnivores have a variable social structure. For example, carnivores such as the spotted hyaena (*Crocuta crocuta*), live in extended social groups comprising of as many as 80 individuals (Gittleman *et al.*, 2001), while others such as lions live in social units called prides. Social carnivores benefit from the complex behavioural organization of such groups, which may involve hunting together, taking care of each other's young and/or protecting the territory held by the group. For instance, in the Serengeti it was shown that adolescent cheetahs living in temporary sibling groups had higher survival than single ones, while adult male cheetahs living in coalitions had higher survival and hunting success than singletons.

1.1.1.4 Demography

Carnivore reproductive ecology is extremely varied. Many species, particularly the large ones, have low reproductive rates (Sillero-Zubiri & Laurenson, 2001). Food availability may affect body conditions of females and thus affect the age at which they start breeding, as well as the resultant litter size (Langvatn *et al.*, 2006).

1.1.1.5 Competition among Carnivores

Many carnivores compete with each other and competitively inferior species may seek to escape this competition by using refuge areas or habitats which do not overlap with home ranges of their competitors. For example, cheetahs have low competitive ability compared to their principal competitors, spotted hyenas and lions (*Panthera leo*) (Durant, 2000). All three predators partly rely upon migratory prey species, and because of the patchy distribution of lions and hyenas, cheetahs persist in the ecosystem by employing predator avoidance behaviour. However, in order for the avoidance to be successful the presence of heterogeneous habitats is important (Durant, 2000).

Predator avoidance thus plays an important role in structuring species communities by promoting coexistence (Durant, 2000), as do strategies such as variation in dietary requirements (Carbone *et al.,* 1999), and the use of heterogeneous habitats (Durant, 1998). Studies suggest that mammalian top predators are key determinants of trophic structure and biodiversity in many terrestrial ecosystems (Caro and Stoner 2003). This is because top predators have an impact on herbivore communities and on predators in lower trophic levels (Caro and Stoner 2003).

It is argued that a reduction in the abundance of large predators can lead to an increase in diversity and population of medium-sized carnivores in an area. This increase in the abundance and diversity of mesopredators can lead to an increase in the predation of smaller and more vulnerable species, which may lead to extinction and therefore loss of biodiversity (Msuha 2009).

1.1.2 Prey population dynamics

An understanding of the relationship between wild carnivore number and food prey as their food resources is important. This will give us opportunity to predict their population dynamics. Carnivore diet is varied just as do their body sizes and habitats. In recent years, within a given area, however, conservation of large carnivore biodiversity throughout the world is extremely challenging due to expanding human populations and the associated impacts on wildlife. These challenges are particularly acute in sub-Saharan African countries which are currently characterised by a rapid increase in human population (Ceballos & Ehrlich, 2006), and unfortunately it is also where information for conservation planning is scarce for most species (Rodriguez & Delibes, 2003).

These challenges are even bigger for carnivores because the populations of many species are declining very fast due to loss of habitat, hunting, depletion of prey, diseases and trade in body parts as well as conflict with humans (Sillero-Zubiri *et al.,* 2001). These declines are also accelerated by inherent biological factors that make carnivores more vulnerable to environmental change (Cardillo *et al.,* 2005). For instance, large carnivores are usually at the top of food chain, which means that they will always be less abundant than their herbivore prey and therefore be more vulnerable to extinction (Sillero-Zubiri & Laurenson, 2001).

Furthermore, because of their large body size and high trophic position, large carnivores require extensive home ranges and large prey populations to survive and therefore only large and relatively intact ecosystems can support viable populations. Such intact ecosystems are difficult to maintain because of increasing human population and the associated demand for land and other resources. Consequently large carnivores tend to suffer first when human population expand into untouched habitats. In places where large carnivores still occur outside protected areas, they are often intentionally or accidentally killed by humans, which can limit their persistence (Woodroffe & Ginsberg, 1998, Woodroffe & Frank, 2005). However this is probably more important in Africa where large carnivores are more abundant and where management may be ineffective because of a lack of sufficient financial and human capacity than in developed countries. It has been shown, for example, that large carnivore populations in North America increased after the introduction of favourable legislation despite increase in human population density. Therefore given effective management structures, large carnivores can coexist in human dominated landscapes (Linnell *et al.,* 2001).

In addition to the direct impacts of people on carnivores as discussed above, loss of habitat has been shown to have significant impact on the abundance and distribution of many species. For example, the decline of the African lion (*Panthera leo*) in central and western Africa (Bauer & Van der Merwe, 2004) and African wild dogs (*Lycaon pictus*) across their entire range in Africa are both primarily due to loss of habitat. The loss of habitat not only affects available habitat for carnivores but also affects the availability of prey species, which in turn affects the abundance and distribution of carnivores (Carbone & Gittleman, 2002). Because of these anthropogenic pressures, the conservation of carnivores to date has focused mainly on the protected area network where human densities are low.

1.1.3 The dynamics land use patterns in Amboseli

It is widely accepted that global biodiversity is changing at an alarming rate (Millennium Ecosystem Assessment, 2005), and that much of this change in biodiversity is induced by human activities (Pimm and Raven, 2000). Of all human impacts on biodiversity, land use change has been singled out as the greatest immediate threat to terrestrial biodiversity because it results in fragmentation and loss of habitats (Jetz *et al.,* 2011). Such changes may lead to restriction of animal movements as well as decline in species richness and abundance.

Existing evidence shows that land use change has negative impact on species. Predictions of the impact of tropical forest clearance show that about 50,000 species may become extinct by 2060 (Pimm and Raven, 2000). Similarly, the 'human footprint' study (Sanderson et al. 2002) suggests that anthropogenic land transformation is the single greatest threat to biodiversity. Furthermore, it is also estimated that 86% of globally threatened mammals on Earth are at risk from habitat change (Baillie *et al.,* 2004).

There are many anthropogenic factors that drive land use change. The most important ones include the need for human settlements, cultivation of crops and other economic activities (Geist & Lambin, 2002). The impacts of these drivers of land use change on biodiversity are different because they differ in the extent to which they modify the quality of habitats. However, land use change due to agricultural expansion is often cited as one of the major threats to biodiversity.

The Millennium Ecosystem Assessment (2005) report draws particular attention to the expansion of crop land across the globe and points out that more land has been converted to agriculture after 1950 than the years before. Generally it is predicted that the impact of land use change on biodiversity will have a much greater effect on tropical countries. This is because species in the tropics tend to have smaller home ranges than those at higher latitudes due to higher diversity of habitats in the tropics (Jetz *et al.,* 2007).

In addition, predictions also suggest that the impact of land use change on biodiversity will be even more severe in the future because land use change affects land cover which ultimately affects climate (Jetz *et al.,* 2007), and climate change affects precipitation patterns and hence overall primary productivity of ecosystems and species richness

1.1.4 Human-carnivore interaction

The interactions between people and wildlife play a pivotal role in shaping the perceptions of people and the development of conservation strategies. Therefore understanding the nature of these interactions is central to the development of effective conservation plans and may be beneficial to both humans and wildlife (Happold, 1995). For example, where large carnivores are visible, they can attract visitors and hence provide an important source of foreign revenue, especially for developing countries (Treves & Karanth, 2003). On the other hand, large carnivores can cause bodily harm to humans, prey on livestock and can act as reservoirs of diseases which affect humans and their domestic animals, particularly dogs (Happold, 1995, Cleavaland *et al.,* 2001). Humans affect large carnivores through land conversion for agriculture and human settlements (Bauer & Van der Merwe, 2004), through hunting of species for subsistence, sport or trophies and through depletion of prey species (Lindsey *et al.,* 2007).

Carnivores come into conflict with humans for a wide variety of reasons. First and foremost, people often see large carnivores as a threat to human life and carnivores prey on livestock causing considerable economic losses to humans. Carnivores also prey on game which humans eat and therefore compete with humans (Inskip & Zimmerman, 2009). Identifying the sources of these conflicts and assessing the attitudes of humans towards carnivores is fundamental for developing effective conservation strategies. Negative attitudes are a major driver of carnivore persecution throughout the world (Woodroffe & Ginsberg, 1998). Human-carnivore conflict over livestock predation is a serious management issue that wildlife managers are facing today (Ogada *et al,* 2003). For example, it is estimated that over 75% of the world's felid species are affected by conflict with people. The severity of the conflict has also been found to increase with species body mass and points out in particular nine species as being most important for conflict with people. These are: caracal (*Felis caracal*), cheetah (*Acinonyx jubatus*), leopard (*Panthera pardus*), lion (*Panthera leo*), (Inskip & Zimmerman, 2009). However it is also important to note that some other species may be locally important as a source of human wildlife conflict and they may not feature at a global scale.

In Africa, killing of carnivores because of livestock loss has been widely reported e.g. between 1980 and 1990 at least 320 lions were killed on farms bordering Etosha National Park in Namibia and in Kenya at least 14 spotted hyenas were reportedly poisoned in a single incident in the Maasai Mara National Reserves, apparently in an attempt to reduce livestock predation (Holekamp & Smale, 1992). Losses due to predation are more common with cattle, sheep and goats (Inskip & Zimmerman, 2009). Such losses can be very severe and may significantly affect local people's livelihoods and therefore their support for conservation.

Wildlife attacks on humans are common in some areas, although the perception of threat to humans is often greater than the real threat (Woodroffe & Ginsberg, 1998).

Encroachment of humans into areas which were predominantly used by wildlife has been highlighted as the underlying reason for increasing attacks by big cats as well as the depletion of wild prey due to human encroachment (Packer *et al.,* 2005).

1.2 Literature review

1.2.1 Literature review on the influence of wild prey densities on livestock predation by large carnivores

The reasons for carnivores preying on livestock vary between areas. Generally it is widely acknowledged that livestock predation often tends to be higher when wild prey availability is less abundant (Mishra *et al,* 2006), although in some areas, predators may learn that livestock are easier to catch, there by leading to some individuals to switch from natural prey to hunting livestock (Woodroffe & Frank, 2005). Livestock predation promotes negative emotional sentiments towards conservation (Nyahongo *et al,* 2013). It leads to indiscriminate persecution of wildlife, in the form of retaliatory killing in retribution for losses (Nyahongo *et al,* 2013). In Tanzania it was shown that lion attacks on humans increased due to reduction of natural habitats and depletion of prey caused by human encroachment (Packer *et al.,* 2005). However it has also been reported that old lions or those with dental problems such as tooth breakage are more likely to attack humans, because they are incapable of normal predatory behaviour (Baldus, 2006). Wildlife attacks on people, even if rare, can have significant effects on conservation programmes that require the support of local communities, as they clearly elicit serious conflict. Combine – human wildlife conflict. There are other proximate causes responsible for the escalating levels of carnivore predation on livestock, such as an increase in local abundance of carnivores, increase in livestock populations or decline in wild prey populations (Mishra *et al.,* 2003). Boydston *et al.* (2003)

studied space use by spotted hyenas in Kenya and concluded that hyena behaviour changed in response to human activities and suggested that such plasticity conferred advantages in human - dominated environments.

Improvements in livestock husbandry, such as the employment of herders and the kraaling of stock (enclosure for livestock), have been shown to considerably reduce the rates of depredation by carnivores (Ogada, *et al,* 2003). Understanding the circumstances surrounding carnivore attacks and mitigating them is a crucial issue for conserving and managing many apex predators. Human-wildlife conflict due to predation affects population dynamics of wild carnivores near park boundaries (Kolowski & Holekamp, 2006). A range of options exist for people attempting to decrease conflict with wildlife, including reducing the likelihood of attacks by using protective measures (such as livestock-guarding dogs and donkeys), electric fencing, improved construction of livestock enclosures, toxic collars, disruptive stimuli and other aversive techniques.

1.2.2 Literature review on predation intensity in relation with season and boma density

The increasing interface between humans and large carnivores is resulting in a worldwide escalation of human–carnivore conflict (Mishra, 2003). Carnivores often cause serious economic losses by preying on livestock. For example, lions (*Panthera leo)* in Africa (Patterson *et al.,* 2004) enter into conflict with humans because of livestock predation.

Livestock predation can cause significant economic losses among pastoralists. For example, Patterson *et al.* (2004) estimated livestock predation to represent 2.6% of the herd's economic value in a Kenyan ranch which incurred a loss of $8749 per annum. Due to such losses and sometimes due to perceived dangers, pastoralists have had a long history of intolerance against large carnivores (Sillero- Zubiri & Laurenson, 2001). However, conservation efforts can be improved by raising the tolerance of pastoralists for wild carnivores through educational and economic incentives (e.g. cheetah on sheep ranches in Namibia) (Marker, Mills & MacDonald, 2003).

1.2.3 Literature review on effects of vegetation types and density on the distribution and dynamics of livestock predation by large carnivores

Large carnivores are particularly vulnerable to habitat loss because they have large home ranges and require extensive, intact habitats to survive (Sillero-Zubiri *et al,* 2001). For example, the loss of habitat is cited as the main threat to cheetahs (Caro, 1994), partly because cheetahs are more vulnerable to spatial fragmentation since heterogeneity in habitat is required for successful predator avoidance (Durant 1998). Furthermore, habitat loss may affect carnivores indirectly by reducing the availability of prey. Carbone and Gittleman (2002) showed that the abundance and distribution of carnivores is strongly related to the population density of their prey species. However, the impact of loss of habitat may be more severe for some species than others, yet to date there are no comprehensive studies that have investigated the impact of habitat loss on carnivore biodiversity, especially in areas which have rich carnivore community such as Kenya.

