MODELLING FACTORS INFLUENCING THE CO-EXISTANCE OF PASTORALISTS AND CARNIVORES AROUND BOTSWANA MAKGADIKGADI/ NXAI PANS NATIONAL PARK

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ABSTRACT

Pastoralists and carnivores conflict is a major conservation and rural livelihood challenge given the high rate at which carnivores population decline and the high rate at which livestock is being depredated. The study aimed at determining the rate of livestock predation with respect to land use management, livestock management, and interaction of wild animals and livestock around Makgadikgadi/ Nxai Pans National Park to model factors influencing their co-existence. The study mostly followed quantitative approach even though a mixed method (a combination of quantitative and qualitative approach) using data from a survey questionnaire in appendix 1for primary data, and the Human Carnivore Conflicts (HCC) 2008-2012 Problem Animals Control (PAC) records in appendix 2 and the 1996-2013 DWNP biomass aerial surveys in appendix 3 as secondary data. A purposive sampling method was used to locate Gweta and Tsokatshaa villages sharing the border with Makgadikgadi Pans National Park to be areas of the questionnaire respondents. With the use of a snow ball process households of pastoralists with cattle posts in Tsokatshaa, Gweta North and Gweta South were identified. Data were analyzed using correlation, linear regression, log linear analysis, micro soft excel and ArcGIS 10.1 since they were from different sources and have to be presented in different formats.

The results from the questionnaire show that 1 of respondents to the questionnaire used land only for livestock production, and 98% definitely familiar with the concept of human wildlife conflicts and identified livestock predation as the main cause of livestock loss in their cattle posts. Pastoralists whose land of production is more than 21 km from the park and land only for livestock production experienced lower rates of predation compared to those land of production is less than 10 kilometers from the park and use their land for both livestock and crop production.

The high frequency of stay in production land that is only for livestock production also lowered the rate of livestock predation.

PAC data showed an increase of predation rate from 2008 to 2010 with most preyed livestock being cattle constituting 59% of the total preyed livestock. Pastoralists experienced higher livestock predation where livestock population were higher than wild prey ($p = 0.053 \approx 0.05$), where the population livestock population was higher than wild prey population and livestock and wild prey interacted frequently, and the availability of carnivores' is high. This is supported by the analysis of Department of Wildlife and Nation Parks (DWNP) aerial surveys 1996-2013 that shows both wild dogs, leopards and lions natural prey are far less than the corresponding livestock biomass as predation is density dependent (Okello, Kirinnge, & Warinwa, 2014). High predation was also experienced where there are many species of carnivores are found and many livestock species are preyed.

Pastoralist owning high the number and species livestock experienced high livestock predation $(p < 0.05)$ showing that minimizing the number and species owned can reduce predation. Herding and kraaling were identified to reduce the predation rates of cattle, goats, horses and donkeys supporting that reducing availability of livestock through effective livestock husbandry should lead to reduced conflict (Valeix, Hemson, Loveridge, & Macdonald, 2012). Calving and watch dogs showed significance in reducing cattle and goats predation respective.

To promote good pastoralists and carnivores' co-existence pastoralists should use land far from the park, stay in their land of production and use it only for one purpose. The population and interaction livestock and wild life should be controlled to minimize predation in the area. The number and species of livestock should be minimized, and practicing herding, kraaling, calving

and using watch dogs to prevent predation in the area hence promoting the co-existence of pastoralists and carnivores.

Key words: Makgadikgadi/ Nxai Pans National Park **,** human carnivore conflict, pastoralists, carnivores, pastoralists-carnivore conflict, livestock, livestock predation, livestock predation rate, wild prey, land use management, species interaction, livestock husbandry, pastoralists and carnivores' co-existence

DISCLAIMER

I declare that this dissertation submitted to School of Graduates, University of Botswana in partial fulfillment of MASTERS IN DEVELOPMENT PRACTICE (MDP) is my own original work and have not been submitted before to any institution for assessment nor publishing purposes. Furthermore, I have acknowledged all sources used in a comprehensive reference section.

Signature: …… Date: ……..

DEDICATION

I dedicate my dissertation work to Jesus Christ because it was through His love that I completed my work. This work is also dedicated to my family and friends whose words of encouragement supported me throughout the process of the study.

THESIS OUTLINE

This thesis is divided into five chapters; Chapter 1 introducing factors influencing the co-existence between pastoralists and carnivores, Chapter 2 reviewing the literature on factors influencing co-existence between pastoralists and carnivores, Chapter 3 discussing the methods used for data collection and analysis, Chapter 4 analyzing and discussing the findings of collected data and Chapter 5 concluding the findings from the study and giving recommendations based on the models drawn from analysis.

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Chapter 1: INTRODUCTION

Co-existence is the state of two or more species being found together in the same place at the same time and however co-existence often reflects the impacts of interactions among species (Holt, 2001).Interaction between species refers to positive and negative associations between species that favor or inhabit mutual growth and evolution populations. It may take the form of competition, predation, parasitism, commensalism or mutualism (Glossary of Environment Statistics, 1997). As species do not exist in isolation but interact with resources, competitors, mutualists and natural enemies (MacArthur, 1972), developing theoretical and empirical tests of spatially explicit multispecies interactions is a contemporary challenge in ecology. While theory of spatiotemporal multispecies interactions is well developed, there are few experimental tests of this theory using highly resolved spatial and temporal data of multiple species involved in indirect interactions; interactions between two species mediated by a third species or other controlling factors. A complete understanding of co-existence requires considering both direct and indirect interactions (Holt, 2001). In addition, the balance of positive and negative characteristics associated to carnivores varies from species to species and with time and place (Hassell et al, 1991, 1994; Holt, 1997; Loveridge et al, 2002). It is clear that even though approaches that are used in other places are used as references, there is no single approach that will guarantee the co-existence of carnivores with people throughout Africa or elsewhere (Loveridge et al., 2002).

Predator-prey interaction have been a sample of ecological modeling, laboratory and field studies since the class papers of Alfred Lotka Vito Voltera in the late 1920s (Roger et al, 2012). The interaction between pastoralists and carnivores is mainly competition thus each species is

affected by the other negatively but the interaction is directly derived by carnivore predation on livestock (Berger, 2006). Therefore, the interaction is between pastoralists and carnivores conditioned by the interaction between carnivores and livestock. Furthermore, the interaction between carnivores and livestock (predation) can be mediated by land use management, interactions of livestock and wildlife (both carnivores and wild prey), and livestock management.

The conflict between human and carnivore is assumed to have existed since Homo-sapiens first domesticated ungulates and that competition between man and predators is perhaps older still (Kruuk, 2002). Similarly, in 2002 a workshop on Lion Conservation Research indicated that worldwide, the big issue with carnivores is livestock raiding inclusive of both large and smaller carnivores (Loveridge et al, 2002). The levels of livestock loss due to predation have been shown to influence conflict and are exacerbated further if the stock concerned is particularly valuable; has cultural or financial significance (Mech, 1981; Sillero-Zubiri & Laurenson, 2001). According to Inskip and Zimmermann (2009), conflict between human and predators is an urgent conservation issue worldwide. The last decades of the 20th century were witness to a dramatic turnaround in policy towards the environment and biodiversity with a range of national and international legislation passed which has committed most of the countries to environmental conservation and its associated biodiversity (Martino & Zommers, 2007). Despite a focused link of biodiversity conservation and human wellbeing, many countries are struggling to implement these conventions the reason being that many species can create direct and severe conflicts with human interests (Thomassen et al, 2011). For pastoralists and carnivores interactions, this conflict typically occurs when wild carnivore prey on livestock and the people affected kill or harm the carnivore. This makes conservation of carnivores problematic because it often places those who wish to restore carnivore population at odd with others who experience economic

losses from livestock predation (Berger, 2006). However, as human populations have grown and countries developed the competition for natural resources have stiffened this conflict has increased but technological advances have given man a considerable competitive advantage over large carnivores as there are many ways to kill carnivores (Hemson, 2003). Large carnivores face serious threats and are experiencing massive declines in populations and geographic ranges around the world (Ripple et al., 2014). Despite the decrease in the population carnivores, the conflict between human and carnivores is increasing worldwide (Nowell & Jackson, 1996; Frank 1998). Consequently, the status and viability of an increasing number of wild populations and species which conflict with humans and their crops and livestock has become questionable (IUN, 2003). The relationship between the rate of pastoralist and carnivore conflicts with the number of carnivores mathematical should be directly proportional of which is not the case as supported by simple interactive model- linear intake function (Owen-Smith, 2007) which derive that the larger the herbivores biomass, the greater the reduction in the amount of vegetation remaining after consumption with herbivores substituted to carnivores and vegetation to livestock respectively. To understand, communicate and clearly predict the conflict an abstract representation of the situation need to be drawn.

According to the General Predator-Prey model (Freedmann, 1980; Brauer & Castillo-Chavez, 2000), the population of the prey species (including livestock) and carnivores increase their numbers when resources are not limiting according to the law;

$$\frac{dN_{prey}}{dt} = k_{\Pr ey} N_{\Pr ey}, \ \ prey = 1,2,3.... \qquad (1)$$

($prey$ stands for any given prey species, k_{prey} the growth rate of prey as time goes on, N_{prey} is the number of a given prey, dN_{prey} is the change in number of a given prey, dt is the change in time and hence $\frac{dN_{prey}}{dt}$ is the change in number of a given prey with respect to time)

Equation (1) implies if there are no carnivores, as long as there is sufficient food and water the population of the prey grows exponential.

The General Predator-Prey model further explains that, the population of carnivores in the absence of prey declines according to the law;

$$\frac{dN_{car}}{dt} = -k_{car}N_{car},\ car = 1,2,3... \qquad (2)$$

(car are different types of carnivore species, k_{car} is the growth rate of carnivores, N_{car} is the number of different carnivores, $\frac{dN_{car}}{dt}$ is the change in the number of carnivores with respect to time)

When the two (prey and carnivores) interact without resources limiting according to equation 1 and 2;

Prey model becomes $\frac{dN_{prey}}{dt} = (k_{prey} - \beta_{prey}N_{car})N_{prey}, prey = 1,2,3..., car = 1,2,3...$ (3)

($-\beta_{prey}$ is the negative growth of the prey as a result of the interaction rate of the prey and carnivores and proportional to prey consumed by carnivores)

Carnivores' model becomes $\frac{dN_{car}}{dt} = (-k_{car} + \beta_{car} N_{prey}) N_{car}, car = 1,2,3..., prey = 1,2,3...$ (4)

(β_{car} is the interaction rate of carnivores and prey which brings a positive growth rate of the carnivore because it reduces the rate of carnivores' deaths due to starvation). This system is often called the Lotka Volterra model (Alfred Lotka, 1925).

When resources are limiting both the prey and carnivore's population growth rates decline;

The growth rate of the prey without interaction with the carnivores will be reduced and the equation (1) becomes

$$\frac{dN_{prey}}{dt} = j_{\Pr ey} N_{\Pr ey} \quad (5)$$

for $j_{prey} < k_{prey}$ or $j_{prey} = k_{prey} - f_{prey}$, $f_{prey} \geq 0$, f_{prey} is the effect of resources limitations on the prey growth rate and j_{prey} is the growth rate of prey when resources are limiting.

Similarly, the growth rate of the carnivore will be reduced when resources are limiting and equation (2) becomes

$$\frac{dN_{car}}{dt} = -l_{car} N_{car} \quad (6)$$

for $-l_{car} < -k_{car}$ or $l_{car} > k_{car}$, $-l_{car} = -k_{car} - f_{car}$ and f_{car} is the effect of resources limitation on carnivores' growth rate.

The interaction of the prey and carnivores when resources are limiting further reduces the growth of the prey and from equation (3), the prey model becomes;

$$\frac{dN_{prey}}{dt} = (k_{prey} - f_{prey} - \beta_{prey} N_{car}) N_{prey} = (j_{prey} - \beta_{prey} N_{car}) N_{prey},\ prey = 1,2,3..., car = 1,2,3...,\ j_{prey} = k_{prey} - f_{prey} \quad (7)$$

The carnivore model too will have a decreasing factor from resources limiting and becomes;

$$\frac{dN_{car}}{dt} = -(k_{car} + f_{car} - \beta_{car} N_{prey}) N_{car} = -(l_{car} - \beta_{car} N_{prey}) N_{car},\ car = 1,2,3...,\ prey = 1,2,3...,\ l_{car} = k_{car} + f_{car} \quad (8)$$

From equation (3) and (4), one can figure out that the interaction negatively affect prey. Limiting factors further negatively increase the growth of prey according to equation (7) and (8) increasingly leading to the affected farmer having conflict with the carnivores if the affected prey is livestock.

The rate of these conflicts appears to be increasing in many areas (Treves & Karanth, 2003) because of human population growth coupled with wealth creation and agricultural practices are presenting threat to many carnivores' species. Worldwide, populations of lions, cheetahs, spotted hyenas, tigers, snow leopards, jaguars, grey wolves, wild dogs and other species continue to decline mainly due to conflict with people (Ginsberg & Macdonald, 1990; Nowell & Jackson, 1996; Hofer, 1998 & Landa et al., 1999). Africa's large carnivores have declined over the last 30 years with several species listed as threatened by the World Conservation Union (Woodroffe et al, 2005; Winterbach et al, 2014). Large carnivores have disappeared from areas of high human density, and the species mostly exposed to human conflict are more prone to extinction (Woodroffe, 2001). Human-wildlife conflict is most prevalent around protected areas, where wildlife populations are greatest and between protected areas where migratory corridors cross unprotected community land (Spira, 2014). It is against this high rate of predation around protected areas that the influence of land use management, interactions of livestock and wildlife (both carnivores and wild prey), and livestock management on the rate of predation is assessed.

Understanding patterns associated with predation can be used to mitigate its effects and promote more stable coexistence of carnivores and humans (Patterson et al., 2004). Similarly, identifying the factors that influence coexistence was classified as fundamental to understanding biodiversity and these important factors include inter specific interactions, spatial and temporal scales (Holt, 2001).

Co-existence between human and carnivores in rural landscapes mainly depends on the extent to which conflicts between carnivores and livestock can be avoided (Fascione et al., 2004). For this reason, reducing the rate of depredation on livestock by carnivores lowers the mortality rate of carnivores that result from their depredation (Ogada et al., 2003). The land use (Mwakatobe et al., 2013; Larson, 2008), interaction between livestock and wildlife (Kala & Kothari, 2013; Mishra, 1997) and livestock management (Woodroffe et al., 2005) have effects on the rate of livestock depredation and hence on the rate of carnivores killed. Good application of the three results in an improved co-existence.

1.1 The influence of land use management on the rate of human carnivore conflicts

Conservation areas cannot contain carnivores without addressing the problems they cause in the neighboring farm land (Van der Meulen, 1977; Mills et al., 1978; Stander, 1990 and 1993), especially where the intensity of pastoralist increases (Van der Meulen, 1977; Anderson, 1981; Stander, 1990; Mesochina et al., 2009; Pellerin et al., 2009). The rapid encroachment of human activities on carnivore habitat leading to the reduction of wilderness as a whole increases the interface between humans and carnivores leading to poor co-existence with large carnivores triggered by livestock depredation (Sisk et al., 1994) especially lions (Chardonnet, et al., 2010). While there are many ecological factors that regulate the levels of conflicts, the intensity of

conflicts is primarily affected by land use zoning and characteristics of attacked farms, villages and livestock enclosures (Meriggi & Lovari, 1996). Human and carnivore conflicts are therefore in many regards a form of land use conflict. Grazing in distance pastures from households has been found to increase the rate of livestock predation and households that graze their livestock in forests near the village suffer fewer losses due to predation (Jackson, 1996). In addition to distance from households, rate of predations is characterized by hotspots close to protected area or reserve borders and decrease with increase in distance to a reserve (Schiess-Meier, Damsauer, Gabanapelo, & Konig, 2007). For example, predators attacked livestock that are grazed in or closed to Jigme Singye Wangchuck National Park central Bhutan (Wang & Macdonald, 2006). To authors such as Madden (2004), human wildlife conflict is increasing in frequency and severity and will probably continue to escalate which contradicts the direct proportionality between number of carnivores and the rate of interaction with human activities.

Agricultural Influence

Agricultural encroachment on carnivore ranges demonstrates the importance of agriculture in sub-Sahara Africa for rural and urban populations; agriculture provides approximately 40% of gross domestic product in sub Saharan Africa and employs over 60% of the labor force (Pye-Smith, 2012). In 2005, Food and Agricultural Organization (FAO) estimated the area of forest exploited or converted to arable land in 1990-2000 to be 5.5 million hectors, an annual rate of loss twice as high as that of South America (FAO, 2005). The spread of cultivated areas near protected areas is rapid: the W-Arly-Pendjari complex in West Africa, for example, has lost 14.5% of its savannah vegetation within 30 kilometers of protected area boundaries (Clerici et al., 2005).

In West and Central Africa, the distribution of carnivores is convergent with cotton growing zone. In several African countries, cotton is the main source of national income and a major tool for rural development. The environmental impact of cotton is difficult to establish because of the complex interaction between development and conservation (Burni & Ghisalberti, 2001). The crop also has harmful consequences for biodiversity, notably; the race for space in the expansion of cotton growing areas into natural habitats, the considerable increase in the case of plant pesticides and fertilizers and competition with cattle herders who are tempted to penetrate into protected areas to find alternative grazing land. Like cotton, sorghum exerts pressure near Botswana protected areas such as Makgadikgadi which is less dominant carnivore stronghold for the country.

Pastoralist affect carnivore habitats mainly through conversion of savannah into grazing range for livestock. In sub Saharan Africa, the population of domestic herbivores is increasing steadily; the grazing area expanded by 0.46% per year between 1970 and 2000 (Chardonnet, et al., 2010). As a result of human demographic growth, the per capita area of grazing land fell from 2650 hectares per inhabitant in 1970 to 1166 hectares in 2000, reflecting the major economic and environmental modifications that the husbandry sector is undergoing today (Tacher, 2002).

The most prevalent land use in Makgadikgadi areas are; conservation areas (parks and photographic areas CT11), pastoral, arable and residential. This land is mostly under tribal or communal land tenure, with which agriculture is the principal form of land use. Livestock production is widespread across the region and population of livestock is increasing (Statistics Botswana, 2014), with arable development more spatially confined. The predominant competing

types of land use in the Makgadikgadi are Pastoral farming (communal farming) and land for wildlife conservation.

1.1. The influence of species interaction on the rate of human carnivores conflicts

The interaction between livestock and wildlife species brings negative impacts to both livestock and wildlife species through; predation, competition for limited resources or transmission of diseases between them (Andrewartha & Birch, 1954). These lead to wide spread conflicts between peole and wildlife over livestock resuling on damage to both people and wildlife involed (Redpath, Bhatia, & Young, 2014). The interaction of livestock and wild herbivores (wild prey) is competition interaction and the interaction of wild carnivores (wild predator) and livestock is a predator-prey interaction.

Influence of carnivore population on the rate of human carnivores conflicts

When the population of carnivore is increased, their predation in the prey increases. This increases the probability of interaction with livestock hence increasing the rate of livestock predation. If there is no interaction between carnivores and prey, carnivores further decrease and from equation 2 the growth rate of carnivores becomes;

$$\frac{dN_{car}}{dt} = -k1_{car} N_{car} \qquad (9)$$

For $-k1_{car} < -k_{car}$ the growth rate of carnivores. When the prey is available, high carnivores' population increases the interaction rate between carnivores and prey including livestock, the prey model becomes;

$$\frac{dN_{prey}}{dt} = (k_{prey} - \beta 1_{prey} N_{car}) N_{prey} \quad (10)$$

From equation 3 the interaction which is directly proportional to predation rate (Maleko et al., 2012), $\beta 1_{prey} > \beta_{prey}$. Since $(k_{prey} - \beta 1_{prey} N_{car}) \Rightarrow 0$, the interaction rate $\beta 1_{prey}$ being very high implies

$$\frac{dN_{prey}}{dt} = (k_{prey} - \beta 1_{prey} N_{car}) N_{prey} \Rightarrow 0 \quad (11)$$

Since livestock is part of prey, the increase in prey depredation result in human carnivore conflict as the number of livestock preyed is directly proportional to human carnivore conflict (Ogada et al., 2003).

When the population or growth rate of carnivores is low from equation 3, $-k_{car} > -k2_{car}$, the interaction of carnivores and prey including livestock becomes $\beta 2_{prey}$ for $\beta 2_{prey} < \beta_{prey}$. Since $\beta 2_{prey}$ is very low, from equation 3

$$\frac{dN_{prey}}{dt} = (k_{prey} - \beta 2_{prey} N_{car}) N_{prey} \Rightarrow k_{prey} N_{prey} \quad (12)$$

because $(k_{prey} - \beta 2_{prey} N_{car}) \Rightarrow k_{prey}$ for $\beta 2_{prey}$ very low. For this case the rate of conflict will be very minimal because they will be low interaction of livestock and carnivores which is identified as the leading factor for human carnivore conflict.

Influence of wild and domestic prey interaction on the rate of human carnivore conflict

Rate of livestock depredation by carnivores can be influenced by local environmental conditions such as abundance of natural prey such as wild prey (Kolowski & Holekamp, 2006). A mathematical model that gives conditions under which the two species that compete for food and space coexist is estimated by, letting N_{prey1} be wild prey and N_{prey2} be domestic prey. Their rate of change due to their interaction is demonstrated by equations;

$$\frac{dN_{prey1}}{dt} = (a - bN_{prey1} - eN_{prey2})N_{prey1} \quad (13)$$

$$\frac{dN_{prey2}}{dt} = (c - dN_{prey2} - fN_{prey1})N_{prey2} \quad (14)$$

Here $\frac{dN_{prey1}}{dt}$ and $\frac{dN_{prey2}}{dt}$ are the growth rates of wild and domestic (livestock) prey respectively. $a, b, c, d, e,$ and f are positive constants showing that there is interaction. This model is derived from the Lotka Volterra model now including competition within individual species (species of the same characteristics).

To determine the point of co-existence of the two species, first step is to determine the equilibrium points for the system;

i. $N_{prey1} = 0$ and $N_{prey2} = 0$ is an equilibrium point $(0,0)$ both species have become extinct. At this point there is no interaction therefore the human carnivore conflict will be

nullified. This point is not of interest because there will be no pastoralism without livestock and no park without wild prey.

ii. $N_{prey1} = 0$ and $N_{prey2} \neq 0$. The right hand side (RHS) of equation (14) becomes 0 if and only if $c - dy - fx = 0$. Since $x = 0$ therefore $c - dy - f0 = 0 \Rightarrow c - dy = 0 \therefore y = \frac{c}{d}$. At this point the only prey will be livestock hence increasing rate of carnivore preying on livestock which leads to high rate of human carnivore conflict. This point is not of interest because the area of study is around a national park and wild preys do exist in the park.

iii. $N_{prey1} \neq 0$ and $N_{prey2} = 0$ the right hand side of equation (13) becomes 0 if and only if $a - bN_{prey1} - eN_{prey2} = 0 \Rightarrow a - bN_{prey1} = 0$ since $N_{prey2} = 0 \therefore N_{prey1} = \frac{a}{b}$. At this point the only prey will be wild prey since they will be no domestic prey. This point is not of interest because the main agricultural practice around Makgadikgadi is pastoral farming and this practice will not exist without livestock.

iv. The point of interest is where both $N_{prey1}, N_{prey2} \neq 0$ or where species of prey co-exist. This implies solutions of equation 15 and 17

$$(a - bN_{prey1} - eN_{prey2})N_{prey1} = 0 \quad (15)$$

from equation 13 can only be calculated from

$$(a - bN_{prey1} - eN_{prey2}) = 0 \quad (16)$$

and

$$(c - dN_{prey2} - fN_{prey1})N_{prey2} = 0 \quad (17)$$

from equation 14 can only be calculated from

$$(c - dN_{prey2} - fN_{prey1}) = 0 \quad (18)$$

Solution from equation (16) and (18) becomes

$$(N_{prey1}, N_{prey2}) = (\frac{ad - ec}{bd - ef}, \frac{bc - af}{bd - ef}) \quad (19)$$

This is the point where $N_{prey1}, N_{prey2} \neq 0$ hence the co-existence point.

The growth rate of livestock prey is greater than wild prey if $ad - ec < bc - af$ from equation (19) hence making the probability of carnivore interacting with livestock prey higher than with wild prey leading to high rate of human carnivore conflict. Based on equation 3,

$$\frac{dN_{prey1}}{dt} = (k_{prey1} - \beta 3_{prey1} N_{car})N_{prey1} \quad (20)$$

and

$$\frac{dN_{prey2}}{dt} = (k_{prey2} - \beta 4_{prey2} N_{car})N_{prey2} \quad (21)$$

with $\beta 3_{prey1} < \beta 4_{prey2}$ showing that carnivores negatively affect livestock more than wild prey.

In contrary, for $ad - ec > bc - af$ in equation (19), makes $\beta 3_{prey1} > \beta 4_{prey2}$ showing a higher growth rate of wild prey than livestock prey. At this point the probability of carnivore interacting with livestock is lower than the probability of carnivore interacting with wild prey. This is a point needed by both the pastoralists and wild life conservation (Maleko et al., 2012) as a

controlled livestock and carnivores interaction. The reintroduction of wild prey has been advocated for as a means of reducing the rate livestock predation but predation on livestock may remain high if domestic ungulates (livestock) are locally abundant (Meriggi & Lovari, 1996). Prey availability governs the movements, abundance and population viability of carnivores (Hayward et al., 2007). The role of alternative wild prey species in reducing livestock predation is approximate and sketchy. It is thought that the presence of wild prey may reduce the frequency on livestock predation. The logic behind this concept is appealing into conflict mitigation recommendations (Hoogestein, 2000) there is a need to investigate this relationship in more detail.

