Dynamics of human-lion conflict in and around the Makgadikgadi Pans National Park, Botswana

by

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Abbreviations and acronyms

A	Avoided
AF	After-Fence period
ANOVA	Analysis of variance
BF	Before-Fence period
CBNRM	Community Based Natural Resource Management
CKGR	Central Kalahari Game Reserve
CSO	Central Statistics Office
DWNP	Department of Wildlife and National Parks
GIS	Geographic information system
GPS	Global Positioning System
HA	Highly avoided
HP	Highly preferred
HWC	Human wildlife conflict
IUCN	International Union for Conservation of Nature
KDE	Kernel density estimate
KGR	Khutse Game Reserve
KRC	Kalahari Research and Conservation
KTP	Kgalagadi Transfrontier Park
MCP	Minimum convex polygon
MEWT	Ministry of Environment, Wildlife and Tourism
MPNP	Makgadikgadi Pans National Park

Notugre	Northern Tuli Game Reserve
P	Preferred
PA	Protected area
PAC	Problem animal control
QENP	Queen Elizabeth National Park
RF	River-Flowing period
SKL	Savuti Khwai Linyanti
SPSS	Statistical Package for Social Sciences
SSIs	Semi structured interviews
UA	Used according to availability
UHF	Ultra high frequency
VHF	Very high frequency
WCN	Wildlife Conservation Network

Abstract

Human carnivore conflict is a state where certain carnivore(s) negatively impacts on human or vice versa. The conflict is not limited to specific carnivore species or spatial coverage. Some of the ways to mitigate the impacts experienced include the erection of the fence in order to eliminate or reduce direct contact of the concerned parties such as along the Boteti River area on the western side of Makgadikgadi Pans National Park (MPNP) in Botswana. This study was conducted in and around the MPNP to assess the human-lion conflict level, and factors that might affect the conflict level before, and after the introduction of the Makgadikgadi fence, and flowing of the Boteti River. Livestock kill data for the year 2000 – 2012 from the Department of Wildlife and National Parks, Botswana were used to measure the human-lion conflict levels. Again, semi-structured interviews were conducted with farmers from 03rd April 2012 - 12th May 2012 to find out farmers perceptions about the conflict level. The reports were divided into 3 periods; Before fence, After fence, and River flowing. The data was further divided into wet and dry season. Human-lion conflict was higher during River flowing and Before fence period than After fence. This proved the effectiveness of the fence since it was intact during After fence period. Generally the conflict was higher during wet season than dry season may be due to the migration of the wild preferred prey (zebra and wildebeest) to the east of the MPNP where they could access water after it rained. This migration therefore might have reduced wild preferred prey abundance hence leading to lions switching to predate on livestock. Additional factors which may have contributed to these conflict levels such as predator-prey abundance and lion movement patterns were assessed. Lion population increase, and decrease in spotted hyena population might be another factor which led to higher lion conflict level compared to other

carnivores. Furthermore, lion home range sizes were larger during River flowing period than Before fence period since during the Before fence period lions might have sat and waited for the prey at the artificial water-pools which were along the river whereas during RF period, water was available in many points where it could be accessed by prey therefore forcing lions to minimise the sit-and-wait hunting strategy. In addition, lion distance to the nearest cattlepost was smaller during RF period since some of the water points were located outside the park therefore forcing lions to access them and at the same time being closer to the cattleposts. Contact between lions and livestock is a major influencer of the conflict together with lion's wild preferred prey abundance in relation to livestock. Implementation of measures such as erection and proper maintenance of the fence are vital to lower the conflict level.

Key words: Barriers, Boteti River, Carnivores, Cattlepost, Farmers, Fence, Human-lion conflict, Migration, Prey, River flow.

Disclaimer

I hereby declare that the dissertation submitted for the M/Phil in Natural Resource Management at the University of Botswana is my own original work and has not previously been submitted to any other institution. I testify that all authors quoted are indicated and acknowledged by means of a comprehensive list of references. The work was completed in a time period ranging from 22/08/2011 to 02/11/2015.

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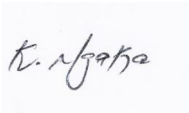

Dedication

This work is dedicated to my Saviour, Jesus Christ for every success which happened because of His love, together with the immeasurable support I got from my parents, Mr and Mrs Ngaka and my three brothers. Special thanks to you my mother Mrs Kelatlhegile Ngaka, I was expecting to defend this thesis while you were still alive but unfortunately that did not materialise. However, only God knows.

Thesis Outline

In Chapter one, a historical background about human-lion conflict, factors influencing the conflict, and possible management efforts will be broadly discussed and then narrowed to this study. Chapter two will give an overview of the temporal distribution of human-lion conflict (actual, and perceived) along the Boteti River area. Chapter three will assess the possible factors which can contribute to the different conflict levels spatio-temporally in relation to predator-prey abundance along the Boteti River area. Chapter four will also assess the possible factors which can lead to the different conflict levels spatio-temporally in relation to lion movement patterns in the Boteti River area. Chapter five will provide a synthesis for the whole study.

Chapter One

1.0 General Introduction

1.1 Human-lion conflict

Human carnivore conflict takes place when carnivores have direct contact with humans and/or their livestock which could cause negative impacts such as injuries, deaths, property damage and/or loss. The conflict has been in persistence from the memorial time when animals started sharing resources such as land with humans (Lamarque et al. 2009) and is not limited to particular species (Manfredo & Dayer 2004) nor geographic areas (Madden 2004). In the Maasai Mara National Reserve in Kenya spotted hyena (*Crocuta crocuta*) and leopard (*Panthera pardus*) accounted for 80% and 48% of sheep (*Ovis aries*) and goat (*Capra hircus*) kills respectively whereas lion (*Panthera leo*) killed 57% of cattle *(Bos taurus)* out of 147 livestock depredation cases (Kolowski & Holekamp 2006). The depredation cases recorded were from March 2003 to April 2004. In Maasai steppe in Tanzania spotted hyena and leopard killed 70%, n = 265 and 22% of sheep and goats respectively whereas lion killed 87%, n = 67 of cattle from 2004 to July 2005 (Kissui 2008). Lions seem to be consistent on the killing of large-sized livestock prey such as cattle. In Gokwe communal land in Zimbabwe chacma baboons (*Papio ursinus*), lions and leopards had 52%, 34% and 12% of livestock kills out of 241 attacks from 1993 to 1996 where lions still predated mostly on cattle (Butler 2000). For the cattleposts in the Shorobe survey block in Botswana Gusset et al. (2009) found that lion and spotted hyena were the predators with higher livestock kills. Factors which might lead to conflict include an increase in lion population, decrease in wild prey abundance (Hemson 2003) and lack of appropriate strategies to stop/minimize lion-livestock direct contact. Lions in Makgadikgadi Pans National

Park (MPNP) in Botswana increased their attacks on livestock when wild prey abundance was lower (Hemson 2003). Other studies (Stander 1990; Patterson 2004; Tumenta et al. 2013) also found the same trend elsewhere. Furthermore, improvements of livestock husbandry such as replacing the thorny brunches which are used to construct enclosures by building clay significantly reduced the livestock attacks in Pendjari National Park in Benin (Bauer et al. 2010).

1.2 Ecology of lions

Lions are the largest of African big cats and the second largest feline predator in the world after the tiger (Schaller 1972). Their mating normally lasts for 2-5 days (Beier et al. 1995). In most cases a maximum of four cubs are born after gestation period of approximately 3.5 months (Boitani & Bartoli 1982; Alden et al. 1995; Stuart & Stuart 2007). Their reproduction is not fixed to any regular time of the year (Bertram 1975; Stuart & Stuart 2000). However, most females normally give birth during rainy season (Alden et al. 1995) to allow for proper care and more food to be provided to the cubs since the lactating females could let any pride cub to suckle from it (Stuart & Stuart 2007). Young ones, called cubs possess some faint spots on their body sides and such spots are lost at adult stage. Young ones usually live with their pride for a period of approximately two years (Boitani & Bartoli 1982; Stuart & Stuart 2007). The adult male's weight ranges from 150-225kg and female between 110 and 152kg (Stuart & Stuart 2000). This leads to males having higher energy need than their female counterparts (Schaller 1976). However, males are considered to be relatively poor hunters compared to the females (Schaller 1972). In addition, males specialise more on killing large-sized prey like buffalo (*Syncerus caffer*) as compared to the females which kill medium-sized such as impala (*Aepyceros*

melampus) (Funston et al. 1998). Lions live in prides of 1-18 adult females, dependent cubs and 1-9 adult males (Packer et al. 1991).

Lions are nocturnal but also considered to be diurnal. Lions can attack grazing livestock during the day while other carnivores such as leopards and spotted hyenas' attacks are mostly during the night therefore putting lions at higher risk of being encountered and killed by farmers (Kissui 2008). For instance, in Waza National Park, Cameroon lions were active (33%) during the night as compared to 13% during the day (Tumenta et al. 2013); in Gokwe communal land, Zimbabwe lions' 76% of livestock attacks were during the night whereas leopards 90% of attacks were during the night (Butler 2000).

1.2.1 Threats faced by lions

Lion numbers are in a decline due to the natural and human induced factors (Dolrenry 2013) such as diseases and being killed in defence of livestock and people (Packer 1996). Other threads which are human induced include human-lion conflict (Dolrenry 2013), habitat loss to human activities like agriculture and trophy hunting (Packer et al. 2009). Lions also experience intense competition from other carnivores such as spotted hyenas over food. For example, in Amboseli and Maasai Mara the spotted hyenas scavenged from lions (Watts & Holekamp 2008). Alarming rate of killing lions and without intervention from government could lead to lion population decline. In Selous Game Reserve, Tanzania there was a massive decrease of lions between 1996 to 2008 due to the high lion off-takes per 1000km^2 Packer et al. (2009).

Currently, lion is classified as 'vulnerable' due to its low population numbers across its range (IUCN Cat Specialist Group 2006). Some African countries such as Botswana still support native lions on fulltime basis while others have them occasionally (IUCN Cat Specialist Group 2006). Human-lion conflict is a major issue contributing to huge declines in worldwide. The conflict is prevalent and widespread where lions share resources with human and livestock. Lion attacks in Tsavo National Park in Kenya constituted of 83.5-95.7% of the total annual attacks which encompassed of other carnivores such as spotted hyena (Patterson et al. 2004). Livestock depredation by lions is the main factor leading to human-lion conflict which results to lions being killed especially by farmers in their community areas throughout the African continent (IUCN Cat Specialist Group 2006). A total of eight lions were killed in MPNP by farmers despite the smaller population that the area had (Hemson 2003).

1.2.2 Lion prey abundance and human-lion conflict

Lions are the heaviest of all African carnivores. Lions specialise on the heavier prey of weight ranging between 190-550kg (Hayward & Kerley 2005). In African savannah ecosystems this weight range includes buffalo, plains zebra (*Equus quagga*) and wildebeest (*Connochaetes taurinus*) (Kissui 2008). They also kill livestock such as cattle. Lions in Waza National Park in Cameroon mostly attacked medium (50-200kg) or large sized (>200kg) prey inclusive of mainly cattle (21.6%) in the livestock category (Tumenta et al. 2013). Lions are the only ones killing large stock which include cattle and donkey (*Equus asinus*) whereas leopards kill smaller stock like sheep, goats and cattle calves occasionally (Butler 2000). In the Kweneng district, near Khutse Game Reserve (KGR) and Central Kalahari Game Reserve (CKGR), Botswana leopards killed more (97%) of small-medium stock like calves, foals, sheep and goats whereas lions killed

much (82%) of large stock such as cattle, horses (*Equus caballus*) and donkeys (Schiess-meier et al. 2007). In addition, many studies (Hemson 2003; Patterson et al. 2004; Tumenta et al. 2013) revealed that livestock depredations by lions are high during seasons/periods when wild prey availability is lower.

1.2.3 Lion population in Africa

Historically lions were abundant all over Africa and other continents (Yamaguchi et al. 2004).

In 1975 there were about 200 000 lions in Africa (Myers 1975), but were reduced to half in 1996 (Nowell & Jackson 1996) and to 35 000 animals by 2013 (Riggio et al. 2013). Recently, lion populations have been increasingly restricted to the Protected areas (PAs) (Stuart & Stuart 2000; Visser 2009) due to persecution by man outside those PAs (Holmern et al. 2007; Tumenta et al. 2013), trophy hunting and habitat loss (Packer et al. 2009). For example, in Kenya, lions were eliminated from agricultural areas and are currently confined to national parks and reserves, and much less frequently in some rangelands (Frank 2010). These PAs are of critical importance to the existing wild population of lions. Tanzania is considered the home for a large number of lions that occur in Africa because of its relatively large amount of land that it has reserved for wildlife (Packer et al. 2011). It has over 40% of the African lions (Riggio et al. 2013) with about 43.7% of its total land area being conserved (United Republic of Tanzania 2009). West and Central Africa has a lower lion population estimate of ~525 and ~2267 respectively whereas Southern African region has a lion population of ~12 081 (Riggio et al. 2013).

1.2.4 Lions home ranges

Animals' home range sizes depend on their metabolic needs (Gittleman & Harvey 1982). Large carnivores require larger areas than smaller carnivores (Harestad & Bunnel 1979; Gittleman & Harvey 1982; Tumenta et al. 2013). Most PAs are not large enough to accommodate many large carnivores, and because of their large home ranges (Treves & Karanth 2003; Tumenta et al. 2013) many of them are still found outside the PAs (Treves & Karanth 2003). Lions in Waza National Park in Cameroon spent 21% of their time outside the park especially during wet season (Tumenta et al. 2013), and this contributed to higher livestock predation rates. For example, a lion outside this park once killed seven cattle, nine sheep and nine goats within a space of four weeks (Bauer & de Iongh 2005). Lions' average home range size in this area was around 1015km^2 and 641km^2 from 2007 to 2009 when calculated from 100% minimum convex polygon (MCP) and 95% kernel density estimate (KDE) (Tumenta et al. 2013).

In Northern Tuli Game Reserve (Notugre) in the south east of Botswana, 82% (n = 14) of the lions killed for almost 10 years occurred outside the PA and lion home range sizes at the area were averagely 69km^2 and 41km^2 for males and females respectively when calculated from 90% KDE (Snyman 2010). In and around the MPNP in Botswana lions predated on livestock in different habitats within the average distance of 3.6km from cattleposts with home range sizes of 726km^2 and 1566km^2 for females and males respectively calculated from 100% MCP (Hemson 2003). Out of 481 households surveyed near the Serengeti National Park in Tanzania 73.4% supported retaliatory killings of the carnivores which mostly predated on livestock outside the park (Holmern et al. 2007).

1.3 Perceptions and attitudes towards lion

People's perceptions and attitudes are shaped by their experiences, cultural norms, expectations and beliefs (Dickman 2010). Government's reaction towards the conflict can also influence people's perceptions and attitudes (Treves et al. 2006). Additionally, perceptions and attitudes are driven by the benefits which communities derive from wildlife such as tourism and whether individual(s) had lost livestock to the predator before (Romañach et al. 2007). The study further revealed that wealthier people such as commercial ranchers were willing to coexist with lions. Furthermore, because lions mostly specialize in larger livestock such as cattle which have higher value to the small-scale farmers, this fuels farmers' negative attitude towards lions compared to other carnivores which kill smaller livestock such as sheep and goats (Hazzah 2006). Lions also tend to be least tolerated by farmers since they cause more livestock losses when compared with other carnivores (Romañach et al. 2007). This intolerance seems to persist despite the presence of strategies such as compensation. For instance, in areas closer to Moremi Game Reserve in Botswana, farmers' willingness to coexist with predators such as lion did not change despite being paid compensation (Gusset et al. 2009). Similar trend for this negative attitude especially to lions was realized in MPNP where Hemson et al. (2009) found that the farmers were still willing to kill lions despite compensation. The study also revealed that people who are engaged in tourism business or working in these businesses had positive attitude towards lions because of the direct economic benefits they receive from the presence of such lions.

1.4 Human-lion conflict mitigation strategies

Mitigation measures used to reduce human-lion conflict include the construction of better livestock enclosures, herding of livestock, balancing wild and domestic prey with predators

through culling of others which might be overpopulated and fencing PAs. Better enclosures around Waza National Park in Cameroon, and Pendjari National Park in Benin significantly decreased depredation on livestock by lions (Bauer et al. 2010). In addition, fences are normally used as a way of reducing livestock-predator interaction (direct and/or indirect contact). A study by Snyman (2010) revealed that there was a higher carnivore conflict in the unfenced Northern Tuli Game Reserve (Notugre), Botswana as compared to Venetia Limpopo Nature Reserve (Venetia), South Africa.

Compensation has been argued in different opinions. In the Queen Elizabeth National Park (QENP) in Uganda, non-compensation policy seemed to be by far the most prevalent cause of communities' retaliatory actions against the lions (Moghari 2009). Compensation payments for livestock losses did not change livestock owners' willingness not to coexist with predators (Gusset et al. 2009).

Mitigation strategies are most likely to have positive results if they are flexible and can accommodate change brought by other conditions such as flowing of the rivers, and if they involved all the stakeholders (Madden 2004). They should be adopted with livestock husbandry being given first priority (Gazzola et al. 2008). The strategies are likely to fail if they do not accommodate full utilization by the people they are designed for. For example, in Uttarakhand in India people found compensation to be useless since they had difficulties in accessing the money due to the forms which were complicated to fill (Ogra & Badola 2008).

The PAs strategy is regarded by some to have failed in Africa since communities in this continent are not interested in conserving wildlife on their lands (Songorwa 1999). This is because African people get conflicted when they are not allowed into the PAs whereas wild animals can cross into their areas. Other mitigation measures include erection of physical barriers such as trenches and fences. Physical barriers control access in and out of the land (Boone & Hobbs 2004). The type of physical barriers established has to be considerate of the presence of other species in the area since these species may reduce the effectiveness of them. Furthermore, habituation to the barrier can also reduce its effectiveness. For example, elephants (*Loxodonta africana*) and leopards could find ways to overcome that barrier from their learnt behaviors (Madden 2004).

In Limpopo National Park in Mozambique, different communities indicated that fencing as a barrier is species specific (Le Bel et al. 2007). A 100km fence passing through KTP was found to be ineffective in stopping the transgression of lions and other predators (Perkins et al. 2014). In the Boteti River region, the Botswana government tried to reduce the conflict between predators in the MPNP and livestock living on the west of the park through construction of a 480km electrified fence along the Boteti riverbed at a total cost of US$437 500 (Gupta 2005; Hazelhurst & Kolk 2006). Farmers around the Boteti River area observed that lions were mostly not deterred by the electric fence followed by elephants and other species (Monametsi 2008). Furthermore, farmers continued to kraal their livestock inside the bomas in the evening for their safety from predation. Since the majority of the livestock was left unattended during the day and expected to come back to be kraaled for the whole night, some of that livestock did not return. Un-attendance

to livestock during the day led to continued killing of livestock in the area. Furthermore, some farmers did not kraal their livestock at night (Hemson 2003).

Successful strategies are the ones that reduce predation on livestock and at the same time allowing livestock to increase in numbers in their habitat (Treves & Karanth 2003). Sometimes people can cause failure of the mitigation measures by their reluctance to implement such measures (Bauer et al. 2010). Knowledge about the root-cause of the conflict is a vital ingredient in solving the problem.

1.5 Statement of the problem

Human-lion conflict is a major driver of lion decline worldwide. Lions are frequently killed by farmers or wildlife managers because they prey on livestock and sometimes kill people (Woodroffe et al. 2006). The conflict can result into the negative attitudes and perceptions of the neighbouring communities towards lions. The community closer to the Boteti River wanted fewer lions near their area (Hemson 2003) due to this conflict. The Botswana government implemented the compensation scheme to the farmers who lost their livestock to lions (Hemson 2003). This was done in order to increase farmers' tolerance to coexist with lions despite the persisting conflict. Another mitigation measure which was implemented was the Makgadikgadi fence. The fence was erected in 2004 also aiming at reducing the persisting conflict. Monametsi (2008) study which was conducted after fence erection showed that lions were the most problem carnivore. The Boteti River once formed a boundary between the lions and farmers and their livestock. The river started flowing again in the mid-2009 after the fence was erected. The river stopped flowing since 1989 (Alexander et al. 2002). Since the river forms part of the lower

system of surface waters flowing from Okavango Delta, it receives water from this delta during dry season (May to August) (Scudder et al. 1993; McCarthy & Larkin 1997) after the period when the upper system received more waters. When it started flowing again many farmers expected it to reform as a barrier and reduces the conflict. However, despite the mitigation measures mentioned earlier and the flowing of the river human-lion conflict persisted in the area. This study seeks to establish whether the combination of the fence and the river have reduced conflict significantly as hoped. Studies of human wildlife conflict in the Makgadikgadi began with Hemson's (2003) work before both the fence was erected and before the river started to flow. After this work Monametsi (2008) studied the conflict when the fence was new but before the river started to flow. This study focuses on three different periods to fully understand the influence of the fence and river-flow on the conflict:

1. Before fence (BF):- (from year 2000 - 2003) is the period when there was no fence and Boteti River not flowing.
2. After fence (AF):- (from year 2006 - 2008) is the period when the conflict fence was intact but the river not flowing.
3. River flowing (RF):- (year 2010 - 2012) this is when the Boteti River was flowing but the conflict fence being porous.

1.6 Research Questions

1. What was the influence of the Makgadikgadi fence and the flowing of Boteti River on the human-lion conflict levels?

2. How did lion and prey abundance influence human-lion conflict before and after river flow?

3. How did lion spatial coverage patterns influence human-lion conflict before and after river flow?

1.7 Hypothesis

1. Fence and river-flow significantly reduced human-lion conflict along the Boteti River area since they are expected to minimize direct contact between lions and livestock.

2. Lion and prey abundance reduces human-lion conflict after river flow due to minimization of direct contact of lion and livestock since more water points could stretch the two to different places.

3. Lion has larger spatial coverage after river flow and therefore reducing human-lion conflict since its contact with livestock is not restricted to fewer water points.

1.8 Objectives

1.8.1 General Objective

To investigate the influences of fence and river-flow on the human-lion conflict along Boteti River.

1.8.2 Specific Objectives

1. To investigate human-lion conflict levels before and after erection of Makgadikgadi fence, and flowing of Boteti River.

2. To investigate the influence of lion and prey abundance on human-lion conflict before and after river flow.

3. To investigate the influence of lion spatial coverage patterns on human-lion conflict before and after the river-flow.

1.9 Theoretical framework

1.9.1 Optimal foraging theory

The theory began its development in 1966 after McArthur and Pianka's publication in 1966 and Emlen in 1966. The theory tries to forecast the behavior of animals during the period of hunting for food (MacArthur & Pianka 1966). The forecast is done based on the assumptions that natural selection is the major factor which influences the animals' foraging behavior and contributes to the animal's fitness (MacAurthur & Pianka 1966). The other important components of the theory include time and energy (MacAurthur & Pianka 1966; Emlen 1966) spent by the animal searching for food until the consumption period. Again time and energy are critical for almost all of the animal's activities such as finding other group members, for reproduction or taking care for the young ones. The theory predicts that an animal will behave in a way that maximizes the net rate of returns (e.g. nutrients, energy) during and after the hunting for food and eating period (MacAurthur & Pianka 1966).

Since then, the theory has received much attention and development from other researchers such as Schoener (1971) and Pyke et al. (1977). The theory was then considered to have three major factors; currency, constraints and decisions (Schoener 1971). Currency is referred to as the most energy gained after the food searching and consumption process; constraints are those components which can lead the animal to fail to have maximum energy returns; and decisions

are the activities practiced by animals in order to maximize energy gains despite the possible constraints available. Pyke et al. (1977) argues that it can be beneficial for an animal to change from one habitat type to another depending on forage characteristics such as forage quality. In addition, the study revealed that this can be in favor of specialization of the animal where more habitat types offer different forages therefore allowing such animal some chance to choose wisely. Another important factor of the optimal foraging theory is the optimal diet model (Farnsworth & Illius 1998). The model states that an animal should be ready to forgo the most profitable forages when some factors such as its abundance are lower and sacrifice with the lesser profitable one(s) which might be more abundant (Farnsworth & Illius 1998). Solomon (1949) revealed that the functional response and numerical response are of great importance since they deal with predator-prey relationship in terms of their density and consumption. The study showed that a predator will focus more in areas where prey density is higher. The overall aim will be to minimize costs in terms of time and energy spent for searching until the consumption period as the theory suggests.

1.9.1.1 Application of the theory to the study animal

Lion's diet is dependent on season and prey availability (Tumenta, et al. 2013). For example, lions of Tana River National Primate Reserve in Kenya resorts to killing baboons (*Papio cynocephalus cynocephalus*) during dry season when the abundance of zebra which is a preferred migratory species drops (Condit & Smith 1994). Furthermore, lions' hunting concentrates along the river where prey abundance is high. Other lions in MPNP modified their spatio-temporal behavior to facilitate switching between livestock and wild prey as availability of these prey species change (Valeix et al. 2012). This reduces the energy expended by the lions searching for

prey. These lions also prefer areas closer to the cattleposts where livestock abundance is higher compared to areas further away. Most of the livestock kills occur within 4-5km from cattleposts during wet season since livestock is abundant closer to the cattleposts (Valeix et al. 2012). The strategies increase the encounter rate of livestock by lions and reduce the time spent searching.

