A Lion Population under Threat

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A Lion Population under Threat

Understanding lion (*Panthera leo* Linnaeus, 1758) ecology and human-lion interactions related to livestock predation in Waza National Park, Cameroon

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General introduction

1.1 Introduction

Top predators play an integral role in maintaining rich ecosystems because they are regulators of food webs (Beschta & Ripple, 2009; Letnic *et al.,* 2009; Fraser, 2009; Miller *et al*., 2001). Recent knowledge on natural processes that maintain biodiversity suggests that top predators have a crucial and irreplaceable role (Terborgh *et al*., 2001). The absence of top predators appears to alter the structure of entire ecosystems, resulting in simplification of ecosystem linkages, shifts in habitat and extinction of species (Terborgh *et al*., 2001). Top predators generally occur in low densities and range widely (Schaller, 1976) to meet their ecological needs. For these reasons they are considered umbrella species. Their conservation is not only relevant for the species themselves but it also promotes the protection of natural biological systems upon which many other species depend (Johnson *et al*., 2007; Estes *et al*., 2011). Commonly known as kings of the African savannah, lions (*Panthera leo*) are the largest of the African top predators. They are a symbol of power and have great traditional and cultural value, as reported in Kenya (Maddox, 2003) and Benin (Sogbohossou, 2004). Lions are keystone species and as such are ecological indicators for wilderness areas (IUCN/SSC, 2006). They are also flagship species in research programmes and charismatic species of great importance to tourism.

As with other large predators, lion conservation seems to be a daunting task. The numbers of lions and their geographic range have declined significantly all over the world (Woodroffe, 2000). The literature suggests that lions were historically widespread, ranging from Southern Africa to Northern Europe and across Central and South Asia (Nowell & Jackson, 1996; Turner & Anton, 1997; Kingdon, 2003). Today there are two remaining sub-species of lion: *Panthera leo leo*, also known as *Panthera*

leo, is restricted to Sub-Saharan Africa while the other, *Panthera leo persica,* with a small endemic population of approximately 400 lions, to the Gir forest in India (Schaller, 1972; Nowell & Jackson, 1996). Lion populations are increasingly becoming threatened throughout Africa. Only three areas in Sub-Saharan Africa are known to host relatively stable populations of 2000 or more individuals, the Serengeti-Mara ecosystem, the Okavango-Chobe-Hawange complex and Kruger National Park. In West and Central Africa, populations are small and fragmented, making them even more vulnerable to threats. Lion experts estimate that there are in total between 23,000 (Bauer & van der Merwe, 2004) and 39,000 (Chardonnet, 2002) African lions remaining. In fact, even less than 10% of the population of African lions as a whole is located in protected areas in West and Central Africa (Bauer & van der Merwe, 2004).

The decline of lion populations is mainly due to the severe range contraction observed in the last century, resulting in increasing human-lion conflicts (Loveridge *et al*., 2001; Kingdon, 2003; IUCN/SSC, 2006). The human population of Sub-Saharan Africa is increasing at a rate of between 2 and 3% per year, accompanied by a strong increase in cropland use and livestock production (IUCN/SSC, 2006; Binot *et al*., 2006; de Iongh & Bauer, 2008). The main threats to lion populations in West and Central Africa (IUCN/SSC, 2006) include loss and fragmentation of habitat, decline of prey populations and retaliatory killing of lions after livestock depredation (East, 1999; Fischer & Linsenmair, 2001; de Iongh *et al*., 2004; Caro & Scholte, 2007; Craigie *et al*., 2010; Bauer & van der Merwe, 2004; Sogbohossou, 2011). In addition, sport hunting of lions in and around protected areas exposes lion populations to disturbances, which have been reported to have a negative impact on population densities and social structure (Whitman *et al*., 2004; Loveridge *et al*., 2007; Packer *et al*., 2011a; Croes *et al*., 2011; Sogbohossou, 2011). Most protected areas in West and Central Africa, such as Waza National Park in Cameroon, are small and the surrounding savannah landscapes are degraded and fragmented, resulting in the isolation of lion populations (Bauer *et al*., 2001). These small and isolated populations face a higher risk of extinction (Woodroffe & Ginsberg, 1998) and are susceptible to inbreeding depression (Karanth *et al*., 2010).

Recent findings suggest that lions in West and Central Africa are genetically different from lions in East and Southern Africa and are more closely related to Asiatic lions (Bertola *et al*., 2011). Morphologically, the Asiatic lions clearly differ from lions in West and Central Africa in traits such

as colour of mane and body mass. There are indications that both are, however, smaller in body mass than lions from East and Southern Africa and that both have a belly fold as a typical trait (de Iongh & Bauer, 2008). This available information suggests that there is a sub-species yet to be defined, further substantiating the need to conserve the lion in this region for the preservation of biological diversity. In order to conserve a species, a sound scientific knowledge is required of its ecology, behaviour and interactions within the social context in which such a species occurs. As stated by Schaller (1972), good science, sound policy and support by local people are needed to enable a species to survive. There is a gap in knowledge on all aspects of lions in West and Central Africa compared to lions of East and Southern Africa.

Lions are impacted by changing ecological conditions induced both naturally (drought, low rainfall) and by the activities of man in the environment (poaching, encroachment and livestock grazing). Because of these pressures on the remaining lion populations, there is a need for ongoing research and monitoring in order to manage and conserve lions and their habitats. Conservation planning in the West and Central African region has been hindered by a general lack of scientific studies across and within lion populations (Bauer *et al*., 2003; Henschel *et al*., 2010; Burton *et al*., 2011; Sogbohossou, 2011). This thesis covers one of the remaining most northern isolated lion populations in Sub-Saharan Africa in Waza National Park, Cameroon. The overall research goal is to fill the gap in knowledge and provide scientific information needed for improved management and conservation of the lion in Central Africa. This study focuses on the following aspects: the status of the Waza lion population and the threats faced by this population; lion spatial ecology; movement and activity patterns of lions; diet composition and prey selection; the effect of moon phase on livestock predation by lions; human-lion conflicts and the methods used by resident and nomadic pastoralists to reduce livestock depredation.

1.2 Lion conservation and population status

The African lion is listed as *Vulnerable* on the global IUCN Red List of Threatened Species. Due to declines and increasing threats, the West African lion population is described as *Regionally Endangered* (Bauer & Nowell, 2004). The species is listed on Appendix II of CITES (Convention on International Trade in Endangered Species), which includes species

that are not necessarily threatened with extinction at the moment but will become extinct if international trade is not controlled. The current status of the species continues to raise concern among lion specialists across its range in Africa. Recent studies indicate that, while populations in East and Southern Africa are relatively stable, it is evident that they are declining at an alarming rate across West and Central Africa (Bauer & van der Merwe, 2004; Bauer *et al*., 2008; Henschel *et al*., 2010). Historically, lions occurred throughout the whole region of North, West and Central Africa, except the coastal forests of West Africa and the Congo basin extending to Nigeria (Nowell & Jackson, 1996). In the Sahara region and in North Africa, lions became extinct during the 19th and 20th century. Compared with the data presented by range states during the lion workshop of 2005 (IUCN/SSC, 2006), recent surveys of lion populations conducted in West and Central Africa further suggest that there are large gaps in the lion's range in this region (Henschel *et al*., 2010),

The region of West and Central Africa hosts in total 1800-4000 adult lions within 11 Lion Conservation Units (Bauer & van der Merwe, 2004; Chardonnet, 2002; IUCN/SSC, 2006). Cameroon is an important range state in Central Africa, having the second largest lion population (240-360) in the region, after the Democratic Republic of Congo (Bauer & van der Merwe, 2004; IUCN/SSC, 2006). However, the number of 240-360 lions is an estimate from 2003 and is expected to be much lower at present, probably approximately 220 adult individuals (Croes *et al*., 2011; Riggio *et al*., *in prep.*). Lions in Cameroon occur in two Lion Conservation Units. The first, the Bénoué complex, which includes three National Parks and 28 hunting zones, is the larger area hosting the majority (200-300) of the country's lion population. This complex is particularly important for lion conservation in the region of West and Central Africa because until recently, it was connected to lion populations in Chad and Nigeria (IUCN/SSC, 2006; Croes *et al*., 2011). Unfortunately, a recent survey in the Gashaka-Gumti protected area in Nigeria, adjacent to this complex, has no longer revealed evidence for the presence of lions in this area (Henschel *et al*., 2010). The second conservation unit concerns Waza National Park, which in contrast to the Bénoué complex, is small and geographically isolated, hosting a small lion population with low probability of genetic exchange with other populations through natural dispersal. However with the legal protection accorded to this park [article 2 (1) decree N°95/466/PM of July 20, 1995] and the protected status of the lion as a category A species in Cameroon [decision N°0565/A/DFAP/SDF/SRC/ of August 14, 1998], the lion population in Waza National Park, even though small, ap-

pears to have been relatively stable for the past three decades of the last century (Bauer, 2003; IUCN/SSC, 2006; Scholte *et al*., 2007; de Iongh & Bauer, 2008).

The historic distribution range of lions in Cameroon extended from the extreme north to the centre region of the country, at the border of the dense equatorial forest (Depierre & Vivien, 1992). No data exist on historic numbers of lions in Cameroon. However, in Waza National Park Flizot (1962) reported 100 lions in the 1960s whilst a population of 40-60 lions was estimated in 2002 through call-up stations in two different studies (Schultz & Turks, 2002; Bauer & van der Merwe, 2004). In the Bénoué complex a population of 200-300 lions was reported around 2003 (Bauer & van der Merwe, 2004; IUCN/SSC, 2006). Recent findings of Croes *et al.* (2011) in this area demonstrated extremely low lion densities in the hunting zones situated between the three national parks in this complex, indicating a recent declining trend. The aim of this research was to analyse the size and structure of the Waza lion population and identify threats faced by this population to give an update of the lion's status.

1.3 Spatial ecology of lions

Information on the spatial ecology of large carnivores is paramount in conservation planning. As with other species of wild fauna, lion conservation in West and Central Africa is challenged by a lack of data on almost all aspects of lion ecology. A species' risk of extinction may be determined both by intrinsic biological traits as well as by exposure to external anthropogenic threats (Cardillo *et al*., 2004). Species at a high trophic level, occurring at low densities, require large areas for ranging, which increases their vulnerability and compounds their extinction risk in heavily-impacted ecosystems. The Waza area is highly impacted by human pressures such as poaching, encroachment for agriculture, digging of fishing canals and grazing by livestock. There is no transitional buffer zone between the park and surrounding human settlements. As described by Bauer (2003), it is a hard-edged park that is surrounded by human population densities of more than 30 inhabitants/km^2. There are more than 100,000 resident farmers, pastoralists and fishermen who use resources in the eastern periphery of the park, not to mention the yearly influx of pastoralists during transhumance from Nigeria, Chad and southern Cameroon. Lions live in family units and are highly susceptible to anthropogenic pressure. This

study investigated the lion's ranging behaviour and its movement and activity patterns inside and outside Waza National Park in order to improve management and conservation planning.

1.4 Lion diet and prey selection

Research on lion feeding ecology elucidates how prey size and abundance determine the lion's diet and how prey availability and accessibility may impact lion populations. This information contributes substantially to the understanding of the lion's behavioural ecology (Mills, 1992). Prey may be available but not accessible for several reasons. Accessibility of prey is influenced by intrinsic factors of the prey species (such as size, mobility and defensive capacity) and external factors (such as habitat cover, geographical barriers and competition with other predators). Prey availability and prey accessibility are also related to prey distribution, which is influenced by season, showing higher dispersion of prey during the wet season and more concentration around water holes during the dry season. These dynamics influence prey selection and hunting success (Fuller *et al*., 1992, Sunquist & Sunquist, 1997), and may also influence the lion's activity pattern and spatial distribution (Henschel & Skinner, 1990). Habitat factors such as grass, shrub and tree cover, time of day, moonlight and weather conditions can also affect the lion's hunting success (van Orsdol, 1984; Stander & Albon, 1993; Mills *et al*., 1995; Funston *et al*., 2001).

The feeding ecology of large savannah carnivores has been well studied in East and Southern Africa (Kruuk & Turner, 1967; Pienaar, 1969; Mills & Biggs, 1993; Hayward & Kerley, 2005). However, there are only a small number of scientific studies on the diet of large carnivores in West and Central Africa (Wanzie, 1986; Gross, 1997; Di Silvestre, 2000; Korb, 2000, Breuer, 2005; Henschel *et al*., 2005), with very few concerning lions (Wiggers, 2007). Studies on lion diet in East and Southern Africa show that lions prefer large prey species irrespective of their availability (Hayward & Kerley, 2005). According to Bauer *et al*. (2008) lions in the region of West and Central Africa prefer medium-sized prey. Recently, another study on lion diet in the Pendjari biosphere reserve in Benin showed, however, that the lions there also preferred large-sized prey such as African buffalo (*Syncerus cafer nanus*), just as lions in East and Southern Africa (Sogbohossou, 2011). This highlights the need for more findings on the lion's diet in the region of West and Central Africa. In Waza National Park large-

sized prey species such as the buffalo have gone locally extinct, which may explain the preference for medium-sized prey. However, also natural medium-sized prey are presently declining in Waza National Park (de Iongh *et al*., 2004; Scholte *et al*., 2007; de Iongh & Bauer, 2008; Foguekem *et al*., 2010). On the other hand, densities of livestock are increasing along the periphery of the park Foguekem *et al*. (2010), and intrusions into the park are also frequent. There are clear indications that lions predate on livestock, thus the contribution of livestock to the lion's diet was also investigated.

A further point of interest concerns the influence of moonlight on livestock raiding. The full moon has been demonstrated to be a reliable indicator of impending danger of lion attacks on humans in Tanzania, because most lion attacks on humans occur during full moon (Packer *et al.,* 2011b). Lion attacks on humans are rare in West and Central Africa, but attacks on livestock are common. This raises the question whether full moon phases also influence the behaviour of lions and predation on livestock in Waza National Park.

1.5 Human-lion conflicts due to livestock predation

Human-lion conflicts are a common problem throughout the lion's range in Africa (Stander, 1990; Butler, 2000; Bauer *et al*., 2001; Loveridge *et al*., 2001; Patterson, 2004; Patterson *et al*., 2004; van Bommel *et al*., 2007) and are a real challenge for lion conservation. This problem is one of the major threats to lion populations, especially in West and Central Africa, as it often results in retaliatory killing of lions (Nowell & Jackson, 1996; Bauer *et al*., 2001; Sogbohossou, 2011). Together with the strong decline of natural prey, human pressures such as high livestock density and habitat encroachment result in frequent interactions between the lion and livestock in areas where humans live at close proximity to wildlife habitats. Factors that make predators vulnerable to local extinction as well as the damage caused by predation have been documented around Waza National Park (Bauer, 2003; van Bommel *et al*., 2007). Methods that could mitigate livestock predation by lions in this park have until recently not been investigated. Recently, Bauer *et al*. (2010) assessed methods that mitigate livestock predation in the region of West and Central Africa. The building of (experimental) enclosures in six villages south of Waza National Park was demonstrated to considerably reduce livestock depredation. In this study, a broader investigation was made of various possible

methods to mitigate human-lion conflicts. This study aims to characterize methods used by resident and nomadic pastoralists for preventing livestock predation by lions, and to investigate the effectiveness of these methods.

1.6 Main aim and research questions of the thesis

The main aim of this thesis is to fill the gap in knowledge on lion research in West and Central Africa compared to East and Southern Africa. Until now, findings on lions in East and Southern Africa have been assumed to hold true for lions in West and Central Africa in the absence of scientific data from this region. This thesis studies lions in the entire Waza National Park including the floodplain area, which have not been studied before. The research aims presented in the above sections lead to the following research questions:

- What is the current population status and social structure of lions in Waza National Park? What are the threats faced by this lion population? (Chapter 2)
- How does the declining prey population impact on the lion's spatial ecology in Waza National park? Are there seasonal and intersexual variations in home range sizes of lions in Waza National Park? (Chapter 3)
- What is the movement and activity pattern exhibited by lions in Waza National Park and what factors influence this pattern? (Chapter 4)
- What constitutes the lion's diet in Waza National Park? How much does livestock contribute to the lion's diet? (Chapter 5)
- Does moon phase influence attacks by lions on livestock in Waza National Park? (Chapter 6)
- How intense are human-lion conflicts around Waza National Park? Do resident and nomadic pastoralists practice the same methods to mitigate predation by lions on their livestock? Which of these methods are effective in mitigating livestock losses to lions? (Chapter 7)

1.7 Study area

Location

The Waza National Park, established in 1968, is located in the extreme north region of Cameroon. Situated between latitudes 10°50' and 11°40'

and longitudes 14°20' and 15°00', it lies in close proximity to the frontiers of Nigeria in the West and Chad in the East. It covers a surface area of approximately 1,700 km^2. It was classified as a biosphere reserve in May 1979 (WCMC, 1983).

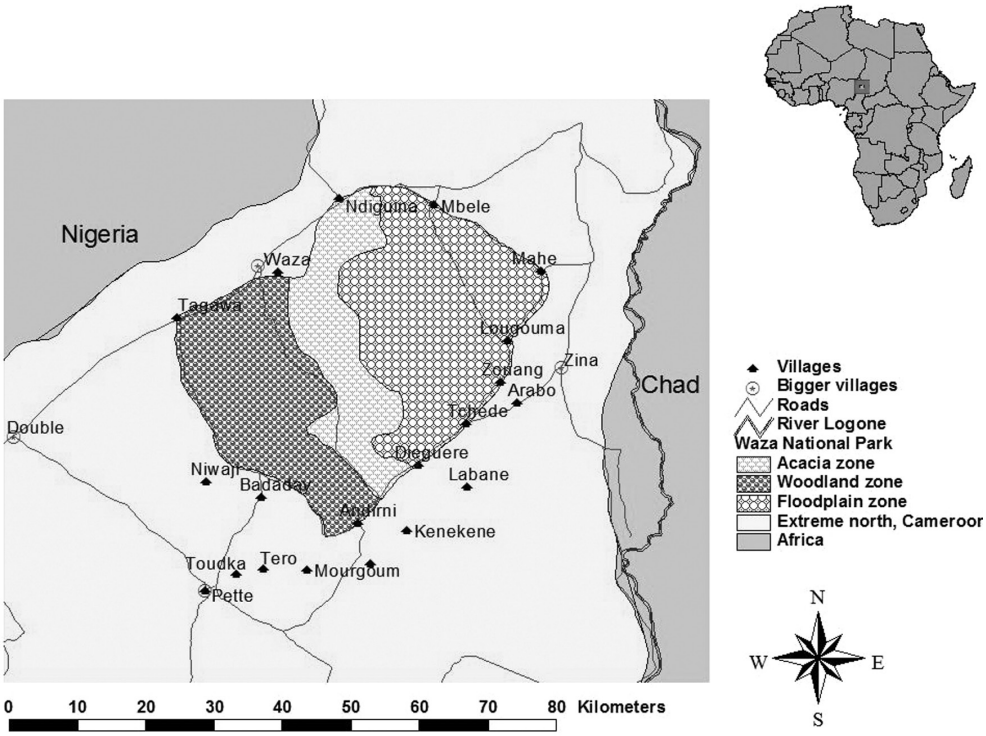

Figure 1.1 **Map of Waza National Park, Cameroon**

Physical environment

Waza National Park is situated in the Sudano-Sahelian ecological zone. The climate is semi-arid tropical characterized by three seasons: a wet season, from June to October; a cold dry season, from November to February; and a hot dry season, from March to May. Rainfall is low and irregular between years, with an annual mean of 600 mm (Beauvilain, 1995). Temperatures vary from a mean minimum of 15º C in December to a mean maximum of 48º C in April. Situated in the Lake Chad basin south of Lake Chad, the topography is flat, ranging from 300-320 m above sea level from east to west. Exceptions include the three granite inselbergs in Waza village, at the park entrance, that rise up to 480 m. Soils in the

western half of the park are sandy while the eastern half has clay soils. The eastern part of the park lies within the Logone floodplain (yaérés) and is inundated during the rainy season and part of the cold dry season with rain and flood waters form the River Logone and its tributaries. There is no permanent flowing water source in the park; rather, there are artificial and natural waterholes that are filled by rain and flood waters. Most of the waterholes dry out during the dry months but some do retain water throughout the year. The flooding of the park and the entire floodplain has been greatly reduced since the construction of the Maga dam in 1976. One of the containment dykes along the Logone River was opened in 1994 by the IUCN Waza Logone project to mitigate the adverse ecological effects caused by the Maga dam on the natural flooding regime of the Waza Logone floodplain.

Biotic environment

Waza National Park has three main vegetation types: 1) In the eastern half with heavy cracking clay soils (vertisols), the floodplain vegetation is dominated by grasses such as *Sorghum arundinaceum, Pennisetum ramosum, Echinochloa pyramidalis, Oriza longistaminata, Hyparrhenia rufa* and *Vetiveria nigritana*; 2) The area between the floodplain and the woodland zones, also with clay soils, consists mainly of *Acacia seyal* trees interspersed with *Balanites aegyptiaca, Pilostigma reticulata* and *Sorghum arundinaceum*; 3) The woodland zone on sandy soils in the west of the park is dominated by *Sclerocarya birrea, Anogeissus leiocarpus* and *Lannea humilis* (Wit, 1975).

Waza National park used to be an important tourist destination, but tourist numbers have dropped from 7,000 per year in the 1990s to 2,000 per year in recent years (Loth, 2004). The park is listed as an Important Bird Area (Fotso *et al*., 2001) and is the first RAMSAR site in the country due to its wetland. Waza National Park is also listed by IUCN as one of the locations for threatened antelopes (East, 1999). It has an important animal diversity, with 379 bird species including the ostrich (*Struthio camelus*) and the black crowned crane (*Balearica pavonina*) (Scholte *et al*., 1999). There are at least 30 species of mammals, including elephant (*Loxodonta africana, africana*), lion (*Panthera leo leo*), giraffe (*Giraffa camelopardalis*), spotted hyena (*Crocuta crocuta*), striped hyena (*Hyaena hyaena*), golden jackal (*Canis aureus*), side-striped jackal (*Canis adustus*), western kob (*Kobus kob kob*), topi (*Damaliscus korrigum*), roan antelope (*Hippotragus equinus*), gazelle (*Gazella rufifrons*), warthog (*Phacochoerus*

africanus), reedbuck (*Redunca redunca*) and Grimm's duiker (*Sylvicarpa grimmia*) (Tchamba, & Elkan, 1995). The last two species are becoming very rare. Species that have become locally extinct during the past two decades include: leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), waterbuck (*Kobus ellipsiprymnus*), bushbuck (*Tragelaphus scriptus*), African buffalo (S*yncerus cafer nanus*) and red flanked duiker (*Cephalophus rufilatus*) (Bauer & Kari, 2001).

Human environment

The Waza National Park is a hard-edged park with no transitional zone between human settlement and the park boundaries. There are about 19 villages near the park boundaries and a host of nomadic camps of pastoralists that practice transhumance in the area. The main production systems around the Waza Logone area are fisheries, animal husbandry and agriculture. Extensive pastoralism is carried out in the areas neighbouring the park. The largest ethnic groups involved in pastoralism are the Fulbé and the Choa Arab. Arab pastoralists are nomadic while the Fulbé can be grouped into nomadic pastoralists and agro-pastoralists. Resident ethnic groups in the floodplain are the Kotoko, who are mainly involved in fisheries, and the Mousgoum, involved in agriculture and small-scale animal husbandry. Most of the villages on the eastern borders of the Waza National Park were formerly within the park and were relocated, except one (Baram village) when the area was given the status of a National Park in 1968.

1.8 Thesis outline

This study comprises eight chapters. The first chapter is a general introduction and review of the study topic. It presents the research questions to be addressed and describes the study site. Chapter two deals with the research question addressing the status of the lions in Waza National Park. This chapter covers a review of the anthropogenic pressure on the park. The third and fourth chapters address lions' use of space and their movement and activity pattern in the park as well as the surrounding landscape. Chapter five examines lion diet composition and lion prey preference within the livestock-dominated Waza Logone area. The sixth chapter examines the relationship between livestock attacks and the lunar cycle. Chapter seven addresses the human-lion conflict in and around Waza National Park, with a focus on the anti-predation management

practices among nomadic and resident pastoralists. The effectiveness of some of the methods used to mitigate livestock predation by pastoralists in the area are tested and described. The last chapter discusses results and draws conclusions from the research findings. The thesis rounds up with recommendations for adaptive management and conservation of the lion in Waza National Park and the region as a whole.

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2

Threat of rapid extermination of the lion (*Panthera leo*) in Waza National Park, Northern Cameroon

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Male lion in Waza National Park, Cameroon

ABSTRACT

Lion populations in West and Central Africa are small and fragmented. In areas where park management is weak, the lion is threatened with extinction. Wildlife management requires knowledge of the population size. The population of lions in Waza National Park (Waza NP) was assessed by individual identification of members of the population. The population was estimated to consist of 14-21 individual adult lions. The age structure was skewed towards adults, with cubs comprising 22% of all lions identified. The sex ratio was also skewed at 1:3 (male: female). Two out of four collared lions were lost to illegal, retaliatory killings within one year; and probably two more males and one more female were also killed during this period. The lion population appears to have declined during the last five years, with a loss of six lions per year, which is a much higher rate than observed in previous decades. Human-livestock pressure has increased tremendously in this period, resulting in frequent human-lion conflicts. To ensure the survival of the lion in Waza NP and in the entire region, the park management needs to intensify efforts to attenuate the pressure from humans and their livestock.

keywords

lion population decline, retaliatory killings, Cameroon

2.1 Introduction

Lion populations in West and Central Africa are under serious threat. Bauer *et al.* (2003) had previously expressed their fears of an increasing risk of extinction of the lion in this region but the situation seems to have aggravated in recent years. Currently, the lion is classified as *Regionally Endangered* in West Africa (Bauer & Nowell, 2004). Unlike in East and Southern Africa where, with a few exceptions, lion populations are large and relatively stable, the West and Central African lion populations are small and their ranges are generally fragmented (Nowell & Jackson, 1996; Bauer & van der Merwe, 2004). Recent estimates in this region range from only 1750 (Bauer & van der Merwe, 2004) to nearly 4,000 individuals (Chardonnet, 2002). Concurrently, a decline of the natural prey base of the lion has been observed in this region (East, 1999; Fischer & Linsenmair, 2001; de Iongh *et al*., 2004; Scholte, 2007; Caro & Scholte, 2007), accompanied by a substantial increase of livestock (Binot *et al*., 2006; de Iongh & Bauer, 2008). Semi-nomadic herding activities in the Sudano-Sahelian belt increase the frequency of interactions between humans, livestock and wildlife, leading to an increase of human-lion conflicts. The replacement of natural prey by livestock and the subsequent increase of human-lion conflicts may therefore be a core factor in the present decline of the West and Central African lion population.