Human wildlife conflicts are escalating and negatively affect conservation strategies and land management. The causes of Human wildlife conflicts are adverse and it is important to consider ecological, human and land use factors. According to Stander (1997), lions living in areas with livestock appeared to prey mainly on wild prey species and livestock predation was infrequent.

1.2. The influence of livestock husbandry on the rate of human carnivore conflict

Livestock carnivore predation and resultant pastoralists carnivore conflicts have been related to livestock management strategies in areas such as Nepal (Oli et al., 1994), Namibia (Marker, 2002), Kenya (Ogada et al., 2003) and Brazil (Conforti & De Azevedo, 2003). Similarly, rate of livestock depredation by large carnivores can be influenced by socio ecological factors including livestock husbandry practice (Meriggi & Lovari, 1996). Many different livestock management practices are employed to prevent livestock predation in different areas of the world, from hi-technology solutions such as toxic collars and the use of electric fence to low technology traditional solutions such as herding, kraaling and the use of guard dogs (Landry, 1999; Ogada et

al., 2003). Effective livestock management practice reduces the rate of livestock interaction with carnivore hence making the fraction of livestock interaction rate in the β_{prey} very small. This implies that the probability of carnivore interaction with livestock goes to zero resulting in no depredations (Tsishchanka, 2010). Therefore from equation (3) $\frac{dN_{prey}}{dt} = (k_{prey} - \beta_{prey} N_{car}) N_{prey}, prey = livestock$ goes to

$$\frac{dN_{prey}}{dt} = k_{prey} N_{prey} \tag{22}$$

since β_{prey} goes to zero and this is a point of good human carnivores coexistence (Ogada et al., 2003).

Poor livestock management practice increases uncontrolled interaction rate of livestock and carnivore resulting in high rate of carnivores preying on livestock (Maleko et al., 2012) leading to a negative growth of livestock. Therefore the livestock growth model becomes;

$$\frac{dN_{prey}}{dt} = (k_{prey} - \beta_{prey} N_{car}) N_{prey} = -\rho N_{prey}, prey = livestock \tag{23}$$

$-\rho$ shows a negative growth rate of livestock since $\beta_{prey} N_{car}$ (livestock and interaction rate) is very high leading to high rate of predation. When $k_{prey} < \beta_{prey} N_{car}$ increases human carnivore conflicts (Tsishchanka, 2010; Ogada et al., 2003). Studies in the East Africa suggest that livestock predation occurs predominately at livestock enclosures (Frank, 1998; Kruuk, 1980) while Stander (1997) in his work in Namibia suggests most predation occurs away from the enclosures.

Extensive management, where livestock ranges unattended over wide areas, has been linked to higher livestock predation rate (Conforti & De Azevedo, 2003), while herding, use of guard dogs and keeping stock in well-made kraals at knight have proved effectiveness in reducing depredation (Linnell et al., 1996; Ogada et al., 2003). Identifying which livestock husbandry is effective can help pastoralists to implement the most efficient ways of protecting their livestock, thereby reducing conflict with carnivores and promoting pastoralists carnivores stable co-existence.

The core problem is lack of understanding how poor land use management, poor species (carnivores, wild prey and livestock) interaction and poor livestock management influence poor co-existence fueled by livestock predation by the carnivores. They are three main factors looked upon as Makgadikgadi is concerned, thus; land use management (Mwakatobe et al., 2013; Larson, 2008), carnivore, wild prey and livestock interaction (Kala & Kothari, 2013; Mishra, 1997), and livestock management (Woodroffe et al., 2005) factors therefore all components can be grouped according to the three. This derived a frame work of the study as defined as a way of packaging and positioning an issue so that it conveys a certain meaning (Menashe & Siegel, 1998) and as a process by which someone packages a group of facts to create a story (Wallack et al., 1993).

1.3. Statement of the Problem

Populations of lions (panthera leo), jaguars (panthera onca), tigers (panthera tigris), eurasian lynx (lunx lynx), iberian lynx (lynx pardinus), snow leopards (uncia uncia), and cheetah (acinonyx jubatus) and several other carnivore species continue to decline at least in part, if not largely due to conflict with human (IUCN, 2003; Nowell and Jackson, 1996). Conflicts between carnivores

with human (pastoral farmers) over livestock have been and still a key factor of large carnivore population decline (Hazzah, 2006; Romanach et al., 2007). This decline in population sizes and distribution of carnivores in Africa because of retributive killings has resulted in some species being increasingly limited to protected areas. Large African land carnivores, some of which are close to the boarder of extinction, may be viewed upon by many as figures of natural beauty. However, for those who are forced to live alongside large carnivores and for those who rely on livestock farming as livelihood, large carnivores may be seen as nothing more than a nuisance. According to a study covering Botswana, Kenya, South Africa, Tanzania, Uganda, Zambia and Zimbabwe most of human carnivore conflicts are influenced by livestock predation (Thavarajah, 2008).

In Botswana, like other countries, populations of large carnivores are sources of conflict with livestock owning people. According to Hemson (2003), many large carnivore populations are under threat from persecution for killing livestock. Some of these large carnivores prey upon livestock cause economic damage and bad will frequently leading to their destruction (Mills, 1998; Mills, 1991; Nowell & Jackson, 1996; Webber & Rabinowitz, 1996). Negative attitudes towards carnivores are often related to economic loss (Lindsey et al., 2005) as a result a small livestock loss to predation is significant to small scale producer (Swarner, 2004; Butler, 2000).

Conservation of large carnivores is necessary because they play an essential role in proper ecosystem functioning by regulating herbivore numbers (Pace et al., 1999) and play an important role as scavengers that clear the veldt of dead carcasses. Carnivores are also source of revenue through tourism attraction. Tourism is an important economic activity in Botswana as it ranked high in contribution to Gross Domestic Product (GDP) (Mbaiwa, 2003). The government has put

in place management and mitigation interventions aimed at reducing attacks on livestock and improving community attitudes towards conservation. The existing interventions include community outreach on husbandry practices, construction of electric game proof fences, nonlethal carnivore control measures and compensation policy to reduce attacks on livestock and improve community attitudes towards conservation. Despite these efforts and a declined number of carnivores, carnivores' predation on livestock is still high and human-carnivore conflicts prevail in cattle posts around Makgadikgadi Pans National Park. Developing appropriate strategies in reducing pastoralists' carnivore conflict, first requires assessing factors associated with that conflict (Karanth et al., 2013). Understanding factors influencing co-existence and applying the efforts to reduce the rate of livestock predation based on the declined number of carnivores (World Resources Institution, 2003) could positively improve human carnivore co-existence by reducing livestock predation rates. Similarly, (Thorn et al., 2012) stressed that effective conflict mitigation require knowledge and understanding of underlying human and environmental conflict drivers. However, few studies have concurrently investigated the influence of both environmental and socio ecological factors on livestock depredation, and fewer have combined this knowledge (Kolowski & Holekamp, 2006).

1.4. Mathematical Preliminary

Minimizing livestock and carnivores interactions promotes human and carnivores co-existence (Linnell, 2013). As a result it is important to control livestock and carnivores interactions to harmonize and stabilize the two sections (Maleko et al., 2012). Based on equation 3, the value of β_{prey} in which prey is livestock need to be minimized such that $k_{prey} - \beta_{prey} N_{car} \approx k_{prey}$. This result in

$$\frac{dN_{prey}}{dt} \approx k_{prey} N_{prey} \quad (24)$$

Showing that livestock being the only prey would grow at a higher rate without interactions with carnivores. Theoretical good land use management, good species interactions and good livestock husbandry minimize livestock and carnivores' interactions hence reduce the rate of carnivores' predation on livestock resulting in good co-existence.

1.5. Theoretical Framework

Theoretical framework is structured to support theory of the study as a result it hypothetical and systematic way of organizing investigations of a study (Shields & Tajalli, 2006). As a result this introduces and describes theory explaining co-existance of pastoralists and carnivores and why the research problem exists. This study was guided by Malthusian theory and Social Constructivist theory based on the following;

1.5.1 Malthusian theory

Since co-existence of pastoralists and carnivores is guided by population, environment and development interactions; the relationship between pastoralists and carnivores' population growth rates increase exponentially based on the birth rate and arithmetic increase of environmental resources can lead to pastoralists and carnivores' population outgrowing their environmental resources making the co-existence of the two difficult (The Johns Hopkins University, 2006). The research need to derive an optimal interaction of these variables promoting good co-existence of pastoralists and carnivores.

1.5.2 Social Constructivist theory

Co-existence can be easily understood by pastoralists using new information and experiences interactively hence the need to recognize importance of prior knowledge and experiences (Mahuika et al., 2011). This has led to pastoralists being given the opportunity to construct their own meaning of their co-existence with carnivores by being involved in the survey as they can provide analytic feedback.

1.6. Conceptual Framework

The concept of framing has been important in research (Tannen, 1993) on which individuals and institutions draw in order to give meaning, sense and direction to people's thinking (Schon & Rein, 1995). Based on the broadly shared perspectives familiar to members of society and researchers as depicted from the literature review, variables constituting to pastoralists-carnivores co-existence represent the overlapping and intertwining of many relations but to give them a meaningful direction the research is bounded as shown in Figure 1.7.

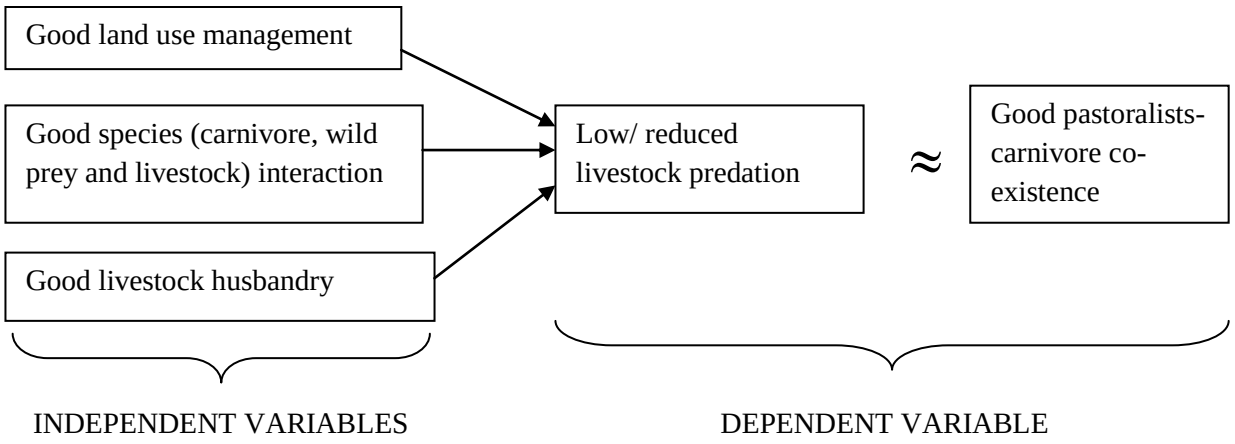

Figure 1.7: **Conceptual frame work**

Core Problem

Lack of understanding how land use management, species interctions and livestock husbandry influence the co-existence between pastoralists and carnivores despite declined number of carnivores and existing human carnivores' conflicts' mitigation strategies.

General Question

Does land use management, species interactions and livestock husbandry influence co-existence between pastoralists and carnivores around Makgadikgadi/ Nxai Pans National Park?

General Objective

To assess how land use management, species interctions and livestock husbandry influence co-existence between pastoralists and carnivores around Makgadikgadi/Nxai Pans National Park.

Specific Objectives

To achieve the main/general objective, the study is divided into three specific sectors constituting to the general objective not necessarily equal in the degree of contribution to the general objective. Specifically the study aimed;

1. To assess how land use management influences the co-existence between pastoralists and carnivores.
2. To assess how species interaction influences the co-existence between pastoralists and carnivores.
3. To assess how livestock husbandry influences the co-existence between pastoralists and carnivores.

Research Hypothesis

I hypothesized that;

1. Land use management negatively affects co-existence between pastoralists and carnivores around Makgadikgadi Pans National Park.
2. Species interaction negatively affects co-existence between pastoralists and carnivores around Makgadikgadi Pans National Park.
3. Livestock husbandry negatively affects co-existence between pastoralists and carnivores around Makgadikgadi Pans National Park.

Significance of the Study

In this study, land use management, species interctions and livestock husbandry influence on the co-existence of human and carnivores are examined and integrated to come with a proper model to reduce human carnivore conflict in Makgadikgadi. The interaction of human, livestock, wild prey and carnivores is seen as a collection of elements that are interrelated and that interact with one another. All the elements which contribute substantially to its inputs and outputs are included in the system. Pastoralists and carnivores interaction is one of the few experimental tests of interactions using highly resolved spatial and temporal data of multiple species involved in indirect interactions; interactions between two species mediated by a third species or other controlling factors. Areas around Makgadikgadi are special since they are near protected areas and there is no integrated human-carnivore study that had ever been studied there. Most of studies on human carnivore conflicts are mainly based on ecological factors or looking at a particular carnivore, for example; the study on behavioral adjustments of a large carnivore to

access secondary prey in a human-dominated landscape which was on the ecological behavior of lions in Makgadikgadi. The study take into consideration that some carnivores like leopards also prey directly on jackals and caracal. However if the leopards are removed the latter two predators' numbers increase. Predation on livestock varies regionally based on factors specific to each particular region (Miller, 2013). Hemson 2003, argues that each geographic location is characterized by unique economic, ecological, political and sociological outline that could eventually regulate the potential for mitigation to succeed. Any attempts to mitigate human carnivore conflict and improve the conservation of the culprit species and other wildlife should be based on an explicit understanding of the conflict patterns. However, many studies indicate that conflict is mostly common amongst communities residing in the vicinity to protected areas (Hemson, 2003; Wang & Macdonald, 2005).

The study gives a mathematical opinion in the formation of strategies that promote co-existence between pastoralists and carnivores. It helps to predict the outcomes of the interaction if variables are changed therefore it works as a formula or model for interaction. It is hoped that the results and recommendations of the study will be used to;

1. Identify ways of reducing conflicts between the people and wildlife not only carnivores nor only around Makgadikgadi Pans National Park but in other protected areas.
2. Provide information to policy makers.
3. Improve local community and park management relationships.
4. Provide significant information that will be used as a reference point to other studies in the related field.

Deciding on the focusing and scoping of the research

Based on the seven criteria; relevance, avoidance of duplication, urgency of data needed, feasibility of study, applicability of results, ethical acceptability, and political acceptability of study the research topic is fit to be investigated (Goyal, 2013). The judgment of topic according to these guidelines is as follows;

1. Relevance: Makgadikgadi area recorded a cumulative high number of wildlife destruction cases from PAC data recorded from 2001 to 2012 which by reference from the literature is the main contributor to human wildlife conflicts of which human carnivore conflicts are a sector and in most of the cases endangered species are involved. The community, wildlife, agricultural, health and department of wildlife and national parks are affected by the current situation hence making it relent to carry out the research that would work as a guide for them to make an informed decision concerning the interaction.

2. Applicability: The losses incurred by the Department of Wildlife and National Parks (DWNP) and farmers make the results of the research applicable because the current interaction of the livestock and carnivores brings conflict between the two. This result in people inputting more for them to produce less thus making a loss and some of the carnivores are on the verge of extinction hence reducing tourism baits. Pastoralists always want to break even for their products and this can be achieved by applying best interaction model between factors influencing human carnivores' conflicts.

3. Feasibility: The researcher needed no extra personnel to collect or analyze data and the data from the sample was through interview questionnaire which made the process

feasible within the allocated time. No extra equipment and funds were required to complete the research.

4. Urgency: If the results of the research are not applied some carnivores will face extinction and the socio economic status of the people in the study area will deteriorate and increasing number of feed baskets from the government therefore it was urgent to carry out this research for it to advice on the optimal co-existence of human and carnivores.

5. Ethical acceptability: No animals were caught or injured during the study-they were no direct contacts between the researcher and animals of concern. The questionnaire that was used for the study was in a way that even the researcher could not recognize the interviewee after interviews. The questionnaire was nameless. The objective of the study was explained to the informants and respondents who would then decide on whether to participate or not.

6. Political acceptability: The community and the department of wildlife and national parks are affected by the human carnivores' conflicts negativity and all need the model that would make the interaction positively benefit the two parties. As circumstances vary (Loveridge. et al, 2002; Rust, 2015), the Makgadikgadi people need to understand, predict and sustainably control livestock predation in their specific area.

7. Avoidance of duplications: Even though studies on human carnivores conflicts have been done most of them were looking on one or two factors causing the conflict no study have been done on the integration of land use, human and ecological factors influencing the

rate of human carnivores conflicts. There is no study has been done on co-existence between pastoralists and carnivores in areas around Makgadikgadi Pans National Park and according to Miller in 2003 predation on livestock varies regionally based on factors specific to each particular region. The behavior of carnivores and patterns of livestock predation varies from species to species and with time and geographic locations (Loveridge. et al, 2002; Rust, 2015).

Chapter 2: LITERATURE REVIEW

This chapter reviewed previous research on pastoralists and carnivores' interactions that provides information promoting pastoralists and carnivores' co-existence. It shows how land use management, species interactions and livestock management had been studied at global, regional and local levels as a result it reviewed studies investigated the effects of variables related the three in pastoralists and carnivores' co-existence. Since the research is modelling factors influencing the co-existence between pastoralists and carnivores around Makgadikgadi/ Nxai Pans National Park in Botswana, this chapter reviewed how these factors where modelled from different environments.

Rarely do human, mainly pastoral communities, co-exist in harmony with wild carnivores (Banerjee et al., 2013). Either communities suffers economical losses due to carnivoves predation on their livestock or carnivores suffer heavy decline in population due to retaliation by communities as a result livestock predation (Nijhawan, 2008; Ogada et al., 2003). Understanding human carnivore conflict which is mainly directly propotional to the rate of livestock therefore becomes very important especially to improve human carnivore coexistence (Banerjee et al., 2013; Patterson et al., 2004).

Organisms live within an ecological community, which is defined as an assemblage of populations of at least two different species that interact directly and indirectly within a defined geographical area (Agrawal, et al., 2007; Brooker et al., 2009; Ricklefs, 2008). The presence or absence of another species can have a profound or little impact on the abundance of the other species (Freeman, 2005). At the sketchy level, ecological interactions can be defined as either intra specific or inter specific interactions (Lang & Benbow, 2013). Intra specific interaction are

those that occur between individuals of the same species while inter specific interactions are those that occur between two or more species. Therefore, pastoralists and carnivores interaction is inter specific interaction. When populations of different species interact, the effects on one on the other may be positive $(+)$, negative $(-)$ or neutral (0). By comparing the populations living alone and together, many types of interactions can be identified (Freeman, 2005). In predation interactions, preys' population growth rate is high when there is minimum interaction between preys and predators, and predators' population growth rate is high is maximum interaction. Since all species occur within ecological communities, these interactions can be affected by and indirectly influence other species and their interactions (Lang & Benbow, 2013). Wildlife generates large negative externalities for people living near them (Hoare, 1999; O' Connell, 1995; Wambuguh, 1998) via the damage associated with the destruction of crops, properties and human life (Swanson, 1994; Sutton, 1997 and 1998). This is contrary to the two directed negative effects highlighting that the damage is to both wildlife and people involved; either resulting in competition for resources, predation and diseases transmission (Andrewartha & Birch, 1954; Redpath et al., 2014) but not limitted to the list. The theory of spatiotemporal multispecies interactions is well developed but there are few experimental tests of this theory using highly resolved spatial and temporal data of multiple species involved in indirect interactions; interactions between two species mediated by a third species or other controlling factors (Hassell et al, 1991, 1994; Holt, 1997). The interactions studied in this dissertation are the pastoralists and carnivores competition which is mainly conditioned by livestock predation because they form a large network of pastoralists-carnivore interactions. The interaction is one of the few studied and tested because it is an interaction of pastoralists and carnivores influenced by the interaction of carnivores and livestock (Hassell et al., 1991, 1994; Holt, 1997). In addition,

livestock predation is controlled by land use management, interaction between livestock and wildlife (both predators and preys), and livestock husbandry (Gusset et al., 2009).

Since the conflict between human and carnivores is assumed to have existed since Homo-sapiens first domesticated ungulates (Kruuk, 2002) and the population of both people and livestock have increased, the conflict between people and carnivores worldwide is on the increase (Frank 1998; Nowell & Jackson, 1996). This conflict with pastoral farmers over livestock depredation is a continuous factor of large carnivore population decline (Hazzah, 2006; Roomanach et al., 2007). Accompanying the human population growth has been the expansion of agricultural land and increased livestock numbers, resulting in increasing isolation of conservation areas and decreasing wildlife (Hackel, 1999).

Trend indicates that human expansion, encroachment and human caused fragmentation are main outstanding causes of human-carnivore conflict. It is widely agreed that carnivores are forced into conflict with human because when natural prey is available, carnivore take wild species in preference to domestic livestock and increasingly prey on livestock as an alternative food source when natural prey densities are low (Hemson, 2003; Nijhawan, 2008; Schiess_Meier et al., 2007; Valeix et al., 2009). In 2008, Sahil further indicated that the gradually diminishing of wild prey population has further intensified attacks on domestic livestock by carnivores (Nijhawan, 2008). Retaliation in the form of elimination of carnivores by local people is the major contributor to diminishing population of large carnivores and this is fuelled multiple kills in each attack causing great economic loss (Butler, 2000; Schiess_Meier et al., 2007; Woodroffe et al., 2007). Livestock production in Africa ranges from large scale ranching operations to small scale

subsistence livestock ownership, and most of pastoralists near to protected area are small scale subsistence livestock producers facing formidable economic pressure (Hemson, 2003).

Predation on livestock varies regionally based on factors specific to each particular region (Miller, 2013). Similarly, Hemson (2003) argues that each geographic location is characterized by unique economic, ecological, political and sociological outline that could eventually regulate the potential for mitigation to succeed. However, many studies indicate that conflict is mostly common amongst communities residing in the vicinity to protected areas (Hemson, 2003; Wang and Macdonald, 2005). This is because areas bordering protected areas often fall within carnivores' home range resulting in regularly coming into contact with livestock and humans (MacDonald, 2005; Treves et al., 2002). In addition, large carnivores require large habitat as their home range even though they occur at small densities as a result population expansion and encroachment into carnivore habitat increases overlaps between carnivores, people and their livestock (Treves et al., 2002). This experience is more frequent in the semi-arid rangelands of eastern and southern Africa where human expansion recent changes in land use have increased the competition between pastoralists, newly settled farmers who own livestock and lions especially around protected areas (Chardonnet, et al., 2010). Like other large carnivores, the African lion requires vast areas to roam but human expansion and subsequent harassment by people increasingly restrict lions to protected areas (Mills, 2010) such as national parks, wild reserves and hunting areas. Most of conflicts in Africa take place on the margin of protected areas: cattle herders often penetrate protected and new villages tend to be established on their boarders, increasing the risk of lion attacks on livestock and people (Bourn & Blench, 1999). According to some recent African studies; Namibian farmers reportedly loss 1.4% of total livestock holding to large carnivores (Maker et al., 2003), compared with 1.8% in Kenya

(Kolowski & Holekamp, 2006), 2.2% in Botswana (Schiess_Meier et al., 2007), and 4.5% in Tanzania (Holmerna et al., 2007).Factors such as habitat type, topography, distribution of villages and livestock, human actions and availability of wild prey significantly influence the risk of attack on livestock (Edge, 2011; Treves et al., 2004; Treves et al., 2011).

More land has consequently been transformed into livestock grazing areas across communal areas in response to population growth (Brooks & Maunde, 2010). Increased numbers of livestock have detrimental effects on rangeland conditions, with results of rangeland degradation across those areas with high livestock densities and livestock persistently encroaching on the edge of protected areas, and sometimes several kilometers inside reserves (Brooks & Maunde, 2010; Schiess_Meier et al., 2007). Human alteration of carnivore habitant has without doubt led to escalated conflicts (Treves & Karanth, 2003). As a fraction of pastoralists in Botswana who live in the close range of wildlife protected areas, Makgadikgadi pastoralists living nearer to the protected area lost more livestock due to predation than those far from the protected area (Hemson, 2003). The problem is exacerbated by the fact that most communities residing close to protected areas are small scale farmers and are usually limited in their financial and knowledge capacity to adapt to the situation; a few predations by carnivores can mean 100% loss and can less afford it (Dickman et al., 2011) leading to retaliatory action by farmers often involving illegal persecution of carnivores and negative attitudes towards their conservation (Hemson, 2003; Valeix, 2012).

2.1 Land use management

Land use in areas adjacent to and at varying proximity from protected areas can influence the integrity of as a conservation tool (Wilson et al., 2014). In the North West Province of South

Africa, land use is one of the most influential determinants of the perceived predation levels (Thorn et al., 2012). Carnivores generate large negative externalities for people living near them (Hoare, 1999; O' Connell, 1995; Wambuguh, 1998) mainly by livestock depredation (Nijhawan, 2008; Ogada et al., 2003). A large radius of an area required by large carnivores and expanded land occupied an increasing human population increasingly restrict carnivores to protected areas (Mills, 2010). This result in most of conflicts taking place on the margin of protected areas as livestock often penetrate protected and new villages tend to be established on their boarders, increasing carnivores' attacks on livestock and people (Bourn & Blench, 1999). To support this, from 49 confirmed wild dogs attacks recorded in Laikipia District in 2003 89.8% occurred on the border of Laikipia/ Baringo National Reserve (Woodroffe et al., 2005).