This study investigates how lions in the MPNP behave after fence erection and Boteti River flow. These lions experience different levels of prey (forage) availability during wet and dry seasons. Additionally, the Makgadikgadi fence and the flow of Boteti River are of interest to the theory. To further understand the lions' behavior at the study area, the study predicted that both the Makgadikgadi fence and Boteti River flow will be some of the major constraints for the lions to successfully prey on livestock hence resulting into lower conflict level for AF and RF period than BF. Livestock is easier to kill and more spatio-temporally predictable than wild prey (Valeix et al. 2012) hence this can reduce time taken searching for prey.

It can be predicted that due to the differing prey densities the lion will prefer to eat livestock when wild prey abundance is lower. This could lead to lions' niche breadth being lower hence indicating that they are specialists. Other predictions were that lions increased their home range sizes after river flow in order to increase prey encounter rate on one side of the river. The reason for such behavior is that prey will be having more points to access water during RF period than during BF hence the "sit and wait" strategy might not be profitable. Furthermore, lion distance to the nearest cattlepost was expected to be higher during RF period since lion's prey (wild and domestic) population was expected to be higher after RF period since water is a pulling factor for most animals. This is because lions prefer wild prey over livestock due to reasons such as the

risks associated with hunting for livestock. Charnov (1976) argued that predators' timing to visit certain habitat types should be chosen wisely. Due to the higher vigilance and population of wild prey these lions were therefore expected to pull lions into the park where they mostly live. In addition, the lower lion distance to the nearest cattlepost during BF period could be argued through Solomon (1949) study which dealt with functional response.

1.9.2 Conceptual framework

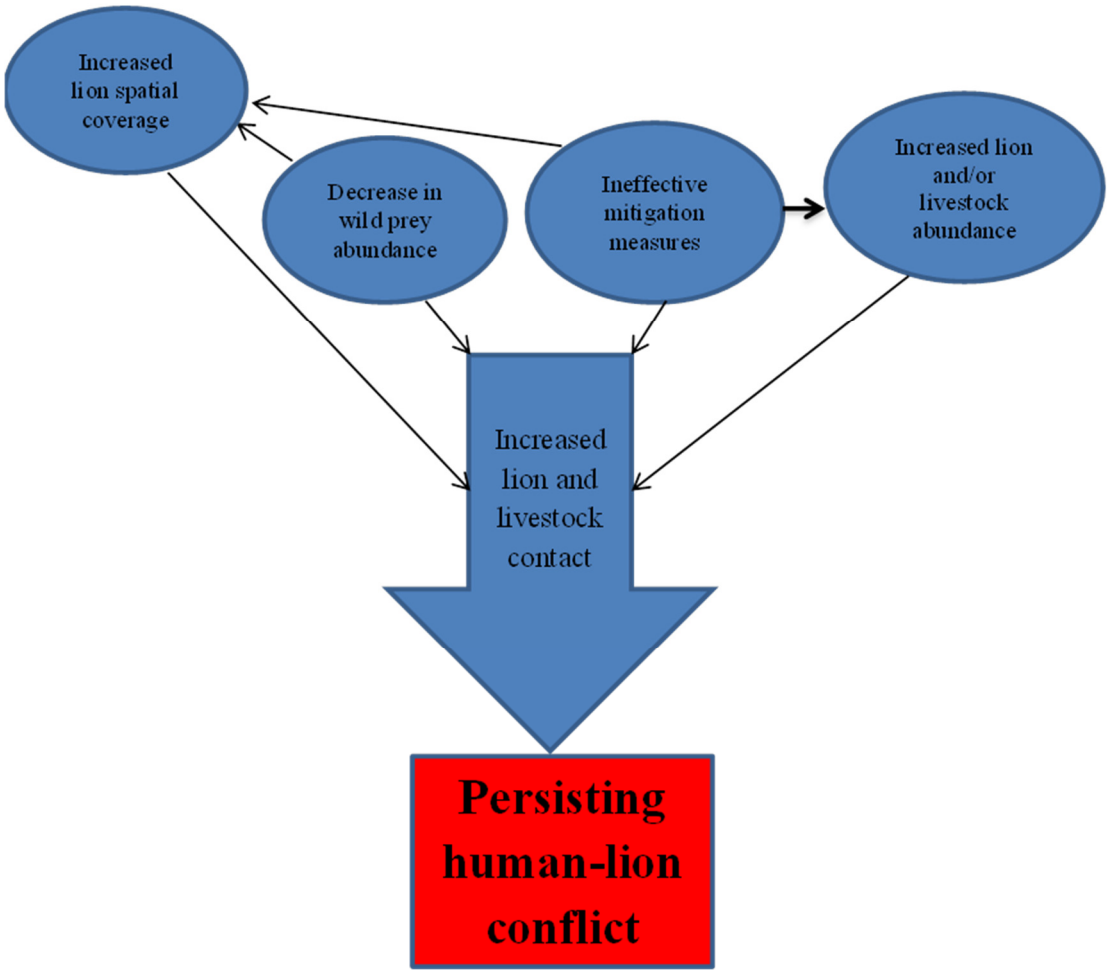

Figure 1.1: The factors influencing the level and persistence of human-lion conflict. The arrows show how each factor could possibly lead to another.

1.10 Materials and Methods

1.10.1 Study area

The study was conducted in and around MPNP in northern Botswana (Figure 1.2 and 1.3). The study site is located between 20-21ºSouth and 24-26ºEast. The area covers approximately 4900km^2 and is composed of differing habitat types. The western boundary of the MPNP is the Boteti River (Figure 1.2). The Boteti River has been a reliable source of water for both wildlife and livestock for decades. Since the river forms part of the lower system of surface waters flowing from Okavango Delta, it receives water from this delta during dry season (May to August) (Scudder et al. 1993; McCarthy & Larkin 1997) after the period when the upper system received more waters. The floods from the delta fill the Boteti River during the dry season (May to August) and with low floods occurring in wet season (December to February) (Scudder et al. 1993).

The river plays a crucial role during dry seasons when wildlife migrates towards the permanent water pools in it. When water was available, it was able to separate livestock from other wildlife. However, after the river had dried up in the 1980s (Alexander et al. 2002), it is reported that livestock depredation by carnivores intensified during this period (Meynell & Parry 2002; Hemson 2003). In addition, livestock managed to get access to the national park.

The only source of water for both wildlife and livestock were pools along the river bed (Figure 1.3) which provided water while the river was still dry. The pools were relatively concentrated at the northern part of the river. Furthermore, since the pools were along the Boteti River area, this encouraged concentration of both predators and livestock at such areas during the period when the river was dry. Consequently livestock and wildlife had frequent opportunity to interact at

these shared resources which possibly resulted into conflict. Farmers began to kill carnivores in defence for their livestock. To try to alleviate the situation, the communities demanded a predator-proof fence in order to separate such predators from livestock even though the constructed fence was not predator-proof (Brooks & Maude 2010). Because predators can dig underground and still find way out of their PA, portion of the fence was supposed to be dug into the ground to stop such predators. The division of water-points by the fence was considered "win-win" situation with the fence zigzagging to position water on both sides (Gadd 2010). The fence was constructed in 2004 and became porous to both livestock and wildlife since some solar-panels which were supposed to keep it electrified were stolen. There were averagely 0.14 lion transgressions/24hours/km of the fence during wet season whereas during dry season there were 0.21 transgressions/24hours/km of the fence (Kesch et al. 2015).

Subsequent maintenance and repair was also inadequate (Brooks & Maude 2010) and carnivores started using the damaged fence portions to cross over to communal areas. Lions largely got outside the park during dry season in order to access water since water was mostly inaccessible from the park side (Kesch et al. 2015). After the river started flowing, it caused some short-circuit, power cuts and flooding in other fence portions (Kesch et al. 2015). It never dried up during RF period. On the eastern side of the park there are vast open areas mainly comprised of the salt pans which hold water for much of the wet season. Water availability in the two sides of the park plays a crucial role in the spatio-temporal distribution of prey and predators.

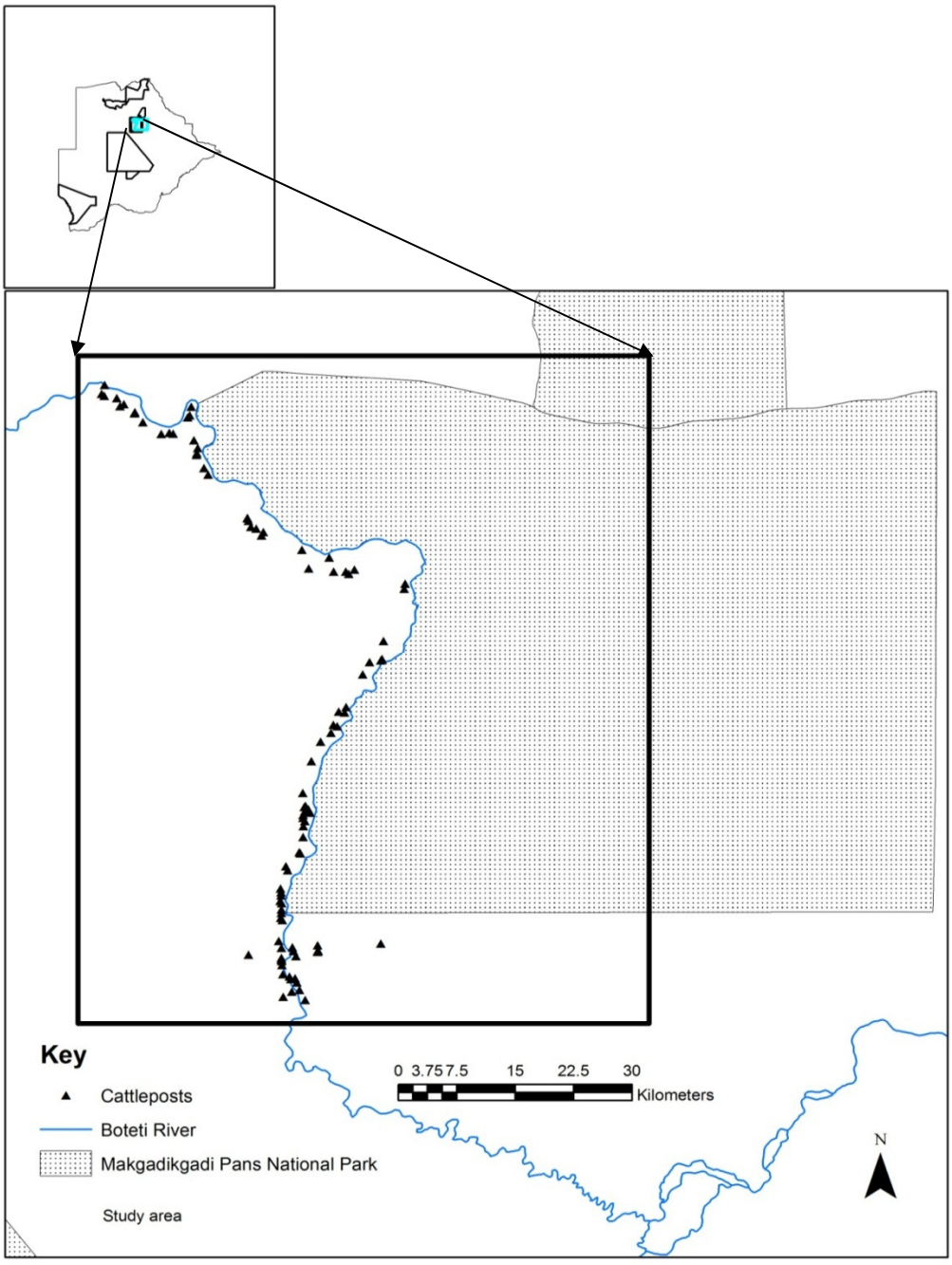

Figure 1.2: Study area location showing the Boteti River and cattleposts which are mostly located within 6km range from the MPNP.

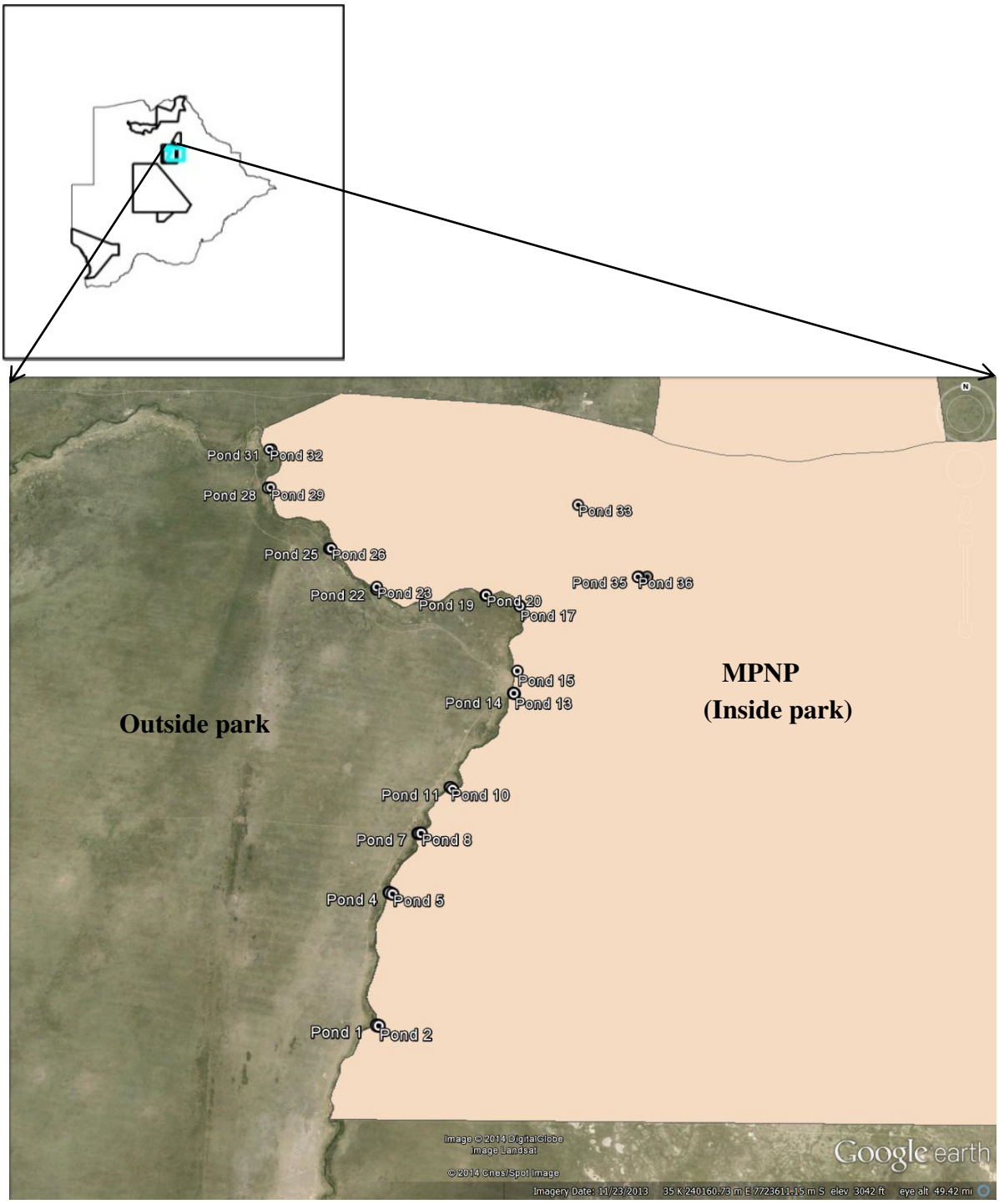

Figure 1.3: Artificial water-points which were maintained during the BF and AF period to provide wild animals with some water (water-points geographical positions were obtained from Department of Wildlife and National Parks (DWNP)).

1.10.1.1 Flora

Vegetation along the river and the surrounding is predominated by savannah woodland and mixed shrub with the following range of species: sicklebush *(Dichrostachys cinerea),* black thorn *(Senegalia mellifera),* camel thorn *(Vachellia erioloba),* velvet raisin *(Grewia flava),* purple-fruit cluster leaf *(Terminalia prunioides)* (Hemson 2003; Bradley 2012) while in the eastern side, scattered species of real fan palm *(Hyphaene petersiana)* are dominant. The dominating grass species include bushman grass *(Stipagrostis uniplumis),* common finger grass *(Digitaria eriantha),* broad-leaved curly leaf *(Eragrostis rigidior)* and sand quick *(Schmidtia pappophroides)* (Bradley 2012). Vegetation distribution in the area can be as a result of variability in soils fertility. The Makgadikgadi soils near the Boteti River are better for vegetation growth as compared to the saline soils (e.g. calcrete) for the west pans (Ringrose et al. 1999).

1.10.1.2 Fauna

The MPNP supports a good number of elephant (*Loxodonta africana*), giraffe (*Giraffa camelopardalis*), gemsbok (*Oryx gazella*), kudu (*Tragelaphus strepciceros*), impala (*Aepyceros melampus*) and steenbok (*Raphicerus campestris*) (See Table 1.1 for population estimates). Among the herbivores found, there are also the migratory ones such as plains zebra (*Equus quagga*) and blue wildebeest (*Connochaetes taurinus*) (See Table 1.1 for population estimates). The carnivores present include the lion (*Panthera leo*) which had a population estimate of 39 in 1999 (Hemson 2003). The estimate was done after conducting calling station surveys. Other carnivores include the brown hyena (*Hyaena brunnea*), spotted hyena (*Crocuta crocuta*), leopard (*Panthera pardus*) and black-backed jackal (*Canis mesomelas*).

Table 1.1: Wildlife species population estimates for the western part of Makgadikgadi (adapted from Chase 2011). The estimates were from the aerial surveys conducted during dry season in 2010.

Species	Population estimate	Confidence interval
Zebra	3287	2939
Wildebeest	26	51
Gemsbok	1090	680
Kudu	141	126
Elephant	712	478
Giraffe	62	120

1.10.1.3 Human livelihoods around the area

The farmers at the cattleposts are mostly from the villages of Phuduhudu, Motopi, Moreomaoto and Kumaga (See Table 1.2 for human population estimates for each village). The majority of the people around the area keep livestock for food, social status and source of income. Their cattleposts are located closer (within 6km) to the Boteti River for providing their livestock with water and for other domestic uses such as building traditional houses (Figure 1.2).

Table 1.2: Human population estimates for the four villages which contributes more of the inhabitants for cattleposts along the Boteti River area as compared to other neighbouring villages. Estimates were adapted from Central Statistics Office (CSO) 2001 and 2011.

Village name	Human population estimate for 2001	Human population estimate for 2011
Phuduhudu	377	564
Motopi	1130	1340
Moreomaoto	526	518
Kumaga	925	758

Most of the residents around the study area depend on the government programmes for their income which is lower whereas other (48%) depend on selling natural resources such as grass for

income generation (Arntzen et al. 2010). They are relatively poor subsistence farmers who depend heavily on rain-fed agriculture for both their crops and livestock (McCulloch 2010). Most pastoralists in the area keep large herds of cattle (*Bos taurus*). Cattle numbers in the Makgadikgadi region increased substantially from 80 000 in the 1980s to over 200 000 in 2010 (McCulloch 2010). Culturally cattle are regarded as a sign of wealth and used to judge a man's ability to provide for his family. As such there is much more cultural significance attached to cattle than to other livestock species such as goats (*Capra hircus*). Livestock in the area comprises entirely of horses (*Equus caballus*), donkeys (*Equus asinus*), goats, sheep, chicken (*Gallus gallus domesticus*) and dogs (*Canis lupus familiaris*). The fewer farmers practice mixed farming and plant crops such as sorghum (*Sorghum bicolor*), maize (*Zea mays*), sugarcane (*Saccharum officinarum*), watermelon (*Citrillus lanatus*) and beans (*Phaseolus vulgaris*) during wet season.

1.10.1.4 Livestock husbandry practices around the area

Livestock husbandry practices in the Boteti area are similar to other Southern African rangelands but different from other regions such as Eastern Africa. In East African rangelands such as Laikipia, livestock are still intensely herded in order to reduce the probability of being stolen. In Southern Africa livestock often grazes unaccompanied by herders and may graze at night which increases the chances of predation (Ogada et al. 2003). Farmers of the Boteti area release livestock from the kraals, leaving them un-herded for the day and conditioned to return to the cattlepost in the evening. This was unlikely to be effective in reducing livestock predation by lions as strays were common (Hemson et al. 2009).

The majority grazed their livestock on the open communal areas adjacent to and surrounding the MPNP. Cattle, and sheep and goats are kraaled inside separate bomas. They are mainly kraaled for safety from predators and thieves. Livestock is normally released from their bomas in the mornings and conditioned to come back for overnight kraaling and water in the evening. Usually the bomas are constructed by thorny bushes such as umbrella-thorn tree (*Acacia tortillis*) or fence.

1.10.2 Synthesis

One of the motivations of this study is that predators especially lions continued to cause conflict with the pastoralists nearer to MPNP. This study was conceived with the purpose to understand the drivers of this conflict and to suggest measures that could reduce or mitigate the situation. The study investigated a number of factors which could be exacerbating the conflict and those that could reduce the conflict.

This thesis has five chapters. Chapter one introduces the study broadly at the beginning but later focuses to the specifics of what is being addressed in this particular study.

Chapter two is the first data chapter and is titled "*Influence of the Makgadikgadi fence and the flowing of Boteti River on the temporal distribution of human-lion conflict*". It gives an understanding of the conflict at different study periods and seasons. In addition, the reported kill incidents were divided according to the type of livestock being killed based on size in order to see whether size had an influence on the conflict. Furthermore, farmers' perceptions towards the conflict level were investigated to find out whether they can match with the reported incidents. The information deduced would mean nothing much if some possible factors which might lead to

the conflict levels would not be investigated, hence the following two data chapters were appropriate for the study.

Chapter three is the second data chapter titled "*Lion and prey abundance and interaction around Makgadikgadi Pans National Park*". Its main focus is to find out how the abundance and interaction influenced the conflict. Both abundance and interaction can also influence movement of the lions hence resulting to the following chapter.

Chapter four is the third and last data chapter titled "*Influence of the Boteti River flow on lion movement patterns and home range sizes in the Makgadikgadi Pans National Park*". It seeks to understand how the river flow could have influenced lion movements and lately human-lion conflict. This chapter being the last of the three data chapters sets a platform for the final one which provides a synthesis and take home message from the study.

Chapter five is the final one which provides a synthesis of the study and conclusion in order to give the reader a consolidated message. The chapter brings together all the stories told in the above chapters to see what they meant.

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Chapter Two: Influence of the Makgadikgadi fence and the flowing of Boteti River on the temporal distribution of human-lion conflict

Makgadikgadi fence and the water flow in the Boteti River (Photo by: K. Ngaka)

2.0 Introduction

2.0.1 Factors influencing the distribution of human wildlife conflict

The spatio-temporal distribution of other factors such as cattleposts proximity to the Protected Area (PA) is critical to the conflict level. Human wildlife conflict (HWC) is increasing in places near wildlife areas (Butler 2000; Ikanda & Packer 2008; Ferguson & Hanks 2012). This could be due to higher chances of direct contact that livestock might be having with carnivores generally which increases closer to PAs leading to the escalation of HWC in these places. It is therefore important to invest in research and monitoring activities to understand conflict levels (Treves 2009) and assess the successfulness of solutions in-place. Perfect or model solutions to HWC have not been identified and successful methods are usually based on trial and error or adaptive management (Nijhawan 2008). It has been suggested that strategies that improve the HWC situation include herding techniques, species of livestock kept, grazing management and improved livestock husbandry (Kaczensky 1999; Hemson 2003; Woodroffe et al. 2007; Sangay & Vernes 2008; Bauer et al. 2010). In particular, livestock husbandry has been suggested as one of the best strategies to mitigate HWC (Mwebi 2007; Woodroffe et al. 2007).

The conflict between lions (*Panthera leo*) and people in the Makgadikgadi area can be linked to factors such as the location of the lion kill incidents and the season (Valeix et al. 2012). The study conducted between 1999 and 2003 revealed that lions, other wildlife and livestock were able to cross in and out of the national park freely therefore increasing the potential for conflict due to increased direct contact between livestock and lions (Hemson 2003). Additionally, the Makgadikgadi region has had a substantial increase in cattle (*Bos taurus*) numbers from 80 000

in the 1980s to over 200 000 in 2010 (McCulloch 2010). This has increased demand for grazing land, leading to livestock and cattlepost encroachment into wildlife areas. The Boteti River stopped flowing in the 1980s enabling cattle to move into the park more frequently therefore intensifying the potential for conflict (McCulloch 2010). The only surface water available for both wildlife and livestock in the western Makgadikgadi was pockets of pools left along the Boteti River bed during dry seasons (Hemson 2003) (Figure 1.3). This significantly increased contact between livestock and carnivores (Brooks & Maude 2010). In trying to reduce this contact, the Government of Botswana constructed a fence along the Boteti riverbed in order to reduce conflict between carnivores in the Makgadikgadi Pans National Park (MPNP) and livestock living to the west of the park at a total cost of US$437 500 (Gupta 2005; Hazelhurst & Kolk 2006). The fence was aligned using a give-and-take system where both livestock and wildlife have almost equal access to the remaining water pools. The Government of Botswana began creating a nationwide network of fences in the 1950s with the aim of controlling foot and mouth disease spread (Mbaiwa & Mbaiwa 2006) but later expanded the focus to other perspectives like HWC. However, Kesch et al. (2015) showed that lions crossed out of the MPNP towards cattleposts in the southern part of Boteti River at a higher rate during the dry season. In the wet season lions moved out of the park in the northern section part. Strategic efforts such as routine checkups and maintenance of the fence are therefore needed to ensure that such fences can fully separate wildlife from livestock.