In Waza National Park, the above trends are all being observed. The lion population seems to have declined from 100 individuals in 1962 (Flizot, 1962) to between 40- 60 in 2002 (Bauer *et al*., 2003; Bauer & van der Merwe, 2004). Similarly the population of the Western kob antelope (*Kobus kob kob*), which is the most abundant natural prey in Waza NP, has dropped dramatically from 25,000 in 1962 to about 6,000 in 2000 and to below 1,600 in 2007 (de Iongh *et al*., 2004; Scholte, 2007; Omondi *et al*., 2007). Regarding livestock, Scholte *et al*. (2003) reported that after the reflooding in 1994, a threefold increase in livestock grazing intensity was observed around Waza NP due to an immigration of pastoralists into the Logone floodplain. According to these authors, antelope numbers increased only slightly as a consequence of the reflooding. These findings were confirmed by an aerial survey conducted by Worldwide Fund for Nature in early 2007, which revealed 21,000 heads of livestock within a 5 km buffer of the park as opposed to only about 2,600 heads of natural prey counted in and around the park (Omondi *et al*., 2007). Recent studies by Croes *et al.* (2011) demonstrated extremely low lion densities in the hunting zones situated between the three national parks in

the Bénoué complex, indicating a recent declining trend in lion numbers. This study explores the changes that might have taken place in the Waza lion population over the years. It presents the lion population status and highlights the illegal killing of lions in and around the park.

2.2 Methods

Study area

This study was performed in the Waza NP located in northern Cameroon. About half of the park (the northern and eastern side) is located within the floodplain of the Logone River. Here the topography is flat with clay soils that are prone to seasonal inundation. The south-western side of the park is situated on sandy deposits of the fringe of the Lake Chad basin. At 320 m above sea level, this part of the Park is about 20 m higher than the north-eastern part. It is slightly undulating, with height differences of a few meters, and is never flooded. The climate of the area is semi-arid tropical.

Waza NP hosts a rich wildlife and is a popular destination for tourists because animals are easily sighted on its open floodplain. The park has no flowing permanent water source but is nourished by flood waters from the rivers Logone and Logomatya as well as rain water. Water is held in artificial and natural reservoirs in the park but during the dry months of the year most of these waterholes dry out. However, waterholes in the floodplain section of the park and a few in the woodland retain water all year round. The park has three distinct vegetation zones, from the west to the east: woodland zone (31%) dominated by *Sclerocarya birrea*, acacia zone (27%) dominated by *Acacia seyal* and floodplain (42%) which consist of grassland. The first two vegetation zones are located in the south-western side of the park while the third vegetation zone is located in the north-eastern side of the park.

Sampling techniques

A combination of methods including total count through individual identification of members in the population and a camera trapping survey were used to census the Waza NP lion population. However, the small number of lion photos taken during the camera trapping survey did not allow for statistical analysis using the program "CAPTURE". The main ap-

proach used for assessing the lion population in Waza NP was therefore a total count, which meant identifying individual lions during the study period, from May 2007 to June 2008. In this way, a description of the entire lion population was achieved by directly observing the lions during field work, lion collaring and from photos made during the camera trapping survey.

At each lion encounter, lions were identified and their location mapped within the park. A pre-structured form was filled in, indicating group size and group composition. Individual features, such as vibrissae patterns, scars and ear cuts were drawn on a full face outline and other features such as broken teeth were noted (Pennycuick & Rudnai, 1970). Photographs of each individual were taken when possible. Assessment of age was done as described by Smuts *et al*. (1970) and Schaller (1972). Structured questionnaires deposited at the entrance to the park were completed by tourists, tour guides and park guards. Questions dealt with when and where lions were sighted, group size and group composition. A total of 95 forms were completed and analysed during the research period. These forms were checked regularly and recent lion sightings were verified by visiting the reported sites.

Lion collaring operations were conducted in May 2007 and May 2008 in Waza NP for monitoring purposes. Four Vectronic GPS-PLUS collars equipped with a VHF transmitter, supplied with a Handheld Terminal that communicates with the collars, were fixed on two male (Adam and Jean-Pierre) and on two female lions (Elizabeth and Fanne) in May 2007. One Vectronic GPS-PLUS collar and two African Wildlife Tracking GPS GSM collars were fixed on one male (Falama) and two female lions (Rossie and Fanne) in May 2008, respectively. Lions were attracted within darting distance using a calling station set-up adapted from Ogutu & Dublin (1998). Calls were played for 30-45 minutes, alternating with 15 minutes of silence, until lions appeared. An MP-3 player connected to a 400 Watt amplifier and two speakers (50 Watt each) placed on the roof of the car supplied the sound playback. Before attaching the bait (kob antelope) firmly to a tree, a trail of about 1 km was made in different directions. Darting was accomplished using a Dan-inject immobilization gun with a 1.5 ml dart containing Zoletil 100. Lions that responded to the calling stations were identified.

A camera trapping survey was conducted from 5 March to 17 April 2008 to provide further information about the lion population in Waza NP. Our

set-up was adapted from Karanth & Nichols, 1998; Karanth & Nichols, 2000 and Henschel & Ray, 2003. Camera trapping sites were selected based on cues such as lion tracks, droppings, sightings and presence of waterholes, while large gaps were randomly filled based on lion minimum home range size in the park. The survey was accomplished by dividing the park into three sampling blocks that almost respected the three vegetation zones of the park. Given the number of cameras available, all 21 cameras were placed in the first block and relocated twice to the second and third blocks for two weeks each. Cameras were revisited after six days to replace batteries and/or film. In accordance with the sizes of the vegetation zones of the park, 22 trapping sites were in the woodland zone, 11 in the acacia zone and 30 in the floodplain zone, bringing the total number of trapping sites to 63. These trapping sites were also considered as sighting sites for they were considered potential sites for encountering lions and were visited at least twice.

Each camera (stealth Cam type MC2-GV), with a built-in infrared movement sensor, was attached to a tree at knee height. A trail, bait and catnip (pheromone) were used to lure lions to the cameras. The kob antelope was chosen as bait and the trail of approximately 300 m was made by dragging the bait ($1/10^{th}$ of an adult kob) from different directions to the trapping site. The bait was attached on a tree opposite the camera at 1.5 m above the ground. The catnip was sprayed at the base of the tree holding the bait and on surrounding trees to retain the lion in the vicinity (McElvain *et al.*, 1942 and Hill *et al.*, 1976).

2.3 Results

Based on the total observations from May 2007 to June of 2008, including the period of the camera trapping survey, a total of 26 individual lions (adults plus cubs) were identified in Waza NP (Table 2.1). At the end of the study period, two collared male lions were killed by livestock owners. In January of 2008, rumours of the killing of a group of lions, one carrying a collar, in a Cameroon-Nigerian border village prompted the tracking of collared lions out of the park. A signal was received from 'Jean-Pierre' in a peripheral village south of the park. After a search in the village with the strongest signal strength, the collar was found hanging from a tree. GPS data obtained from the collar revealed that the lion stopped activity at another location 4 km from where the collar was found. The location was visited and after an intensive search, lion scat was collected but there

were no signs of the lion carcass. At about 700 m from this location (the next location fix), a cattle carcass was found. Attempts to investigate the village nearest to these sites were aggressively frustrated. Visits to other location fixes outside of the park revealed many cattle carcasses. The villagers were intolerant of livestock depredation by lions. When a signal was later received from 'Adam', the situation was similar. Although the time interval between when he was killed and when the collar was discovered was relatively short, no carcass was recovered. Visits to his location fixes also revealed carcasses of raided livestock.

An adult female and two other adult males were probably also killed. Two large cubs (CM1 and CM2) and one small cub (C9) most likely also did not survive. Of the 18 individual lions remaining, three were males, eleven females and four cubs. All sightings made by tourists, guides and guards were verified and there were no other individuals identified. There were also no new individuals in photographs taken during the camera trapping survey besides those already known. Lions identified during the camera trapping survey were F4, M4, C7, C8, CM5, CM6, M3 and Falama (Table 2.1).

Table 2.1 **Observations of individuals and groups of lions in Waza NP from May 2007 to June 2008. F = adult female; M = adult male; CM/CF = male/female cub,*= killed, M1, M2 & F2 = probably killed, CM1, CM2 &C9 = probably death, CF3 & CF4 = cubs to sub-adults**

Date	Location	Group composition	Group size	Encounter
05-05-07	Gobe	Jean-Pierre, Elizabeth, F1, CM1, CM2, CF3, CF4	3	Collaring
06-05-07	Gamzemia	Fanne	1	Collaring
10-05-07	Louloubaya	Adam, M1, M2, F2	4	Collaring
17-05-07	Sawarware	Jean-Pierre	1	Telemetry
17-05-07	Gobe	Elizabeth, F1, CM1, CM2, CF3, CF4	2	Telemetry
20-05-07	Dalazoa loop	Adam, M1, M2, F2	4	Telemetry
21-05-07	Sawarware	Jean-Pierre	1	Telemetry
21-05-07	Sawarware	M3, F3	2	Field work
21-05-07	Gobe	Elizabeth, F1, CM1, CM2, CF3,CF4	2	Telemetry
21-05-07	Talabal	Fanne	1	Telemetry
16-01-08	Kouloudika	CM5, CM6	0	Field work
19-01-08	Louloubaya-Bodelaram	F4	1	Field work
23-01-08	Village south of park	*	0	18-11-07

02-02-08	Louloubaya-Bodelaram	F4,M4,C7,C8,C9	2	Field work
07-03-08	Bodelaram	F4,C7,C8	1	Field work
20-03-08	Sawarware	Fanne	1	Field work
29-03-08	Kouloudika-Louloubaya	Adam	1	Telemetry
08-04-08	Gamzemia	Falama	1	Field work
15-04-08	Mbouiet-Zeila	F1,F3,F5,F6	4	Field work
15-04-08	Goumboure-maram	Rosie, F7,CM5,CM6	2	Field work
16-04-08	Mengeng	Falama	1	Field work
16-04-08	Mengeng	M3	1	Field work
16-04-08	Gamzemia	Fanne	1	Field work
29-04-08	Waza NP limit	*	0	04-04-08
30-04-08	Dalazoa	F4,M4,C7,C8	2	Field work
01-05-08	Gamzemia-Mengeng	Fanne,M3	2	Field work
18-05-08	Gamzemia	Falama	1	Collaring
18-05-08	Gouboure-maram	Rosie,CM5,CM6	1	Collaring
19-05-08	Sawarware	Fanne,M3,F8,F9	4	Collaring
28-05-08	Alaza	F5,F6	2	Field work
28-05-08	Alaza	Falama	1	Telemetry
04-06-08	Alaza	Fanne, F8	2	Field work
05-06-08	Toukouneram	M3	1	Field work
11-06-08	Gouboure-maram	F4,M4	2	Field work
12-06-08	Mbouiet	Elizabeth	1	Telemetry

Collaring = lions sighted during collaring operations, Telemetry = lions sighted after receiving signals from collars and Field work = lions sighted during other field activities other than telemetry

The total surface area which was visited at least twice, including the roads and all camera trapping sites, represented 63% of the park. One may be tempted to extrapolate the number of identified lions to the total area of the park. This is not realistic however, as in the hot dry season both natural prey and cattle remain close to waterholes and lions follow their prey. All waterholes within the park were inside the investigated

area. Therefore, the observed number is assumed to be the total population inside the park. However, there may also be a number of lions close to waterholes outside the park, where the cattle concentration is also high. It is assumed that this would consist of seven adult individuals at most. Therefore, the total Waza lion population is assessed at 14-21 adult individuals.

In total six lion groups were mapped in this park. There were two groups in the woodland zone. One consisted of two small cubs, a female and an adult male whose mane was not well developed. The other was made up of two older male cubs and two adult females. The remaining four groups in the floodplain zone showed the fission-fusion patterns, splitting up at times into singles or pairs. A group of four adult females was identified, occasionally seen in pairs; a group of an adult female, two sub-adult females and an adult male; and two solitary adult lions, male and female. The sex ratio based on mature individuals was 1:3 while the percentage of cubs in the population was 22%. The average group size of lions in this park was 1.6. Figure 2.1 presents the population pyramid, which shows an upside-down structure.

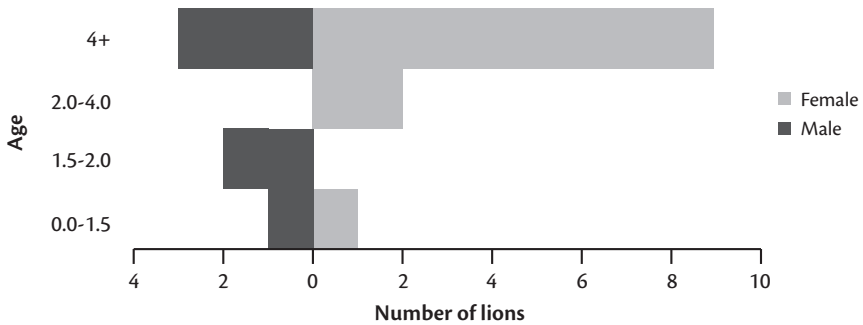

Figure 2.1 **Population pyramid of Waza NP lions in 2008 (n=18)**

During the camera trapping survey, a total of 1914 photographs were taken: 1008 "blank" photos, 437 photos of carnivores (12% large carnivores and 36% small carnivores), 186 photos of herbivores (21%) and 283 photos of humans and/or cattle (31%) (Figure 2.2). Blank photographs included those triggered by monkeys, birds, falling leaves and sand storms. The human and/or cattle category consisted of herdsmen, cattle, poachers and probably fishermen, all within the park. In the woodland zone of the park, 2 out of the 22 camera trapping sites had photo-

graphs of humans and/or cattle; in the acacia zone 1 out of 11 and in the floodplain 17 out of 30.

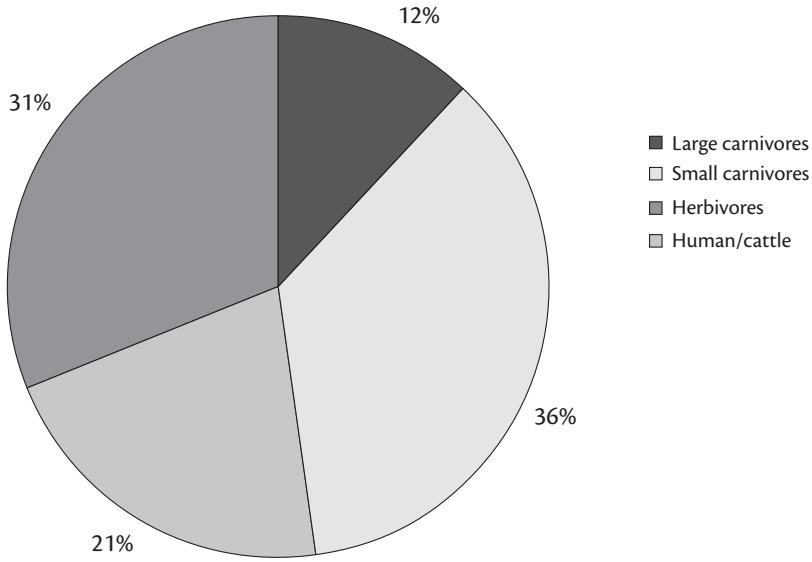

Figure 2.2 **Percentage of photographs taken of large carnivores, small carnivores, herbivores & humans/cattle in Waza NP, 2008 (n=906)**

2.4 Discussion

The current estimate of 14-21 adult lions in Waza NP differs greatly from the estimate of Bauer *et al*. (2003) and Bauer & van der Merwe (2004). The decline reported by Bauer *et al*. (2003) from 100 individuals in 1962 to 40-60 individuals around 2002 implied that approximately one lion was lost every year. The present findings when compared with Bauer et al. (2003) and Bauer & van der Merwe (2004) demonstrate an alarming rate of about 6 lions lost in Waza NP each year. At this rate, the lion will most likely be extinct in Waza NP within the next four years. There may be more than the assessed seven lions further away from the periphery of the park, given the fact that GPS data from the collared lions indicate that lions do make long excursions outside the park. However, such large scale movements were unlikely during the critical period that the survey was conducted. At this period all water dries out except for waterholes in the park and a few at the periphery that retain water. Most natural prey congregate at these waterholes and lions do stay close for easy meals.

The killing of two reproductive males within one year represents a higher percentage of research lions (50%) lost to illegal, retaliatory killings than that (25%) reported by Bauer (2003). Although the numbers are too small to give much weight to this difference, they must not be overlooked given the small size of this population. The death toll may be higher than the confirmed cases as indicated above. 'Adam' for instance, was in a group of four lions during collaring (a coalition of three adult males and one adult female). He was sighted several times with the members of his group after collaring. Rumors about the killing of this group in a Cameroon-Nigerian border village were effectively confirmed from the GPS data of 'Adam' which revealed that this group was located around the borders between November and December of 2007. When he was sighted in March of 2008, he was alone. Adam, however, met his end at the hands of nomadic Uuda pastoralists during a short excursion to their camp, 500 m from the park limit. 'Jean-Pierre', the other collared lion killed, left his group shortly after collaring. Because of seasonal floods and the dispersal of the declining natural prey population, lions leave the park and follow migrating nomadic livestock. Outside the park, lions raid livestock and consequently come into conflict with humans. Retaliatory killings are illegally carried out by livestock owners using bow and arrows poisoned with cobra venom. These results together with the case reported by Bauer (2003) suggest that lions are regularly being killed illegally in and around this park, even though there are no systematic records. Although lions are mostly killed in retaliation for taking livestock, poaching seems to be going on as well. The carcasses of both lions were never recovered. Communities around the park attach socio-economic value to various parts of the lion and there are indications of trade in these animal parts.

The lion population age structure is skewed towards adults, indicating a negative growth for the lion population in this park. External threats such as illegal killings which increase mortality in this population will likely drive it to local extinction if the causal factors are not halted. The presence of cubs in the population (22%) and a sex ratio of 1:3 however, indicate that the population still has a reproduction capacity.

The results of the camera trapping survey supported the conclusion that the human-livestock pressure on the park is very heavy. Out of 63 trapping sites, human/cattle were present at 20. Compared to other groups of animals captured by the camera traps, human-livestock represented 31% of the photographs. During field work, poachers, fishermen, herds-

men and cattle herds ranging from 150 to 2,000 heads were occasionally encountered. This situation confirms the conjecture made by Scholte (2003) that the disappearance of wildlife in nearby Kalamaloué National Park due to advanced human encroachment forms was a bleak perspective for Waza NP.

Nevertheless, although the current status of the Waza lion population seems critical, there are still possibilities for this population to fully recover and stabilize. Studies in East and Southern Africa have shown that lion populations are resilient. When park management is good, ensuring better habitat conditions, a lion population is able to recover within a short period of time. This suggest that, if an immediate attempt is made by the government to stop all illegal activities within the park and its peripheries, the lion population in Waza NP will recover. Specifically, the park boundaries should be clearly demarcated to prevent intrusion by herdsmen and their livestock. Furthermore, an increase in security patrols would substantially increase the effectiveness of conservation efforts, as demonstrated by Hilborn *et al*. (2006) and Dobson & Lynes (2008). Eventually, management should consider raising awareness and sensitizing all communities involved.

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3

Changing prey abundance as a driver of lion (*Panthera leo*) home range size in Waza National Park, Cameroon

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Based on article submitted to the *Journal of Mammalian Biology*

Lion collaring operation in Waza National Park, Cameroon

ABSTRACT

The spatial ecology of African lions (*Panthera leo*) was studied from 2007 to 2009 in Waza National Park, Cameroon, by equipping seven individuals with GPS/UHF radio-collars. Mean home range estimates using 100% minimum convex polygons (MCP) and 95% kernel-density estimation (KDE) were respectively 1015 km^2 and 641 km^2. The lions spent a considerable amount of time outside the park during the study period (21%), resulting in significantly larger wet season home ranges than in the hot dry season when they were largely within the park. Time spent outside of the park coincided with increased livestock predation, especially by males. The seasonal variation observed in home range appeared to be mainly due to prey dispersal, flooding and migrating livestock. Mean home range size was observed to have increased by 58.6% within the last decade. This increase observed in home range was attributed to recent declines in wild prey abundance and may also indicate a trend of general degradation of the park due to intense human pressure. The change observed in the lion's ranging behaviour was remarkable, with lions crossing the highway parallel to the park to the Cameroon-Nigerian borders. There is an urgent need for measures to restore the integrity of the park, which could include the construction of a fence along the western boundary of the park to prevent lions moving across the parallel highway.

Key words

African lions, GPS tracking, Radio telemetry, Spatial behaviour, Livestock conflict

3.1 Introduction

A home range is the area used by an individual animal species for its regular activities of food gathering, mating and caring for its young (Burt, 1943). Carnivore home range size varies across and within species in relation to a wide range of factors, including body mass, prey availability, social interactions, habitat quality and reproductive status (Gittleman & Harvey, 1982; van Orsdol *et al*., 1985; Viljoen, 1993; Adams, 2001; Spong, 2002; Hemson, 2003; Bauer & de Iongh, 2005). Abundant food and a high quality habitat allow an animal to meet its biological requirements in a relatively small home range and vice versa (Gittleman & Harvey, 1982; MacDonald, 1983).

The lion is a social cat that lives in family units called prides, consisting of related females and their young accompanied by one or a coalition of related or unrelated adult males (Schaller, 1972; Bygott *et al*., 1979; Packer *et al*., 1991). Although pride size varies from 2 to 18 related adult females, most typical prides contain four adult lionesses, their cubs and accompanying males (Schaller, 1972). Lionesses typically defend a permanent home range, which can persist for many generations, with pride males defending these as well during periods of tenure with a pride (Bygott *et al*., 1979). Large home ranges overlap extensively with those of adjacent prides, while small home ranges tend to have little overlap (Schaller, 1972; van Orsdol *et al*., 1985). Like other large carnivores at the apex of the trophic level, lions typically occur at relatively low densities and require large areas in which to range.

There are many challenges associated with the conservation of carnivores, including both anthropogenic and ecological factors. Large range requirements associated with negative interactions with humans have led to decline in many of the world's carnivores. A large carnivore's home range size is thus a good predictor of its extinction probability relative to the size of the protected areas (Woodroffe & Ginsberg, 1998; Woodroffe, 2001). Large and relatively intact areas for the protection of carnivores are becoming rare. Particularly in West and Central Africa, increased anthropogenic activity as a consequence of rapid human population growth has resulted in a reduction and fragmentation of natural habitats for lions (Nowell & Jackson, 1996; Bauer & Nowell, 2004) and increasing persecution (Tumenta *et al*. 2010).

Knowing the spatial scale at which ecological processes occur is fundamental to making informed decisions on wildlife management and conservation. To effectively mitigate conflicts between lions and people an improved understanding of the spatial ecology of large carnivores such as the lion is crucial to ensure continued survival of their populations (Marker *et al*., 2007; Karanth & Chellam, 2009).The spatial ecology of lions has been scarcely studied in West and Central Africa, with the exception of studies in Waza National Park, Cameroon (Bauer & de Iongh, 2005) and in Pendjari Biosphere Reserve, Benin (Sogbohossou, 2011). In contrast, the home range size of the lion is well documented in East Africa, ranging from very small (e.g. 25-51 km^2 in Nairobi National Park) to relatively large (e.g. 30-400 km^2 in the Serengeti) (Schaller, 1972; Gittleman & Harvey, 1982; van Orsdol *et al*., 1985; Schaller, 1972). However in arid and hyper-arid areas of Southern Africa lion home ranges can be as large as 4500 km^2 in the Kgalagadi Transfrontier Park (Funston, 2011) and 7337 km^2 in the Kunene Region (Stander, 2006). The variation in home range size between lion populations thus calls for site-specific estimates.

Lion home range size also differs between sexes, which is thought to be a result of differences in body mass between male and female lions (Bauer & de Iongh, 2005), and consequently in energetic needs (Schaller, 1972). Group size and territoriality are social factors that also influence home range size (Packer *et al*., 2005); with home range size increasing with group size (van Orsdol *et al*., 1985). Larger prides require more prey and therefore larger areas, depending on prey biomass and prey density.

The most important factor that influences lion home range size, however, is prey abundance (van Orsdol *et al*., 1985; Bauer & de Iongh, 2005), with lion home range size being negatively correlated with prey abundance (van Orsdol *et al*., 1985; Bauer & de Iongh, 2005; Loveridge *et al*., 2009). As there have been drastic declines of natural prey populations in Waza National Park in the last decade (Scholte *et al*., 2007; de Iongh *et al*., 2008; Foguekem *et al*., 2010) we expected that this should have resulted in lion home ranges having increased in size (Bauer & de Iongh, 2005), augmenting the conservation challenges faced by lions there. This study therefore attempted to investigate the drivers of lion home range size in Waza National Park, northern Cameroon, in a region where this important biological parameter was relatively little understood. Furthermore, seasonal and intersexual variations in home range size were investigated to provide data needed for the planning and implementation of conserva-

tion policies and management of protected areas in Waza, and the region as a whole.

3.2 Materials and methods

Study area

The study was conducted in Waza National Park (1,700 km^2), situated in the far northern Sudano-Sahelian savannah region of Cameroon. Rainfall in this area is low and irregular between years, with a mean annual rainfall of 600 mm (Beauvilain, 1995). The climate is semi-tropical, with temperatures ranging from 15º C (January mean minimum) to 48º C (April mean maximum). The area has three characteristic seasons: a wet season, from June to October; a cold dry season, from November to February; and a hot dry season, from March to May. A floodplain of the Logone River comprises 42% of the parks surface area and is seasonally inundated with water and dominated by heavy cracking clay soils (vertisols), and coarse grasses. The other habitats in the park include two woodland vegetation zones dominated by *Acacia spp* and *Sclerocarya birrea*. Key lion prey species occurring in the park in order of importance in the lion's diet are Buffon's kob (*Kobus kob kob*), topi (*Damaliscus korrigum*), roan antelope (*Hippotragus equinus*), red fronted gazelle (*Gazella rufifrons*), warthog (*Phacochoerus africanus*) and giraffe (*Giraffa camelopardalis*) (Tumenta *et al*., *in review*).

Lion sedation and collaring

Seven lions were immobilized and radio-collared between 2007 and 2009, four of these with GPS-PLUS download collars (from VECTRONICS Aerospace) and three with African Wildlife Tracking (AWT) GPS GSM collars. Only one of the AWT collars fitted to female lion L5 worked during the study period. The Vectronic collars were fitted to males L1 and L2 and lionesses L3 and L4. Table 3.1 presents details of the researched lions. The lions were captured by free darting after being attracted using a calling station set-up adapted from Ogutu and Dublin (1998). For the collaring protocol, the same procedure was used as Bauer and de Iongh (2005).

Table 3.1 Lions sedated and collared in Waza National Park, Cameroon in 2007-2008

	L1	L2	L3	L4	L5
Name	Adam	Jean Pierre	Fanne	Elizabeth	Rossie
Sex	Male	Male	Female	Female	Female
Body weight	160 ± 5 kg	186 kg	110 kg	103 kg	96 kg
Habitat	Woodland	Floodplain	Floodplain	Floodplain	Woodland
Start date	10-05-07	05-05-07	06-05-07	05-05-07	18-05-08
End date	04-04-08	18-11-07	25-09-07	12-06-09	01-02-09
Study period	±11 Months	± 7 Months	± 5 Months	± 23 Months	± 8 Months
Number of fixes	14883(1856)*	8740(1069)*	6620(822)*	34902(4378)*	1306*

*Four-hour selection of GPS location fixes for home range calculations, L1-L5= Lion number

Lion tracking

After collaring, the lions were closely monitored in the field from 2007 to 2009 through radio telemetry. Tracking was done from a four-wheel-drive vehicle using a VHF-radio transmitter following the methods described by Bauer (2003). The reception range of the transmitter was about 4 km at ground level and about 15 km from the top of the highest inselberg in the park. The GPS unit in the collars recorded at scheduled intervals of 30 min a fix of GPS coordinates and the local temperature. When a signal was obtained from any of the lions with a VHF receiver, communication was then established between a handheld UHF terminal and the collar to obtain the most recent location fixes. The last GPS location fix of the lion was then put into a hand held GPS unit to track down the lion for observation.