Human wildlife conflict is a great concern for many regions in Botswana (Brooks & Maunde, 2010). As one of the protected areas, there is high prevalence of human wildlife conflict around the Makgadikgadi and Nxai National Park (Brooks & Maunde, 2010; Hemson, 2003; Ngaka, 2016; Rutina et al., 2015). More land has been transformed into livestock grazing areas based on the increased cattle herd from 80000 in 1980s to over 200000 in 2010 in the Makgadikgadi region increasing the spatial distribution across the region (Brooks & Maunde, 2010) hence widening the zone of interaction with carnivores. The increasing human population and resultant increasing pressure on land resources increase the conflict between protected areas management, wild animals and neighboring communities. Livestock are persistently encroaching on the edge of protected areas, and sometimes several kilometers inside reserves (Hemson, 2003; Schiess_Meier et al., 2007). Human alteration of carnivore habitant has without doubt led to escalated conflicts (Treves & Karanth, 2003). As a fraction of pastoralists in Botswana who live in the close range of wildlife protected areas, pastoralists living around Makgadikgadi Pans

National Park are exposed to high human carnivore conflicts (Hemson, 2003; Rutina etal., 2015) even though negative perceptions and attitudes by local communities towards carnivores have been reported (Gontse et al., 2012; Hemson, 2003). Carnivores especially lions avoid areas within 3 kilometers and 1kilometer to cattle posts during migratory and when migratory wild prey are not available (Hemson, 2003; Valeix et al., 2012), lack of viable buffer zones and high intensities of opposing forms of land use in the proximity of Makgadikgadi and Nxai National Park negate good coexistence between human and carnivores (Brooks & Maunde, 2010). In addition, livestock killed by Makgadikgadi lions are averagely beyond 4 kilometers from the cattle posts (Valeix et al., 2012). Based on average distance travelled by carnivores taking the center of a protected area as their home and average distance travelled by livestock, pastoralists producing nearer to Makgadikgadi/ Nxai Pans National Park lost more livestock than those far from the park showing similar patterns suggested by reports from Southern Kalahari, Okavango and Khutse game reserve (Hemson, 2003).

2.2 Species interaction

Factors such as habitat type, topography, distribution of villages and livestock, human actions and availability of wild prey significantly influence the risk of attack on livestock (Edge, 2011; Treves et al., 2004; Treves et al., 2011). Co-existence being influenced by predation rates which is density dependent, can be estimated from the number of livestock in a boma (Okello et al., 2014), number of wild prey (Winterbach et al., 2014) and the number of wild carnivores.

2.2.1 Wild carnivores and livestock interaction

The carnivores and human conflict is leading to carnivore population declines in areas were carnivore species and people cohabit or interact temporarily on boarders of protected areas.

Continuing interaction between livestock and wild carnivores characterizes many of Northern Botswana's rural agricultural settlements bordering national parks and game reserves. The scenario is more dominate near protected areas because according to Woodroffe (2001), the decline of population sizes and distribution of large carnivores in Africa has resulted in some species being increasingly limited to protected areas. The increase of carnivore density in protected areas increases their rate of interaction with livestock in places closer to protected areas. As a result the growth rate of livestock,

$$\frac{dN_{prey}}{dt} = (k_{prey} - \beta_{prey} N_{car}) N_{prey} = -\rho N_{prey} \quad (25)$$

becomes negative due to higher predation emanating from a higher rate of interaction (β_{prey}) between livestock and carnivores consequently leading to increased rate of human carnivore conflict. The high value credited to protected carnivores by international audience is not reflected at the local level, where local communities suffer substantial, diverse costs from their presence. The populations of large carnivores in Botswana fuel the conflict between livestock owning people and carnivores (Hemson, 2003). For example, in Makgadikgadi Pans area, livestock predation by lions is perceived as the major negative impact of wildlife by local people and the killing of lions by local people is a Department of National Parks' concern (Nagafela & Kalikawe, 1993). Despite a small population of lions in Makgadikgadi having density of $0.74 lions/100 km^2$ compared to more arid areas in Namibia and Kalahari, 20.5% of adult lions were killed by livestock owners in 12 months (Funston, 2001; Ngaka, 2016; Stander & Hanssen, 2003).

2.2.2 Wild and domestic prey interaction (wild herbivores and livestock interaction)

The role of alternative wild prey species in reducing livestock predation is approximate and sketchy. It is thought that the presence of wild prey may reduce the frequency on livestock predation (Valeix et al., 2012). The logic behind this concept is appealing into conflict mitigation recommendations (Hoogestein, 2000) there is a need to investigate this relationship in more detail. Stander (1997) suggests that lions living in areas with livestock appeared to prey mainly upon wild prey species and that livestock predation was infrequent. Frank (1998) noted that livestock predation appears to be less frequent on the same ranges where the ration of wild life to livestock is highest. There is speculation that the abundance of wild prey may influence the frequency of livestock predation by carnivores for example; Hoogestein (2000), Minzutani (1999) and Rasmussen (1999). The disproportionate presence of wild ungulates and domestic livestock where livestock greatly outnumbered wild ungulates around Indian trans-Himalaya resulted in the killing of livestock by wild carnivores (Mishra, 1997). In Churo area inhabited by Pokot people, many of them keen hunters and livestock out competes wild prey suffered serious livestock depredation by wild dogs while the rest of studied area inhabited by mainly by Massai and Samburu pastoralists who rarely if ever experienced less livestock depredation by wild dogs (Woodroffe et al., 2005). The two highest mean densities of sheep and goats dung were recorded at two sites where livestock predation had occurred most frequently (Woodroffe et al., 2005). In 1996, field surveys carried in spring-summer season indicated that the bharal one of the prey abundance did not exceed 100 individuals which was approximately one tenth of the 1054 livestock owned by 80 households seemed to be related to the 18% of preyed livestock over a period of 1.5 years (Mishra, 1997). A similar experience was recorded across different

settlements around Gir sanctuary which showed a positive correlation between annual livestock killed by lions and livestock density across different settlements ($r^2 = 0.34, \quad p < 0.001$), lions killed almost four times the number of livestock per settlement per year in high livestock density area than in low livestock density area (Sundararaj et al., 2012). During winter months when leopard's wild prey was abundant inside Machiara National Park (MNP), fewer livestock was killed by leopards but during summer when wild prey was less abundant more livestock was killed (Dar et al, 2009). This trend was also shown in a study conducted between April 1994 and April 1996 in the Nyamandlovu cattle ranching area, natural prey density was high based on spoors, visual sightings and reports from the ranchers and their staff as a result the survey revealed that during the 2 years period wild dogs consumed < 26 livestock showing that they were feeding predominantly on wild prey (Rasmussen, 1999). In Kgalagadi, Ghanzi and western strata of the Central Agricultural zones of Botswana, conflict reports were more frequently than expected ($P = 0.05$) in grids with 0% wild prey biomass ($\alpha = 0.05, \quad Z = 2.4977$) and the conflict reports was consistently below the mean of 0.49 when the percentage wild prey biomass exceeded 20% (Winterbach et al., 2015). The reduction in in livestock attacks by cheetahs in areas having more than 20% wild prey biomas showed that the population of wild prey can be used estimate the level or rate of pastoralists and carnivores conflicts (Winterbach et al., 2015). Even though the relation was not quantified in the areas around Makgadikgadi areas, the increased cattle herd over the past 30 years has been associated with the increasing of the spread of poor human carnivore co-existence (Brooks & Maunde, 2010). Based on the Makgadikgadi seasonal trend in livestock predation records, livestock predation was related to wild prey availability showing a decrease in the rate of livestock predation when migratory wild prey was present in abundance (Valeix et al, 2012). Furthermore, Makgadikgadi lions showed a

preference on preying on migratory wild prey over livestock when they are available even though shifted to livestock in the periods when migratory wild prey is scarce (Valeix et al, 2012). As a result, when migratory zebra and wildebeest in Makgadikgadi moved to other areas livestock predation increased (Hemson, 2003). However, there are few data to quantify this effect and establish a relation between wild prey abundance, livestock abundance and livestock predation frequencies. While suggestive Frank notes that these weak trends need to be examined in more details (Frank, 1998).

2.3 Livestock husbandry

Large carnivores such as lions and leopards rarely take cattle and small ruminants, lions mostly prey on livestock during the dry season when livestock grazes away from villages without protection (Croes et al., 2006). Studies in the East Africa suggest that livestock predation occurs predominately at livestock enclosures (Frank, 1998; Kruuk, 1980) while Stander's work in Namibia (1997) suggests most predation occurs from the enclosures. In contrary in three villages namely Ngurdoto, Ngongongare and Ngarenanyuki around Arusha National Park (Tanzania) predation cases were reported few due to the practice of building livestock enclosures (bomas) (Maleko et al., 2012). Much more emphasis has now been placed on the role that static defenses (enclosure construction, dogs and night watchmen) should have on reducing livestock predation. Evidence from East Africa suggests that static defenses are important (Frank, 1998; Kruuk, 1980; Ogada et al., 2003). In Botswana the laissez faire herding strategy shows that many un-herded livestock are available to lions away from the kraals, thus nullifying any role that static defenses may play (Ogada et al., 2003). Furthermore, data from lion movements and diet suggest that lions exploit this system to minimize the chances of contact with people and access livestock

as food resource (Ogada et al., 2003). Similarly, where herding traditions have been lost the coexistence between wild dogs and local communities have not been achieved in the northern Kenya (Woodroffe et al., 2005) and hence approprate livestock husbandry minimises wild dog predations on livestock. All attacks in the Laikipia District in the northern Kenya involved free ranging livestock; wild dogs did not attck livestock inside bomas (Woodroffe et al., 2005). Based on the above references, livestock husbandry have an effect on the rates of livestock depredation and hence on the numbers of carnivores killed and the coexistence of the two. The livestock husbandry that the study is looking for is the one with minimum carnivore livestock interaction which promotes good co-existence between pastoralists and carnivores around Makgadikgadi/ Nxai Pans National Park, thus;

$$\frac{dN_{prey}}{dt} = (k_{prey} - \beta_{prey} N_{car}) N_{prey} = k_{prey} N_{prey} \qquad (26)$$

For only prey being livestock and carnivore livestock interaction $\beta_{prey} \to 0$ since their interaction is minimized.

In Makgadikgadi, effective livestock husbandry is said to reduce availability of livestock to wild carnivores hence reduced livestock predation (Valeix, Hemson, Loveridge, & Macdonald, 2012). This is supported by the lowest probability of livestock predation across all species of predator and livestock prey for small herds accompanied by dogs (Woodroffe et al., 2007)

Chapter 3: METHODOLOGY

This chapter describes how the study was carried out. It covers the study area, research design, the population and sample, and data collection and analysis.

3.1 Study Area

The primary data was gathered in Gweta and Tsokatshaa villages because the probability of residents owning cattle posts around Makgadikgadi Pans National Park is high. Gweta is a small village in the Central District in Botswana located about 205 kilometers east from Maun and about 100 kilometers west from Nata considered the gate way to Makgadikgadi Pans (Badimo et al., 2015). Tsokatshaa is 30 kilometers north easterly of Gweta. There are 40 cattle posts in these localities (Statistics Botswana, 2014). According to Human Carnivore Conflict (HCC) distance from Problem Animal Control (PAC) block season 2008-2012, the cattle posts were divided into 3 blocks; Gweta North, Gweta South and Tsokatshaa in which Gweta South was on the south of the A3 road from Maun to Francistown and Gweta North was on the A3 road while Tsokatshaa was around Tsokatshaa village. In addition, locations were classified as near, far and very far from the park if they are 0-10km, 11-20km, and >21km from the park's boundaries.

The Makgadikgadi/ Nxai Pans National Park is situated almost halfway between Nata and Maun on the Francistown A3 road to Maun. The area was declared a game reserve in 1970 and in 1992 its boundaries were extended and a National Park status was attained presently covering approximately $4900 km^2$ (Johnson et al., 2010). Lying south east of the Okavango delta and surrounded by the Kalahari Desert, Makgadikgadi is not a single pan but many pans with sandy desert in between, the largest being the Sua, Ntwetwe and Nxai pans as shown in figure 3.1.1.

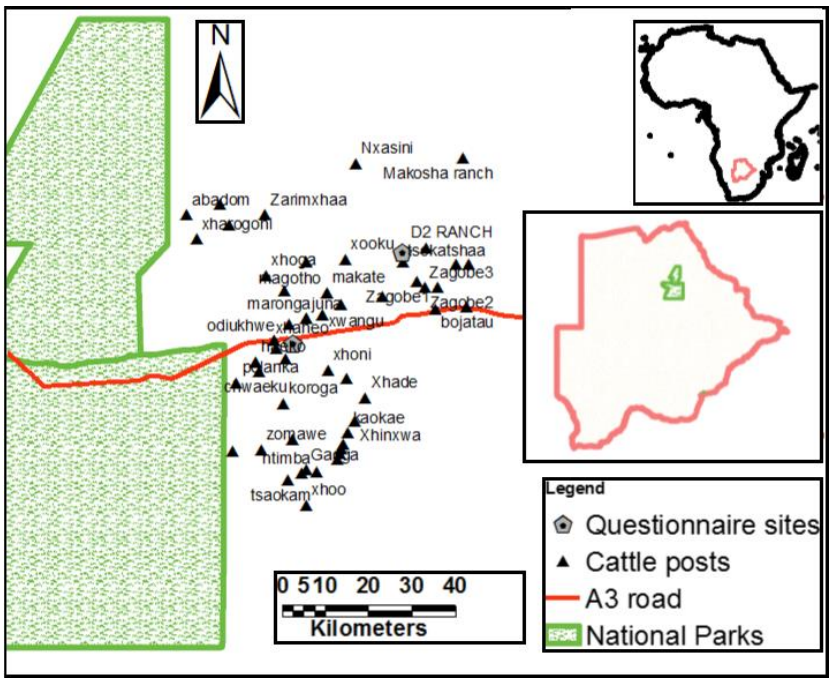

Figure 3.1.1: **Study Area in Spatial Form**

Further out of the pans, the vegetation is grassland and shrub savanna dominated by Mophane with different combinations (Badimo et al., 2015). In Tsokatshaa the vegetation is colophospertum mophane, terminali sericea/ combretum imberbe and combretum SPP, and for Gweta North and Gweta South the vegetation comprises of colophospertum Mophane, terminalia sericea and adonsonia digitata. Very little wildlife can exist in Makgadikgadi during harsh dry season of strong hot winds and salt water making it habitat for migratory animals, including wildebeest and Africa's biggest zebra population and the large predators such as Kalahari lions, leopards, wild dogs, cheetahs, and brown and spotted hyenas.

Livestock production is widespread across the region with arable development more spatially confined making pastoral farming (communal farming) and land for wildlife conservation predominant competing land use in Makgadikgadi area.

3.2 Research design

The study mostly followed quantitative approach even though a mixed method (a combination of quantitative and qualitative approach) was used since the study aimed at modelling factors influencing the co-existence of pastoralists and carnivores around Botswana Makgadikgadi/ Nxai pans national park. The study was more on the examination of factors, and testing effects of their relationships and interactions on the co-existence of pastoralists and carnivores making quantitative research important. Closed ended questions from the questionnaire, and numerical data recorded in problem animal control for the period 2008 to 2012 and 1996-2013 biomass aerial surveys in cattle posts around Makgadikgadi pans national park were used to test relationships and interactions of variables on dependent variable. Qualitative data mainly community's opinions and suggestions about pastoralists and carnivores in the study area was collected using open ended questions. Opinions of respondents are difficult to investigate but the adaptability of survey studies to collect this data proved it to be the optimal design for this study (Gravetler & Forzano, 2012; Rose, et al., 2015). A survey using questionnaire to collect data was advantageous in this study since it is efficient in collecting large amount of data given the short time and time (Rose et al., 2015). The objectives of the study clearly show that the study attempted to test a theory in the co-existence of pastoralists and carnivores hence analytic survey design was used (Avedian, 2014; Gravetler & Forzano, 2012; Rose et al., 2015). Since land use, species interactions and livestock husbandry are known to affect pastoralists and carnivores' co-existence, an abduction approach was used to develop a philosophical understanding or model for areas around Makgadikgadi/ Nxai Pans National Park.

3.3 Target population and sampling

Purposive sample method was used to select 2 villages around Makgadikgadi area thus Gweta and Tsokatshaa near Makgadikgadi/Nxai National Park. This was a judgmental selection since Makgadikgadi/ Nxai Pans National Park is a protected area where carnivores are found based on source-sink dynamics. Gweta North, Gweta South and Tsokatshaa areas were purposively sampled based on their distance from Makgadikgadi/ Nxai Pans National Park. Since sample unit was the local people having cattle posts around the park, 50 respondents were identified using a snowball technique. In this case, the respondents identified were asked if they know other pastoralists in their village and where they could be found. The information provided was used to locate and identify other pastoralists. Even though the researcher received 10 more than cattle posts in the area it must be noted that some cattle posts were not represented despite a higher number of respondents than cattle posts. This therefore suggests that these cattle posts are not part of the primary data analysis. Out of forty cattle posts in the area, eighteen cattle posts were represented making the sample 45% of the total cattle posts found in the area. From the sample; 44% of respondents owned cattle posts in Tsokatshaa, 20% owned cattle posts in Gweta North and 36% owned cattle posts in Gweta South. The rate of sheep predation was not included in the analysis and discussions because only two respondents indicated that they own sheep therefore no pattern of predation can be drawn.

3.4 Data collection tools

Since the study used both the primary and secondary data different instruments were used to collect data. Instruments used are explained under each data set;

Sources of primary data

Primary data was collected from household survey by administering a questionnaire in Appendix 1 containing closed and open ended questions to collect both quantitative and qualitative data. Appendix 1 was divided by; 1) Demographics 2) Effects of land use management in human carnivore conflicts 3) Effects of interaction between livestock and wildlife in human carnivore conflicts 4) Effects of livestock management on human carnivore conflicts as outlined in the Appendix 1. In cases where the respondents did not know how to read and write the researcher read and asked the respondent to answer and the researcher would fill the answer given. Similarly, the researcher interpreted in Setswana and recorded answers in cases respondents did not understand English.

Sources of secondary data

In addition to primary data, secondary data was obtained from past studies in Makgadikgadi including published and unpublished reports. The existing data was mainly from the Department of Wildlife and National Parks (DWNP); the Human Carnivore Conflicts (HCC) 2008-2012 Problem Animals Control (PAC) records and the 1996-2013 DWNP biomass aerial surveys. Even though the data for 2011 was not availed in HCC 2008-2012 PAC records, average livestock predation rate was calculated. Documented records from DWNP and statistics Botswana were used to get information on population size trends. The spatial data for Botswana was derived from Botswana map (survey maps).

3.4.1 Questionnaire pre testing

Appendix 1 was piloted prior to use in Gweta to minimize ambiguities, improve clarity and assess internal reliability using 10 pastoralists. Following the recommendation from the pre testing amendments were made where necessary and subsequently the instrument was used in the study.

3.5 Data Analysis

The nature of data collected was both quantitative and qualitative. The main aim in my data analysis was to find numerical relationships and patterns to model and estimate the point in which pastoralists and carnivores in areas around Makgadikgadi can co-exist. Qualitative data was analyzed using descriptive master sheet analysis where data was cleaned, edited and coded. Quotations of some key informants were used to give the final report a deep and backed analysis. This was represented in a descriptive form to explain the numerical data of the study.

Quantitative and coded qualitative data were analyzed using statistical analysis by computer packages of Statistics Packages for Social Sciences (SPSS) PC version 21 and Micro Soft Excel. This was achieved after cleaning the questionnaire and coding the answers given by respondents. The coded answers were then entered in SPSS and analyzed according to study objectives and hypothesis. SPSS software has been used as it provides in-depth investigation in data analysis and visualization (Landau & Everitt, 2004). The survey was designed to produce a small margin of error so that its findings have atleast a 90% confidence interval even though 95% confidence interval is generally required by most researchers (Anderson, 2006). Reliability, regression, co relation and log linear regression analysis was used to analyze the data. Reliability analysis was used to detect observer bias and therefore it was used to avoid it. Correlation and linear

regression are the most commonly used techniques for investigating the relationship between two or more quantitative variables and since the research main objective is to assess how independent factors influences the dependent variable it was important to use correlation and linear regression analysis. Correlation analysis was used to quantify the strength of relationship between variables while the nature of relationship between dependent variable (rate of livestock predation) and independent variables (land use management, livestock management and interaction between livestock and wild life factors) was analyzed by regression (Landau & Everitt, 2004). Since the rate of livestock predation is influenced by different factors and factors interactions (Dorresteijn et al., 2014), log linear regression analysis was used to test those different factors that are used in the cross tabulation and their interactions for statistical significance. The data was presented in the form statistical diagrams such as graphs and tables for visual clarity. Micro Soft Excel was used to capture data and draw some graphs from DWNP PAC and the 1996-2013 biomass aerial surveys.

ArcGIS 10.1 was used to analyze spatial data with the aim of linking the spatial and attributes (land use management, interactions between wildlife and livestock, and livestock management) patterns. The geographical information was processed to produce the final maps as given in figure 3.5.1.

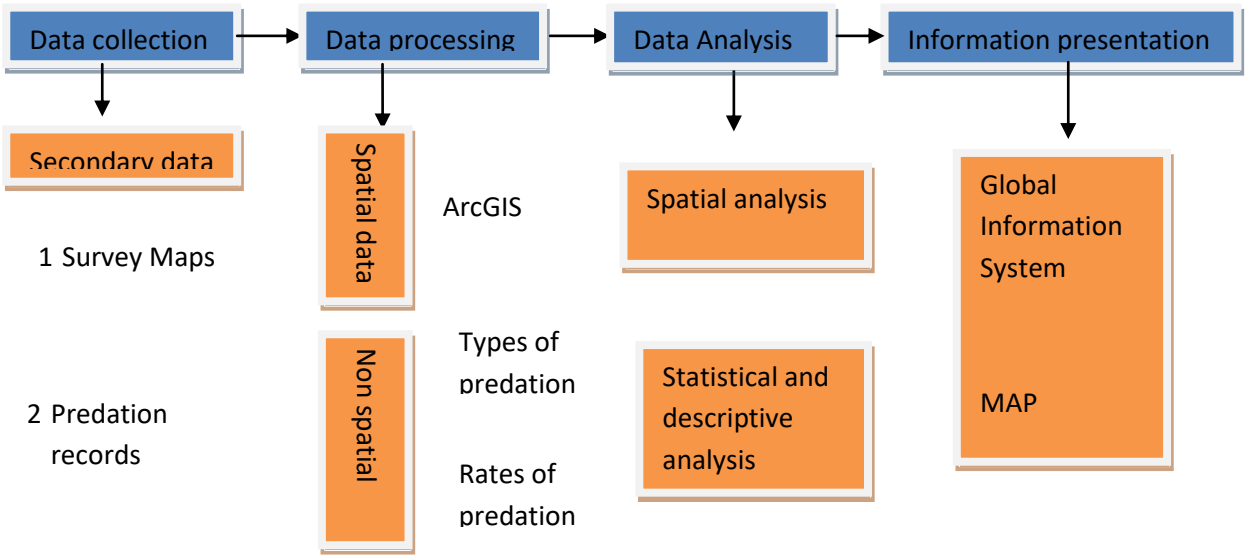

Figure 3.5.1: **Methodology used to produce maps of the study**

The final results are presented in the form of narratives, statistical diagrams, and the integration of spatial and attributes data was used produce the map of the study area.

3.6 Limitations of the study

Identification of pastoralists was mainly expected to begin at the Department of Wildlife and National Parks through the use of database on reported cases of carnivore livestock predation. While this approach was expected to generate a significant number of respondents, field work indicated otherwise, the main limitation was that the department does not keep databases with villages' house numbers and the house numbers in villages are not distributed in any formal order.

A major constraint encountered in data collection was lack of official records on interaction between the community and carnivores. For example; there were no official recorded data on

numbers of livestock and incidence of carnivore preying on livestock even the location of respondents' cattle posts availed by the local community. Such data could have given both quantitative and qualitative support to the confirmations by the respondents that there exists a problem in the interaction. As a result, numbers and rates derived from the responses to the questionnaire are taken as crude quantitative data. In spite of this problem, the study still gave useful insights into the problem of pastoralists and carnivore co-existence in Gweta and Tsokatshaa.

The researcher was also constrained by in adequate transport facilitation mainly fuel since the data was collected from villages far from Maun where Okavango Research Institute is situated. The time factor also posed a challenge as to complete one questionnaire it took more time than it was expected. Some respondents were exhausted during the course of the interview leading them giving biased information in order to complete the questionnaire. Despite a relatively relaxed atmosphere in villages, people always treated the researcher with suspicion and not readily willing to disclose the exact situation in their cattle posts. The research was faced with information asymmetry where by some respondents gave biased information because some respondents felt insecure to discuss their cattle posts matters.

The researcher had initially intended to involve all cattle posts in Gweta and Tsokatshaa. However owing to time and transport constraints this was not possible. The large distance between cattle posts was the impediment. It was also impossible to interview in cattle posts at the time of field work, therefore the researcher could not observe cattle post settings.