Fenced carnivore populations are usually better managed at lower costs than unfenced (500 dollars per km^2 fenced budget and 2000 dollars per km^2) (Packer et al. 2013). Both fences and rivers can be considered to act as barriers to livestock and wildlife movement which could help reduce HWC. However problems arise when the barrier is affected, such as by poor fence

maintenance, or low rainfall to keep the river flowing. The barrier is thus less effective and boundary transgressions by lions become possible (Kesch et al. 2015).

2.0.2 Influence of the fence on human-lion conflict

Fences are usually constructed to delineate land ownership and to control access to land (Boone & Hobbs 2004) but have also been erected to separate livestock from wildlife in several locations of Africa (e.g. Zimbabwe, Wildlife Research Area (Butler 2000); South Africa, Greater Kruger Area (Lagendijk & Gusset 2008); Phinda Private Game Reserve (Hunter et al. 2007). Wildlife-proof fences are considered by some to be effective at preventing conflict between wildlife and humans (Packer et al. 2013). However, fences that restrict the movements of wildlife and livestock have both positive and negative impacts on human, wildlife and habitat (Woodroffe et al. 2014). Even though fences can be used to reduce HWC and the impact of introduced predators, they are expensive to maintain and can block migration routes of other animal species (Hayward & Kerley 2009).

By separating wild and domestic herbivores, fences also have potential to reduce competition for resources between the two. In the Boteti River area, zebra (*Equus quagga*) and wildebeest (*Connochaetes taurinus*) reduced their foraging distance from 17km (before the fence in 2003) to 10km (after fence in 2009) (Ferguson & Hanks 2012). This has the potential to increase concentration of wild prey in fewer places and possibly reduce carnivore predation on livestock.

Lions tend to stay longer in areas where they had successful kills (Valeix et al. 2011). A lion's kill success rate can be influenced by prey catchability and higher encounter rate. Conversely, fences tend to compromise the carrying capacity of areas (Scofield et al. 2011) when they concentrate animals in fewer places. Another undesirable outcome is that animals react towards

the fence in different ways such as by jumping over, crawling through, burrowing under and breaking the fence depending on species. Lions of Makgadikgadi were less deterred by the fence than other carnivores (Monametsi 2008).

2.0.3 Influence of the river on human-lion conflict

Few studies show that rivers can act as natural barriers to carnivores' movement: Cozzi et al. (2013)'s study in the Okavango Delta in Botswana showed that rivers and floodplains were more permeable to lions than other species. However, lions highly crossed the river during periods when water was lower (Cozzi et al. 2013). Deep rivers such as the Chobe River contribute to the failure of lions to cross to other side (Nijhawan, 2008). Factors that can contribute to deep waters and include the breakage of dams built closer or along the river. Water is also a significant factor in the distribution of wildlife and livestock especially during dry seasons. People often settle around areas close to water bodies that wildlife also uses which results in conflict. Generally more kills are made closer to water-points (de Boer et al. 2010; Valeix et al. 2010; Davidson et al. 2013).

This study focuses on three different periods to fully understand the influence of the fence and river-flow on the conflict: 1) Before Fence (BF):- (from year 2000 - 2003) is the period when there was no fence and Boteti river not flowing; 2) After Fence (AF):- (from year 2006 - 2008) is the period when the conflict fence was intact but the river not flowing; 3) River Flowing (RF):- (year 2010 - 2012) this is when the Boteti River was flowing but the conflict fence being porous.

2.1.0 Research Questions

1. What are the levels of human-lion conflict in relation to the conflict caused by other carnivores?

2. What is the influence of fence and river over the levels of human-lion conflict during the three periods?

3. What are the livestock types killed by lions over the three periods?

4. What are the farmers' perceptions on the influence of fence and river on human-lion conflict?

2.1.1 Hypotheses

1. Human-lion conflict will be higher than for other carnivores since lions require more food intake since their bodies are larger than other carnivores.

2. Human-lion conflict will be lower during the AF and RF period than BF.

3. Large livestock species tend to be killed at a higher rate for all the three study periods since they fall under the preferred prey body mass for the lions.

4. Farmers will be positive about the human-lion conflict outcomes during AF, and negative for BF and RF period.

2.1.2 General Objective

To assess the influence of the fence and flowing of Boteti River on the temporal distribution of lion predation on livestock along the Boteti River.

2.1.2.1 Specific Objectives

1. To compare human-lion conflict with conflict caused by other carnivores.

2. To assess the influence of fence and river on changes in human-lion conflict levels during the three study periods.

3. To assess changes in livestock type killed by lions during the study periods.

4. To assess farmers perceptions on the influence of the fence and river on human-lion conflict over the three study periods.

2.2.0 Materials and Methods

2.2.1 Study area

This study was carried out in the areas along the Boteti River near MPNP (Figure 2.1). The area provides a good opportunity of studying the effect of electric-fence which was used as a mitigation measure. Additionally, the area gives opportunity to assess the effect of re-flowing of Boteti River on human-lion conflict. These unique features motivated this study together with the migration of zebra and wildebeests during wet and dry seasons which allows for assessment of the conflict during different wild prey abundance status. MPNP falls within a range of 20-21^{o}South and 24-26^{o}East and covers approximately 4900km^{2}. The study area which is located closer to the Boteti River, west of MPNP composed of relatively thick vegetation which include blackthorn tree (*Acacia mellifera*), sicklebush (*Dichrostachys cineria*). MPNP is the home for many wildlife species such as large herbivores like elephant (*Loxodonta africana*) which could be involved in crop raiding, and smaller herbivores which include steenbok (*Raphicerus campestris*). Other herbivores found in the area are the migratory ones such as zebra and

wildebeest. This prey is the most preferred by lions (Hayward & Kerley, 2005). Carnivores found in the place include the lion (*Panthera leo*), brown hyena (*Hyaena brunnea*), spotted hyena (*Crocuta crocuta*), leopard (*Panthera pardus*) and black-backed jackal (*Canis mesomelas*).

The people around this study area are from different ethnic groups such as Bakalanga, Bakurutshe, Bangwato, Bananja, Barotsi, Bakwe, Bayeyi, Bateti and Nyadzwabye. Mostly these people rely on pastoral farming than arable since large herbivores such as elephants could possibly raid their crops. Furthermore rainfall is unreliable therefore not being conducive for these farmers to depend on it for cultivating crops whereas livestock could access water from the ponds constructed by Department of Wildlife and National Parks (DWNP) along the Boteti River. Locally rainfall ranged from 50mm which is referred to be the drought period to 1200mm which is regarded as the wet period (Thomas & Shaw, 1991). Rainfall period normally ranges from November to April. Due to lack of water availability in other neighbouring places, farmers here are located closer (within 6km range) to the Boteti river (Figure 2.1) for easier access to water for livestock and other domestic uses such as construction of their traditional mud houses. Other livestock species kept by farmers apart from cattle include horses (*Equus caballus*), donkeys (*Equus asinus*), goats (*Capra hircus*), sheep (*Ovis aries*), chicken, and dogs. However, cattle are mostly preferred since they are traditionally used as a sign for wealth, and used in many occasions such as paying the bride price (bogadi or lobola in Setswana) compared to other livestock. Majority of the livestock is grazed on the open communal area. As a way to reduce or eliminate theft and livestock killings by carnivores, farmers enclose their cattle, sheep and goats inside the kraals during the night. Materials used for the construction of these kraals include

thorny bushes such as umbrella-thorn tree (*acacia tortillis*) or fence. Most of the farmers practice a cheap way of taking care of their livestock whereby livestock is being left to graze alone and expected to return to the kraal during the evening. The practice can be attributed to less man-power since mostly the children would be gone to school in the neighbouring villages. However, some of the farmers who practised mixed or arable farming ploughed sorghum, maize, sugarcane, watermelon and beans during wet season.

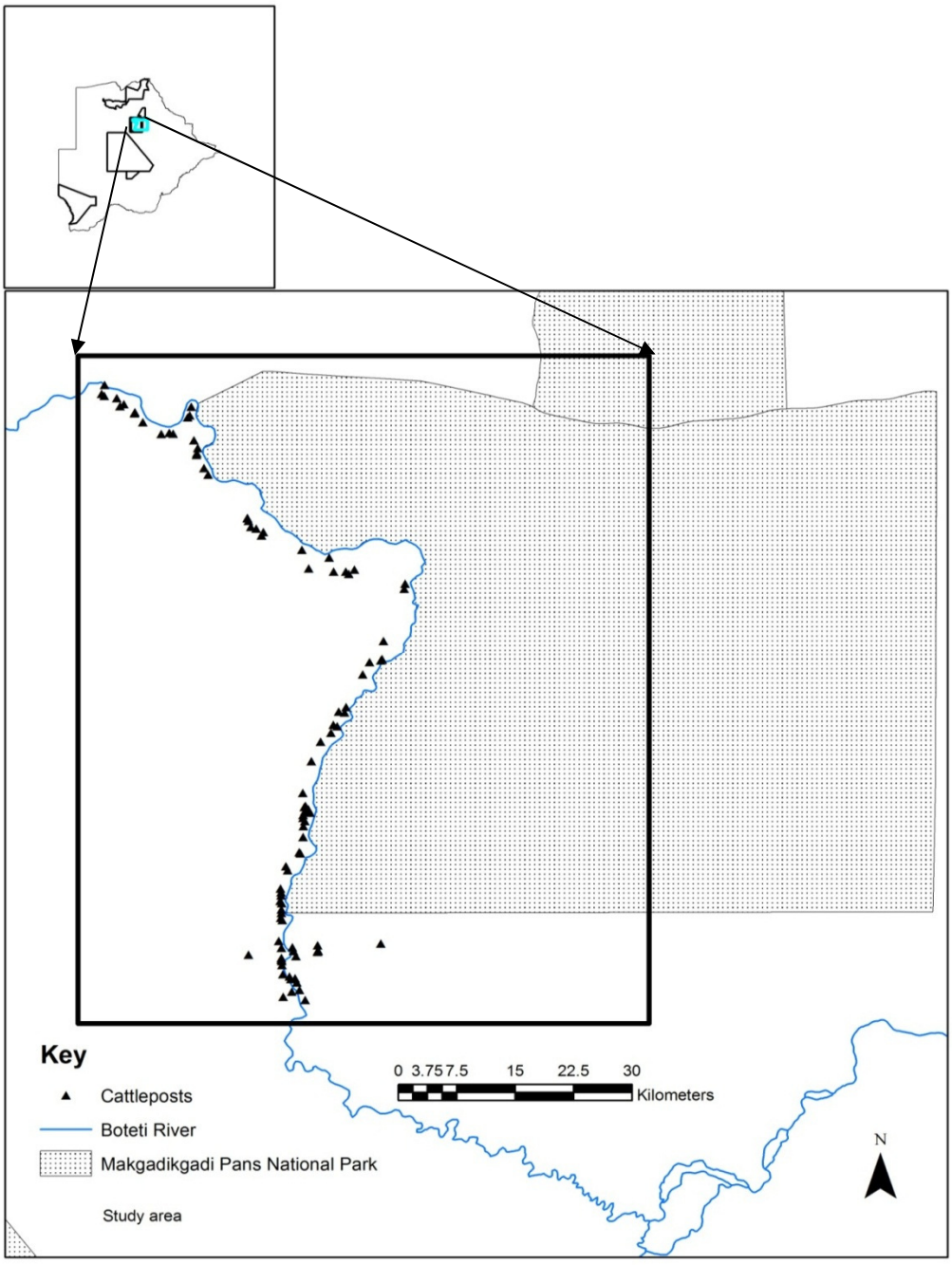

Figure 2.1: The study area location along the Boteti River and cattleposts which are mostly located closer (within 6km) to the river.

2.2.2 Data collection

2.2.2.1 Problem Animal Control (PAC) data

Problem Animal Control (PAC) is a unit under the DWNP in Botswana. The objective of the unit is to promote coexistence between wildlife and human. The unit widely captures data on the incidents of problem animals including carnivores. The captured data is used for activities such as assessing the incidents to pay compensation to the affected farmers. It provides details including the date of the incident, name of the livestock owner, livestock species and the total number being affected, location of the incident and the wildlife species which committed the damage.

PAC data for the years 2000 - 2012 was collected from DWNP in Rakops office. Since the Makgadikgadi fence was constructed in the year 2004 and 2005, data gathered during these years were excluded from the analyses. In addition, data for the year 2009 was also excluded because the Boteti River started flowing in the mid-2009. Livestock kills were then grouped according to their body mass in kilograms (kg). The following groups were then made with different weight ranges: Large (bull, cow, ox, heifer and horse):- 180-300kg, Medium (donkey):- 110-130kg, Small (calf, foal sheep and goats):- 34-80kg (DAGRIS 2007).

2.2.2.2 Interviews

Semi-structured interviews (SSIs) were conducted to assess the farmers' perceptions on the level of conflict they had with lions and the number of livestock they lost to predation for the three study periods. One advantage of using this method is that it allows an interviewee to further

explain the situation being asked about. Ninety-nine households were interviewed. Interviewees were given options to participate in the survey and they were not forced to answer questions they were not comfortable with. Because communities living adjacent to PAs experience higher levels of HWC (Gusset et al. 2009) interviews were only conducted on farmers closer to the park boundary. All the interviewees were on the western side of the river. I repeated some of the questions asked by Hemson in 2003 to allow comparison between the two periods. There were a few additional questions for the farmers to further clarify the conflict situations between the periods.

Only those cattleposts which had been established before the fence in the Boteti region were visited from the 03rd April to the 12th May 2012. All cattleposts within 6km range were visited to be interviewed but unfortunately people were absent in other cattleposts hence that is why they were skipped. The distance range of cattleposts visited was guided by two main reasons; most of the livestock farmers in the area are located within 1.9 – 5.6km from the river (Motsholapheko 2009) and generally communities living closer to the PAs experience higher conflict (Ferguson & Hanks 2012). When the study was conducted, 79.8% (n=79) of the cattleposts visited were within 2km distance range from the river. Interviewees were directed to respond by comparing their perceptions of the conflict situation during the three periods; BF, AF, and RF as stated. For this reason only elders who have experience on these periods were selected for the interviews. One interviewee was chosen to represent a particular cattlepost. Majority of the owners of the cattleposts were males (85.9% males, n = 85 and 14.1% females, n = 14). Male owners of the cattleposts were the dominant group (49.5%) interviewed whereas the rest was composed of relatives such as brother, son, cousin and herd boy. Each interview lasted for an average of one

hour since most of the questions asked did not require much explanation. Most questions required a simple yes / no answer which were later given numeric states (e.g. Yes=1 and No=2) in order to facilitate statistical analysis, but with a follow-up question to allow further explanation (e.g. Did the flowing of Boteti river influence the conflict? answers being Yes=1, No=2 and Do not know:- then followed by *further clarification of the periods individually* if the answer was a yes / no.) (See Appendix one). Farmers were asked to judge the study periods in order to state which one was relatively worst and which one was better in-terms of the livestock kill incidents caused at that particular period. Farmers were allowed to state how the fence managed the conflict in comparison to the three study periods. These perceptions were then expressed as percentages.

2.3.0 Data analysis

Data was analysed using IBM Statistical Package for Social Sciences (SPSS) Statistics 21 software. Livestock kill incidents made by lions were grouped into the three study periods (BF, AF, and RF) and seasons (wet and dry) in order to assess the temporal distribution of human-lion conflict in the area. The incidents were further sub-grouped on yearly basis to facilitate between and within years analyses. The data met the normality assumptions after being tested with Levene's test. Analysis of Variance (ANOVA) test was used to find out whether there is a significant difference in the human-lion conflict level in the PAC reports during the three study periods, and wet and dry seasons for such periods. Additionally, the incidents were grouped according to livestock body mass. ANOVA was also used to test for significant difference in the number of livestock kill incidents based on their body mass for the three study periods and seasons. Furthermore, Least Significant Difference (LSD) test was used in order to specifically

find the significant difference between variables which were more than two such the three study periods. Lastly, human perceptions towards the conflict over the three periods were assessed to estimate the perceived conflict levels for the study periods and further grouped into wet and dry season to understand the seasonal differences.

2.4.0 Results

2.4.1 Temporal distribution of reported cases of human-lion conflict

From 2000-2012, 1796 livestock kill incidents from confirmed carnivore species and 19 by unknown carnivore species were reported at the DWNP (Table 2.1). Table 2.1 shows that lion accounted for 74% of the attacks, followed by leopard (11 %), wild dog (*Lycaon pictus*) (7%), cheetah (*Acinonyx jubatus*) (3 %) and Crocodile (*Crocodylus niloticus*) (2 %). Occasionally, hyena, jackal and caracal (*Caracal caracal*) also attacked livestock. Generally, lion predation on livestock was higher during BF period (25.3 ±2.9 reports/month) and for RF period (27.4 ±3.4 reports/month) than for AF (11.2 ±3.4 reports/month) ($F_2 = 7.01$, $P < 0.05$) (Figure 2.2). Reports for BF period were not significantly different from for RF period ($F_2 = 7.01$, $P > 0.05$) (Figure 2.2). However, reports for AF period were significantly different from ones for BF and AF ($F_2 = 7.01$, $P < 0.05$ for all comparisons). Generally, wet season reports/month (26.1 ± 2.6) were significantly higher than those for dry season (16.6 ± 2.6) ($F_1 = 6.51$, $P < 0.05$) (Figure 2.2). Reports for wet season during BF and AF periods were significantly higher than for dry season ($P < 0.05$ for all comparisons, Figure 2.2) while reports between seasons were not significantly different for the AF period ($F_1 = 6.51$, $P > 0.05$) (Figure 2.2).

Table 2.1: Cumulative number of attacks caused by different carnivores at different cattleposts. The livestock kill incidents were from the period 2000-2012 with the year 2004, 2005 and 2009 being excluded for the reasons mentioned.

Carnivore species	**Reported livestock kills**
Caracal (*Caracal caracal*)	1
Cheetah (*Acinonyx jubatus*)	44
Crocodile (*Crocodylus niloticus*)	38
Hyena (*Crocuta crocuta*)	16
Jackal (*Canis mesomelas*)	9
Lion (*Panthera leo*)	**1334**
Leopard (*Panthera pardus*)	206
Wild-dog (*Lycaon pictus*)	148
TOTAL	**1796**

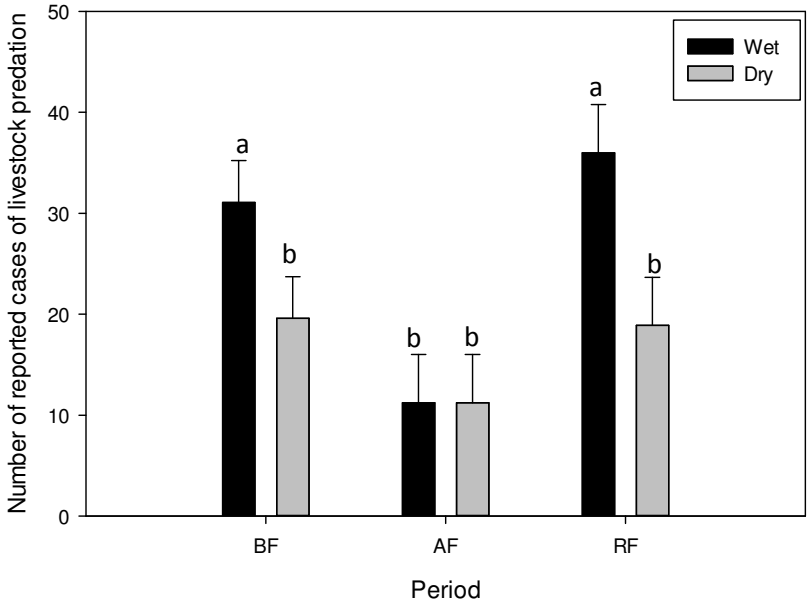

Figure 2.2: Conflict level before and after fence erection and river flow during wet and dry seasons. Same letters (e.g. a,a) means that there was no significant difference between the groups whereas different letters imply significant difference. The bars present a visual presentation of how significantly the conflict levels are.

2.4.2 Assessment of lion kill data across the study periods

Large livestock kills by lions were significantly higher than for the medium and small sized stock (Large: 41.5 ±3.2 reports; Medium: 9.6 ±3.2 reports; Small: 12.9 ±3.2 reports) for all periods ($F_2 = 29.3$, $P < 0.05$) (Figure 2.3) and seasons (F_1, $P < 0.05$) (Figure 2.3). However, there was a significant decline and increase in the number of large livestock predated upon by lions between BF and AF periods and AF and RF periods, respectively (Figure 2.3). The average number per month of large livestock predated upon by lions were 40.1 ± 5.1, 21.7 ± 5.9 and 62.7 ± 5.9 for BF, AF and RF periods, respectively. However, there were no significant changes in number of medium and small livestock predated upon by lion among the three periods (Figure 2.3).

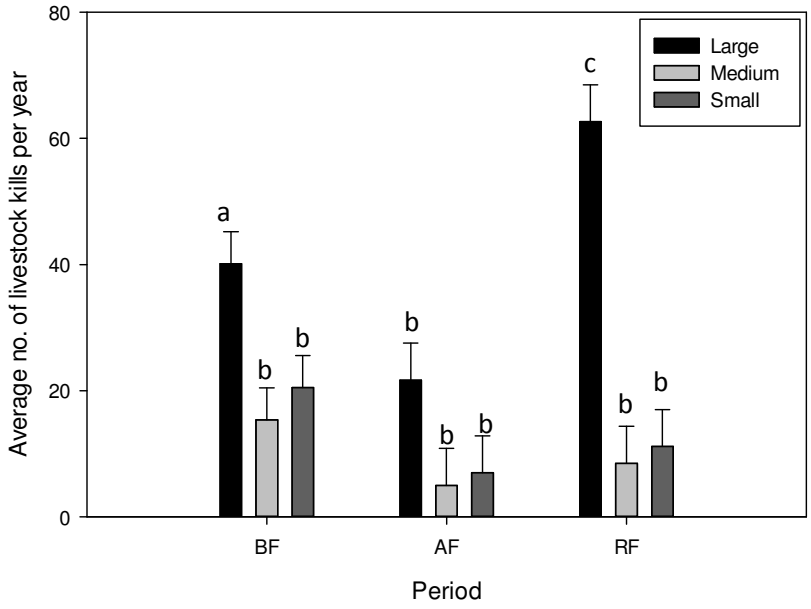

Figure 2.3: Size distribution of livestock kills over the three periods in the Boteti River area. Grouping was done on animal body-mass basis for the reported lion kill cases attended by DWNP. Same letters (e.g. a,a) means that there was no significant difference in the number of livestock killed between the groups whereas different letters imply significant difference.

2.4.3 Farmers' perceptions on the influence of the fence and the flowing of the river

Out of the 99 farmers interviewed, 94 farmers answered the questions concerning their perception to the conflict before and after fence and river flow. Of these, 94.8% (n=82) indicated that the conflict situation was worst during the BF and RF periods (Figure 2.4) and 97.4% (n=84) indicated that the conflict was better during the AF period. Thirty-four percent (34.2%) said the situation is becoming worse again because the fence had openings in it even though the river was flowing (Figure 2.4).

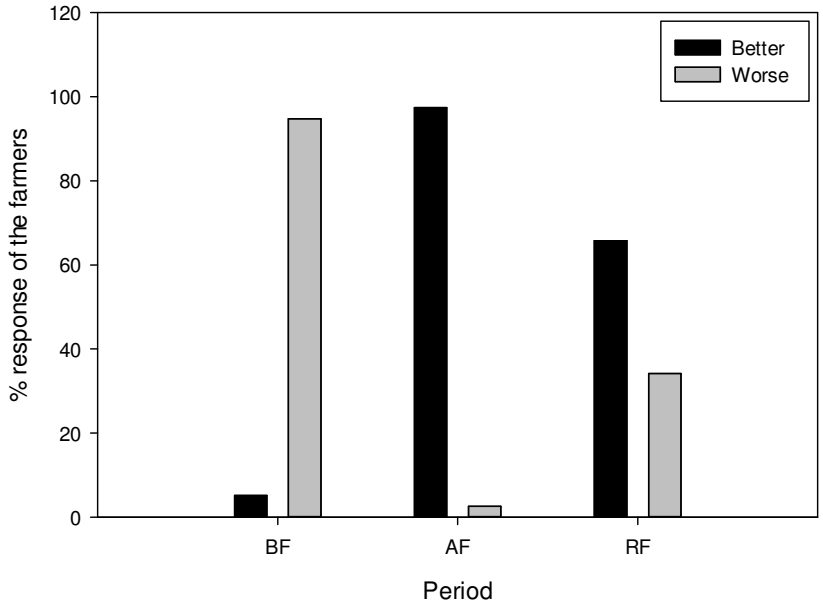

Figure 2.4: Farmers perceptions towards the conflict level during the three study periods.