Data analysis

The data were imported into Arcview 3.2 GIS (ESRI 1992) for analyses using the extension packages Spatial Analyst and Animal Movement (Hooge & Eichenlaub, 2000). Home range sizes of lions were calculated using Minimum Convex Polygon (MCP) (Bauer & de Iongh, 2005; Marker *et al*., 2008; Jhala *et al*., 2009) and the Fixed Kernel (Marker *et al*., 2008; Jhala *et al*., 2009) methods for the entire data set during one year of the study. Home ranges for the different seasons were calculated using the Fixed Kernel method, with the 100% MCP presented for comparison with earlier and other studies. A large number of fixes was obtained for the

entire data set with 48 data points per day. To facilitate analysis and reduce the probability of autocorrelation, a 4-hour selection was carried out on the data, reducing the data size to 6 points per day. The Fixed Kernel test was used to calculate home range metrics; the outer boundary set at 95%, the core area 50% and hotspots 5% (White & Garrot, 1990). The smoothing factor was chosen using the Least Square Cross Validation (LSCV) procedure (Kernohan *et al*., 2001) and was 0.02 for all calculations. Differences in mean home range size between season and sex were calculated with t-test in the SAS software. A one-sample t-test was performed to compare the mean MCP of this study with that reported by Bauer & de Iongh (2005).

3.3 Results

Home range

The collar fitted on lioness L3 became dysfunctional 5 months after it was attached. Lions L1, L2 and Lioness L5 were killed 11, 7 and 8 months after collaring, respectively (De Iongh *et al*., 2009; Tumenta *et al*., 2010). Lioness L4 provided data for the entire two-year study period. However, all the lions provided more than the required minimum number (60) of fixes for home range estimation (Spong, 2002). Data from all the lions covered the different seasons of the year except for lioness L3, which had no data for the cold dry season. For comparison with a previous study in Waza National Park on lion home range (Bauer & De Iongh, 2005), only one year's data from four lions collared at the same time was analysed.

Four lions (L1-L4) collared in 2007 provided sufficient fixes for home range size estimations, which varied from 307 km^2 to 1384 km^2 (mean 1015 km^2) using the Minimum Convex Polygon (MCP) method (Figure 3.1). L5 had no data during 2007 and was excluded from the total home range calculations. By comparison the mean for the 95% Fixed Kernel home range estimates was 641 km^2 (Table 3.2).

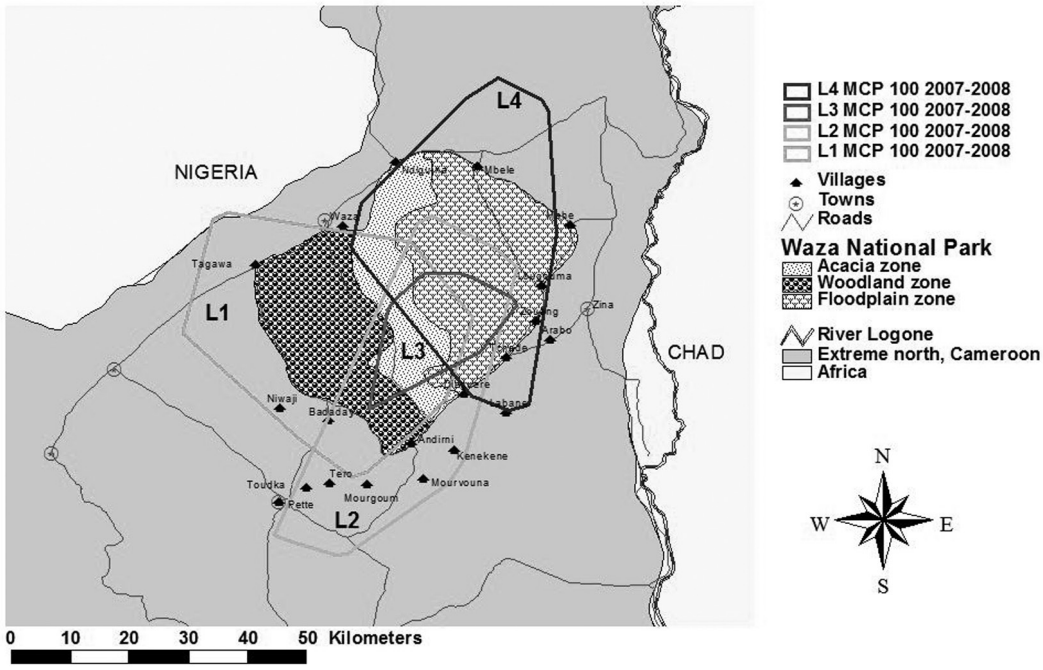

Figure 3.1 **Minimum convex polygon (100%) home range estimates of four radio-collared lions in Waza National Park, Cameroon in 2007-2008**

Table 3.2 **Home range (km²) estimates of four radio-collared lions in Waza National Park Cameroon in 2007-2008**

Lion ID	MCP 100 All data	95% Ker All data	50% Ker All data	5% Ker All Data	Cold dry season*	Hot dry season*	Wet season*	Group size
L1	1384.4	799.8	26.4	1.7	421.9	127.7	874.4	4
L2	1148.7	734.5	98.7	2.9	348.4	90.2	685.1	2
L3	307.1	246.9	80.4	2.8	–	107.2	259.9	1
L4	1220.8	780.7	66.4	1.9	505.9	200.7	359.5	–
Average	1015.2	640.5	68.0	2.3	425.4	131.5	544.7	–

*95% Fixed Kernel estimates; L1 & L2 were male lions; L3 & L4 were female lions

Lions had significantly larger mean home ranges during the wet season (545 km^2, SD= 285.1) compared to the hot dry season (132 km^2, SD= 77.2) (F=5.65, P=0.04, df=2, 3). The home ranges of males were observed to be 65.8% larger than those of females according to the Minimum Convex Polygon estimation (mean MCP 1267 km^2, SD= 166.7 vs. 764 km^2, SD= 646.1). However this difference was not significant. Male and female lions showed a difference in home range size across the different seasons, with both sexes having their smallest home range during the hot dry season. The males had the largest home range (mean 780 km^2) during the wet season, whilst the home ranges of the females were largest during the cold dry season (mean 506 km^2). A comparison of the mean MCP home range of this study (1015 km^2) with the mean MCP home range in 2000 (640 km^2) showed no significant difference. The mean home range of this study, however, was 58.6% larger than the mean home range recorded in 2000.

The Kernel contour home range of collared lions varied markedly during the year and especially during the three seasons (Figure 3.2a-d). These figures show that the home ranges of all of the lions were completely within the park during the hot dry season, with core areas and hotspots (50% and 5% kernel home ranges) located at water holes retaining water during the dry months of the year. The core areas for lions in the floodplain zone of the park shifted to the *Acacia* and woodland zones during the wet season and for male lions were located outside the park during the cold dry season. Lions in the woodland zone of the park had home ranges (L1=1384 km^2) comparable to lions in the floodplain zone of the park (L2=1022 km^2 and L4= 1220 km^2). Overall, most of the GPS location fixes (56%) of the lions were located in the floodplain vegetation zone of the park, 22% in the Acacia vegetation zone and 22% in the woodland vegetation zone (Table 3.3).

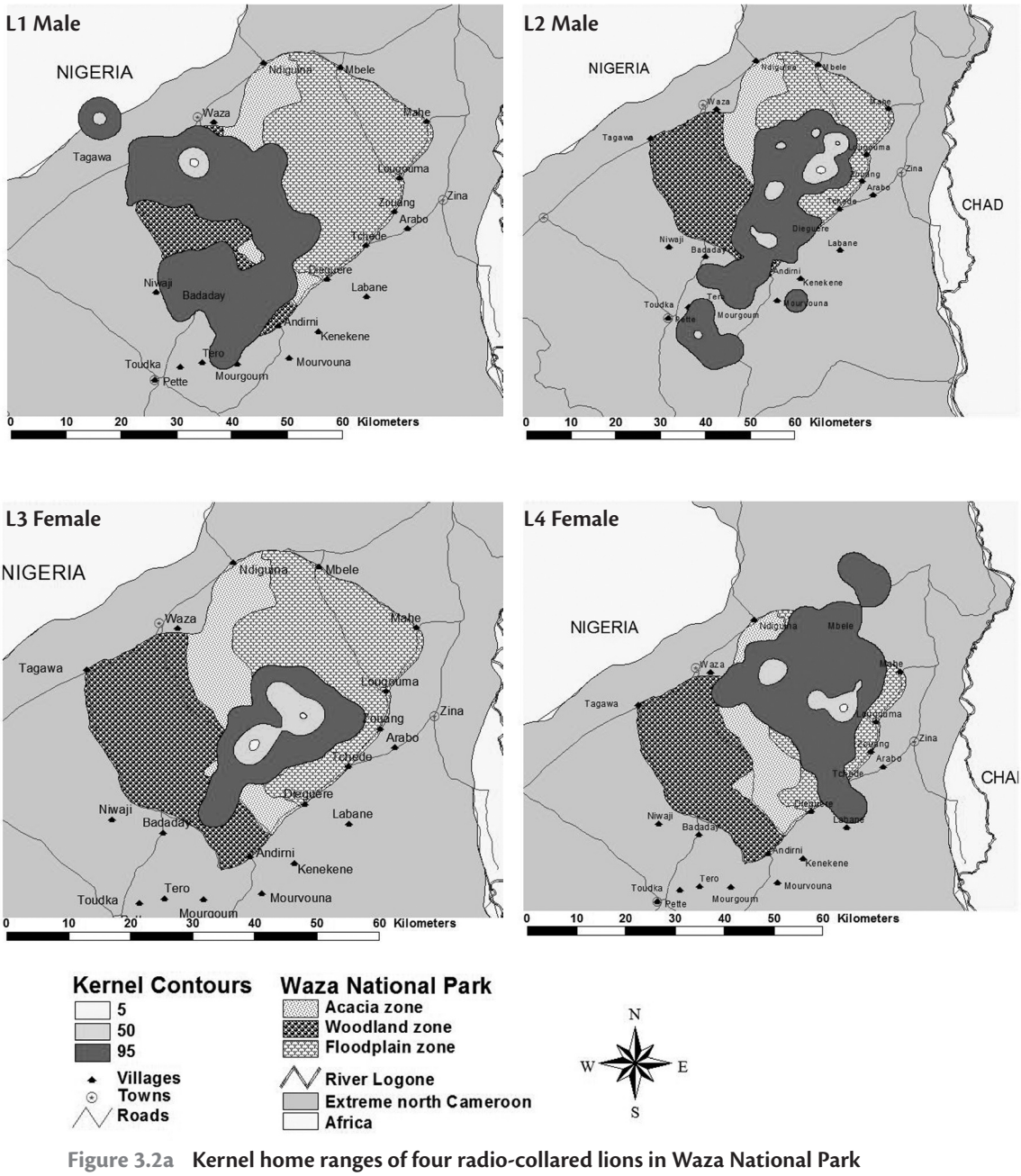

Figure 3.2a Kernel home ranges of four radio-collared lions in Waza National Park

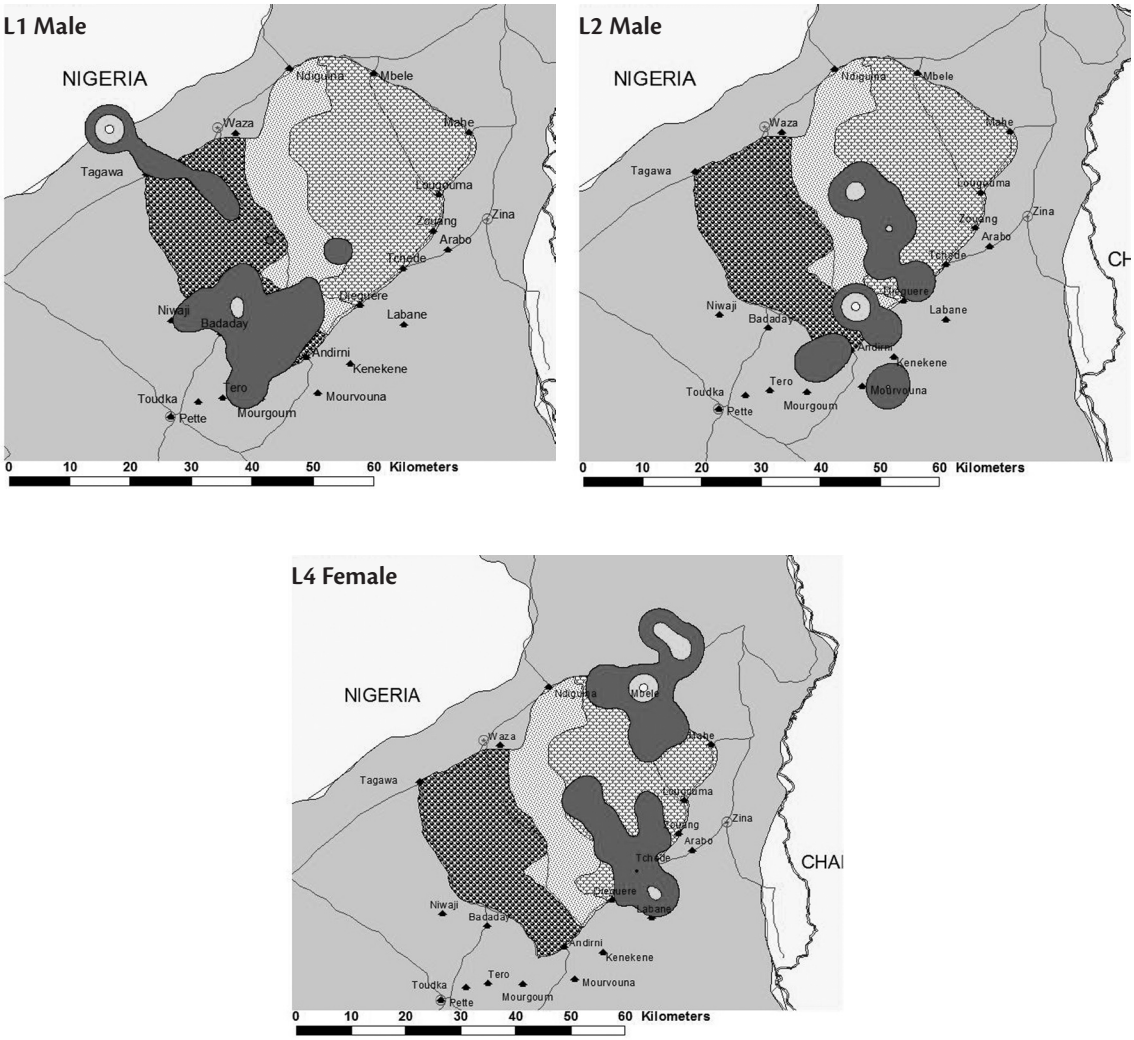

Figure 3.2b Kernel home range of two lions and one lioness in Waza National Park in the cold dry season

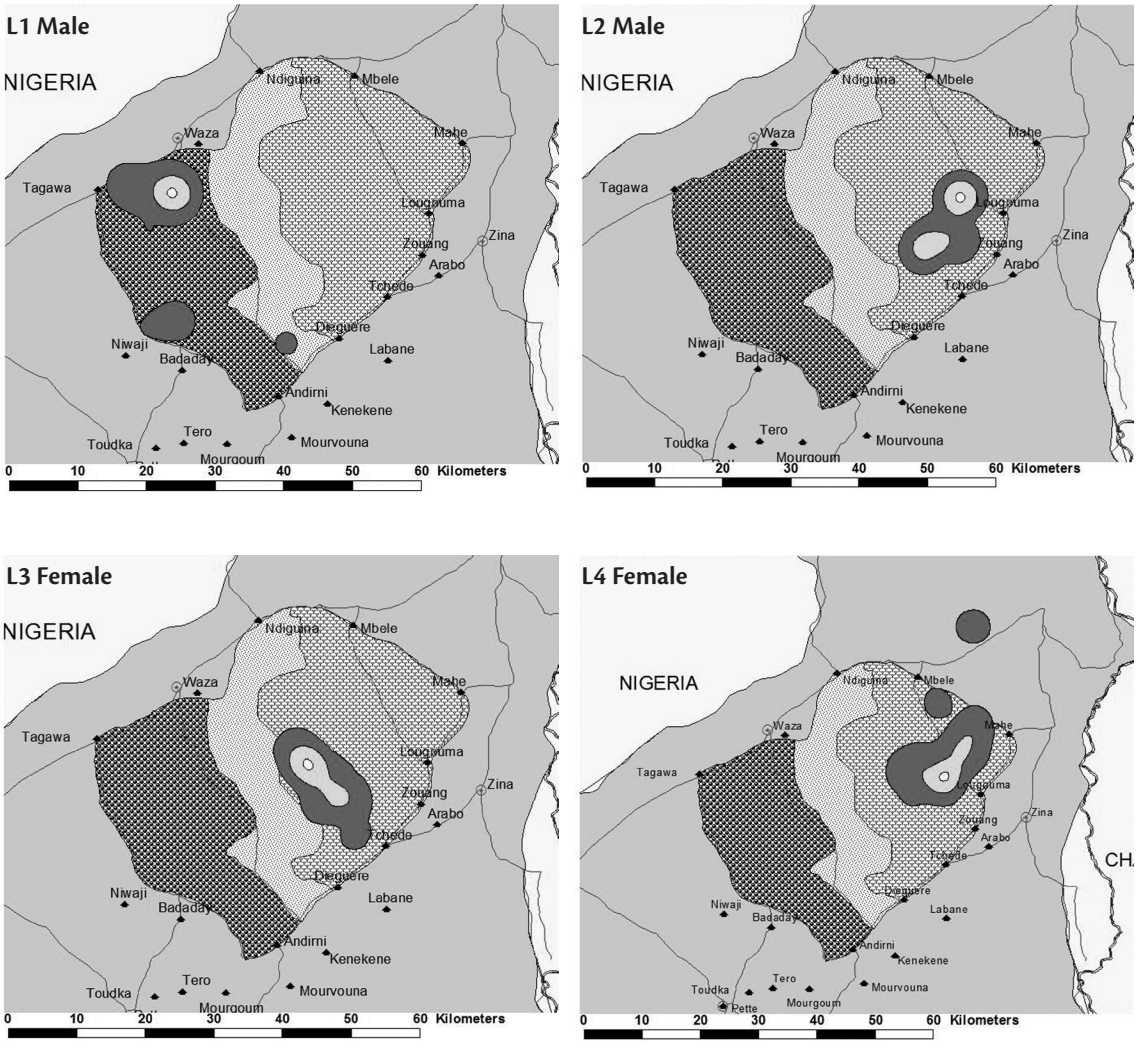

Figure 3.2c Kernel home ranges of four radio-collared lions in Waza National Park in the hot dry season

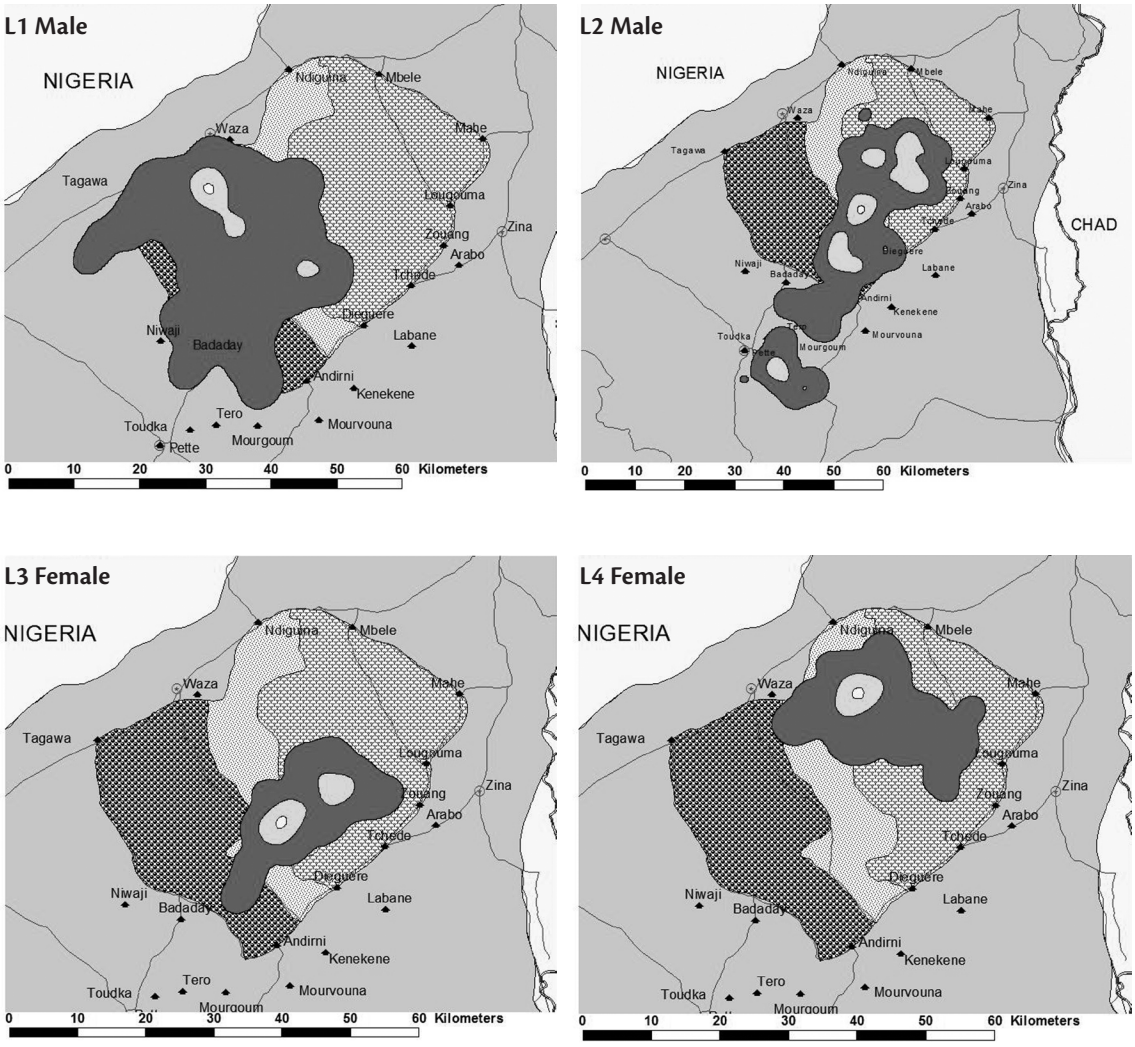

Figure 3.2d Kernel home ranges of radio-collared lions in Waza National Park in the wet season

Table 3.3 Percentage of GPS location fixes indicating presence of lions in different vegetation zones of Waza National Park, Cameroon in 2007-2008

LION	Woodland	Acacia	Floodplain	Inside park	Outside park
LI	75.1	22.9	1.9	68.7	29.0
L2	9.3	27.2	63.5	79.1	20.8
L3	4.1	37.7	58.2	100,00	–
L4	0.0	12.6	87.4	86.1	13.6
All lions	22.1	22.1	55.9	79.1	20.7

Crucially, 21% of the GPS fixes were located outside the park (Table 3.3), with lions spending most time outside park during the cold dry season (57% of fixes), less during the wet season (39%), and the least during the hot dry season (7%). Overall, males spent more time outside the park (25%) than females (14%). Three of the four collared lions appeared to have home ranges that overlapped considerably with human land use, including settlements, farmland and cattle routes (Figure 3.1). Lioness L3 did not leave the park limits.

Social structure

The group size excluding cubs <2 years old of radio-collared lions varied from 1 to 4. Based on sightings during the study period, the mean group size of lions in the entire park was 1.6 (n=21 sightings). The male: female ratio was 1:3 and percentage of cubs was 22% (n=21). The 100% MCP home range of the collared lions overlapped extensively in the central part of the park (Figure 3.1). The 50% fixed kernel home range core areas of lion L2 and lioness L4 were located at the same water hole in the floodplain vegetation zone of the park, indicating that they belonged to the same group. Lions L1 and lionesses L3 and L5 had their core areas located at different water holes in the park. The five radio-collared lions belonged to four different lion groups in the park.

3.4 Discussion

The home range estimate of this study (mean 1015 km^2) is an increase of 58.6% over the previous estimate (630 km^2) recorded in 2000 by Bauer & De Iongh (2005). Statistical analysis did not provide any significant difference for the means. However, this could be attributed to the high standard deviation observed in our data, which was the effect of an in-

fluential outlier. When the outlier was dropped from the analysis, mean MCP for this study was significantly larger ($P<0.05$) than that reported in 2000. Thus as predicted by the prey abundance relationship (van Orsdol *et al*., 1985), lions in Waza National Park during our study had larger home ranges as a reflection of the decline in prey abundance. Also when compared with home range data from studies in West and Central Africa for lions in Pendjari NP, Benin (Sogbohossou, 2011), lions in Zakouma NP, Chad (Vanherle, 2005), and lions in Bénoué NP in Cameroon (Schoe, 2007), Waza NP home ranges were observed to be larger than in any of these studies. In Pendjari NP, Benin (West Africa) which has a prey biomass of 615-1665 kg/km^2, the average home range size of lionesses was 256 km^2 (Sogbohossou, 2011) compared to the 764 km^2 in this study, where the prey biomass was 142 kg/km^2. This clearly reflects increases in home range size in response to decline in prey abundance. The home ranges of lions in Waza National Park were observed to be larger than those reported for lions in East Africa as well (Gittleman & Harvey, 1982; Schaller, 1972), but similar to home range sizes in the arid and semi-arid parts of Southern Africa (e.g. Etosha National Park, Namibia ≈ 600 km^2, Stander, 1991). They were, however, smaller than the home ranges of lions in the arid southern Kalahari (≈ 2823 km^2, Funston, 2011) and the hyper-arid Kunene area (≈ 7337 km^2, Stander, 2006).

We are confident that the difference observed in home range size for lions in Waza National Park between this study, and the study of Bauer & de Iongh (2005), was due to the dramatic decline in prey populations reported within the last decade (Scholte, 2007; Foguekem *et al*., 2010). During this period, prey biomass declined from ≈ 800 kg km^2 in 2000 (Bauer & de Iongh, 2005), to 632 kg km^2 in 2005 (de Iongh *et al*., 2008; Bauer *et al*., 2008), and then to as low as 142 kg km^2 in 2007 (Foguekem *et al*., 2010). Furthermore, this may explain recent increases in the levels of livestock depredation. In 2001, Bauer (2003) found that livestock comprised 10% the diet of lions in Waza National Park, but this has now increased to 22% (Tumenta *et al*., *in review*). In conclusion, these findings add further support to the assertion that the home range size of lions is driven by an inverse relationship with prey abundance (van Orsdol *et al*., 1985; Bauer & de Iongh, 2005; Loveridge *et al*., 2009). In effect, therefore, the carrying capacity for lions in Waza National Park has declined substantially within the last decade, as home range size is known to correlate directly with lion abundance in a specific area (Hemson, 2003).

Similar to the findings of Bauer & de Iongh (2005), the home ranges of male lions were observed to be larger than those of females, supporting the intersexual differences in body mass. The intersexual difference in home range could also be driven by the fact that female ranging behaviour is correlated with the distribution of resources, whereas that of males in addition to the distribution of resources is associated with the distribution of females (Loveridge *et al*., 2009).