Some of the constraints were solved by the following measures;

Problem of transport was solved by walking long distances from the camp site to reach respondents. For people who understood the questionnaire, they were not interviewed but given the questionnaire to fill. This was done to increase the rate of completing questionnaires.

For biased and asymmetry information was solved by thorough explanation of the purpose of the study to respondents before they started giving the information that was needed from them. The respondents were assured of the ethical considerations; respondents were assured that all information collected would be treated in confidence, anonymous and only used for the purpose of the study.

Chapter 4: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents data gathered from the field; the chapter presents results for each specific research question. The results were divided into four sections: the first section presents the influence of the respondents' demography on the rate of predation. The remaining three main sections are based on the specific objectives of the study: 1) to assess the influence of land use management on the rate of livestock predation; 2) to assess the influence of species interaction on the rate of livestock predation; 3) to assess influence of livestock husbandry on the rate of livestock predation.

The rate of livestock predation as the independent variables for the analysis was the first to be calculated using the data from DWNP PAC records since pastoralists - carnivores' co-existence was found to be inversely proportional to the rate of livestock depredation (Mech, 1981; Sillero-Zubiri & Laurenson, 2001). Therefore, it is important to find the direction of the growth rate of predation to drive the stability of their co-existence. From the 356 number of reported livestock depredation cases for the period 2008-2012 in Appendix 2; 56.5% from Gweta South, 36% from Gweta North and 7.5% from Tsokatshaa respectively.

The average depredation rates (r) for lion, leopard and wild dogs calculated dependent on the distance from the park as per data in Appendix 2 using equation (1) $r = \frac{\ln(N - N_0)}{t}$ for initial predation (N_0), final predation (N) and time taken (t) from initial to final predation are shown on table 4.1.1. The distances were classified as; near when it is $0-10km$ from the park's

boundaries, far when it is $11-20km$ from the park's boundaries and very far when it is greater $20km$ from park's boundaries.

Table 4.1.1: **THE RATE OF LIVESTOCK PREDATION BY CARNIVORES**

Block and distance from the park		Leopards' average livestock predation rate	Lions' average livestock predation rate	Wild dogs' average livestock predation rate
Gweta South	Near	-0.22907	0.189391	-0.17329
	Far	-0.08922	0.0759871	-0.17329
	Very far	0.238692818	0.057762265	0.34657359
Gweta North	Near	0	0.146259	0
	Far	-0.31061333	0.3151593	-0.17329
	Very far	0.022717	0.222661	0.086643
Tsokatshaa	Near	0	0.397257	0
	Far	0.20118	0.12645	0
	Very far	0.201179739	0.086643398	0.086643398

Based on table 4.1.1, in all the three blocks for areas very far from the park (more than 20 kilometers from the park) predation growth rate for the three tested predators was positive this shows that predation was increasing at places more than 20 kilometers from the park. Leopard predation rate increased as distance from the park increases implying that people having cattle posts near the park experienced low rate of predation than those having cattle posts very far from the park. This trend was experienced again on wild dogs' rate of predation. Lions' predation rate followed an opposite trend for Gweta South and Tsokatshaa, with higher rate of predation near the park and lower rate of predation very far from the park. This implies that lions' predations increases as distance from the park decreases or when approaching the park. The pattern of lions' predation on livestock with reference to distance from park in Gweta North was not clear since

highest rate was recorded at far distance, lowest rate recorded near the park while medium rate was recorded at distance very far from the park.

On average both leopards and lions' livestock predation growth rate were increasing at 0.035851897 and 0.256939017 respectively. Wild dogs' livestock predation average growth rate showed a slight decrease at -0.078333938. According to the average predation rates, both the leopard and lion rate of predation are increasing hence leading to poor stability of co-existence with human while the decrease on livestock predation by wild dogs improves human wild dogs co-existence. Even though the average predation rates for leopards and lions are positive and negative for wild dogs, it is not obvious that consecutive years' predation rate follow the directions of averages. Figure 4.1.1 shows individual components of the average growth rates of predation by $P(t) = P(0)e^{rt}$, $P(t)$ being predation at given time t, $P(0)$ being the initial predation, r being the growth rate of predation and t being the time range or time taken (Tsishchanka, 2010) .

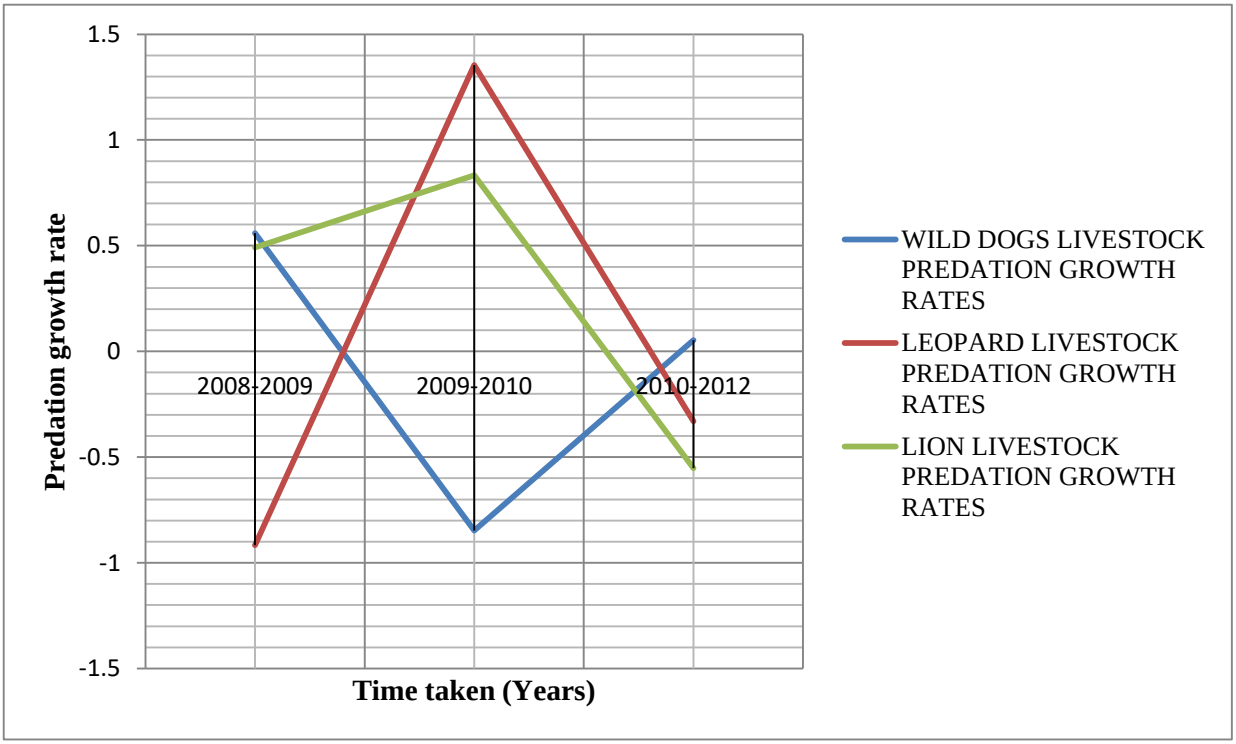

Figure 4.1.1: **Overall livestock predation growth rates for the study area for 2008-2012**

Even though primary prey species depends on abundance and easy to catch by carnivores; wild dogs had been reported to mostly prey on small prey being goats, sheep and young larger livestock (cattle, horses and donkeys) (Moreton Bay Regional council, 2012; Tshimologo, 2014). Similarly, leopards had been rarely reported to prey on large preys weighing up to three times its adult's weight and hence prey on livestock such as goats, sheep and young horses, donkeys and cattle (Gurwin, 2017; The Maryland Zoo, 2014) making wild dogs and leopards' livestock to be the same and equal. Contrary, lions require medium to large prey to survive (Funston, et al., 2016) hence prey on cattle, donkeys, horses and their young ones making lion predation on livestock the main form of conflict between carnivores and pastoralits as these livestock form about $\frac{2}{3}$ livestock owned (Chardonnet, et al., 2010). The reported predation rates are taking place on the decreasing livestock prey biomass for wild dogs, leopards and lions

at $r = -0.04437$, $r = -0.04437$ and $r = -0.04361$ respectively according to DWNP 1996-2013 aerial surveys as shown in table 4.1.2. Therefore, the increasing livestock predation by leopards and lions calculated from 2008-2012 DWNP PAC would result in a further decrease in leopards and lions livestock prey biomass.

Table 4.1.2: **Livestock prey biomass for 1996-2013 according to DWNP aerial surveys**

Year	Wild Dogs Livestock Prey	Leopard Livestock Prey	Lion Livestock Prey
1996	157.16333	157.16333	314.32667
1999	188.44333	188.44333	376.88667
2002	179.90819	179.90819	359.81638
2004	218.76000	218.76000	437.52000
2006	120.15000	120.15000	240.30000
2012	25.32345	25.32345	50.64690
2013	29.42440	29.42440	58.84881

4.2 The perceived influence of the respondents Demography on the rate of predation

4.2.1 General demographics of the respondents

Out of 50 respondents, 46% (23) of respondents were female and 54% (27) were male. The data shows that most of the respondents were farmers representing 68% of the total sample, followed by people unemployed at 14%, then people employed out of cattle posts at 10% and lastly by students at 8%. The dominancy of the sample by farmers shows that it was easy for a higher number to assess the conflicts as they are the ones affected hence the sample represented the needed fraction of the population. 62% of respondents at the time of the survey were single and 38% were married but 24% of respondents were from families headed by female while 76% were from male headed. The minimum age group interval of respondents recorded list

representatives while the maximum group interval recorded highest number of representatives as shown in figure 4.1.1.1.

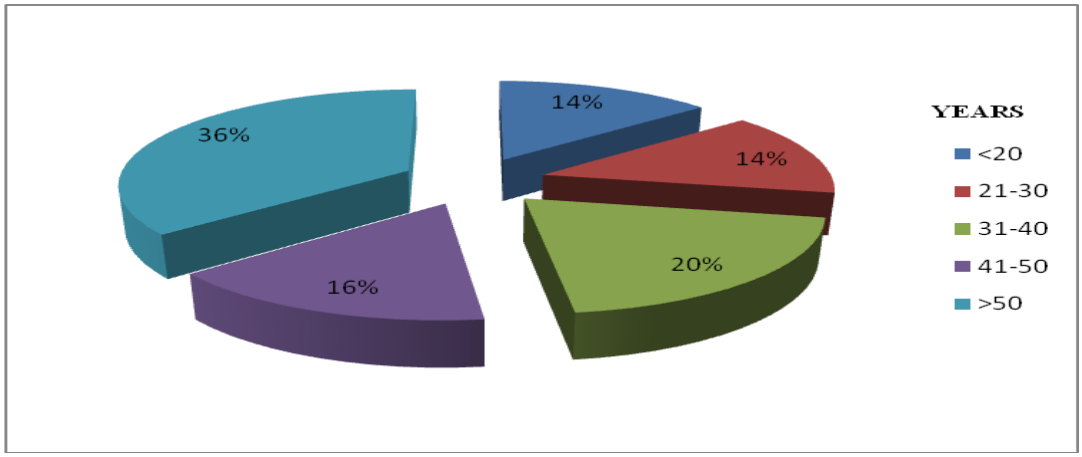

Figure 4.1.1.1: **Age distribution of respondents**

Even though respondents are of different age, 80% have used the land for livestock production for more than 15years, 4% for 11-15 years, 8% for 6-10years, 4% for 1-5years, and only 2% used the land for less than 1 year. The longer producers stay in the production area increases the chances of experiencing the patterns of carnivore livestock predation hence making the sample reliable on issues concerning conflicts between them and carnivores mainly caused by livestock predation. 98% of respondents indicated that they are definitely familiar with the concept of human wildlife conflict with 22% saying they always experience the conflict, 52% often, 16% sometimes, 2% seldom and 6% never experienced the conflict. This gives the researcher confidence on the data gathered because the sample is familiar with the issue investigated. All who responded in the section indicated that the main cause of human wildlife conflicts in their area is livestock predation hence the main common human wildlife conflict in the area is pastoralist-carnivore conflict. This shows that there is poor co-existence between pastoralists and carnivores. The majority 30% $(n = 50)$ of respondents had no formal education

while only 12% had tertiary education. The information obtained is from the rightful people who are forced to pastoral practices by their education back ground and rely mainly on agriculture for their income because they do not qualify for any profession. Figure 4.1.1.2 summarizes the education level of respondents in the sample used in the study.

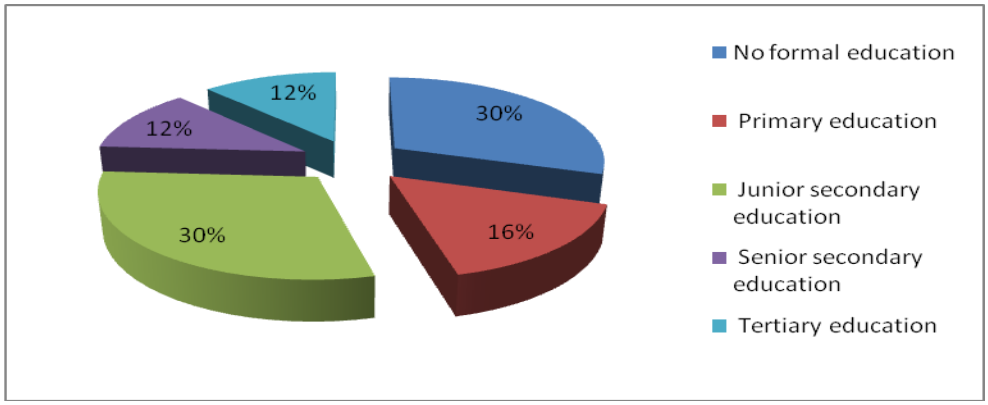

Figure 4.1.1.2: **Education status of respondents**

4.1.2 Perceived Influence of respondent demographics on carnivore predation on livestock

Even though the demographics were not part of the specific objectives of the research, some of its components showed significant contribution to the rate of livestock predation using regression analysis;

Cattle rate of predation

Significant components $(p \leq 0.1)$ of the demographics contribute 21.8% of the rate of cattle predation with all tested components contributing 46.7% of the rate of predation. Sex, marital status and family head were the only components significantly contributed to the rate of cattle predation showing that male, married respondents and respondents from a male headed families

perceived cattle rate of predation to be low. As a result the average density growth rate of livestock reduces to $r < -0.04432$ hence $N_f = N_0 e^{((-0.04432)-c_1)t}$ (40) for N_f final density, N_0 initial density, t time take from initial to final density and $c_1 > 0$ as the effect of female , un married and respondents from families headed by female. Level of education correlated with the rate of cattle predation at $(P = 0.109 \approx 0.10)$ and this shows that according to respondents' perception producers with higher education (secondary to post-secondary experienced lower rates' of cattle predation than producers with lower level of education (primary and non-formal education)

Male participants, participants from male headed families and married participants indicated that they have experienced low rate of cattle predation. Similarly, producers with high level of education thus from secondary to post-secondary education experienced lower level of cattle's rate of predation which complement that education affects many aspects of human lives including their relationship reserves and their natural resources (Richard, 2011).

Goats' rate of predation

The main cause of livestock loss is the only significant component of demographics in goats' rate of predation $p \leq 0.1$ contributing 18.1% out of a total of 42.5% contributed by demographics components on the rate of goats' predation. Pastoralists who perceived predation as the main cause of livestock loss experienced higher rate of goats' predation. Therefore, growth rate of livestock density average decrease from $r = -0.04432$ due to goats' predation in areas where predation is the main cause of livestock resulting in;

$$N_f = N_0 e^{((-0.04432)-g_1)t} \quad (41)$$

for N_f final density, N_0 initial density, t time take from initial to final density and $g_1 > 0$ as the effects of the main cause of livestock loss in the study area.

Horse rate of predation

Demographics components contributed 56.3% of horse predation with significant components contributing 31.7% of horse predation. Sex ($P = 0.01 < 0.05$) significantly influenced respondents rating of horse predation. Male respondents rated horse predation lower than female respondents therefore, according to female respondents livestock density highly decrease from $r = -0.04432$due to horse predation. According to female respondents livestock density growth highly decrease resulting in;

$$N_f = N_0 e^{((-0.04432)-h_1)t} \quad (42)$$

for N_f final density, N_0 initial density, t time take from initial to final density $h_1 > 0$ as the effects of female respondents on the rate of horses' predation. Men indicated that they experienced low rate of horse predation as compared to women. Even though the significance for age, duration of land use for livestock production and experience of human wildlife conflict ($P = 0.10$) by respondents is low. It is clear that these negatively affect livestock density;

$$N_f = N_0 e^{((-0.04432)-h_2)t} \quad (43)$$

for N_f final density, N_0 initial density, t time take from initial to final density $h_2 > 0$ as the effects of producers aged more than 50 years, people who used the land for livestock production for more than 15 years and people who always experience human wildlife conflicts experienced

high rate of horse predation. Similarly, the intersection of respondents' level of education and their occupation was perceived to significantly predict horse rate of predation at $P = 0.109 \approx 0.10$. From the intersection, people having higher education (secondary and post-secondary education) and are doing only farming as an occupation perceived horse rate of predation to be low.

Donkey rate of predation

Sex $(P = 0.05)$ is the only significant demographics component that can be used to predict the rate of donkey predation. This shows that female respondents rated donkey predation to be higher compared to male respondents. Therefore, according to female respondents the average livestock's density further decrease from $r = -0.04432$due to perceived donkey rate of predation.

4.3 Influence of land use management on the rate of livestock predation

Gweta South experienced the highest predation rate contributing 56.5% of total predation in the three blocks of cattle post for the period 2008-2013 as displayed by the statistics in Table 4.2.1.

Table 4.2.1: **Number of reported predation per blocks for the period 2008-2012**

Blocks of cattle posts	**Number of predation reported**	**% of total reported predation**
Gweta north	128	36.0
Gweta south	201	56.5
Tsokatshaa	27	7.6
Total	**356**	**100.0**

The growth of livestock predation rate showed a positive gradient from areas near the park $(0-10km)$ to areas very far from the park $(\geq 21km)$ for leopards and wild dogs in Gweta South,

Gweta North and Tsokatshaa. The trend shows that farmers near the park experienced lower livestock predation rates by leopards and wild dogs than farmers very far from the park. This was also displayed by lions' average predation growth rates in Gweta North showing that there are higher livestock predations by lions in areas very far from the park than in areas near the park. In Gweta South and Tsokatshaa, lions average livestock predation rate showed areas near the park experienced higher lions' livestock predation than areas very far from the park. The livestock predation growth rates by carnivores in the study area are graphically shown on figure 4.2.1.

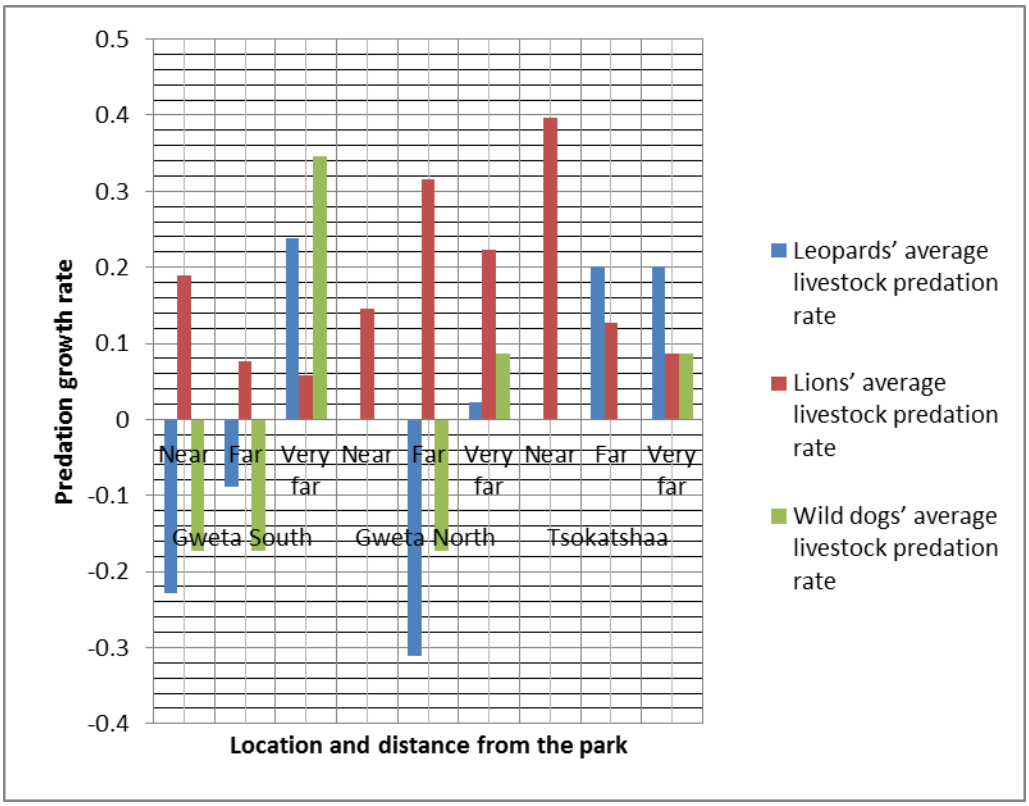

Figure 4.2.1: **Livestock predation growth rates by carnivores with respect to location and distance**

Distance from the park and how pastoralists (farmers) use the land positively correlate $p = 0.000 \leq 0.01 \ (n = 50)$ showing that farmers $0-10km$ from the park use land only for livestock production while farmers $\geq 11km$ from the park use land for both livestock and arable farming. Farmers from similar distance category from the park supported their land use and recommending as a way of land use management that could be used to reduce human wildlife (carnivore) conflicts $(p = 0.01)$ hence promoting good co-existence. This shows that farmers $< 11km$ from the park recommended land to be used only for livestock production while those $\geq 11km$ recommended land to be used for mixed product (livestock and arable production).

For the 47 predation cases recorded in Tsokatshaa, the average growth rates of wild dogs, leopards and lions' livestock predation showed an increase giving positive growth of 0.183102048, 0.268239652 and 0.110829384 respectively based exponential growth and decay theorem (Tsishchanka, 2010). This shows that on average the three carnivores do have conflict with human in Tsokatshaa due to livestock predation; the highest conflict being against leopard followed by wild dogs and lastly against lions. After transforming by 1 number of predations the growth rate of predation as in figure 4.2.2 shows a positive gradient for both carnivore predations implying that there is poor co-existence between human and the three carnivores.

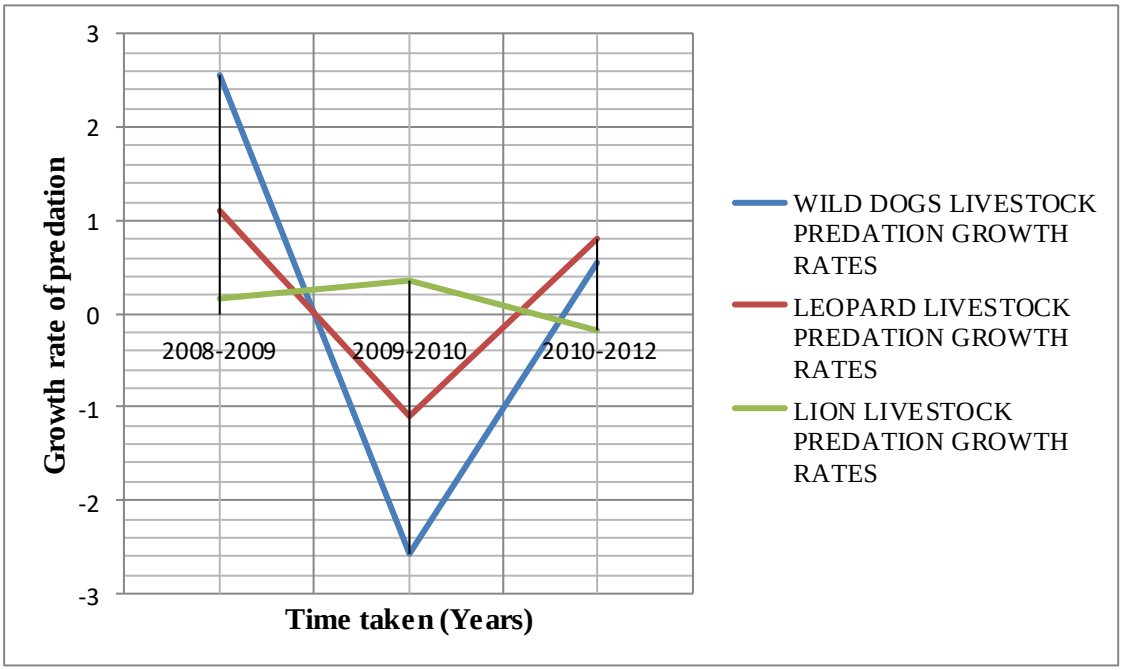

Figure 4.2.2**: Livestock predation growth rates in Tsokatshaa for the period 2008-2012**

From the 160 predation cases reported in Gweta North, average predation growth followed a similar tread to that of the whole study area even though not of similar quantity but of the same direction. Wild dogs' average livestock predation growth rate showed a negative growth of -0.081770486 while leopards and lions' average livestock predation growth rates showed positive growth of 0.152715122 and 0.244560364 respectively. In Gweta North poor co-existence between human and carnivores (leopards and lions) is fueled by the increase in livestock predation by these carnivores. On average, the decrease in the rate of livestock predation by wild dogs promotes stable human wild dogs' co-existence. Figure 4.2.3 shows gradients of livestock predation growth rates for easy interpretation.

