# LEOPARD POPULATION DENSITY AND COMMUNITY ATTITUDES TOWARDS LEOPARDS IN AND AROUND DEBSHAN RANCH, SHANGANI, ZIMBABWE

A thesis submitted in fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
of
RHODES UNIVERSITY

Department of Zoology and Entomology

By

**PHUMUZILE NYONI**

DECEMBER 2015

**SUPERVISOR: DR D. M. PARKER**

# ABSTRACT

Leopards (*Panthera pardus*) are regarded as one of the most resilient large carnivore species in the world and can persist in human dominated landscapes, areas with low prey availability nd highly fragmented habitats. However, recent evidence across much of their range reveals declining populations. In Zimbabwe, 500 Convention for the International Trade in Endangered Species (CITES) export tags are available annually for leopards as hunting trophies, despite limited accurate data on the leopard populations of the country. Moreover, when coupled with the massive land conversions under the controversial National Land Reform Programme (NLRP), leopard populations in Zimbabwe are in dire need of assessment. My study was conducted on Debshan ranch, Shangani, Zimbabwe, which is a commercial cattle (*Bos indicus*) ranch but also supports a high diversity of indigenous wildlife including an apparently healthy leopard population. However, the NLRP has resulted in an increase in small-holder subsistence farming communities around the ranch (the land was previously privately owned and divided into larger sub-units). This change in land-use means that both human and livestock densities have increased and the potential for human leopard conflict has increased. I estimated the leopard population density of the ranch and assessed community attitudes towards leopards in the communities surrounding the ranch. To estimate population densities, I performed spoor counts and conducted a camera trapping survey. Questionnaire interviews were used to assess community attitudes. My spoor counts provided a leopard density estimate of 13.57 leopards/100km$^2$ compared to the camera trapping estimate of between 2.0 and 6.9 leopards/100km$^2$. Although the high density estimate derived from the spoor counts is possible for Debshan because leopards are the apex predators and are adequately protected, potential edge effects are not yet fully understood. Thus, the more conservative estimate of 2.0 leopards/100km$^2$, derived from the camera trapping survey, is probably more appropriate. Attitudes towards predators amongst respondents surrounding Debshan (n = 140) were neither too negative nor positive, attitude index had a mean score of 1.7 ± 3.8 (range: -7 – 10). No single predictor variable used in my analysis was able to adequately explain why the communities held these negative views. However, livestock losses were repeatedly listed by respondents as being one of the main reasons for their lack of tolerance towards predators. The density estimate of 2.0 leopards/100km$^2$ translates to a population of 9 – 26 leopards within Debshan ranch. This density estimate is too low considering the habitat type at Debshan ranch but should be interpreted with caution as it lacks fundamental elements like age and sex ratio. Moreover, the interaction of the leopard population with the surrounding communities is currently unclear. As a precautionary measure, I recommended reducing the annual hunting quota for Debshan from five to one leopard. Future work should aim to improve the attitudes of the surrounding communities to secure broader landscapes for leopard conservation while also reconciling density estimates to fully understand the leopard population of the region.

# TABLE OF CONTENTS

**ACKNOWLEDGEMENTS**

I can do all things through Christ, who gives me strength (Philippians 4 v 13). Thank you LORD that you have brought me this far.

I would like to express my deepest gratitude to my supervisor: Dr D. M. Parker; thank you for continued support right through this project. Your enthusiasm and easy go attitude made this work enjoyable and even fun at times. Your instantaneous response to emails about anything, from questions on camera trap setups, countless drafts all to the final details of thesis writing, you were always on time. Thank you for your motivation and gently encouraging me to be independent. For your hospitality and generosity you showed me when I went to Rhodes University, thank you. This great work would not have been without you, THANK YOU.

To Dr G. K. Purchase, my co-supervisor, my mentor, my sister, my friend: I bless the day you came to my life. You have been my voice of reason, my encouragement and helped me come this far. Thank you for your assistance in doing the proposal, getting financial assistance and logistically as I settled in and all at the ranch. You have been an invaluable part to this project. God bless you

To Colin Edwards, General Manager at Debshan ranch, thank you for making my time at the ranch so enjoyable and comfortable, for building the most beautiful research accommodation Netty has ever experienced, for organising transport for me whenever I needed to travel to or from town and for making sure everything is available and functioning at its best: cameras, vehicle, and even going an extra mile to loan me your personal compass, thank you.

To Duncan MacFadyen, thank you for your contagious enthusiasm, your swift response to my emails and your passion for the leopard work.

To the owners of Debshan ranch, Mr and Mrs Oppenheimer, thank you for granting me such a wonderful opportunity to work at such a spectacular place and for being generous with your time and resources at all times, am really grateful.

To Edward Mpofu, thank you for your companionship throughout the field work, being more than a driver, your great ideas and knowledge of the ranch in and out made moving around easier, your interest in the questionnaire interviews, not to mention your patience during the gruelling exercise of setting up the cameras, getting them to focus while doing the crawl test, all through to countless times digging the car out of piles of sand or mud as we went around the communities, your hard work paid off, thank you!!!!

For help with my data analyses in R and DENSITY, my sincerest gratitude goes to Armand, Gareth, Rebecca, Allie and Megan. Thank you guys for your invaluable help.

To Kevin and Fay, thank you for your company as we shared accommodation at the research centre, you have been like parents to me, for sharing your rich wildlife experiences and for the supply of research papers, your help with GIS and mapping programs and for proofreading and critical analysis of chapters two and five.