2.5.0 Discussion

2.5.1 Temporal distribution of reported cases of human-lion conflict

Lion predation on livestock was more frequent than those by other carnivores (Table 2.1). This can be attributed to the fact that lions are larger in body-size than other carnivores such as leopards therefore their energy requirement tends to be also higher. As a result lion would have to kill more livestock to meet the energy required. One of the predictions was less conflict levels during the periods after the fence was constructed and after the river began to flow than before either since the two factors were expected to be effective barriers to separate lions from livestock. This hypothesis is not supported by the data. Human-lion conflict was equally high during BF as during RF period (Figure 2.2). It is highly likely that the initial lack of barrier during the BF period led to the high conflict level as lions had unlimited direct contact with livestock. Secondly the water-pools which were constructed along the river (Figure 1.3) may have resulted in congregations of livestock and lions in smaller areas. This probably have fuelled direct contact and leading to higher conflict level for BF than RF period (Figure 1.3).

Further analysis showed that cumulatively, BF and RF period had higher conflict level than AF period (Figure 2.2). Since there was no active barrier during BF period lions and livestock could directly interact together. Also during RF period the conflict level was higher may be because the fence had some openings as revealed by Kesch (2015) and the expected barrier (river) was partially permeable hence failing to separate lions from livestock. The lack of separation might have led to lion-livestock kills either inside or outside the park. The conflict level was also higher during the wet season than dry season for the BF and RF period whereas it was not significantly different for AF period. This is because the migratory wild prey, zebra and

wildebeests move to the eastern side of the park in large numbers after it had rained therefore leaving livestock as an option for lion prey (Hemson 2003). Even if the wild prey migration might have continued, the fence was in a better state to minimise direct contact between lion and livestock which led to lower conflict level for AF period. The conflict was significantly different for wet and dry season during BF and RF period since the possible barrier; Boteti River might have not actively separated lions from livestock hence leaving the two to continue interacting directly. Water-bodies are considered to be more permeable to lions than fences (Cozzi et al. 2013) which could contribute to more reports during RF period. In addition, water in the Boteti River contributed to the higher conflict level as both lions and livestock could easily meet at this point which still encourages their interaction and then the conflict. Bauer et al. (2010) also indicated that the HWC become intense in a pasture with permanent water supply.

Hemson (2003) found that some lions stayed behind at the Boteti River region when migratory wild-prey (zebra and wildebeest) move to the east of the MPNP and switched their diet to livestock during wet seasons therefore leading to higher conflict level. Furthermore, some livestock was stray since farmers and herders simply waited for them to come back for kraaling for the night and others ending up not returning (Setlhare, pers comm; Hemson 2003). This can be proved by Hemson (2003) who revealed that most of the livestock kills were outside the boma. For AF period, livestock kill incidents were lower than the two periods since the fence acted as a barrier therefore minimising lion-livestock interaction. However, there is a possibility of the farmers to have reported lion kills than for other carnivores to claim compensation since lion was the only carnivore compensated for. Also some farmers might have deliberately and falsely reported lion kills for the reason above since they said reaction from DWNP to verify which carnivore has made a kill was slower. In addition, lions are able to secure kills from other

smaller carnivores such as wild dogs (Creel & Creel 1996) which could increase chances of misinterpretation of the original carnivore that initially made a kill.

2.5.2 Assessment of livestock kill groups for the three periods

Generally there was a decrease in the number of kills for large stock from BF to AF period since there was a barrier to separate lions from livestock. Large livestock group was highly predated by lions for BF and RF periods (Figure 2.3). Lions prefer a weight range which cattle falls into. Also cattle which forms the bulk of large livestock category is capable of moving longer distance from its cattlepost as compared to other livestock species (Hemson 2003). This increases chances for intersecting with the lions especially when moving towards near the park boundary. Jackson (1996) showed that increase in grazing distance increases vulnerability of predation. Comparative to other livestock, cattle depend on water-point and forage quality of which these two are not easily found together within a shorter distance (Verlinden 1997). Some farmers do not kraal their cattle and donkeys during drought periods so that they can eat grass which has some moisture (dew) in the early mornings. This practice could also lead to cattle moving longer distances which still put them at higher risk of predation. This study did not investigate reasons why cattle appeared to be the most preferred prey by lions. But other studies (Power 2002; Hayward & Kerley 2005) proved lions to specialise within certain prey of particular weight range. Radloff & Du Toit (2004) found that minimum prey mass was not related to predator mass whereas maximum prey mass was significantly related to the predator mass.

Medium and small livestock kills did not change significantly for the three study periods while for large group more kills were for RF period (Figure 2.3). Even though small group was affected less frequently, it might be killed at higher numbers per incident or scene compared to

other groups. This is due to the fact that small sized kills are known to be under-represented in many studies of large carnivore diet as they are consumed whole or entirely removed by scavengers (Radloff & Du Toit 2004).

2.5.3 Farmers' perceptions on the influence of the fence and the flowing of the river

Most of the farmers (94.8%) perceived that the conflict level was worst during BF period compared to the other two periods (Figure 2.4) because there were no active barrier(s) to minimise/eliminate direct contact between lions and livestock. Additionally, majority of the farmers (95.6%) perceived that the conflict level was lower for AF period (Figure 2.4) since the fence was still intact to keep lions and livestock separate. Monametsi (2008) study also showed that 96% of the local people perceived that the fence managed the movement of both wildlife and livestock even though lion was ranked to be the carnivore least impeded by the fence. Lions are not tolerated to live closer to the cattlepost since pastoralists only heavily rely on livestock for their livelihood such as; paying children school fees and buying family food (Otukile Ndana, pers. comm). Conflicts become more intense when the presence of lions in a particular area poses some threat to the nearby human welfare (Saberwal et al. 1994). During the RF period, many farmers (65.8%) perceived that human-lion conflict was lesser (Figure 2.4) since the river-flow and other areas where fence was still upright could partially separate lions from livestock. They stated that the river had more water which resulted into fewer lions crossing to the cattlepost side, and fewer or no livestock crossing to the park side hence lesser conflict. Farmers' perceptions did not match with the data from livestock kill reports only for the RF period. This might have been due to the fact that they felt that they contributed to the failure of solving the problem. The farmers were involved in the suggestions as to how the conflict could be resolved

initially where an agreement made was that the fence had to be erected. They also knew that some of their community members might have stolen the solar-panels therefore leading to the failure of the fence being electrified.

The solution to HWC in general appears to lie with the local people themselves. Community or farmers' involvement in managing the conflict has been suggested to be critical (Hackel 1999; Mattson et al. 2006; Wang & Macdonald 2006). People's perception towards the conflict does not always match the reality (Distefano 2004) and other studies (Hemson 2003; Wang & Macdonald 2006) showed that the perceptions towards HWC are highly influenced by the substantial benefits they get from animals involved.

2.6.0 Summary

This chapter can be concluded as follows:

- Lion caused more livestock kills compared to other carnivore species.
- Human-lion conflict level was lower during AF period and dry season.
- Lion mostly killed cattle which have large body size.
- The Makgadikgadi fence significantly reduced human-lion conflict therefore indicating its importance especially during the intact stage. The river-flow was not an effective barrier between livestock and lions.
- Farmers believed the conflict was worst during BF period and better for AF and RF period. They continued to perceive Boteti River as one barrier which can separate lions from them together with their livestock.

2.7.0 Link to the next chapter

Human lion conflict level is a crucial element that can be measured in different ways, for example, through the use of PAC data, and farmers' perceptions. Carrying capacity for the lions and other large carnivore populations, and their prey (wild prey and livestock) population has to always be kept in check. However, the interaction between large carnivores and prey populations can also be influenced by some factors such as water points like rivers, barriers such as fence which can determine access to certain resources and areas. The next chapter will be focused on these aspects of large carnivore, and prey population dynamics in relation to the three study periods.

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Chapter Three: Lion and prey abundance and interaction around Makgadikgadi Pans National Park

3.0 Introduction

Understanding the interaction between lions (*Panthera leo*) and their prey is important if we are to understand lion population dynamics and the best way to conserve them (Fuller & Sievert 2001). The interaction between lions and their preferred wild prey species is significant in understanding predation effects on domestic prey (Schiess-Meier et al. 2007). The abundance of preferred wild prey can influence lion predation rates (Fuller & Sievert 2001; Hayward et al. 2007) and lions can alter their foraging behavior to respond to seasonal fluctuations in wild prey abundance (Hemson 2003; Honer et al. 2005; Balme et al. 2007; Valeix et al. 2012). Carnivore-prey relationships are further influenced by rainfall and vegetation productivity (East 1984). Prey population can be controlled through top-down approach such as by predators, or bottom-up approach such as by food limitation. Generally, the number and type of animals that can be supported in a habitat are determined by the amount and distribution of food, shelter, and water in relation to the mobility of the animal (Thomas et al. 2004). Seasonal changes in wild prey abundance can influence carnivore diet selection and can determine whether carnivores should switch to livestock or not (Fuller & Sievert 2001; Valeix et al. 2012). Lion prey mainly on livestock when their preferred wild prey such as zebra (*Equus quagga*) and wildebeest (*Connochaetes taurinus*) emigrates. In addition, lions in the Makgadikgadi region of Botswana move closer to human settlements and livestock grazing areas when their migratory wild prey is scarce (Hemson 2003). Most of the lions in the Makgadikgadi ecosystem were resident and

switch between wild migratory prey and livestock when wild migrants become scarce (Valeix et al. 2012).

The flowing of the Boteti River due to floods from the Okavango Delta is likely to influence the spatio-temporal distribution of wildlife and livestock. Water-dependent species such as buffalo (*Syncerus caffer*), wildebeest and zebra often increase in abundance near water sources (Redfern et al. 2003; Yoganand & Owen-smith 2014; Ogutu et al. 2014). The use of habitats surrounding water surfaces can also create inter- and intra-specific competition, and heterogeneity in forage resources. When access to water is high, wildlife's negative impacts on the surrounding habitats can be minimal.

Carnivore-prey dynamics is very important in understanding carnivore population dynamics, (Fuller & Sievert 2001), foraging behaviour (Hanby et al. 1995, Höner et al. 2005, Balme et al. 2007), interspecies competition and movements (Hayward et al. 2009). A seasonal change in wild prey abundance influence carnivore diet selection and often has a direct influence on human-carnivore conflict (Fuller & Sievert 2001; Frank et al. 2005). For example, all male lions were stock raiders with larger home-ranges during good periods and smaller during lean periods (Hemson 2003).

3.0.1 Prey abundance

Prey availability is affected by abiotic factors (e.g. distance to water) and biotic factors (e.g. forage quality and quantity) and the latter affect carnivore distribution. Ecology of different herbivores is affected by lot of mechanisms in a different way. In the Serengeti ecosystem and in Kruger National Park, zebra were less sensitive to food shortage but more sensitive to predation

as compared to other grazing bovids (Grange & Duncan 2006). Most of the wild prey species had a steep population decline in the 1980s such as the ones which had their migratory routes blocked by the Kuke fence (Williamson & Mbano 1988).

3.0.2 Estimation of lion and other carnivores' population

Carnivore population can be estimated from different methods such as spoor counts and calling stations. This population can be influenced by other factors such as prey distribution and abundance. Distribution of resources is not uniform in both space and time. African ecosystems involve complex multi-species predator-prey systems (Sinclair et al. 1985; Mills & Biggs 1993), further compiled by dramatic fluctuations in environmental conditions, caused by variable rainfall (Smuts 1978a; Viljoen 1993; Mills et al. 1995). Prey availability affects large carnivore reproduction and recruitment (Fuller & Sievert 2001), foraging behaviour (Hanby et al. 1995; Balme et al. 2007) and movements (Hayward et al. 2009). For example, there is a strong correlation between lion and prey density (Bauer et al. 2008).

3.0.3 Niche breadth

Niche breadth is a term used to describe how specialized or generalized an animal of interest is (Colwell & Futuyma 1971). Being specialized means that an animal has fewer prey species treated as food whereas a generalist has a wide range of prey species being treated as food (Colwell & Futuyma 1971). Niche breadth of carnivores including lions can be influenced by prey abundance such that when prey abundance is lower, they limit their prey selectivity.

3.0.4 Lion's livestock prey preference

This concept is used to understand how lion selects its food relative to its abundance. Species preference is ranked as "preferred, avoided or used according to its availability" based on its selectivity and abundance. However, other factors influence lion's prey preference such as prey encounter rate, body mass, habitat use, anti-predator behavior (Hayward & Kerley 2005) and environmental factors such as vegetation height (Hopcraft et al. 2005).

This study focuses on three different periods to fully understand the influence of the fence and river-flow on the above factors: 1) Before Fence (BF):- (from year 2000 - 2003) is the period when there was no fence and Boteti river not flowing; 2) After Fence (AF):- (from year 2006 - 2008) is the period when the conflict fence was intact but the river not flowing; 3) River Flowing (RF):- (year 2010 - 2012) this is when the Boteti River was flowing but the conflict fence being porous.

3.1.1 Research Questions

1. How has lions' prey densities changed during the three periods for the study area?
2. How did the lion population change during the three periods for the study area?
3. What was lion's niche breadth during the three periods for the study area?
4. What was lion's livestock prey preference for the different livestock types and weight ranges during the three periods for the study area?

3.1.2 Hypotheses

1. Lions' prey densities did not change for the three study periods.

2. Lion population did not change during RF from BF period.

3. Lions' niche breadth was the same for the three study periods.

4. Lions' livestock prey preference was the same for the three study periods.

3.1.3 General Objective

To determine relationships among the lion and prey abundance, lion niche breadth and livestock prey preference during BF, AF, and RF period in the Makgadikgadi Pans National Park (MPNP).

3.1.3.1 Specific Objectives

1. To compare lion prey abundances in BF, AF and RF period in the study area.

2. To determine differences in lion population estimates between BF, AF and RF period in the study area.

3. To assess lion's livestock niche breadth during BF, AF and RF period in the study area.

4. To determine lion livestock prey preference for different livestock types for BF, AF and RF period in the study area.

3.2.0 Materials and Methods

3.2.1 Study area

The study was conducted in MPNP, Botswana which falls within range of 20-21^{o}South and 24-26^{o}East (Figure 3.1). The area covers approximately 4900km^2 and composed of differing habitat types. On the western side of the park there is the Boteti River which forms boundary between

the park and the communal land. The area within the close range of this river is comprised of relatively thick vegetation which are inclusive of: blackthorn tree (*Acacia mellifera*), sicklebush (*Dichrostachys cineria*) comparative to the eastern part of the park. The river never dried up during the time of this study. On the eastern side of the park there are vast open areas mainly comprised of the salt pans and few scattered real fan palm (*Hyphaene petersiana*) tree species. The pans hold water for a shorter period of time during wet season. Water availability in the two park sides plays a crucial role in the spatio-temporal distribution of prey and predators.

Herbivore diversity ranges from the larger herbivores which include the elephant (*Loxodonta africana*) and giraffe (*Giraffa camelopardalis*) and smaller herbivores which include impala (*Aepyceros melampus*) and steenbok (*Raphicerus campestris*). Among the herbivores found, there are the migratory ones such as zebra (*Equus quagga*) and wildebeest (*Connochaetes taurinus*). The carnivores present include the lion (*Panthera leo*), brown hyena (*Hyaena brunnea*), spotted hyena (*Crocuta crocuta*), leopard (*Panthera pardus*) and black-backed jackal (*Canis mesomelas*). Farmers are located closer (within 6km) to the Boteti river for providing their livestock with water and other domestic uses. Most farmers are pastoralists with large herds of cattle (*Bos taurus*). Culturally cattle are regarded as a sign for wealth and used to judge man's power to provide for the family as compared to other livestock. Some of the livestock reared by the farmers include; horses (*Equus caballus*), donkeys (*Equus asinus*), goats (*Capra hircus*), sheep (*Ovis aries*), chicken and dogs. Majority grazed their livestock on the open communal area. Cattle are kraaled inside the boma separately from sheep and goats for safety from predators and thieves. Usually the bomas are constructed by thorny bushes such as umbrella-thorn tree (*acacia tortillis*) or fence. These farmers practice a traditional low cost of husbandry where livestock is being left to graze alone and expected to return to the boma during the

evening. However those who practised mixed farming plough sorghum, maize, sugarcane, watermelon and beans during wet season.

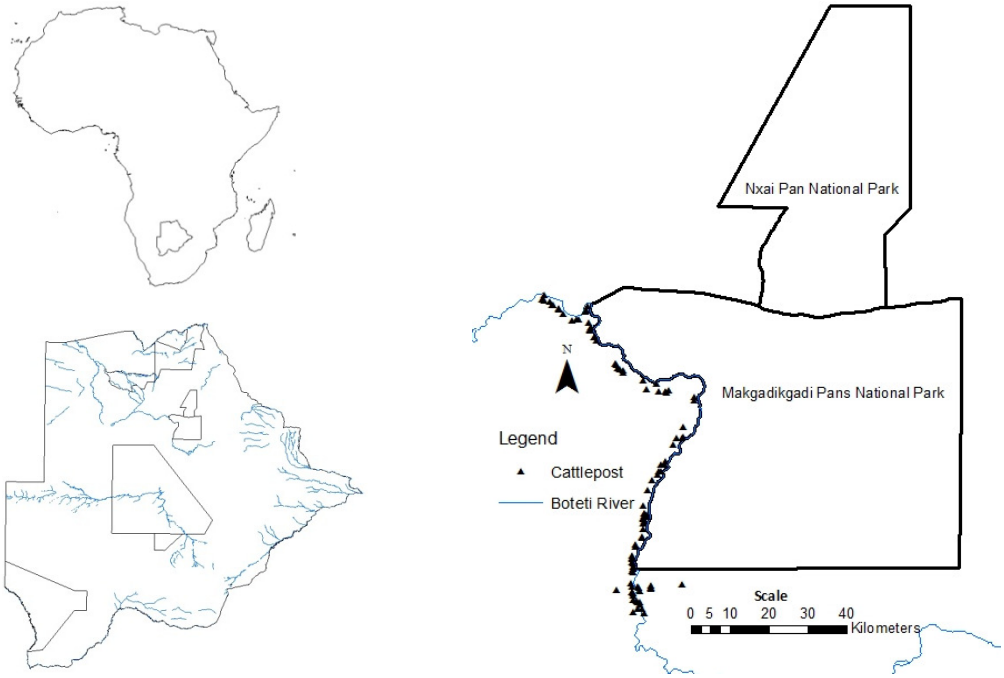

Figure 3.1: Map of the Makgadikgadi Pans National Park where the lion and prey population estimations were conducted.

3.2.2 Data collection

3.2.2.1 Prey abundance

The study was conducted in the MPNP, Botswana (See chapter one for more details). Department of Wildlife and National Parks (DWNP) aerial survey data was used to estimate the abundance of different species of the likely prey species for the three study periods. These aerial surveys used distance sampling technique which is popularly used for estimating the abundance of biological populations. The methods used for distance sampling include line transects and point transects (See Norton-Griffith 1978 for more details). The data used was for dry season aerial surveys of 2001, 2002, 2003, 2006 and 2012. All of the surveys were conducted in the dry

season to improve visibility of animals as the majority of the vegetation during this season was dry and defoliated. The transect method was used for the data collection (see Norton-Griffith 1978) whereby observations were done from the air on both large wildlife and livestock species. As the DWNP aerial survey data did not categorize livestock into different age or sex groups data from Central Statistics Office (CSO) was used to provide age groups of the animals. For example, cattle were categorized into bull, oxen, cow, tolly, male calf, female calf under CSO data while they were grouped as cattle for the DWNP aerial survey data. Prey was sub-divided into three groups; Preferred, Avoided, and Livestock.

3.2.2.2 Estimation of lion and other predators' carrying capacity

3.2.2.2.1 Estimation of lion and other carnivores' population at the potential carrying capacity from aerial surveys

The calculation of lion population can involve the use of preferred wild prey biomass (see Hayward et al. 2007). The aerial survey data was used to generate this estimate for the study area. The Hayward et al. (2007) model was then used to calculate lion population estimation at carrying capacity. Preferred prey by lions used in this study were obtained from Hayward & Kerley (2005). They classified the following wild prey species as lion preferred prey; zebra, wildebeest, gemsbok (*Oryx gazella*) and giraffe. Following Hayward & Kerley (2005) livestock was not used to calculate lion densities. Spotted hyena did not have preferred prey species (Hayward 2006; Hayward et al. 2007). Adult female body mass as stated by Stuart & Stuart (2000) was used in the prey biomass calculations. Three-quarter (3/4) of this adult female body mass was used in-order to cater for the young and sub-adults in the population (Hayward et al.

2007) because small and medium prey is usually under-represented during the aerial surveys (Hayward 2006). Hayward model have been used by other studies such as Omoya et al. (2013) to estimate the potential lion carrying capacity;

$y = 10^{(-2.158+0.377x)}$ (Hayward et al. 2007; Omoya et al. 2013)

Where: y is lion density (*a*/km^2 where *a* is the number of the lions) and *x* is $\log_{10}$(preferred prey biomass in kg.km^{-2})

This study considered Hayward et al. (2007) model over the Loveridge & Canney (2009) model. The Hayward et al. (2007) model gives allowance for the fact that lions can still survive without their preferred prey species in a particular area. Some other models are inadequate as they assume that there will be no lion(s) without the presence of preferred prey species.

3.2.2.2.2 Estimation of lion population from the calling stations

Calling stations were used to provide lion population estimates together with estimates of other large predators. I used the same census method used by Hemson (2003) to allow comparison of the results. For BF period, the surveys were conducted from the 20 August 1999 to 29 September 1999 whereas for RF period they were conducted from 20 September to 30 September 2012. Surveys were done from 1900hrs to 0400hrs only once during each study period in order to minimize the lions from getting habituated to the sounds played. A sound of a distressed buffalo (*Syncerus caffer*) calf and warthog (*Phacochoerus africanus*), and lion and spotted hyena sounds were played using a 12-Volt amplifier connected to 4 x 25W-8Ω horned speakers positioned on top of a car (Land-rover, V8 model). The speakers were perpendicularly positioned to each other to have wider area coverage. Spotlight was used to search for any lion or predator which might

have approached the vehicle. Binoculars were used during the search of predators too. We then recorded the number of lions visible, their sex and their body conditions. Locations of the calling stations were plotted using the Global Positioning System (GPS) so that the future stations could be established at the same points for comparison purposes. Each survey lasted for an hour with each of the four sounds running for 10mins and 5mins break. Light was shone around every 2.5mins to check whether there might be some predators approaching. All calling stations were conducted after sunset (after 19:00hrs). Weather conditions were assessed before the survey so that they could not be conducted under strong windy conditions and heavy rains to minimize bias. All stations were at least 5km apart to avoid overlapping of surveyed areas and recounting of the predators.

Thirty-nine calling stations were conducted in the park (MPNP) for each period (Figure 3.2) which spatially covered 22.5% of the MPNP. Lions' response radius to calling stations differ between studies (e.g. Ogutu & Dublin 1998; Winterbach et al. 1998; Kiffner et al. 2009; Snyman 2010; Omoya et al. 2013) and was tested several times to better the precision of the study.

The effective lion response range used in the Okavango Delta of 3.0km and 4.0km (Winterbach et al. 1998) were used for lion population estimate calculations in this study. This was done to allow for the differing landscape features which might affect the maximum distance range audible to lions. The 3km and 4km radius effective ranges covered 28.3km^2 and 50.3km^2 areas respectively at each calling station. The 39 calling stations conducted yielded 1102.7km^2 and 1960.4km^2 for the respective radius stated.

The study conservatively used 60% response rate as per the recommendation of Winterbach et al. (1998) as the habitats are similar with a majority of them being open tree savannah and grasslands. All our calling stations operated for a maximum of one hour each since studies showed different times of arrival at stations Kiffner et al. (2008) had 36min and Omoya et al. (2013) had 30min as the average arrival time at the stations.

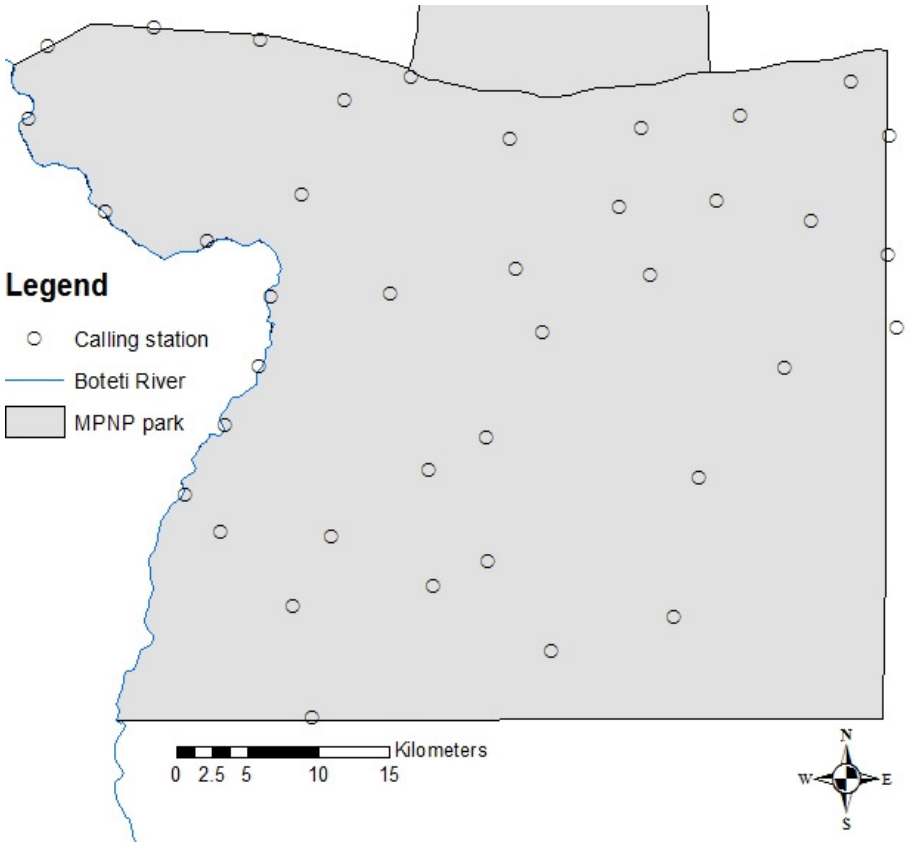

Figure 3.2: Calling stations geographical locations. The calling stations were repeated (during RF period) in the similar positions as to those conducted by Hemson (2003) during BF period.