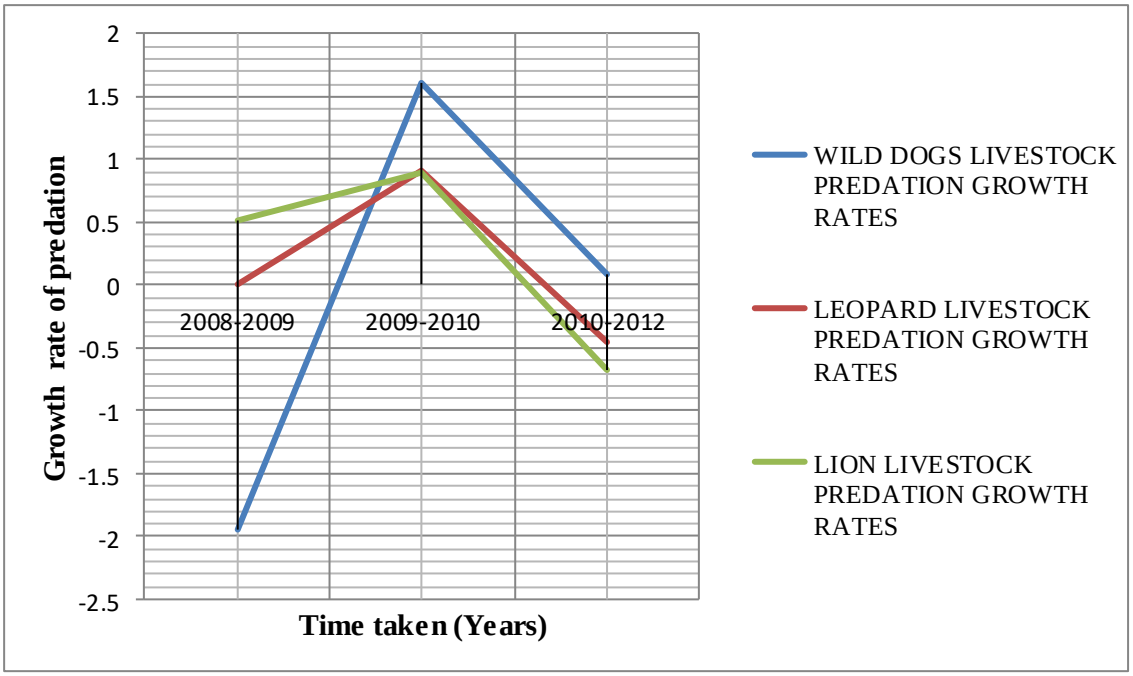

Figure 4.2.3: **Livestock predation growth rates in Gweta North for the period 2008-2012**

Similarly, from the 242 livestock predation reported cases in Gweta South the growth rate of lions' average predation rate shows an increase of 0.284844626. On average the predation growth rate for wild dogs and leopards show a decrease of -0.189905714 and -0.736868911. Based on predation rate as inversely proportional to the stability of co-existence between human and carnivores leopards do more co-exist with human than wild dogs and lions in Gweta south. Using the exponential growth and decay theorem (Tsishchanka, 2010), figure 4.2.4 is showing the components used to derive averages of the rates of predation in Gweta South.

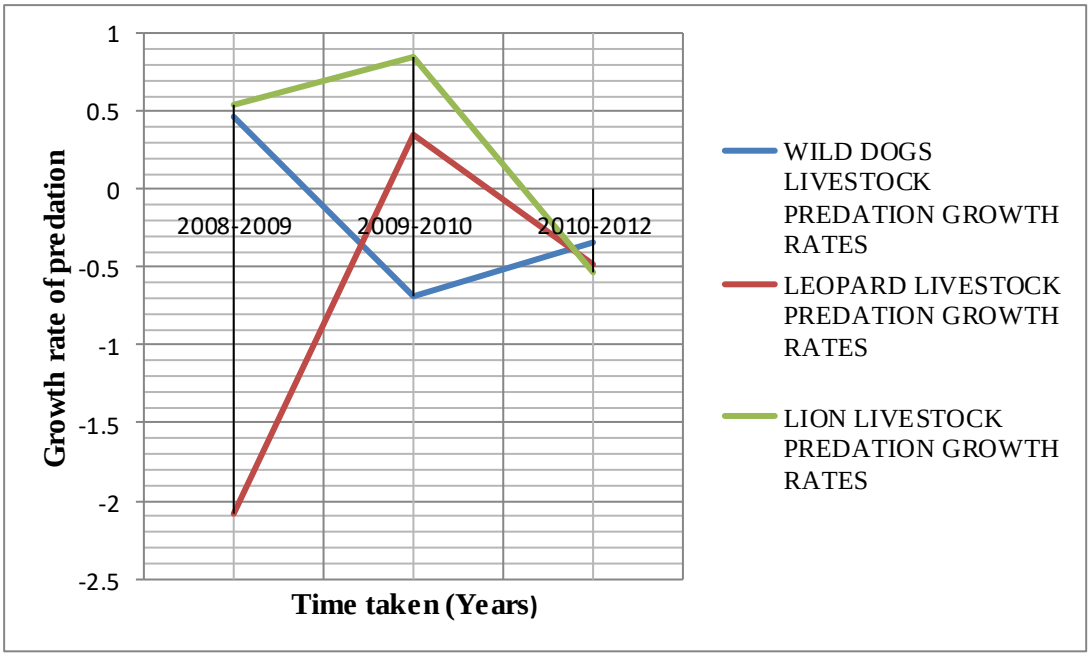

Figure 4.2.4: **Livestock predation growth rates in Gweta South for the period 2008-2012**

4.2.1 Influence of land management on carnivore predation rate on Cattle

Based on regression analysis in table 4.2.1.1, land use ($p = 0.035 < 0.05$), land use recommended ($p = 0.091 < 0.10$) and the cause of human carnivore conflict ($p = 0.028 < 0.05$) significantly predicated cattle predation in the area showing that pastoralists using land only for livestock production, recommended land use for only livestock production and have identified livestock predation as the main cause of human carnivores conflict experienced low rate of cattle predation. The interaction of land recommended, cause of human carnivore conflicts, and comments and suggestions on land use has become more significant ($p = 0.026 < 0.05$). Based on the interaction the growth rate of cattle,

$$\frac{dN_{cattle}}{dt} = (k_{cattle} - \beta_{cattle} N_{car}) N_{cattle} \qquad (6.2.2)$$

will increase with time when land use is recommended and converted to only for livestock production and producers know that livestock predation is the main cause human carnivore conflict in the study area. This implies $|-\beta_{cattle} N_{car}|$ decrease with time(t) for k_{cattle} the growth rate of cattle and $-\beta_{cattle} N_{car}$ the cattle predation rate by carnivores resulting in the average livestock prey biomass growth rate increase $(r > -0.04412)$ for the initial $N_0 = 88.27321$in appendix 3. Land used for mixed production experienced higher the rate of cattle predation than land use only for livestock production. The interaction of high population of carnivores, poor livestock management, and short distance from the park was placed at highest position of causes of conflict therefore the increased significance of causes of conflicts implies that the interaction contribute to high rate of cattle predation and reduces the average growth rate of livestock prey biomass $(r > -0.04412)$ in the region.

Table 4.2.1.1: **Land management factors influencing carnivore predation on cattle**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	-140.744464	220.712836	50.000	-.638	.527	-584.059242	302.570314
Distance from the parks	28.236545	73.927445	50	.382	.704	-120.251098	176.724189
Stay	5.691343	60.591007	50	.094	.926	-116.009276	127.391962
Land use	70.288764	32.396745	50.000	2.170	.035	5.217987	135.359542
Land use recommended	36.577139	21.213953	50.000	1.724	.091	-6.032341	79.186618
Causes of human carnivore conflicts	39.363618	17.339858	50.000	2.270	.028	4.535489	74.191748
Comments/ suggestions on land use	6.754843	6.225286	50.000	1.085	.283	-5.749012	19.258698
Distance * Stay * Land use	-7.390214	34.291303	50	-.216	.830	-76.266324	61.485896
Land recommended * cause of human carnivore conflicts * comments/ suggestions on land use	-3.304555	1.445280	50.000	-2.286	.026	-6.207486	-.401625

a. Dependent Variable: Categories of cattle predation.

Given the distance from the park, the rate of staying in the land used for livestock production and how the land is being used as the main effects in table 4.2.3; the interactions between distance from the park*land use categories $(P = 0.007 < 0.01)$, and the rate of staying in the land*land use categories $(P = 0.119 \approx 0.1)$ cannot be removed without affecting the model as they are significant in predicting the rate of cattle predation in the study area. Pastoralists whose pastoral areas are close to the park and use land for mixed purposes (both livestock and arable farming) experienced high rate of predation. Similarly, pastoralists who spend more time in their land for production and use land only for livestock production experiences low rate of cattle predation.

Table 4.2.3: **Log linear analysis on the effect of land use management on cattle rate of predation**

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		DISTANCEFROMPARK*STAY* LANDUSECATERGORIES	.000	0	.	
	Deleted Effect	1	DISTANCEFROMPARK*STAY* LANDUSECATERGORIES	.059	16	1.000	2
1	Generating Class[b]		DISTANCEFROMPARK*STAY, DISTANCEFROMPARK*LAND USECATERGORIES, STAY*LANDUSECATERGORIE S	.059	16	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*STAY	3.914	16	.999	2
		2	DISTANCEFROMPARK*LAND USECATERGORIES	13.860	4	.008	2
		3	STAY*LANDUSECATERGORIE S	7.160	4	.128	2
2	Generating Class[b]		DISTANCEFROMPARK*LAND USECATERGORIES, STAY*LANDUSECATERGORIE S	3.973	32	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*LAND USECATERGORIES	14.038	4	.007	2
		2	STAY*LANDUSECATERGORIE S	7.338	4	.119	2
3	Generating Class[b]		DISTANCEFROMPARK*LAND USECATERGORIES, STAY	11.311	36	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*LAND USECATERGORIES	14.038	4	.007	2
		2	STAY	107.068	4	.000	2
4	Generating Class[b]		DISTANCEFROMPARK*LAND USECATERGORIES, STAY	11.311	36	1.000	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Goats' rate of predation

Comments and suggestions on land use $(p = 0.090 < 0.1)$ was the only significant source predicted the rate of goats predation in the area studied with a negative estimate as shown in table 4.2.4. Since the interaction of reduction in the population of wild life*fencing of the production land*increased distance from the park were placed in the maximum position the rate of predation can be reduced by applying the interaction of these measures. Therefore to promote co-existence in the study area the population of wild life should be reduced, fencing of the production land and distance from the park should be increased. These factors will increase the growth rate of average livestock prey biomass $r > -0.04412$ for the initial biomass of 88.27321 at 2013 such that $N_f = 88.27321e^{rt}$ given time $t = y - 2013$ for y the year of the final biomass N_f.

Table 4.2.4 **Land use factors influencing carnivore predation on goats**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	392.516949	475.066615	50	.826	.413	-561.682429	1346.716327
Distance from the park	41.312199	159.122875	50	.260	.796	-278.295502	360.919900
Stay	-49.062795	130.417266	50	-.376	.708	-311.013583	212.887992
Land use	34.054221	69.731386	50	.488	.627	-106.005390	174.113832
Land use recommended	-14.374020	45.661327	50	-.315	.754	-106.087494	77.339455
Cause of human carnivore conflicts	-21.557204	37.322648	50	-.578	.566	-96.521949	53.407542
Comments/ suggestions on land use	-23.201137	13.399427	50	-1.732	.090	-50.114679	3.712405
Distance * Stay * land use	37.304723	73.809271	50	.505	.615	-110.945561	185.555006
Land use recommended * cause of human carnivore conflicts * comments/ suggestions on land use	1.782695	3.110849	50	.573	.569	-4.465628	8.031019

a. Dependent Variable: Categories of goats' predation.

Similarly, goats' predation rate can be derived using the interactions of; distance from park*land use categories and staying rate in the land for livestock production*land use categories using the distance from the park, the rate of staying in the land used for livestock production and how the land is being used as the main effects . Like in the rate of cattle predation; pastoralists whose pastoral areas are close to the park and use land for mixed purposes (both livestock and arable farming) experience high rate of goats predation as a result the average livestock prey growth is reduced to $r < -0.04412$ with initial livestock biomass of 88.27321 in 2013, and pastoralists who spend more time in their land for production and use land only for livestock production were perceived to experience low rate of goats' predation hence promote positive average growth rate of livestock prey biomass $r > -0.04412$. This is supported by the high rate of livestock predation by coyotes experienced in hilly large pastures with typically sparsely population of pastoralists (Henderson & Spaeth, 1980). The log linear analysis table 4.2.5 shows the significance of the one way effects and any higher order effects on the rate of goats' rate of predation given distance from the park, rate of staying in land for livestock production and land use categories as the main effects of the model of goats' rate of predation on the study area.

Table 4.2.5: **Log linear analysis on the effects of land use management on goats' rate of predation**

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		DISTANCEFROMPARK*STAY*LANDUSECATERGORIES	.000	0	.	
	Deleted Effect	1	DISTANCEFROMPARK*STAY*LANDUSECATERGORIES	.059	16	1.000	2
1	Generating Class[b]		DISTANCEFROMPARK*STAY, DISTANCEFROMPARK*LANDUSECATERGORIES, STAY*LANDUSECATERGORIES	.059	16	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*STAY	3.914	16	.999	2
		2	DISTANCEFROMPARK*LANDUSECATERGORIES	13.860	4	.008	2
		3	STAY*LANDUSECATERGORIES	7.160	4	.128	2
2	Generating Class[b]		DISTANCEFROMPARK*LANDUSECATERGORIES, STAY*LANDUSECATERGORIES	3.973	32	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*LANDUSECATERGORIES	14.038	4	.007	2
		2	STAY*LANDUSECATERGORIES	7.338	4	.119	2
3	Generating Class[b]		DISTANCEFROMPARK*LANDUSECATERGORIES, STAY	11.311	36	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*LANDUSECATERGORIES	14.038	4	.007	2
		2	STAY	107.068	4	.000	2
4	Generating Class[b]		DISTANCEFROMPARK*LANDUSECATERGORIES, STAY	11.311	36	1.000	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Horse rate of predation

Land use ($p = 0.043 < 0.05$) significantly predicted the rate of horse predation showing that pastoralists using land only for livestock production experienced lower rate of horse predation compared to those using land for mixed production (livestock and crop production) as shown in

table 4.2.6. Land used for mixed production reduces the average livestock prey biomass growth rate $r < -0.04412$ with initial biomass of 88.27321 in 2013.

Table 4.2.6: **Land use factors influencing carnivore predation on horses**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	1153.681159	585.473025	50	1.971	.054	-22.276020	2329.638338
Distance from the park	-241.595096	196.103342	50	-1.232	.224	-635.480251	152.290060
Stay	-195.147421	160.726493	50	-1.214	.230	-517.976083	127.681241
Land use	178.718870	85.937097	50	2.080	.043	6.109131	351.328608
Land use recommended	-54.602085	56.273109	50.000	-.970	.337	-167.629951	58.425780
Cause of human carnivore conflicts	2.779774	45.996505	50.000	.060	.952	-89.606925	95.166473
Comments/ suggestions on land use	-.288124	16.513480	50.000	-.017	.986	-33.456425	32.880178
Distance * stay * land use	113.665504	90.962689	50	1.250	.217	-69.038434	296.369443
Land use recommended * cause of human carnivore conflicts * comments/ suggestions on land use	-.275596	3.833816	50.000	-.072	.943	-7.976042	7.424849

a. Dependent Variable: Categories of horse predation.

The interactions between distance from the park*land use categories and the rate of staying in the land*land use categories are significant in predicting the rate of horses' predation in the study area as shown in Table 4.2.7 based on the distance of production land from the park, the rate of staying in the land used for livestock production and how the land is being used as the main effects. Therefore pastoralists whose cattle posts are far from the park and use their land for only livestock production experienced low rates of horses' predation. Similarly, pastoralists who are always or always have someone in their cattle posts and use their land of production only for

livestock production experience low rate of horses' predation. These increase the average livestock prey biomass growth rate to $r < -0.04412$ with initial livestock prey biomass of 88.27321in 2013 by reducing the average carnivore predation growth rate on livestock.

Table 4.2.7: **Log linear analysis on the effects of land use management on horses' rate of predation**

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		DISTANCEFROMPARK*STAY*LANDUSECATERGORIES	.000	0	.	
	Deleted Effect	1	DISTANCEFROMPARK*STAY*LANDUSECATERGORIES	.059	16	1.000	2
1	Generating Class[b]		DISTANCEFROMPARK*STAY, DISTANCEFROMPARK*LANDUSECATERGORIES, STAY*LANDUSECATERGORIES	.059	16	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*STAY	3.914	16	.999	2
		2	DISTANCEFROMPARK*LANDUSECATERGORIES	13.860	4	.008	2
		3	STAY*LANDUSECATERGORIES	7.160	4	.128	2
2	Generating Class[b]		DISTANCEFROMPARK*LANDUSECATERGORIES, STAY*LANDUSECATERGORIES	3.973	32	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*LANDUSECATERGORIES	14.038	4	.007	2
		2	STAY*LANDUSECATERGORIES	7.338	4	.119	2
3	Generating Class[b]		DISTANCEFROMPARK*LANDUSECATERGORIES, STAY	11.311	36	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*LANDUSECATERGORIES	14.038	4	.007	2
		2	STAY	107.068	4	.000	2
4	Generating Class[b]		DISTANCEFROMPARK*LANDUSECATERGORIES, STAY	11.311	36	1.000	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

Donkey rate of predation

All sources are not significantly predicting the rate of donkey predation. Table 4.2.8 further shows the components of land use management and their significance on the rate of donkeys' rate of predation.

Table 4.2.8 **Land use factors influencing carnivore predation on donkeys**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	712.609764	599.715378	50	1.188	.240	-491.954024	1917.173552
Distance	-78.712145	200.873798	50.000	-.392	.697	-482.179043	324.754753
Stay	-154.846636	164.636363	50.000	-.941	.351	-485.528504	175.835232
Land use	-29.768906	88.027622	50	-.338	.737	-206.577590	147.039777
Land use recommended	5.533213	57.642022	50.000	.096	.924	-110.244195	121.310620
Cause of human carnivore conflicts	21.129555	47.115427	50.000	.448	.656	-73.504565	115.763674
Comments/ suggestions on land use	5.106961	16.915191	50.000	.302	.764	-28.868200	39.082122
Distance * stay * land use	79.456482	93.175469	50.000	.853	.398	-107.691955	266.604920
Land use recommended * cause of human carnivore conflicts * comments/ suggestions on land use	-1.775214	3.927078	50.000	-.452	.653	-9.662983	6.112555

a. Dependent Variable: Categories of donkey predations.

The interactions between distance from the park*land use categories and the rate of staying in the land*land use categories are significant in predicting the rate of donkeys' predation in the study area as shown in Table 4.2.9. According to respondents' perception pastoralists whose pastoral areas are close to the park and use land for mixed purposes (both livestock and arable farming) experience high rate of predation as a result the average livestock prey biomass growth reduces to $r < -0.04412$. Contrary, pastoralists who spend more time in their land for production and use land only for livestock production experiences low rate of cattle predation as a result the

average livestock prey biomass increases to $r > -0.04412$ with initial livestock biomass of 88.27321in 2013. Therefore succeeding livestock biomass $N_s > 88.27321$ being calculated as $N_s = 88.27321e^{rt}$ with $t = s - 2013$ and s the year of the calculated biomass.

Table 4.2.9: **Log linear analysis on the effects of land use management on donkeys' rate of predation**

Step[a]			Effects	Chi-Square[c]	df	Sig.	Number of Iterations
0	Generating Class[b]		DISTANCEFROMPARK*STAY*LANDUSECATERGORIES	.000	0	.	
	Deleted Effect	1	DISTANCEFROMPARK*STAY*LANDUSECATERGORIES	.059	16	1.000	2
1	Generating Class[b]		DISTANCEFROMPARK*STAY, DISTANCEFROMPARK*LANDUSECATERGORIES, STAY*LANDUSECATERGORIES	.059	16	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*STAY	3.914	16	.999	2
		2	DISTANCEFROMPARK*LANDUSECATERGORIES	13.860	4	.008	2
		3	STAY*LANDUSECATERGORIES	7.160	4	.128	2
2	Generating Class[b]		DISTANCEFROMPARK*LANDUSECATERGORIES, STAY*LANDUSECATERGORIES	3.973	32	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*LANDUSECATERGORIES	14.038	4	.007	2
		2	STAY*LANDUSECATERGORIES	7.338	4	.119	2
3	Generating Class[b]		DISTANCEFROMPARK*LANDUSECATERGORIES, STAY	11.311	36	1.000	
	Deleted Effect	1	DISTANCEFROMPARK*LANDUSECATERGORIES	14.038	4	.007	2
		2	STAY	107.068	4	.000	2
4	Generating Class[b]		DISTANCEFROMPARK*LANDUSECATERGORIES, STAY	11.311	36	1.000	

a. At each step, the effect with the largest significance level for the Likelihood Ratio Change is deleted, provided the significance level is larger than .050.
b. Statistics are displayed for the best model at each step after step 0.
c. For 'Deleted Effect', this is the change in the Chi-Square after the effect is deleted from the model.

4.4 Species interaction influence on the rate of livestock predation

To assess the direction of co-existence which is approximately directed by the predation rates being density dependent (Okello, Kiringe, & Warinwa, 2014), the researcher analyzed the data from the Department of Wildlife and National Parks (DWNP) aerial surveys for the years; 1996, 1999, 2002, 2004, 2006, 2012 and 2013 for areas around Makgadikgadi and Nxai National Park. Based on the four categories of preys; livestock, lion/ hyena prey (buffalo, zebra, wild beast, gemsbok and giraffe), leopard prey (impala, kudu and duiker) and wild dog prey (impala and kudu) density the researcher determined the direction of coexistence based on whether natural prey density is greater or less than livestock. It is estimated that where natural prey density is less than livestock provides more successful opportunities for livestock predation by carnivores and vice versa (Okello, Kiringe, & Warinwa, 2014). Table 4.3.1shows different natural prey and livestock density for the study area from 1996 to 2013 even though it is not sequential and equally time distributed.

Table 4.3.1: **COMPARISONS OF THE WILD AND LIVESTOCK PREY BIOMASS FROM 1996-2013 AERIAL SURVEYS**

Year	Wild Dogs Wild Prey	Wild Dogs Livestock Prey	Leopard Wild Prey	Leopard Livestock Prey	Lion Wild Prey	Lion Livestock Prey
1996	0.58235	157.16333	0.00000	157.16333	0.58470	314.32667
1999	0.00000	188.44333	0.85441	188.44333	0.43606	376.88667
2002	0.00000	179.90819	0.00000	179.90819	0.00000	359.81638
2004	0.00000	218.76000	0.00000	218.76000	0.00000	437.52000
2006	0.00000	120.15000	0.00000	120.15000	0.00000	240.30000
2012	0.65712	25.32345	0.93282	25.32345	2.48554	50.64690
2013	1.42318	29.42440	1.66428	29.42440	7.87539	58.84881

According to the DWNP 1996-2013 aerial surveys, livestock prey for wild dogs, leopards and lions' biomass is greater than wild prey for the respective carnivores in all the years recorded. In all the years presented, both wild dogs, leopards and lions natural prey are far less than the corresponding livestock biomass. These therefore suggest that the probability of livestock predations is higher than wild or natural prey for all predators (Okello, Kirinnge, & Warinwa, 2014).

The growth rate of densities of livestock preys based on $N_f = N_0 e^{rt}$ for N_0 as initial population, N_f as final/ population of concern, r the rate of growth and t time taken in years from population exponential growth and decay shows an average negative growth for both wild dogs, leopards and lions' prey at $r = -0.04437$, $r = -0.04437$and $r = -0.04361$ respectively. Even

though livestock density is greater than wild prey for all predators in all years its average growth rate is negative at $r = -0.04432$ based exponential growth and decay theorem (Tsishchanka, 2010). These lead to;

$\frac{dN_{wilddogprey1}}{dt} = -0.04437N_{wilddogprey1}$ (25) for $N_{wilddogprey1}$ the number of wild dogs' livestock prey, $\frac{dN_{leopardprey1}}{dt} = -0.04437N_{leopardprey1}$ (26) for $N_{leopardprey1}$ the number of leopards' livestock prey, and $\frac{dN_{lionprey1}}{dt} = -0.04361N_{lionprey1}$ (27) for $N_{lionprey1}$ the number of lions' livestock prey. Equations 25, 26 and 27 can be rewritten as

$N_{fwiddogprey1} = 29.42440e^{-0.04437t}$ (28) for $N_{fwiddogprey1}$ the final population of wild dogs' livestock prey and 29.42440 the initial population of wild dogs' livestock prey in 2013,

$N_{fleopardprey1} = 29.42440e^{-0.04437t}$ (29) for $N_{fleopardprey1}$ the final population of leopards' livestock prey and 29.42440 the initial population of leopards' livestock prey, and

$N_{flionprey1} = 58.84881e^{-0.04361t}$ (30) for $N_{flionprey1}$ and 58.84881 representing the final and initial populations of lions' livestock prey respectively with 2013 the initial year. The time is the difference between final year and initial year (2013).