Although a majority of the GPS location fixes of the lions within the park were recorded in the floodplain vegetation zone, one cannot conclude that this zone was the most important for lions; this could have been more related to the fact that the floodplain vegetation zone makes up the largest proportion of the park. Lions in the floodplain where observed to shift their core areas to the *Acacia* and Woodland zones in the wet season. This was not only because of shifts in prey distribution, but also because of the inundation of the floodplain zone during the wet and part of the cold dry seasons. However, during the hot dry season, water is the primary limiting factor for ungulate (prey) populations within the park. This means that ungulates congregate at waterholes, briefly creating locally high prey densities, resulting in lions having their smallest home ranges at this time of year. On the other hand, in the wet season water becomes available everywhere allowing prey to disperse within the entire park. The resulting prey scarcity within the park causes lions to range more widely and to move outside of the park in search of prey, thus extending their home range. These patterns are similar to those described by Bauer & de Iongh (2005), but the extent of the wet season dispersal has increased over the last decade and now also includes ranging across the highway parallel to the western limit of the park.

Another possible explanation for lions ranging furthest from the park boundaries in the wet season is related to livestock management. In the hot dry season, wild prey congregate at waterholes within the park whereas livestock, especially cattle, are present in high concentrations just out of the park boundaries and make intrusions into the park to water. When the rains come, the pastoralists move their herds south of the park area, to locations where they spend the wet season. Due to the lion's dependence on livestock as prey (Tumenta *et al*., *in review*), they may follow the pastoralists and their cattle away from the park to their wet season sites. This was alluded to in the wet season of 2007, when villagers in Dogba 45 km from the park boundaries attested that lions were

present in their area only when nomadic pastoralists arrived with their cattle (van Berkel, 2007).

Both males made excursions out of the park, including a distance of 12 km from the park border for lion L1, and up to 27 km for lion L2. Both males had their core area outside of the park during the cold dry season. Lion L1 occupied an area at the Cameroon-Nigeria national boundary, which was open to a higher risk of persecution. This behaviour could render the lions even more vulnerable to persecution and retaliatory killings. Border crossing by lions from Amboseli, Kenya to Tanzania has also been reported after the 2009 drought that caused prey populations to decline in Amboseli (Visser, 2010). Lioness L4 also ventured out of Waza National Park in 2007, moving a distance of 17 km away from the park. During 2008, however, this lioness remained within the park, as did lioness L5. There were reports confirmed by this research of lion presence and attacks on livestock as far as 45 km from the park during the wet season (van Berkel, 2007). Bauer & de Iongh (2005) also observed individual differences regarding lion ranging and livestock depredation. The male lion Hamidou was a habitual problem animal, spending most of his time outside the park and feeding primarily on livestock. One female, in contrast, never left the park and was not observed taking livestock. The other collared lions periodically left the park, where they presumably killed livestock. It is clear that lion-livestock conflicts are serious in the areas surrounding Waza National Park. The local population ranked depredation a priority problem (Bauer, 2003). However, locals do not seem to make much effort to solve the problem and attacks do at times result in retaliatory killing (de Iongh *et al*., 2009; Tumenta *et al*., 2010). Nonetheless, when one considers that 22% of the lions' diet comes from livestock (Tumenta *et al*., *in review*), people do indeed show remarkable levels of tolerance.

Although the lion population in the park has declined to between 14-21 individuals (Tumenta *et al*., 2010), the average group size of lions did not change in the last decade. This rule out the presumption that the home range size of lions might have increased as a consequence of an increase in lion group size (van Orsdol *et al*., 1985; Packer *et al*., 2005). The lion group size of 1.6 observed in this study is similar to 1.5-1.6 reported by Bauer *et al*. (2003), as was the overall male to female ratio of 1:3. It is interesting to note that lion populations in West and Central Africa generally have about the same average group size, typically below three individuals (Bauer *et al*., 2003).

The larger home ranges observed in this study is another indication that the state of the wildlife populations in Waza National Park is in sharp decline, with ungulate (prey) populations deteriorating due to ineffective park protection and management. To restore the populations of the prey species and that of lions, a concerted effort will be needed to implement measures to reverse the existing trends. In particular, the lions need to be prevented from crossing the highway and ranging to bordering Nigeria. A solution may be found in the construction of a partial fence along the western limit of the park. Such a fence would probably considerably reduce the area needed to be surveyed by park staff, concentrating efforts and scarce finances to a more limited area. Management should enforce temporal mapping of pastoral activities around the park base on the seasonal ranging behaviour of the lion.

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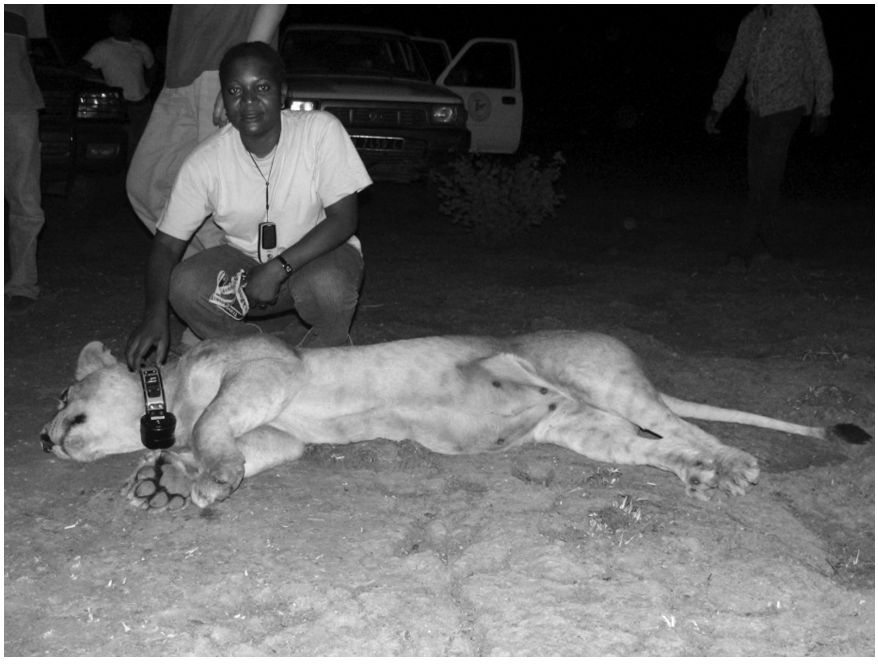
4

Movement and activity patterns of lions (*Panthera leo*) in a semi-arid savannah of Waza National Park, Cameroon

Pricelia N. Tumenta



Radio-collared female lion in Waza National Park, Cameroon

ABSTRACT

Movement and activity patterns were studied for lions in Waza National Park, Cameroon. Lions were radio collared and tracked through radio telemetry. GPS data downloaded from collars were analyzed to determine the lions' movement and activity. The lions covered distances ranging from 0.6 to 41.5 km daily and were more active during the hottest period of the year. Males covered significantly longer distances (7.5 km) than females (5.6 km). However, significantly different was the distance covered by females in the day during the hot dry season (2.2 km) than the males (1.3) km. Lions were more nocturnal than diurnal in their activity, with crepuscular peaks at sunrise and sunset. Lions were generally more active inside (27% of the time) than outside (24% of the time) the park and were more nocturnal outside than inside the park. The Waza lion population seems to be vulnerable to various threats. The main factor that impacts lion movement and activity in Waza National Park may be disturbance caused by anthropogenic interactions including intrusions by local people and possibly tourism in the park. Further research is needed to elucidate this aspect of lion ecology in Waza National Park.

Key words

Panthera leo, movement, lion activity, Waza National Park

4.1 Introduction

Existing studies on the African lion rarely include data concerning their movement and activity patterns. According to Hayward & Hayward (2007), there are only three published studies in East and Southern Africa in this domain for the entire continent. The lack of interest in research on top predators and the relatively high cost needed for such research (Sogbohossou, 2011), has created a gap in knowledge in almost all aspects concerning lions in West and Central Africa.

Radio telemetry permits the collection of data on the movement and activity patterns of top predators. Movement of an animal is defined as a change in the spatial location of the whole individual in time and is a fundamental characteristic of life, driven by processes that act across spatial and temporal scales (Nathan *et al*., 2008). Movement in lions is mainly related to finding resources, seeking refuge, reproduction and territorial defense. Lion activity is defined as the physical movement of an individual over a set distance during a period of time, taking into account the distances that a lion can move (Hayward & Hayward, 2007). Understanding the movement and activity patterns of lions is essential for developing and implementing conservation efforts.

Both ecological and anthropogenic factors influence the movement and activity patterns of lions. Anthropogenic activities such as poaching, tourism, and livestock intrusions may alter the movement and activity patterns of carnivores (George & Crooks, 2006). Lions are social cats that live in family units known as prides and may be highly susceptible to anthropogenic interactions (Woodroffe & Ginsberg, 1998; Woodroffe, 2000; Gittleman *et al*., 2001). The distribution of prey and other habitat features such as water holes influence the movement of lions within their home range (Valeix *et al*., 2010). As with home range, local abundance of prey affects lion movement (Spong, 2002). Schaller (1972) demonstrated the localization of lion movements near rivers in the Serengeti with high prey abundance during the dry season. In areas with low density of suitable prey and poor hunting conditions, lions are known to cover longer distances (Ogutu & Dublin, 2002; Hemson, 2003). Total distances covered by a nomadic male in the Serengeti ranges from 5 to 21.5 km per day vs. 1.3 to 14.5 km a day for a pride (Schaller, 1972). Preliminary studies on lion movement in Bénoué National Park, Cameroon with relatively low prey numbers, revealed that males cover on average 18.6 km per day while females travel 13.2 to 14 km per day (Shoe, 2007).

Lion activity may be influenced by habitat quality, human activity and season. They are nocturnal in areas where there is little cover to stalk prey or where they are persecuted by humans (Mogensen *et al*., 2011). Activity of lions peaks between 17.00 h and 18.00 h, and before 08:00 h. However hunting, feeding and mating may occur at any time of the day depending on weather conditions (Schaller, 1972). On average, lions are perceived as very indolent (Schaller, 1972), and spend about 20-21 hours per day inactive, about 2 hours walking and 40 to 50 min eating. There are exceptions, however: several days of not feeding may be followed by a night with 5 to 6 hours of eating. In contrast with this, Hayward and Hayward (2007) also documented a crepuscular activity pattern for lions in Addo Elephant National Park but lions in this park were active for 41% of the time in 24 hours (10 hours). Social structure and morphological features also influence lion activity pattern. Lions that were not members of a pride were more active than lions living in groups, which could afford safety mechanisms (Hayward & Hayward, 2007). The pale pelage of lionesses, especially sub-adults, reflects heat thereby reducing the animals' heat load and permitting activity during hot periods (West & Packer, 2002). Male lions, on the other hand, with a mane and darker pelage due to increased testosterone at maturity, are more impacted by heat (Hayward & Hayward, 2007). They are thus less active during the hot periods of the day.

From the literature studied, we expected the lions in Waza National Park to cover long distances daily, reflecting their home range size during the various seasons of the year and the low prey density in the Park. We also expected lions in Waza National Park to show a high activity pattern and to be more nocturnal in their activity because of the high anthropogenic pressure on the park. Female lions in Waza National Park were expected to be more active during the day and hot periods of the year than males.

4.2 Materials and methods

Study area

Waza National park is small (1,700 km^2) and isolated, located in the ecologically-fragile and drought-prone zone of Sub Saharan Africa. In this region, desertification has had a significant negative impact on the quality of lion habitat (Chardonnet *et al*., 2005). Rainfall is low and irregular between years. The climate is semi-tropical, with temperatures ranging

from 15º C (January mean minimum) to 48º C (April mean maximum). The area has three characteristic seasons: a wet season, from June to October; a cold dry season, from November to February; and a hot dry season, from March to May. A floodplain of the River Logone, which comprises part of the park, is intercepted by legal migratory routes of cattle from Nigeria, Chad and southern areas of Cameroon. Conflict between wildlife and humans is intense in villages around the park (Bauer & Kari 2001; Tchamba & Elkan, 1995; van Bommel *et al*., 2007; Tumenta *et al*., 2010) suggesting land use interference. The area around the park is densely inhabited by fishermen, agriculturists and pastoralists who were attracted by resources and activities initiated by the Waza Logone Integrated Conservation and development Project (Scholte, 2003).

Data collection and analyses

Lions were captured by free darting after being attracted using a calling station set-up adapted from Ogutu & Dublin (1998). For the collaring protocol, the same procedure was used as Bauer & de Iongh (2005). Four collared lions, whose collars were scheduled to record location fixes every 30 min, provided data for the calculations of distances and activity patterns. Distances between GPS location fixes were calculated in ArcView using successive distances. Activity patterns were measured as a binomial by recording whether or not the lion moved more than 100 m during each 30 min of the day, slightly modified from Hayward & Hayward (2007). A comparison was made for activity patterns in the dry, wet and cold seasons. Diurnal and nocturnal activities were measured by selecting activity between sunrise (at 06:00 h) and sunset (18:00 h) for diurnal activity and between sunset and sunrise for nocturnal activity. Seasonal movements were divided into three seasons; the hot dry season from March-May; the wet season from June-October; and the cold dry season from November-February. Calculations of distances moved by lions were then performed in Microsoft Excel and SPSS to determine daily, diurnal and nocturnal distances during the different seasons. Normality of data was calculated with a Kolmogorov-Smirnov test. Significant differences between male and female lions, day and night as well as significant differences between lions inside and outside the park were calculated with a Mann-Whitney U test. Significant differences in seasonal variation were calculated with the Kruskal-Wallis non-parametric one-way ANOVA on ranks with the Tukey post-hoc test.

4.3 Results

Movement

Lions in Waza National Park covered distances ranging from 0.6 to 41.5 km daily. The overall mean daily distance traveled by lions in Waza National Park was estimated at 6.8 km, SD=5001.4. The four lions (L1-L4) covered mean daily distances ranging from 5.6 to 8.4 km. Differences in the distances travelled by the four lions were significant (χ^2=38.278, df=3 P<0.001). Males moved significantly longer distances (7.5 km, SD=5125.3) than females (5.6 km, SD=3581.3) (z= -5.118, P<0.001). The lions covered significantly longer distances during the night (4.5 km, SD=3008.8) than during the day (1.5 km, SD=1387.1) (z= -20.379, P<0.001). Lions covered their longest daily distances during the hot dry season and the shortest during the cold dry season (Table 4.3) (χ^2=74.782, df= 2, P<0.001). Females covered longer distances during the day than males during all seasons (Table 4.1) and this difference was significant during the hot dry season (z= -4.759, P<0.001). Lions in the woodland zone of the park covered a slightly shorter daily distance (7.8 km) than lions in the floodplain zone of the park (8.4 km).

Table 4.1 **Movement of lions (distances in km) in Waza National Park, 2007-2009**

	Males			Female			All		
	Day	Night	24 hrs	Day	Night	24 hrs	Day	Night	24 hrs
All data	1.11	6.34	7.45	1.65	3.96	5.61	1.54	4.45	6.8
Cold dry season	1.04	3.26	4.3	1.71	3.09	4.8	1.24	2.91	4.15
Hot dry season	1.28	7.37	9.57	2.2	4.8	6.08	2.44	5.02	7.46
Wet season	1.1	8.35	9.45	1.23	4.06	5.29	1.19	5.26	6.45

Daily distances traveled by lions inside the park were not different from distances traveled outside the park (5.5 km and 5.3 km), respectively. Individual lions, however, showed differences in movement patterns inside and outside the park. Lion L1 covered significantly greater distances inside than outside the park, 7.3 km compared to 4.7 km daily (z= -5.512, P<0.001). Lion L4 moved a slightly longer daily distance inside the park (5.4 km) than outside (4.9 km), but this difference was not significant. Males covered a longer daily distance inside the park than outside (1.2 km and 0.7 km), respectively (z= -3.898, P<0.001). During the day, lions covered significantly longer distances inside (1.6 km) than outside the park (0.8 km) (z= -7.502, P<0.001).

Activity

The lions were active 24% of the time throughout the 24-hour cycle, with lion L1 being the most active of all collared lions (active 26% of the time). They were most active during the night (33% of the time) with crepuscular peaks at sunrise and sunset, and reduced their activity during the hottest parts of the day (Figure 4.1).

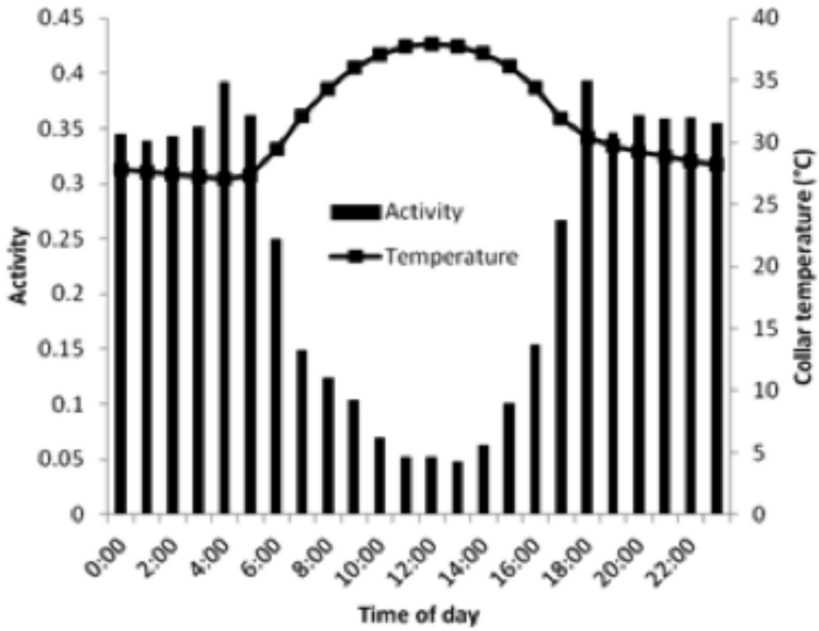


Figure 4.1 **Percentage daily activity of collared lions in Waza NP, 2007-2009**

During the day, lions were active 13% of the time. Male lions showed a different activity pattern from females during the 24-h cycle. Males were more active during nocturnal hours whereas females were more active during the day (Figure 4.2).

Lion activity differed with season (Table 4.2) (χ^2=51.169, df= 2, P<0.001). The lions were least active during the cold dry season (19% of the time). Females were significantly more active (16%) than males (0.9%) during the day in this season (Z= -4.454, P<0.001). Male lions were most active during the wet season (28% of the time) while female lions were most active during the hot dry season (26% of the time). Lions in the woodland zone of the park were more active (26%) than lions in the floodplain zone of the park (24%).

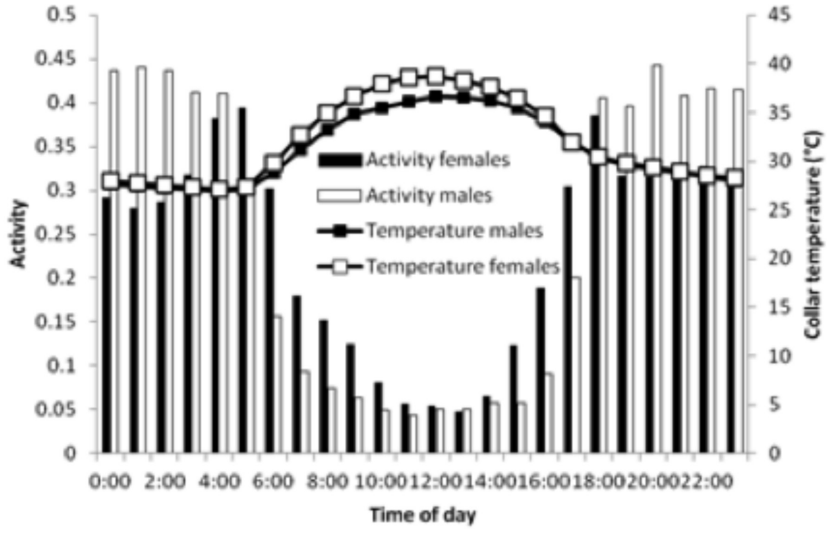


Figure 4.2 **Percentage daily activity of male and female lions in Waza NP, 2007-2009**

Table 4.2 **Activity of lions in Waza National Park (% activity per 24 hour), 2007-2009**

	Males			Female			All		
	Day	Night	24 hrs	Day	Night	24 hrs	Day	Night	24 hrs
All data	0.08	0.38	0.24	0.14	0.32	0.23	0.13	0.33	0.24
Cold dry season	0.09	0.23	0.16	0.16	0.25	0.21	0.15	0.23	0.19
Hot dry season	0.09	0.43	0.26	0.18	0.33	0.26	0.16	0.34	0.25
Wet season	0.08	0.48	0.28	0.11	0.36	0.24	0.10	0.40	0.25

Figures in table are averages multiplied by 100 to obtain % activity

Overall, lions were more active inside (27% of the time) than outside the park (24% of the time) ($z= -3.219$, $P<0.005$) (Figure 4.3).

During the day, lions were more active inside than outside the park whilst the reverse was true during the night (Table 4.3). In other words, the lions were more nocturnal outside than inside the park. Lion L1 had the highest activity (active 41% of the time during the 24-hour cycle) outside the park of all the radio-collared lions.

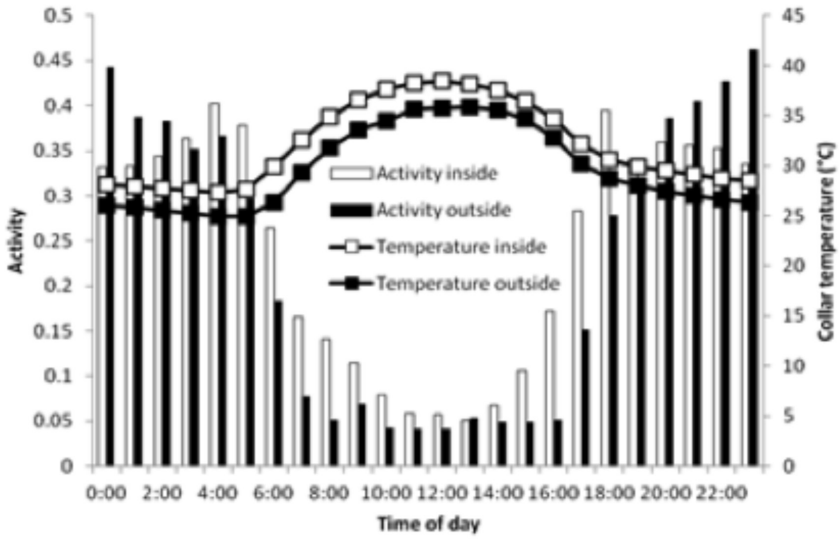


Figure 4.3 **Percentage daily activity of lions inside and outside Waza NP, 2007-2009**

Table 4.3 **Activity of lions in inside and outside Waza National Park (% activity per day), 2007-2009**

	Males		Female		All	
	Inside	Outside	Inside	Outside	Inside	Outside
All data	0.27	0.36	0.24	0.39	0.27	0.24
Day	0.09	0.08	0.15	0.13	0.14	0.09
Night	0.43	0.45	0.32	0.47	0.33	0.46

4.4 Discussion

The daily distances covered by lions in Waza National Park were long compared to those recorded by Shoe (2007) for lions in Bénoué National Park in Cameroon. The Bénoué ecosystem is still relatively intact and affords better habitat resources than Waza National Park. The average daily distances did not reflect the home range sizes of lions during the various seasons in the park. The lions covered the longest distance when home range size was smallest, during the hot dry season (Tumenta *et al*., *in review*). This is the period when prey congregate at waterholes and the lions also stay close. Movement during this period is localized around the waterholes, concurring with Schaller (1972) and Spong (2002). However

the lions in Waza NP covered the longest distances during this period. A possible explanation for this behaviour could be the anthropogenic pressure on the park. Lion activity was also recorded to be highest during this period. Human activities such as poaching, intrusions by pastoralists and local people are intensified during the hot dry season, when water and pasture are scarce in the surrounding areas and only found in the floodplain. Many local people and pastoralists enter the park at this time of the year. Poachers dig hide-outs close to waterholes from where they shoot game and smoke the meat on the site. The hot dry season is also the peak period for game viewing in Waza National Park. Tourists drive through the park and stop at waterholes (where wildlife is concentrated) for game viewing. These anthropogenic activities may perturbate the lions' normal activity pattern causing them to move more for cover and safety during these hot months. Disturbance by tourists and mega-herbivores, which are mammals exceeding 1000 kg such as elephants and giraffes, causing lions to show a high activity pattern has been reported before in Addo Elephant National Park (Hayward & Hayward, 2007). As elsewhere, male lions covered longer distances than females, reflecting their higher energetic needs (Schaller, 1972).

Lions in Waza National Park were active for about 6 hours of the 24-h cycle, which differed from the 3-4 hours of activity reported in the Serengeti (Schaller, 1972). Although we recorded 24% of activity during the 24-hour cycle, which was different from the 41% recorded by Hayward & Hayward (2007) in Addo Elephant National Park, both findings may be comparable. We scored movements of more than 100 m within 30 min as active, whereas Hayward & Hayward (2007) scored movement more than 100 m within 1 hour as active. The difference in methodology may explain the observed differences in activity. Females moved longer distances and were more active during the day during all the seasons. This can be explained by the fact that females are more temperature tolerant than males, as observed by West & Packer (2002) and Hayward & Hayward (2007).

The distances traveled by lions in Waza National Park were long, possibly reflecting the state of the habitat. The activity pattern raises some concerns that need further investigation. The lion population appears to be subjected to certain forms of stress. Prey abundance may not be the only factor influencing lion ecology in Waza National Park. Other factors that impact lion movement and activity in Waza National Park may be disturbances from various forms of anthropogenic interactions taking place in

and around the park. Further research is needed to investigate the drivers of the movement and activity patterns of lions in the park.

Acknowledgements

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5

Feeding ecology of the African lion in a livestock dominated area, Waza National Park, Cameroon

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Based on article submitted to the journal *Mammalia*

Carcass of cattle inside Waza National Park, Cameroon

ABSTRACT

The feeding ecology of lions (*Panthera leo*) was investigated in and around Waza National Park (Waza NP), Cameroon. Diet was determined using lion scat and GPS cluster analysis of carcasses in the field. Results of analyses revealed a broad dietary niche, with lions consuming 14 different prey species in and around the park. The majority of species selected were medium and large prey (medium 50-200 kg; large >200 kg), the western kob (*Kobus kob kob*) being the most common prey species in the diet of lions. Livestock was demonstrated to be an important prey for lions, constituting 22% of their diet. Lions seemed to consume livestock on a regular basis in order to survive, selecting zebu cattle more (80%) than other livestock. There was evidence of ongoing livestock intrusions into the park, with cattle constituting 18% of prey consumed inside the park. The Acacia vegetation zone of the park was the most important habitat for the consumption of prey species. Wild prey was also consumed outside the park, revealing excursions by wild prey outside of park borders. Total prey consumption inside the park was higher than outside, indicating that the park still is an important source of prey for lions. Prey consumption by lions followed the presence and abundance of prey species in and around Waza National Park, with lions showing a preference for wild prey over livestock. Management efforts that can reduce the intrusions of livestock into the park and reverse the declining trends of wild prey populations will significantly reduce predation of livestock and prevent persecution of lions in this park.