3.2.3 Niche Breadth

Problem Animal Control (PAC) data was used to calculate niche breadth with the aim of determining the specialisation of lions on livestock prey species. Levins (1968) measure of niche breadth was used for the calculations using the following equation:

$$B = \frac{1}{\sum Pi^2}$$

where B is the Levins measure of niche breadth and Pi is the proportion of livestock type predated by lion. In-order to calculate this measure for a certain species, lion kills for that particular livestock species were counted. Calculations were done per each season for the three periods.

3.2.4 Lion livestock prey preference

Jacobs' index (Jacobs 1974) was used to determine lion livestock prey preference:

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

where D is the lion's livestock prey preference, r is the proportion of lion's total kills for particular livestock type in a certain site, and p is the proportion of abundance of that particular livestock species. The outcomes of the calculations ranged from +1 (highly preferred livestock prey), 0 (livestock prey being used as expected) to -1 (highly avoided livestock prey). The criteria for lion prey preference stated (ranging from +1 to -1) was further sub-divided to classify the different levels of preference to better distinguish them. This was categorised into 5 levels; >+0.51 to +1.0 as highly preferred, +0.1 to +0.50 as preferred, +0.1 to -0.1 being used according to availability, -0.1 to -0.5 being avoided, and <-0.51 to -1 being highly avoided.

For this study PAC data was used as a measure of the frequency on lion kills of different livestock types. Only livestock prey was used to calculate prey preference for the three periods since the overall aim was to assess the level of livestock predation at different times of wild prey availability, i.e. lower wild prey abundance during wet season, and higher wild prey abundance during dry season. For prey abundance estimation the aerial survey and CSO data were used. From the aerial survey data, three prey groups (Large, Medium and Small) which were derived in Chapter 2 were used in the lion livestock prey preference calculations. To further sub-divide this livestock prey into sub-groups based on age ranges, CSO data was used (CSO 2003; 2008; 2013). This is because the aerial survey records did not present different livestock species according to their different age groups. For example cattle were presented in one category, being cattle. The groups were further categorized into weight groups as; Cattle-Large, Cattle-Medium, Cattle-Small, Horse, Donkey, Sheep and goats. This was done for further understanding of the type of livestock species, and which livestock size was affected most in-relation to others.

3.3.0 Data analysis

Data was firstly cleaned to facilitate accurate analysis through deletion of some years which were not used in the analysis i.e. during time when the fence was still constructed (2004-2005), and when the river started flowing (2009) to avoid bias. Data was amended to facilitate the analysis such as through grouping of lions' wild prey species into preferred and avoided according to Hayward & Kerley (2005) (Table 3.1).

Table 3.1: Wild prey classification according to lion preference (Adapted from Hayward and Kerley, 2005).

Preferred prey	Avoided prey
Giraffe (*Giraffa camelopardalis*)	Impala (*Aepyceros melampus*)
Gemsbok (*Oryx gazella*)	Ostrich (*Struthio camelus*)
Wildebeest (*Connochaetes taurinus*)	Steenbok (*Raphicerus campestris*)
Zebra (*Equus burchellii*)	Duiker (*Sylvicapra grimmia*)

Lions' livestock prey species were firstly categorised into one group. Wild prey groups and livestock were analysed depending on their location, in- and outside the park. Analysis of Variance (ANOVA) was used to test for significant difference in prey densities between the groups during the three periods in- and outside the park. This was done after the data met normality assumptions with Levene's test. Least Significant Difference (LSD) test was conducted to specify where the significant difference is between the three periods. Secondly, lion and other carnivore population estimates at carrying capacity were calculated using Hayward et al. (2007) model (see methods section). Population estimates were analysed for the three study periods at in- and outside the park to cater for all the three periods. T-test was used to test for significant difference between lion population estimate for in- and outside the park. Lion population estimates were calculated from the calling station surveys even though data for AF period was missing since the survey was not done during this period. Chi-square was used to test for significant association between lion population and the study periods. Thirdly, lion's niche breadth was determined for the three study periods and for wet and dry seasons. Only lions' livestock prey species were used. ANOVA was used to test for significant difference of the niche breadth between the three periods, and the two seasons using Statistical Package for Social Sciences (SPSS). Lastly, lions' livestock prey preference was calculated using Jacob's index of preference after sub-dividing livestock species into groups depending on their body mass. The

aerial survey and CSO data were used for calculating lions' livestock prey preference during the three study periods. The preference was categorised into highly preferred (HP), preferred (P), used according to availability (UA), avoided (A), and highly avoided (HA).

3.4.0 Results

3.4.1 Spatio-temporal distribution of prey

3.4.1.1 Prey distribution in and outside the park

Lion prey was sub-divided into three groups; Preferred, Avoided, and Livestock. Lion prey densities were significantly higher during RF than BF and AF periods (BF = 0.63 ±0.54 animals/km^2; AF = 0.54 ±0.54 animals/km^2; RF = 2.64 ±0.54 animals/km^2) ($F_2 = 4.17$, $p < 0.05$). Prey density was also significantly higher outside the park than inside (Inside park = 0.646 ±0.44 animals/km^2; Outside park = 1.89 ±0.44 animals/km^2) ($F_1 = 4.17$, $p = 0.05$) (Figure 3.3, and 3.4). Generally preferred wild prey and livestock prey densities were significantly higher than avoided wild prey (Preferred = 1.99 ±0.59 animals/km^2; Avoided = 0.06 ±0.44 animals/km^2; Livestock = 1.76 ±0.59 animals/km^2) ($F_2 = 4.17$, $p < 0.05$). Interactions between i) lion prey group densities and area; ii) lion prey group densities and study periods; iii) area and period; iv) lion prey group densities, area and period were not significant ($p > 0.05$). The preferred prey was the only species which was significantly higher during RF period than the other two periods while others were not significantly different leading to no significant interaction between lion prey group densities and period.

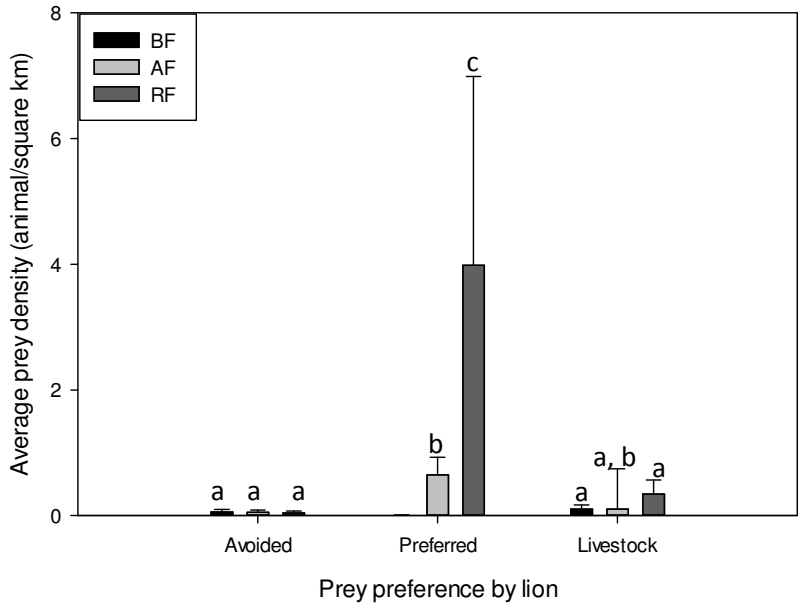

Figure 3.3: Lion prey distribution across the three study periods. Prey was classified in-relation to preference status by the lion. The distribution was only for the prey inside the park. Same letters (e.g. a,a) means that there was no significant difference between the prey categories whereas different letters (e.g. a,b) imply that there was a significant difference.

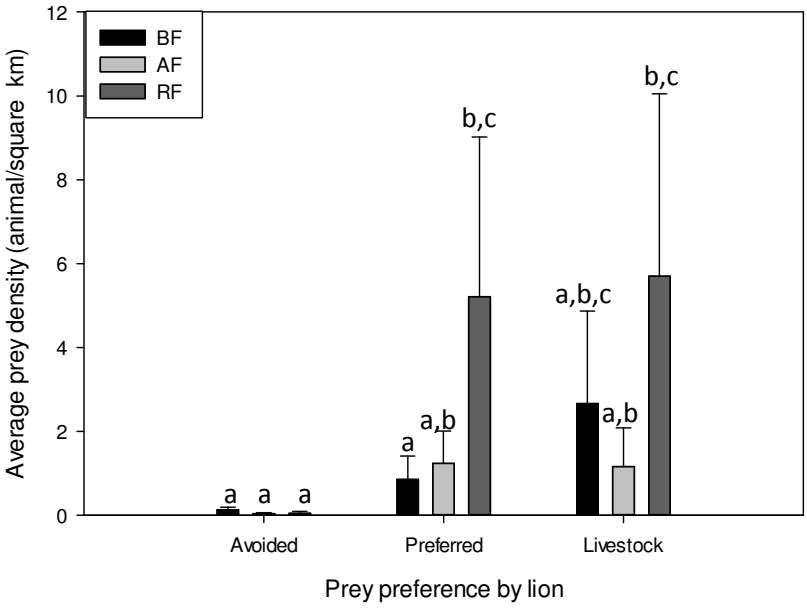

Figure 3.4: Lion prey distribution across the three study periods. Prey was classified in-relation to preference status by the lion. The distribution was for the prey outside the park. Wild prey was categorised as avoided, and preferred as shown by Hayward & Kerley (2005) (See Table 3.1) whereas livestock was grouped as one. Same letters (e.g. a,a) means that there was no significant difference between the prey categories whereas different letters (e.g. a,b) imply that there was a significant difference.

3.4.2 Lion and other large carnivores' population estimate

3.4.2.1 Estimation of lion population at carrying capacity from aerial surveys

The results are limited to the lion carrying capacity estimate (inside and outside the park) during dry season only because the aerial surveys were conducted during this season for improved vision of animals during their counts. There was no significant difference between periods for the lion carrying capacity estimate inside the park (T-test: F_2, $p > 0.05$) whereas the lion population estimation at carrying capacity was significantly different between periods for outside the park (T-test: F_2, $p < 0.05$) (Table 3.2).

Table 3.2: Lion density (lion/km^2) estimates from Hayward et al. (2007) model in the study area. The estimates were done for inside and outside the park area. The estimates were calculated using aerial survey data.

Period	Area	Lion density estimate	Spotted hyena density estimate
BF	Inside park	0.016	0.068
AF	Inside park	0.070	0.168
RF	Inside park	0.151	0.269
BF	Outside park	0.082	0.186
AF	Outside park	0.095	0.202
RF	Outside park	0.165	0.284

3.4.2.2 Lion population estimate from calling station survey

The 39 conducted calling stations covered 22.5% of the MPNP area for upper estimate and 40.0% for the lower estimate for the lions. Hemson (2003) recorded only two lions in those 39 calling station surveys done during BF period whereas this study recorded a total of 6 (1lion and

5lions for both stations) in the different calling station locations for RF period. No lion(s) responded vocally towards the calling stations. Only two out of the 39 stations (5.1%) attracted lions during BF, and for RF period. There was a significant association for the lion populations and periods (X^2 (18) = 358.92, $p < 0.05$), and between lions and spotted hyenas (X^2 (1) = 183.23, $p < 0.05$). Unfortunately there was no data for AF period to allow comparison of all periods (Table 3.3).

Table 3.3: Carnivore population estimates in the MPNP for BF and RF period.

Predator	**Carnivore population for BF period**		**Carnivore population for RF period**	
	Upper estimate	**Lower estimate**	**Upper estimate**	**Lower estimate**
Lion	15 (3.0km radius)	8 (4.0km radius)	44 (3.0km radius)	25 (4.0km radius)
Average	**12 ±1.5**		**35 ±5.0**	
Brown hyena	16 (2.75km radius)	12 (3.2km radius)	5 (2.75km radius)	4 (3.2km radius)
Average	**14 ±2.0**		**5 ±0.5**	
Spotted hyena	48 (2.75km radius)	35 (3.2km radius)	16 (2.75km radius)	12 (3.2km radius)
Average	**42 ±6.5**		**14 ±2.0**	

3.4.3 Lions' niche breadth

The lions' niche breadth was significantly different for the three periods (BF = 3.51 ±0.22; AF = 2.14 ±0.25; RF = 2.91 ±0.25) ($F_2 = 8.51$, $p < 0.05$). Niche breadth was significantly different between the seasons (Wet = 2.35 ±0.20; Dry = 3.36 ±0.20) ($F_2 = 13.11$, $p < 0.05$). Interaction between period and season was not significant ($F_2 = 3.13$, $p > 0.05$) (Figure 3.4). Dry season niche breadth was higher than wet season for all the periods.

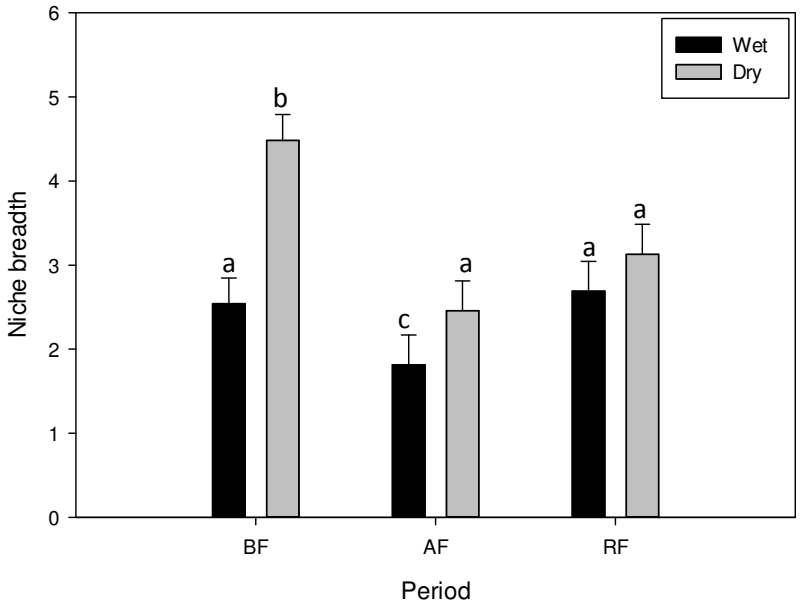

Figure 3.5: Lion niche-breadth for the study periods during wet and dry seasons. Same letters (e.g. a,a) means that there was no significant difference between the niche breadth whereas different letters (e.g. a,b) imply significant difference.

3.4.4 Lions' livestock prey preference

Most of the documented data concerning lion prey preference (e.g. Hayward & Kerley 2005) focused on wild prey compared to domestic prey of similar weight range such as cattle. Small and Medium stock were highly preferred during BF period (Figure 3.6). Only Medium stock was avoided during AF period. During RF period all the livestock groups were avoided; Medium and Small stock being highly avoided, and Large stock avoided. Cattle-Large, horse, sheep and goats were highly preferred during BF period after sub-division of the livestock using CSO data (Figure 3.7). Sheep and goats were highly avoided for AF period whereas only three livestock groups; cattle-Large, cattle-Medium and horse were preferred. All of the six groups were avoided during RF period but cattle-Large, horse, sheep and goats being highly avoided (Figure 3.7).

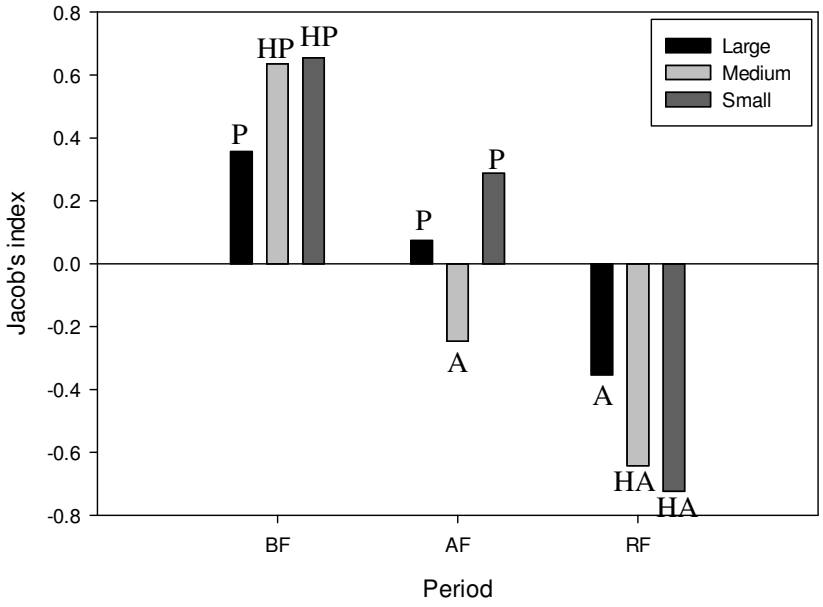

Figure 3.6: Prey (livestock) preference at different periods. Calculated from Jacob's index of preference. The following abbreviations were used to clarify the preference; HP:- highly preferred, P:- preferred, UA:- used according to availability, A:- avoided, HA:- highly avoided.

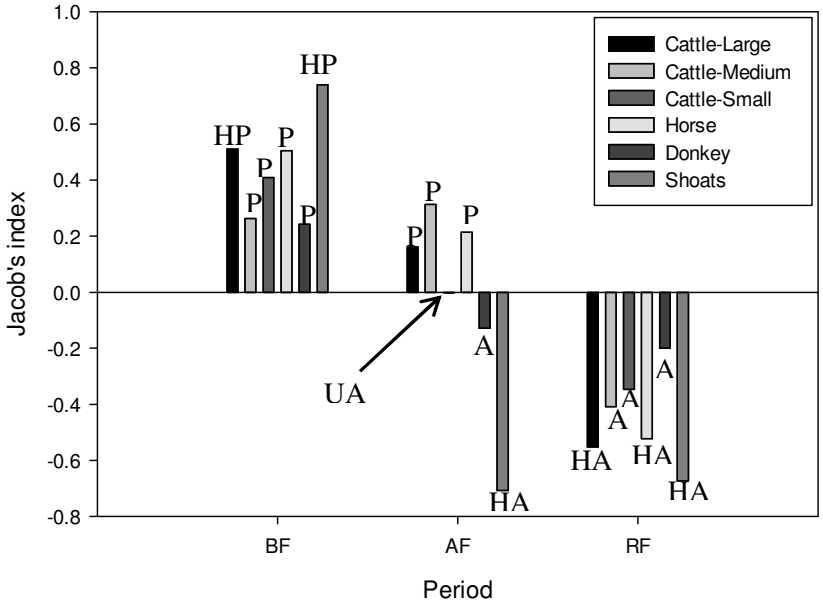

Figure 3.7: Prey (livestock) preference for livestock weight ranges for the different periods. The following abbreviations were used to clarify the preference; HP:- highly preferred, P:- preferred, UA:- used according to availability, A:- avoided, HA:- highly avoided.

3.5 Discussion

3.5.1 Spatio-temporal distribution of prey

As the data I used for this study were extracted only from aerial surveys which were only conducted during the dry seasons I could not make any conclusions about the wet season. The RF period had the highest prey density (Figure 3.3 and 3.4). This could probably be due to the increased water availability after river flow which acted as a pull factor therefore leading to an increase in both domestic and wildlife species density within the immediate area (Figure 3.3 and 3.3). As expected livestock prey was higher outside the park compared to inside because it is illegal for it to graze in the park. The community in the study area also regard possession of livestock especially cattle as more valuable than other livestock species such as sheep and goats. This cultural practice might have made them to keep a considerable number instead of selling a surplus. In order to save their stock from harsh environmental conditions, other farmers grazed their stock inside the park even though it is illegal. The other suggestion is that livestock could have been enclosed inside the park during AF period. The above reasons probably led to no significant difference for livestock densities across the periods inside the park (Figure 3.3). Both wild and livestock prey distribution was area-related; more wild prey inside the park and more livestock outside the park (Figure 3.3, 3.4) for the same reason mentioned above. Some of the factors such as limited resources e.g. food inside or outside the park could lead to wild prey or livestock prey to go either way. Since there was no barrier to stop entrance of livestock prey into the park for BF period, livestock found easier ways to get into the park (Brooks & Maude 2010). Lack of a barrier therefore favored livestock which can travel longer distances like cattle to get

into the park and possibly negatively affect some areas used by wild prey such as by overgrazing. Zebra herds in MPNP travelled longer distances for foraging because their preferred areas such as those closer to water-points were overgrazed by livestock (Brooks 2005). Herbivore population distribution is influenced by food quality and quantity (Bailey 1996). Farmers also used the area for better grazing pastures (Hemson 2003) hence the higher livestock prey density compared to AF and RF periods (Figure 3.3, 3.4). Due to the construction of Makgadikgadi fence in the western park side, wild prey and livestock prey had no/limited opportunity to get to the either side of the park boundary. The movement restriction could be another factor leading to higher wild prey density inside the park and higher livestock density outside (Figure 3.3, and 3.4). Since during RF period the fence was partially permeable both wild prey and livestock could cross the park boundary to the other side. Farmers were still bound to graze their livestock outside the park since it is illegal for it to graze inside the area. Most of the water points in the area could be accessed outside the park boundary (Kesch et al. 2015). This led to wild prey species to get outside the park hence making their density to be higher for RF period (Figure 3.4).

3.5.2 Abundance of different carnivore species

The results showed a significant increase in lion abundance between the three consecutive periods (Table 3.2) except for the spotted hyena and brown hyena population estimate from calling stations (Table 3.3). Lions in fenced reserves are usually limited by density dependence factors whereas those in unfenced reserves are relatively more sensitive to human wildlife conflict (HWC) (Packer et al., 2013). Lions' safety outside the park is usually compromised. For example, majority of lion deaths (>80%) occurred outside the park area in Northern Tuli Game

Reserve (Snyman 2010). The MPNP lions can experience the both density dependence factors and the conflict since the park is partially fenced. Since Brooks & Maude (2010)'s report regarded the area around Boteti River as a human lion conflict hotspot the fence erection helped to save lions from exposure to livestock interactions which could expose them to persecution by farmers. Lion population increased while other large carnivores such as spotted hyena decreased (Table 3.3). Large carnivores are capable of limiting the density of smaller carnivores especially by out-competing them such as aggressively getting their kills (Palomares & Caro 1999; Watts & Holekamp 2008). The argument might have benefited lions hence resulting into their population increase.

3.5.3 Lions' livestock niche breadth

Migratory wild prey species, zebra and wildebeest which form the bulk of lions' diet return to the Boteti River during dry season (Valeix et al. 2012) where they could access water. The presence of these species together with livestock prey during the dry season is expected to increase lions' food niche width because of wide variety of food choice as compared to the wet season whereby the relatively abundant food is livestock leading to the significantly different lions' niche breadth for the season (Figure 3.5). Species with a wider range of food choice is less likely to be negatively affected by the scarcity of other food resources (Swihart et al. 2003). No significant difference for the lions' livestock niche breadth for wet season could be a result of limited prey abundance. As livestock is always available for the two seasons unlike wild prey, during wet season lions' diet becomes relatively limited since the migratory wild prey move to the eastern side of the park. This is supported by the results (Figure 3.5) whereby lions' livestock niche breadth was smaller during wet season than dry season which implied that they were more

specialized, thus killing certain prey species mostly than others. Dry season niche breadth was higher than that for wet season for all the periods (Figure 3.5). The limited lion prey during wet season could therefore result into higher human lion conflict than for dry season.

3.5.4 Lions' livestock prey preference

The study divided livestock prey into sub-groups and performed their lion preference status. Even though wild prey was not analysed for this parameter due to lack of data on lion kills for wild preys the study expect to provide the relevant authorities with strong knowledge concerning the livestock type and age which can be possibly in a lion preference range. Knowing livestock type and/or age preferred could provide bases for resolving the human lion conflict. This study classified prey species into several categories to understand which body size is mostly preferred by lions and this strength is limited in other studies which did not differentiate between body sizes (Valeix et al. 2012).

All livestock prey species were preferred during BF period (Figure 3.6). This is because lions' wild preferred prey species densities were lower for BF period inside the park (Figure 3.3) possibly because livestock increased competition over food nearer to the Boteti River (Ferguson & Hanks 2012). For RF period all livestock prey species were avoided (Figure 3.6 and 3.7) since lions' wild preferred prey (zebra and wildebeest) densities were higher. The encounter rate of this prey type by lions could be higher therefore correlating with lion predation chances as documented in some studies (e.g. Scheel 1993). In addition, the encounter rate could be higher since after the erection of Makgadikgadi fence some degraded pastures in the park recovered hence leading to lions' wild preferred prey species such as zebra travelling shorter distances as

stated earlier. Furthermore small and medium prey tend to be generally under-represented since they can be wholly consumed within a relatively shorter time (Owen-Smith & Mills 2008).