Taking the prey biomass to be uniform as shown table 4.1.1.2 according to 1996 to 2013 DWNP, the growth rates of the three carnivores' livestock prey for very far distance from the park are;

$N_{fwiddogprey1} = 29.42440e^{((-0.04437)-0.34657)t} = 29.42440e^{-0.39094t}$ (31),

$N_{fleopardprey1} = 29.42440e^{((-0.04437)-0.23869)t} = 29.42440e^{-0.28306t}$ (32) and

$$N_{flionprey1} = 58.84881e^{((-0.04361)-0.05776)t} = 58.84881e^{-0.10137t} \quad (33)$$ in Gweta South,

$$N_{fwiddogprey1} = 29.42440e^{((-0.04437)-0.08664)t} = 29.42440e^{-0.13101t} \quad (34)$$

$$N_{fleopardprey1} = 29.42440e^{((-0.04437)-0.02272)t} = 29.42440e^{-0.06709t} \quad (35)$$ and

$$N_{flionprey1} = 58.84881e^{((-0.04361)-0.22266)t} = 58.84881e^{-0.26627t} \quad (36)$$ in Gweta North, and

$$N_{fwiddogprey1} = 29.42440e^{((-0.04437)-0.08664)t} = 29.42440e^{-0.13101t} \quad (37),$$

$$N_{fleopardprey1} = 29.42440e^{((-0.04437)-0.20118)t} = 29.42440e^{-0.24555t} \quad (38)$$ and

$$N_{flionprey1} = 58.84881e^{((-0.04361)-0.08664)t} = 58.84881e^{-0.13025t} \quad (39)$$ in Tsokatshaa. For time (t) being the difference between the final year and initial year (2013). It is clear that for the succeeding of 2013 in all blocks of study area livestock biomass will be continuously decreasing due to carnivores (wild dogs, leopards and lions) on livestock.

From the sample $(n = 50)$, 36% of respondents indicated that the population of carnivores in the area of production is very high and 32% indicated that the population is high which sum up to 68% of respondents indicating that the population of carnivores in the area is above average. The carnivores indicated to be the most predominate in the area are hyenas. Hyenas alone contribute the highest part of the reported cases of carnivores mainly found in the area recorded by 26% of respondents. Therefore if the cases in which the pastoralists reported more than one type of

carnivore are included, the hyena is reported by more than 26% of respondents. Since most of predators reported in the PAC records are compensated for their predation gives a deviation from the actual predation rates and reported rates. In the PAC records lions constitute the highest number of predation at 73.6% whilst hyenas reported cases are less than 1%.

Cattle are reported to be the main livestock preyed in the area of study with 24% of respondents reported the cattle as the only livestock preyed in their cattle posts and this trend of being the highest livestock preyed was similarly reported in PAC predation records for 2008-2012 accounting for 59%. Contrary cattle losses to predation are much less common, proportionately than sheep losses although individual cattle are usually worth more than individual sheep (Henderson & Spaeth, 1980).

58% of respondents indicated that the population of carnivores highly increases the rate of livestock predation with 40% indicating that the population of carnivores increases the rate of predation. This implies 98% of respondents revealed that the population of carnivores does increase the rate of livestock predation in their area of production. This therefore implies that high population of carnivores increasingly decreases the population growth of livestock in the area. According to 98% of respondents, the equation of interaction between livestock and carnivores with respect to livestock growth becomes;

$\frac{dN_{livestock}}{dt} = (k_{livestock} - \beta_{livestock} N_{car}) N_{livestock} \rightarrow -ve$ (40) meaning that the growth rate of livestock decreases. Indicating that $k_{livestock} < \beta_{livestock} N_{car}$, for $K_{livestock}$ the growth rate of livestock without interaction with carnivore and $\beta_{livestock} N_{car}$ the growth rate of livestock with interaction with carnivores or predation rate.

The availability of carnivore habitats is said to be very high by $40\%(n=50)$ and high by $30\%(n=50)$. 42% indicated that carnivore habitats highly increases the rate of livestock predation and 46% revealed that it increases the rate of predation. This implies that 86% of respondents pointed that; $(k_{livestock}-\beta_{livestock}N_{car})N_{livestock}\rightarrow -ve$ because of the availability of carnivore habitats in their grazing lands.

The interaction of livestock, wild prey and carnivores

Livestock population is said to be extremely higher than wild prey by 24% respondents and 54% indicated that it is higher than wild prey. The interaction of livestock and wild prey is indicated to be very high by 12% of respondents, high by 52%, medium by 4%, low by 30% and very low by 2% of respondents. 54% of respondents indicated that the interaction of livestock and wild prey increases the rate of livestock predation. Therefore 54% of respondents showed that livestock growth rate decreases because of predation due to high interaction of livestock and wild prey. 40% of respondents showed that the interaction of livestock and wild prey does not affect the rate of livestock predation and only 6% indicated that the interaction of livestock and wild prey decreases the rate of livestock predation. This implies that;

54% of respondents indicated that $\frac{dN_{livestock}}{dt}=(k_{livestock}-\beta_{livestock}N_{car})N_{livestock}\rightarrow -ve$ due to interaction with wild prey. $\therefore \left|-\beta_{livestockcar}N\right|$ increases due to interaction of livestock and wild prey.

40% of respondents indicated that $\frac{dN_{livestock}}{dt} = (k_{livestock} - \beta_{livestock} N_{car}) N_{livestock} \to 0$ due to interaction with wild prey. $\therefore \left| -\beta_{livestock} N_{car} \right|$ is constant and 6% of respondents indicated that $\left| -\beta_{livestock} N_{car} \right|$ increases due to the interaction of livestock and wild prey. This means only 6% of respondents showed that $\frac{dN_{livestock}}{dt} = (k_{livestock} - \beta_{livestock} N_{car}) N_{livestock} \to +ve$ due to interaction of livestock and wild prey in the area of study.

10% of respondents indicated that the population of carnivores is extremely higher than the population of wild prey and 56% showed that the population of carnivore is higher that the population of wild prey. This indicates that 66% of respondents revealed that the population of carnivores is more than the population of wild prey in the area. Table 4.3.5 shows the rating of the population of carnivores based on the population of wild prey in the area.

Table 4.3.5: **The population of carnivores compared to wild prey**

Carnivore population rated out of wild prey population	Frequency	Percent
Extremely higher	5	10.0
Higher	28	56.0
Equal	4	8.0
Lower	11	22.0
Extremely lower	2	4.0
Total	50	100.0

The study shows that livestock predation rate was increased by the comparison of populations of carnivores and wild prey. Only 24% of respondents indicated that the population of carnivores

as compared to wild prey does not affect the rate of livestock predation. Figure 4.3.5 shows how the comparison of carnivores and wild prey population affect the rate of livestock predation.

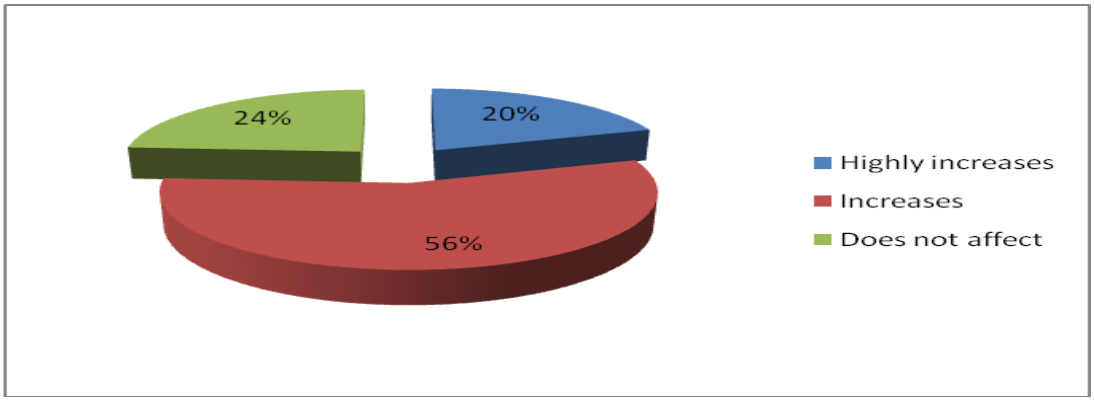

Figure 4.3.5: **The effects of carnivores compared to wild prey populations on livestock predation**

4.4.1 Influence of species interaction on carnivore predation rate on cattle

The population of livestock compared to wild prey $F(1,50.000) = 3.9$, $p = 0.053 \approx 0.05$ significantly predicted the rate of cattle predation. The interaction of livestock population compared to wild prey population * interaction rate of livestock and wild prey * effects of livestock and wild prey interaction became more inversely significant $F(1,50) = 2.369$, $p = 0.130 \approx 0.1$. There is 95% confidence that the higher the population of livestock as compared to wild prey, the higher the rate of cattle predation. The population of livestock as compared to wild prey is directly proportional to the rate of cattle predation. This implies that as the number of cattle increases as compared to the number of wild prey $-\beta_{cattle} N_{car}$ further decreases. Therefore, $\frac{dN_{cattle}}{dt} = (k_{cattle} - \beta_{cattle} N_{car}) N_{cattle} \rightarrow -ve$ (41) meaning that the growth in cattle population is decreased by predation. For k_{cattle} being the growth rate of cattle without interaction with carnivores and $-\beta_{cattle} N_{car}$ being the growth rate of cattle with interaction with carnivores due to the population of livestock compared to wild prey. Table 4.3.1.1 further shows

the components of carnivores, wild prey and livestock interaction, and their significance on the rate of cattle rate of predation.

Table 4.3.1.1: **Species interaction factors influencing carnivore predation on cattle**

Parameter	**Estimate**	**Std. Error**	**df**	**t**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	**Upper Bound**
Intercept	-183.446163	194.174714	50.000	-.945	.349	-573.457555	206.565228
Carnivore population	-25.900966	22.381928	50.000	-1.157	.253	-70.856392	19.054460
Carnivore mainly found	-4.132862	4.438365	50	-.931	.356	-13.047581	4.781857
Livestock preyed	6.891277	8.399259	50.000	.820	.416	-9.979131	23.761686
Carnivore population effect	-13.160380	56.986658	50.000	-.231	.818	-127.621451	101.300691
Availability of carnivore habitat	3.087864	22.879489	50.000	.135	.893	-42.866942	49.042670
Effect of carnivore habitat	35.066715	43.409812	50	.808	.423	-52.124459	122.257889
Livestock compared to wild prey population	71.334671	36.002542	50.000	1.981	.053	-.978563	143.647905
Interaction rate of livestock and wild prey	33.716677	27.524958	50	1.225	.226	-21.568827	89.002182
Effects of livestock and wild prey interaction	39.994541	32.727979	50	1.222	.227	-25.741538	105.730621
Carnivores compared to wild prey	6.774084	18.212391	50	.372	.712	-29.806579	43.354747
Effects of carnivore and wild prey interaction	-29.216271	30.729392	50	-.951	.346	-90.938071	32.505530
Carnivore competition effects	.023654	.072000	50	.329	.744	-.120961	.168269
Comments on the interaction to promote coexistence	-.020310	.040145	50	-.506	.615	-.100945	.060324
Carnivore population * carnivore mainly found * livestock preyed	.032992	.414554	50.000	.080	.937	-.799665	.865648
Carnivore population effect * availability of carnivore habitat * effect of carnivore habitat	-.635402	5.155125	50	-.123	.902	-10.989775	9.718972
Livestock compared to wild prey population * interaction rate of livestock and wild prey * effects of livestock and wild prey interaction	-5.735432	3.726360	50	-1.539	.130	-13.220047	1.749183
Carnivores compared to wild prey population * effects of carnivore and wild prey interaction * carnivore competition effects	-.002655	.014501	50	-.183	.855	-.031781	.026471

a. Dependent Variable: Categories of cattle predation.

4.4.2 Influence of species interaction on carnivore predation rate on goats

Livestock preyed $F(1,50) = 2.994$, $p = 0.092 < 0.1$, carnivore population effects on livestock predation $F(1,50) = 3.193$, $p = 0.080 < 0.1$, availability of carnivore habitats $F(1,50) = 2.754$, $p = 0.103 \approx 0.1$, effects of availability of carnivore habitats $F(1,50) = 3.144$, $p = 0.082 < 0.1$, and carnivore population compared to wild prey $F(1,50) = 3.501$, $p = 0.067 < 0.1$ significantly predict goats' rate of predation. Cattle are the most reared livestock and in most cases pastoralists who keep cattle have small number of goats from the analysis, the rate of goats' predation is inversely proportional to the rate of cattle predation. The higher the availability of carnivore habitats, habitats effects on predation and carnivores' population as compared to wild prey increases the rate goats' predation. Table 4.3.2.1 further shows the components of carnivores, wild prey and livestock interaction, and their significance on goats' rate of predation.

Table 4.3.2.1: **Species interaction factors influencing rate of carnivore predation on goats**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	712.724062	386.152090	50	1.846	.071	-62.885236	1488.333360
Carnivore population	-54.933763	44.510576	50	-1.234	.223	-144.335886	34.468361
Carnivore mainly found	-6.717941	8.826505	50	-.761	.450	-24.446498	11.010616
Livestock mainly preyed	-28.661628	16.703470	50	-1.716	.092	-62.211535	4.888278
Carnivore population effect	-202.516472	113.328438	50	-1.787	.080	-430.143339	25.110394
Availability of habitat	-75.509414	45.500067	50.000	-1.660	.103	-166.898988	15.880160
Effect of carnivore habitat	153.067126	86.328386	50	1.773	.082	-20.328540	326.462793
Livestock compared to wild prey population	-31.269394	71.597669	50	-.437	.664	-175.077544	112.538757
Interaction rate of livestock and wild prey	-16.333123	54.738435	50	-.298	.767	-126.278505	93.612259
Effects of livestock and wild prey interaction	19.370393	65.085598	50	.298	.767	-111.357877	150.098663
Carnivores compared to wild prey population	-67.772714	36.218684	50	-1.871	.067	-140.520083	4.974654
Effects of carnivore and wild prey interaction	25.698141	61.111041	50	.421	.676	-97.046998	148.443280
Carnivore competition effects	-.123013	.143184	50	-.859	.394	-.410607	.164582
Comments on the interaction to promote coexistence	.111485	.079836	50	1.396	.169	-.048871	.271842
Carnivore population * carnivore mainly found * livestock mainly preyed	.673901	.824417	50	.817	.418	-.981990	2.329792
Carnivore population effect * availability of carnivore habitat * effects of carnivore habitat	8.016749	10.251913	50	.782	.438	-12.574825	28.608323
Livestock compared to wild prey population * interaction rate of livestock and wild prey * effects of livestock and wild prey interaction	-2.172801	7.410552	50	-.293	.771	-17.057333	12.711730
Carnivores compared to wild prey * effects of carnivore and wild prey interaction * carnivore competition effects	.031454	.028838	50	1.091	.281	-.026469	.089377

a. Dependent Variable: Categories of goats' predation.

4.4.3 Influence of species interaction on carnivore predation rate on horses

Carnivore mainly found in the area $F(1,50.000) = 3.792$, $p = 0.057 < 0.1$, availability of carnivore habitat $F(1,50) = 3.531$, $p = 0.066 < 0.1$, livestock population as compared to wild prey $F(1,50) = 3.275$, $p = 0.076 < 0.1$,and effects of livestock and wild prey interaction

$F(1,50) = 5.725,\ p = 0.021 < 0.05$ significantly contributed to the rate of horse predation. The Hyena was at first place in carnivores found in the area of study which implies the negative estimate indicates that hyenas are the main cause of horses' predation. The rate of horses' predation is high in areas of low carnivore habitats which mean horses are left unattended. The higher the number of livestock as compared to wild prey the higher the rate of horses' predation. The interaction of; carnivore population*carnivore mainly found in the area*livestock mainly preyed $F(1,50.000) = 2.863,\ p = 0.097 < 0.1$ and livestock population compared to wild prey population*interaction rate of livestock and wild prey*effects of livestock and wild prey interaction $F(1,50) = 3.666,\ p = 0.061 < 0.1$ contributed significantly to the rate of horse predation. Table 4.3.3.1 further shows the components of carnivores, wild prey and livestock interaction, and their significance on horse rate of predation.

Table 4.3.3.1: **Species interaction factors influencing rate of carnivore predation on horses**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	-450.946748	463.096987	50	-.974	.335	-1381.104421	479.210925
Carnivore population	-10.871498	53.379780	50.000	-.204	.839	-118.087942	96.344946
Carnivore mainly found	-20.611884	10.585280	50.000	-1.947	.057	-41.873044	.649275
Livestock preyed	-4.102969	20.031813	50.000	-.205	.839	-44.338050	36.132111
Carnivore population effect	-29.279421	135.910331	50	-.215	.830	-302.263354	243.704512
Availability of carnivore habitat	-102.538427	54.566437	50	-1.879	.066	-212.138343	7.061488
Effect of carnivore habitat	134.509787	103.530232	50.000	1.299	.200	-73.436803	342.456378
Livestock compared to wild prey	155.387002	85.864264	50	1.810	.076	-17.076447	327.850451
Interaction rate of livestock and wild prey	81.002626	65.645648	50	1.234	.223	-50.850539	212.855791
Effects of livestock and wild prey interaction	186.757785	78.054593	50	2.393	.021	29.980521	343.535049
Carnivores compared to wild prey	22.963565	43.435641	50	.529	.599	-64.279488	110.206618
Effects of carnivore and wild prey interaction	-17.146304	73.288064	50.000	-.234	.816	-164.349713	130.057105
Carnivore competition effects	-.198752	.171715	50	-1.157	.253	-.543652	.146149
Comments on the interaction to promote coexistence	.073589	.095745	50	.769	.446	-.118719	.265898
Carnivore population * carnivore mainly found * livestock mainly preyed	1.672814	.988691	50.000	1.692	.097	-.313031	3.658659
Carnivore population effect * availability of habitat * effect of habitat	7.107406	12.294716	50	.578	.566	-17.587257	31.802069
Livestock compared to wild prey * interaction rate of livestock and wild prey * effects of livestock and wild prey interaction	-17.015215	8.887183	50	-1.915	.061	-34.865647	.835218
Carnivores compared to wild prey population * effects of carnivore and wild prey interaction * carnivore competition effects	.033836	.034584	50	.978	.333	-.035629	.103300

a. Dependent Variable: Categories of horse predation.

4.4.4 Influence of species interaction on carnivore predation rate on donkeys

The interaction of carnivore population*carnivore mainly found*livestock mainly preyed $F(1,50) = 2.349,\ \ p = 0.132 \approx 0.1$ contributed significantly to the rate of donkey predation. Table 4.3.4.1 further shows the components of carnivores, wild prey and livestock interaction, and their significance on donkeys' rate of predation.

Table 4.3.4.1: **Species interaction factors influencing rate of carnivore predation on donkeys**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	210.309005	496.953392	50	.423	.674	-787.851259	1208.469270
Carnivore population	5.418536	57.282305	50	.095	.925	-109.636359	120.473432
Carnivore mainly found	-11.604569	11.359155	50	-1.022	.312	-34.420104	11.210966
Livestock mainly preyed	-20.907117	21.496312	50.000	-.973	.335	-64.083732	22.269497
Carnivore population effect	-54.174386	145.846554	50	-.371	.712	-347.115812	238.767039
Availability of carnivore habitat	35.807240	58.555717	50.000	.612	.544	-81.805380	153.419859
Effect of carnivore habitat	-67.633986	111.099190	50	-.609	.545	-290.783275	155.515304
Livestock compared to wild prey population	46.885077	92.141686	50	.509	.613	-138.186946	231.957100
Interaction rate of livestock and wild prey	-20.231149	70.444914	50	-.287	.775	-161.723923	121.261626
Effects of livestock and wild prey interaction	104.089635	83.761061	50	1.243	.220	-64.149407	272.328676
Carnivores compared to wild prey	-6.120358	46.611163	50	-.131	.896	-99.741635	87.500918
Effects of carnivore and wild prey interaction	53.637758	78.646057	50	.682	.498	-104.327497	211.603013
Carnivore competition effects	-.103669	.184269	50	-.563	.576	-.473785	.266447
Comments on the interaction to promote coexistence	-.134015	.102744	50	-1.304	.198	-.340383	.072353
Carnivore population * carnivore mainly found * livestock preyed	1.626039	1.060973	50	1.533	.132	-.504988	3.757066
Carnivore population effect * availability of habitat * effect of habitat	-4.491763	13.193566	50.000	-.340	.735	-30.991820	22.008294
Livestock compared to wild prey population * interaction rate of livestock and wild prey * effects of livestock and wild prey interaction	-9.317592	9.536913	50	-.977	.333	-28.473045	9.837862
Carnivores compared to wild prey * effects of carnivore and wild prey interaction * carnivore competition effects	.030987	.037113	50	.835	.408	-.043556	.105531

a. Dependent Variable: Categories of donkey predations.

Based on availability of carnivores habitats in the study area, population of livestock compared to wild prey, interaction rate of livestock and wild prey, and population of carnivores compared to wild prey as categories of the predation model removing the main effects $K = 1$

$(P = 0.000 < 0.05)$ shows a significant effect on the model. The population of carnivores compared to the population of wild prey $(P = 0.000 < 0.01)$ is significant showing that there was a higher livestock predation where the carnivores' population is higher than wild prey. The two way interactions $K = 2$ $(P = 0.000 < 0.05)$ have a significant detrimental effect on the donkey's predation model as shown in Table: 4.3.4.2. Livestock compared to wild prey population* interaction rate of livestock and wild prey $(P = 0.149 \approx 0.1)$, and availability of carnivores' habitats* interaction rate of livestock and wild prey $(P = 0.011 \approx 0.01)$ interactions are significant livestock predation. The integration of higher population livestock compared to wild prey, and higher interaction of livestock and wild prey result in higher rate of donkeys 'predation. Furthermore, in cases where carnivores' habitats are high and the interactions of livestock and wild prey are high the rate of donkeys' rate of predation experienced was high.

Table 4.3.4.2: **K-Way and Higher-Order Effects on Livestock Predation**

			Likelihood Ratio		Pearson		Number of
	K	df	Chi-Square	Sig.	Chi-Square	Sig.	Iterations
K-way and Higher Order Effects[a]	1	624	308.025	1.000	1525.000	.000	0
	2	608	151.387	1.000	1243.387	.000	2
	3	512	44.549	1.000	43.830	1.000	3
	4	256	2.718	1.000	1.612	1.000	2
K-way Effects[b]	1	16	156.638	.000	281.613	.000	0
	2	96	106.838	.211	1199.556	.000	0
	3	256	41.830	1.000	42.218	1.000	0
	4	256	2.718	1.000	1.612	1.000	0

df used for these tests have NOT been adjusted for structural or sampling zeros. Tests using these df may be conservative.

a. Tests that k-way and higher order effects are zero.

b. Tests that k-way effects are zero.

These imply that in areas where livestock is higher than wild prey and where there is high interaction between wild prey and livestock, livestock predation is high. In addition there is high livestock predation rate in areas where there are more carnivore habitats and interaction rate between livestock and wild prey is high.

4.5 Influence of livestock husbandry on the rate of carnivore predation on livestock

According to the data gathered 98% of respondents owned cattle, 80% owned goats, 62% owned horses while 54% owned donkeys.

4.5.1 Influence of livestock husbandry on the rate of carnivore predation on cattle

A total of 2021 cattle were owned by respondents; 72%($n = 50$) of respondents owned less than fifty cattle while only 2% owned 230 cattle which was the only number of cattle on the range of $201-250 cattle$. Table 4.4.1.1 shows the range of number cattle owned by the respondents.

Table 4.4.1.1 **Number of cattle owned by respondents**

Range of number of cattle owned	**Frequency**	**Percent**
≤ 50	36	72%
$51-100$	9	18%
$101-150$	1	2%
$151-200$	1	2%
$201-250$	1	2%

The number of cattle owned and the rate of cattle predation do correlate ($p = 0.104 \approx 0.1$). Therefore the rate of cattle predation can be directly derived from the number of cattle owned by the pastoralist. Pastoralists who own a higher number of cattle experience a higher rate of cattle

predation as compared to pastoralists in the same area who own a lower number of cattle. The rate of cattle predation as revealed by respondents is shown in Table 4.4.1.2.

Table 4.4.1.2 **Rate of cattle predation**

Rate of predation	**Frequency**	**Percentage of respondents**
<5%	15	30.0
6-10%	8	16.0
11-15%	11	22.0
16-20%	7	14.0
>20%	7	14.0
no response	2	4.0
Total	50	100.0

18% of respondents indicated that they have not experienced cattle predation. The highest case of predation is reported to have been caused by lions reported by 26% of respondents and it was followed by 24% which indicated that hyenas caused the predation. 12% of respondents reported that hyenas and wild dogs preyed on their cattle leading to an increase on the rate of cattle predation caused by hyenas in the area. Carnivore involved in cattle predation correlate with the rate of cattle predation $p = 0.141 \approx 0.1$. This implies that where hyenas were reported to be the cause of predation the rate of predation was high. Figure 4.4.1.1 shows carnivores involved in cattle predation according to respondents.