To all the management and staff at Debshan ranch, thank you for making my stay exciting and helping me in any way you could: Mberi for your friendship, Steve for your rich knowledge on leopards and the wild, Douglas Mpofu for taking your time to introduce me to the local authorities for my questionnaire survey and to everyone else for the kindness and hospitality, you are a great family.

To Buhlebenkosi Ngwenya, your assistance and company for the duration of your internship was refreshing.

To all the communities that willingly took their time to answer my questions and share their experiences, thank you, and to all the Councillors and RDC staff that granted me the permission to go into their areas, and the local heads that organised village meetings for me.

To my family: my parents in every way, my brothers and sisters, my friends, thank you for believing in me (even when I was not too sure myself) and spurring me on throughout and for your prayers.

To my dear husband who stood by me through it all, when I had to be away from home for the greater part, for seeing the bigger picture and his visits all the way to Grahamstown, thank God for you, you are my heaven sent.

To Bongie, for having to take up all the duties at home while I was away and managing to juggle it with your own made my work load a lot lighter and manageable, thank you my dear.

**For financial sponsorship and material provision**

The following generously provided financial aid to cover my tuition, travel expenses and living costs, thank you to:

- The Solon Foundation
- Dr D. M. Parker and Rhodes University
- Maureen Stewart
- Duncan and Netty Purchase

Debshan ranch owners and management kindly provided me with accommodation, a vehicle and also purchased equipment (cameras and GPS collars), thank you.

## LIST OF ABBREVIATIONS AND ACRONYMS USED

AICc - Akaike's Information Criterion
BVC - Bubye Valley Conservancy
CA - Communal Areas
CAMPFIRE - Communal Areas Management Programme for Indigenous Resources
CBNRM - Community Based Natural Resources Management
CHAs - Controlled Hunting Areas
CI - Confidence Interval
CITES - Convention on International Trade in Endangered Species of Wild Fauna and Flora
CML - Conditional Maximum Likelihood
CV - Coefficient of Variation
ESRI - Environmental Systems Research Institute
FAO - Food and Agriculture Organisation
FMD - Foot and Mouth Disease
FML - Full Maximum Likelihood
FTLRP - Fast Track Land Reform Programme
GB - Gigabyte
GPS - Global Positioning System
HLC - Human Leopard Conflict
HMMDM - Half Mean Maximum Distance Moved
HWC - Human Wildlife Conflict
ICA - Intensive Conservation Area
IUCN - International Union for Conservation of Nature
LUTs - Land Use Types
MB - Megabyte
MMDM - Mean Maximum Distance Moved
MMDMOSA - Mean Maximum Distance Moved Over Study Area
MP - Megapixel
MuMiN - Multi-Model Inference
NACSO - Namibian Association of CBNRM Support Organisations
NDF - Non-Detriment Finding

| | |
|---|---|
| NGOs | - Non-Governmental Organisation |
| NLMP | - National Leopard Management Programme |
| NLRP | - National Land Reform Programme |
| PA | - Protected Area |
| PAC | - Problem Animal Control |
| PMC | - Phinda-Mkhuze Complex |
| PWMA | - Parks and Wildlife Management Authority |
| RDC | - Rural District Council |
| SECR | - Spatially Explicit Capture Recapture |
| UN | - United Nations |
| UTM | - Universal Transverse Mercator |
| VIF | - Variance Inflation Factor |
| WBLRP | - Wildlife Based Land Reform Policy |
| WildCRU | - Wildlife Conservation Research Unit |

# CHAPTER 1

## GENERAL INTRODUCTION

### The leopard: Ecology and distribution

The leopard (*Panthera pardus* Linnaeus 1758) is the fourth largest in the felidae family after the tiger (*Panthera tigris*), the lion (*Panthera leo*) and the jaguar (*Panthera onca*) (Nowell and Jackson 1996) but it is the largest spotted cat in Africa. The leopard has the greatest geographic distribution of any felid, inhabiting 40 countries in Africa, occurring in the Middle East, the Far East, northwards to Liberia and south of Sri Lanka (Myers 1976; Skinner and Chimimba 1990; Nowell and Jackson 1996; Henschel *et al*. 2008). In North Africa, leopard occurrence is rare, and they are only found in the Moyen and Haut Atlas Mountains of Morocco as well as in the Akfadou National Park in Algeria and Libyan plateau of Egypt (Cuzin 2003). South of the Sahara, leopards occur widely throughout West Africa; Senegal, Guinea Bissau, Sierra Leone, Liberia, Nigeria, Cameroon and Gabon and further east in Ethiopia, Somalia and parts of Sudan (Nowell and Jackson 1996).

In southern Africa, leopards remain broadly, though erratically, distributed within their historical limits (Henschel *et al*. 2008). Leopards are widespread in Namibia except along the coastal desert with their distribution extending eastwards throughout Botswana (Skinner and Chimimba 2005). Due to intensive farming activities and ranching developments in Zimbabwe, leopards have been eradicated in certain areas but still occur throughout the country (Skinner and Chimimba 2005). The leopard's distribution extends south of the Zambezi river in Mozambique (Skinner and Chimimba 2005) and in some parts of South Africa, in KwaZulu-Natal (Balme *et al*. 2007), throughout the Limpopo province and infrequently in the Free State and Cape provinces (Friedmann and Daly 2004). However, Ray *et al*. (2005) estimated that leopards have disappeared from at least 36.7% of their historical range in Africa with the most noticeable range loss observed in the Sahel belt as well as in Nigeria and South Africa.