3.6.0 Summary

The prey abundance and distribution is highly affected by the necessary resources such as forage and water. The latter directly affect carnivore distribution and abundance. Increase in wild prey species densities inside the park for the AF and RF periods possibly contributed to the increase in lion population in two ways: Firstly, more prey automatically implies enough food for these lions hence relatively successful reproduction rate. Secondly, the wild prey mostly was within the park therefore possibly reducing chances of the lions to getting outside the park for food where they get exposed to the conflict with farmers.

The spatio-temporal changes of the wild prey (zebra and wildebeest) densities have a significant input in the distribution of the large carnivores such as lions. This contributed to lions' preference for all livestock prey species during BF period and avoidance during RF period. In addition resident lions studied had their niche breadth lower during wet season when the migratory wild prey moved to the western side of the park.

3.7.0 Link to the next chapter

Predator-prey abundance knowledge is most important for conservation in many forms; for better management of site carrying capacity, and early warning system for some species' extinction. If all these factors such as wildlife and livestock population management are considered there could be less conflict. However we cannot resolve the conflict only from the knowledge of predator-prey population without considering the spatio-temporal distribution of the affected

predators and prey. The following chapter will therefore look into spatio-temporal movement patterns of the lions in order to understand as among other things the frequency of the lions getting outside the park. This could help with the prediction of the conflict level since when lions are outside the park, there will be relatively high chance of direct contact with livestock therefore increasing the conflict level likelihood.

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Chapter Four: Influence of the Boteti River flow on lion movement patterns and home range sizes in the Makgadikgadi Pans National Park

A female collared lion (*Panthera leo*) in the Makgadikgadi Pans National Park (MPNP) (Photo by: P. Mothathobi)

4.0 Introduction

Home range can be defined as the area in-which an individual travels within for various activities such as food gathering, mating and caring for young ones (Burt 1943). Carnivores travel from one place to another in-response to these same factors including hunting for food (Valeix et al. 2011), avoiding danger, to find shelter from hazardous weather conditions such as the sun and rain, and to find other members. An understanding of carnivore movement is important since it can help predict the outcomes which are associated with movements such as human-carnivore conflict. Home range sizes vary from one carnivore species to another due to factors such as their differing body sizes whereby large-bodied ones require larger home ranges as their metabolic needs increase (Harestad & Bunnel 1979; Belcher & Darrant 2004; Visser et al. 2009). They also vary within the individuals or groups of the same species (Visser et al. 2009) and from one place to another. For example, lion home range size varied from 25-51 km^2 in Nairobi National Park in Kenya (Schaller 1972), 4500 km^2 in Kgalagadi Transfrontier Park (KTP) in South Africa (Funston 2001) and 7337 km^2 in Kunene region in Namibia (Stander 2006).

Factors influencing home range sizes include habitat quality (Creel & MacDonald 1995; Funston et al. 1998), water accessibility (Druce et al. 2004; Visser et al. 2009), distance to the human-dominated areas like cattleposts (Valeix et al. 2012; Oriol-Cotterill et al. 2015), physical barriers (Spong 2002) like fence, suitable habitat for prey catchability (Valeix et al. 2011) and raising the cubs, inter- and intra-specific competition (Druce et al. 2004), and pride structure (Ngwenya et al. 2013). Home range size is normally positively correlated with the dispersion of prey resources, dispersion being a measure of how homogenous resources are distributed in an environment (Macdonald 1983). Food abundance profoundly influences carnivore movement patterns.

4.0.1 Influence of food abundance on lion's home range size

Carnivore home range sizes are affected by the food availability necessary to meet their energy requirements (Macdonald 1983; Grant et al. 1992). Carnivores' home range size lower limit is influenced by food availability (Van Orsdol et al. 1985) and upper limit by energy spent for various activities like patrolling the territory (Bertram 1973). The migratory species such as zebra (*Equus quagga*) and wildebeest (*Connochaetes taurinus*) influenced the lion home ranges sizes in Tarangire National Park in Tanzania due to their fluctuating abundances (Laizer et al. 2014). Thus home range sizes were larger during wet season than for dry season relative to prey abundance and distribution i.e. larger home ranges in the wet season as the large herbivores being zebra and wildebeests disperse to other places since water would be accessible in many points whereas during dry season many herbivores concentrate along the Tarangire River as it would be the only place to access water. Another study in Pendjari Biosphere Reserve in Benin (Sogbohossou 2011) also confirmed that lion home range size's season dependence was negatively correlated with food and water availability. Home range sizes here were smaller during dry season than wet season. In Pendjari, prey biomass ranged from 615-1665 kg/km^2 and lion home range size being around 20-400 km^2 (Loveridge et al. 2009), Waza National Park in Cameroon prey biomass varied from 400-800 kg/km^2 with lions' home ranges being around 600-1000 km^2 (Bauer & de Iongh 2005). Lion movement follows the optimal foraging theory such that they limit movement when food is highly available (Packer et al. 2005; Pontzer & Kamilar 2009; Visser et al. 2009). For example, mean home range sizes for lions in Waza National Park, Cameroon increased by 58.6% in a period of 10 years due to the decline in wild prey (Tumenta et al. 2013). Conversely other studies found that lions do not change their home ranges where

there is potentially stable preferred prey species. For example, lions in Makalali, South Africa did not increase their distance travelled after the increase in size of the conservancy area, and introduction of other lions possible due to abundance of prey species (Druce et al. 2004). The opposite has been also suggested whereby lion's movement increases because of low abundance of their preferred prey species. For example, the preferred large wild prey in Waza National Park in Cameroon constituted about 34% of all the wild prey species and lions spent more time outside the park during wet season when wild prey inside the park was less abundant (Visser et al. 2009). The major reason was that lions might be killing livestock especially cattle (*Bos taurus*) because of their large size since the preferred large wild prey species were relatively low in abundance. Lions living in relatively abundant prey generally spend less time to locate and have a successful kill (Visser et al. 2009) hence leading to smaller home range size. Resident lions in Makgadikgadi moved closer to the cattleposts and used smaller home ranges when wild prey was scarce (during wet season) (Hemson 2003; Valeix et al. 2012). However other factors such as pride size have been argued in different ways where Ngwenya et al. (2013) found that larger prides have larger home ranges in Hwange National Park in Zimbabwe whereas Spong (2002) found pride size not to be correlated with home range size in Selous Game Reserve in Tanzania.

4.0.2 The influence of water availability on prey dispersion and the impact on lion's home range size, and water as a barrier

Water is another important requirement influencing lion prey distribution therefore the latter dictating lions' movement patterns. When water is scarce lion prey tend to concentrate nearer the available water-bodies which then contributes to the reduction in lion's movements, and the

opposite is true. Most of the water-points in MPNP dry-up during dry season (Valeix et al. 2012) and as observed elsewhere (Druce et al. 2004; Loveridge et al. 2009; Visser et al. 2009). After rainfall in wet seasons prey species disperse to other places to access water hence leading to lions following them, this in-turn increases lions' home range sizes. Earlier studies showed high preference of riverine areas by lions due to factors mentioned earlier (Spong 2002; Druce et al. 2004; Lehmann et al. 2008; Tumenta et al. 2013; Jacobson et al. 2013). Rivers normally provide favorable conditions for cover, protection for the cubs (Snyman 2010) and prey capture. For example, more kills were recorded within a closer range towards the waterholes than further away (Mills 1984; Davidson et al. 2013). Resident lions along the Boteti River always ranged closer to the water-points (Valeix et al. 2012). Introduction of artificial water-points into an area can change prey species movement patterns and predators as well (Owen-Smith 1996). For example, in Kruger National Park in South Africa, the increase in the number of permanent water sources led to the introduction of other new lion prides (Smuts 1976) which was an indication that they have moved out of their previous home ranges. Water can also act as a barrier which could therefore possibly limit some animals' movement. However, water permeability can be species-specific such as in the Okavango Delta of Botswana (Cozzi et al. 2013). The study showed that water was partially permeable (14.4%) to lions even though it highly deterred (<2%) other carnivore species. The amount of water is regarded to be negatively correlated to the likelihood of lions crossing a river (Cozzi et al. 2013).

4.0.3 Lion movement patterns

The lion is regarded as a carnivore species that has suffered most from conflict with humans (Patterson et al. 2004). Lions' movement patterns in relation to being either inside or outside

their PAs can influence human-lion conflict. When moving outside the park there is a higher chance of them to encounter livestock and kill it and/or have direct contact with farmers whom will revenge by killing or injuring them. Tumenta et al. (2013) found that lions spent 21% time outside Waza National Park in Cameroon during wet seasons than during hot dry seasons. The time spent outside the park is directly proportional to the increase in livestock predation (Visser et al. 2009; Tumenta et al. 2013). Another study by Sogbohossou (2011) revealed that lions living along the edge of Pendjari Biosphere Reserve in Benin spent only 25% of their time inside the protected area (PA). These lions are being at higher risk of getting injured/killed by the neighboring farmers due to the considerable amount of time spent by these lions in the unprotected areas. For example, in Northern Tuli Game Reserve (Notugre) the majority (82%) of the lion mortality was found outside the border of this unfenced reserve (Snyman 2010). Generally lions cause higher conflict when wild prey dispersed to far places due to increased water abundance (Sogbohossou 2011). However during dry season the smaller home ranges tend to be located at the edge of the park which still pose some threats to the lions (Sogbohossou 2011). People are also regarded as one of the influencers of lions' movement patterns. Lions respond to the seasonal movement of people by usually relocating away from habitats occupied by man (Valeix et al. 2012). At times lions would relocate to further places during times when humans are likely to start being active (Nijhawan 2008). Even though water and other habitat qualities are vital for lions' probabilities to catch prey, lions tend to reduce their habitat use wherever people are closer (Schuette et al. 2013). Pride structure can be another factor determining success of the lions' kills and a lions' movement patterns. Solitary lions have been observed moving closer to villages more often than pride lions since they could successfully hunt for livestock than wild prey (Ngwenya et al. 2013). This could be a relevant reason for this

solitary lions not to spend more energy hunting for wild prey which is relatively hard to kill. Lion movement was found to end-up after a successful kill or unsuccessful when temperature rises (Visser et al. 2009).

This study focuses on two different periods to fully understand the influence of the fence and river-flow on the lion movement patterns and home ranges: 1) Before Fence (BF):- (from year 2000 - 2003) is the period when there was no fence and Boteti river not flowing; 2) River Flowing (RF):- (year 2010 - 2012) this is when the Boteti River was flowing but the conflict fence being porous.

4.1.1 Research Questions

How did the Boteti River flow influence lion movement patterns and home range sizes at different periods, and seasons in the study area?

4.1.2 Hypotheses

1. River-flow resulted in a decrease of lion home range sizes for both wet and dry seasons of the two study periods.
2. River-flow increased distance of lions to the nearest cattlepost.
3. Lions spent most time inside the park during the RF than BF period.
4. Lions daily travel distance was higher during BF period than RF.

4.1.3 General Objective

To assess the influence of Boteti River flow on lion movement patterns and home range sizes at different periods, and seasons in the study area.

4.2.0 Materials and Methods

4.2.1 Study area

This study was conducted along the Boteti River which lies on the western part of MPNP, Botswana (Fig 4.1). The park is located on the north-east (20 – 21°S and 24 – 26°E) side of the country and covers approximately 4900km^2. The Boteti River forms the lower part of the Okavango Delta and receives most of the water from it. Most of the inflow into the Boteti River takes place during dry season (around May - July) depending on the timing of rainfall in the upper Okavango Delta part. However it dried up in the early 1990s (Swatuk & Motsholapheko, 2008) and started flowing again in the mid-2009. It forms a boundary between wildlife which is supposed to be inside the park and farmers together with their livestock which are supposed to be in the communal area. The river has a crucial role in the spatio-temporal distribution of carnivores, herbivores, farmers, livestock and other agriculture related activities. The bulk of the prey, zebra and wildebeest migrate to the eastern side of the park during wet season immediately after rainfall since they could also access water in the area and return back to the river side after the pools which had some water dried up. Among other herbivores in the area are elephant (*Loxodonta africana*), giraffe (*Giraffa camelopardalis*), impala (*Aepyceros melampus*) and steenbok (*Raphicerus campetris*). Carnivores in the area include lion (*Panthera leo*), spotted hyena (*Crocuta crocuta*), brown hyena (*Hyaena brunnea*), leopard (*Panthera pardus*) and black-backed jackal (*Canis mesomelas*).

Majority of the farmers locate themselves closer (within 6km range) in order to have easier access to water from the river. This location helps the farmers to provide water for their livestock, crops and other domestic activities such as construction of the traditional mud houses. Mostly farmers here keep livestock such as cattle, donkeys (*Equus asinus*), goats, sheep (*Ovis aries*) and dogs. Cattle are the ones kept in large numbers since they have a higher value both economically and socially. A traditional form of herding where livestock is being released from the kraals in the mornings and expected to come back in the evenings to be enclosed inside those kraals is mostly preferred by the farmers of the area. This practice end up leading to some of livestock not returning back and ending up being stray. The stray livestock is being exposed to predation by lions and other carnivores which results into human-lion conflict.

Figure 4.1: Map of the study area, MPNP where the collared lions mostly roamed.

4.2.1 Collaring of the study lions

In the previous study conducted by Hemson (2003) twenty-eight lions (7 adult males, 17 adult females, 3 sub-adult males and 1 sub-adult female) were collared during BF period. Eighteen were fitted with very high frequency (VHF) radio-collars and 10 fitted with GPS/VHF collars. The GPS-collars were programmed to take 13 fixes during the night starting from 18:00 to 06:00 and one fix at 09:00 then lastly another at 16:00 (see Hemson 2003). Data from this study was extracted and re-analysed for better comparison of the three study periods with the focus being only on the lions which always lived along the western side of the MPNP since that was the study area.

In this study during RF period, a total of three registered veterinarians were used to collar and remove the collars from the study lions. The drugs which were used to immobilize these lions included medetomidine, ketamine and zoletile/telosol, and atipemazole was used as a reversal drug. Different amounts of the drugs were used depending on the conditions of the particular lion. The lions were collared at different positions on the western side of MPNP. Seven lions were collared (2 males and 5 females) during RF period to monitor their movements. The males were of the same pride and four of the five lionesses were from different prides. Three were fitted with satellite collars, three with GPS/VHF collars and one with VHF collar. Satellite collared lions were always checked for their locations every time where internet could be accessed. The lions GPS locations were then downloaded from the website: http://www.vectronic-aerospace.com. The collars were set to take fixes every 30minutes during the whole night starting from 1500hrs to 0830hrs. A maximum of 36 fixes was therefore supposed to be recorded per night.

Collared lions were tracked using the receiver, co-ax and antenna from a 4x4 Land-Rover for further data collection. Elevated areas were used when tracking to have a wider coverage range of the signal. For the GPS collars, an ultra high frequency (UHF) receiver was used together with co-ax and antenna to download data from them. The downloaded data consisted of geographical coordinates, date, time and optional sensor information. There are two types of radio-tracking; continuous tracking which involves collection of data over a shorter period of time whereas for discontinuous allows one to locate an animal at either discrete or random time intervals throughout the study period. Discontinuous tracking was used for this study since it plays major role in terms of home-range size determination.

A total of eight collared lions were used for the analysis with five and three for BF, and RF period respectively (Table 4.1). Data from all the study lions for both periods were not acquired at exactly the same time-period due to some reasons which include technical problems of some collars which were put together. During BF period, one collar had a longer life-span of 38 months (from January 2000 to February 2003). Other collars on average lasted for about 15.3 months whereas the one with the least life-span lasted for nine months. For the RF period, one collar with longer life-span lasted for 23 months, and 6 months for the one with least life-span. Only data acquired after January 2000 was considered for BF period since that is the timeframe used for other chapters.

Table 4.1: A list of study lions and their detailed description which include sex, collar lifespan and the study period when they were collared. Lions were named as shown in the first column labeled Lion where by during BF period their names were adapted from Hemson's study and for RF period collar numbers were used for their names with an M or F letter at the end to indicate whether it is a male or female.

Lion name	Sex	Collar lifespan	Months	Study period
Chase	Female	May 2001 – December 2002	20	BF
Chun-Li	Female	May 2002 – January 2003	9	BF
Nikita	Female	May 2001 – May 2002	13	BF
Right	Female	January 2000 – February 2003	38	BF
Ugly	Male	May 2001 – April 2002	12	BF
4482F	Female	December 2010 - October 2012	23	RF
10268F	Female	July 2011 – December 2011	6	RF
6638M	Male	November 2011 – March 2013	17	RF

4.3.0 Data analysis

Both males and females' home-range sizes and other calculations were averaged together without treating them separately since males' sample size for the two periods was smaller (one male per each period). Thus data collected from the study lions was used to: calculate their home range sizes, assess their distance relative to the nearest cattlepost, assess their movement patterns inside and outside the park for wet and dry seasons, and calculate lions daily travel distance.

A total of 49197 GPS-points were used to analyse distance of the study lions from the nearest cattlepost. Rainfall data from the Department of Wildlife and National Parks (DWNP) weather stations in the park was used to delineate between wet and dry seasons within periods to enhance precision. ArcGIS 9.3 was used to analyse lion spatial data and provide the following; home-range size calculations for the periods, seasons, different time-periods. Minimum convex polygon (MCP) was performed for lion(s)' home range calculations. It is one of the few methods

used widely and easily comparable between studies (Harris et al. 1990; Hemson 2003). Its disadvantage is that range boundary encompasses all the fixes therefore including occasional fixes beyond the main area of activity. The range area can end up including large areas which are never visited. To correct this error, concave polygons are used even though they are not comparable between studies (Harris et al. 1990). A 50% Kernel Density Estimation (KDE) was performed to find where the animal spent most of the time. Due to lack of consistency in the methods used to calculate home range size (Powell 1994), MCP was also used to enhance better comparison with other studies. All the methods have certain problems which make none of them to be a solution for all situations (Anderson 1982).

Lion spatial data was categorized according to distance from the nearest cattlepost(s) at different time-periods and seasons for the two periods. Distance from the cattlepost(s) was categorized into three groups; 0 – 5km:- Near, 5.1 – 10.0km:- Far and 10.1km – beyond:- Very far. Reasons for the grouping were based on the distance that cattle could possibly travel from their cattlepost and the probability of locating them inside the park.

The lion spatial data was also used to calculate the percentage of GPS points located inside the park and those located outside. This was done in order to help with guidance as to whether the human-lion conflict has a relationship with lions' movement patterns. The movement patterns were calculated for each period per season per time-period.

Lions daily travel distance was calculated using Microsoft-Excel. The same GPS coordinates used to analyse the above parameters (e.g. lion distance to the nearest cattlepost) were used to calculate lions daily travel distance using following equation:

$$Distance = \sqrt{((y_n - y_{n+1})110000)^2 + ((x_n - x_{n+1})110000)^2}$$ Visser (2009)

Where x_n and y_n are the latitude and longitude of the GPS point n (Visser 2009). The time-periods used for the above parameters were still used to calculate the average lion distance at different times of the day, for each season per study period. The distance calculated was in meters.

Statistical Package for Social Sciences (SPSS) 21 was used to find significant differences with some tests such as Analysis of Variance (ANOVA) in the above mentioned parameters and significant association (Chi-Square) between the parameters and study periods, seasons and time-periods. Microsoft-Excel was used to calculate lion daily travel distance for the study periods together with cleaning-up the data for further analyses.

4.4.0 Results

4.4.1 Influence of the river-flow on lion home-range sizes

The GPS data from the collars used for this study aided with the calculations for lion home range sizes, distance to the nearest cattlepost, their position inside or outside the park, and lion daily travel distance. Only two periods were used for the home ranges analysis. Generally, RF period home ranges (844.6 ±26.8km^2) were significantly larger than ones for BF period (560.9 ±50.8km^2) (F_1, $p < 0.001$). There was no significant difference between home ranges sizes for

the two seasons of the two periods (Dry: 1257.09 ±4.77km^2; Wet: 1243.90 ±5.17km^2) (F_1 = 3.52, $p > 0.05$) (Figure 4.2). There was a significant interaction between period and season (F_1 = 822.44, $p < 0.001$). The home range size was larger during dry season than wet season for BF period whereas for RF it was opposite (home range size larger during wet than dry season) (Figure 4.2) hence the interaction.

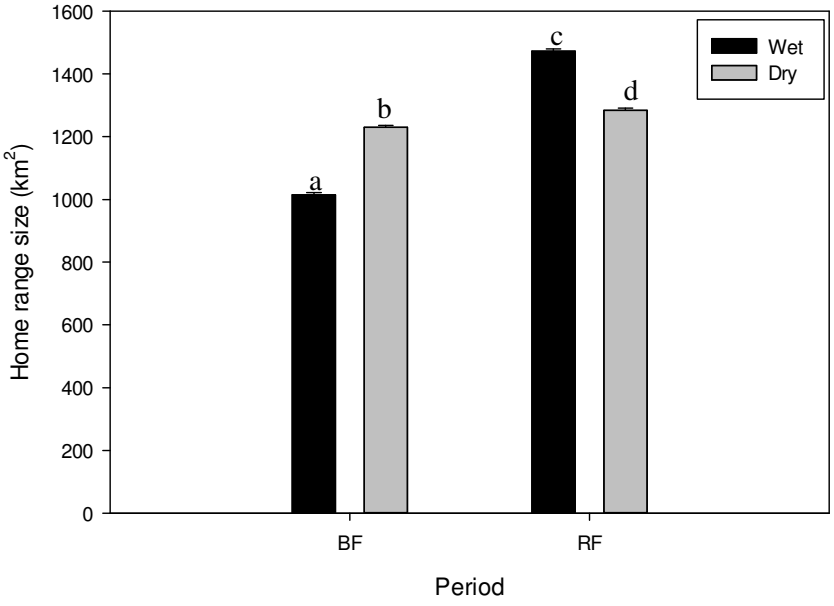


Figure 4.2: Mean lion home range sizes for wet and dry seasons during BF and RF periods. Same letters (e.g. a,a) means that there was no significant difference between the home range sizes whereas different letters (e.g. a,b) imply that there was a significant difference.

4.4.2 Assessment of lion distance to the nearest cattlepost

Lions' distance to the nearest cattlepost was significantly larger during BF period (9.83 ±0.24km) than for RF period (6.86 ±0.31km) (F_1 = 59.15, $p < 0.001$). Cumulatively the distance was significantly larger during dry season (9.15 ±0.27km) than for wet season (7.54 ±0.0.28km) (F_1 = 17.31, $p < 0.001$, Figure 4.3). Interaction between period and season was significant (F_1 = 32.31, $p < 0.001$) (Figure 4.3). Distance to the nearest cattlepost for BF period was larger during

dry season (Dry = 11.73 ±0.30km; Wet = 7.93 ±0.36km) whereas it was larger during wet season for RF period (Wet = 7.15 ±0.42km; Dry = 6.57 ±0.45km) (Figure 4.3).

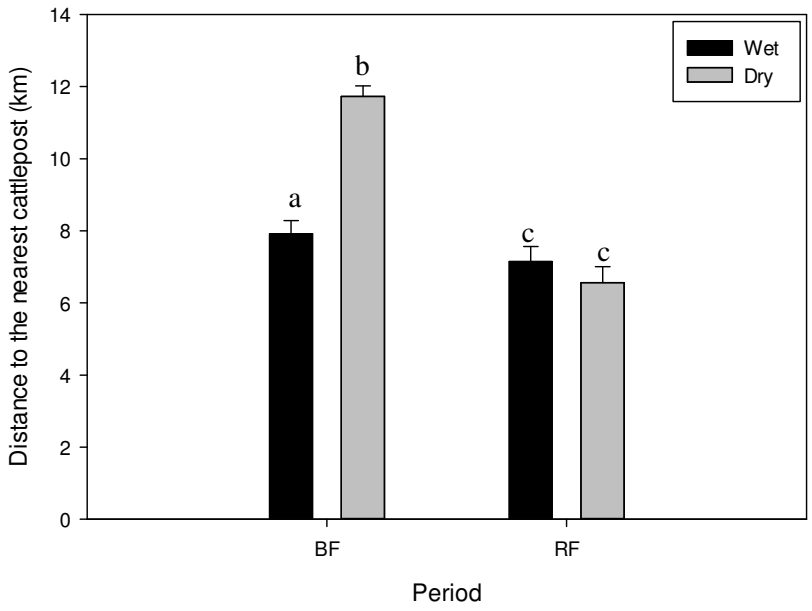


Figure 4.3: Mean distance between the lion and the nearest cattlepost. Lions were always relatively close to the cattleposts for RF period compared to BF. Same letters (e.g. a,a) means that there as no significant difference between the lion distance to the nearest cattlepost whereas different letters (e.g. a,b) means that there was a significant difference.