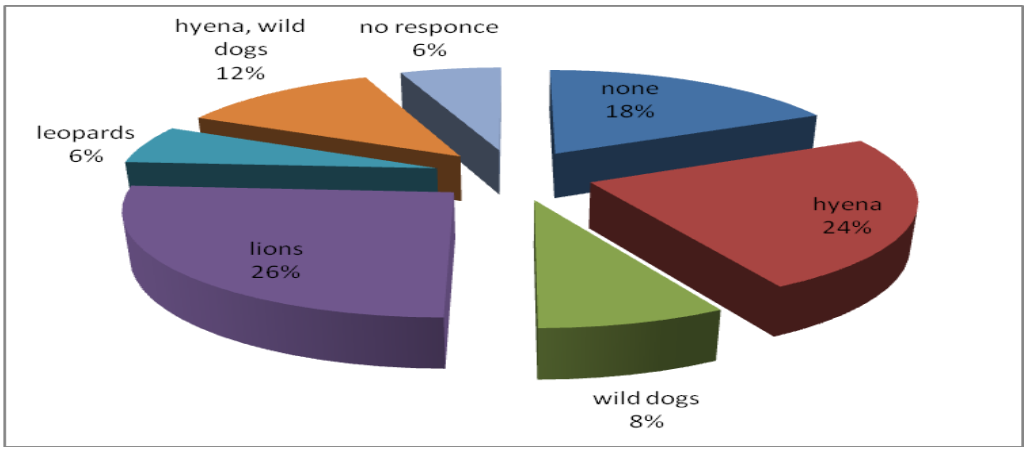

Figure 4.4.1.1 **Carnivores involved in cattle predation**

The rate of cattle predation did not correlate with carnivores involved in goats' predation $p = 0.260 > 0.1$ and carnivores involved in donkeys' predation $p = -0.317$ but positively correlate with carnivores involved in horse predation $p = 0.076 < 0.1$. This indicates that carnivores involved in cattle predation do attack horses too.

Herding and its effectiveness negatively correlate with the rate of cattle predation at $(p = -0.150)$ and $(p = -0.128)$ respectively. This proves that if herding is done seriously the rate of cattle predation could be minimized or even nullified. The effectiveness of kraaling is inversely proportional to the rate of cattle predation $(p = 0.049 < 0.05)$; respondents who kraal their cattle at night recorded low rate of cattle predation as compared to those who did not kraal and most of predation at night occurred outside the kraal.

32% of respondents kept only Tswana cattle breed in their cattle posts and as a breed reported to be susceptible to predation by 28% of respondents, cattle breed kept and breeds susceptible to predation correlated with the rate of cattle predation. Pastoralists who invest more on cattle

reported less cattle rate of predation thus economic management and cattle rate of predation negatively correlate ($p = -0.150$).

The number of cattle, goats and donkeys ($p < 0.01$, and cattle breed ($p \approx 0.05$) significantly influence cattle rate of predation. This shows farmers owning higher the number of livestock (cattle, goats and donkeys) and kept multi different breeds of cattle experienced higher rate of cattle predation as compared to those who keep a small number and single breed a farmer had the higher rate of cattle predation experienced. The significance of the carnivores involved in goats and donkeys' predation ($p < 0.01$), and rate of goats and donkeys' predation ($p < 0.01$) in cattle predation shows that high number of these carnivores and their predation resulted in high cattle predation. Similarly, the significance of the integration of carnivores involved cattle, goats, horses, and donkeys' predation ($p = 0.097 \approx 0.10$) shows that the rate of cattle predation was high because of high carnivores' population. Herding ($p = 0.061 \approx 0.05$), and the interaction of herding * kraaling* calving practice ($P = 0.011 = 0.01$) significantly reduced the rate of cattle predation. This shows that herding can be supplemented by kraaling and calving to further reduce rate of cattle predation. Pastoralists who keep predation records experience low rate of cattle predation. Table 4.4.1.3 shows components of livestock management and their significance on cattle rate of predation.

Table 4.4.1.3: **Livestock husbandry factors influencing rate of carnivore predation on cattle**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	191.721837	112.831052	48.000	1.699	.096	-35.140198	418.583871
Number of cattle	.287240	.008799	48.000	32.646	.000	.269549	.304931
Carnivore involved in cattle predation	.009284	.006849	48.000	1.356	.182	-.004486	.023054
Number of goats	-.404053	.071852	48.000	-5.623	.000	-.548521	-.259586
Categories of goats predation	-5.330335	1.720278	48.000	-3.099	.003	-8.789187	-1.871484
Carnivore involved in goats	1.320302	.428369	48.000	3.082	.003	.459008	2.181596
Number of horses	-.054670	.321946	48.000	-.170	.866	-.701985	.592645
Categories of horse predation	.421980	1.344302	48.000	.314	.755	-2.280920	3.124880
Carnivore involved in horse predation	-.095558	.296729	48.000	-.322	.749	-.692171	.501056
Number of donkeys	-2.250564	.663241	48.000	-3.393	.001	-3.584099	-.917028
Categories of donkey predation	5.037247	1.844301	48.000	2.731	.009	1.329031	8.745462
Carnivore involved in donkey predation	-1.040021	.380032	48.000	-2.737	.009	-1.804127	-.275916
Predation measures (Herding)	-15.212695	7.926620	48.000	-1.919	.061	-.724842	31.150233
Carnivores controlled by herding	-.023294	.098049	48.000	-.238	.813	-.220435	.173846
Effectiveness herding	.014690	.066938	48.000	.219	.827	-.119899	.149278
Predation measures (kraaling)	-171.429122	109.820101	48.000	-1.561	.125	-392.237234	49.378990
Carnivores controlled by kraaling	-.571580	.378283	48.000	-1.511	.137	-1.332169	.189009
Effectiveness of kraaling	1.205228	2.101500	48.000	.574	.569	-3.020120	5.430576
Cattle breeds kept	.029821	.015982	48.000	1.866	.068	-.002312	.061954
Breeds susceptible to predation	.006813	.007739	48.000	.880	.383	-.008746	.022373
Breeds resistant to predation	.002352	.007977	48.000	.295	.769	-.013687	.018392
Calving practice	.749957	1.183139	48.000	.634	.529	-1.628903	3.128818
Rate of records keeping	1.331091	.883101	48.000	1.507	.138	-.444503	3.106684
Economic management of livestock production	-1.862868	1.591004	48.000	-1.171	.247	-5.061796	1.336061
cattle * goats * horse * donkey	4.179178E-006	3.180004E-006	48.000	1.314	.195	-2.214649E-006	1.057300E-005
Carnivores involved in cattle predation * carnivores involved in goats predation * carnivores involved in horse predation * carnivores involved in donkey predation	1.858413E-010	1.098861E-010	48	1.692	.097	-3.509839E-011	4.065811E-010
Herding * kraaling * calving practice	-4.854265	1.845957	48.000	-2.630	.011	-8.565810	-1.142720

a. Dependent Variable: Categories of cattle predation.

4.5.2 Influence of livestock husbandry on the rate of carnivore predation on goats

A total of 1134 goats were owned by respondents; 72% of respondents owned 50 and less goats, 4% owned 51–100 goats and 4% owned 101–150 goats. The maximum number of goats owned was 120 owned by two respondents. The number of goats owned negatively correlate with the rate of goats' predation ($p = -0.032$) showing that respondents perceived higher rate of carnivore predation on goats to be occurring to producers owning small number of goats. Table 4.4.2.1 reveals the rate of goats' predation according to the data gathered.

Table 4.4.2.1: **Rate of goats' predation reported by 50 respondents**

% or rate of predation	Frequency/ number of respondents	Percent
<5%	7	14.0
6-10%	8	16.0
11-15%	8	16.0
16-20%	4	8.0
>20%	13	26.0
no response	10	20.0
Total	50	100.0

The highest number of respondents indicated that they experience more than twenty percent goats' predation. 26% of respondents showed that jackals are involved in their goats' predation and hyena predation was reported by 14%. Figure 4.4.2.1 shows carnivores involved in goats' predation and their frequencies according to the fifty respondents.

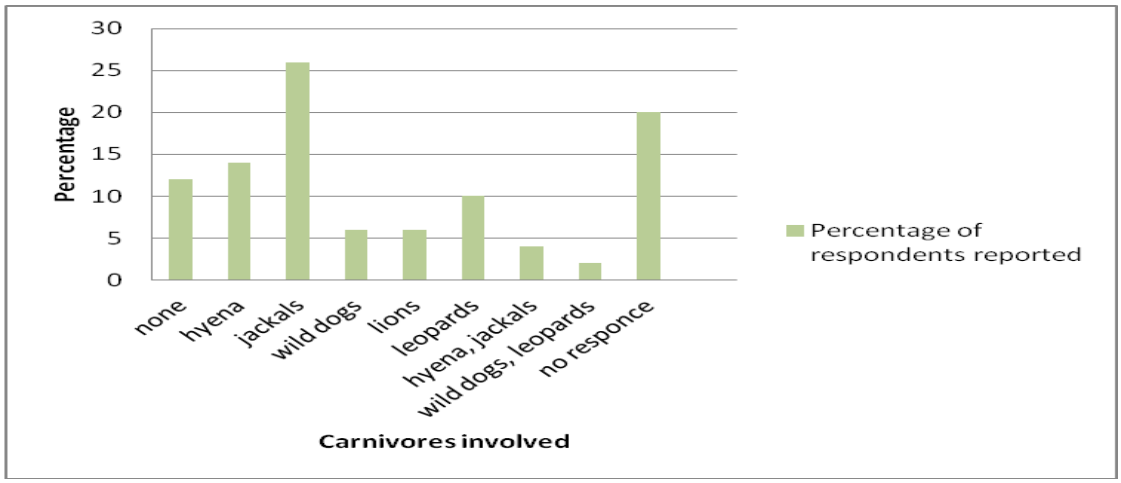

Figure 4.4.2.1: **Carnivores involved in goats predation according to 50 respondents**

Carnivores involved in goats' predation correlate with the rate of goats' predation $(p = 0.100)$ in showing that a higher the number of different carnivores found in the area increases the rate of goats' predation. The negative correlation $(p = -0.106)$ of rate of horses and goats' predation shows that the rates of predations on horses were opposite the rates of predations on goats. This was further supported by the perceived correlation between carnivores involved in horse predation and the rate of goats' predation which shows that one is a secondary prey. Donkey rate of predation correlates with the of goats' predation $(p = 0.102 \approx 0.1)$ with carnivores involved in donkeys' predation negatively correlating $(p = -0.102)$ with the rate of goats' predation. It is perceived that the trend of donkey predation is uniform with the rate of goats' predation.

Effectiveness of herding and kraaling negatively correlate with the rate of goats' predation which implies when herding and kraaling are done properly the rate of goats' predation could be reduced. Watch dogs use as a predation measure showed no correlation with goats' rate of predation because few people use dogs to control predation. The rate of goats' predation is less for people who spend more in their livestock production this is evidenced by a negative

correlation between the rate of goats' predation and economic management of production ($p = -0.136$).

The number of cattle and donkeys ($p < 0.05$) significance in the rate of goats' predation shows that pastoralist owning high number of cattle and donkeys experience high rate of goats' predation. The significance of the rate of donkeys' predation ($p < 0.01$) on the rate of goats indicated that pastoralists experienced a similar frequency trend for goats and donkeys. Goats' predation was high in areas where there is a high number of carnivores involved in goats and donkeys' predation ($p < 0.01$). Carnivores controlled by herding ($p = 0.10$), and carnivores controlled by watch dogs ($p < 0.05$) significantly reduced the rate of goats' predation. These show that if a high number of carnivores can be controlled by herding and watch dogs their effective use would promote co-existence. Table 4.4.2.2 shows components of livestock management and their significance on goats' rate of predation.

Table 4.4.2.2: **Livestock husbandry factors influencing rate of carnivore predation on goats**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Intercept	15.210786	11.716437	48.000	1.298	.200	-8.346689	38.768261
Cattle	.001981	.000772	48.000	2.565	.013	.000428	.003534
Carnivore involved cattle predation	-.000533	.000670	48.000	-.795	.431	-.001881	.000815
Goats	-.004340	.006911	48.000	-.628	.533	-.018235	.009555
Carnivore involved goats predation	.249012	.000183	48.000	1361.607	.000	.248644	.249379
Horse	.035983	.031488	48.000	1.143	.259	-.027329	.099294
Categories of hose predation	.089979	.117852	48.000	.763	.449	-.146977	.326936
Carnivore involved in horse predation	-.019866	.026076	48.000	-.762	.450	-.072296	.032563
Donkey	-.230967	.058945	48.000	-3.918	.000	-.349484	-.112450
Categories of donkey predation	.568520	.124415	48.000	4.570	.000	.318367	.818673
Carnivore involved donkey predation	-.117549	.025606	48.000	-4.591	.000	-.169033	-.066065
Predation measures (herding)	-.076424	.846765	48.000	-.090	.928	-1.778959	1.626110
Carnivore controlled by herding	-.015747	.009906	48.000	-1.590	.118	-.035664	.004170
Effectiveness of herding	.003141	.006520	48.000	.482	.632	-.009968	.016249
Predation measures (kraaling)	-14.125081	11.382829	48.000	-1.241	.221	-37.011794	8.761631
Carnivore controlled by kraaling	-.043949	.039667	48.000	-1.108	.273	-.123706	.035807
Effectiveness of kraaling	.009133	.208759	48.000	.044	.965	-.410605	.428871
Predation measures watch dogs	-.436128	.671227	48.000	-.650	.519	-1.785719	.913464
Carnivore controlled watch dogs	.298581	.131347	48.000	2.273	.028	.034490	.562672
Effectiveness of watch dogs	-.168846	.141746	48.000	-1.191	.239	-.453845	.116153
Rate of records keeping	.109348	.080902	48.000	1.352	.183	-.053316	.272012
Economic management	.006739	.144500	48.000	.047	.963	-.283798	.297276
cattle * goats * horse * donkey	8.055625E-008	3.120562E-007	48.000	.258	.797	-5.468749E-007	7.079872E-007
Carnivore involved in cattle predation* carnivore involved in goats predation * carnivore involved in donkey predation * carnivore involved in horse predation	3.442400E-012	1.063798E-011	48.000	.317	.752	-1.794564E-011	2.463044E-011

a. Dependent Variable: Categories of goats predation.

4.5.3 Influence of livestock husbandry on the rate of carnivore predation on horses

At the time of the research the sample owned a total of 214 horses with 30 horses as the highest number of horses owned by a single pastoralist. From the 62% of the sample which owned horses; 19 respondents owned $1-5$ horses, 7 respondents owned $6-10$ horses, 2 respondents owned $11-15$ horses, 20, 22 and 30 horses were owned by 1 person respectively. The rate of horses' predation correlated with the number of horses owned by individuals ($p = 0.011 \approx 0.01$). Therefore, pastoralist owning a high number of horses experienced high rate of horse predation. Lions were indicated as the horse predator by the highest number of respondents (16%) and carnivores involved in horse predation correlates with the rate of predation ($p = 0.069 \approx 0.05$) so horses are mostly preyed where lions are involved and where there are many different species of carnivores. Figure 4.4.3.1 and figure 4.4.3.2 show carnivores involved in horse predation and the rate of predation as indicated by respondents respectively.

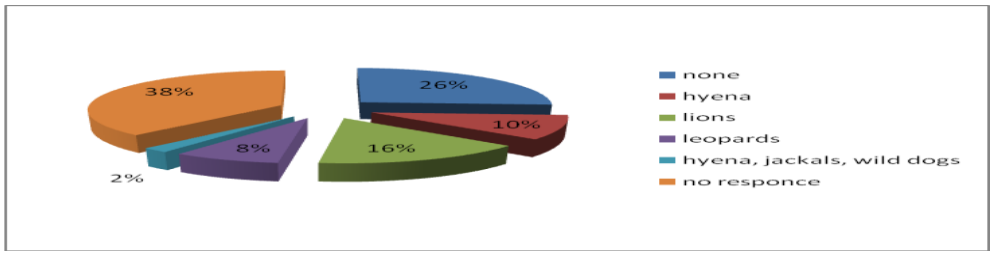

Figure 4.4.3.1: **Carnivores involved in horses' predation**

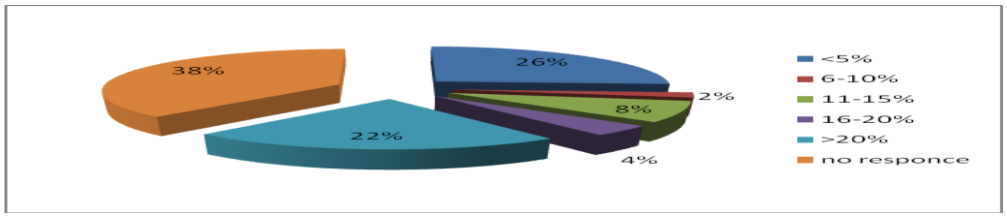

Figure 4.4.3.2: **The rate of horses' predation indicated by respondents**

Donkeys' rate of predation and the interaction of the number of cattle*goats*horses*donkeys correlate with the rate of horses' predation which implies that there is a direct linkage between the number of livestock owned and the rate of horses' predation. Herding effectiveness, kraaling and economic management of production negatively correlate with the rate of horses' predation. These therefore means that if money is spent to improve herding and kraaling so that they are practiced properly the rate of horses' predation is minimized. Carnivores involved in horses' predation, rate of donkey predation, carnivores involved in donkeys' predation, and rate of recording keeping significantly predict the rate of horses' predation. People who always keep livestock predation records experience low rate of horse predation as compared to those who never keep records. Table 4.4.3.1 shows components of livestock management and their significance on horses' rate of predation.

Table 4.4.3.1: **Livestock husbandry factors influencing rate of carnivore predation on horses**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
intercept	10.547541	14.268607	48.000	.739	.463	-18.141416	39.236499
cattle	-.000383	.000944	48.000	-.405	.687	-.002281	.001516
Carnivore involved cattle predation	.000397	.000819	48.000	.485	.630	-.001250	.002044
goats	.008246	.008380	48.000	.984	.330	-.008603	.025094
Carnivore involved goats' predation	-.000125	.000223	48.000	-.561	.577	-.000574	.000324
horse	.027141	.038365	48.000	.707	.483	-.049998	.104280
Carnivore involved in horses' predation	.221256	.000216	48.000	1023.472	.000	.220821	.221691
donkey	.026726	.072089	48.000	.371	.712	-.118219	.171671
Categories of donkeys' predation	.374105	.142488	48.000	2.626	.012	.087614	.660595
Carnivore involved in donkeys' predation	-.076688	.029342	48.000	-2.614	.012	-.135684	-.017692
Predation measures (herding)	.161354	1.036806	48.000	.156	.877	-1.923284	2.245991
Carnivore controlled by herding	-.012364	.012000	48.000	-1.030	.308	-.036492	.011764
Effectiveness of herding	.005392	.007947	48.000	.679	.501	-.010586	.021370
Predation measures (kraaling)	-9.173088	13.877997	48.000	-.661	.512	-37.076671	18.730495
Carnivore controlled by kraaling	-.032284	.048358	48.000	-.668	.508	-.129514	.064946
Effectiveness of kraaling	-.001726	.255675	48.000	-.007	.995	-.515795	.512344
Predation measures (watch dogs)	-.401186	.820036	48.000	-.489	.627	-2.049980	1.247608
Carnivore controlled by watch dogs	.149255	.159417	48.000	.936	.354	-.171274	.469785
Effectiveness of watch dogs	-.152210	.172206	48.000	-.884	.381	-.498453	.194034
Rate of records keeping	-.156939	.096460	48.000	-1.627	.110	-.350885	.037006
Economic management	-.054787	.176799	48.000	-.310	.758	-.410264	.300691
cattle * goats * horse * donkey	-5.887768E-007	3.726198E-007	48.000	-1.580	.121	-1.337979E-006	1.604256E-007
Carnivore involved in cattle predation * carnivore involved in goats' predation* carnivore involved in horses' predation * carnivore involved in donkeys' predation	4.335657E-012	1.299181E-011	48.000	.329	.744	-2.178506E-011	3.025637E-011

a. Dependent Variable: Categories of horse predation.

4.5.4 Influence of livestock husbandry on the rate of carnivore predation on donkeys

During the time of data gathering a total of 210 donkeys were owned by the sample. The highest number of donkeys owned during the time of study was twenty which was owned by a unit and

the highest number of respondents $12\%(n=50)$ owned 20 donkeys. 24% of respondents owned ≤ 5 donkeys, 18% owned $6-10$ donkeys, 8% owned $11-15$ donkeys and 4% owned $16-20$ donkeys. From the 27 people from the sample who own donkeys, 13 people recorded more than 20% of donkey predation making $26\%(n=50)$ of the sample. Figure 4.4.4.1 shows the rating of donkey predation according to respondents.

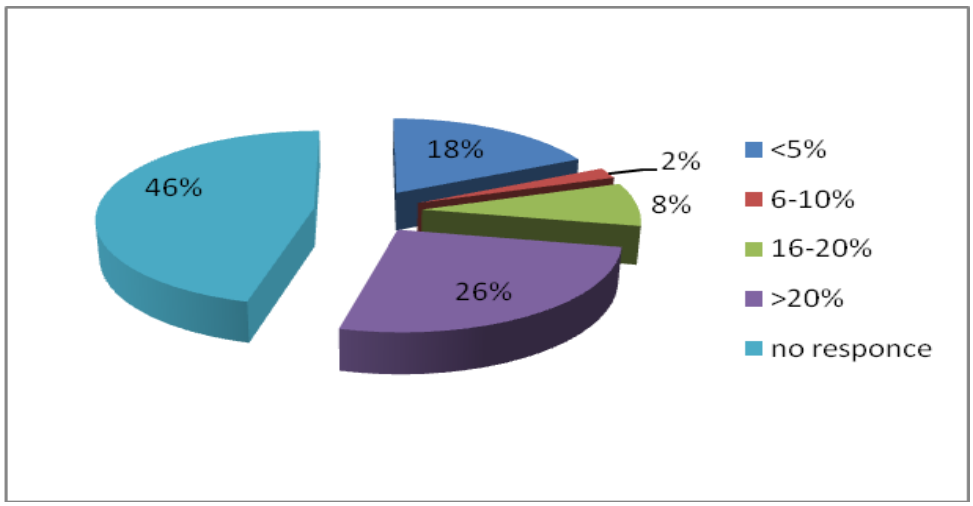

Figure 4.4.4.1: **Rate o f donkey predation reported by respondents**

The number of donkeys preyed and the number of donkeys owned by pastoralist correlate $(p=0.079<0.1)$. This means pastoralists who own high number of donkeys experienced a high rate of predation. Hyenas' predation was the highest recorded by 20% of respondents. Table 4.4.4.1 reveals carnivores involved in donkeys' predation as reported by respondents.

Table 4.4.4.1: **Carnivore involved in donkey predation**

Carnivores	Frequency	Percent	Valid Percent	Cumulative Percent
none	10	20.0	20.0	20.0
hyena	10	20.0	20.0	40.0
wild dogs	2	4.0	4.0	44.0
lions	4	8.0	8.0	52.0
leopards	1	2.0	2.0	54.0
no response	23	46.0	46.0	100.0
Total	**50**	**100.0**	**100.0**	

The rate of donkey predation negatively correlates $(p = -0.061 < -0.05)$ with carnivores involved in donkeys' predation which implies that where hyenas are involved in predation the rate of predation is high. Herding effectiveness and kraaling negatively correlate with the rate of donkeys' predation at $(p = -0.150 \approx -0.1)$ and $(p = -0.182 \approx -0.1)$ respectively. This means predation can be reduced by proper herding and kraaling. Herding dogs and the rate of donkeys' rate of predation do not correlate. The sum of the number of cattle, goats, horses and donkeys correlate with the rate of donkeys' predation $(p = 0.113 \approx 0.1)$ which implies that the higher the number of both livestock the higher the predation rate. Therefore there is a direct proportion between rate of predation and number of livestock.

The numbers of goats, carnivores involved in donkeys' predation and the use of watch dogs significantly predict the rate of donkeys' predation. Table 4.4.4.2 shows components of livestock management and their significance on donkeys' rate of predation.

Table 4.4.4.2: **Livestock husbandry factors influencing rate of carnivore predation on donkeys**

Parameter	Estimate	Std. Error	df	t	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
intercept	-6.916704	14.419329	48.000	-.480	.634	-35.908708	22.075301
Cattle	-.001150	.000942	48.000	-1.221	.228	-.003044	.000744
Carnivore involved in cattle predation	.000204	.000829	48.000	.246	.807	-.001463	.001871
Goats	-.014519	.008226	48.000	-1.765	.084	-.031058	.002020
Carnivore involved goats predation	3.827879E-005	.000226	48.000	.169	.866	-.000416	.000493
Horses	-.005847	.038854	48.000	-.150	.881	-.083969	.072274
Carnivore involved horses' predation	3.133913E-005	.000219	48.000	.143	.887	-.000409	.000472
Donkeys	.059587	.072517	48.000	.822	.415	-.086218	.205392
Carnivore involved donkeys' predation	.205919	.000257	48.000	802.163	.000	.205403	.206435
Predation measures (Herding)	.250707	1.049642	48.000	.239	.812	-1.859740	2.361154
Carnivore controlled by herding	-.012187	.012028	48.000	-1.013	.316	-.036371	.011997
Effectiveness of herding	.002720	.008040	48.000	.338	.737	-.013446	.018887
Predation measures (Kraaling)	8.015345	14.010482	48.000	.572	.570	-20.154618	36.185308
Carnivore controlled by kraaling	.031525	.048774	48.000	.646	.521	-.066541	.129592
Effectiveness of kraaling	-.112650	.258484	48.000	-.436	.665	-.632366	.407066
Predation measures (watch dogs)	1.121374	.814761	48.000	1.376	.175	-.516814	2.759561
Carnivore controlled by watch dogs	.081983	.161053	48.000	.509	.613	-.241835	.405801
Effectiveness of watch dogs	.180896	.172476	48.000	1.049	.300	-.165891	.527683
Rate of records keeping	-.124192	.096054	48.000	-1.293	.202	-.317321	.068937
Economic management	.197304	.176815	48.000	1.116	.270	-.158207	.552814
cattle * goats * horse * donkey	4.344478E-007	3.722121E-007	48.000	1.167	.249	-3.139349E-007	1.182830E-006
Carnivore involved in cattle predation * carnivore involved in goats predation * carnivore involved in horse predation * carnivore involved in donkeys predation	4.544543E-012	1.314341E-011	48.000	.341	.735	-2.188099E-011	3.077007E-011

a. Dependent Variable: Categories' of donkey predations.