Nevertheless, facilitating the leopard's wide distribution and persistence across a wide range is a number of its attributes. Firstly, the leopard has the widest habitat tolerance of all felids (Nowell and Jackson 1996), occurring in areas with as little as 50 mm annual rainfall (Monod

1965), but still able to penetrate areas with even less rainfall by utilising river courses (Stuart and Stuart 1989). Leopards also occur in areas receiving > 2000 mm of rainfall per year (Hunter *et al*. 2013). It is the only species which occupies both tropical rainforest and arid desert habitats (Nowell and Jackson 1996).

In addition to habitat variation, the leopard is well renowned as a generalist predator with both morphological and behavioural adaptations to this end (Nowell and Jackson 1996). The leopard has been shown to subsist on prey from as small as a dung beetle (Scarabaeoidea family) up to an adult eland (*Tragelaphus oryx*), though they show preference for small-medium sized ungulates (Stuart and Stuart 1992). Bailey (1993) recorded at least 92 prey species for leopards in sub-Saharan Africa. This dietary flexibility allows the leopard to compete successfully, and coexist with, superior predators such as lions and spotted hyenas (*Crocuta crocuta*) (Betram 1982; Scheepers and Gilchrist 1991; Bailey 1993). Moreover, to avoid kleptoparasitism of its kills, the leopard caches kills up trees or drags them and puts them under cover (Bothma and Le Riche 1984; Bailey 1993). The leopard will also readily scavenge, making up for any dietary restrictions (Stuart 1986). Stander *et al.* (1997) argued that the solitary and secretive behaviour of leopards also enables them to avoid the costs of defending carcasses against larger and gregarious carnivores.

Leopards are also able to persist in human dominated landscapes as evidenced by a number of studies recording leopard presence in/near human settlements (e.g. Turnbull-Kemp 1967; Guggiesberg 1975; Tello 1986; Martin and de Meulenaer 1988; Hamilton 1986b; Odden *et al*. 2014). Their elusive and nocturnal behaviour, together with their solitary habits, enables leopards to penetrate human areas with little or no detection. Martin and de Meulenaer (1988) reported that only 13 % of leopard range is inside Protected Areas (PAs); highlighting the versatility of the leopard in human dominated landscapes.

**Conservation of the leopard**

The leopard was listed in Appendix 1 of the Convention on International Trade of Endangered Species (CITES) in 1975 (Martin and de Meulenaer 1988). Appendix 1 includes species threatened with extinction and trade is therefore strictly controlled (CITES 2006). The status of the leopard in the sub-Saharan Africa region has, however, been debated since the 1960s due to fear about the impact of the then considerable international trade in leopard skins (Myers 1976; Nowell and Jackson 1996). To determine the leopard's status in Africa, a number of studies were conducted at local, regional and national scales (Myers 1976; Eaton 1978; Hamilton 1981; Martin and de Meulenaer 1988). Martin and de Meulenaer (1988) estimated the leopard sub-Saharan population at 714 000 leopards based on their density/rainfall regression. Though this estimate has been criticised as a gross overestimation (Jackson 1989; Norton 1990), it remains the only quantitative attempt to estimate potential populations across such a large geographic scale. The population for Zimbabwe was estimated at 16 064 leopards by Martin and de Meulenaer (1988).

The leopard is currently listed on the International Union for Conservation of Nature (IUCN) red list as Near Threatened (Henschel *et al*. 2008). However, in 1986 leopards were listed as Vulnerable, but downlisted to Near Threatened in 1988 and again 1990 (Henschel *et al*. 2008). In 2002, the leopard was further downgraded to Least Concern as studies revealed it to be a resilient species with a wide geographic range and leopard populations were assumed to be stable (Henschel *et al*. 2008). However, in 2008, it was upgraded to Near Threatened in the wake of new research showing that the species was declining in large parts of its range due to habitat loss and fragmentation, hunting for trade and Problem Animal Control (PAC) (Henschel *et al*. 2008). Despite the species' large global range, relatively little ecological data are available throughout its range which inhibits the assessment of current management practices (du Preez *et al*. 2014).

**Trophy hunting of leopards in Zimbabwe**

Leopards are hunted for sport in Zimbabwe and their skins are exported to generate income for land owners and the state (Child 1995). Hunting on state land, previously called Controlled Hunting Areas (CHAs), has been happening since the 1960s. In 1975, leopards could also be hunted on private properties and this was governed by the Parks and Wildlife Act (1975). Safari hunting in Communal Areas (CAs) was legitimised by the Parks and Wildlife Act Amendments (1982) and first legislated in 1989 under the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) (Hamilton 1986; Anderson *et al*. 1993). CAMPFIRE allows local communities some control over the management of natural resources with the emphasis on wildlife hunting, ecotourism and harvesting for meat (Murindagomo 1989).