Key words

Diet composition, Prey preference, Scat analysis, GPS data clusters, African lion

5.1 Introduction

Efforts to conserve lions are often challenged by increasingly complex requirements broadly associated with human population growth. Amongst a list of requirements, lions require a diverse and stable prey base to meet their energetic needs. Lion diet thus varies across a range of predator-prey and environment-related variables (Funston *et al*., 2001; Radloff & du Toit, 2004). The morphology, behavior and spatial distribution of both predator and prey limit prey supply to predators. Lions prey upon a broad range of species, typically ranging from medium to large-sized mammals. Lions in East and Southern Africa select a higher proportion of large prey (Hayward & Kerley, 2005; Owen-Smith & Mills, 2008) than lions in West and Central Africa (Breuer, 2005; Bauer *et al*., 2008). Lion prey weight varies from 190-550 kg, the most preferred weight being 350 kg (Hayward & Kerley, 2005). Prey species outside the preferred weight range are generally avoided. Lions are commonly thought to be opportunistic in their feeding (Schaller, 1972; Hayward & Kerley, 2005) and to consume prey according to availability (Mills & Shenk, 1992; Breuer, 2005; Bauer *et al*., 2008). Yet prey preference is influenced by many factors, notably: prey size, prey availability (density and scarcity) and prey vulnerability (Schaller, 1972; Carbone *et al*., 1999; Hayward & Kerley, 2005).

According to Carbone *et al*. (1999), the energetic requirements of large carnivores favour the selection of large-sized prey. Schaller (1972) suggests that lions rarely select small mammals and birds because the energy spent on capturing and consuming the prey exceeds the energy intake. Therefore, large predators are expected to hunt the largest prey that can be safely killed (Sunquist & Sunquist, 1997).

Prey availability influences the selection of prey by lions. If a prey species is killed more often than would be expected according to chance based on its abundance, it is considered a preferred prey species (Hayward & Kerley, 2005). Predators have been reported to increase their attacks on livestock as a consequence of low wild prey availability (Mishra, 1997; de Iongh *et al.*, 2004; Woodroffe & Frank, 2005). Hemson (2003) found that lions in the Makgadikgadi National Park, Botswana, increased their frequency of livestock predation during seasonal periods of low wild prey availability. Patterson *et al*. (2004) also recorded that livestock depredation increased during the lean season, when native prey is less accessible in Tsavo National Park. In Faro National Park and the surroundings of the Bénoué complex in Cameroon, diet analysis revealed that the abun-

dant western kob was the most common prey item in the lion's diet, with livestock absent from the diet of all carnivores in this area (Weladji & Tchamba, 2003; Breuer, 2005).

Prey vulnerability is another factor that also influences prey selection. Livestock lack the physiological or morphological adaptations to escape from predators. They are easier to catch than wild prey and are thus considered vulnerable. Lions have also been recorded to take a-typical prey under certain conditions. In Chobe National park, they have been reported to take very large prey such as elephants (*Loxodonta africana*) when sufficiently stressed (Power & Compion, 2009).

The wild prey base for lions in Waza NP has declined progressively in recent decades, precipitated by a severe rinderpest outbreak in 1982/83, impact of the Maga dam on the natural regime of the Waza Logone floodplain, drought (Scholte, 2005; Scholte *et al.*, 2007), and more recently, intensive human encroachment and poaching (de Iongh *et al.*, 2008, 2009; Foguekem *et al.*, 2010, Tumenta *et al.*, 2010). The lion population in Waza NP has also suffered persecution by herders in retaliation for livestock depredation. As a result, the population size has dropped from 50 in 2002 to less than 20 in 2008 (Bauer & van der Merwe, 2004; Tumenta *et al.*, 2010). Aerial counts of mammals in 2007 revealed a minimum of 3,466 herbivorous mammals in the entire park, in contrast to a minimum of 21,000 livestock counted in a 5-km peripheral zone east of the park (Foguekem *et al.*, 2010).

Therefore we expect that lions in Waza NP may start to switch their diet to the more abundant livestock, given its profitability as a large-sized and vulnerable prey. Furthermore, because of the low natural prey density, we expect lions to be less selective and to consume a wide range of prey species. To test this, we assumed that the proportions of prey species detected in lion scat and carcasses identified at GPS clusters will reflect the actual proportions of prey in the park. The proportion of livestock relative to natural prey species in the diet of Waza lions has important management implications for lion conservation in this park.

5.2 Materials and methods

Study Area

Waza NP lies between latitudes 10°50' and 11°40' and longitudes 14°20' and 15°00'. The climate is Sudano-Sahelian and semi-arid tropical. Rainfall is low and irregular between years, with a mean annual rainfall of 600 mm (Beauvilain, 1995). Temperatures range from 15º C (January mean minimum) to 48º C (April mean maximum).

Waza National Park has three main vegetation types: 1) In the eastern half with heavy cracking clay soils (vertisols), the floodplain vegetation is dominated by grasses such as *Sorghum arundinaceum, Pennisetum ramosum, Echinochloa pyramidalis, Oriza longistaminata, Hyparrhenia rufa* and *Vetiveria nigritana*; 2) The area between the floodplain and the woodland zones, also with clay soils, is consists mainly of *Acacia seyal* trees interspersed with *Balanites aegyptiaca, Pilostigma reticulata* and *Sorghum arundinaceum*; 3) The woodland zone on sandy soils in the west of the park is dominated by *Sclerocarya birrea, Anogeissus leiocarpus* and *Lannea humilis* (Wit, 1975).

Waza NP has an important animal diversity, with at least 30 species of mammals including elephant (*Loxodonta Africana),* lion (*Panthera leo*), giraffe (*Giraffa camelopardalis*), spotted hyena (*Crocuta crocuta*), striped hyena (*Hyaena hyaena*), western kob (*Kobus kob kob*), topi (*Damaliscus korrigum*), roan antelope (*Hippotragus equines*), red fronted gazelle (*Gazella rufifrons*), warthog (*Phacochoerus africanus*), reedbuck (*Redunca redunca*) and Grimm's duiker (*Sylvicarpa grimmia*) (Tchamba & Elkan, 1995).

Methods

Observing lions at kills in areas of low prey density with intense human pressure is difficult. Lion diet was investigated using two methods: scat analysis and GPS cluster search for carcasses of prey consumed by lions (Breuer, 2005; Anderson & Lindzey, 2003; Sand *et al*., 2005; Tambling *et al*., 2010)

Lion Scat Analysis

Lion scat samples were collected from January to June, 2008 and 2009 in and around Waza NP. When more than one scat sample was found in the same location, only one sample was analyzed because pride members eat from the same kill. Faecal samples were sun dried, then ground in a mortar and washed in a 1 mm sieve, using hot water to separate hair from other organic material. Separated hairs were washed in acetone, hydrated in 100% ethanol and dried on filter paper (Breuer, 2005 citing Ramakrishnan *et al*., 1999). Hair was analyzed macroscopically (form, length and colour), using a stereo microscope and microscopically (for scale patterns) under a light microscope following methods described in Breuer (2005). A reference collection of prey hair was made from hairs of ungulates collected during the research period. Scale patterns were compared with this reference collection, as well as a reference collection from animal hides at Naturalis, the National Centre for Biodiversity in Leiden, The Netherlands.

GPS cluster search for prey species consumed by lions

Lions were collared in May 2007 and in May 2008 in Waza NP for monitoring purposes. Four Vectronic GPS-PLUS collars equipped with a VHF transmitter, supplied with a handheld terminal that communicates with the collars, were attached on two males (L1 &L2) and two females (L3&L4). In addition, an African Wildlife Tracking (AWT) GPS GSM collar was attached to a female (L5). GPS positions were regularly downloaded from the collars, the locations of clusters of lion positions entered into a handheld GPS unit and the sites visited to investigate the lion's diet.

Studies have indicated that lions are most active during the night and feed on average 4-5 hours when a kill of reasonable proportion is acquired (Schaller, 1972). Therefore the nocturnal GPS position clusters of three hours and longer within a range of 50-m radius were selected. The GPS-point in the middle of the cluster was entered into a GPS unit and the location was visited by car and on foot. At the location of the selected fix, we searched for carcasses within a 100-m radius. Carcasses found further than 100 m were not considered to have been consumed by one of the collared lions during the study period. Location, species, and size (small, <50 kg; medium, 50-200 kg; large, >200 kg; Bauer *et al.*, 2008) were noted. Mean adult female body weight (Kingdon, 1997) was used for biomass calculations of prey. Age of the carcasses (time of kill) was

roughly estimated in the field and was later compared with the exact locations of GPS-collared lions. We assumed the presence of a collared lion at a kill when the lion was within 50 m of the carcass at the time of the kill.

Data analysis

Prey selection was calculated using frequency of occurrence expressed as percentages. The relative frequency (r/R) is the relation of identified prey items (r) to the number of all prey items found during analysis (R) according to Breuer (2005). The fractions of each prey species found in the diet of lions were used to calculate percentage of prey consumed during various seasons, in different vegetation zones, inside and outside the park, by male and female lions and also the percentage of wild prey and livestock consumed. Chi-square tests were performed to test the differences in prey consumed in various vegetations, seasons, according to prey size, inside and outside the park, during the day and night, by male and female lions; and the difference in wild prey and livestock consumption. A Bonferonni correction was applied to the chi-square results, and a new P-value was calculated from the overall P-value of 0.05, based on the number of tests performed on the data. The results of the chi-square test were then weighted on the calculated P-value, which was approximately 0.01.

Prey preference was calculated for the GPS cluster data according to Jacobs' index with log (Q) giving positive values for preference and negative values for avoidance (Jacobs, 1974), with the formula D=(r-p)/(r+p-2rp), where r is the proportion of GPS-pointed kills for a particular species (the fraction of a species in the diet) and p is the proportional availability of that species (the fraction of the species in the habitat). Prey preference was calculated only for species for which abundance estimates were available. Data of prey abundance were derived from large mammal censuses in Waza National Park in 2007 and 2010 (Foguekem *et al*., 2010; Saleh, 2010)

5.3 Results

A total of 174 scat samples were collected in Waza NP during the study period and 206 prey items were identified. Analysis of these samples revealed a total of eight different prey species selected by lions in Waza NP.

GPS cluster data revealed a total of 14 prey species from 162 carcasses of prey species identified. Prey species common to both techniques included the western kob (*Kobus kob kob*), topi (*Damaliscus korrigum*), roan antelope (*Hippotragus equinus*), red-fronted gazelle (*Gazella rufifrons*), warthog (*Phacochoerus africanus*), giraffe (*Giraffa camelopardalis*), cattle (*Bos primigenius indicus*), and shoats (sheep and goats). There was no significant difference in the proportions of the eight key prey species in the diet of Waza NP lions as investigated with the two research methods (Table 5.1; χ^2=11.820, df=7, P=0.107). Thus for further analysis only the GPS cluster data was used, as it revealed all eight prey species found in the scat analysis.

Table 5.1 Numbers and percentages of key prey species selected by lions in Waza NP, 2008-2009

Prey species	GPS clusters		Scat samples	
	Number of prey items	Percentages (%)	Number of prey items	Percentages (%)
Kob	38	25.7	64	31.1
Topi	27	18.2	40	19.4
Roan	21	14.2	33	16.0
Gazelle	6	4.1	10	4.9
Warthog	4	2.7	21	10.2
Giraffe	21	14.2	9	4.4
Cattle	28	18.9	24	11.7
Shoats	3	2.0	5	2.4
Total	**148**		**206**	

In addition to the eight species listed above, the GPS cluster data (n=162) identified marabou stork (Leptoptilos crumeniferus), horse (*Equus ferus caballus*), jackal (*Canis aureus*), reedbuck (*Redunca redunca*) and ostrich (*Struthio camelus*). The percent contribution of each prey species to the total diet of lions was determined (Figure 5.1). The most important prey item was the western kob (23%), followed by topi (17%), cattle (17%), roan antelope (13%) and giraffe (13%). Overall, wild prey constituted 78% of the lion's diet, calculated on a number basis, against 22% contributed by livestock (χ^2=52.25, df=1, P<0.05).

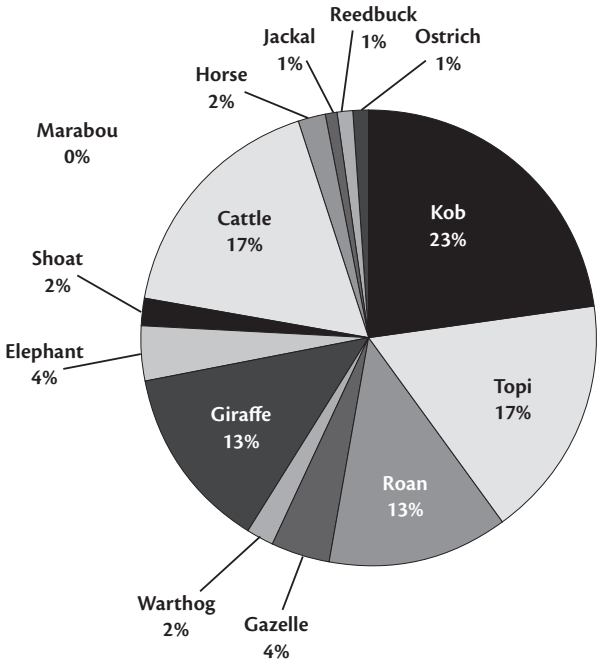

Figure 5.1 **Percentage of various prey species of wild prey and livestock in lion diet, Waza National Park (n=162 carcasses), 2008-2009**

Most prey species (48.8% of total) consumed by lions belonged to the large-sized prey category, followed by medium-sized prey (40.7%) and small-sized prey (10.5%) (Figure 5.2). The differences between the size categories when calculated for carcasses identified during the study period were significant (χ^2=39.59, df=2, P<0.05).

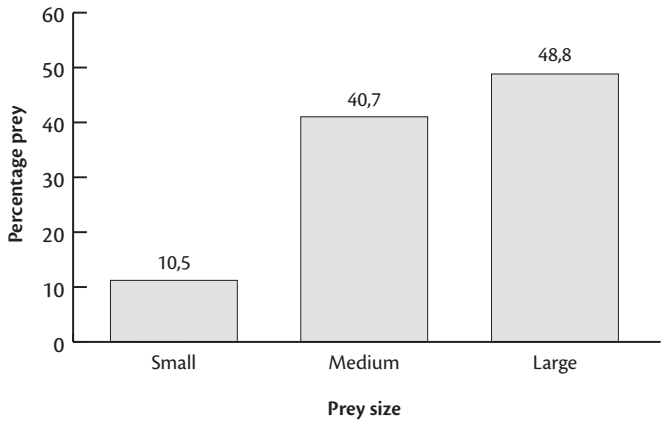

Figure 5.2 **Consumption of prey species according to size category by lions, Waza NP (n=162 carcasses), 2008-2009**

The highest number of prey species were consumed in the Acacia vegetation zone (38.3%), followed by the woodland vegetation zone (34.6%) and the floodplain vegetation zone with 27.2% (Figure 5.3). However prey consumption within various vegetation zones of the park was not significantly different.

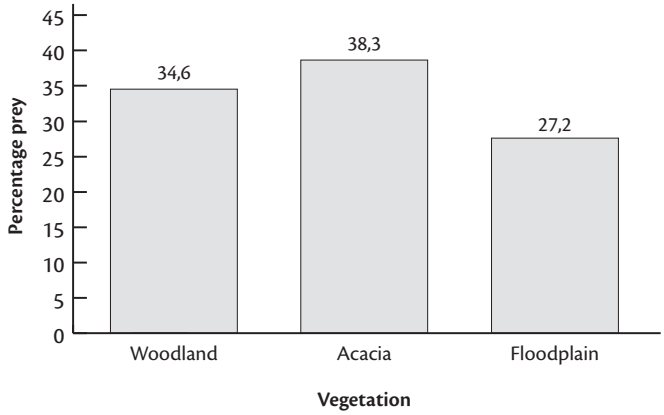

Figure 5.3 **Consumption of prey species by lions in different vegetation zones in Waza NP (n=162 carcasses), 2008-2009**

In all three seasons (cold dry, hot dry and wet), significantly more wild prey was consumed than livestock (χ^2=12.689, df=1, P<0.005). Irrespective of prey type (wild prey and livestock), the highest predation was recorded during the wet season, followed by the cold dry season while the lowest predation was recorded during the hot dry season (Figure 5.4). Predation was not significantly different between the cold dry and wet seasons, but predation during these two seasons was significantly higher than predation during the hot dry season (χ^2=13.78, df=2, P=0.05). Livestock was more often consumed during the cold dry season than during the wet and the hot dry season (χ^2=17.2, df=2, P<0.005)

Male and female lions showed a difference in predation on livestock and on wild prey across the seasons. Female lion predation on livestock was significantly higher during the cold dry season than during the wet season and hot dry season (χ^2=23.519, df=2, P<0.005). Male lion predation on livestock was rather higher during the wet season than during the cold dry season and the hot dry season but this difference was not significant.

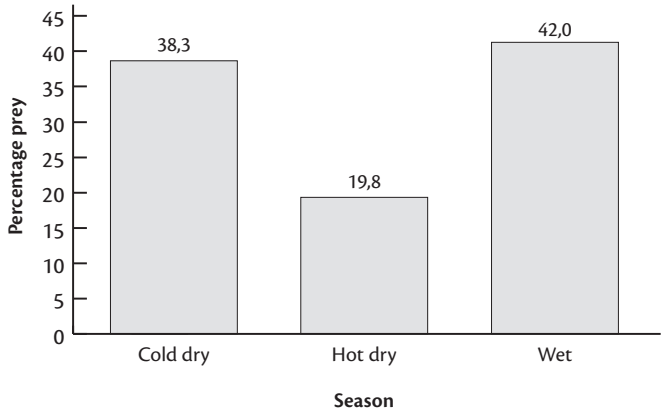

Figure 5.4 **Consumption of prey species by lions during different seasons in Waza NP (n=162 carcasses), 2008-2009**

The most preferred prey species according to Jacobs' index was red-fronted gazelle, followed by warthog, whereas the most avoided prey species was roan antelope (Table 5.2). The gazelle, warthog and all species of livestock were mostly consumed during the cold dry season. However, only cattle was significantly consumed during the cold dry season (χ^2=15.5, df=2, P<0.001). Topi, roan and giraffe were mostly consumed during the wet season while the western kob was mostly consumed during the hot dry season but these were not significant (Figure 5.5).

Table 5.2 **Prey preference of lions revealed by carcasses from GPS cluster data in Waza NP (n=162 carcasses), 2008-2009**

Prey Species	Number of prey items	Abundance in Waza NP	Body mass	3/4*Body Mass	% of Prey Species	% Prey Available	Jacobs' index
Kob	38	1,562	69	52	25.68	6.45	-0.06428
Topi	27	848	113	85	18.24	3.5	0.139135
Roan	21	148	252	189	14.19	0.61	-5.40648
Gazelle	6	28	20	15	4.05	0.12	1.228893
Warthog	4	21	60	45	2.7	0.09	1.132813
Giraffe	21	604	815	611	14.19	2.49	-0.21672
Cattle	28	17,459	330	248	18.92	72.12	0.020167
Shoats	3	3,543	35	26	2.03	14.63	0.294821

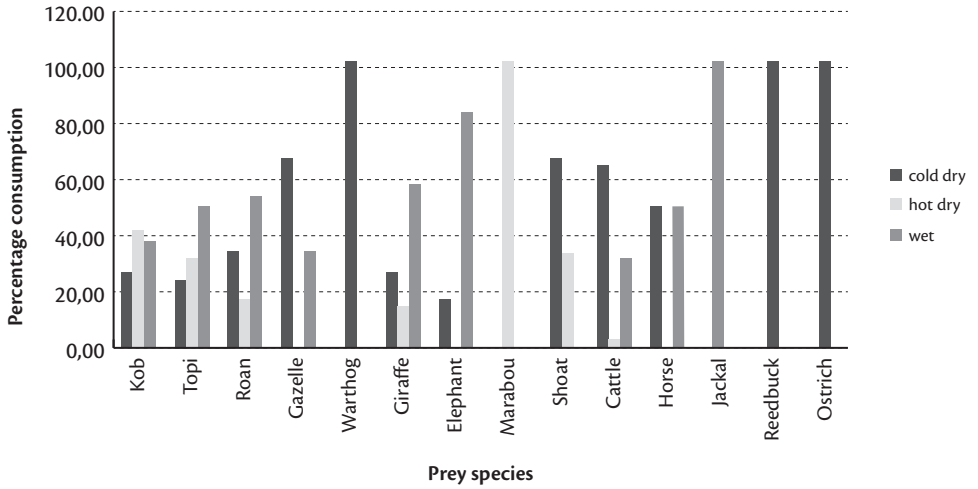

Figure 5.5 **Different prey species consumed by lion in Waza NP during different seasons (n=162 carcasses), 2008-2009**

A majority of the prey (67.3%) were consumed at night (χ^2=19.36, df=1, P<0.05). Prey species consumed inside the park (81%) were significantly higher than prey species consumed outside the park (19%) (χ^2=64.22, df=1, P<0.05). Cattle constituted 18% of prey consumed inside the park. Significantly more wild prey was consumed inside than outside the park (χ^2=111.8, df=1, P<0.05). However, about 6.7% of wild prey predation took place outside the park. Inside the park, male and female lions consumed both wild prey and livestock while outside the park only the males consumed both types of prey; females consumed only livestock.

5.4 Discussion and conclusion

The use of scat analysis together with the GPS cluster method was an attempt to describe the diet of lions in Waza National Park with the ultimate goal of improving conservation efforts. The shortcomings of the scat analysis method were offset by the GPS cluster method, which was able to link data about prey species to the location and time of the kill, and to the sex of lions. The GPS cluster technique of identifying carcasses has proven useful and recommendable to determine lion diet in Waza National Park. It should be noted however, that this method works best when the GPS cluster data is not more than six months old; GPS-pointed kills should be searched at the end of the dry season of the study season.

Lions were found to consume a wide range of ungulate species encountered in and around Waza National Park. The niche breadth of lions included 14 prey species of both wild prey and livestock. Prey proportions in lions' diet reflected more or less the proportion of occurrence of wild prey species in Waza National Park, with a preference for medium to large-sized ungulates. The lions were however, similar to the lions in East and Southern Africa in selecting a higher proportion of large-sized prey (Hayward & Kerley, 2005; Owen-Smith & Mills, 2008) but different from findings recorded in West and Central Africa on lion diet by previous authors (Breuer, 2005; Bauer *et al*., 2008). The recent decrease in medium-sized prey (Scholte *et al*., 2007) and an increase in cattle predation observed in this study could be responsible for the difference between these findings with those of Bauer *et al*. (2008).

Prey preference indices, however, were not dictated by the relative abundance, with the most preferred species namely red-fronted gazelle and warthog being relatively less abundant than more common medium and large-sized species. The preference for warthog could be explained by the slow evasion rate shown by this species and also the fact that the lion hunts them inside their burrows (Druce *et al*., 2004). What remains unclear is the high preference for the red-fronted gazelle.

Of concern, however, was that livestock comprised as much as 22% of the lion's diet within and outside the park, confirming earlier studies on livestock depredation in the Waza NP area based on interviews (Bauer & Kari, 2001; van Bommel *et al*., 2007; Bauer *et al*., 2008; Bauer *et al*., 2010; Tumenta *et al*., *in press*). Cattle comprised 80% of the livestock consumed by lions, highlighting the lion's preference for large prey when hunting livestock (Kruuk, 1980; Mills, 1992; Karani, 1994; Funston, 2001). However, with respect to the preference index, lions showed the lowest preference for cattle, indicating that although they are abundant, lions prefer to hunt wild prey species. This can most probably be attributed to the persecution that generally follows the consumption of livestock (de Iongh *et al*., 2009; Tumenta *et al*., 2010).

The acacia vegetation zone of the park turned out to be the richest in prey species occurrence, and lions consumed the highest amount of prey in this zone. During the dry season all except one watering point in this zone were found to be dry. These results highlight the need for management to rehabilitate the watering points in this zone, in order to prevent animals from moving out to areas easily accessed by poachers during this

period. Livestock predation was highest during the cold dry season, coinciding with the period when migratory livestock is moving into the area to spend the dry months of the year. Management should intensify surveillance of the park boundaries during this period, as this has proven to reduce livestock intrusions into the park and to cut down livestock depredation (Bauer *et al*., 2010, Tumenta *et al*., *in press*). Male and female lions both moved out of the park but showed differences in prey consumption. The highest predation took place at night, concurring with earlier studies on livestock depredation in Waza National Park (Bauer & Kari, 2001; van Bommel *et al*., 2007; Tumenta *et al*., *in press*) and elsewhere (Ogada *et al*., 2003; Hemson, 2003; Patterson *et al*., 2004; Frank *et al*., 2005). The majority of prey was consumed inside the park (81%), cattle constituting 18% of this amount. This provides evidence of cattle intrusions into the park for pasture and water, calling for continuous surveillance by park management. Although only a small amount (6.7%) of wild prey predation was recorded out of the park, it would be necessary for future research to determine why wild prey move out of the park.

The diet of lions in Waza National Park is quite diverse, reflecting the low wild prey biomass now available in the park. Prey consumption by lions followed the presence and abundance of wild prey species in and around Waza National Park. Livestock, especially cattle, have become an important prey for lions in Waza National Park. It is not preferred however, most probably because of the persecution that follows its consumption. The future of lions in this park depends on the efforts that management will deploy to reduce livestock intrusion into the park and to increase populations of wild prey, in order to prevent lions from consuming livestock.

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6

The effect of moon phase on lion (*Panthera leo*) activity patterns and livestock depredation: a case study in Waza National Park, Northern Cameroon

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Based on article submitted to *Oryx, International Journal of Flora & Fauna*

Radio telemetry in Waza National Park, Cameroon

ABSTRACT

Lion-livestock conflicts are recognized as one of the main factors contributing to the decline of lions in West and Central Africa. We investigated the effects of moon phase on livestock predation and lion activity, in order to understand the role that moon phase plays on the hunting behaviour of lions and circumstances leading to livestock predation. We collared five lions (2 males, 3 females) to record their GPS positions at 30-min intervals, for a total of 48 fixes per day and used the GPS-Cluster method to obtain information about the lion's prey preference in relation to moon phase. The results showed that moon phase has no significant effect on lion activity. An increase in livestock predation was observed during full moon phases but was not significantly different from predation during new moon phases. Further research is needed to gather more data on livestock predation during moon phases. This information could be useful to generate practical recommendations for conflict mitigation.

Key words

lion-livestock conflict, moon phase, GPS-Cluster method

6.1 Introduction

The loss, degradation and fragmentation of suitable lion habitat, mainly as a result of rapid human population growth, pose a major threat to the lion population in both West and Central Africa (IUCN SSC Cat Specialist Group, 2006; Bauer & Nowell, 2004). Over the past three decades, encroachment of settlements and agricultural fields around and into protected areas have coincided with an increase in poaching activities (Bauer *et al*., 2003; de Iongh *et al*., 2009; Tumenta *et al*., 2010) as well as a higher frequency of contact between people, their cattle and lions (IUCN SSC Cat Specialist Group, 2006). Retaliatory killing of lions by livestock owners is considered to be one of the most important factors contributing to the decline in lion numbers in Central Africa, and especially in Waza National Park, Northern Cameroon (Bauer *et al*., 2003; Tumenta *et al*., 2010).

Distance to the park boundary and season appeared to be important factors determining the occurrence of livestock predation in Waza National Park (van Bommel *et al*., 2007). In villages close to the park, livestock predation was high irrespective of season, while in villages farther from the park, livestock predation was low and mainly occurred during the wet season. Overall, more incidences of livestock predation by lions were reported during the wet season, when natural wild prey is more dispersed and becomes more difficult to catch (de Iongh & Bauer 2008). Livestock was demonstrated to be an important prey to lions in Waza National Park, constituting 22% of their diet; however livestock appeared not to be a preferred prey species (van Rijssel, 2008; Tumenta *et al*., *in review*).