Conflict between people and large carnivores undermines the viability of populations that are nominally protected and those living outside protected areas. Where large carnivores have been studied in reserves, most of the recorded mortality has been caused, deliberately or accidentally, by people (Ogada, *et al,* 2003). These deaths—due to shooting, poisoning, accidental snaring, and road accidents—occur mostly on or outside the borders of unfenced reserves and are particularly common where reserves are surrounded by areas supporting high densities of people. This mortality creates population "sinks" around protected areas; the resulting edge effect appears strong enough to cause local extinction.

The cost of livestock predation is greater where people's livelihoods depend entirely on livestock keeping (Ogada, *et al,* 2003). Losses due to depredation are common with cattle, sheep and goats (Atickem *et al,* 2010). Loss of a single domestic animal creates serious socio-economic problems to affected families. However, diseases have been reported to contribute to far more livestock losses than predation in some Tanzanian areas (Nyahongo *et al,* 2013).

1.3 Problem statement

Like elsewhere in the country, increasing human encroachment into predator range in Amboseli is displacing prey species resulting in increased livestock-predator interactions that in turn increase livestock predation incidents. Livestock predation is therefore the main reason why the local community kills large carnivores such as lion, leopard, cheetah and jackals in the Amboseli Ecosystem. In addition, suppressed carnivore populations, particularly of lions, are also partly attributed to diseases like Canine distemper and Feline Immunodeficiency Virus which have killed a substantial number of carnivores in the recent past.

Existing data from the Amboseli Ecosystem indicate that approximately 108 lions were killed in the region between 2001 and 2006 in spite of a generous consolation program which pays people for livestock lost to predators in Mbirikani Group Ranch. Most of the killing of the predators was through poisoning and spearing, both in retaliation for livestock killed by lions and for traditional ceremony called *Olamayio* (young men proving their manhood).

Indiscriminate killing is the key threat to the survival of large carnivores in Amboseli ecosystem. This study aims to enhance large carnivore conservation by gaining knowledge of the spatial and temporal distribution of livestock predation by large carnivores around the park and to design the mitigation measures aimed at developing viable local conservation strategies.

1.4 Justification and Significance of the study

To ensure carnivore survival, it is critical to establish the nature, extent and trends of human/carnivore conflict through monitoring to support planning and management. Knowledge of the spatial and temporal aspect of livestock predation by large carnivores is important to reduce livestock. This information is also important determinant of large carnivore distribution, movement and ranging patterns around the park and their spatial use of wildlife corridors and dispersal areas. The information is expected to be used in developing practical species conservation strategies and identify potential carnivore conflict hotspots and conservation zones. Others include developing outreach materials to educate communities on the importance of co-existence with large carnivores for the Community Partnership and Education Programmes.

1.5 Research Hypothesis

1. There is no seasonal and spatial impact on Livestock predation by large carnivores around Amboseli NP

2. Prey density and abundance has no influence on livestock predation by large carnivores around Amboseli NP.

1.6 General Objective

The general objective of this study waas determine the spatial and temporal variation of livestock predation by large carnivores and their predisposing factors around Amboseli National Park in Southern Kenya.

1.7 Specific Objectives

1. To determine the influence of wild prey densities on livestock predation by large carnivores around Amboseli National Park.
2. To determine the relationship between livestock predation intensity by large carnivores according to season and boma density around Amboseli National Park.
3. To determine the effect of vegetation types and density on the distribution and dynamics of livestock predation by large carnivores around Amboseli National Park.
4. To determine large carnivore species specific predation intensities on livestock around Amboseli.

CHAPTER TWO: STUDY AREA, MATERIAL AND METHODS

2.1 Description of Study area

Amboseli National Park (Figure 1) is located in the central-southern part of Kenya and is part of Loitoktok Kajiado County. The park covers approximately 392 km^2 and lies a distance of 260 km South of Nairobi. The Park is surrounded by four group ranches: Olgulului, Eselenkei, Mbirikani, and Kimana. These group ranches are dispersal area for wildlife from the park during wet season.

The park is a dry season refuge for both wildlife and Maasai livestock. Olgulului and Kimana group ranch are immediate neighbours that surround the park completely. Olgulului is one of the largest and most important group ranches for wildlife dispersal from Amboseli National Park.

The Amboseli basin contains permanent swamps that provide vital water source all year-round. The wetlands are fed by springs originating from snow melt water at the nearby Mt. Kilimanjaro. During the dry season these wetlands are the only water source in the area. In the wet season, seasonal floodplain called Lake Amboseli, forms on the north-west of the park. The flood plain is used by migratory animals. These seasonal differences of water availability induce migratory movement patterns in the Amboseli wildlife and Maasai livestock (Groom, 2007). During the wet season, herbivores disperse throughout the ecosystem but during the dry season the animals concentrate in the park and its permanent wetlands. The dispersal areas adjacent to the park are very important. "The wildlife reliance on dispersal areas can be explained by the fact that no park or reserve is a self- sufficient, all-encompassing ecosystem (Sindiga, 1995). Amboseli ecosystem is a typical example of a semi – arid and arid savannah e.g. zones V and VI (Bekure *et al.,* 1991) in Eastern Africa.

Large carnivores are very susceptible to poisoning and their populations are slow to recover in areas from which they have been extirpated. Hence, their numbers are severely depleted outside protected areas. Their limited ability to recover in areas where they have been extirpated makes them reliant on conservation efforts, save for spotted hyena, which appears to persist in areas of high human population density. The area has got various biodiversity values which are discussed as follows.

2.1.1 Amboseli Swamps

The bigger part of the Amboseli ecosystem is semi-arid. Nevertheless, water springs associated with Mt. Kilimanjaro emanate at the basin of the ecosystem and give rise to several swamps which are critical to maintaining wildlife in the ecosystem. The high primary productivity of the swamps is able to sustain a vast array of wildlife species in a semi-arid environment and contributes to the high biodiversity and tourism value of the ecosystem.

2.1.2 Geology and Soil

Quaternary volcanic soils dominate on the north-eastern slopes Killimanjaro, encouraging rain-fed agriculture around the town of Oloitoktok. Basement rock soils are found on the rest of the park, especially at Ilkisongo, making only pastoralism possible. The dark to red to reddish brown sandy soils are low in fertility despite the rapid growth of grass on them during the rains. Darker brown-to-black (black cotton) alluvial clays accumulate in seasonal runoff lines and low-lying areas impede drainage, where they trap nutrients and support growth for a while after the rains.

In general, even where volcanic soils are presents, soil fertility in the ecosystem is a tenuous matter, underlain as it is with nutrient-impoverished basement quartzites, crystalline limestone, schists, and gneisses. The soils in and around the Pleistocene lake bed are an unfriendly mix of saline accumulations that form calcrete pavements, support only a meager seasonal grass growth, and produce a ferocious albedo the vertical energy of which is believed to repel clouds and delay the onset of rains compared with surrounding areas. The soil chemistry in the immediate vicinity of the springs and swamps is less saline due to dilution by the groundwater and percolation of salts to the margins of the groundwater zones.

2.1.3 Climate and Hydrology

The ecosystem is characterized by low and seasonal bimodal rainfall. The long rainy season is from March until May, while short come in October till end of December. The dominant vegetation in the Amboseli Ecosystem is open grassland with widespread Acacia woodlands and patches of swamp-edge grasslands and forest belt of the Mt. Kilimanjaro. The spatial and temporal variation in hydrology characterizes the area with surface water found only in few permanent streams, predominantly as a result of the influence of Mt. Kilimanjaro water flowing under gravity and emerges from underground in form of springs that feed the rivers and swamps together with rainfall.

In the rangelands, such as Amboseli ecosystem, the close relationship between rainfall and primary production makes rainfall the most important climatic variable. The seasonal distribution of rainfall governs the fundamental patterns of range utilization by the nomadic pastoralists and migratory wildlife, while long term fluctuations can affect their overall abundance and the health, economic welfare and political stability of the people dependent upon them.

Water is a critically important resource that determines the survival of any animal, particularly in arid and semiarid environments. The importance of water to the survival of wildlife has been discussed widely in literature (Ogutu and Owen-Smith, 2003). Lamprey (1964) noted the importance of water particularly in the dry season when he suggested that water was the most important limiting factor in the number and distribution of game animals in the savannah of East Africa.

The effects of water on wildlife species and livestock and their dependence on it have been described (Ogutu and Owen-Smith, 2003). Most water-dependent species are grazers while most browsers are water-independent further discussed the influence of water availability and seasonality on the distribution of various species and provided profiles of distance-to-water for various species and found that during the dry season most animal species were concentrated around water sources, while during the wet season the animals were spread out. The availability of ephemeral water sources during the wet season permitted animal dispersal.

Seasonal movements of large mammals between dry and wet season ranges are attributed to water availability; pasture conditions or combination (Western, 1975). Dry season concentrations are due largely to water availability. Rainy (1980) noted that most animals were concentrated close to the Ewaso Nyiro River during the dry season in the study area. Other factors such as predator avoidance and competition also do influence animal movements.

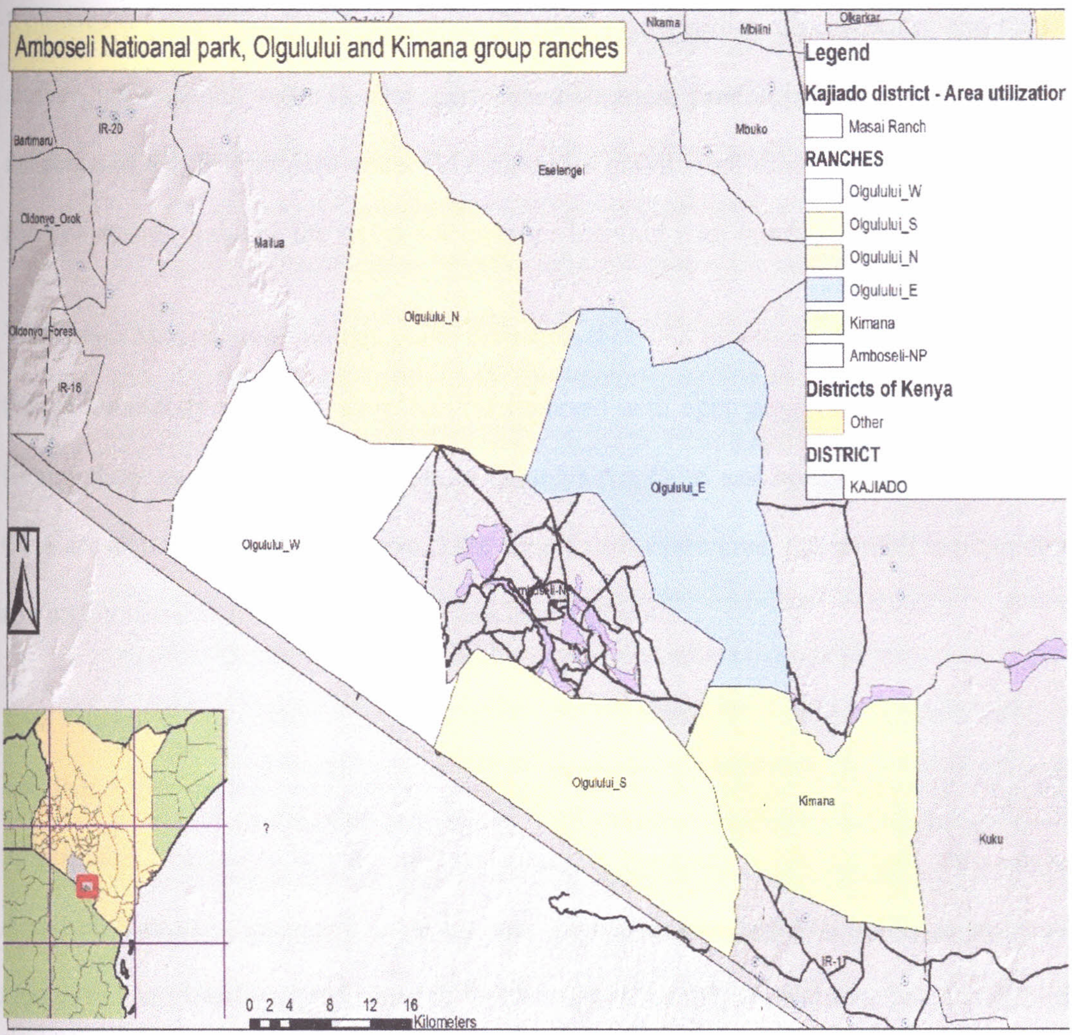


Figure 2.1: Amboseli National Park, Olgulului and Kimana group ranch (Source this study).

2.1.4 Vegetation

The Amboseli ecosystem falls under the Chyulu/Kilimanjaro volcanic natural region which is an Acacia dominated dry woodland savannah. This vegetation type supports the pastoralist lifestyle and a wide array of savannah wildlife species, the cornerstone of tourism in the ecosystem.

The dominant vegetation in the Amboseli Ecosystem is open grassland with widespread Acacia woodlands and patches of swamp-edge grasslands and forest belt of the Mt.