In Zimbabwe, hunting leopards for export started in 1983 with the export quota set at 80 leopards/year (CITES 1985). In 1985, during the 5$^{th}$ meeting of the Parties to the CITES in Bueno Aires, the leopard export quota was increased to 350 (CITES 1987) following arguments by Child (1984) that the quota of 80 barely met the needs of safari hunting on state land and did not cover the requirements of a growing wildlife industry on private land. In 1989, an export quota of 500 leopards/year was approved at the 7$^{th}$ meeting of the conference of the Parties in Lausanne, Switzerland (CITES 1989). This quota remains in place today, despite increased human populations (Williams 2012) and subsequent habitat and prey depletion as a result of the land redistribution programme in Zimbabwe (Gandiwa *et al.* 2013). The high annual leopard quota allocation, coupled with the paucity of information on leopard populations (Ray et al. 2005; Balme *et al*. 2013), may be negatively affecting the leopard populations within Zimbabwe (Purchase 2006; Balme *et al* 2009). Significantly, after Purchase’s (2006) study of leopards in the Marula district, Zimbabwe, revealed concerns about over-exploitation of the leopard population, the Zimbabwe Parks and Wildlife Management Authority (PWMA) initiated a National Leopard Survey Programme (NLSP). The PWMA partnered with WildCRU/Oxford University and the Zambezi Society in a nationwide programme assessing leopard status using spoor counts, camera trapping and habitat assessments (NLMP 2008).

The nationwide survey conducted spoor counts across 48 123 km$^2$ (12 % of the country) (Zambezi Society 2013) and camera trapping in some of the areas. Fig 1.1 below shows the leopard density estimates for the areas that have been assessed (Lindsey and Mandisodza-Chikerema 2012). The survey results suggested that leopard population densities in Zimbabwean PAs were similar to those reported in protected areas elsewhere in comparable habitat (Bailey 2005, Balme *et al*. 2010), but that the species occurs at lower than expected densities in areas that have been impacted by human disturbance (Lindsey and Mandisidza-Chikerema 2012). In addition, Grant (2012) assessed leopard densities and home ranges in the Marula Intensive Conservation Area (ICA), Mangwe area, Zimbabwe and found densities of between 4.79 and 5.12 leopards/100km$^2$ and recommended an annual quota of 5 leopards/year for the entire Mangwe area (200 km$^2$). Du Preez *et al*. (2014) later estimated leopard density at Bubye Valley Conservancy (BVC) at between 2.8 – 5.9 leopards/km$^2$. The Mangwe and BVC leopard density estimates represent areas with increased human densities and limited protection along with the consumptive use of the leopards (Grant 2012; du Preez *et al.* 2014). Given that PAs only constitute about 16 % of the country's land area (Parks and Wildlife Act 1975, 1996) and that PAs may only support 13 % of the leopard population (Martin and de Meulenaer 1988; Marker and Dickman 2005), the contribution of non protected areas is fundamental for the perpetuation of the leopard in Zimbabwe. Bond *et al*. (2004) mentioned that prior to the land reform programme in 2000, Zimbabwe had about 2.7 million hectares of land set aside as game ranches. However, significant portions of these ranches had been settled by subsistence farmers and deforested, making them inadequate for supporting viable leopard populations (Lindsey *et al.* 2011). Considering the extent of habitat loss and land use conversion over the past 15 years, the annual leopard quota of 500 is likely to be excessive (Grant 2012).

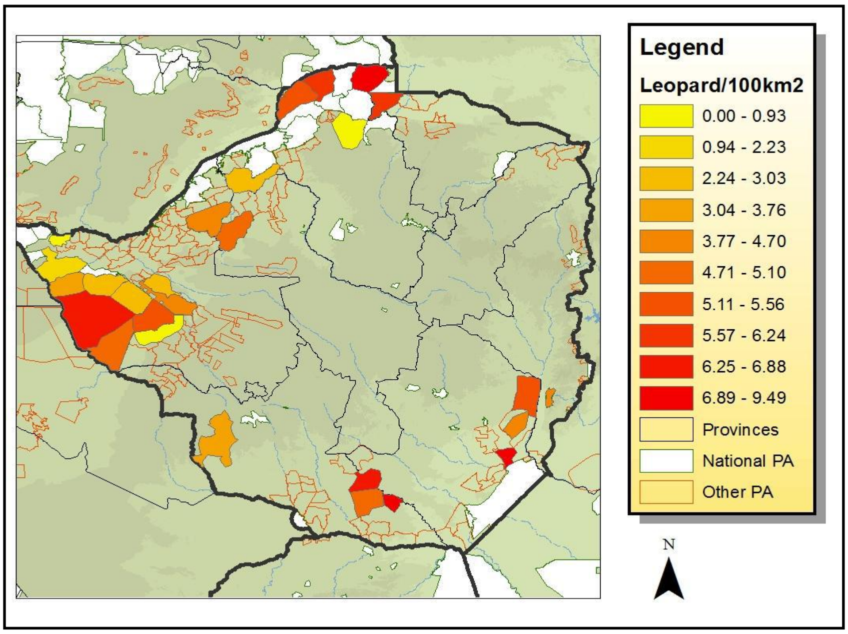


**Fig 1.1**: A map of Zimbabwe showing the estimated leopard densities for certain areas that were surveyed using spoor counts and/or camera trapping carried out by the WildCRU, Zambezi Society and the PWMA (taken from Lindsey and Mandisodza-Chikerema 2012)