4.4.3 Spatial distribution of Lions' GPS-points inside and outside the park for wet and dry seasons

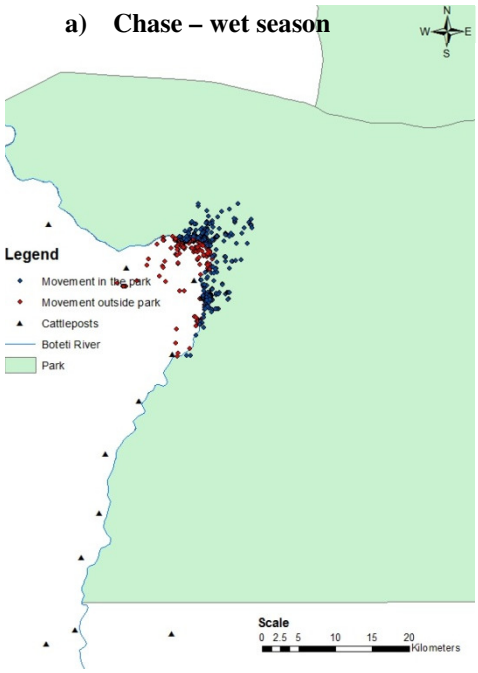
There was a higher proportion of GPS-points inside the park (85.8 ±5.8) than outside the park (13.8 ±5.8) ($F_1 = 75.82$, $p < 0.001$). There was a significant interaction between period and area ($F_1 = 8.06$, $p < 0.05$). The proportion of lion GPS-points located outside the park was very low for RF period whereas it was higher for BF period (Table 4.2; Figure 4.4). Lions were getting outside the park relatively more often for BF period (25.4% points) than RF period (2.3% points) (Table 4.2; Figure 4.4). However there are two exceptions where a female lion spent more than

50% time outside the park during BF period while for RF period, all lions were mostly (>95%) inside the park (Table 4.2; Figure 4.4).

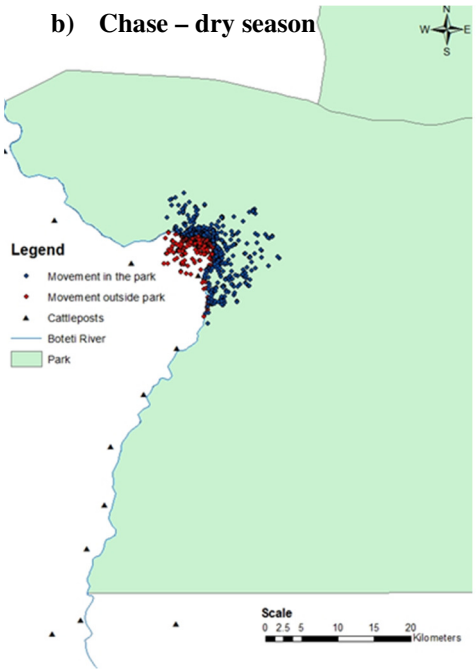
Table 4.2: Lion movement patterns/points for wet and dry seasons for both BF and RF periods, represented as percentages of cumulative points recorded based on location, inside the park vs outside the park. Lions were named as shown in the first column labeled Lion where by during BF period their names were adapted from Hemson's study and for RF period collar numbers were used for their names with an M or F letter at the end to indicate whether it is a male or female.

LION	**Wet season**		**Dry season**	
BF period	Inside the park (%)	Outside park (%)	Inside the park (%)	Outside park (%)
Chase	51.7	48.3	21.1	71.9
Chun-li	98.1	1.9	99.7	0.3
Nikita	92.3	7.7	98.2	1.8
Right	47.8	52.2	62.9	37.1
Ugly	79.5	20.5	87.7	12.3
Average	**73.9±0.103**	**26.1±0.103**	**73.9±0.148**	**24.7±0.135**
RF period				
4482F	98.1	1.9	96.6	3.4
10268F	98.9	1.1	100	0
6638M	95.5	4.5	97.2	2.8
Average	**97.5±0.010**	**2.5±0.010**	**97.9±0.010**	**2.1±0.010**

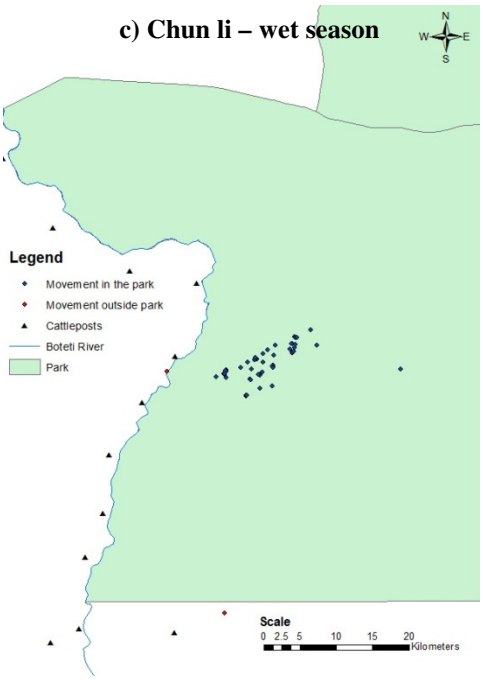
a) Chase – wet season



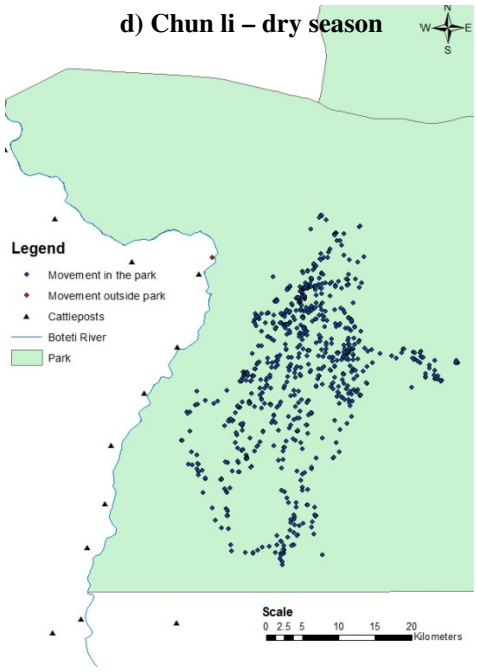
b) Chase – dry season



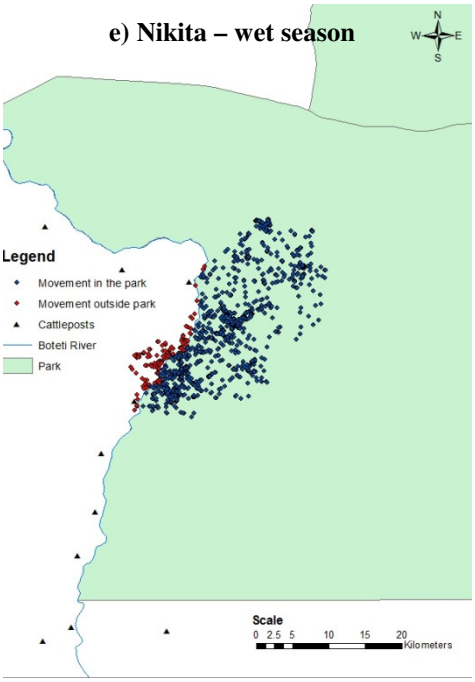
c) Chun li – wet season



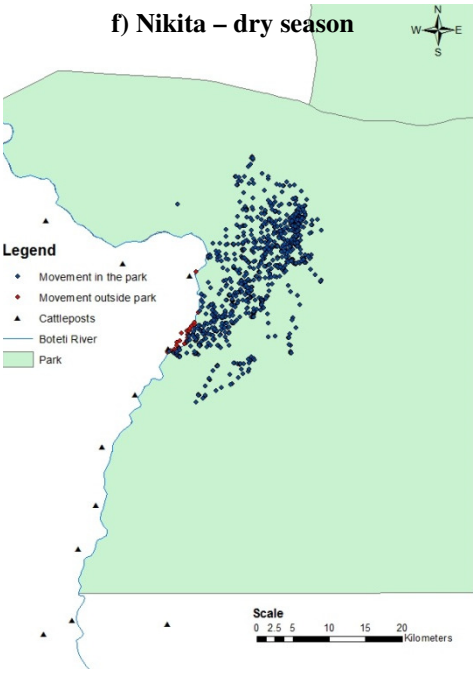
d) Chun li – dry season



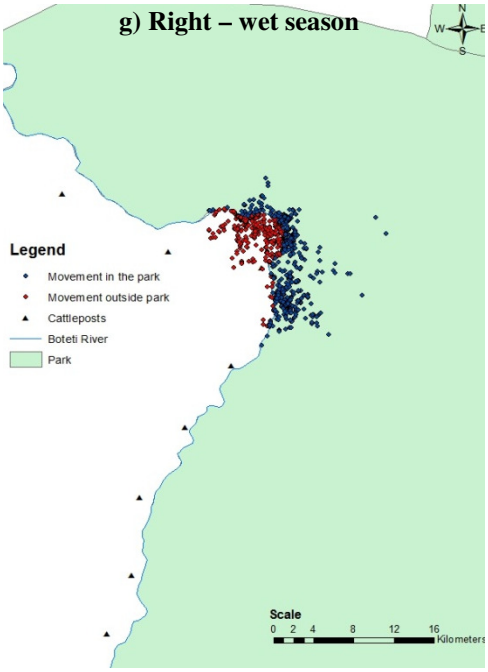
e) Nikita – wet season



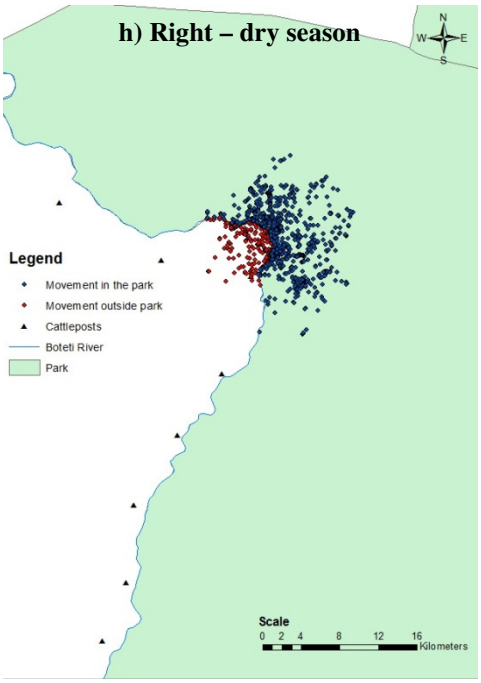
f) Nikita – dry season



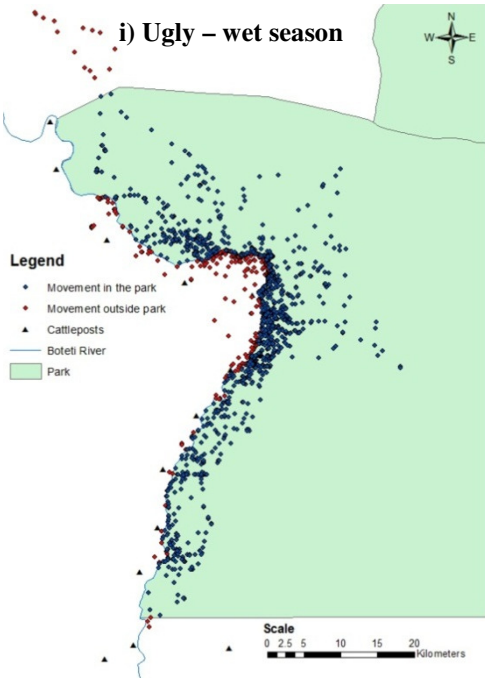
g) Right – wet season



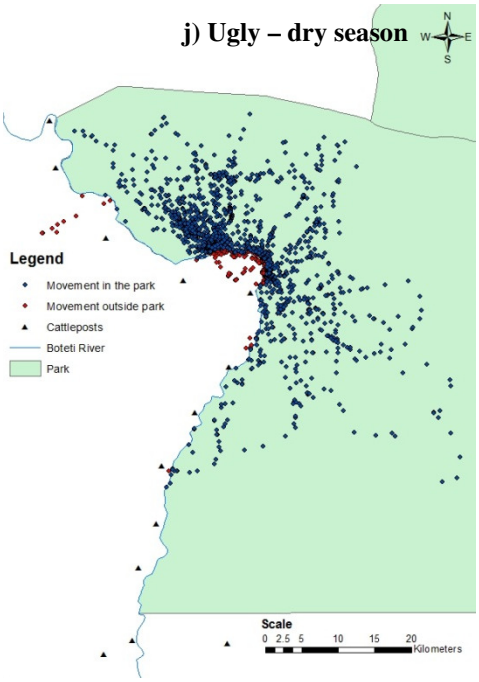
h) Right – dry season

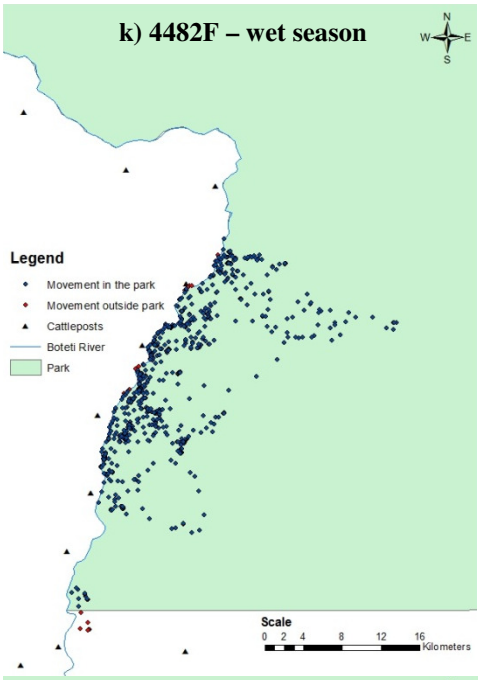


i) Ugly – wet season



j) Ugly – dry season




k) 4482F – wet season
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Movement in the park
Movement outside park
Cattleposts
Boteti River
Park
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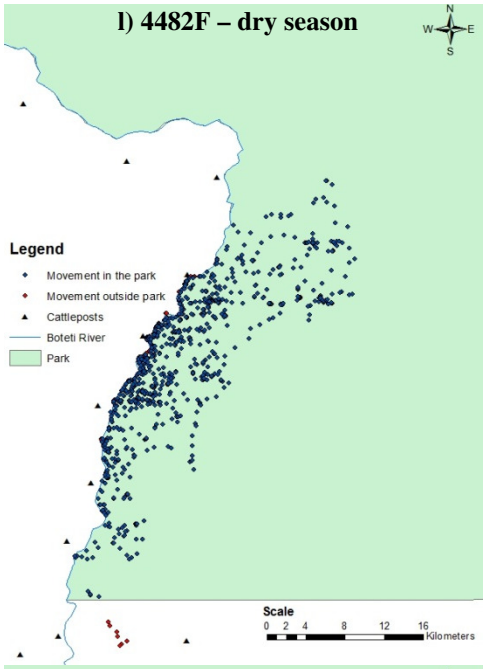
Kilometers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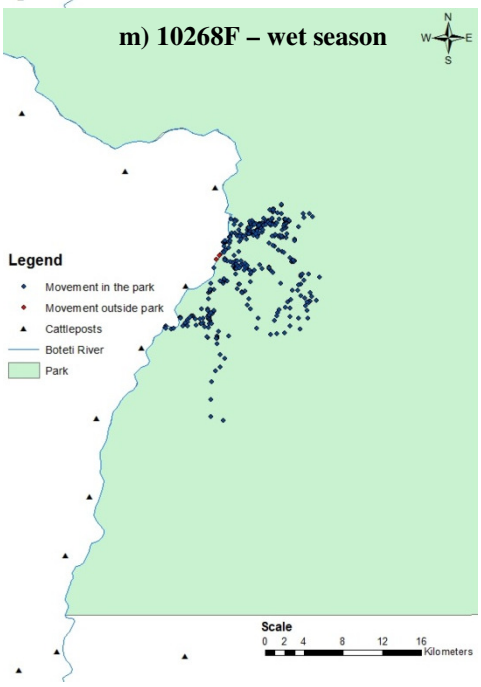
m) 10268F – wet season
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Movement outside park
Cattleposts
Boteti River
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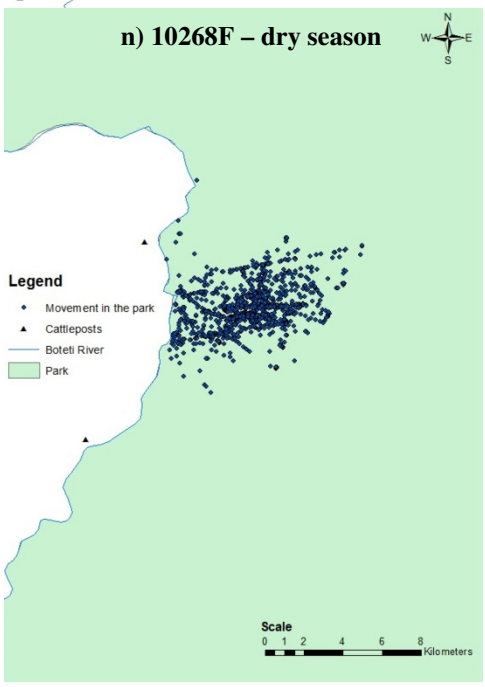
Kilometers


n) 10268F – dry season
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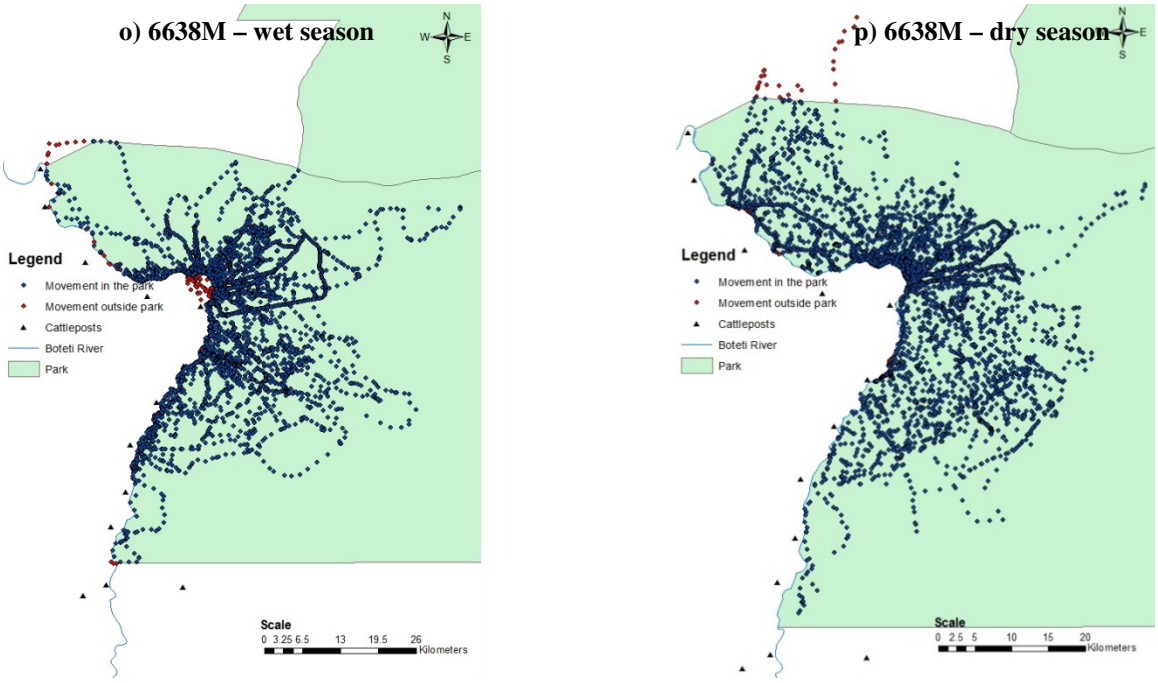

Figure 4.4(a-p): Spatial distribution of the lions' GPS points in- and outside MPNP during wet and dry season.

4.4.4 Lions daily travel distance

Daily travel distance for lions during BF period (1947.07 ±285.9m) were significantly larger than those for RF period (939.18 ±341.7m) ($F_1 = 5.12$, $p < 0.05$). However, there was no significant difference for daily travel distance between the seasons ($F_1 = 0.38$, $p > 0.05$) (Figure 4.5). The interaction between period and season was not significant ($F_2 = 0.37$, $p > 0.05$) (Figure 4.5). Daily travelled distance was not significantly different between the two seasons of the same period (BF-Dry = 1673.79m ±404.35m, BF-Wet = 2220.36 ±404.35m; RF-Dry = 937.83 ±483.29m, RF-Wet = 940.53 ±483.29m) (Figure 4.5).

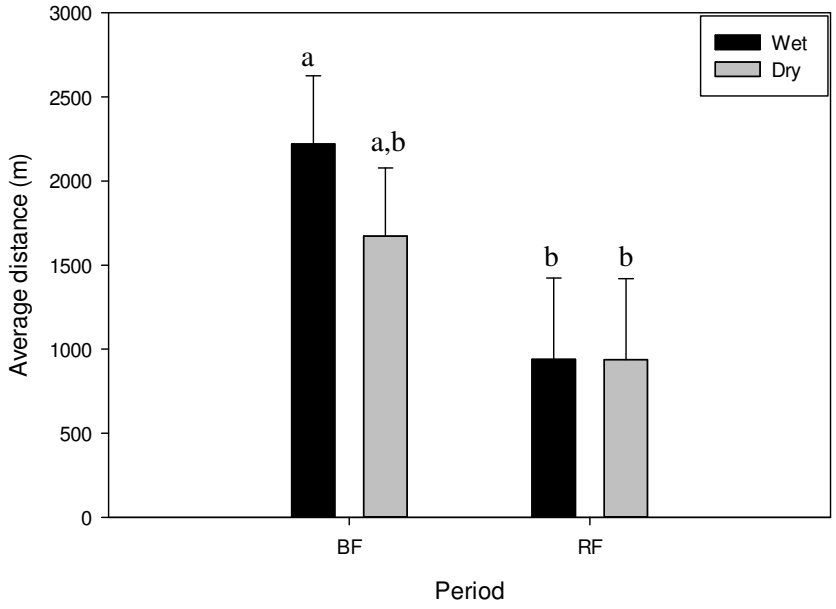

Figure 4.5: Lions' daily travel distance for BF, and RF period per season. Same letters (e.g. a,a) means that there was no significant difference between the lion daily travel distance whereas different letters (e.g. a,b) means that there was a significant difference.

4.5.0 Discussion

4.5.1 Influence of River-flow on lions' home range sizes

Home range sizes for this study were within the range found by other studies (e.g. Schaller 1972; Stander 2006). The larger home range sizes during RF than BF period (Figure 4.2) might be influenced by the flowing of Boteti River. During BF period wild and domestic prey species congregated at fewer water-points as compared to when the river was flowing, where there were relatively more water-points for the prey to access. To increase chances of prey catchability lions therefore had to travel and/or chase the prey during RF period unlike during BF where lions might have waited at fewer places where prey drank. Lions might had waited and predated on livestock in the cattleposts closer to the artificial water-points during BF period therefore causing

conflict when they did not successfully kill wild prey. Additionally, lions must travelled longer distance searching for wild prey along the river during RF period and switched to predating on livestock when it was hard to have a wild prey kill. The above reasons might have contributed to the high conflict levels for both BF and RF period. Home ranges sometimes shift in spatial coverage to allow better access to prey. For example, the Makgadikgadi lions, especially those termed as resident changed their home ranges over space and time to increase chances of encounter with prey (Valeix et al. 2012). Thus during wet season the lions moved to areas where they could encounter livestock (during lower wild prey abundance period) whereas for dry season lion movement might be due to increasing chances of encountering wild prey. The home range sizes were not significantly different between the seasons of the two periods (Figure 4.2). Due to the wild prey abundance changes in lions' home range sizes could have not changed but shifted spatially for the reason mentioned earlier. Despite of the limitations such as the smaller sample size of the lions based on their sex other factors such as the males' home ranges and movement patterns varying with those of the females were known. For example the denning female lions normally occupy smallest home range and other studies (e.g. Paul et al. 2003) showed that they spend more of their time with their cubs.

4.5.2 Assessment of lion distance to the nearest cattlepost

Lion distance to the nearest cattlepost was larger during BF period than RF (Figure 4.3) since some of the water points were accessible outside the park therefore forcing lions to get out to the cattlepost side. Previous studies (e.g. Redfern et al. 2005) showed that prey abundance is influenced by water distribution. Cumulatively the distance was larger during dry season than wet season (Figure 4.3). The migratory species, zebra and wildebeest which form a large

proportion of the lion wild prey migrate to the east of the park during wet season which therefore result into the resident lions moving closer to the river and/or outside the park to access livestock prey species. When comparing seasons across the two periods, distance to the nearest cattlepost was larger during dry season than wet season for BF period and vice versa for RF period hence the significant interaction between period and season (Figure 4.3). Similar reason mentioned above should have influenced this pattern whereby lions distance to the nearest cattlepost was larger during dry season for BF period since these study lions had to increase access probabilities to the highly abundant livestock prey species by relocating closer to cattleposts. However the trend had changed for RF period seasons. Here lions needed to balance their wild prey catchability with the domestic prey since the wild prey could have been relatively hard to find and successfully make a kill since their drinking points increased. In cases when lions did not successfully kill wild prey they would have to sacrifice and make an easy kill of the domestic prey.

4.5.3 Lions' movement patterns inside and outside the park

The higher proportion of the lion GPS-points which was located inside the park (Table 4.2; Figure 4.4) could be influenced by the fact that safety chances are higher in this area. Lions could have experienced some injuries and/or their pride members being killed by farmers outside the park and had a learned behavior concerning the risks associated with their movement outside the park. Lions highly prefer wild prey over the domestic which majority of their preferred prey (wild) is mostly located inside the park (Woodroffe et al. 2005). Lions could also successfully make livestock kills inside the park since livestock was also found in the area in case of an unsuccessful wild prey kill. Lions went outside the park more often for BF period than during RF

period (Table 4.2; Figure 4.4). During RF period there was a Makgadikgadi fence which was partially permeable but wherever possible it could act as a barrier. For BF period lions' movement was not deterred by any barrier hence accounting for the higher chances of their movement to outside the park. Generally lion populations are expected to be restricted to the protected areas because of conservation status of those areas. However due to lions' larger area requirement, most of the PAs are failing to accommodate lion spatial requirement leading to lions being exposed to the outside of their protection zone where they cause conflict with the pastoralists.