Kilimanjaro. The spatial and temporal variation in hydrology characterizes the area with surface water found only in few permanent streams, predominantly as a result of the influence of Mt. Kilimanjaro water flowing under gravity and emerges from underground in form of springs that feed the rivers and swamps together with rainfall.

Traditional Maasai communities graze their livestock and practice subsistence agriculture in the predominantly semi-arid savannah interspersed with open acacia woodlands (Acacia and Commiphora *sp*). The hunting blocks of Lake Natron GCA and northern portion of Monduli GCA are also found within the area. Like west Kilimanjaro area, the rainfall is unpredictable and highly variable from year to year (less than 350 mm).

2.1.5 Fauna

The list of herbivores and carnivores sighted during this study are given in Appendix I. birdlife and vegetative density has not changed markedly over the past three decades. Amboseli National Park is one of the 60 Important Bird Areas (IBA's) in Kenya and thus it is recognized as globally significant for bird conservation. The ecosystem has a rich birdlife, with over 400 species recorded, of which 40 are birds of prey (Western 1995)

Though Amboseli ecosystem is a semi arid environment, it supports a wide range of ungulates, which in turn support carnivores such as lion, leopard, cheetah, hyena, jackals, civets, and serval cats (Moss *et al.,* 2001). This agglomeration of ungulates makes Amboseli an important wildlife conservation area in Kenya. The ungulates habitat utilization pattern is similar to that of the Maasai livestock and thus, Amboseli Ecosystem is a test case of how wildlife conservation and pastoralism can coexist.

2.2 Materials and Methods

2.2.1 Study Design

This study adopted descriptive survey design. According to Neuman (2003), descriptive research supports the development of precise measurements and reporting of characteristics of some population of phenomena. The design enables the researcher to collect in-depth information about the population being studied (Chadran, 2004). The design was used since it enables the researcher to answer questions concerning the existing situation and collection of quantifiable data from the sample population. Saunders *et al.* (2000) opined that descriptive research is often used as the next step in exploratory research, which attempts to clarify and explore an idea, event or poorly understood phenomena, or to develop propositions for further enquiry. According to Sekaran (2000), descriptive studies construct paradigms that offer a complete theoretical picture through either qualitative or quantitative data. Orodho (2005) further observes that descriptive survey designs are used in preliminary and exploratory studies to allow researchers to gather information, summarize, present and interpret them for the purpose of clarification. This design was deemed the most appropriate for the study.

The study was conducted in Amboseli National Park (ANP) and neighbouring two group ranches. Two group ranches Olgulului and Kimana were selected for the study as they totally engulf the ANP.

2.3. Data collection techniques

2.3.1 Vegetation sampling techniques

Assessing how environmental changes such as vegetation dynamics affect the distribution and animal populations is becoming increasingly important. To find out if there is any relationship we measured vegetation characteristics such as vegetation classes and vegetation densities. We then evaluated if this vegetation attributes has any influence on livestock predation pattern by large carnivores. We classified vegetation in the two group ranches and Amboseli National Park, into five categories; 1) Woodland 2) Scattered trees 3) Grassland 4) Swamps/water body 5) Cropland (fig 2.2)

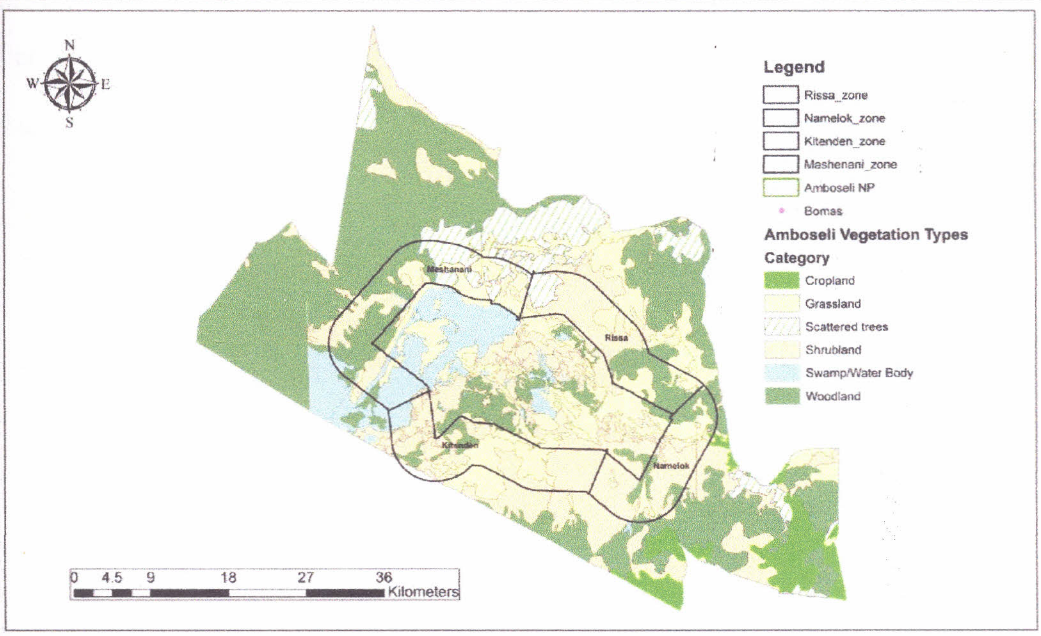


Figure 2.2: Amboseli vegetation classes in 2012

In order to relate predation occurrences with vegetation attributes, resource availability such as water that may influence predator movement and predation incidences, within each vegetation classes we also recoded and measured; 1) Vegetation densities

2) Availability of water points 3) Number of bomas/settlement and 4) Number of livestock predation.

A rectangular quadrant of 20x40 meter was used for sampling vegetation (Fig 2.3) and a GIS sampling tool used to determine location of coordinate boundaries and placement of each quadrants. This was done randomly within the vegetation strata.

The Park was buffered at an interval of five kilometers, and Bomas that falls within this region were equally buffered at five kilometers too (Fig 2.4). Sample plots were randomly established to conducted vegetation survey. In total 36 out of 120 sample plots (30% of the plots covering an area of 936.7km^2) were sampled, which consisted of 42% of the whole study area.

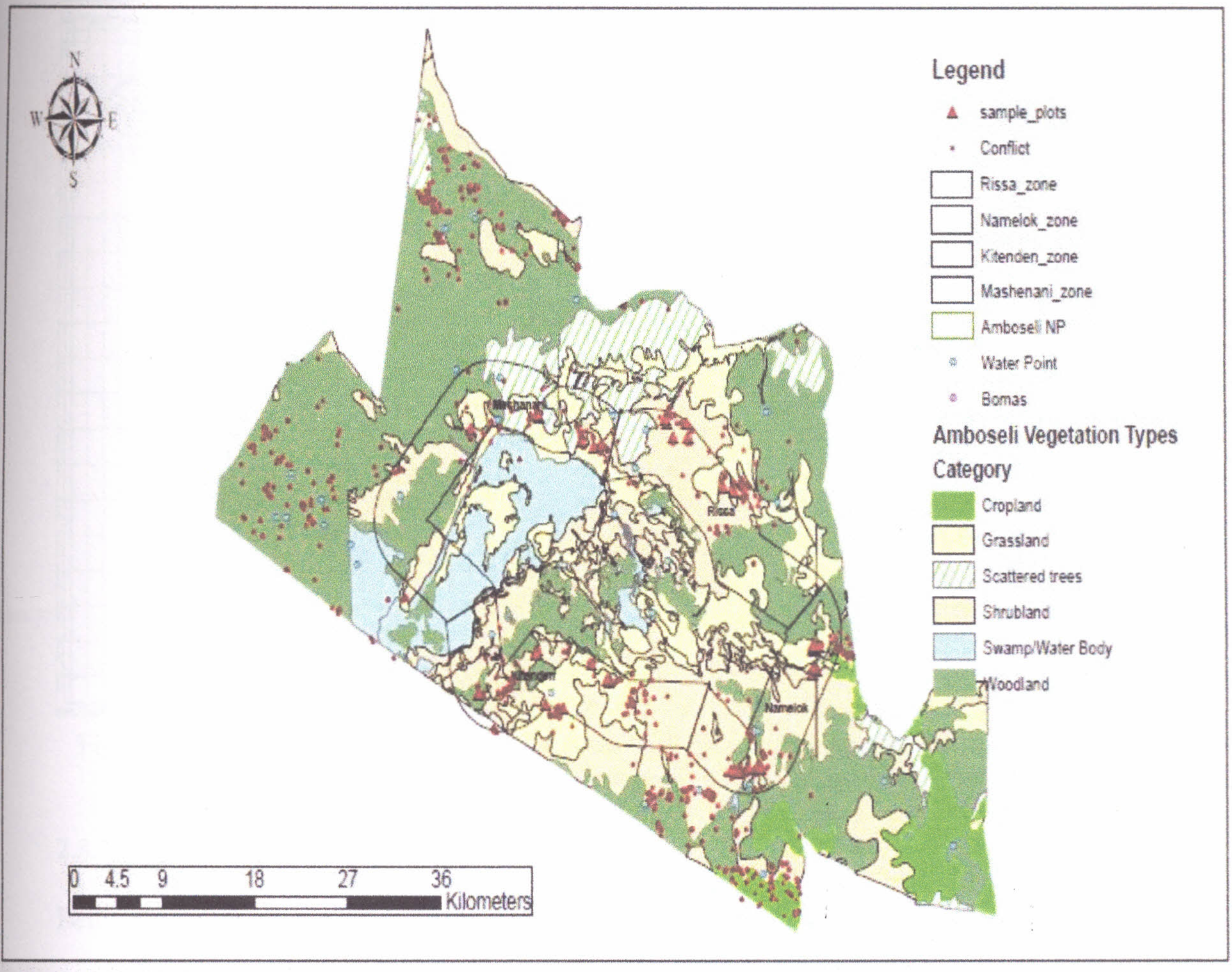


Figure 2.3: Amboseli vegetation sampling plots used for vegetation density survey (Source: this study).

After the plot was marked then identification was done for each plant species and density measurements made within each plot. Also measurement of foliage cover and basal coverage were carried out.

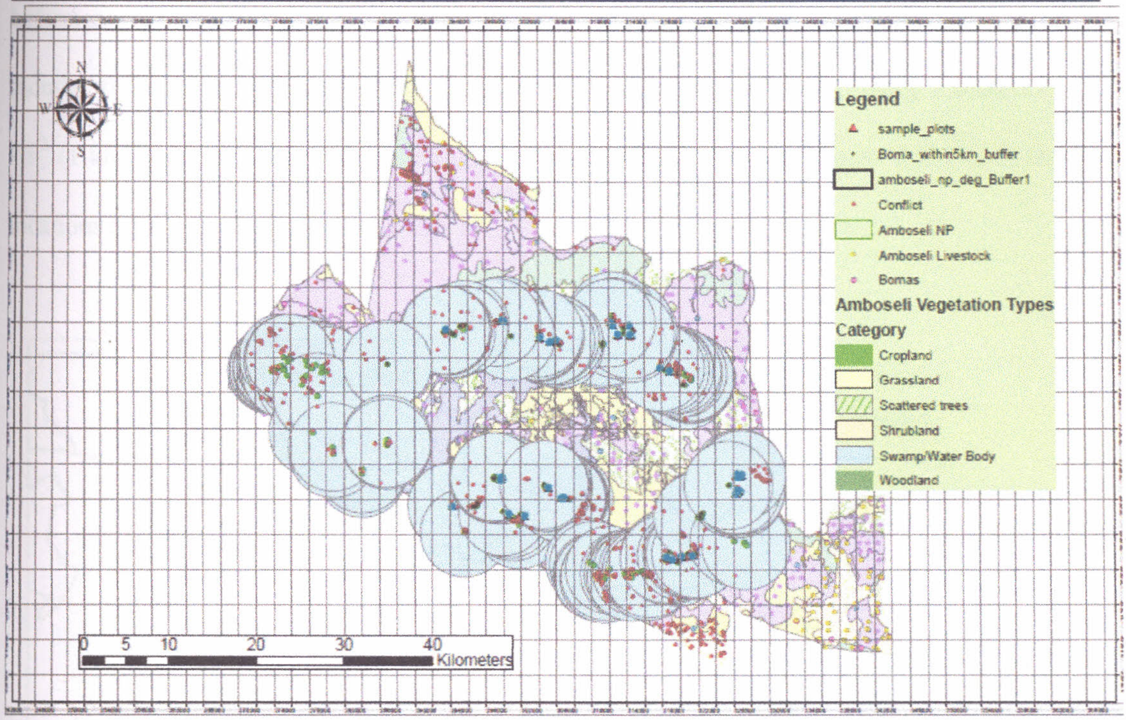


Figure 2.4: Amboseli vegetation sample plots with 5km buffer around conflict bomas and 5km from Amboseli National park boundaries.

2.3.2 Herbivore counts

Belt transect method was employed for herbivore counts. Transects used measured two kilometres long and 500 meters wide on either side.

Ten belt transects (Figure 2.3) were established in the study area. Of these, five transects were established in Amboseli National Park and five in the neighbouring group ranches.

Sampling animals along transect was done monthly during the study period (July 2012 to July 2013). Counts were done in the morning (06.00-08.00 hrs) and in the evening (16.00-18.00 hrs). During the counts, all herbivores larger than 5kg (dik dik) were counted within a distance of 500m on either side of a 2km long transect.