Lindsey *et al.* (2011) revealed that leopards contribute 8 – 20 % of gross national trophy hunting income in East and southern Africa, this is a large contribution by one species given that a large variety of species which are hunted. However, this high contribution is coupled with little scientific input on the allocation of harvest quotas and the operation of hunting practices (Balme *et al*. 2012). The above scenario is worrying given the declining status of leopards as a result of habitat loss and persecution (Ray *et al.* 2005). With Zimbabwe having one of the highest leopard quotas (Lindsey and Mandisodza-Chikerema 2012) in the sub-Saharan region, accurate leopard density and distribution information is crucial for guiding management decisions and action. Also important to consider in the hunting industry is that only males are supposed to be hunted (Spong *et al*. 2000; Purchase 2006; Balme *et al*. 2012). However, females and young males (< 3 years old: Balme *et al*. 2012) have been discovered from trophy hunted leopard collections. For example, Spong *et al.* (2000) found that 28.6 % of trophies hunted from 1995 – 1998 in Tanzania were females. As females directly contribute to the reproductive capacity of the population (Spong *et al.* 2000), their inclusion in the trophy offtake has an added negative consequence for population viability (Martin and de Meulenaer 1988; Spong *et al.* 2000). The impacts of trophy hunting on the leopard populations are difficult to ascertain (Henschel *et al*. 2008; Balme *et al*. 2012) but Balme *et al*. (2009) and Packer *et al*. (2011) have shown that poorly regulated hunting leads to increased mortality coupled with low recruitment and population declines.

**Human leopard conflict in Zimbabwe**

The coexistence of leopards and humans has consequences for both parties involved. Positive interactions between humans and carnivores include benefits from trophy hunting and ecotourism (Weber and Rabinowitz 1996), aesthetic beauty and appreciation of nature associated with traditional values (Dickman *et al*. 2014). As large carnivores are often also apex predators, they also serve as reliable indicators of ecosystem health (Pitman 2012) through top-down control that is, carnivores are able to prevent the increase of herbivores that would otherwise significantly reduce plant biomass through increased grazing pressure (Miller *et al.* 2001) while also protecting weaker species from competitive exclusion as they provide ecological boundaries thus altering the behaviour of superior species (Pitman 2012). Large carnivores also influence intraguild interactions as they can also suppress mesopredator populations, keeping them at optimum capacity (Crooks and Soule 1999; Ripple *et al.* 2014; Carter *et al.* 2015).

However, despite all the positive interactions, negative interactions between humans and leopards also exist, leading to human leopard conflict (HLC) (Treves and Karanth 2003; Elliot 2004). As the human population increases, demand for land also increases leading to the exploitation of wildlife habitats for needs such as agriculture, urbanisation, infrastructure and development (IUCN 2004). Habitat loss and fragmentation is recognised as one of the greatest threats to carnivore populations along with prey depletion by people (Ngoprasert *et al*. 2007; Henschel *et al*. 2008). Prey depletion has ripple effects as, in the absence of natural prey, carnivores turn to livestock to supplement their dietary needs (Inskip *et al*. 2014). However, even in the presence of adequate wild prey, carnivores may become habituated to livestock killing especially if livestock are poorly managed and, because livestock are relatively easy to catch (Tjibae 2001; Gusset *et al*. 2008). Livestock depredation consequently leads to retaliatory killing of carnivores by humans as a reaction to the real but also the perceived threats posed by the carnivores (Woodroffe and Ginsberg 1998; Lindsey *et al*. 2005).

Due to the inherent difficulty in confining leopards within protected areas PAs, control over leopard movements is impracticable (Dickman 2010). Hence, leopards within PAs regularly move beyond their boundaries into the neighbouring properties (Gandiwa *et al*. 2013). These leopard movements have implications for the communities living adjacent to PAs as they may suffer livestock depredation by leopards, giving rise to negative attitudes as well as retaliatory killing (Kansky and Knight 2014). Moreover, prey depletion within and around PAs by local communities through illegal hunting (poaching) as well as habitat destruction, indirectly depleting herbivory food availability, encourages further livestock depredation (Pitman 2012).

Recent considerations of the territoriality of leopards shows that their home ranges are not set on human made boundaries but rather biological boundaries (Grant 2012), thus revealing the prevalence of shared populations among different properties (Balme *et al*. 2009). The movement of leopards across multiple properties is an important point to consider in the setting up of hunting quotas to reduce the chances of excessive offtakes as determined by human boundaries. However, costs and benefits resulting from leopard presence are seldom evenly distributed across the landscapes, leading to some communities or properties bearing more costs than others (Romanach *et al*. 2007). For example, a few livestock destroyed from a communal farmer’s herd may be proportionately higher and more painful compared to a similar loss but from a larger herd (Loveridge *et al*. 2010). Equitable benefit and cost sharing is thus imperative across the communities supporting leopard populations (Policy brief 2012).

The Non Detriment Finding (NDF) process meeting was held for the first time in 2012 in Zimbabwe (Lindsey and Mandisodza-Chikerema 2012). The report revealed that the national survey identified the key factors influencing leopard densities to be the level of human disturbance, the region, and the density of spotted hyenas and lions (Lindsey and Mandisodza-Chikerema 2012). The results showed that leopard densities were relatively high in the PAs of Zimbabwe, but lower in areas impacted by humans. The authors reported that the leopard's national population size, trends and spatial distribution in the country are unknown and large areas of Zimbabwe are poorly understood in terms of leopard conservation (Grant 2012; Lindsey and Mandisodza-Chikerema 2012; du Preez *et al*. 2014).