Hunting decisions in lions are influenced by prey preference, the chance of success, the possible risks associated with the hunt of a particular prey and the level of food deficiency, also defined as hunger (Cooper *et al*., 2007). The wrong choice can result in energy misspent in an unsuccessful hunt, injury or even death (Hayward, 2009). Prey preference of lions is affected by prey size, prey availability and prey density (Hayward & Kerley, 2005; Schaller, 1976). Lions are opportunistic predators and may eat whatever they can catch but in most cases fewer than five species, most of them >200 kg, contribute to about three-quarters of the lions' diet (Schaller, 1976).

Several factors contribute to lion hunting success, some of which are related to the prey itself. These include morphological characteristics

which make them to escape predators, diverse physiological factors that decrease the species' vulnerability and behaviour patterns which reduce the chance of meeting a lion (Schaller, 1976; Valeix *et al*., 2009; Valeix *et al*., 2011). Features of lions that affect hunting success include the age and sex of the lion, the method of hunting used as well as the number of lions (group size) involved in the hunt (Schaller, 1976). It is known that lions have little stamina and are therefore not able to chase an animal rapidly over long distances (Schaller, 1976). For this reason, it is important for the lion to approach its prey as close as possible and seek every possible advantage to catch the animal before it has time to get to full running speed (Schaller, 1976). Environmental factors that influence hunting success in lions include the height and density of vegetation, terrain and wind direction, the time of day and presence of moonlight (Schaller, 1976; van Orsdol, 1984; Funston *et al*., 2001; Hayward & Kerley, 2005).

When conditions are favourable, lions hunt mainly at night, when they can stalk their prey with greater chance of success under the cover of darkness (Schaller, 1976; van Orsdol, 1984). According to Schaller (1976) lions are well aware of the advantage of darkness. Lions adjust their nocturnal hunting periods to coincide with moonless hours, and nocturnal hunts are more successful during moonless hours (i.e., when the moon is below the horizon) than moonlit hours, irrespective of cloud cover (van Orsdol, 1984; Funston *et al*., 2001). Attacks by lions on humans also occurred more frequently when the moon is faint or below the horizon (Packer *et al*., 2011).

The suggested impact of moon patterns on lion hunting behaviour could have major implications for livestock depredation by lions, and thus for lion conservation in livestock-dominated habitats. The present study investigated the effects of moon phase on livestock predation and lion activity patterns in Waza National Park, Cameroon. We expected that livestock predation would be higher during full-moon phases, when hunting success on natural prey is low. Livestock are domesticated animals and do not have morphological and physiological adaptations to escape predators and are considered as an easy meal compared to wild prey. We also expected that both male and female lions would be less active during full moons.

6.2 Materials and methods

Study area

The study was conducted from January to May 2009 in Waza National Park (10°50' and 11°40' and longitudes 14°20' and 15°00'). Waza National Park is a Biosphere Reserve of approximately 1,700 km^2 and is situated in the Sudan-Sahel zone of Northern Cameroon. The park is a typical hard-edge park, without fences or any transition zone between the park and the bordering villages. Consequently, wild and domestic animals can move freely out of and into the park. The topography of the area is flat with the exception of three basaltic inselbergs around the entrance of the park. The climate is soudano-sahelian, semi-arid tropical. The most prominent wildlife in the park are the various antelope species. These include the western kob (*Kobus kob kob*), korrigum (*Damaliscus lunatus korrigum*), roan (*Hippotragus equinus*), red-fronted gazelle (*Gazelle rufifrons*), reedbuck (*Redunca redunca*) and the grey duiker (*Sylvicapra grimmia*) (Bauer *et al*., 2003; Scholte *et al*., 2007; Tchamba & & Elkan, 1995).

GPS Technology

Four Vectronic GPS-Plus collars were attached to two male and two female lions and were programmed to record positions (fixes) at 30-min intervals, so that a total of 48 fixes could be received per day (Sand *et al*., 2005). A single African Wildlife Tracking GPS GSM collar was attached to a lioness and programmed to record fixes at 4-hour intervals, so that a total of six fixes could be received per day. To minimise biases caused by time gaps between fixes resulting from infrequent system failure we selected > 90% registered fixes (i.e., days with at least 44 fixes recorded out of the total possible 48 fixes) for analyses. In total 18% of the data was discarded due to collar failure (197 days out of 1068 days). Activity was measured as a binomial by recording whether or not the lion moved more than 100 m during 30 min of the day (Hayward & Hayward, 2007). If the lion moved more than 100 m in 30 min we recorded it as being active during that half an hour. We calculated the distances travelled 30 min in Excel by means of GPS data and the following equation: $D = \sqrt{[(x_2 - x_1)^2 + (y_2 - y_1)^2]}$. To calculate the daily movement distances (covering a 24-hour period), GPS-derived distances (minimum distance between two consecutive GPS points) travelled during the daytime were added up. Similarly, the nocturnal movement distances (covering a period of 12 hours from 18:00 until 06:00) were calculated by adding up the GPS

derived distances travelled during the night. We determined the daily variation in movement between male and female lions by comparing the average daily movement distances (per 24-hour period) of both sexes. To determine the effect of moon phase on the nocturnal activity of the lions, we compared the average nightly distances travelled during full-moon phases in relation to new moon ("dark moon") periods. Full moon and new moon phases include the day of actual full or new moon and 2 nights before and after the given moon phase. Only the half-hourly data obtained from the four Vectronic GPS-Plus collars were used in our lion activity analyses.

GPS-Clusters

Lions are known to be most active during the night, and normally most hunting occurs between 18:00 h and 6:00 h. Lions tend to spend 4-5 hours consuming prey of reasonable size (Schaller, 1976), during which movement is negligible. Therefore, only GPS fixes during long periods (3 hours or longer) of nocturnal inactivity (when the distance between two consecutive GPS points was ≤ 50 meters) were selected. It was assumed that such GPS clusters (GPS points aggregated in space and time) indicated the location of carcasses killed and/or consumed by a lion. The approximate GPS coordinates of the potential carcass sites were thus determined and subsequently visited. Only GPS-Cluster sites of less than 1-year old were visited; GPS-Cluster sites older than 1 year were considered to be too old to deliver reliable carcass search results.

Once a carcass was found, the species was identified and characterised as wild prey or livestock, and where possible the sex and life stage (juvenile, sub-adult, adult) were determined. The carcass was also aged according to one of three categories: recent (when hair or pieces of flesh were still present or when the bones were brownish in colour) and old (when the bones were white and solid with no hair or flesh present) and very old (when the bones were completely white and porous). Any carcass remains found outside a 100-m search radius were considered to not be associated with the collared lion.

Verification of the GPS-Cluster method

To test the reliability of the GPS-Cluster method, a total of 57 random control cluster sites were generated, of which 30 sites were located in the floodplain and 27 in the woodland/acacia zone. Search methods and

ageing criteria for this control procedure were the same as for the actual cluster sites.

Data analyses

Statistical tests were performed in SPSS 16.0 (SPSS Inc., 2007). To minimize bias resulting from difficulties with ageing older carcasses, all very old carcasses (>12 months) were removed from the data set and were not included in the analyses. All data were checked for normality using the Kolmogorov-Smirnov test and log transformed. The effect of moon phase on livestock predation was analysed using a Fisher Exact Test. The number of livestock carcasses observed during full moon was compared to the number of carcasses observed during new moon phases. The variations in lion movement between males and females for moon phase were calculated with a Mann-Whitney U test. A chi-square test of goodness-of-fit was also used to calculate the difference between the frequency of finding a carcass on a control cluster site and the frequency of finding a carcass on an actual cluster site.

6.3 Results

In total, we visited 219 actual GPS-Cluster sites and 57 random control GPS-Cluster sites for verification purposes. Details on the number and age distribution of the carcasses found at the actual and the control GPS-Cluster sites are presented in Table 6.1. The frequency of finding a carcass on actual cluster sites was significantly higher (54%) than the frequency of finding a carcass on control cluster sites (12%) (χ^2=13.508, df=1, P<0.001; Figure 6.1). This suggests that there is a 78% ((54-12)/54*100%) chance that the carcass found at the actual cluster site is indeed from the collared lion involved. The majority of the carcasses found at actual cluster sites were old (87%), whereas the majority of carcasses found at the control cluster sites were very old (74%) (Table 6.1).

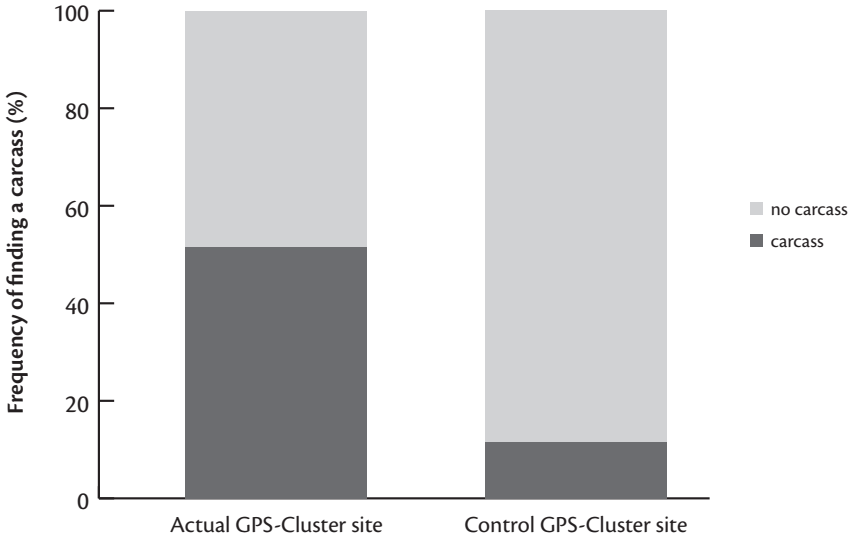

Figure 6.1 **The frequency of finding a carcass at an actual cluster site and at control cluster site expressed as percentage of all clusters visited**

Table 6.1 **Number, percentages and age distribution of carcasses found at the actual and control GPS-Cluster sites**

Carcass age class	Actual GPS-clusters (219 sites visited)	Control GPS-clusters (57 sites visited)
Recent	10 (8%)	4 (21%)
Old	104 (87%)	1 (5%)
Very old	6 (5%)	14 (74%)
Carcass total:	120	19

The number of livestock carcasses documented for full moon phases was higher than that for new moon phases (Figure 6.2) but this difference was not significant.

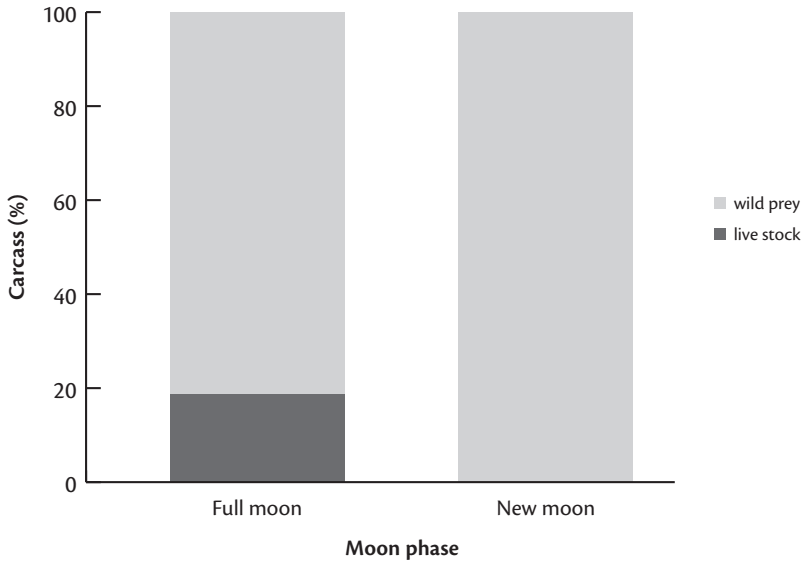

Figure 6.2 **The amount of livestock and wild prey carcasses recorded for full moon (n=24) and new moon (n=36) periods expressed as percentages of the total amount of carcasses found**

Distances walked by males (6774 m/night, SD=5685, n=57) during new moon phases were similar to distances walked by males during full moons (8662 m/night, SD=6934, n=53) (Z= -1.349, P>0.05, Figure 6.3). Similarly, distances walked by female lions during new moons (5463 m/night, SD=3108, n=60) did not differ compared to full moons (5223 m/night, SD=3299, n=59) (Z= -0.505, P>0.05; Figure 6.3). Male lions covered similar distances (mean of 6774 m/night) to female lions (5463 m/night) during new moon phases (χ^2=0.23, df=1, P>0.05; Figure 6.3). During full moon phases, however, males covered significantly larger distances (8662 m/night) than females (5223 m/night) (χ^2=7.202, df=1, P<0.05; Figure 6.3).

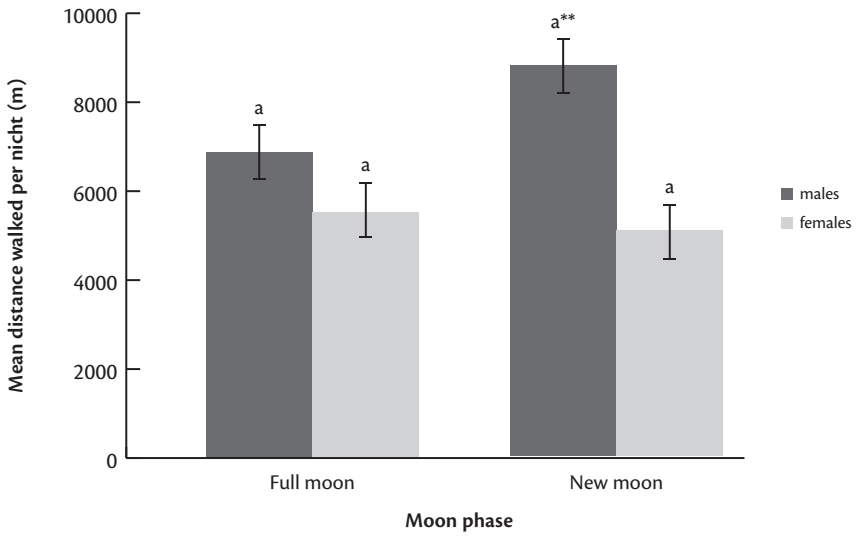

Figure 6.3 **The effect of moon phase on male and female lion activity**
**** indicates significant intersexual differences of lions (N=60)**

6.4 Discussion

Prey densities in Waza National Park are much lower than prey densities in a number of national parks in East and Southern Africa (Bauer *et al*., 2008), which potentially leads to lower prey encounter rates. As a result, lions may be forced to actively search for prey even if hunting conditions are not favourable (i.e., during full moon phases), which may explain why Waza lions are almost equally active during full and new moon phases.

Interestingly, it was found that male lions were more active than females during full moons. It is known that male lions are larger than females and therefore have higher energy requirements (Schaller, 1976). As a result, male lions have to hunt larger prey or more frequently than females in order to fulfil their energy requirements. A general lack of large prey species (Bauer *et al*., 2008), and low prey densities in Waza National Park may force male lions to actively search for food and hunt in unfavourable conditions (such as, during full moon) in order to survive. In accordance, Schaller (1976) and van Orsdol (1984) found that low hunting success rate and small prey size requires lions to constantly move long distances at night. Territorial behaviour in males (such as patrolling) may also provide reasons for this difference in activity between male and female lions.

Former studies showed that moon patterns influence hunting behaviour and hunting success in lions (Schaller, 1976; van Orsdol, 1984; Funston *et al*., 2001, Packer *et al*., 2011). The latter found predation by lions to be positively associated with new moon phases; lions also have a much higher hunting success rate during new moons. Our results indicated that livestock predation is higher during full moon than during new moon phases, but not significantly. This may indicate that lions compensate for the lower hunting success rate during full moon phases by hunting livestock. However more data is needed to be able to draw such a conclusion.

The GPS-Cluster method used to obtain information about the lion's diet has not only been proven to be successful in this study but also in other studies on lion (Tambling *et al*., 2010; Valeix *et al*., 2011, puma (Anderson & Lindzey, 2003) and wolf predation (Sand *et al*., 2005; Franke *et al*., 2006). An essential part of the reliability of the GPS-Cluster method is related to the ageing of carcasses. It is important to determine whether the age of the carcass corresponds with the age of the GPS-Cluster. For future use of this method it is recommended that only recent GPS-Cluster data (less than 6 months old) should be used as it will deliver the most accurate and reliable results. Furthermore, the decomposition rates of carcasses may differ under varying environmental conditions. It is therefore advised to study and determine the decomposition rate of a carcass prior to carcass search efforts in order to assist with the accurate ageing of carcasses in the field. This can be done by locating a few fresh carcasses in the study area and monitoring their rate of decomposition. As GPS-Clusters of more than 3 hours are somewhat biased towards large prey species, it is recommended that GPS-Clusters of more than 2 hours instead of more than 3 hours be selected in areas that lack large prey species.

6.5 Conclusion

The scarcity of water and pasture in this semi-arid area of Waza National Park is the main reason why pastoralists enter the park with their livestock, risking the loss of their stock to lion predation. They also prefer to graze livestock at night to avoid flies and encounters with park authorities. They are however ignorant that the lunar cycle could have an effect on livestock predation. This study provides new insights into livestock predation by lions, and could have great implications for conflict mitigation, with more data. It is recommended that the possibility of increased livestock predation during full moon phases be investigated further, and

that local communities be sensitized regarding the protection of their livestock accordingly.

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7

Livestock depredation and mitigation methods practiced by resident and nomadic pastoralists around Waza National Park, Cameroon

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Husbandry practices around Waza National Park , Cameroon

ABSTRACT

Conflict between humans and lions (*Panthera leo*) is a key factor driving population declines of lions in Africa, especially in communal lands and on the edges of small protected areas. We assessed this conflict in Waza National Park (Waza NP), Cameroon in 2008 through an interview survey. A total of 207 resident and 174 nomadic pastoralists were interviewed. Results indicated high levels of livestock depredation around the park, with attacks occurring most often at night. Lons were economically a substantial threat, accounting for total losses of €100,000 per annum. Per household, resident pastoralists lost one cow while nomadic pastoralists lost two cows per annum equating to about €260 and €520, respectively. To mitigate these losses, resident pastoralists used enclosures for nocturnal protection of their livestock more often than nomadic pastoralists, who tended to herd livestock more during pasture. Improved mitigation methods pertaining to herding practice, the use of enclosures and the presence of dogs, resulted in a reduction of 25% total livestock depredation and 50% cattle depredation. Education to improve the pastoralists' awareness on the ranging behaviour of lions during different seasons and periods of day could reinforce the effectiveness of these mitigation strategies. Improvement of park management and especially law enforcement would help ease human-lion conflicts.

Key words

Human-lion conflict, mitigation methods, predation incidence

7.1 Introduction

Livestock depredation by large carnivores is a widespread problem in Africa and it undermines conservation efforts in many protected areas. Globally, the numbers of large carnivores are declining rapidly, often as a direct result of conflict over livestock (Ogada *et al*., 2003; Patterson *et al*., 2004; Treves & Karanth, 2003; Woodroffe & Frank 2005; Bauer *et al*., 2008). Poaching, habitat degradation and excessive trophy hunting are also serious problems (Henschel *et al*., 2010; Packer *et al*., 2010; Bennett, 2011). Lions suffer these problems perhaps more than most other large African carnivores, and some populations have been reduced to the brink of extinction, thereby necessitating intense conservation efforts (de Iongh *et al*., 2009). This is particularly the case in the savannahs of Central and West Africa, where lion populations are small and highly fragmented (Bauer *et al*., 2003, Bauer & Nowell, 2004), and are disappearing at an alarming rate (Henschel *et al*., 2010). In semi-arid regions of sub-Saharan Africa, drought conditions precipitate frequent intrusions by pastoralists and their livestock into protected areas having water and pasture. A secondary, but important background factor driving conflicts is the depletion of natural lion prey (Packer, 2007; de Iongh & Bauer, 2008), making lions more dependent on livestock.

Various conservation measures have been employed to prevent and resolve conflict between humans and imperiled predators, including compensation schemes, fencing of protected areas, and focused livestock husbandry practices. In some cases, compensation measures do facilitate conflict mitigation (Mishra *et al*., 2003; Verdade & Campos, 2004) but success with this management tool has been mixed (Nyhus *et al*., 2003). Fencing helps keep predators from moving out of protected areas, but fences can have a negative impact on both prey (Ben Shahar, 1992) and predator (van Dyk & Slotow, 2003) populations. Compensation and fencing are both extremely costly, and may not be feasible in parts of Africa where little capital is invested into conservation efforts (Blom, 2001). Husbandry practices and effective park management, therefore, seem to be the most likely solutions to mitigate conflict in many areas.

Review of the literature on husbandry practices to mitigate conflicts with predators has shown that livestock depredation can be substantially reduced (Ogada *et al*., 2003; Frank *et al*., 2005; Packer, 2007; Woodroffe *et al*., 2007 and Bauer *et al*., 2010). Successful measures include the presence of dogs both at pastures and enclosures at night, herding of smaller

livestock herds by adults instead of by children (Packer, 2007), constructing bomas with thick walls and few outlets, and much human activity at bomas (Frank *et al*., 2005). In contrast to the situation in East and Southern Africa, little is known in West and Central Africa about methods that can successfully mitigate livestock depredation (Bauer *et al.,* 2010). As a result, human-lion conflicts in the region have continued to intensify, threatening the survival of lions in Waza NP (de Iongh *et al*., 2009; Tumenta *et al*., 2010). This has prompted further investigation of livestock depredation and the methods practiced by pastoralists to mitigate the conflict. The study was designed to derive information from both resident and nomadic pastoralists using the Waza area.

7.2 Materials and methods

Study area

Waza National Park is located within the Waza Logone area, near the Logone River in the Lake Chad depression (Figure 7.1). It covers a surface area of approximately 1,700 km^2 and lies between latitudes 10°50' and 11°40' and longitudes 14°20' and 15°00'. The climate is Sudano-Sahelian, semi-arid tropical, with three seasons: rainy season (June to October), cold dry season (November to February) and hot dry season (March to May). Rainfall in this area is low and irregular between years, with a mean annual rainfall of 600 mm (Beauvilain, 1995). Temperatures range from 15º C (January mean minimum) to 48º C (April mean maximum). There is no permanent flowing water, but a number of natural and artificial water reservoirs that fill during the rainy season, some of which retain water throughout the dry season. The eastern half of the park is periodically inundated during the rainy season, flooded by excess water from the Logone River and its branches the Logomatya and Lorome Mazra. The area including Waza NP holds water and pasture re-growth far into the dry season, when water in the surrounding grassland has completely dried out. For this reason, many pastoralists enter this area with their livestock each year for a period of 6-8 months (Scholte, 2005). This results in a very high concentration of livestock around Waza NP, with frequent intrusions into the park.

Methods

The primary method of data collection was structured interview surveys (Piran *et al*., 2005). As this is a self-reporting measure, it is open to possible biases from both interviewers and respondents. As a preparatory step, informative meetings were held in the area to raise awareness on research activities around Waza NP, and also to identify the villages involved in livestock rearing. Maps of lion movements produced from GPS radio-collars guided the selection of villages for the survey. Structured interviews were held with 207 village residents and 174 nomadic pastoralists in camps, in 22 localities around Waza NP. Camps located within 2 km of villages were considered to be in the same locality. Not all localities surveyed had both pastoralist communities. In small villages and nomadic camps, all livestock owners were interviewed, whereas in larger villages about 50% of the livestock owners was interviewed. Household interviews were conducted by two Agricultural Engineering students from the University of Dschang, Cameroon, accompanied by interpreters who spoke the local languages.

The interview covered the incidence of predation by large carnivores on various species of livestock, during different seasons, and at different times of the day. Further questions on husbandry practices assessed whether livestock was herded by day, and whether they were confined by night. Other factors responsible for livestock loss around Waza NP were also investigated. Data was analyzed using SPSS 16.0. Data was tested for normality and where data appeared not to be normally distributed, a square root transformation was carried out to normalize data before further analysis. A one-way ANOVA was use to analyse predation incidence with the different management methods, among different pastoralists and during different periods of the day. Differences in husbandry methods practiced by the different groups of pastoralists were tested with a Chi-square test. A correlation analysis was used to establish the relationship between number of shepherds per herd and livestock depredation incidence.

7.3 Results

Resident and nomadic pastoralists differed significantly ($P<0.01$) in the average number of individuals and number of huts per family and in the number of livestock owned (Table 7.1).

Table 7.1 Characteristics of resident and nomadic pastoralists around Waza National Park, 2008

Characteristics	Pastoralist	
	Resident (n = 207)	Nomadic (n = 174)
Family size	12	10
Number of huts	6	4
Mixed herd size	84	218
Sheep	18	32
Goats	14	72
Cattle	52	114

A total of 55,845 livestock were counted in the area during the survey. Although predation on livestock occurred in all localities surveyed (Figure 7.1), some were more affected than others. Localities west and east of the park experienced intense predation in the same magnitude just as

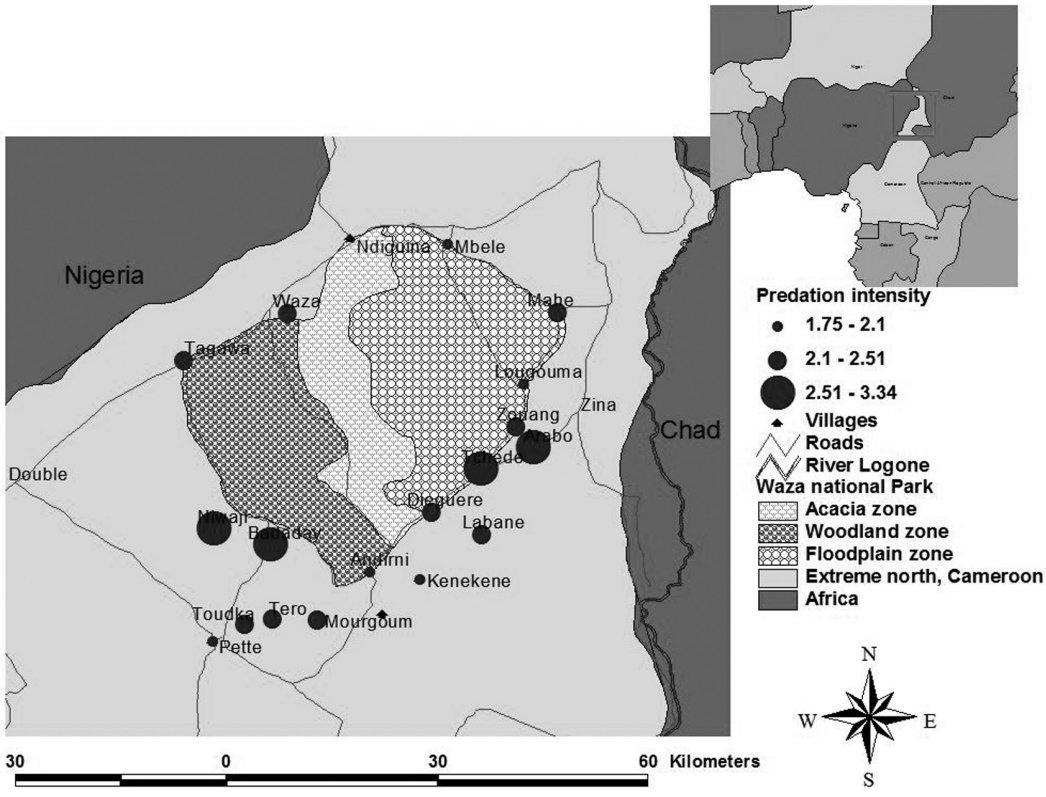

Figure 7.1 Mean livestock number lost per annum to lion predation in localities around Waza National Park, 2008

did localities south of the park. Only 2 out of the 22 localities surveyed experienced low predation. Three predator species were responsible for livestock depredation around Waza NP, namely lions, spotted hyenas (*Crocuta crocuta*) and jackals (*Canis aureus*). Major livestock species predated upon included cattle, sheep and goats (Table 7.2).