Materials used for the counts included binoculars and a Bushnell range finder. Transect counts were conducted during the morning (06:00 - 08:00) and afternoon (16:00-18:00), before most herbivores sought shelter outside or on the fringes of the park. During twelve months, thirteen complete transect counts were conducted, each comprising 5 transects of 2 km^2 (1 km wide, 500m on each side of the track). The following Figure 2.5 shows transect locations both in and outside the Park.

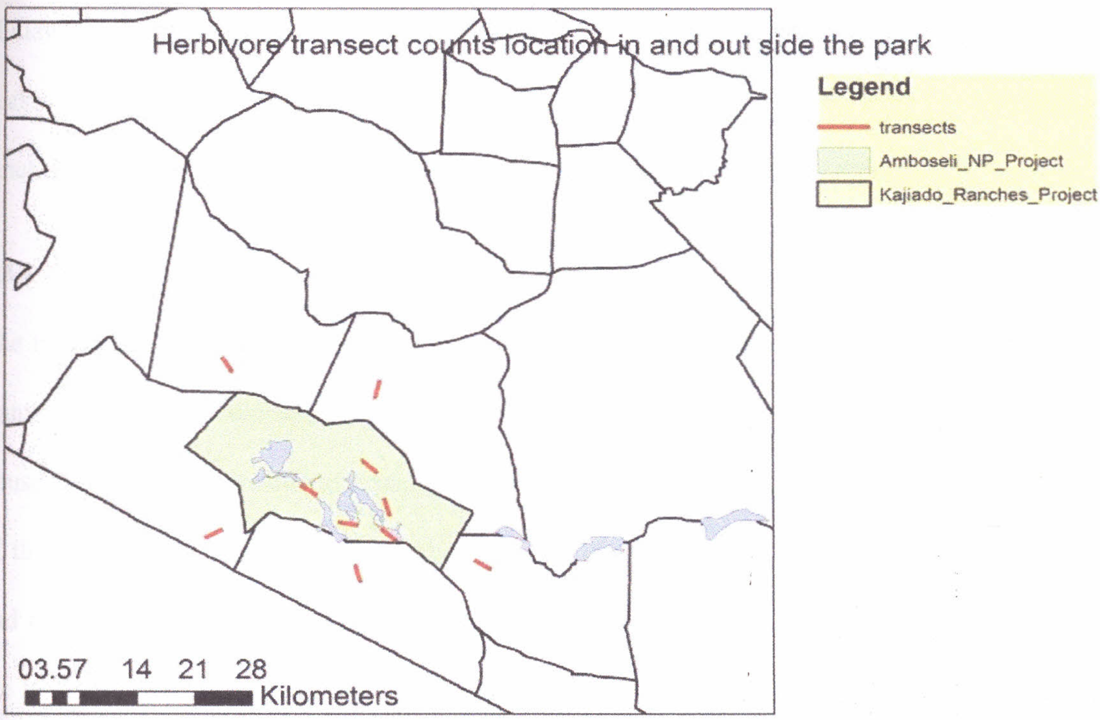


Figure 2.3: Transect locations both in and around Amboseli National Park 2012 (source: this study)

2.3.3 Assessment of livestock predation trends and ascertaining the carnivore species.

To ascertain if livestock was killed by carnivores or natural death, Livestock were categorized in three categories of cattle, shoat (sheep, goat) and donkey, other livestock were not included since these were common livestock within the study area. Once an incident was reported the livestock carcass were carefully examined for claw marks on such parts as throats. Animal spores and other marks were recorded too. This helped in verification, other details recorded were date of occurrence, time, livestock owner, Place names/GPS coordinates, livestock types and age and, predator species involved. To ascertain predators responsible, we first and foremost divided conflict into day and night. Predators such as cheetahs, jackals and wild dogs were known to prey during the day, while lions and hyenas can fall in both day and night. For the two predators we further assessed marks and posisition of claws or injuries on livestock. It was observed that lion most kill by holding animal at the neck – below while hyenas attack from behind. The study area was conducted in two group ranches of Olgulului and Kimana that together engulf Amboseli National park.

2.3.4 Assessment of settlement (Boma) pattern around the park

The traditional Maasai village, or boma, in this region consists of a collection of wooden-frame huts, covered with mud and dung, surrounding a central cattle enclosure. A number of household heads may reside at a boma with their personal dwellings built in distinct sections of the boma. Each household head keeps his cattle in the shared central enclosure at night and maintains a separate enclosure among his huts, in which only his own sheep and goats are kept at night (Homewood and Rodgers, 1991; Burnsilver et al., 2003). Livestock were typically driven out of the boma between 08:00 and 09:00 hours for grazing and returned to the boma just before sunset. All herds outside of the boma are referred to here as grazing herds and were always monitored by one to several herders.

We used GPS and GIS techniques to map all the settlements (Bomas) around the park and monitored all the livestock predation in relation to distance from the Park boundary. Buffering was done at 2.5km, 5km, 7.5km and 10km distances from the park boundary, bomas and conflict occurrence within each distance were recorded.

2.3.5 Ascertain of conflict data

In the month of June, 2012, I also held meetings with KWS rangers and community representatives (group ranch officials) and elders from two group ranches and discussed study objectives and request landowners to inform their local scout of depredation events occurring either at the boma or during grazing, as soon as possible after they occurred. Since similar systems are already established by Kenya Wildlife Service and Ogulului predator consolation scheme, it was widely known by local villagers that our research was not anything new. There was thus no apparent incentive for exaggerating or fabricating claims, but I nevertheless made every effort to confirm all incidents based on available evidence. Conflict reports were collected from July 2012, through July 2013.

2.4 Data Analysis

Mean numbers of monthly livestock killed by large carnivores in dry and wet season were compared using two sample t-test. The median numbers of the livestock killed per type of livestock for each large carnivore type were analysed using Kruskkal Wallis test and Mann-whitney- U test. Collected data was used to show spatial location and distribution of livestock and predation in relation to park boundary. The relationship between the livestock killed (dependent) with settlement/boma density (Independent) was tested using Pearson correlation and regression test.

CHAPTER THREE: RESULTS

3.1 Influence of wild prey densities and distribution on livestock predation trend

Prey diversity and density in Amboseli National Park transect counts was conducted according to methods described by Buckland et al., (2001). Five transects were selected within Amboseli NP and outside the park at the same locations from July 2012 to July 2013. Each transect was 2km long and 1km wide (500 m on each side).

The densities of herbivores in the Amboseli National Park and surrounding group ranches wild herbivore density (Per Km^2) for the period from July 2012 to July 2013 by location (Inside Park and Outside Park) were shown in figure 3.1. The number and density of prey species sampled in transect counts by season are shown in Table 3.1. The results shows among the potential prey species counted wildebeest and zebra were the most numerous in the park. The wildebeest to zebra ratio over the entire study period was 1:1.95. For the large herbivores Elephants and cape buffalos were the most frequently encountered with 1266 and 323 counts respectively.

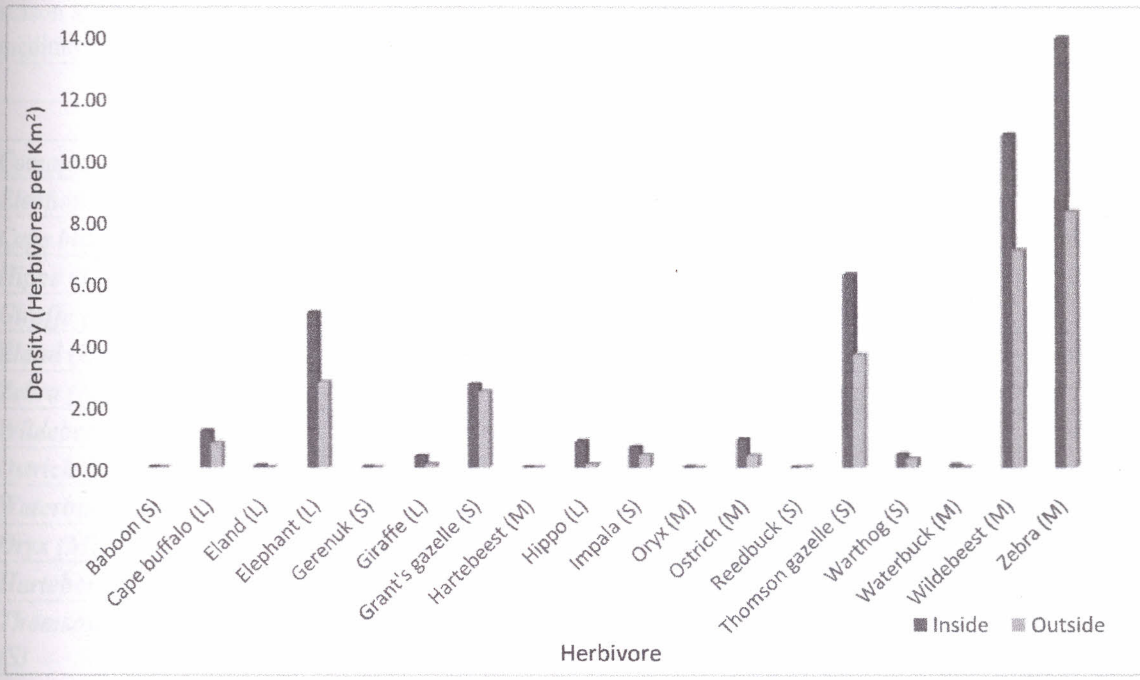


Figure 3.1: ANP herbivore density (per km2) per species from July 2012 to July 2013 by location (inside the park and outside the park).

The gazelles were the most abundant small herbivores with Thomson gazelle having 1611 counts and Grant gazelle with 841. As surrounding areas were drying up starting mid-June, more prey moved towards the park's permanent water sources. The following Table 3.1 shows the herbivore counts and overall density from July 2012 to July 2013 both inside and outside the park. The period covers both dry and wet seasons of the year. The herbivores are put into three categories; large herbivores (L), medium herbivores (M) and small herbivores (S).

Table 3.1 Herbivore counts and overall density (per km2) from July 2012 to July 2013 by season (Dry and wet) and by location (inside the park and outside the park) (n=12 during dry season and n=14 in wet season). The herbivores are divided into large herbivores (L), medium (M) and small herbivores (S)

	Inside the park				**Outside the park**			
	Dry season		Wet season		Dry season		Wet season	
Common name	Count	Density	Count	Density	Count	Density	Count	Density
Elephant (L)	744	8.50	71	0.95	311	3.55	140	1.87
Cape buffalo (L)	136	1.55	57	0.76	67	0.77	63	0.84
Hippo (L)	88	1.01	51	0.68	9	0.10	9	0.12
Giraffe (L)	46	0.53	15	0.20	8	0.09	10	0.13
Eland (L)	2	0.02	9	0.12	0	0.00	0	0.00
Zebra (M)	1589	18.16	677	9.03	860	9.83	488	6.51
Wildebeest (M)	1281	14.64	473	6.31	802	9.17	343	4.57
Ostrich (M)	108	1.23	40	0.53	35	0.40	30	0.40
Waterbuck (M)	13	0.15	1	0.01	0	0.00	0	0.00
Oryx (M)	3	0.03	0	0.00	0	0.00	0	0.00
Hartebeest (M)	1	0.01	0	0.00	0	0.00	0	0.00
Thomsongazelle (S)	777	8.88	239	3.19	386	4.41	209	2.79
Grant's gazelle (S)	289	3.30	151	2.01	268	3.06	133	1.77
Impala (S)	82	0.94	27	0.36	62	0.71	6	0.08
Warthog (S)	53	0.61	16	0.21	26	0.30	22	0.29
Gerenuk (S)	2	0.02	0	0.00	0	0.00	0	0.00
Reedbuck (S)	0	0.00	0	0.00	2	0.02	2	0.03
Baboon (S)	0	0.00	0	0.00	0	0.00	0	0.00

Table 3.2 Mean and standard deviation of densities inside the park

Dry season			Wet season		
Density (x)	d = (x –mean)	d^2	Density (x)	d = (x –mean)	d^2
8.5	5.16	26.6256	0.95	-0.41	0.1681
1.55	-1.79	3.2041	0.76	-0.6	0.36
1.01	-2.33	5.4289	0.68	-0.68	0.4624
0.53	-2.81	7.8961	0.2	-1.16	1.3456
0.02	-3.32	11.0224	0.12	-1.24	1.5376
18.16	14.82	219.6324	9.03	7.67	58.8289
14.64	11.3	127.69	6.31	4.95	24.5025
1.23	-2.11	4.4521	0.53	-0.83	0.6889
0.15	-3.19	10.1761	0.01	-1.35	1.8225
0.03	-3.31	10.9561	0	-1.36	1.8496
0.01	-3.33	11.0889	0	-1.36	1.8496
8.88	5.54	30.6916	3.19	1.83	3.3489
3.3	-0.04	0.0016	2.01	0.65	0.4225
0.94	-2.4	5.76	0.36	-1	1
0.61	-2.73	7.4529	0.21	-1.15	1.3225
0.02	-3.32	11.0224	0	-1.36	1.8496
0	-3.34	11.1556	0	-1.36	1.8496
0	-3.34	11.1556	0	-1.36	1.8496
Mean = 3.34 δ = 1.75		515.4124	Mean = 1.36 δ = 2.4		105.0584

For dry season: δ= 1.75

For wet season: δ= 2.4

Table 3.3 Mean and standard deviation of densities outside park

Dry season			Wet season		
Density (x)	d = (x –mean)	d^2	Density (x)	d = (x –mean)	d^2
3.55	1.74	3.0276	1.87	0.78	0.6084
0.77	-1.04	1.0816	0.84	-0.25	0.0625
0.1	-1.71	2.9241	0.12	-0.97	0.9409
0.09	-1.72	2.9584	0.13	-0.96	0.9216
0	-1.81	3.2761	0	-1.09	1.1881
9.83	8.02	64.3204	6.51	5.42	29.3764
9.17	7.36	54.1696	4.57	3.48	12.1104
0.4	-1.41	1.9881	0.4	-0.69	0.4761
0	-1.81	3.2761	0	-1.09	1.1881
0	-1.81	3.2761	0	-1.09	1.1881
0	-1.81	3.2761	0	-1.09	1.1881
4.41	2.6	6.76	2.79	1.7	2.89
3.06	1.25	1.5625	1.77	0.68	0.4624
0.71	-1.1	1.21	0.08	-1.01	1.0201
0.3	-1.51	2.2801	0.29	-0.8	0.64
0	-1.81	3.2761	0	-1.09	1.1881
0.02	-1.79	3.2041	0.03	-1.06	1.1236
0	-1.81	3.2761	0	-1.09	1.1881
Mean = 1.81 δ = 3.0		165.1431	Mean = 1.09 δ = 1.79		57.761

For dry season: δ= 3.0

For wet season: δ= 1.79

(a) Significance test for the difference in wildlife densities outside and inside the park

i. during the dry season

Hypothesis to be tested: there is no difference between the mean densities of wildlife outside and inside the park during the dry season.