## Rationale for the study

Due to the importance of whole landscapes (be they intact natural habitats, undisturbed land or human settlements) at ensuring long term viability of leopards, and other wide ranging large carnivores (Ngoprasert *et al.* 2007), it is essential to understand the contribution of every available habitat to leopards. To eventually understand the leopard population as a whole, the individual studies undertaken in different parts of the country with unique habitats and other conditions such as level of protection afforded, human presence, habitat fragmentation and other variables will collectively provide invaluable information. The majority of studies on leopards in Zimbabwe have been carried out on protected areas with limited human interference (Lindsey and Mandisodza-Chikerema 2012). However, Debshan ranch in the centre of the country (see Chapter 2) presents a unique case of a commercial cattle (*Bos indicus*) and wildlife ranch in a previously unstudied environment. Furthermore, the increased human densities and livestock around the ranch present opportunities to also investigate and understand human interactions with leopards. With the ranch having practised leopard trophy hunting for over 20 years without any detailed investigation/understanding of their leopard population, my study will answer crucial questions such as leopard population density and community attitudes towards leopards that are vital for guiding leopard management. In addition, data on leopard population density for the area can contribute towards the National Leopard Population Survey.

## Aim and objectives

**Aim**

The overall aim of my study was to estimate the leopard population density within Debshan ranch as well as assessing the attitudes of the communities surrounding Debshan ranch towards leopards.

**Objectives**

1. To determine the density of leopards on Debshan ranch using two complimentary techniques;
2. To assess community attitudes towards leopards in the areas surrounding Debshan ranch;
3. To make recommendations for future management of leopards on Debshan ranch and at national level.

# CHAPTER 2

# STUDY SITE

## General description and background to Debshan ranch

My fieldwork took place on Debshan ranch (Fig 2.1), Shangani, in the Matabeleland South province of Zimbabwe, and within the Insiza District (central coordinates: 29°15´ E; 19°35´ S). Debshan ranch is 450 $km^2$ in size and lies 100km north-east of Bulawayo (the second largest city in Zimbabwe) along the Bulawayo-Harare highway. The name Debshan is a combination of De Beers (the world's leading diamond company) and Shangani (where the ranch is situated). Debshan is more than 100 years old and is owned by the Oppenheimer family, being passed down from generation to generation. The earliest title deeds for the ranch date back to 1898. The ranch was enlarged from the 1920s to the 1950s when its current size was reached (Colin Edwards, General Manager, pers. comm.).

Debshan is a private, commercial cattle (*Bos indicus*) ranch with a large herd (approximately 4000) of cattle. Cattle ranching has been practised for over a hundred years with the ranch stocking about 8 000 cattle/year prior to the National Land Reform Programme (NLRP) in 2000 (Dale *et al*. 2014). The ranch practised conventional paddocking until 2012 when it switched to a holistic management approach (Mberi 2013). Holistic management is a decision-making framework which aims to regenerate the natural ecosystem and be economically viable, as well as provide socially sound management of the grasslands of the world (Savory 1978). In the paddocking system, cattle (an average of 120) were kept in paddocks (each about 324 ha in size) for about 30 days (Colin Edwards, General Manager, pers. comm.) and when they had sufficiently grazed it, were moved to another one (Beetz and Rinehart 2010). However, the introduction of holistic management ushered in a new system. Cattle were subdivided into larger herds (approx. 350 cattle per herd) and each herd assigned to a team of four herders who monitor it throughout the day. In the morning, the cattle are taken out to graze and then returned to temporary kraals/corrals (Fig 2.2) in the evening. Most of the kraals are 60 m x 60 m in size but can be as large as 100 m x 100 m (Mberi 2013), size being determined by the age class of the cattle, season of the year and area quality (i.e. whether densely or sparsely vegetated). These kraals are moved to new sites every two weeks. The principle applied here is high-intensity, short-duration grazing (Savory 1978; Tiedeman 1986), whereby cattle are bunched together in a small area to graze and trample the grass. The cattle excreta and the grass then decompose and are incorporated into the soil as nutrients, thus increasing soil fertility and subsequent vegetation growth (Mberi 2013). The main reasons for the adoption of holistic management were;

I. An observed increase in the elephant (*Loxodonta africana*) population resulting in an increase in paddock fence destruction, rendering fence management costly (Mberi 2013); and

II. A large number of cattle being killed by predators namely; leopards (*Panthera pardus*), lions (*Panthera leo*) and hyena species (Mberi 2013) when the paddocking system was in use.

The adoption of holistic management has substantially reduced the depredation rate of cattle on the ranch (Purchase 2012). Zero predation was recorded immediately after the initiation of the holistic management but it has slowly started increasing again with an occasional calf taken from inside a kraal, at most one a month (Steve Collins, Section Manager, pers. comm.).