4.5.4 Lions daily travel distance

The significantly larger daily travel distance for BF period than RF period (Figure 4.5) could be due to as a result of relatively fewer prey abundance during BF therefore some successful kills being made after travelling and chasing. River flow might have increased prey abundance and distribution hence increasing chances of lions encountering prey. Also if some of the lions already occupied the fewer water-points during BF period then others would have to travel larger distances to find prey and make a kill. There was no significant difference for daily travel distance between the seasons (Figure 4.5). This could be due to the fact that during dry season lions have relatively high wild prey abundance which they prefer than livestock and therefore they spend more time chasing them for food since they are faster and vigilant than livestock. Furthermore, wild prey is relatively hard to successfully make a kill which is a reason as to why lions would travel larger distance (Visser et al. 2009). During wet season these lions take more time trying to locate livestock which is relatively less abundant in the park hence also ending up covering up larger distances. The same reason applies to the situations whereby there was no

significant interaction between period and season (Figure 4.5). Prey species vigilance tend to be positively correlated with the predator species sizes (Kluever et al. 2009) because of the potential that larger predators have in successfully attacking them (prey). As lions are the largest predator species in the study area all the prey species might have been more vigilant to their stimuli and avoiding such areas for safety. This could possibly lead to lions covering larger distance in order to locate such prey.

4.6.0 Summary

This chapter can be concluded as follows:

The larger home ranges for RF period than BF, and the larger daily travel for BF than RF implies that lions were covering larger distances but within a relatively compressed spatial coverage during BF than RF. This also supports the reason why lions' distance to the nearest cattlepost was larger for RF than BF. As stated lions covered larger distances in search of food during RF since the river flow resulted into many access points to water by prey than during BF. This might have resulted into higher conflict level due to the increased chances of direct contact between lions and livestock. Again during BF the conflict was also higher possibly due to lions waiting for livestock at places closer to the fewer water points. However it is unfortunate as the study did not have lion spatial data for AF period but the current data could be a prove to why the conflict was high for the two periods, BF and RF period. The larger lion distance to the nearest cattlepost during RF than BF is confirmed by the fact that lions moved outside the park more often for BF than RF.

4.7.0 Link to the next chapter

Lion home ranges and movement patterns can influence the way human lion conflict occurs. Concentration of lions in relatively few areas can lead to other weaker prides or individuals to switch to livestock prey hence the conflict increasing. It is necessary to integrate all the parameters in order to make informed decisions on how the human lion conflict can be reduced or eliminated. The following chapter will merge all the parameters discussed above (chapter 2, 3 and 4) and their inter-relationships will be discussed on how they can influence the conflict between lion livestock.

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Chapter Five: Conclusion and Recommendations

5.0 Synthesis

Human Wildlife Conflict has well been studied across the globe but there is still more that needs to be covered in order to understand the dynamics of this conflict. Many studies done so far focused on understanding the pure scientific ecology of the problem animal species rather than collectively studying all the important socio-ecological parameters to understand their inter-relationships. However a study by Kolowski & Holekamp (2006) was a bit inclusive as it covered spatio-temporal and physical characteristics of livestock depredations by large carnivores but did not address the social component of the conflict. Dar et al. (2009) studied the patterns and perceptions of human-carnivore conflict but their study was limited as it did not cover the ecological component. This study deduced information on both the actual and perceived conflict issues, and was guided by the following:

- Temporal distribution of the conflict incidents along the Boteti River during the following periods: i) Before Fence (BF):- the period when there was no fence and Boteti River not flowing; After Fence (AF):- the period when the fence was intact but the river not flowing; and River Flowing (RF):- the period when the Boteti River was flowing but the fence having some openings.
- The influence of lion (*Panthera leo*), and prey abundance on livestock predation during BF, AF, and RF period in the MPNP.
- The influence of Boteti River flow on lion movement patterns and home range sizes at different periods, and seasons in the study area.

In Chapter 1, background information on the origin and dynamics of human-lion conflict were synthesized. Historically Africans have been agriculturalists, depending on rearing livestock and/or cultivating crops. The activities were done based on natural resources such as water availability which was mostly from rainfall. This led to some farmers positioning themselves closer to naturally permanent or seasonal water sources where they shared this water with wildlife. This interaction resulted into human wildlife conflict and killing of wildlife. A need to reduce/eliminate the conflict outcomes arose for the benefit of the wildlife and farmers. Strategies such as erection of fences had to be implemented.

Chapter 2 summarized the human-lion conflict by firstly comparing it in relation to other conflicts caused by the available carnivore species. The study supported the findings from Monametsi (2008) research where lion had higher kill incidents than other carnivores. Lions have an advantage of scavenging a larger percentage of their food from other carnivores and some of the prey which might have died from diseases, starvation, injuries among others (Kruuk & Turner 1967). In addition, lions' population increase, and hyena population decrease (Table 3.3) also favored the lions therefore increasing their fighting power and position to outcompete hyenas (Watts & Holekamp 2008). Chapter 2 further focused on partitioning of the human-lion conflict (actual and perceived) into three study periods (BF, AF, and RF period, See chapter one). The results revealed that lion predation was lower during AF period than BF, and RF. Additionally the predation rates differed between two seasons. Lion predated more on large livestock. However, prey selection by predators could be a result of other competitors over such food and not always relating to predator-prey body size (Radloff & Du Toit 2004). Majority of the farmers stated that the conflict was less after erection of electric-fence, and immediately after river flow. However these results could have been inconclusive without chapter 3 and 4 which

supported the different conflict levels experienced depending on factors such as; study period and season.

The other two chapters which followed; Chapter 3 and 4 addressed some possible factors which might be leading to the conflict level of specific study period; BF, AF, and RF. In chapter 3, I showed the changes in lion prey, and predators' populations at different spatial patterns; in- and outside the park. Human-lion conflict was higher during BF, and RF period than AF (Chapter 2) even though prey abundance, wild and domestic did not change significantly for these periods (Chapter 3). Lions are regarded to be opportunist stalk-and-ambush hunters which select areas of easier prey-catchability over the ones with higher prey densities (Hopcraft et al. 2005). Lion distance to the nearest cattlepost was larger during RF than BF period (Figure 4.5). These lions could wait for their prey at the water-pools (see Figure 1.3) since water was a crucial and limited resource during BF period hence automatically those lions were nearer to the cattleposts.

Most of the lion-kills especially the water-dependent prey such as wildebeest (*Connochaetes taurinus*) are concentrated nearer to the water points (e.g. ponds, river) like in Klaserie Private Nature Reserve in South Africa (de Boer et al. 2010). Waiting for wild prey at the water points provide another opportunity for lions to predate on livestock which is regarded as an easy prey if those lions' hunting process was not successful for wild prey. The strategy might have saved these lions some extra energy that could have been spent searching for food. The advantage of the strategy can be supported by the fact that livestock was avoided during RF period (Figure 3.6 and 3.7) even though the conflict was high (Figure 2.2). This can be due to the increase in wild preferred prey species, zebra (*Equus quagga*) and wildebeest (Chapter 3) which might have increased lions' chances of prey catchability by getting concentrated at the water-points during times when they drink. Water-

points, and vegetation cover play an important role for encountering prey (Hopcraft et al. 2005) and improving chances for prey catchability. The hunting strategy used by lions support a critical choice for places which possess some vital resources which can force prey to forgo their safety in-order to access such resources. Human-lion conflict was higher during the wet season than in the dry season for both BF, and RF period (Figure 2.2). This can be attributed to lion distance to the nearest cattlepost which was larger during dry season than wet season (Figure 4.3). The movement pattern increase chances for lions to encounter and kill livestock during wet season since most of wild prey, zebra and wildebeest which are the bulk of wild prey preferred by lions (Hayward & Kerley 2005) would have migrated to the east of MPNP. Similarly in Waza National Park in Cameroon, the two study lions which left the park during wet season caused conflict with nearby farmers (Bauer & de Iongh 2005).

Lion movement patterns are usually done in response to prey distribution and abundance (Macdonald 1983). BF, and RF period both had higher conflict level even though lions spent relatively more time outside the park during BF than RF period. Carnivore abundance and distribution in a multi-use landscape is governed by factors such as ecological carrying capacity, and social carrying capacity (Woodroffe et al. 2005).

Lions mostly killed large livestock (Figure 2.3). This is proved by their smaller niche breadth which implied that they specialized on those large livestock (Figure 3.4). Lions prefer prey with a weight range of 190-550kg which can be killed with possible minimum or no risks (Hayward & Kerley 2005) with maximum energy gains and minimum expenditure which is why warthogs (*Phacochoerus africanus*) are mostly being killed due to their lower vigilance, and being slow (Scheel 1993). Furthermore Chapter 3 revealed that wild preferred prey density increased both in- and outside the park but still the conflict being higher during RF period which might have

been due to limited access to lions since they are not safer outside the park. Lions' safety outside the park can also be proved by the more time they spent inside the park (Chapter 4). In chapter 4, I showed that lions were far from the nearest cattlepost during RF period even though the conflict was still higher (Chapter 2). This might be due to the available wild preferred prey, which was more abundant (Chapter 3) and acting as a pull factor to the lions.

5.1 Conclusion

Human-lion conflict can be influenced by different factors at different spatio-temporal scales. Abundance and accessibility of the lions' wild preferred prey in relation to livestock can influence human lion conflict level. Lions' wild preferred prey abundance which keeps on changing due to factors such as water availability (termed as wet, and dry season) can influence the conflict level. Prey accessibility can be governed by barriers such as electric-fence. Domestic prey can always be available but not being accessible to lions therefore leading to lower human lion conflict level. Other influencing factors include lion movement patterns. Further research should consider sampling enough number of lions to allow comparison of factors depending on lion sex. And lastly, larger home range sizes can be accompanied by some costs which include more time and energy required to travel, possibly increasing chances of encountering with competitors (Grant et al. 1992). Alternatively, smaller home range sizes can be experienced to fulfill other requirements which include taking care of the young cubs (Visser et al. 2009; Snyman 2010).

The study will play an important role in terms of advancing scientific knowledge about how lions could behave in response to the two factors, fence and the river together with the fluctuating wild prey abundance which are influenced by wet and dry seasons. These factors mentioned above are also expected to alert the farmers about the human-lion conflict and may be act as an early warning system to them hence this could help them improve their livestock husbandry depending on the expectations during wet and dry season.

5.2 Management implications and recommendations

Spatio-temporal distribution of forage, and water can affect prey in many ways; herbivore populations are maintained by forage amounts especially during the critical periods such as dry season (Illius & O'Connor 2000); the abundance of prey grazing over a certain area usually influences the level in which such area would be degraded especially during the dry season (Yoganand & Owen-smith 2014) which can impact on its carrying capacity. The latter also affect predators such that they will be affected by prey abundance, distribution, and mostly accessibility. Knowledge of wild prey population is therefore vital in suggesting effective mitigation strategies for addressing the persisting human-lion conflict. As a way of keeping the balance in prey abundance and distribution water should always be availed at all cost along the Boteti river area even when the river is dry to attract wild prey. To increase wild prey abundance even within the park, water should also be provided in some areas inside the park so that such wild prey could attract some lions therefore diverting their attention to only concentrate along the river. This is so because the river is closer to the cattleposts and as such lions will be more exposed to livestock and tempted to cross out of the park where they could be killed by farmers. However, there are other negative impacts accompanied by this water provision such as the

piosphere since more animals will be attracted towards fewer places. In addition, this might lead to other lion prides which are far from the water-points running short of food hence they might be outcompeted by the ones closer to such areas. This is likely to result into such outcompeted lions to switching to killing livestock outside the park. A majority of the large mammalian carnivores prioritise wild prey over the domestic (Woodroffe et al. 2004). Improving wild prey availability in the area might help to lower the conflict. It is vital to maintain a proper functional balance between predator-prey populations. This applies to both wild prey, and domestic one since a fewer number of wild prey could lead to lions switching to domestic prey. More domestic prey could lead to degraded land especially at cattlepost side and then find ways to get into the park where they could be predated; more lions could result into some being pushed outside the park and continue causing the conflict. Additionally, the erection of an electric-fence could be one of the best possible ways to mitigate the conflict due to the reasons that follow; it would keep away the domestic prey especially cattle (*Bos taurus*) which are more abundant hence could intensify competition over forage with wild prey species, zebra and wildebeests which form the bulk of lions' preferred species in the area (Chapter 3). Lesser/no access into the park by domestic prey could lead to lesser degradation of some areas and improve both forage quality and quantity which could also reduce the distance travelled by wild prey, zebra and wildebeests. Increasing wild prey abundance would therefore increase lions' food which might lead to decreased livestock predation; re-involvement of the necessary stakeholders such as farmers would also be crucial in achieving the best possible mitigation measure (Chapter 2). Dickman (2010) revealed that social factors are mostly not considered when dealing with human wildlife conflict (HWC) even though they are crucial. The Makgadikgadi fence caused death of some lion wild prey species such as zebra, adults and juveniles since they were blocked from accessing

water through their normal routes (Hazelhurst & Vander Kolk 2006). Fence alignment should therefore consider other important factors such as; resources distribution for satisfaction of all the parties involved, other animal species in the area which might destroy it frequently to access the limited resources hence creating a way out for lions. Fence should be checked regularly for its maintenance.

Community Based Natural Resource Management (CBNRM)'s importance to the neighboring farmers should be emphasized. This could lead the community to have a sense of ownership to the resources such as wildlife and try to protect it. Lastly, farmers should be encouraged to practice better livestock husbandry to improve safety of their livestock (Mankgatau, pers. comm). This can be attained by kraaling them at night since lions are more active during such times. Farmers should aim to keep their livestock within the recommended carrying capacity to prevent overgrazing. Consistent research is needed to keep the authorities informed about the before and after effects of the implemented mitigation strategies.

5.3 Limitations of the study

The study relied on Problem Animal Control (PAC) data collected from the Department of Wildlife and National Parks (DWNP) for lion, and other carnivores' kill incidents (Chapter 2). This can lead to an overestimation of large carnivore population and lion kill incidents since they can scavenge some kills from other smaller carnivores which can therefore lead to mistaking of the original carnivore which made a kill. Additionally, smaller prey can wholly be consumed quickly and therefore leading to its under-representation during lion kills recordings (Radloff & Du Toit 2004). I initially planned to collect lion scat samples which could cater for both wild,

and domestic prey especially smaller prey to facilitate some analyses such as lions' niche breadth, and prey preference. The lion scat sampling could not be done due to budget constraints. Still this was not going solve the problem since lions could also scavenge kills from other carnivores.

Research should be an on-going process in order to allow consistent flow of information. This can lead to better decision making by the relevant authorities hence policy making could also be informed. The study suffered from some insufficient data such as; calling station data for AF period (Chapter 4). Chapter 4 was therefore not completed according to the initial plans of the project even though I compensated the problem through lion population estimate at carrying capacity which also is not a true reflection of the available carnivores at that particular period. Other methods (e.g. spoor count) for lion and other carnivores' population estimation should be considered to minimize the risk of under-estimation of those populations as carnivores might get used to the calling station equipment when frequently conducted. In addition, other alternative methods could offer opportunity of including other carnivores such as leopards and black-backed jackal among others instead of being limited to lion and hyena which broadens the data-base for future studies.

Some of the collars stopped working during the study period. This ended up elongating the data collection period for the study since the GPS coordinates were very crucial for activities such as; lions' home range size calculation, lion distance to the nearest cattlepost, spatial distribution of lions' GPS-points in- and outside the park, lions' daily travel distance (Chapter 4). Failure of some collars led to smaller sample size of the study lions (one male and two females) during RF period. This contributed to the lack of calculations of lion movement patterns over different study periods, and seasons based on their gender. Research showed that male lions utilize their

space differently from their female counterparts. Female lions showed higher preference for the areas closer to water (Lehmann et al. 2008) since this could increase chances of success to capture prey. Males are regarded to possess larger home ranges in-order to increase mating opportunities and defend their territories while females' home range sizes are smaller and driven by factors such as prey abundance and pride size (Macdonald 1983; Loveridge et al. 2009). Furthermore male lions are mostly stock-raiders as compared to the females (Bauer & de Iongh 2005).

5.4 Future work

This study mainly focused on the Boteti River area for some reasons which include; the area being regarded as a conflict hotspot (McCulloch 2010); the uniqueness of the area allowed examination of the conflict level after two major factors which are the electric-fence and the river flowing, and inter-relationships between prey and predators in both wet and dry seasons. However there are still some of the key research questions which need to be looked into as part of future research. They include:

- What are the livestock predation rates for the residential lions (ones permanently living in the Boteti River side, and ones in the Makgadikgadi pans side), and migratory ones in the MPNP?
- How does the human perception and attitude over the persisting human-lion conflict differ depending on their different occupations (those working at the tourism related sectors, and those who spend most of their time (>50%) at the cattlepost, and ones who spend more time (>50%) at the villages) around MPNP?

- How does the habitat type influence the success rate of livestock predation compared to wild prey kills in and around MPNP?
- What is the lions' niche breadth over both wild, and domestic prey in the MPNP?
- What is the lions' prey preference for both wild, and domestic prey in the MPNP?
- How does lion's gender influence its movement patterns for both in- and outside MPNP?

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Appendices

Appendix One: Farmers' Questionnaire

Background Information

DATE_____ PLACE_____ C/P NAME_____

GPS POINTS_____and _____ Person interviewed name:_____
Occupation at c.p:_____

1. Who is the owner of this cattle post?
   MALE=1 FEMALE=2

2. How many years have you been here?

0-2	3-4-	4-6	7-8	8>

3. Do you own livestock? YES=1 NO=2

4. How many Livestock are based at the cattlepost?

	1-50	51-100	101-150	151-200	201>
Cattle					
Donkeys					
Horses					
Goats					
Sheep					

5. Are you happy being near the national park? 1=YES, 2=NO, 3=DON'T KNW WHY?

1	Like being near the river	2	Predators kill livestock and endanger ppl
3	Better grazing in park and problem of cows going there	4	Get water from there
5	Cannot get the cattle if they go in the n.p.	6	Proud of the wildlife
7	Too many animals	8	Cattle can be infected by diseases by wild animals
9	Better grazing inside the park	10	Don't have anywhere else to go
11	Takes up too much land	12	No compensation if cattle killed in the park
13	Limited grazing area	14	Not allowed to kill predators
15	Limits me	16	Jacks complain
17	Too close	18	Likes animals
19	It is interesting and beautiful	20	Tourism
21	Wild animals do not come to my cattlepost	22	Competition btwn wild grazers
23	It is my home	24	I can get a job there
25	No jobs	26	Others

6. a)How much livestock do you sell annually?
   b)Where?

   c)How much money do you get a year in Pula?
   d)How much livestock do you lose from;

1	Theft =	2	Diseases =	3	Predation =
4	Others				

Conflict Level

7. a) Do you ever see lions? 1=YES, 2=NO, 3=DONT KNW
   b)Where?

1	Near cattlepost	2	Inside national park
3	On the tar road	4	Near safari camp
5	Dead at the kgotla	6	Others

   c)What did lions do when they saw you?

1	Ran away	2	They hide
3	Nothing	4	They wanted to kill us
5	They were killing/eating livestock	6	Others

8. a)Have you lost livestock to lions in the last 2 years?
   b)How were they herded? (method used to go and fetch cattle)

9. a)How many lions do you think are there in the Makgadikgadi Pans National Park?
   b)How many lions do you think are there near your cattlepost?
   c)Are they always there?

10. a) Has the **fence** influenced the Human-Lion conflict:
    YES=1 NO=2 DONT KNW=3
    b) What were conditions like **before** the fence and **immediately after** its erection then **now**?

	Better				Worse
Before	1	2	3	4	5
After					
Now					

11. a) Did the **flowing of the Boteti river** influence the conflict?
    YES=1 NO=2 DONT KNW=3
    b) What were conditions like **before** and **immediately after** the flowing of the river then **now**?

	Better				Worse
Before	1	2	3	4	5
After					
Now					

Management and Interventions to Prevent Livestock-loss

12. How do you take care of your livestock?

13. Who herds this livestock?

1	Headperson	2	Owner
3	Herdboy	4	Relative of headperson
5	Employee	6	Headperson and relative thereof
7	Friends	8	Others

14. The way you fetch your animals, is it different in the dry season and in the wet season? 1=Yes 2=No 3=Don't know
    If yes HOW?

1	In the rainy season, they are herded to avoid crops	2	Dry season, cattle are not collected to graze during the night
3	Herds them closer if he hears lions	4	Leave in bush when there is more grass
5	Only fetched in during the wet season	6	Herds in dry season
7	Only fetched in dry season	8	Others

15. a)What proportion of livestock are herded at night?

b)How are they herded?

1	Free range in day and collected at night	2	Tended during day and collected at night
3	Free range at night and come back in evening	4	Others

16. Do you herd them away from national park?

1	YES	2	NO	3	DON'T KNW

17. Would you like to improve the way your animals are looked after?

1	We have no money for that	2	Herd livestock away from the n.p
3	Hire more ppl for herding	4	Others

Mitigation Measures after Livestock-loss and Farmers Assessment

18. a)Where do you report livestock loss?

1	Wildlife office	2	Police
3	Kgotla	4	Others

b)How quickly do the DWNP arrive?

19. a)How often do the DWNP/PAC come (visit/month)?

b)What do the PAC do?

1	Keeping lions inside the park	2	Tell them that their cattle are outside kraal
3	Patrol using searching light/chase lions	4	Deal with them after the predators have killed
5	Just pass through	6	Report dead cattle to their owners
7	Take care of wild animals	8	Investigate how predators live
9	Put collars on lions so they can kill cattle	10	Attend kgotla meetings
11	Stay at the DWNP camp	12	Wake you up at night to tell you if your cattle are out at night

c)Are they good at their job?

20. a) Are you happy with the compensation scheme? YES=1 NO=2 DONT KNOW=3

b) How long does compensation take? (months)

c) If NO how could the compensation be improved?

1	More money	2	Faster
3	Give cattle as compensation	4	Provide fences for cattle
5	Put DWNP office closer	6	It is fine
7	Others		

Management Measures before and after Livestock-Loss

21. a)Who is responsible for livestock predation?

1	Owners	2	Wildlife dept
3	Govt	4	No-one
5	Inside park = owner, outside = govt	6	Inside park = govt, outside = owner
7	Headman	8	Herdboy
9	Lions	10	Lion-researchers
11	Safari-camps	12	Others

b)Why?

1	They deal with/protect wildlife
2	They are the ones that deal with the problem animals
3	Because govt needs to make fence
4	New law makes them responsible as they stopped us from killing lions

5	Predators keep on killng
6	Predators kill outside the park sometimes
7	Do not have any power over predators
8	The owner is one in charge of cattle
9	No one takes responsibility of predation
10	They are failing to keep lions under control
11	They own them
12	DWNP delivers lions with helicopters
13	Ask Jesus
14	They are not doing anything
15	They eat meat
16	Others

22. What do you think the **GOVT** could do to reduce livestock predation?

1	Fence	2	Allow them to kill lions
3	Fence with electric fence	4	Reduce number of predators
5	Herd lions away frm the cattleposts	6	Kill the predators
7	Move park away frm ppl	8	Nothing
9	Provide better kraals	10	Provide means to pump water to the kraal
11	Provide feed for cattle	12	Force ppl to provide water water inside kraal and herd cattle at night
13	Govt is in charge	14	Increase compensation
15	Relocate lions to another park or zoo	16	Move people away from park
17	Kraal lions	18	Others

23. What do you think **YOU** could do to stop livestock predation?

1	Improve kraal	2	Nothing else
3	Always herd cattle into kraal	4	Tell govt to make fence
5	Kill predators	6	Herd cattle all day
7	Buy a cattlepost protected by above	8	Hire a herdboy
9	Feed cattle in kraal	10	Look after/protect cattle better
11	Complain to govt/report to PAC	12	Chase lions away
13	Help patrol fence	14	Move away
15	Make money from lions	16	Others

24. a)Do you like living with lions? YES=1 NO=2 DONT KNOW=3
b)WHY?

1	They kill our livestock		2	Born and grew up with them	
3	Can kill people		4	We've accepted them	
5	They are like witches		6	Good for tourism	
7	Others				

25. a)Have you killed any lions? 1=YES, 2=NO, 3=DONT KNW
b)Do you try? 1=YES, 2=NO, 3=DONT KNW
c)If YES How?

1	Using a gun	2	Trapped and shot	3	Poisoning	4	Others

General Open Questions

c)Do you have anything positive to say about lions? 1=YES, 2=NO, 3=DONT KNW
d)What is it?

1	Tourism avenue	2	Likes to see
3	Others		

e) Do you consider them a valuable tourist resource?

26. Do you think that Botswana benefits from tourism?

27. Why do you think Botswana benefits from tourism?

28. Do you gain any financial benefit from tourism/wildlife?

29. Do you think that money from tourism in your area gets put back into your local community?

30. What is the level your education?

1	Never attempted to go to school		2	Primary	
3	Secondary		4	Senior school	
5	Tertiary		6	Others	

31. Any other additional information…

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