Available data of density outside the park (dry season):

Mean density outside the park ($\mu 1$) = 1.81

Standard deviation ($\delta 1$) = 3.0

Number of animals (n1) = 18

Available data of density inside the park (dry season)

Mean density outside the park ($\mu 2$) = 3.34

Standard deviation ($\delta 2$) = 1.75

Number of animals (n2) = 18

The z-score is calculated as follows:

$$Z = 2.28$$

For a one tail test at 5%, level of significant, the critical value (z-score) is 1.65. Since the calculated value is greater than the critical value (from tables) the null hypothesis (H0) is rejected. This implies that the there is a significant difference between the two mean densities and hence there is a higher wildlife density outside the park than inside during the dry period.

ii. during the wet season

Hypothesis to be tested: there is no difference between the mean densities of wildlife outside and inside the park during the dry season.

Available data of density outside the park (dry season):

Mean density outside the park ($\mu 1$) = 1.09

Standard deviation ($\delta 1$) = 1.79

Number of animals (n1) = 18

Available data of density inside the park (wet season)

Mean density outside the park ($\mu 2$) = 1.36

Standard deviation ($\delta 2$) = 2.4

Number of animals (n2) = 18

The z-score is calculated as follows:

$$Z = 0.54$$

For a one tail test at 5%, level of significant, the critical value (z-score) is 1.65. Since the calculated value is less than the critical value (from tables) the null hypothesis (H0) is accepted. This implies that the two mean densities are not equal and hence there is no significant difference in wildlife density outside the park and inside it during the wet period.

(b) Significance test for the difference in wildlife densities during dry and wet season

(i) inside the park

Hypothesis to be tested: there is no difference between the mean densities of wildlife during the dry and wet season inside the park.

Available data of density during the dry season (inside the park):

Mean density outside the park ($\mu 1$) = 1.81

Standard deviation ($\delta 1$) = 3.0

Number of animals (n1) = 18

Available data of density during the wet season (inside the park):

Mean density outside the park ($\mu 2$) = 1.09

Standard deviation ($\delta 2$) = 1.79

Number of animals ($n2$) = 18

The z-score is calculated as follows:

Z = = 2.83

For a one tail test at 5%, level of significant, the critical value (z-score) is 1.65. Since the calculated value is greater than the critical value (from tables), the null hypothesis (H0) is rejected. This implies that the two mean densities are not equal and hence there is a significant difference in wildlife densities during the dry period and wet period inside the park. As such, there is more wildlife inside the park during the wet season.

(ii) outside the park

Hypothesis to be tested: there is no difference between the mean densities of wildlife during the dry and wet season inside the park.

Available data of density during the dry season (inside the park):

Mean density outside the park ($\mu 1$) = 3.34

Standard deviation ($\delta 1$) = 1.75

Number of animals ($n1$) = 18

Available data of density during the wet season (inside the park):

Mean density outside the park ($\mu 2$) = 1.36

Standard deviation ($\delta 2$) = 2.4

Number of animals (n2) = 18

The z-score is calculated as follows:

$$Z = 2.83$$

For a one tail test at 5%, level of significant, the critical value (z-score) is 1.65. Since the calculated value is greater than the critical value (from tables), the null hypothesis (H0) is rejected. This implies that the two mean densities are not equal and hence there is a significant difference in wildlife during the dry period inside the park.

According to Table 3.1, there were more wild herbivores within the park during the dry season than the wet season, thus a higher density of wild herbivores inside the park during the dry season. This implies that as the dry season advanced, more wild herbivores sought shelter inside the park, but moved out during the wet season. The same pattern prevailed outside the park, with more wildlife being available during the dry season than the wet season. Thus, wildlife density inside and outside the park varied with season. There were more wild herbivores in and around the park during the dry season than the wet season.

3.2 Livestock Predation Intensity in relation to Season and Boma density

3.2.1 Livestock Predation and Seasonal Variation

Analysis on the prey density inside the park during the dry and wet season showed more herbivores were spotted in the park during the dry season than in the wet season. The Figure

3.2 shows the total monthly livestock attacks by predators recorded around the Amboseli National Park, Kenya, from July 2012 to July 2013.

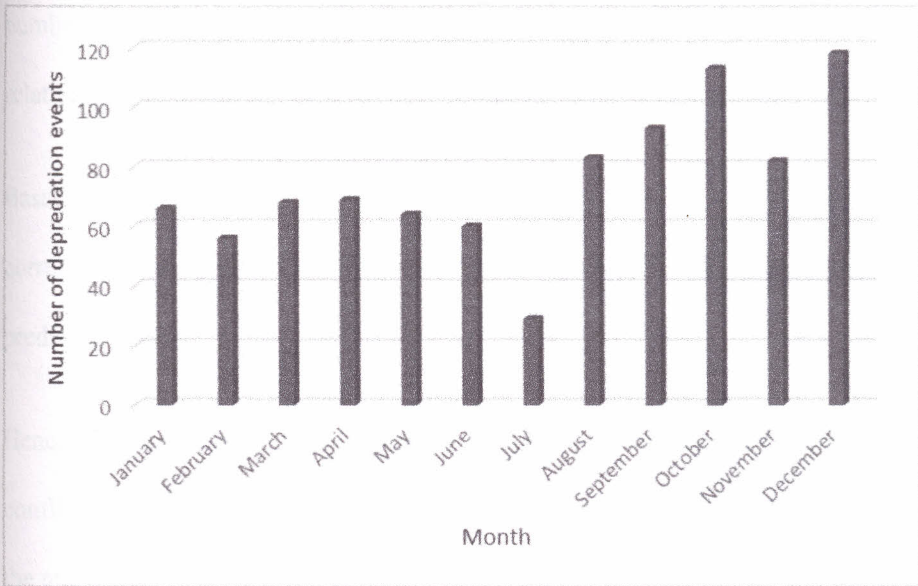


Figure 3.2: Monthly livestock attacks by predators around ANP, July 2012 to July 2013

From Figure 3.2, there was predation frequency highest from August to October; the driest months in the area and lowest in July after four months of raining. Monthly attack frequency had no significant relationship with total monthly rainfall as the Pearson correlation test yielded only a correlation coefficient of 0.004 ($p = 0.897$, $n = 1409$). The number of livestock attacked during wet months (706) (January, February, March, April, November and December) were higher than those attacks that took place in dry season (703) (May, June, July, August, September and October). In the four zones, more than 55% of all the attack incidences occurred during the dry months especially between September, October and December. Thus, there is no relationship between rainfall and livestock predation by large carnivores in Amboseli Ecosystem

3.2.2 Influence of Boma Density/Settlement Pattern on Livestock Predation

The study sought to determine the influence of human settlement (Boma) density on the number of livestock attacks by large carnivores. The following Table 3.2 shows the relationship between settlement density and number of livestock attacks by large carnivores.

Based on vegetation zonation in and around the park recorded, Pearson product moment correlation coefficient (r. 0.95) to find if there was correlation bomas and number of predation events.

Hence, the coefficient of correlation between the number of bomas and the number of conflicts was 0.95. This depicts a strong positive correlation, which implies that the higher the number of bomas, the greater the frequencies of predation as livestock are concentrated in a small area.

3.2.3 Distance of Settlement from the Park and Number of Livestock Attacks

The spatial distribution of settlement density and number of conflict occurrence at specific distance from the park were mapped and are shown in Figures 3.3, 3.4 and 3.5.

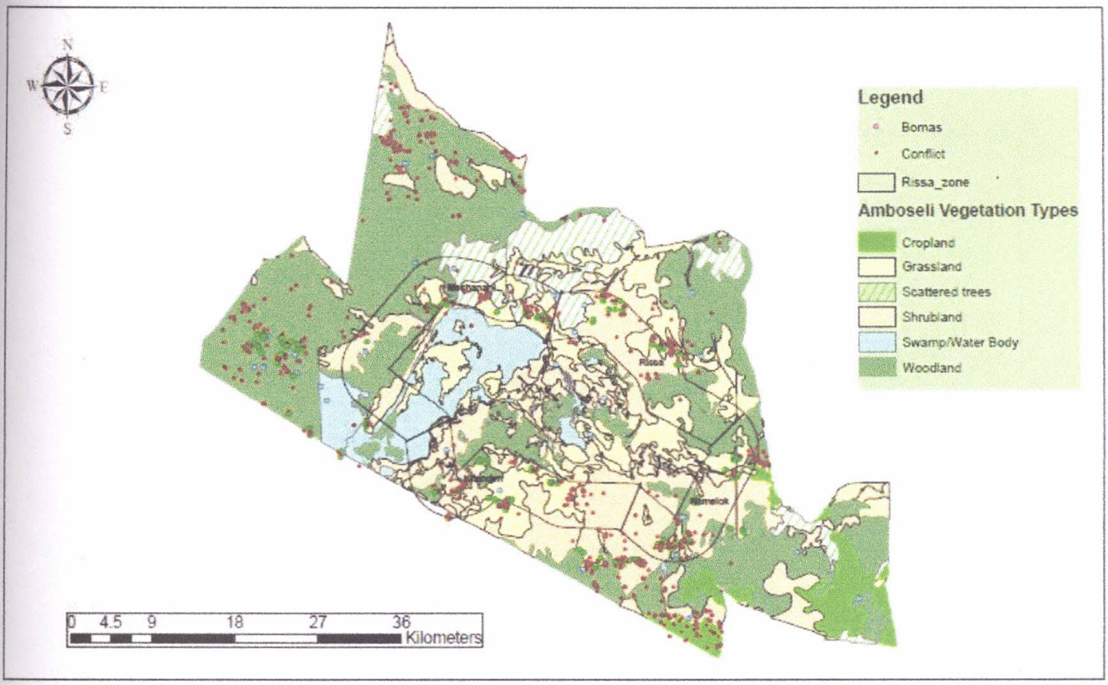


Figure 3.3: Spatial distribution of livestock predation incidences during the period July 2012 to July 2013 (Source this study)

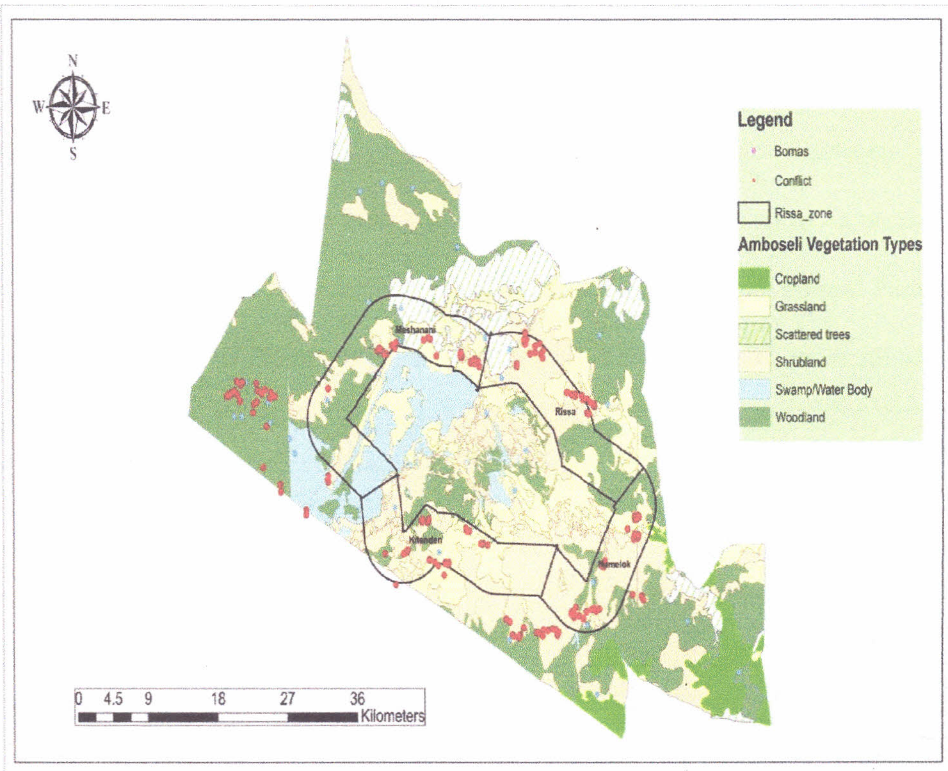


Figure 3.4: Distribution of Bomas around the National Park during the period July 2012 to July 2013.

