ASSESSMENT OF RESOURCE USE AND LANDSCAPE RISK FOR AFRICAN LIONS (*PANTHERA LEO)* IN EASTERN BOTSWANA

by

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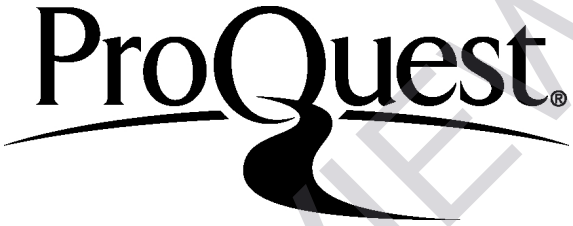

ASSESSMENT OF RESOURCE USE AND LANDSCAPE RISK FOR AFRICAN LIONS (*PANTHERA LEO)* IN EASTERN BOTSWANA

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African lion (*Panthera* leo) populations have declined in recent decades due to various anthropogenic factors with range contraction of over 75% and an estimated 20,000 – 30,000 left in Africa. The majority of extant lion populations are of small size, and geographically isolated from each other further compromising their persistence. The purposes of this study were to 1) examine anthropogenic factors affecting the social organization of lions, 2) determine lion resource utilization and 3) identify and create predictive lion corridors in the Greater-Mapungubwe Transfrontier Conservation Area (GM-TFCA). Results from our study indicate that high rates of indiscriminate anthropogenic mortality constrained population size in the NTGR where 94.7% of adult mortality occurred outside the reserve. Understanding how animals utilize the landscape is central to conservation biology. We also investigate lion habitat resource selection by means of resource utilization functions (RUF). We found that at the population level elevation in the dry season was the only significant factor detected for lion space use ($\hat{\beta}$ ± SE) (-0.278 ± 0.107). Lions showed a strong avoidance of close proximity to human settlements at the individual level across seasons with over 66% (12/18) selecting for areas further away from human settlements. Lions moved randomly across the landscape independent of vegetation type. While isolated small protected areas (PA's) fall short of

preserving wide-ranging, low density species like lions, a network of small PA's connected by corridors can in itself function as a larger body through which the viability and sustainability of lions can be maintained. For this we implement Circuit Theory modeling in an attempt to identify lion corridors within the GM-TFCA. Nine potential lion corridors stemming from six core territories were identified in this study. Within the 9 corridors, three barriers were identified - all located on the South African side of the TFCA restricting lion movement. Successful lion conservation lies in continued protection of existing protected areas and the creation of corridors that link them together.

DEDICATION

"For I know the plans I have for you, declares the Lord, I have good plans for you, not plans to hurt you. I will give you hope and a good future"

Jeremiah 29:11

First and foremost I dedicate this to my Lord and Savior, Jesus Christ. Needless to say this journey has seen its fair share of mountain tops and deep, dark valleys too. No matter what the need or circumstances were, I have always found my strength, peace and hope in Him. I also dedicate this to my parents, Thys and Elize. Without their unwavering support, encouragement, and guidance this would never have happened. Lastly, but certainly not least, I dedicate this to my beautiful wife, Kristen. Her boundless love, compassion, and more importantly, patience with me is something I will treasure for the rest of my life. I could not have done this without you by my side.

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"Is not the lion a mirror of man? How did we get the lion's share? By being superior to the lion we had to be better at what the lion was best at – dominating his world. Now we must understand that past to deal with the future – how to rule the world means how to rule ourselves. Thus study of the lion in his domain is a key to understanding our adaptations as the new dominant social predator – at the core, our heart, our predatory nature is the problem of human life. The lion is us!" – Randall Eaton

Introduction

The global human population now exceeds 7 billion and estimated median projection figures are set at over 9.5 billion people by 2050 (United Nations 2013). The demand for space and natural resources is higher than ever before (Gordon et al. 2012; Smil 2013). People have become the primary driving force behind many of the biggest threats facing ecosystems (Brooks et al. 2008). As a result, global biodiversity is rapidly deteriorating with 21-36% of 5,282 extant terrestrial mammal species currently being threatened with extinction (Schipper et al. 2008). With one in four mammal species facing extinction, Schipper et al. (2008) further estimates that the populations of one in two is declining and approximately 188 species are listed as Critically Endangered with 29 of those already presumed extinct. Overall 52% of all mammal species, for which population trends are known, are declining with only 5% of species listed as Threatened

either having stable or increasing population trends (Schipper et al.. 2008). Habitat loss and over harvesting constitutes 40% and 17% respectively of global threats to extant mammal species survival (Schipper et al. 2008).

In Africa, it is estimated that during the last century the human population has grown from 100 million to over 1.1 billion (Haub and Kaneda 2013). A common thread throughout various studies driving fauna and flora to extinction include the destruction of natural habitat, poaching, over utilization of natural resources and human-wildlife conflict. Illegal trade in wildlife is considered to be the second largest area of organized crime after illegal drug trade with an annual turnover of over $90 billion dollars (Angulo et al. 2009). With an ever growing human population and the demands it brings to sustain it, protected areas have become crucial for the conservation and preservation of wildlife (Gaston et al. 2008; Foster et al. 2014).