Herding was practiced by 62% of respondents and it was indicated by 50% as very effective, 8% as effective and was neutral about its effectiveness. Kraaling was practiced by 43% of respondents; 60% of respondents indicated that kraaling is very effective way of controlling

carnivore predation, 20% indicated that it is effective and 4% was neutral about its effectiveness. Only 30% of respondents used watch dogs as a predation measure; 26% indicated that watch dogs are very effective in controlling carnivore predation, 4% indicated that it is effective and 6% was neutral about the effectiveness of watch dogs in carnivore predation prevention.

Herding, watch dogs, fencing of the park and kraaling were suggested to be used to prevent predation. People kept different breeds of cattle and the most breed kept was Tswana breed. The highest number of respondents indicated that Tswana breed was susceptible to predation and Brahman was indicated to be resistant to predation. 70% of respondents always practice calving and 44% strongly agree that calving help in reducing the rate of cattle predation. 42% of respondents always keep livestock predation records and 54% strongly agree that records keeping help in reducing the rate of livestock predation. The majority of respondents showed that economic management of production in the area was cheap with only $2\%(n=50)$ indicating the economic management very expensive. Figure 4.4.5 display rating of the economic management of production as rated by respondents.

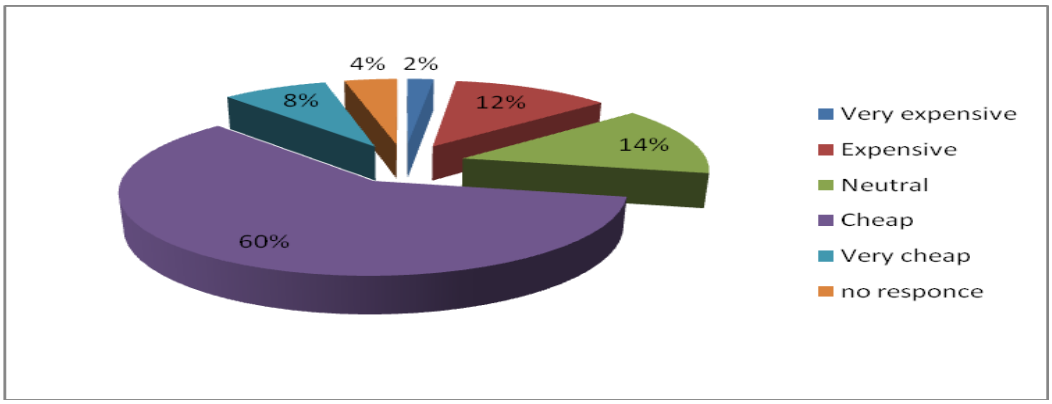

Figure: 4.4.5 **Economic management of livestock in the area**

Chapter 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

Livestock predation was indicated by the literature as the main cause of pastoralists-carnivore conflict hence leading to poor co-existence between pastoralists and carnivores (Chardonnet, et al., 2010; Nijhawan, 2008). As a result, local people look at carnivores as a liability rather than an economic and social status advantage, thus making carnivore conservation efforts to be perceived a contradiction to the socio economic endeavors of the people living in the close vicinity to the park. Few experimental tests of multiple species involved in indirect interactions; interactions between two species mediated by a third species or other controlling factors on pastoralists-carnivores interaction compelled the research. The main aims of the research was to; determine and analyze the rate of livestock predation given land use management, interaction of wild animals and livestock, and livestock management. Different components of land use management, interaction of wild animals and livestock, and livestock management were identified to contribute significantly in the rate of livestock predation. Hyenas were the most problem carnivores in the area of study which caused the highest number of predation recorded by the respondents but in the reported cases for the year 2008-2012 Problem Animals Control records lions were recorded as the most problem animals causing the modal predation in the area. The highest preyed livestock is cattle from both the field data collected through the questionnaire and the reported predation in the PAC.

5.1.1 Land use management

Land use was identified to contribute to livestock predation by carnivores; pastoralists who use land only for livestock production experienced low rate of livestock predation as compared to

those who use land for mixed production. The interaction of high population of carnivores, pastoralists not staying in livestock production areas and short distance between the park and livestock production land highly caused human carnivore conflicts in the study area.

5.1.2 Interaction between livestock and wildlife

Carnivore mainly found, availability of carnivore habitats, and livestock populations as compared to wild prey were significant in the overall rate of livestock predation. The hyena contributed to most of predations in the area; where predation was caused by hyenas its rate was high. In areas where habitats were high the rate of predation recorded was high too. There was a direct proportion between the availability of carnivores' habitats and the rate of livestock predation. The higher the number of livestock as compared to wild prey the higher the rate of livestock predation. This shows that carnivores prey on livestock as a substitute when wild prey is not enough.

5.1.3 Livestock management

Number of livestock owned by a pastoralist and the number of different varieties of livestock directly proportional affect the rate of livestock predation. The higher the number and number of varieties of livestock a pastoralist own the higher he or she experience high rate of predation. Similarly, pastoralists owning multiple varieties of cattle breeds experienced high rate of cattle predation. Herding, kraaling, watch dogs and records keeping are negatively or inversely proportional to the rate of predation.

5.2 Conclusions

The prevailing conflicts caused by livestock predation are from some of ways land use is managed, species interact, and livestock husbandry.

Livestock prey for wild dogs, leopards and lions' biomass is greater than wild prey in the area of study and population of carnivores has been identified to be high. High population of carnivores and availability of their habitats, high population of livestock compared to wild prey, high interaction rate of livestock and wild prey, high number and different species of carnivores, and the integration these factors form species interaction states negatively affecting the co-existence between pastoralists and carnivores. Livestock prey for wild dogs, leopards and lions' biomass is greater than wild prey in the area of study and population of carnivores has been identified to be high. Predation rate has been identified to be high where population of livestock is higher compared to wild prey, high availability of carnivores' habitants, many carnivores' species found and many species of livestock preyed. The integration of high population livestock compared to wild prey, high carnivores' population and species, high interaction rate of livestock and wildlife, and high population and different species of livestock increased the livestock predation rate hence negatively affecting the co-existence of pastoralists with carnivores.

Farmers near the park $(0-10km)$ experienced lower rate of predation by leopards and wild dogs than in areas very far from the park $(>20km)$ for Gweta South, Gweta North and Tsokatshaa. Lions' predation was higher near the park in Gweta South and Tsokatshaa than in areas very far from the park. Land use had a great effect on both cattle, goats, horses and donkeys' rate of predation as pastoralists using land for mixed production experienced higher rate of livestock predation than those using land only for livestock production. Furthermore, the interaction of

short distance from the park and mixed production, and low frequency in land of production and mixed production increased livestock predation.

In livestock husbandry, the number of livestock kept and different species kept increased the rate of livestock predation; the rate of cattle predation was high where cattle breeds kept were high $(P = 0.068)$, high number of cattle $(P = 0.000)$, high number of goats $(P = 0.000)$, and high number of donkeys $(P = 0.01)$. Similarly, the rate of goats' predation was high for pastoralists keeping high number of cattle and goats. Finally, the rate of donkey predation was high for pastoralists with high number of cattle, goats, horses and donkeys $(P = 0.084)$.

The results of the study do not agree with the hypothesis that land use management, species interaction and livestock husbandry negatively affects co-existence between pastoralists and carnivores around Makgadikgadi Pans National Park but there are some practices promoting the co-existence between pastoralists and carnivores. Pastoralists who practiced kraaling, herding, calving and watch dogs as predation measures experienced lower rate livestock predation.

Predation rate has been identified to be high where population of livestock is higher compared to wild prey, high availability of carnivores' habitants, many carnivores' species found and many species of livestock preyed. The integration of high population livestock compared to wild prey, high carnivores' population and species, high interaction rate of livestock and wildlife, and high population and different species of livestock increased the livestock predation rate hence negatively affecting the co-existence of pastoralists with carnivores.

Recommendations from the analysis should be applied to promote co-existence of pastoralists and carnivores so that the change rate of livestock become; $\frac{dN_{livestock}}{dt} = (k_{livestock} - \beta_{livestock} N_{car}) N_{livestock}$, goes to $\frac{dN_{livestock}}{dt} = k_{liveststock} N_{livestock}$ (7.2) since $\beta_{livestock}$ which is the predation rate goes to zero. Integrating equation (7.2) gives $N_{livestock} = e^{k_{livestock} t + c} = C_1 e^{k_{livestock} t}$ for C being a constant of integration and $c_1 = e^c$. This shows that the number of livestock will increase exponentially with time when recommendations that reduces the rate of livestock predation and promote co-existence between pastoralists and carnivores.

5.3 Recommendations

Action must be taken to reduce the rate of livestock predation to a level and in a form that ensures sustainable co-existence between pastoralists and carnivores. The study considered livestock predation as dependent on land use management, interaction between livestock and wildlife and livestock management. In other words, minimization or maximization of the rate of livestock predation is a result of interaction actions by stakeholders from the three sectors. While some of these recommendations are not new, all were derived from the findings of the study. Therefore many of them serve as reinforcement on existing recommendations that have been raised by other livestock-carnivore interactions researchers in different parts of the world.

Sound policy and management interventions can often reverse ecosystem degradation and enhance the interaction of elements of the ecosystem but knowing when and how to intervene requires substantial understanding of both the ecological and social systems involved (World Resources Institution, 2003). Better information is a pre requisite for sounding decision making;

the information that is given to the PAC unit by pastoralists should be correct not only for the purpose of being compensated. From predation standpoint, records help producers to identify loss patterns, in addition to providing a baseline data which can be used for making decisions on what type, and how much predator damage control is economically feasible (Henderson. E. R. & Spaeth. W. C., 1980). Records also help in identifying critical problem areas which may require correction action. A wrong input produces a wrong output leading to wrong application of policies by the government ending up with uncontrollable predation rate. There are no studies done on the coexistence of pastoralists and carnivores and most studies are concentrated on the patterns on the movement of carnivores and their population. Environmental and outreach education is important in changing people's perceptions and creating situational awareness. According to the literature, often local communities do not know the main aims of protected areas leaving them feel excluded. Through outreach and education programmes, understanding of the importance of protected area and wild animals' behavior can contribute to reduction in livestock predation by carnivores and hence promote co-existence of pastoralists and carnivores.

Awareness about the wildlife should be increased among local communities around the park. The management of the park or the government should offer part time employment for some members of the communities to teach others on wildlife behavior and how predation can be prevented in areas of high population of carnivores. The out of school education and training (OSET) programmes in areas around the park should be mainly based on promotion of co-existence between people and wild animals in which pastoralists and carnivores are a sub set. The government should increase education and conservation awareness raising efforts in local communities. An education population is expected to tolerate the presence of wild animals and

know their importance in the eco system. The high rate of conflicts can be due to high percentage of low educated people next to the park and redundant labor in the cattle posts.

5.3.1 Land use management

The government should demarcate grazing lands far from the parks to reduce the interaction of wild animals and livestock. Pastoralists should locate kraals away from areas where predators have been frequently sighted (Good, et al., 2008). In addition, grazing lands should be fenced so that migratory carnivore do not trespass leading to predation. Barrier fences have been used to control problematic wildlife species since ancient times and its role in management of human wildlife conflicts has been recognized in Kenya (Kassilly, et al., 2008) and it offers non-toxic solution. Now, there is a convincing evidence that practical fences can be designed, built and maintained to limit the movement of livestock predators as well (Henderson. E. R. & Spaeth. E. R., 1980). It is also recommended that pastoralists should stay in their production areas and practice only livestock rearing in the area as findings show that, pastoralists who use the area only for livestock rearing and having high rate of staying in the area for production experienced low rate of livestock predation. If pastoralists have hired herders it is recommended that they make sure that herders stay with livestock. Studies have shown that the main deterrent in avoiding attacks on livestock by predators is human presence (Good et al., 2008).

5.3.2 Interaction between livestock and wildlife

The population of carnivores should be regulated and there is a need to strengthen the park management to ensure that there is effective surveillance and high level of detecting carnivores that are out of the park boundaries. In general the population of carnivores, wild prey and livestock in areas around parks should be regulated such that both the carnivores and livestock's

populations are not higher the population of wild prey. According to Hoogestein in 2000, it is thought that the presence of wild prey may reduce the frequency on livestock prey. This suggests that where the population of wild prey satisfies the population of carnivores the rate of livestock predation is minimized. Even though this is appealing conflict mitigation recommendation, there is a need to investigate this relationship in more detail. The breeding of livestock should be matched to the seasons of local wild game population wherever possible and pastoralists should be helping to maintain a healthy game population on land used by livestock since it will provide natural prey for predators (Good et al., 2008). Predator habitant should be minimized in the area for production as it was show by findings as directly proportional to the rate of livestock predation; pastoralists should clear bushes in the area of production and around kraals to reduce the cover available for predators to use.

5.3.3 Livestock management

Livestock management can greatly reduce losses to predators (Good et al., 2008). Attentive herding of livestock has been linked to lower predation rates (Creel & Creel, 2002; Henderson & Spaeth, 1980; Ogada et al., 2003) and 62% of respondents in the sample said they herded their livestock. However most of herders are uneducated people which could reduce their effectiveness in the prevention of predation. Herders should be people who are trained on wild life and understanding the patterns of predations and carnivores to control. Kraaling was practiced by 43% and the use of watch dogs was use by 30%. According to the findings of the study, watch dogs control many carnivores involved in goats' predation and this implies that if watch dogs can be used effectively to control carnivores the rate of goats' predation can be reduced. The use of these husbandry techniques is low and people should be encouraged to use

them effectively. Guard dogs have reportedly been used successfully for many centuries in Europe and Asia to protect livestock from bears and wolves, and a significant reduction in sheep losses to coyotes has been demonstrated (Henderson & Spaeth, 1980). In general, producers without guarding dogs lost greater proportion of their ewes and lambs from all causes and from coyotes than did producers with guarding dogs, and 90.9% of 22 producers that used guarding dogs in 1986 rated their dogs' predator control performance as excellent or good (Andelt, 1992). All husbandry techniques clearly rely on the effective use. Despite the use by some respondents, predation was reported to have occurred either outside the kraal at night, when livestock was unattended or when watch dogs were not present. Ensuring livestock husbandry techniques are implemented well by pastoralists has significant benefits in reducing the rate of predation. The population of livestock has an influence in the implementation of livestock husbandry which implies that the population of livestock should be allocated a sufficient technique not having too many animals herded by one herder. In general, large flocks of sheep tend to have a higher total predator loss in terms of numbers than smaller flocks (Henderson & Spaeth, 1980). Livestock of similar predator or one type of livestock should be kept to avoid divisions in attention so that there is no time in which it is left unattended. Record keeping should be practiced and trends of predation should be studied so that new techniques are adopted to reduce predation which is the main cause of conflict hence improving pastoralists and carnivores' co-existence.

Since the union of two or more strategies is greater than individual strategy or equals to one individual strategy if and only if one strategy purely contains other strategies, it is highly recommended to use integrated predation control measures wherever possible to promote good co-existence between pastoralists and carnivores.

5.4 Recommendations for further research

The research has yielded useful results and conclusions on modeling how land use management, species interactions and livestock husbandry to achieve good co-existence between pastoralists and carnivores, however some areas were uncovered and need further study. Therefore, it is important to identify and discuss the need for further research on modeling factors influencing the co-existence. More studies need to be done on how carnivores and pastoralists can sustainable live together in their community settings. Studies on traditional methods of managing conflicts are needed because most of the people in the area are not educated and mostly use tradition measures (Chardonnet, et al., 2010). It is also important to integrate seasons in modeling factors influencing pastoralists and carnivores as predation rate vary depending on seasonal variations (Moreton Bay Regional Concil, 2012; Snow leopard trust, 2017).

Since land use, species interactions and land use are not discrete practices, it is important to have further research how their integration influence pastoralists and carnivores' co-existence as most studies examine one particular factor (Graham, Beckerman, & Thirgood, 2005).

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APPENDIX 1: QUESTIONNAIRE FOR THE LOCAL COMMUNITY

QUESTIONNAIRE FOR THE LOCAL COMMUNITY

Dear Respondents

I am Nkobi Enock doing Masters in Development Practice in the University of Botswana (UB) School of Graduate Studies. I am undertaking a study to assess factors influencing co-existence between pastoralists and carnivores around protected areas-a case study of communities around Makgadikgadi Pans National Park.

The findings of this study will be mainly used to fulfill the researcher's requirements to complete my studies. . It is hoped that the results and recommendations of the study will be used to;

1. Identify ways of reducing conflicts between the people and wildlife not only carnivores nor only around Makgadikgadi Pans National Park but in other protected areas.
2. Provide information to policy makers.
3. Improve local community and park management relationships.
4. Provide significant information that will be used as a reference point to other studies in the related field.

It is against this background that I humbly seek your inputs and participation on this subject matter. I will highly appreciate your participation and your views are very important. Please note that the views and expressions you provide will be given the utmost confidentiality they need.

Thank you in advance for your contribution.

Section 1: DEMOGRAPHIC DATA

a) Sex: [ ] M [ ] F

b) Age: [ ] <20 [ ] 21-30 [ ] 31-40 [ ] 41-50 [ ] >50

c) Marital status

[ ] Single [ ] Married [ ] Separated [ ] Divorced

d) Family headed by [ ] M [ ] F

e) Education level

[ ] No formal education [ ] Primary [ ] Junior Secondary [ ] Senior Secondary [ ] Tertiary

f) Occupation of the respondent ……...

g) How long have you been staying in the area practicing agriculture?

[ ] <1 year [ ] 1-5years [ ] 6-10years [ ] 11-15years [ ] >15 years

h) Are you familiar with the concept of human wildlife conflict?

[ ] definitely [ ] may be [ ] may be not [ ] definitely not

i) Have you ever experienced human wildlife conflict?

[ ] always [ ] often [ ] sometimes [ ] seldom [ ] never

j) What was the cause of the conflict? ……..

k) Looking at the following, which is the main cause of livestock loss?

[ ] livestock predation [ ] theft [ ] drought [ ] disease

l) Location of cattle post? ……

Section 2: EFFECTS OF LAND USE MANAGEMENT IN PASTORALISTS CARNIVORE CONFLICTS

a) How far is the national park from your area?

[ ] <5km [ ] 6-10km [ ] 11-15km [ ] 16-20 km [ ] >20 km

b) Do you stay in the land you use for livestock production?

[ ] always [ ] very often [ ] sometimes [ ] almost never [ ] never

c) How large is the land under your house hold control?

[ ] <50 hectares [ ] 51-100 hectares [ ] 101-150 hectares [ ] 151-200 hectares [ ] undefined

d) How do you use the land?

[ ] only for livestock [ ] mainly for livestock [ ] mixed [ ] mainly arable [ ] only arable

e) Which land use do you recommend to be used in your area to reduce human carnivore conflicts? Give reasons.

……

……

……

……

f) List causes of human carnivore conflict in your livestock production and arrange them starting with the highest cause.

1. ……
2. ……
3. ……
4. ……

g) Make suggestions or comments on how land use can be managed to promote co-existence of human and carnivores

……

……

……

……

……

Section 3: EFFECTS OF INTERACTION BETWEEN LIVESTOCK AND WILDLIFE IN PASTORALISTS CARNIVORE CONFLICTS

a) How is the population of carnivores in your area?
   [ ] very high [ ] high [ ] moderate [ ] low [ ] very low
b) Which carnivore is mainly found in your area? ……
c) Livestock species mainly preyed? ……
d) How does the population size of carnivores affect rate of livestock predation in your area?
   [ ] highly increases [ ] increases [ ] does not affect [ ] decreases [ ] highly decreases
e) Availability of suitable carnivore habitats in your area?
   [ ] very low [ ] low [ ] medium [ ] high [ ] very high
f) How do carnivore habitats affect the rate of human carnivore conflicts?
   [ ] highly increases [ ] increases [ ] does not affect [ ] decreases [ ] highly decreases
g) How is the population of livestock compared to wild prey?
   [ ] extremely higher [ ] higher [ ] equal [ ] lower [ ] extremely lower
h) Interaction rate of livestock and wild prey?
   [ ] extremely higher [ ] higher [ ] equal [ ] lower [ ] extremely lower
i) How livestock wild prey interaction does affects livestock predation?
   [ ] highly increases [ ] increases [ ] does not affect [ ] decreases [ ] highly decreases
j) How is the population of carnivores compared to wild prey?
   [ ] extremely higher [ ] higher [ ] equal [ ] lower [ ] extremely lower
k) How is the population affecting livestock predation?
   [ ] highly increases [ ] increases [ ] does not affect [ ] decreases [ ] highly decreases
l) How do carnivore competitions affect livestock predation in your area?
   ……
   ……
m) Make suggestions or comments on how the interaction can be improved to promote co existence……
   ……
   ……

Section 4: EFFECTS OF LIVESTOCK MANAGEMENT IN PASTORALISTS CARNIVORE CONFLICTS

a) Which livestock do you keep? List them in the table in the table below indicating their number, rate of predation and carnivore involved.

Livestock	**Number**	**Rate of predation**	**Carnivore involved**
TOTAL			

b) List predation measures you use in your house hold, time of use and effectiveness;

Predation measures	**Time of use**	**Carnivore controlled**	**Effectiveness**
			[ ] very effective [ ] effective [ ] neutral [ ] ineffective [ ]very ineffective
			[ ] very effective [ ] effective [ ] neutral [ ] ineffective [ ]very ineffective
			[ ] very effective [ ] effective [ ] neutral [ ] ineffective [ ]very ineffective

c) Do you know other anti-predation measures that can be used in your area and if yes which one do you recommend?

……

……

……

d) Which breeds of cattle do you keep? ……

e) Which cattle breed is more susceptible to predation? .....

f) Which cattle breed is more resistant to predation? ……...

g) Season of high predation?

[ ] summer [ ] autumn [ ] winter [ ] spring

h) Do you practice calving?

[ ] always [ ] often [ ] sometimes [ ] seldom [ ] never

i) To what extent do you agree that calving can reduce the rate of livestock predation in your area?

[ ] strongly agree [ ] agree [ ] neutral [ ] disagree [ ] strongly disagree

j) Do you keep livestock predation records in your house hold?

[ ] always [ ] often [ ] sometimes [ ] seldom [ ] never

k) To what extent do you agree that records keeping can reduce the rate of livestock predation? Give reasons

[ ] strongly agree [ ] agree [ ] neutral [ ] disagree [ ] strongly disagree

……

……

……

l) Economic management of livestock in the area?

[ ] very expensive [ ] expensive [ ] neutral [ ] cheap [ ] very cheap

m) Make suggestions or comments on how livestock management can be improved to promote co-existence

……

……

……

APPENDIX 2: DATA RECORDED IN PROBLEM ANIMAL CONTROL FOR THE PERIOD 2008 TO 2012

Year	**Distance from the park**	**Wild dogs' predation**			**Leopards' predation**			**Lions' predation**		
		Gweta North	Gweta South	Tsokatshaa	Gweta North	Gweta South	Tsokatshaa	Gweta North	Gweta South	Tsokatshaa
2008	Near	0	1	0	0	2	0	6	4	0
	Far	5	2	0	0	8	0	3	10	1
	Very far	1	2	0	3	1	0	4	1	0
2009	Near	0	1	0	0	0	0	7	12	3
	Far	1	2	2	0	0	0	11	14	0
	Very far	0	5	1	3	2	2	6	5	2
2010	Near	0	0	0	0	0	0	21	26	7
	Far	1	1	0	0	5	0	11	48	1
	Very far	2	3	0	6	6	0	10	2	0
2012	Near	0	0	0	2	1	0	8	13	0
	Far	2	0	1	0	2	2	7	13	1
	Very far	3	2	0	2	2	0	1	0	3

APPENDIX 3: DEPARTMENT OF WILDLIFE AND NATIONAL PARKS 1996-2013 BIOMASS AERIAL SURVEYS IN CATTLE POSTS AROUND MAKGADIKGADI PANS NATIONAL PARK

Year	Wild Dogs Wild Prey	Leopard Wild Prey	Lion Wild Prey	Total Biomass	Wild Biomass	Livestock Biomass
1996	0.58235	0.00000	0.58470	473.41849	1.81988	471.49000
1999	0.00000	0.85441	0.43606	587.68390	22.37919	565.33000
2002	0.00000	0.00000	0.00000	543.04150	3.31693	539.72457
2004	0.00000	0.00000	0.00000	680.91465	24.55609	656.28000
2006	0.00000	0.00000	0.00000	387.81344	27.31995	360.45000
2012	0.65712	0.93282	2.48554	94.89505	11.83950	75.97035