From Figures 3.3 to 3.5, it is observed that the number of conflicts reduced as the distance from the park increased. Subjecting the distances from the park to position of attack and the number of livestock attacks, it was found that there was a negative correlation between distance from the park and number of conflicts ($r = -0.905$, $p = 0.095$, $N=5$). This implies that the nearer the boma to the park, the higher the number of attacks while the farther away the boma was from the park, the fewer the attacks by wild carnivores. Therefore those bomas close to the ANP were more likely to suffer attack on livestock than those which were 10 km or more way.

3.3 Habitat aspects and related livestock predation

We used Pearson correlation to find out if there was any correlation between vegetation densities and livestock predation incidents shown in (Table 3.2). This shows a weak negative correlation between vegetation densities and conflict around Amboseli National Park.

Table 3.4 Correlation between vegetation Densities and predications incidences

Amboseli conflict zones	Average vegetation densities (X)	No.Of conflicts (Y)	XY	X^2	Y^2
Rissa	0.01	214	2.14	0.0001	45796
Namelok	0.42	204	85.68	0.1764	41616
Kitenden	0.03	225	6.75	0.0009	50625
Meshanani	0.02	208	4.16	0.0004	43264
Total	**0.48**	**851**	**98.73**	**0.1778**	**181301**

- 0.5862 $r = -0.531$ correspond to $z = 0.59154$ raid $p = 0.9272$ which is significant.

Environmental changes like presence or absence of rainfall affect vegetative cover, which determines the livelihood of wild herbivores that large carnivores feed on. In the absence or scarcity of herbivores, the carnivores have to seek alternative food supply, hence frequent livestock attacks.

Vegetation loss is a major cause of biodiversity decline in African savanna parks. The following Figure 3.6 & 3.7 shows the vegetation status in different zones in Amboseli National Park. The blue shade in Fig.3.7 shows annual long term average vegetation densities, greenness and biomass for the month of December.

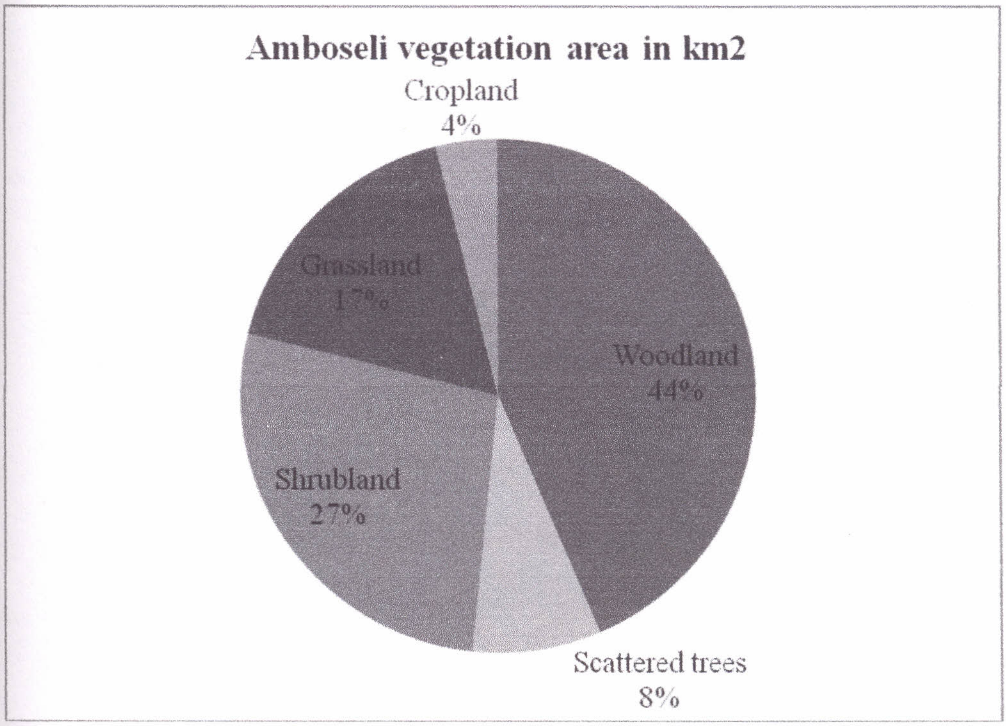


Figure 3.5: Amboseli vegetation areas characterization for the period July 2012

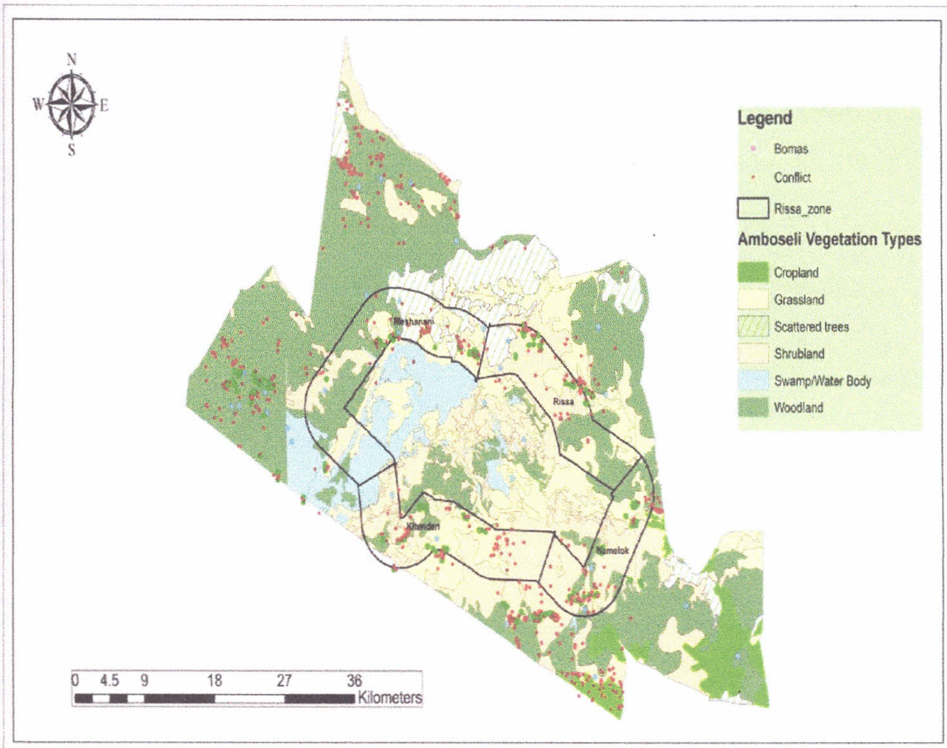


Figure 3.6: Vegetation Status in Different Zones in Amboseli in 2012 and associated number of conflicts (Source – this study)

3.4 Seasonal variation of predation trends

Data from rainfall stations in Amboseli National Park ware analyzed for the period of July 2012 to July 2013. Figure 3.8 shows the rainfall pattern for Amboseli National Park during the period, July 2012 to July 2013. The two rainfall peaks were observed during April (140.2 mm) and November-December (mean 50.8 ± 3.67 mm). The average annual rainfall at the time of study was 29.73 ± 40.33mm. There was no rainfall recorded in the months of July, August, September and January.

The rainfall pattern in Amboseli National Park was rather low for most of the parts of the year, as depicted in the following Figure 3.9.

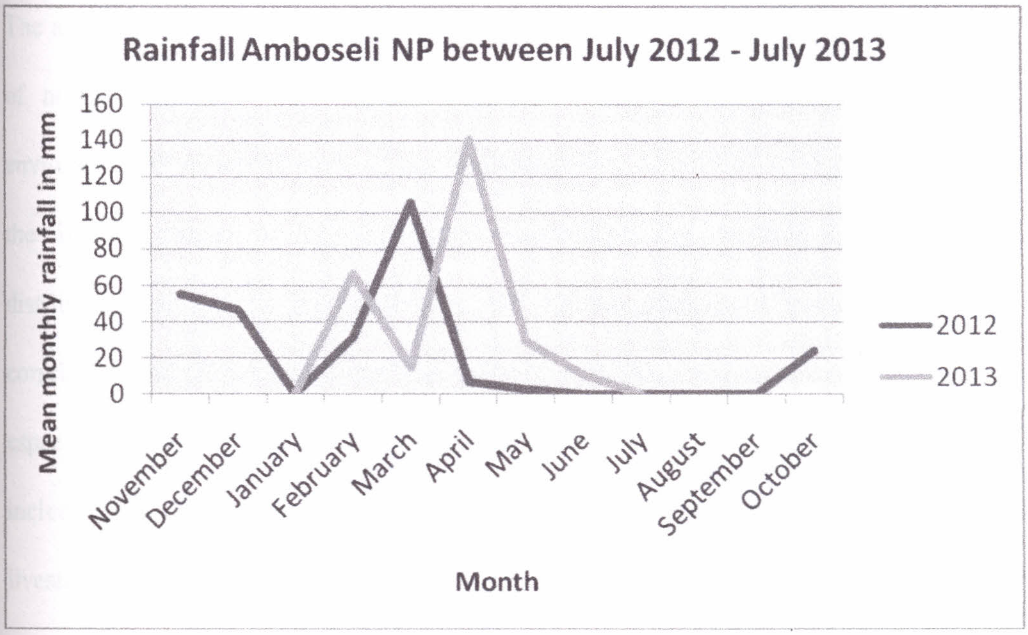


Figure 3.7 Amboseli National Park rainfall pattern for July 2012 – July 2013.

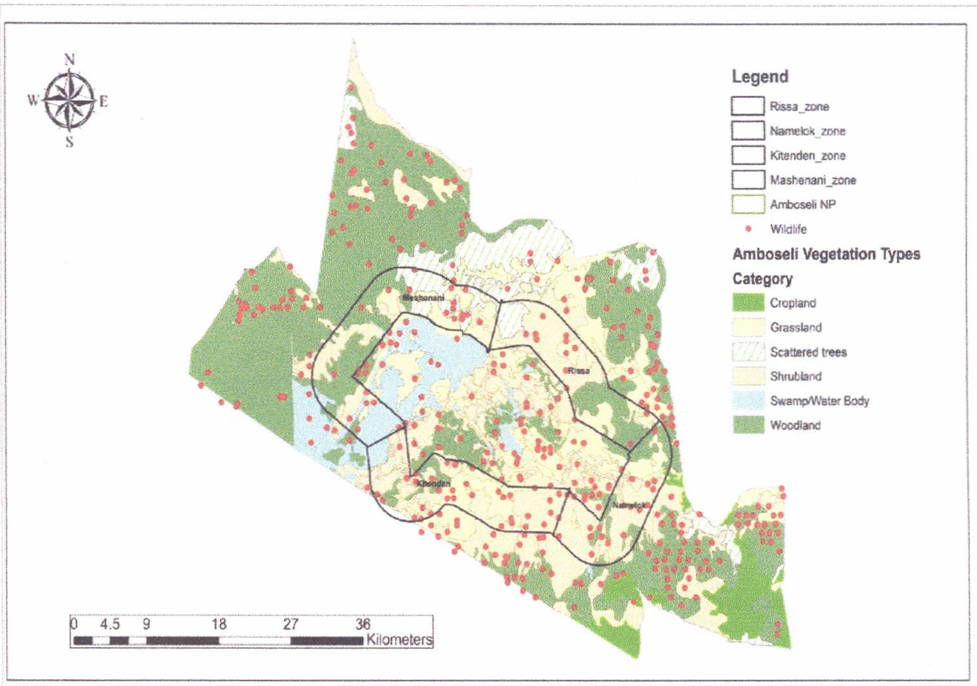
In Amboseli ecosystem a dryland savannah, wildlife distribution is influenced by rainfall and water availability. As the area dried out wildlife concentration are observed in the park because of permanent swamp. Since the Amboseli basin is the only area with natural, permanent water during the dry season. Before passing on to consider the evidence for this, data on the distribution of animal species in relation to dry season water supply are required. Water is more or less ubiquitous during the rains and animals are rarely more than a few kilometres from the nearest available water source.

However, there was a negative and significant correlation between the wildebeest number monthly and amount of rainfall (r = -0.593, p= 0.033). The number of wildebeest in ANP increased with increasing rainfall. The higher the amount of rainfall, the lower the number of wildebeest. There was no significant correlation between the other herbivores spotted inside and outside the park and rainfall.

The attacks by carnivore species were spatially clustered. This conforms to the assumption of non-homogenous distribution of natural resources needed by the animals. Some environmental variables such as human settlement, density of wild prey greatly influenced the observed pattern of carnivore attack distribution. For example the relationship between distribution of attacks by carnivores and human settlement pattern showed a positive correlation and shows significant ($r= 0.766$, $p = 0.131$, $n=5$) indicating that some carnivores especially hyenas preferred to keep a certain distance from human settlements. Conflicts included attacks by lions, leopards, and hyenas that resulted in either death or injury of livestock.