There are approximately 133,000 protected areas across the globe, covering an estimated 12% of land surfaces (Butchart, et al. 2010) with the African continent boasting a large abundance of protected areas (IUCN 2015). From these, 16.8% are comprised of Transfrontier Conservation Areas (TFCA) (Mittermeier et al. 2005) - a concept whereby fences between wildlife areas in two or more neighboring countries are dropped to create one large conservation area facilitating free animal movement and managed jointly by the respective countries (Mittermeier et al. 2005). Unfortunately today even the largest of protected areas are simply not big enough to maintain viable and sustainable populations of wide-ranging species (Gurd et al. 2001; Linnel et al. 2001) illustrating the need and importance of both small and non-protected areas.

Small, fragmented wilderness areas are difficult to manage and the wildlife populations inhabiting such areas are exposed to many threats that directly compromise their viability. Fencing off these areas is associated with several problems, particularly exacerbating the isolation thereof (Hayward and Kerley 2009). Current approaches attempt to alleviate these problems by creating large conservation areas with buffer zones and implementing conflict-mitigation initiatives (Woodroffe et al. 2005).

Edge effects are a major concern for populations of large predators living in small protected areas (Woodroff and Frank 2005). Brashares (2001) illustrated how human density and reserve size had a direct correlation to carnivore extinction in West Africa. According to the International Union for Conservation of Nature (IUCN 2008) Red list of Threatened Species, over 44% of felids are included in the top three categories of threat (Critically Endangered, Endangered, and Vulnerable). The top conservation priorities suggested for wild felids are to preserve healthy source populations, and if successful to create genetic corridors linking these populations (Weber and Rabinowitz 1996; Rabinowitz 2014).

At the top of the food chain large carnivores are a vital component of any healthy ecosystem despite typically occurring at low densities (Carbone et al. 2002; Kissui and Packer 2004; Ripple et al. 2010; Ripple et al. 2013; Ritchie et al. 2012; Ripple et al. 2014). Their presence in ecosystems structure habitats and energy networks from top to bottom in various forms, mostly through predation on large herbivores and by limiting meso-predator populations through intra-guild competition (Ritchie et al. 2012; Ripple et al. 2010; Ripple et al. 2013; Ripple et al. 2014). Large carnivores are difficult to conserve

because they require large home ranges, have low reproductive rates, encompass a wide dietary niche which typically includes large prey, typically occur at low densities and they pose a risk to human safety (Cardillo et al. 2004; Cardillo et al. 2005; Carbone et al. 1999; Purvis et al. 2000, Holmern et al. 2007, Packer et al. 2005; Hobcraft et al. 2005).

In many ways large carnivores can be regarded as the miners' canaries of healthy ecosystems and biodiversity (Macdonald et al. 2010). As top predators in an environmental cascade large carnivores fulfil an important niche in an otherwise healthy ecosystem and their successful conservation as a species can benefit a wide range of biodiversity.

Species of large carnivores, can be considered a keystone species and described as a single species that make a significant impact on communities, but constitute only a low proportion of the community biomass (Paine 1966; Mills and Shenk 1992; Mills et al. 1995; Power et al. 1996). Large carnivores bring value and functionality to any ecosystem (Packer et al. 2003) and can be regarded as tools for species biodiversity and conservation. For example, Berger et al. (2001a) showed an increase of avian fauna biodiversity in Yellowstone National Park (YSNP) mainly due to the re-introduction of gray wolves (*Canus lupis*), which predate on larger prey species leaving larger carcasses available for scavenging raptors. Wolves were also shown to positively affected river systems in YSNP through their predation pressure on resident elk (*Cervus elaphus*) (Ripple and Beschta 2005; Beschta and Ripple 2008).

With an increasing human population coinciding with the destruction of natural habitat to facilitate the resource and space needs of people, it is inevitable that conflict

will continue to arise between people and wildlife (Woodroffe and Ginsberg, 1998). African lions (*Panthera leo*) are quite often one of the primary species involved in conflict situations on the African continent (Stander 1990; Bauer et. al 2003; Hemson 2003; Kissui 2008), since they have the ability to roam over large areas, prey on large animals (Schaller 1972; Radloff and du Toit 2004; Patterson et. al 2004; Hayward and Kerley 2005; Kolowski and Holekamp 2006; Holmern et al. 2007; Kissui 2008), especially livestock, and pose as high risk to humans (Treves and Treves 1999; Packer et al. 2005; Ikanda 2009). Their presence is often conspicuous, much more so than that of other more elusive large carnivores, such as leopards (*Panthera pardus*) (Balme et al. 2009). It is for these reasons that lions are often persecuted and killed by local farmers and herdsman.