Table 7.2 Number of livestock (with percentages in parenthesis) predated upon per annum by lions, spotted hyaenas and jackals around Waza National Park, 2008

Predator	Livestock species (prey)			
	Cattle	Sheep	Goat	Total
Lion	425 (84)	62 (12)	22 (4)	509 (100)
Hyena	91 (8)	799 (72)	227 (20)	1117 (100)
Jackal	0	85 (14)	537 (86)	622 (100)

Spotted hyenas were reported to be responsible for most of the attacks on livestock (50%, n=2248), followed by jackals (28%), and lions (22%). However, lions predated more on cattle, whereas hyenas predated mainly on sheep, and jackals mostly on goats (Table 7.2). In terms of financial loss, lions ranked highest, accounting for total losses of €100,000 per annum or €260 per household per annum. Predation on livestock was significantly higher for nomadic pastoralists than resident pastoralists (Table 7.3). Losses related to cattle were in the ratio 1:2 for resident and nomadic pastoralists, respectively. For both types of pastoralists, predation was significantly higher during the night than during the day ($F=54.1$; $df=1,379$; $P<0.01$). Nomadic pastoralists experienced a mean loss of six livestock per annum during the night compared to a mean loss of two during the day ($F=14.8$; $df=1, 172$; $P<0.01$) per household. Predation incidence per household or herder was similar during the wet (3) and dry seasons (4).

Table 7.3 Mean livestock losses per household due to predation for resident and nomadic pastoralists around Waza National Park

Predation	Resident pastoralists	Nomadic pastoralists	Statistical significance
All predators on cattle	1.01	1.76	P<0.01
Lions on all livestock	0.92	1.83	P<0.01
Hyenas on all livestock	1.69	4.41	P<0.01
Jackals on all livestock	1.85	1.37	NS
All predators on all livestock	4.46	7.62	P<0.01

In addition to predation (4%) as a cause of livestock loss, there are annual losses to disease (4%) and theft (3%). When these losses were translated into financial terms, loss to disease ranked highest (€175,000), followed by theft (€161,000) and predation (€150,000). Although predation ranked last economically among the three causes of livestock loss, it was perceived as the most serious threat to livestock production by 70% (n=381) of the respondents.

Predation management practices

Both resident and nomadic pastoralists practiced some traditional protective methods to minimize depredation of their livestock. These included herding (60.9%), the use of enclosures to keep livestock at night (26.8%), and the use of dogs (42.3%) to alert owners to the approach of predators. Herding was practiced significantly more (χ^2=1.9, df=1, P<0.01) by nomadic than by resident pastoralists. Among resident pastoralists that herded their livestock, 42% (n=60) of the herders were adults, while among nomadic pastoralists, 72% (n=124) of the herders were adults. A significant difference in losses to predation existed (χ^2=16.2, df=1, P<0.01) between herds that were herded by adults and those herded by children. Resident pastoralists experienced a mean loss of two heads of livestock per household per annum for herds herded by adults, compared to a mean loss of eight for herds herded by children. Nomadic pastoralists experienced a mean loss of five heads of livestock per household per annum for herds herded by adults compared to a loss of 16 for herds herded by children. Predation decreased as the number of shepherds per herd increased (Pearson correlation, r = -0.1*) for nomadic pastoralists.

The use of enclosures to keep livestock at night was more common among resident than nomadic pastoralists (χ^2=1.0, df=1, P<0.01). For resident pastoralists, the use of enclosures did not change the incidence of predation by all predators. Resident pastoralists owning enclosures lost a mean of four heads of livestock, compared to a mean of five heads per household by those that did not own enclosures. When looking at predation only by lions, however, this difference became significant: those who owned enclosures lost one head of livestock compared to two lost by those who did not own enclosures (P<0.01). Furthermore, the type of enclosure influenced the incidence of predation. Among resident pastoralists that owned enclosures, 43% (n=99) of the enclosures were solid (made of earth) while 57% were weak (made of thorny bushes). Losses

from solid enclosures were a mean of two animals, compared to seven heads of livestock per household for weak enclosures. The use of enclosures by nomadic pastoralists was limited and thus could not be computed.

Only 33% of resident pastoralists owned dogs, compared to 53% of nomadic pastoralists (χ^2=16.4, df=1, P<0.01). The presence of dogs had no significant influence on predation among resident pastoralists. Those owning dogs experienced a mean loss of five animals, which was similar to the four heads of livestock lost by those who did not own dogs. On the other hand, nomadic pastoralists owning dogs lost on average six heads, while those without dogs lost 10 heads of livestock per household.

When livestock husbandry methods were combined, resident pastoralists who did not practice any form of protective management experienced a mean loss of four compared to three heads of livestock by those who practiced at least all three management methods investigated. For nomadic pastoralists, those that did not practice any form of management experienced a mean loss of 12 compared to nine heads of livestock by those using these protective measures. Overall, a reduction of about 25% in livestock depredation was observed with the application of predation management methods (herding by adults, good enclosures and presence of dogs) for both resident and nomadic pastoralists. However, depredation specifically of cattle by lions decreased for both pastoralist groups by 50% with the three predation management methods applied.

In addition, other local socio-cultural and traditional methods were assumed to deter predators from livestock depredation. Most pastoralists (70%, n=381) believed that reciting certain verses from the Koran would keep predators away from their herds. Furthermore, 52% of pastoralists burnt fetish products during the night where they kept livestock. Some technical measures practiced locally included the use of fire (40%) and scare-crows (24%). Some pastoralists also set up local alarm systems to alert them to the approach of predators at night (40%). Most of them (65%) used wind direction when herding livestock to pasture in order to avoid lion predation. None of these methods were further tested.

7.4 Discussion

Our findings demonstrate that predation by lions and other predators (hyena and jackal) was a serious issue in all localities surveyed around Waza NP, confirming that this is a persistent management problem in the area (Bauer & Kari, 2001; Bauer *et al*., 2003; van Bommel *et al*., 2007; Bauer *et al*., 2010). This study showed that localities west and east of the park faced intense conflict with predators. Previously Bauer & Kari (2001) had demonstrated that predation was intense only along the southern boundary of the park. Recent changes include the increased presence of large herds of livestock especially at the western limit of the park. Furthermore, changes in the administrative management and the subsequent collapse of park management have contributed to the settlement of pastoralists in this area from neighbouring countries. The situation seems to have worsened resulting in a drastic decline of the natural prey base (Scholte *et al*., 2007; Foguekem *et al*., 2010), which in turns means that large predators depend more on livestock than before (de Iongh & Bauer, 2008).

Economically, lions were shown to be the most important predator, mainly killing cattle, which have the highest monetary value. Livestock rearing is a major activity and source of income for pastoralists around Waza NP. It is also a cultural way of life for nomadic pastoralists, who sell and utilize dairy products especially from cattle for subsistence, passing their assets down from generation to generation. The loss of cattle has important economic and cultural consequences. Nomadic pastoralists lost twice as many heads of cattle to predation than did resident pastoralists. This was explained by the fact that they typically owned twice as many cattle. They also seemed to make more intrusions into the park for water and pasture, as well as for social reasons. They perceived that they became famous among their clan when they ventured into the park and would get greater acclaim if they were caught and released for violating park rules.

The majority of livestock losses took place during the night. Pastoralists, especially nomads, commonly graze their livestock at night from about 22:00 h until 02:00 h. This is to avoid high daytime temperatures, flies and because of food scarcity (Bauer, 2003). The practice, however, exposes livestock to more predation, as lions and hyenas are known to be more nocturnal than diurnal in their activities (Hayward & Slotow, 2010). The difference in predation observed between resident and nomadic

pastoralists could be well due to differences in husbandry practices. The use of enclosures to protect livestock at night was more common among resident pastoralists. Nomadic pastoralists, being mobile (Moritz *et al*., 2010), considered the building of enclosures time-consuming and expensive. They are therefore not likely to adopt this method to protect their livestock from lions.

Predation was similar during the dry and wet seasons. This differs from previous findings that showed predation on livestock to be higher during the wet season in this area (Bauer *et al*., 2003; van Bommel *et al*., 2007). Our findings were rather similar to predation during the dry season described by Scholte (2005). Natural prey in Waza NP normally congregates at waterholes during the dry season, resulting in temporary residence of lions around these waterholes, where they easily find prey. It appears that lions are now predating on livestock even during the dry season, indicating how critical the hunting situation has become for lions in Waza NP. Moreover, intrusions into the park for resources by pastoralists have increased as a consequence of ineffectual park protection, resulting in an almost permanent presence of livestock in the park during the dry season (de Iongh *et al*., 2009).

The economic loss suffered by pastoralists was higher for disease and theft than for predation. Conversely, predation was considered the most serious threat to livestock production, probably because of the conservation attention accorded to predators. The tolerance of local people concerning the presence of predators and to conservation seems to have declined compared to the findings of Bauer & Kari (2001), which is another indication of a deteriorating situation. Within one year, two collared lions were killed by pastoralists in retaliation for livestock depredation (de Iongh *et al*., 2009; Tumenta *et al*., 2010).

Several husbandry methods were identified in the Waza NP area but only three were tested: herding of livestock, the use of enclosures and the use of dogs. Resident and nomadic pastoralists applied these methods differently to mitigate livestock depredation. Although we based our study on self reporting, which might to some extent be biased, the methods reported were similar to those described by Packer (2007), Frank *et al*. (2005), Ogada *et al*. (2003), Woodroffe *et al*. (2007) and Bauer *et al*. (2010). Herding was practiced significantly more often by nomadic pastoralists and effectively reduced predation only when herds were accompanied by adults, supporting the findings of Packer (2007) and Frank

et al. (2005). Similarly, increasing the number of herders per herd proved to reduce predation. Resident pastoralists did not invest much time in herding livestock, probably because they were engaged in other activities such as farming and fishing. This may also explain why most of their herds were accompanied by children. Nomadic pastoralists, on the other hand, who always accompanied their livestock, had the tendency to exploit challenging areas such as the park for water and pasture. This probably explains the high losses they suffered even though most of their livestock were accompanied by adults.

Strong enclosures significantly reduced livestock losses to all predators, confirming the findings of Frank *et al*. (2005) and Bauer *et al*. (2010). This study further underscores that only enclosures with specific characteristics, in this case made of earth rather than thorny bushes, can effectively reduce livestock losses. The majority of enclosures surveyed was made from light Acacia branches and were both weak and porous. Considering the percentage of resident pastoralists that used enclosures, there are prospects that this group could adopt the use of improved enclosures to mitigate livestock losses. This solution appears to be difficult for nomadic pastoralists to adopt because only a few of them used enclosures.

The presence of dogs during herding and at enclosures did not seem to be effective in reducing predation among resident pastoralists, contrasting with the findings of Ogada *et al*. (2003) and Woodroffe *et al*. (2007). A possible reason could be the fact that dogs in this area are not trained as guard dogs. Our findings revealed that there is no single solution for mitigating livestock depredation around Waza NP, but a combination of predation management methods appears to be effective.

Livestock predation remains an important problem around Waza NP. The reduction of the lion population in this park is mainly caused by retaliatory killing of lions for livestock depredation (de Iongh *et al*., 2009, Tumenta *et al*., 2010). However, the correlation between number of lions killed and livestock depredation necessitates investigation in future (Bauer *et al*., 2010). Also worthwhile is a cost-benefit analysis of the methods employed to mitigate livestock depredation. In the meantime, the various effective methods practiced to reduce predation around Waza NP could provide a basis for a significant mitigation of conflicts if they would be applied appropriately by both groups of pastoralists. Education and awareness on the ranging behaviour of lions during different seasons and periods of the day should also be improved for all pastoralists. Furthermore

and very importantly, park management should improve park protection by organizing more effective patrols, and introduce penalties for breaching of rules. If this is not achieved, improved enclosures and herding will not stop the retaliatory killing of lions for taking livestock, which could lead to their extirpation in the Waza ecosystem.

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8

Discussion, conclusions and recommendations

8.1 Discussion

The lion is the largest and best-known African top predator. Top predators play an integral role in maintaining rich ecosystems as regulators of food webs (Beschta & Ripple, 2009; Letnic *et al.,* 2009; Fraser, 2009; Miller *et al*., 2001; Terborgh *et al*., 2001). Despite their ecological importance and their being one of the world's most attractive animals in the tourism industry, lions have disappeared from much of their historical range and are threatened in part of their present range. There are presently some 23,000 to 39,000 lions left in Africa, with less than 4000 in West and Central Africa (Chardonnet, 2002; Bauer & van der Merwe, 2004; Riggio *et al*., *in prep*).

Threats faced by lions are complex, making their conservation challenging. There is probably no other carnivore species whose distribution range and numbers have shrunk over the past century to the extent of the lion's (Smithers, 1983; IUCN/SSC, 2006). The main threats to lions are habitat loss, prey base depletion and indiscriminate killing, mainly as a result of retaliatory or pre-emptive killing to protect livestock (Bauer *et al*., 2008; Tumenta *et al*., 2010). These threats are driven by the ever-increasing human population density and the consequent demand for food and natural resources, resulting in a rapid deterioration and fragmentation of the remaining lion habitats (Karanth & Chellam, 2009). The survival of lions and other top predators depends on how effectively scientists, conservationists, governments, local people and society at large will study, understand, collaborate and take action to meet the ecological needs of these species. There are variations in local ecological and

anthropogenic factors impacting lion populations. In my PhD research I have studied the Waza lion population with respect to ecological and anthropogenic factors impacting its survival. Particular attention is given to its population status, spatial ecology, movement and activity pattern, its diet and conflict with humans due to livestock predation, and to possible measures to mitigate this predation.

Conservation of lions in Waza National Park

Several authors report the alarming rate at which lion populations are declining across West and Central Africa (Bauer & van der Merwe, 2004; IUCN/SSC, 2006; Bauer *et al*., 2008; Henschel *et al*., 2010). The Waza lion population, one of the best-studied lion populations in the region of Central Africa, seems now to be one of the most threatened. In West Africa, lion populations in Kainji Lake National Park and Yankari Game Reserve are in a similar deplorable situation (Henschel *et al*., 2010). There has been a progressive reduction of all wildlife in Waza National Park in the 2000s because of various factors (Scholte *et al*., 2007; Foguekem *et al*., 2010; de Iongh *et al*., 2010).

The main factor that has contributed to the deterioration of Waza National Park and has resulted in drastic declines in wildlife numbers is poor management, partly as a consequence of insufficient financial and human resources. This situation was further exacerbated by a change to the park's management in 2007. The new management was characterized by a significant decrease in anti-poaching patrols, together with the issuance of illegal permits to fishermen and pastoralists to use park resources (de Iongh *et al.*, 2010). During 2008-2010 the poaching pressure on the park intensified, resulting in mass killing of antelopes and predators. Poaching activities and livestock intrusions, especially from neighbouring countries, were frequently observed in the park. The elimination of the western kob was on average four animals per day. During this period, within two years, a total of three collared lions out of seven were killed by pastoralists (Tumenta *et al*, 2010).

The findings of my study reflect very well the pressure on the park and its resources. Lion numbers have dropped drastically from 40-60 in 2002 (Bauer, 2003; Bauer & van der Merwe, 2004) to 14-21 in 2008 (Tumenta *et al*., 2010). There are strong indications of an existing trade in lion body parts, such as skin and meat. Of all collared lions killed during the research period, no carcasses were retrieved (Tumenta *et al*., 2010). Only

one carcass was found of an uncollared lioness, when poachers were surprised by tourists on a game drive (B. Croes, pers. comm.). There was also some evidence of a trade in live lion cubs from Waza National Park to neighbouring Nigeria. Villagers of Niwaji at the south-western limit of Waza National Park reported two lion cubs being sold to Nigerian traders (A. Ndjida, pers.comm.). A few months later, the administration of the Gombe State University in Nigeria reported in a newsletter interview that Waza National Park was the source of the lion cubs acquired for the University Zoo (Hamagam, 2010). The observed decline in numbers is not limited to the lion; the elephant population in Waza National Park was reported to have declined by 70% in the same period (Foguekem *et al*., 2010). The camera trapping survey conducted for the present study confirms the high human-livestock pressure on the park. Compared to other species of animals captured by the camera traps, humans and livestock represented 31% of the photographs (Tumenta *et al*., 2010). Kalamaloué National Park further north of Waza has suffered this same fate; today all wildlife has disappeared from that park (Scholte, 2003). Although lion populations are resilient, they may not be able to recover when numbers drop even further than the current all-time low. Lion numbers have sometimes dropped elsewhere, such as in the Amboseli National Park and the Ngorongoro Crater reserve, mainly because of drought and disease. These populations have all bounced back following appropriate and effective management. However in the Ngorongoro crater the lion population showed a very low heterozygosity after this event, which enhanced the risk of inbreeding depression (Packer *et al*., 1991).

Another background factor that has contributed to the current state of Waza National Park is the poor implementation of co-management. In general, protected areas are better managed when there are conservation projects (Bruner *et al*., 2001). In this way, Waza National Park benefited from this sort of protection in the 1990s, with the presence of the IUCN Waza Logone project in the area. The project had as its main objective to redress the negative ecological effects caused by the construction of the Maga dam by partly restoring the natural flooding regime of the Waza Logone area, including Waza National Park (Loth, 2004; Scholte, 2005). As part of efforts to conserve the natural resources of the park and to ameliorate the living conditions of communities close to the park, a co-management regime was initiated. However, the project ended without acquiring sufficient funds for the co-management regime to operate effectively (de Iongh *et al*., 2010). Poorly understood by both the park management and the local communities, the co-management regime

became unofficially operational without any appropriate system set in place to guarantee its functioning (A. Saleh, pers. comm.). Two studies in the park on the co-management regime clearly indicate that this regime in fact resulted in increased human pressure on the park (Mohamadou, 2003; Ledauphin, 2006). Threats to wildlife and the lion in particular included poaching, intrusion by livestock leading to human-lion conflicts and unsustainable exploitation of other natural resources (de Iongh *et al*., 2010). This pressure had its toll on wildlife numbers in the park. After the pilot re-flooding in 1994, numbers of all herbivore species in the park initially increased. The most abundant antelope, the western kob (*Kobus kob kob*) increased to approximately 9,000 in 2000 (Scholte *et al*., 2007), after which numbers have declined to less than 2,500 in 2004 (Saleh, 2004) and to below 1,600 in 2007 (Foguekem *et al*., 2010).

Lion survival strategies in Waza National park

As stated earlier, the findings of this thesis clearly reflect a lion population under stress. The dramatic decline in lion numbers and the large home range size reported in this study illustrate the pressure on the park. The home range size of lions has increased from a mean of 630 km^2 (Bauer & de Iongh, 2005) to a mean of 1015 km^2 (Tumenta *et al*., *in review*). The lions were shown to move more during the hot dry season, indicating disturbance of the lion population. The Waza lions were nocturnal in their activity with crepuscular peaks, again pointing to disturbance, as elsewhere in Africa. However, the lions' activity pattern was exceptionally high, suggesting that the lions were constantly moving in search of prey and in order to avoid humans. The dietary niche of the lions was quite broad, reflecting the low prey biomass now available in Waza National park. High concentrations of livestock in the periphery of the park (Scholte, 2005; Foguekem *et al*., 2010) greatly influenced the lion's diet, comprising approximately 22% of lion diet. The interview survey on the human-lion conflicts revealed that pastoralists lose an important amount of income to lion predation annually. Per household, resident pastoralists lose one head of cattle whereas nomadic pastoralists lose two per annum, equating to about €260 and €520, respectively (price level 2010). The home range size, movement and activity patterns, and the diet of lions in Waza National park follow survival strategies that reflect the pressure on the park. The lions extend their home ranges, move more during very hot periods to catch scarce prey and to avoid human interference, and supplement their diet with livestock to survive.

Is there a future for lions in Waza National Park?

The Waza lion population will go locally extinct in 10 years time if the current trend continues. There is an urgent need to greatly improve the protection of Waza National Park in order to save the lion and other wildlife from disappearing. The effectiveness of park protection correlates with basic management activities such as enforcement and direct benefits to local communities (Bruner *et al*., 2001). The government will need to train and equip park personnel that can handle the current challenges to the park. To be effective, the financial resources allocated to the park must be increased. Anti-poaching patrols must be frequent, effective and continuous to prevent intrusions into the park. The local communities living close to the park should be empowered to reinforce the park's protection by directly benefiting from the presence of the park. The latter can be achieved through a well organized and implemented co-management regime. The Communal Area Management Programme for Indigenous Resources (CAMPFIRE) in Zimbabwe has been a success story of a co-management regime for the conservation of natural resources. As local communities are empowered to protect their natural resources while benefiting from the proceeds, poaching is greatly reduced, wildlife numbers are increased and habitats upgraded.

The protection of Waza National Park has been weak until recently. Recent changes in the park's management by the government in an effort to save the park and its resources (de Iongh *et al*., 2010); suggest a better future as enforcement is greatly being improved. Elsewhere in West Africa, in the Pendjari biosphere reserve in Benin, the lion population is healthy and at least stable (Sogbohossou, 2011). The park management is good compared to Waza National Park, park revenues are channeled back to the park itself and the local communities benefit directly from park proceeds. A conservation project is underway in Pendjari and together with government efforts; the area is being better protected. As suggested by stakeholders during a workshop organized in 2009 in Waza, addressing the need for an improved management of Waza National Park and its resources, the government has suspended the co-management regime (de Iongh *et al*., 2010) pending its re-organization. When poorly implemented, co-management can have devastating consequences on the park and its resources. Although there have been some efforts by the government to increase the annual budget of the park (A. Ndjidda, pers. comm.), much still needs to be done. International conservation funders will need to fund and manage projects in the park for its effective protection. The gov-

ernment should seriously consider sharing the revenues accruing from the park with the local communities in order to guarantee the future of lions in Waza National Park.

With less than 20 adult individual lions remaining in Waza National Park, one wonders what the future holds for this population. In general, a lion population of less than 50 adult individuals is considered not viable (IUCN/SSC, 2006). Improving on the genetic variation of lions in Waza National Park will only become relevant after an improvement of the park's protection will have reversed the current trend of lion decline in the park. Small isolated lion populations with no possibilities of exchange with other lion populations may suffer inbreeding depression and loss of genetic variation. Such populations are also more vulnerable to loss of habitat, as well as stochastic events such as disease-induced mortality or extreme drought. A possible way to maintain the existence of such a lion population would be to increase the genetic variation through assisted migration of individuals from another lion population. For the case of the Waza lion population, the Bénoué complex may serve as a source population, being the closest Lion Conservation Unit. This entails managing the two Lion Conservation Units as a meta population and translocating immobilized breeding males from the more viable population to the less viable one (P. Funston, pers. comm.). This management option however, requires a large amount of funding and expertise to intensively monitor the lion populations. Therefore further research should confirm if the heterozygosity of lions in Waza National Park is affected by the small population size.

8.2 Conclusions

The following conclusions can be drawn from this study:

1. Due to retaliatory killings by pastoralists, the lion population in Waza National Park has declined dramatically with at present less than 20 adult individuals surviving. If nothing is done to stem the trend, the lion population will become locally extinct in 10 years' time.

2. As predicted, the recent decline in wild prey abundance has resulted in an observed increase in the mean home range size of lions in Waza National Park, indicating a trend of general degradation of the park due to intense human pressure.

3 During the wet season, when the park is flooded, lions in the floodplain zone move their core areas to higher elevations in the floodplain, subsequently to the woodland zone and eventually out of the park.

4 The lions move out of the park during the wet season, following pastoralists and their livestock to their wet season sites, thus extending their home range size during this period.

5 During the hot dry season the distribution of lion home ranges is directly related to prey distribution at permanent waterholes in Waza National Park.

6 Lion movement in Waza National Park follows patterns observed elsewhere; however lion activity is relatively high especially during the hot dry season when home ranges are smallest. This may indicate the high disturbance on the population during this period by livestock intrusion and probably tourism, as well as the effect of low prey densities.

7 The lions in Waza National park have a broad dietary niche of 14 prey species, however only five medium to large-sized species constitute the bulk of their diet. The most common natural prey species in the diet of lions in Waza National Park is the western kob.

8 Livestock contributes an important percentage (approx 22% number base) of the lion's diet in Waza National Park. Livestock predation by lions mostly occurs in the night.

9 Livestock predation by lions is intensifying in localities neighbouring Waza National Park. A combination of improved traditional mitigation methods can substantially reduce livestock losses to predation.

10 Resident and nomadic pastoralists practice different mitigation measures to reduce livestock losses. The effectiveness of the measures is generally low but can be improved by implementing better enclosures for resident pastoralists and herding by adults rather than children for nomadic pastoralists. For a better and effective management of the human-lion conflict problem, mitigation measures must be tailored to the needs of the two groups of pastoralists.

8.3 Recommendations

- A complete halt to intrusions into the park by livestock, fishermen, poachers and collectors of other natural products will greatly reduce the human-lion conflicts in Waza National Park. These activities are already forbidden; improvement is possible through effective law enforcement. The government needs to train and equip more park staff, and also improve on the funding mechanism of projects in the park. The government should set up an intelligence network to combat poaching and illegal activities in the park in collaboration with the Rapid Intervention Battalion of the army that fights against armed robbery in the region.

- For conservation efforts to be effective in Waza National Park, local communities living close to the park should be made to benefit from the revenues generated from the park. A percentage of the revenues generated from park entrance fees should be paid to the local communities. This will motivate the communities around the park to act as custodians of the park and its resources. Tourism in the park should be better developed and organized to be ecologically friendly and to generate more income. Game drives, for instance, should be coordinated and performed by the park management. Communities could be mobilized to perform cultural dances for tourists at the Waza Lodge and to also supply farm products to the lodge management.

- Human-lion conflicts due to livestock predation should be considered as a trans-frontier problem that needs to be examined within the Lake Chad Basin Commission. Efforts should be made towards intensifying pastoralism in the Waza Logone area, which is an important resource area for pastoralists and fishermen who migrate from various countries in the Lake Chad Basin yearly for resources such as pasture, water and fish.

- Further research is needed to confirm whether the heterozygosity of the Waza lion population is affected by the small population size and relative isolation. If this is the case, assisted migration could be applied, to improve the genetic variation of the population by bringing in breeding male lions into the population from the Bénoué complex. This management option requires extensive financial resources and expertise. For this to be feasible, the government should solicit financial support from international conservation donors.