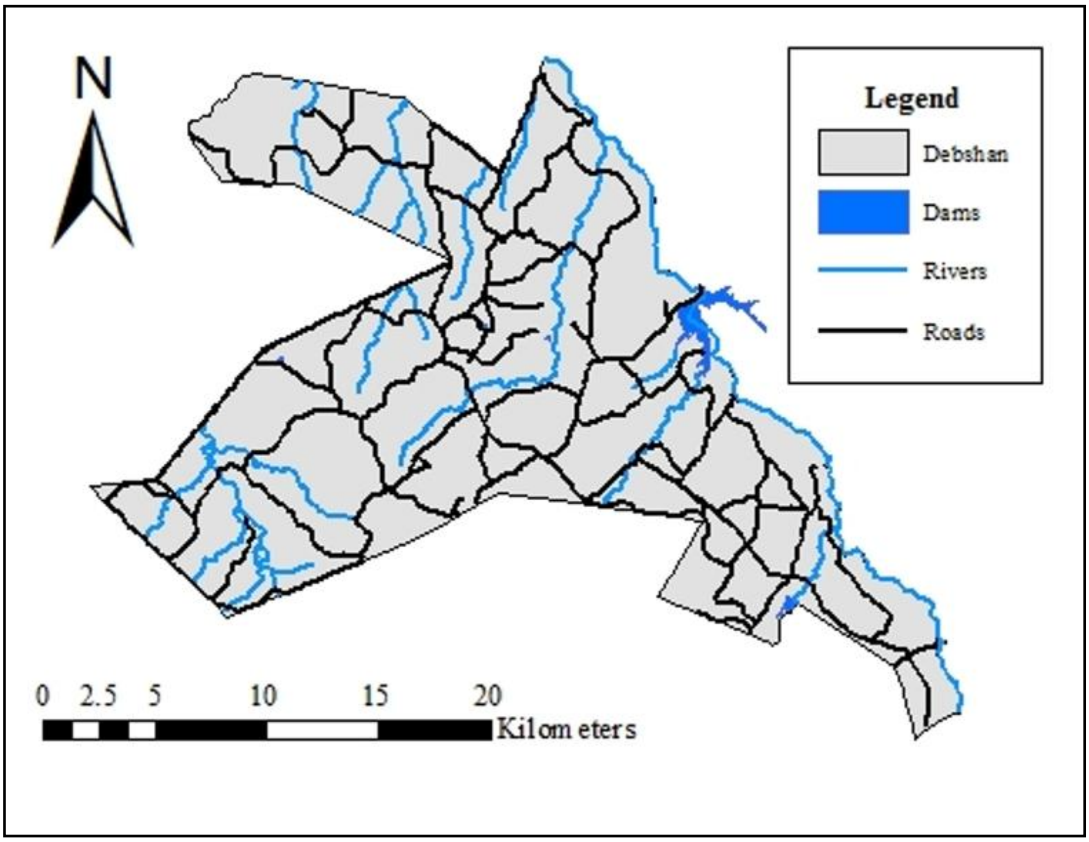


**Fig 2.1**: A map of Debshan ranch, Shangani, Zimbabwe showing the extensive road network and the river systems.


**Fig 2.2:** Examples of the mobile kraal enclosures made of boma sheeting (A) and showing herders' housing and lighting facilities (B) which are situated immediately adjacent to the kraal.

**Climate**

Zimbabwe is situated in the sub-tropics and Shangani is located in the hot semi-arid climate region (Peel *et al*. 2007). There are three distinct seasons recognized in Zimbabwe: the hot/wet season which runs from November to mid-April, the cold/dry season from late April to July, and the hot/dry season from August to November (FAO 2006). Zimbabwe is also divided into agro-ecological regions known as Natural Regions on the basis of the rainfall pattern, temperature, altitude, soil fertility and vegetation type (Anderson *et al*. 1993). The quality of the land resource declines from Natural Region I to V (Moyo 2000) with reference to its ability to support agriculture (Ndebele *et al*. 2005). Natural regions I – III have high agricultural productivity with declining potential as the amount of rainfall received declines from > 1000 mm to 650 mm per year (Anderson *et al*. 1993; Ndebele *et al*. 2005; FAO 2006). Owing to the low and, more importantly, erratic nature of the rainfall in natural regions IV and V (< 450 – 650 mm/year), the most viable enterprises become cattle production under extensive production systems as well as wildlife production (Vincent and Thomas 1961; Moyo 2000; FAO 2006). The study area falls within Natural Region IV and is thus ideally suited for cattle and wildlife production (Ndebele *et al.* 2005). Due to poor soils and low rainfall, crop production is limited to drought tolerant crops such as millet (*Eleusine coracana*) and sorghum (*Sorghum bicolor*) species varieties (FAO 2006).

**Rainfall**

Mean annual rainfall recorded between 1915 and 2000 was 612 mm (Dunham *et al* 2003). Total rainfall received per year from 1993 to 2014 is shown in Fig 2.3. The highest rainfall recorded in 2000 of 1121.5 mm was as a result of the Tropical Cyclone Eline (TCE) which resulted in significantly higher and consequently destructive rainfall (United Nations Country Team 2000; Reason and Keibel 2004). During the three days of TCE, stations near the interior escarpment of northeastern South Africa received rainfall of 400–550 mm (about three times the February mean) (Reason and Keibel 2004). Thereafter, the years 2006 and 2014 also recorded the high levels of rainfall (Fig 2.3). The mean annual rainfall from 2001 – 2014 was 582 mm (Debshan rainfall record sheet, unpublished data), having most of the rains from mid-November to April, December being the wettest month.