Lion populations have been severely affected in recent decades, with an estimated 20,000 – 30,000 free-ranging lions left in Africa and range contraction of over 75% (Riggio et al. 2013; IUCN 2013; Bauer et al. 2015). Overall lion numbers have declined by 43% over the past two decades and recent studies estimate that lion populations in west and central Africa will decline by 67% in the next 20 years and east African populations by 37% (Bauer et al. 2015). Lions in West Africa are listed as regionally Endangered on the IUCN red list with east- and southern African populations listed as Vulnerable. On December 21, 2015 the US Fish and Wildlife Service announced that lions in central and West Africa be listed as Endangered, along with the Critically Endangered sub-population (*Panthera leo persica*) in India's Gir Forrest, under the

Endangered Species Act (ESA) with lions from east and southern Africa listed as Threatened (U.S. Fish and Wildlife Service 2016).

In southern Africa, many small lion populations have been fenced in an attempt to allow lions to persist in a human dominated landscape (Packer et al. 2013; Hayward and Kerley 2009). Populations within protected areas, however, are still exposed to legal and illegal hunting, road kills, poisoning and snaring (Woodroffe and Ginsberg 1998). Illegal killing, poaching, problem animal control, and loss of habitat are believed to be more serious threats to lion conservation than legalized safari hunting (Whitman et al. 1997). These human-induced mortalities affect lion populations in various ways, further compromising their viability and likelihood of survival (Woodroff and Ginsberg 1998; Woodroffe 2000; Snyman et al. 2015).

Lions are probably one of the best studied terrestrial carnivore species to date. Studies range from social structure dynamics (Schaller 1972; Packer and Pusey 1982; Packer et al. 1987; Van Orsdol 1984; Packer et al. 1990; Packer et al. 2005), to territoriality (Schaller 1972; Funston 1999, 2003), inter-specific competition (Cooper 1991; Mills and Biggs 1993), reproduction (Schaller 1972; Pusey and Packer 1987; Funston et al. 2003), and disease (Packer et al. 1991; Roelke and Parker 1996; Kissui and Packer 2004). Studies have also illustrated the threats and dangers that lion populations face in protected areas (Woodroffe and Ginsberg 1998; Woodroffe and Frank 2005, Loveridge et al. 2007; Snyman et al. 2015).

Lions are considered naturally absent from true deserts and equatorial rainforests (Hunter 2011) and are found across a diverse range of habitats but predominantly associated with woodland and grassland savannas (Nowell and Jackson 1996; Hunter 2011). Lion population growth and stability are largely determined by social and ecological factors such as density, tenure of residential male lion coalitions, the number of females in a pride, intergroup competition, group territoriality, and prey availability (Van Orsdol 1984; Packer et al. 1990; 2005; Mosser and Packer 2009). Frequent removal of resident males may influence successful reproduction, either through factors such as infanticide or through reproductive suppression until social stability within the pride is restored (Smuts 1982; Whitman and Packer 1997). The removal of adult females, the main breeding units of a pride, can also seriously influence successful reproduction and lion population growth as larger groups have higher rates of reproductive success and tend to gain access to the best quality habitats (Packer et al. 1988; Loveridge et al. 2007; Mosser and Packer 2009). The loss of cubs and sub-adults would impact population size and future reproductive potential. Many factors influence cub survival, including disease (Kissui and Packer, 2004; Packer et al. 1991; Roelke and Parker 1996), starvation (Packer and Pusey 1995), predation (Schaller 1972; Kruuk 1972), and infanticide (Packer et al. 1990; Pusey and Packer 1987). In certain lion populations infanticide seemingly plays a key role in cub mortality, accounting for 30% of cub deaths in the Serengeti (Packer et al. 1990; Pusey and Packer 1987; Whitman and Packer 1997; Van Orsdol 1984; Packer and Pusey 1983; Bertram, 1975; Packer and Pusey 1997; Packer et al. 2001).

Lions are highly social animals that live in fission–fusion groups (Van Orsdol 1984; Packer et al. 1990; Whitman and Packer 1997), and they are thus susceptible to population disturbances from humans. Lion prides are permanent social units that consist of adult females, their dependent cubs and a resident male coalition (Schaller 1972; Packer and Pusey 1982). Male lions typically reach maximum reproductive success between the ages of 7 and 8 (Packer et al. 1988).

Lion prides are predominantly regulated by social factors (Packer et al. 1990; Van Orsdol 1984; Packer et al. 2005), but food availability has a large influence on those social mechanisms (Van Orsdol et al. 1985). Lions are also known to form prides for various reasons, one being communal cub defence against infanticide males (Packer et al. 1990; Pusey and Packer 1984). Lion prides may vary in size depending on ecological and social factors (Packer and Pusey 1982; Van Orsdol 1984; Packer et al. 1990; Packer et al. 2005). Resident adult females are regarded as the core of a lion pride. Lion prides are defined by having at least two adult females living together, while groups of lions are considered to be those without two or more adult lionesses. Females usually give birth in synchrony and the cubs are raised communally, which is one of the reasons for pride-living (Bertram 1975; Van Orsdol 1984; Packer et al. 1990). Litters may vary from one to six cubs, but the average is usually two to three. Females spend their entire lives in their natal pride and seldom disperse (Packer and Pusey 1982; Van Orsdol 1984; Packer et al. 1990; Packer et al. 2005). Female dispersal is usually due to immigrating male coalitions after an initial pride take-over. Males form coalitions and will challenge and take tenure over a pride of females by ousting the resident males and sub adults, but also kill all small