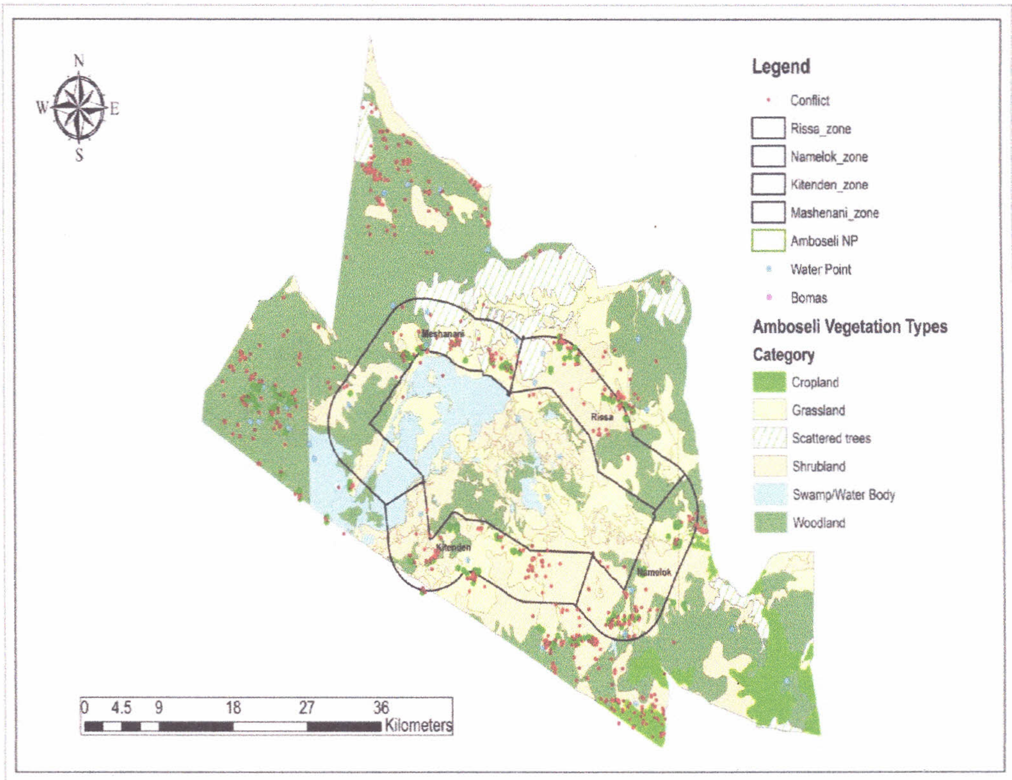
3.5 Relationship vegetation (land cover) and livestock predation incidences

For many years these group ranches have provided free dispersal areas and migration corridors for wildlife from various National Parks. Figure 3.8 (A&B) shows land cover, wildlife and livestock distribution in Amboseli ecosystem.



A

Figure 3.8 A&B Land cover and human activities in relation to wildlife and livestock distribution in Amboseli ecosystem for period July 2013



B

3.6 Contribution of different carnivores to livestock predation

A total of 1409 predation events were recorded from July 2012 through to July 2013. Every incident was attributed to a specific predator, based on visual confirmation of the predator, its tracks, claw marks, or the condition of the livestock carcass and confirmed reports by KWS rangers and community guards.

Hyenas were involved in 360 of the 1409 reported incidents (40%), with Jackals, Cheetah and lions involved in 24.5%, 18.3% and 17.2%, respectively (Fig. 3.9)

Figure 3.11 shows the livestock predation in the five zones surrounding the ANP and the proportion of attacks which each predator was responsible.

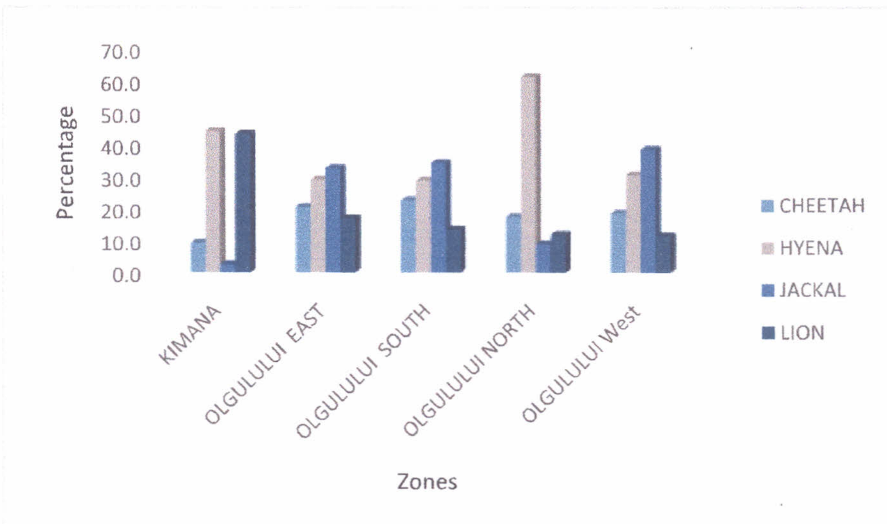


Figure 3.9: Livestock predation in areas around ANP and the predators' responsible period, July 2012 to July, 2013.

As shown in Fig. 3.10, the lion was the most consistent predator in all the settlement areas studied followed by hyena. Livestock predation by lion was comparatively low in occurance in all six sites. Lions caused intolerable livestock losses.

The following Figure 3.10 shows the involvement of cheetah, lion, jackal and hyena in attacks on 6 categories of livestock predation incidents in ANP during the 11-month study period. The total number of attacks by each carnivore is listed in parentheses after category heading. ''B'' indicates attacks at the bomas (inside); ''G'' Indicates attacks while grazing (Outside the boma).

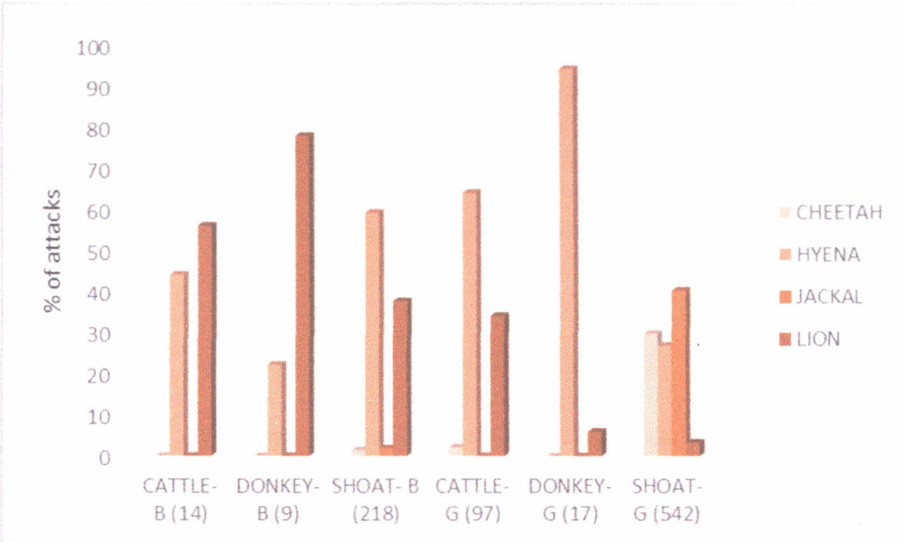


Figure 3.10 Involvement of cheetah, lion, jackal and hyena in 6 categories of livestock predation incidents in ANP during July 2012 to July 2013.

During the attacks, carnivores killed 1409 stock animals with the following distribution: 1255 sheep and goats (89%), 129 Cattle (9%) and twenty five, (2%) donkeys. Hyenas, jackal, lion and cheetah were responsible for 53% (n = 750), 17% (n = 243), 15% (n= 215) and 14% (n = 201) of the livestock deaths, respectively. Cheetah accounted for 15% and 1.5% of all shoats and cattle killed respectively, but never attacked donkeys. Lions killed 8 donkeys, but accounted for 40% (n = 52) of all cattle kills and 12% of shoats. Hyenas were the leading killers with 54% (n=698) of all sheep and goats combined, 58% (n=75) of all cattle (calves) and 68% (n=17) of all donkeys. Jackals only attacked sheep and goats (n=243).

Seventy-two, (72%) of the 1409 recorded attacks were directed at grazing animals (outside the bomas) with the remaining thirty eight, (38%) attacks occurring inside the bomas. Hyenas attacked grazing herds more often than controlled herds (61% and 39%, respectively; Chi square test p = 0.445) and were responsible for 56% of attacks on grazing herds of sheep and goats. Lions attacked controlled livestock (n = 103) more than they attacked grazing herds (n = 52), and were involved in 56% of attacks on grazing cattle herds. Conversely, cheetahs attacked grazing herds (n = 163) less than livestock in bomas (n = 3) and were responsible for 30% of all attacks on sheep and goats in bomas. Out of the 250 attack incidences reported inside the bomas, 30% and 26% of them were in Kimana and Olgulului North respectively while attacks outside the bomas were well distributed in the four zones, except Kimana which had the least number of attacks while grazing herds.

For this study, the 24 hour day was divided into late night (1am to 4am), early morning (5am to 8am) and mid-morning (9am to 12am). The other 12 hours were divided into afternoon (1pm and 4pm), evening (5pm and 8pm) and early night (9pm to 12am). Most attacks reported indicated that conflicts were most frequent during evening, late night and mid-morning. Figure 3.11 shows the daily time of predation occurrences in the different zones around Amboseli National Park.

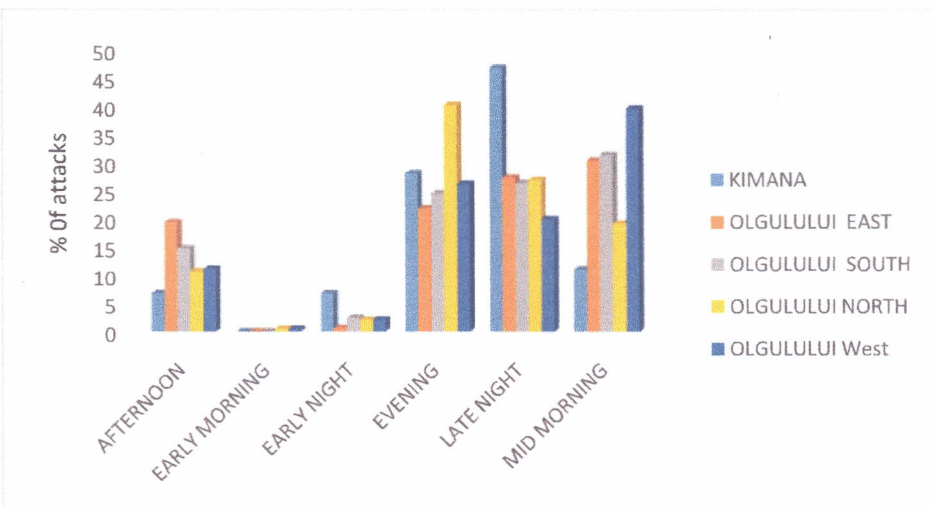


Figure 3.11 Daily times of human wildlife conflicts in the different zones around ANP.

Only few attacks occurred during early morning hours (2) and early night (23). The patterns across the zones were similar although with difference in frequencies, where Kimana and Olgulului group ranch had the highest prevalence levels of attacks during the evening and late night hours.

Most of the Cheetahs and jackal attack occurred during mid-morning (52%, 57%) and afternoon (33%, 22%). Attacks by hyenas were seen during evening (59%) and late night (27%). Lions attacked mainly during late night (79%). It was only jackals that attacked through early morning.

CHAPTER FOUR: DISCUSSION

4.1 Prey abundance and its influence on livestock predation trends

The study found that wild prey densities greatly influence livestock predation by large carnivores. When the wild prey are abundant, the carnivores can find the wild herbivores much easier and therefore the carnivores do not need to go for livestock, except in situations where the livestock are not taken care of, like when there are no herders taking care of livestock while grazing, or where the livestock boma is not well fenced. This finding is in agreement with the finding by (Mishra *et al,* 2003), who found that one of the causes responsible for the escalating levels of carnivore predation on livestock, include an increase in local abundance of carnivores, increase in livestock populations or decline in wild prey populations.

Similar studies elsewhere found that the rates of livestock depredation by large carnivores can be influenced by local environmental conditions such as abundance of natural prey (Meriggi and Lovari, 1996; Mizutani, 1999; Stoddart *et al.,* 2001; Polisar *et al.,* 2003) and rainfall (Patterson *et al.,* 2004; Woodroffe and Frank, 2005). Wildebeest and zebra were found to be the most abundant medium size wild herbivores found in the studied location. For the large herbivores, elephants and cape buffalos were the most abundant while the gazelles were the most abundant small herbivores. These herbivores provide meals to the carnivores whenever they are in abundance, but their shortage encourages the large carnivores to hunt livestock. This finding agrees with the finding of Ramakrishnan et al. (1999), who explained that the reliance of carnivores on other animals for food commonly brings carnivores into direct conflict with humans, especially in areas where native wildlife has been extirpated and replaced by domesticated stock. The wild carnivores then predate on domesticated livestock.