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Summary

A Lion Population under Threat

Understanding lion (*Panthera leo L*, 1758) ecology and human-lion interactions related to livestock predation in Waza National Park, Cameroon

Keywords

Lion (*Panthera leo),* population status, spatial ecology, lion diet, human-lion interactions, lion predation mitigation, Cameroon

The lion was historically one of the most widely distributed terrestrial mammals on the globe. Currently, the lion exists only in a few range countries in Sub-Sahara Africa and a small population in the Gir forest in India. In Cameroon, the lion's range is currently limited to the Guinea-Sudan and Sahel savannahs in the northern region, south of Lake Chad. Lion populations in West and Central Africa are increasingly becoming threatened throughout their remaining range. The threats impacting lion populations are generally anthropogenic in nature, including habitat destruction, prey depletion, conflicts with livestock owners, diseases (zoonoses), inbreeding depression due to fragmentation and isolation, and illegal trade. In order to cope with these threats and to conserve the remaining lion populations, continuous research and monitoring of the lion populations is required. However, lion conservation in West and Central Africa suffers from a general lack of data within and across lion populations. My research aims to provide scientific data needed to support a better management and conservation of lions in the Central African region with a focus on Waza National Park in Cameroon. Investigations focus on lion ecology and the human-lion conflicts due to livestock predation in this park.

Reliable population estimates are indispensible for wildlife management and conservation. The lion population in Waza National Park appears to experience a striking decrease. The number of adult lions has declined from 40-60 in 2002 to 14-21 in 2008, which represents a reduction of about 65% in 6 years. Furthermore the population age structure is

skewed towards adults, producing an inverted pyramid. The sex ratio is 1 male to 3 females and the mean lion group size is only 1.6 lions. All these characteristics point to a population under high pressure. And indeed, the human-livestock pressure on the park is enormous, 31% of photographs captured by camera traps, set to count lions in this study in 2008, were of humans and livestock in the park. The estimated mortality rate of approximately six lions dying per year mainly as a result of retaliatory killing for livestock predation and poaching is alarming. The retaliatory killing is done by herders, as the lions increasingly predate on cattle due to the strong decline of their natural prey. All in all, the lion population is expected to be extirpated in 10 years' time, if nothing is done to reverse the situation.

The low natural prey density now available in Waza National Park is also reflected by the large lion home range sizes observed in this study. The home ranges of the lions, expressed as 95% minimum convex polygon (MCP), have increased from a mean of 630 km^2 in 2000 to 1015 km^2 in 2008. These home ranges are the largest reported so far in the region of West and Central Africa. Many of these ranges presently extend to areas outside the park, causing lions to spend on average 21% of their time outside the park. This results especially in larger wet season and cold dry season home ranges. In the hot dry season, home ranges are smallest and the lions largely remain in the park close to the water holes, where they still find prey during this period. Time spent outside of the park coincides with increased livestock predation. The seasonal variation observed in home range size appears to be mainly due to the availability of water, of natural prey, and of migrating livestock as alternative prey.

While lions stay in the park during the hot dry season, they surprisingly move over longer distances than during other seasons, which indicate that even during this season prey has become scarce. Males cover longer distances than females. Lions in Waza National Park are nocturnal in their activities with crepuscular peaks at sunrise and sunset. The lions are generally more active inside than outside the park and move outside mostly at night. The lion's diet in Waza National Park shows a niche breadth of 14 different prey species. However the bulk of the diet consists of five prey species, of mainly medium-sized (50-200 kg) and large-sized (> 200 kg). The western kob (*Kobus kob kob*) is the most common wild prey of lions, but livestock (predominantly cattle) presently constitutes as much as 21.6% of the diet (on a number basis), resulting in conflicts with livestock owners. In fact, all observed characteristics of the diet and

movements of the lion reflect a survival strategy of lions under highly disturbed conditions.

The conservation problem of lion mortality by retaliatory killing by pastoralists is exacerbated by ongoing livestock intrusions into the park. Even inside the park, cattle constitute 18% of the lion's diet. Wild prey species are also consumed outside the park (6.7% of prey consumed outside the park), suggesting excursions of the natural prey species beyond the park boundary. Despite the much higher abundance of livestock over natural prey, lions appear to prefer wild prey over livestock, which becomes clear when applying the Jacobs' index of relative abundance. This finding is important as a basis for practical recommendations for conflict mitigation in and around Waza National Park.

Conflicts between humans and lions due to livestock predation is a key factor driving population decline of lions in Africa, especially on the edges of small protected areas without transitional buffer zones. Pastoralists around Waza National Park suffer high levels of livestock depredation, with most attacks occurring at night. Economically, lions are a substantial threat, accounting in the Waza area for total losses of €100,000 per annum (price level 2010). Per household, resident pastoralists lose one head of cattle whereas nomadic pastoralists lose two per annum, equating to about €260 and €520, respectively (price level 2010). The pastoralists make some efforts to reduce losses to lion attacks, mostly consisting of keeping livestock in enclosures at night and herding during pasture. However, these measures appear not to be sufficiently effective. Application of the best practices which are already being used now by a percentage of the pastoralists, proved useful in reducing total livestock depredation by 25% and cattle depredation even by 50%. A further improvement of these methods is possible; therefore the human-lion conflicts around Waza National Park could theoretically be largely prevented. It has become clear however, that different methods will have to be adopted by the resident and nomadic pastoralists in order to effectively mitigate livestock predation by lions, as nomadic pastoralists have few easy options. These herders therefore pose the greatest challenge. Another point is that substantial prevention of cattle predation, as is recommended here, will further limit food availability for the lion. Prevention of predation must therefore go hand in hand with a better protection of the natural prey so that prey populations can increase again and lions will no longer rely on livestock for survival.

Although the Waza lion population, one of the most viewed lion populations in the region of Central Africa, now seems to be most threatened, concerted conservation efforts could still save this population from local extinction. Studies in the Ngorongoro crater in Tanzania show that the lion is in fact quite resilient; its population can bounce back and increase rapidly after a positive change in conditions, given its rapid reproductive rate. For the Waza lion population to increase and to regain its former status, the government must greatly improve park protection through the park management authority and law enforcement, as well as providing financial and human resources for the park. During my study, funds to open the roads of the park for game viewing (tourism) never arrived in time. Furthermore, local communities living close to the park must receive direct benefits from park revenues, which after all the years of existence of the park is still not the case. Such measures, particularly including economic benefits from the park by the local population, may then lead to a positive attitude and support for conservation efforts by the local human population, thus forming a "social buffer" along the periphery of the park against intruding strangers.

Samenvatting

De leeuw heeft historisch een zeer grote verspreiding over de continenten van de aarde, groter dan veel andere zoogdieren. Meer recent komt de leeuw nog slechts voor in een beperkt aantal landen in Afrika, terwijl nog een kleine populatie aanwezig is in het Gir reservaat in India. In Kameroen is de verspreiding van de leeuw beperkt tot de Guinea-Sudan en Sahel savannes in het Noorden, tot aan het Tsjaad meer. De populaties van leeuwen in West en Centraal Afrika worden in toenemende mate bedreigd in hun gehele leefgebied. De belangrijkste bedreigingen komen door menselijk toedoen, waaronder habitat vernietiging, uitroeien van prooidieren, conflicten met veehouders, ziekten, inteelt als gevolg van isolatie en fragmentatie van populaties, en illegale handel. Om deze bedreigingen te kunnen bestrijden en om de resterende leeuwen populaties te beschermen, is een permanent programma van monitoring en onderzoek nodig. Dergelijk onderzoek vindt op ruime schaal plaats in Oost en Zuid-Afrika. Daarentegen is er een groot gebrek aan onderzoeksgegevens in West en Centraal Afrika, waar de omstandigheden geheel anders zijn. Mijn onderzoek richt zich op het genereren van wetenschappelijke gegevens over de ecologie ven de leeuw in West en Centraal Afrika en over conflicten met veehouders, die gebruikt kunnen worden voor een verbetering van beschermings- en beheersactiviteiten in deze regio.

Betrouwbare populatieschattingen vormen een belangrijke voorwaarde voor het beheer en behoud van populaties wilde dieren. De populatie leeuwen in Nationaal Park Waza in Kameroen vertoont een sterke afname in recente jaren. Het aantal volwassen leeuwen is gedaald van 40-60 in 2002 tot 14-21 in 2008, hetgeen een afname inhoudt van 65% in 6 jaar. Bovendien vertoont de leeftijdsstructuur een oververtegenwoordiging van volwassen dieren, resulterend in een omgekeerde leeftijdspiramide. De geslachtsverhouding is 1 manlijke leeuw op 3 leeuwinnen en de gemiddelde groepsgrootte bedraagt 1,6 individuen. Al deze kenmerken wijzen op een populatie die onder hoge druk staat. De druk van veehouders op het park is inderdaad zeer groot, 31% van de foto's die op leeuwenwissels gemaakt zijn tijdens een *camera trap survey* hadden betrekking op mensen of vee. De uit bovenstaande gegevens geschatte mortaliteit in de populatie van 6 leeuwen per jaar (dat wil zeggen van meer dan 10% per jaar), vooral als

gevolg van conflicten met veehouders en stroperij, is alarmerend. Leeuwen worden gedood door veehouders als gevolg van een toename in de predatie van vee door leeuwen, hetgeen op zijn beurt het gevolg is van een sterke afname van natuurlijke prooidierpopulaties. De verwachting is dat, als geen maatregelen genomen worden om het tij te keren, de leeuwenpopulatie in een periode van10 jaar uitgestorven zal zijn.

De lage dichtheden van natuurlijke prooidieren in Nationaal Park Waza zijn deels een verklaring voor de dynamiek van de *home ranges* van leeuwen. De *home ranges*, uitgedrukt als 95% Minimum Convex Polygon(MCP), zijn toegenomen van gemiddeld 630 km^2 in 2000 tot gemiddeld 1015 km^2 in 2008. Deze *home ranges* zijn de grootste die ooit gerapporteerd zijn in de regio van West en Centraal Afrika. Veel *home ranges* blijven niet beperkt tot de grenzen van het park, leeuwen brengen gemiddeld 21% van hun tijd door buiten het park. Dit blijkt met name uit de grote *home ranges* gedurende het koude droge seizoen en het natte seizoen. In het warme droge seizoen zijn de *home ranges* het kleinst. De leeuwen verblijven in dit seizoen in het park dicht bij de waterpunten, waar nog voldoende prooidieren kunnen worden gevonden. Na afloop van dit seizoen, in mei-juni, gaan de leeuwen het park uit; in deze periode verlaten ook de natuurlijke prooidieren het park en verspreiden deze zich over de omgeving van het park. De variatie in *home range* oppervlakte blijkt daarmee vooral gerelateerd aan de aanwezigheid van water, natuurlijke prooidieren en vee.

Terwijl leeuwen gedurende het warme droge seizoen in het park blijven, leggen ze gedurende de beide andere seizoenen verassend grote afstanden af, opnieuw een indicatie dat de prooidieren schaars zijn geworden. Daarbij leggen manlijke leeuwen grotere afstanden af dan leeuwinnen. De leeuwen van Waza NP zijn vooral actief 's nachts met een piek in de activiteit gedurende de avond en de ochtend. Leeuwen zijn meer actief binnen het park dan buiten het park en zijn buiten het park ook vaker 's nachts actief, dat wil zeggen als de aanwezigheid van veehouders geringer is.

Het dieet van de leeuwen in Waza National Park bestaat uit 14 verschillende soorten prooidieren. Het grootste deel van het dieet bestaat echter uit 5 soorten prooidieren, vooral van medium lichaamsgewicht (50-200 kg) en van hoog lichaamsgewicht (>200kg). De Westelijke Kob (Kobus kob kob) is de meest algemene prooi van leeuwen, maar het is verontrustend te constateren dat vee (vooral runderen) op dit moment al 21,6%

van het dieet uitmaakt (gebaseerd op het aantal prooidieren), met als gevolg ernstige conflicten met veehouders. De resultaten van de dieetstudie, gecombineerd met home ranges en de bewegingen) van leeuwen wijzen op een overlevingsstrategie van de leeuwen onder sterke menselijke verstoring.

Het probleem van een hoge mortaliteit van leeuwen als gevolg van conflicten met veehouders wordt verergerd door de hoge illegale aanwezigheid van vee in het park. Zelfs binnen de grenzen van het park hebben leeuwen gemiddeld nog 18% vee in hun dieet. Wilde prooidieren vormen dus binnen het park het belangrijkste dieet (82%), maar worden ook buiten het park geconsumeerd Maar daar beslaan ze slechts 6,7% van het dieet. Dit geeft aan dat er toch nog wel natuurlijke prooidieren buiten de grenzen van het park aanwezig zijn. Alhoewel de dichtheden van vee in bijv. een deel van het droge seizoen zowel binnen als buiten het park veel hoger zijn dan die van natuurlijke prooidieren, blijken leeuwen toch een voorkeur voor natuurlijke prooidieren te hebben boven vee, zoals kon worden afgeleid uit toepassing van de zgn. Jacobs index voor relatieve abundantie. Dit is een belangrijk resultaat uit het oogpunt van praktische aanbevelingen voor het beheer van het park.

Het conflict tussen lokale bewoners en leeuwen over de predatie van vee is een sleutelfactor voor het uitsterven van leeuwenpopulaties in West en Centraal Afrika, in het bijzonder buiten de grenzen van parken die geen bufferzone hebben. Veehouders rond het Waza Nationaal Park blijken last te hebben van extreem hoge verliezen aan vee door leeuwen, waarbij de meeste predatie ‘s nachts plaatsvindt. Daarbij is er een (niet-significante) indicatie voor een toename van de predatie gedurende volle maan perioden. In totaal zijn leeuwen verantwoordelijk voor een economische schade rond Nationaal Park Waza van Euro 100.000 (prijsniveau 2010). Per huishouden verliezen residente veehouders gemiddeld één koe per jaar aan predatie door leeuwen, terwijl nomadische veehouders gemiddeld twee koeien per jaar verliezen, gelijk aan respectievelijk Euro 260 en Euro 520 per jaar (prijsniveau 2010). Veel veehouders proberen maatregelen te nemen om hun vee te beschermen tegen predatie door leeuwen, meestal door het gebruik van zgn. *boma’s* waarin het vee ‘s nachts wordt gehouden, of door gerichte bescherming door herders en honden van kuddes vee in het veld. Een verbetering van de methoden, dat wil zeggen een algehele doorvoering van de nu gebruikte methoden die het meest effectief bleken te zijn, zal naar schatting een reductie opleveren van 25% op vee (koeien, schapen, geiten) en zelfs van 50% op runderen alleen.

Verdere verbetering van deze methoden is mogelijk door het bevorderen van *best practices*. Hieruit blijkt dat op deze manier het conflict tussen mens en leeuw rond Nationaal Park Waza grotendeels kan worden opgelost. Uit het onderzoek is echter gebleken dat de sedentaire en de nomadische veehouders niet dezelfde *best practices* kunnen toepassen om op een effectieve wijze de predatie door leeuwen te reduceren. Daarbij bleek het voor nomadische veehouders lastiger om voldoende effectieve maatregelen te nemen dan voor de sedentaire veehouders, vanwege hun mobiliteit. Voor de nomadische veehouders zal het daarom een grote uitdaging blijven om de predatie voldoende te verminderen. Verder is het duidelijk dat een significante reductie van de vee-predatie door leeuwen hand in hand zal moeten gaan met een betere bescherming van de natuurlijke prooidieren, zodat leeuwen niet op vee hoeven te overleven. Bij voldoende herstel van de prooipopulaties zullen ook voor nomadische veehouders de verliezen afnemen, gezien de voorkeur van de leeuwen voor de natuurlijke prooidieren.

Alhoewel de leeuwenpopulatie in Nationaal Park Waza, één van de best onderzochte populaties in de regio West en Centraal Afrika, bedreigd is met uitsterven, is het nog steeds mogelijk de populatie te redden door gecoördineerde beschermings- en beheersmaatregelen. Onderzoek in de Ngorongoro krater in Tanzania heeft aangetoond dat leeuwenpopulaties redelijk veerkrachtig kunnen zijn na een sterke reductie; de populatie kan door snelle reproductie in een vrij korte tijd herstellen indien de omstandigheden verbeterd zijn. Om het voor de leeuwenpopulatie in Nationaal Park Waza herstel mogelijk te maken, zal de overheid de bescherming van het park significant moeten verbeteren, door het versterken van het parkbeheer en de toepassing van wetgeving, zoals de bos wetgeving. Daartoe zullen afdoende financiële middelen beschikbaar moeten worden gesteld, in het bijzonder voor de aanstelling en uitrusting van parkwachters. Gedurende mijn onderzoek bleek geen geld beschikbaar om de wegen van het park open te houden ten behoeve van toeristen. Ook ontvingen, in strijd met de bos wetgeving op dit punt, de lokale gemeenschappen rond het park geen deel van de parkinkomsten. Aan het einde van mijn onderzoek bleek dit nog steeds niet het geval te zijn. Dergelijke maatregelen zijn essentieel, vooral financiële bijdragen voor de lokale bevolking, omdat ze zullen resulteren in een positieve houding van de lokale bevolking ten aanzien van de leeuw en de op deze soort gerichte beschermingsmaatregelen. Hierdoor wordt een sociale buffer gevormd rond het park tegenover vreemde indringers van buiten het park.

Resume

Une population de lion menacée

Comprendre l'écologie du lion (*Panthera leo L*, 1758) et les interactions homme-lion en lien avec la prédation du bétail dans le Parc National de Waza, Cameroun

Mots clé

Lion (*Panthera leo*), statut de la population, écologie spatiale, régime alimentaire du lion, atténuation prédation du lion, Cameroun

Le lion était historiquement l'un des mammifères les plus répandus sur le globe terrestre. À l'heure actuelle, le lion n'existe plus que dans les aires proteges de quelques rares pays d' Afrique sub-saharienne et une petite population dans la forêt de Gir en Inde. Au Cameroun, l' aire de distribution du lion est actuellement limité aux savannes soudano-guinéennes et, du Sahel dans la région nord, au sud du lac Tchad. Les populations de lions en Afrique centrale et occidentale sont de plus en plus menacées dans toute son aire de répartition restante. Les menaces qui impactent sur les populations de lions sont généralement de nature anthropique, y compris la destruction des habitats, raréfaction des proies, les conflits avec les éleveurs, les maladies (zoonoses), la dépression de consanguinité due à la fragmentation et à l'isolement, et le commerce illégal. Pour faire face à ces menaces et à la conservation des populations de lions restants, la recherche continue et le suivi des populations de lion sont requises. Cependant, la conservation du lion en Afrique centrale et occidentale souffre d'un manque général de données au sein et entre les populations de lions. Ma recherche vise à fournir des données scientifiques nécessaires pour appuyer une meilleure gestion et conservation des lions dans la région d'Afrique centrale en mettant l'accent sur Parc national de Waza au Cameroun. Les enquêtes portent sur l'écologie du lion et les conflits homme-lion en raison de la prédation du bétail dans ce parc.

Des estimations fiables sont indispensables pour la gestion et de la conservation de la faune. La population de lions du parc national de Waza

semble éprouver une diminution frappante. Le nombre de lions adultes a diminué de 40 à 60 en 2002 à 14-21 en 2008, ce qui représente une réduction d'environ 65% en 6 ans. En outre, la structure par âge de la population est biaisée en faveur des adultes, produisant une pyramide inversée. Le sex-ratio est de 1 mâle pour 3 femelles et la taille moyenne du groupe est lion seulement 1,6 lions. Toutes ces caractéristiques indiquent une population sous haute pression. Et en effet, la pression humaine et de l'élevage sur le parc est énorme, 31% des photos prises par des pièges photographiques, fixés pour compter les lions dans cette étude, en 2008, étaient des humains et des animaux dans le parc. Le taux de mortalité estimé à environ six lions qui meurent chaque année est alarmant, principalement abattus en représailles de la prédation du bétail et le braconnage. Le massacre de représailles est fait par les bergers, comme les lions de plus en plus font de la predation sur le bétail en raison de la forte baisse de leurs proies naturelles. Dans l'ensemble, la population de lions devrait avoir disparu dans 10 ans, si rien n'est fait pour inverser la situation.

La faible densité des proies naturelles maintenant disponible au parc national de Waza est également reflétée par les grandes tailles des domaines vitaux des lions observés dans cette étude. Les domaines vitaux des lions, exprimés en polygone convexe minimum de 95% (PCM), ont augmenté d'une moyenne de 630 km^2 en 2000 à 1015 km^2 en 2008. Ces domaines vitaux sont les plus importants signalés jusqu›à présent dans les régions d'Afrique centrale et l'Ouest. Plusieurs de ces domaines actuellement s' étendent à des aires en dehors du parc, ce qui amene les lions à dépenser en moyenne 21% de leur temps à l'extérieur du parc. Cela entraine surtout en saison des pluies et sèches froides de plus grands domaines vitaux. Pendant la saison sèche chaude par contre les domaines vitaux sont les plus faibles et les lions restent en grande partie dans le parc à proximité des points d'eau, où des proies sont encore disponibles durant cette période. Le temps passé à l'extérieur du parc coïncide avec la prédation accrue du bétail. La variation saisonnière observée dans la taille du domaine vital semble être principalement due à la disponibilité de l'eau, de proies naturelles, et de la migration des animaux comme des proies de rechange.

Alors que les lions restent dans le parc pendant la saison sèche et chaude, ils se deplacent étonnamment sur de plus longues distances que durant les autres saisons, ce qui indique que, même au cours de cette saison la proie est devenue rare. Les mâles couvrent de plus longues distances que

les femelles. Les Lions du Parc National de Waza sont nocturnes dans leurs activités avec des pics crépusculaires au lever et au coucher du soleil. Les lions sont généralement plus actifs à l'intérieur qu'à l'extérieur du parc et de se déplacent en dehors la plupart du temps la nuit. Le régime alimentaire du lion dans le parc national de Waza montre une largeur de niche de 14 différentes espèces de proies. Toutefois, la majeure partie du régime alimentaire se compose de cinq espèces de proies, de la masse corporelle moyenne principalement (50-200 kg) et grandes (> 200 kg). Le kob ouest (Kobus kob kob) est la proie la plus commune sauvage des lions, mais le bétail (principalement les bovins) constitue actuellement autant que 21,6% de l'alimentation (sur une base nombre), ce qui entraîne des conflits avec les propriétaires de bétail. En fait, toutes les caractéristiques observées de l'alimentation et les mouvements du lion lions reflètent une stratégie de survie dans des conditions très perturbées.

Le problème de la conservation notamment celui de la mortalité des lions tues en représailles par les pasteurs est exacerbé par des intrusions de bétail en cours dans le parc. Même à l'intérieur du parc, les bovins constituent 18% du régime alimentaire du lion. Les proies sauvages sont également consommés à l'extérieur du parc (6,7% des proies consommées en dehors du parc), suggerant une excursion des proies naturelles au-delà des limites du parc. Malgré l'abondance beaucoup plus élevée du bétail sur des proies naturelles, les lions semblent préférer les proies sauvages sur le bétail, ce qui devient évident lorsque l'indice de l'abondance relative de Jacob est appliquee. Ce constat est important, car la base de recommandations pratiques en vue l'atténuation des conflits dans et autour du parc national de Waza.

Les conflits entre les humains et les lions due a la prédation du bétail est un facteur moteur de la baisse de la population de lions en Afrique, en particulier sur les bords de petites aires protégées des zones tampons sans transition. Les éleveurs autour de Parc national de Waza souffrent de niveaux eleve de déprédation du bétail, la plupart des attaques se produisent la nuit. Sur le plan économique, les lions sont une menace importante, responsables dans la zone de Waza pour des pertes totales de € 100.000 par an (2010 niveau des prix). Par ménage, les pasteurs résidents perdent une tête de bétail tandis que les pasteurs nomades perdent deux par an, ce qui équivaut à environ € 260 et € 520, respectivement (2010 niveau des prix). Les pasteurs font des efforts pour réduire les pertes dues aux attaques de lions, principalement composés de garder

le bétail dans des enclos pendant la nuit et de la conduite du troupeau au cours des pâturages. Toutefois, ces mesures ne semblent pas être suffisamment efficaces. L'application des bonnes pratiques qui sont déjà utilisées aujourd'hui par une frange des pasteurs, se sont avérées utiles pour réduire la déprédation du bétail totale de 25% et la déprédation du bétail, même de 50%. Une autre amélioration de ces méthodes est possible, par conséquent les conflits homme-lion autour de Parc national de Waza pourraient théoriquement être largement évités. Il est devenu évident, cependant, que différentes méthodes devront être adoptées par les pasteurs nomades et résidents dans le but d'atténuer efficacement la prédation du bétail par des lions, puisque les pasteurs nomades ont peu d'options faciles disponibles. Ce groupe d' éleveurs pose donc le plus grand défi. Un autre point important est que la prévention de la prédation du bétail, comme il est recommandé ici, va limiter encore davantage la disponibilité de nourriture pour le lion. Prévention de la prédation doit donc aller de pair avec une meilleure protection de la proie naturelle de sorte que les populations de proies peuvent augmenter à nouveau et les lions ne dépendront plus de l'élevage pour leur survie.

Bien que la population de lion deWaza, l'une des populations de lions les plus vues dans la région de l'Afrique centrale, semble maintenant être la plus menacée, les efforts concertés de conservation pourraiet encore sauver cette population en voie d'extinction locale. Des etudes dans le cratère du Ngorongoro en Tanzanie montrent que le lion est en fait assez élastique, sa population peut rebondir et croître rapidement après un changement positif des conditions, compte tenu de son taux de reproduction rapide. Pour que la population de lion de Waza lion d'augmente et retrouve son ancien statut, le gouvernement doit améliorer considérablement la protection du parc par l'autorité en charge de la gestion du parc et de l'application des lois, ainsi que la fourniture de ressources financières et humaines pour le parc. Au cours de mon étude, les fonds pour ouvrir les routes du parc pour observer les animaux sauvages (tourisme) ne sont jamais arrivés à temps. En outre, les communautés locales vivant à proximité du parc doivent recevoir des prestations directes de recettes des parcs, qui après toutes ces années d'existence du parc n'est pas encore le cas. Ces mesures, en particulier, y compris les avantages économiques du parc par la population locale, peuvent alors conduire à une attitude positive et de soutien pour les efforts de conservation de la population humaine locale, pouvant ainsi former un «amortisseur social» le long de la périphérie du parc contre les intrus étrangers.

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Curriculum vitae

Pricelia N. Tumenta was born on the 12th of August 1973 in Ndop, Cameroon. She studied Zoology after her secondary school in 1992 at the University of Jos in Nigeria. After graduating with a Bachelor of Science degree in Zoology in 1996, she proceeded to the University of Ibadan in Nigeria where she studied and graduated with a Master degree in Wildlife Management in 1999.

During her undergraduate study, she participated in a World Health Organization project that investigated responses by Cutaneous Leishmaniasis patients in Nigeria to two heat shocked proteins. Her Masters research studied the utilization of natural resources by women in a protected area in the North West region of Cameroon.

In 2007 she was granted the opportunity by the Institute of Environmental Sciences, Leiden University in the Netherlands to study a PhD. She conducted field work of her PhD research on lions in Waza National Park in Cameroon, under the supervision of Profs Helias Udo de Haes and Hans de Iongh of the Institute of Environmental Sciences, Leiden University which resulted to this thesis.

She currently works as a teaching staff in the Department of Forestry in the University of Dschang in Cameroon. She is an active member of the Network on Lion Conservation in West and Central Africa (ROCAL) and the African Lion Working Group (ALWG), both instrumental in lion conservation in Africa. She received funding for this study from the Institute of Environmental Science and a conference grant from ANSTI. She has been actively involved with some conservation actions on lions to promote their persistence and coexistence with humans; funded by National Geographic Big Cat Initiative in Waza National Park in Cameroon.