Our goal was to elucidate relationships between various ecological factors and temporal variation in conflict frequency in the vicinity of the Reserve, and to assess the influence of village and enclosure characteristics on relative vulnerability to carnivore attack. Our study on large carnivore's predation on livestock provides a unique opportunity to associate detailed information regarding relation to spatial and temporal predation pattern and trends.

There are more wild herbivores inside and in the surrounding areas of the park during the dry season than during wet seasons. In other words, there is higher wild herbivore density inside and around the park during the dry season than the wet season. This is probably due to the fact that as the rain subsides, most of the surrounding areas lose vegetation and water holes dry up. Amboseli National Park, however, retains water and pasture resources and therefore the animals keep close to feed and drink Amboseli Wetlands.

Although there were more frequent livestock attacks during the dry season than the wet seasons, there was no significant relationship between livestock attack and total monthly rainfall. The frequency in attacks could simply be incidental rather than as a result of lack of wild herbivore during dry seasons. The finding disagrees with a study by Norton-Griffths (1977), who found that the seasonal distribution of rainfall governs the fundamental patterns of range utilization by the nomadic pastoralists and migratory wildlife. This difference could be due to the nature of Amboseli National Park, which retains water during dry seasons as other parts of the surrounding land dry up.

There is a direct correlation between livestock attack by wild herbivores and the number of human settlement around Amboseli National Park. A Pearson correlation analysis of the two variables yielded a strong positive correlation between the two variables, with a correlation coefficient of 0.766. Thus, the number of settlements is high, there is a high frequency of livestock attack by large carnivores but when the number of settlements is low, the attack is less frequent. The finding is in agreement with that of Saberwal *et al.* (1994), who assert that increasing human populations is one of the key factors that contribute to increased livestock predation by large carnivores.

4.2 Effect of resources use and boma vulnerability to predator invasion

The distance from settlement area to Amboseli National Park affects the frequency of livestock predation by large carnivores. A Pearson product moment correlation analysis of the two variables yielded a correlation coefficient of - 0.905, indicating a very strong negative correlation. This value means that the shorter the distance, the greater the frequency of livestock attack while the greater the distance from the park, the less the frequency of livestock attack by large carnivores. This finding agrees with Conforti and de Azevedo, (2003), who found that human wildlife conflict, can be particularly serious where rural people live in close proximity to protected areas.

Environmental changes have significant effect on livestock predation by large carnivores. When the vegetation is thin, the frequency of livestock predation is higher. This is due to the fact that as the vegetation thins, wild herbivores move further away to seek greener pastures. There are therefore just a few wild herbivores for the carnivores to feed on. Thus, the carnivores prey on livestock as an alternative.

Of all attacks and predation on livestock by large herbivores, the hyena has the highest frequency of responsibility for the attacks. However, they are followed closely by lion, which in certain circumstances, are the only predators responsible for livestock attacks. The jackal and cheetah are less responsible for livestock attacks. This finding agrees with that by Patterson *et al.* (2004), who state that one of the main livestock predators in Africa is the lion.

Considering all attacks on livestock, the hyena emerged as the leading predator and preyed on sheep and goats combined cattle and donkeys.

Spatial data analysis indicated that hyenas, as opportunistic feeders, are making regular visits to bomas not for livestock primarily, but rather for discarded food and other edible items. Large bomas, with more human activity, would thus be most attractive to hyenas interested in exploiting refuse and opportunistic attacks on livestock should therefore be more likely to occur at these bomas. Given the attractiveness of these sites to foraging hyenas, secure refuse disposal at bomas may reduce hyena attack frequency.

While our findings suggest that leopards avoid dense aggregations of human settlements, they do not indicate leopards select smaller bomas, as did the results of Ogada *et al.* (2003). Our results may suggest trade-off in boma selection by leopards. While isolated bomas offer a reduced level of human activity and thus reduced probability of predator detection, bomas with fewer enclosures or livestock offer reduced opportunities to access appropriately vulnerable prey. As in Ogada *et al.* (2003), our observation indicated that dogs were generally ineffective in deterring leopard or hyena attacks; these were further supported by villager reports suggesting that dogs were killed and eaten by both predators with some frequency.

Although many villagers reinforced pole fences with iron sheeting, barbed wire or thorn bush to close gaps and remove possible footholds, leopards appeared capable of capitalizing on small weaknesses in these reinforcements.

Cheetahs attacked mainly shoats and cattle, but never killed donkeys, while jackals only attacked sheep and goats. Majority of livestock are attacked during grazing in the fields, with a relatively smaller fraction being killed while in their respective sleeping places. However, the lion attacked controlled livestock (while inside their pens) than in the grazing fields. This finding contradicts that done by Ogada *et al* (2003), who found that about 75% of kills occurred at night while the remaining 25% took place while livestock were grazing out in the field.

Most of livestock attack at night by large carnivores took place in late in the evening while the livestock were in the bomas, mid morning or late in the afternoon. Very little livestock attacks took place during in the early morning. In the same way, there is relatively less attacks early in the night compared to those occurring late at night.

4.3 Conclusion

Although our data indicate that human activity not specifically designed to deter predators may be ineffective in reducing attack probability, active guarding of bomas (e.g. posting night guards, sleeping in huts within enclosures), particularly with the help of lights, may prove effective. Investment of effort in guarding enclosures, a practice rarely utilized in our study area, would be most beneficial during the rainy season, when attacks are most common, and could likely be relaxed when migratory herds are present. On the basis of the research findings outlined in the previous section, it is clear that livestock predation by large carnivores is a major concern not only to the pastoralists whose livestock are attacked, but to conservationists as well. Due to the predation, the carnivores are susceptible to retaliatory attacks that are bound to reduce their numbers greatly. However, the magnitude of attack can be reduced if the herders took the initiative to guard against attacks either at night in the bomas or even during grazing in the fields.

With respect to our finding that the size and isolation of a bomà can influence its vulnerability to predator attack, similar findings in North America regarding wolf depredation on cattle farms (Mech et al., 2000) indicate that these factors may be important spatial predictors of livestock attacks not only by African predators, but by predators worldwide. Our study has demonstrated that monitoring of both socio-ecological and environmental variables, coupled with detailed depredation information, can be useful in generating practical recommendations for conflict mitigation. In addition, knowledge of the movements and behavior of predators involved in depredation events can offer important insight into the effectiveness of depredation prevention measures.

4.4 Recommendations

4.4.1 Policy Recommendations

Pastoralists living near national parks and other predator infested environments should closely herd their livestock during the day to ensure that they are not attacked by large carnivores. Since the livestock must venture out to the field to graze, the remedy to predation by large carnivores is only through guarding the grazing animals by armed herders using bows and arrows, spears, clubs and other deterrent weapons.

Pastoralists should construct strong cattle bomas to ensure that predators cannot enter through the walls or roof of the sheds where cattle are kept. Preferably, the cattle sheds should be made of stone or strong wood instead of small tree posts, twigs or acacia. They should also avoid keeping livestock in open sheds at night.

Livestock owners near parks should keep guard dogs that can alert the owners of any predators intruding or passing near cattle sheds. This would alert the owners about the presence of such intruders, who would then defend the sheds using weapons like bows and arrows, spears and where possible shotguns that ca scare away the predators but not kill them. Groups of families can construct a common boma or cattle shed where livestock can be kept as a group. The common shed can then be strengthened with stones or strong wood that cannot be broken into by carnivores. Further, a group of people (men) can build a room next to the communal shed, which would then be responsible for the security of the livestock kept in the shed.

Human settlements should be positioned far away from the animal parks to prevent the carnivores from reaching them easily. It was found that the nearer the human settlement to the park, the higher the frequency of attack. Thus, keeping human settlements away from the park is one way to avoid predation of livestock by the carnivores.

Livestock keepers should be very vigilant towards late night since this is the time at which the carnivores attack more frequently. Where possible, and especially where a communal shed is used, people (men) should take turns to guard the sheds to ensure that any predator activity is detected in good time and the predator scared away by whichever means possible.

Herders should graze their livestock from early morning and break as it approaches midday. This is because there was very little or no attacks on grazing livestock early in the morning. But the frequency of attacks increased as the day approached midday, and peaked late in the afternoon.

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APPENDICES

Appendix I: Carnivores and herbivores sighted during the study

The larger mammals of Amboseli Basin	
Herbivores	**Carnivores**
Elephant *Loxodonta africana*	Lion *Panthera leo*
Cape buffalo *Syncerus caffer*	Leopard *Panthera pardus*
Giraffe *Giraffa camelopardalis*	Cheetah *Acinonyx jubatus*
Hippo *Hippopotamus amphibius*	Spotted hyena *Crocuta crocuta*
Eland *Taurotragus pattersonianus*	Striped hyena *Hyaena hyaena*
Zebra *Equus burchelli*	Hunting dog *Lycaon pictus*
Wildebeest *Connochaetes taurinus*	Golden jackal *Canis aureus*
Hartebeest *Alcelaphus cokii*	Side-striped jackal *Canis adustus*
Waterbuck *Kobus ellipsiprymnus*	Bat-eared fox *Otocyon megalotis*
Oryx *Oryx b. callotis*	Aardwolf *Proteles cristatus*
Bushbuck *Tragephus massaicus*	Serval *Felis serval*
Lesser kudu *Tragelaphus imberbis*	Caracal *Felis caracal*
Bohor reedbuck *Redunca redunca*	African wild cat *Felis libyca*
Impala *Aepyceros melampus*	African civet *Viverra civetta*
Grant's gazelle *Gazella granti*	Honey badger *Mellivora capensis*
Thomson's gazelle *G. thomsoni*	Zorilla *Ictonyx striatus*
Gerenuk *Litocranius walleri*	Marsh mongoose *Atilax paludinosus*
Kirk's Dik-dik *Rhynchotragus kirki*	Dwarf mongoose *Helogale parvula*
	Grey mongoose *Herpestes pulverulentus*
	Slender mongoose *H. sanguineus*
	Large-spotted genet *Geneta tigrina*
	Small-spotted genet *Geneta servalina*

Appendix II: Survey data sheet for herbivore density and abundance.

Transect Code: yy mm dd tt

Name Data Recorder: _ **Date**: ____

Transect Number: ___________ **Time**: Start __Finish: ___

Weather / Wind Conditions: ___

Species	Number						
	Left	Right	Neonates	Perpendicular distance	Habitat types	Habitat conditions	Water availability

Habitat condition (grass greenness): 1) 100-75% 2) 75-50% 3) 50-25% 4) 25-0%

Water availability: 1) Waterlogged 2) Artificial/ground water 3) Swamp water 4) Dry

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Appendix III: Survey for wildlife attacks on livestock in time and space

Date	Predator responsible	Livestock involved	Number	GPS location	Time Of incident
	Lion Cheetah Hyena Wild dogs	Goats Cows Sheep Donkey			
	Lion Cheetah Hyena Wild dogs	Goats Cows Sheep Donkey			
	Lion Cheetah Hyena Wild dogs	Goats Cows Sheep Donkey			
	Lion Cheetah Hyena Wild dogs	Goats Cows Sheep Donkey			
	Lion Cheetah Hyena Wild dogs	Goats Cows Sheep Donkey			
	Lion Cheetah Hyena Wild dogs	Goats Cows Sheep Donkey			
	Lion Cheetah Hyena Wild dogs	Goats Cows Sheep Donkey			

Annex IV: sample plots GPS coordinates

Bomas	longitude	latitude
Ole Naonyisho	292227.000000	9699155.000000
Ole Kilasho	300402.000000	9698094.000000
Noolasit	298671.000000	9698315.000000
Ole Musenyi	297868.000000	9702512.000000
Nkuren	297735.000000	9702196.000000
Ole Saturu	304902.000000	9700173.000000
Mepukori	304789.000000	9700110.000000
Sainepu	304603.000000	9700151.000000
CB	303138.000000	9701358.000000
Meiseyieki	316493.000000	9693411.000000
Ntobirr	317154.000000	9693149.000000
Ole Koyo	318166.000000	9693512.000000
Enkarmama	319371.000000	9693573.000000
Nkaroyia	324263.000000	9700583.000000
Ole Kerri	324561.000000	9701037.000000
Keempwa	324648.000000	9700957.000000
Seyiai	324354.000000	9701059.000000
Leboo	324692.000000	9702545.000000
Kitoye	324392.000000	9702508.000000
Ntukai	324417.000000	9702669.000000
Sukari	324384.000000	9702686.000000
Montia	324377.000000	9702826.000000
Katatei	324980.000000	9702728.000000
Ole Kilankisa	316865.000000	9714576.000000
Orborrui	315810.000000	9714951.000000
Ole Rapei	303365.000000	9717880.000000
Ole Kureroi	312291.000000	9719782.000000
Olegei	311041.000000	9718749.000000
Ole Nairesiai	310408.000000	9719721.000000
Ole Nkukuu	312445.000000	9718725.000000
Ole Nteke	310251.000000	9720066.000000
Ntipapa	304086.000000	9718104.000000
Sairiamu	302228.000000	9718383.000000
Ormalimui	298149.000000	9720204.000000
Ole NaingÆanya	297936.000000	9720322.000000
Koole	291577.000000	9719289.000000