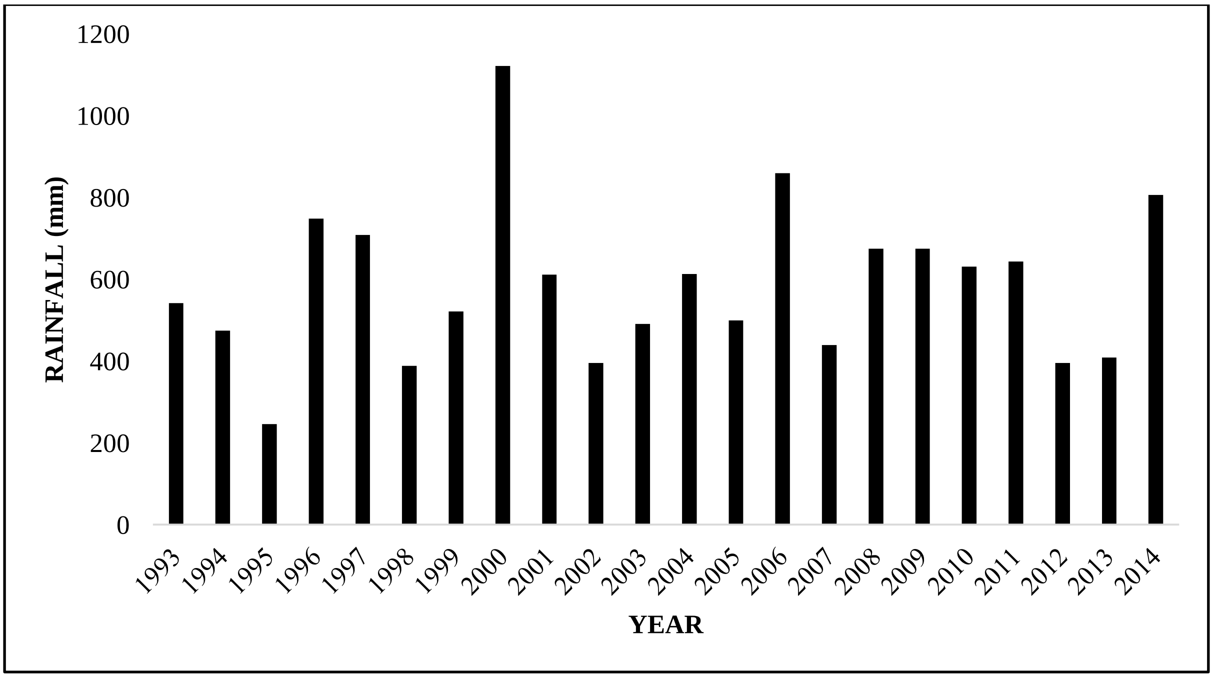


**Fig 2.3:** Annual rainfall received by Debshan ranch from 1993 to 2014.

Over the study period (climate year 2013 – 2014), Debshan received 806 mm of rain with most of it falling between December and March (Fig 2.4).

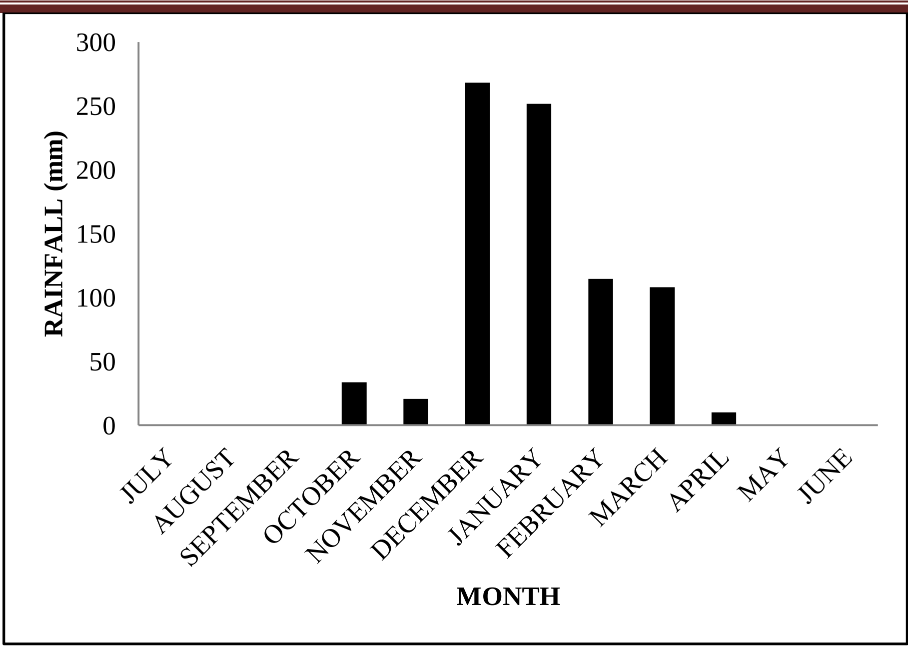


**Fig 2.4:** Monthly rainfall on Debshan ranch from July 2013 – June 2014 (total 806 mm).

**Temperature**

The mean annual temperature for Zimbabwe ranges between 18 – 19 ˚C at about 1400 m above sea level (asl) and averages 32 ˚C at 450 m in the Limpopo River Valley (Mugandani *et al*. 2012). Mean maximum temperatures are low in the winter months (June-July) and highest during October (Vincent and Thomas 1960; Department of Meteorological Services 1981; Anderson *et al*. 1993; Mugandani *et al*. 2012). Debshan lies between 1230 and 1414 m asl (Dunham *et al*. 2003) and the average day time summer temperatures can reach 30 ˚C. There is also an increased occurrence of fires during the hot dry season (Dale *et al*. 2014). Winter temperatures are very low and even colder during the night with frost common in June and July in some years (Dunham *et al*. 2003). No temperature records are available for the ranch.

**Topography, soils and vegetation**

Natural region IV is dominated by greyish brown sands and sandy loams derived from granite rocks (FAO 2006). The landscape of most of Debshan ranch is gently undulating and covered in yellowish/brown, medium to coarse-grained loamy sands derived from granite (Robertson 2013, unpublished data). These soils are relatively infertile and frequently poorly-drained and support vegetation types that are usually distributed in a catenal pattern (Dunham *et al*. 2003).

On the south-east section of the ranch and on Mahwe hill, the rocks are mafic or ultramafic and give rise to fertile red soils. Along the Shangani River and other major rivers, there is fertile dark brown clay soil which developed on the alluvium. Towards the centre of the ranch and stretching to the western side, the soils are sandy loamy soils. (Robertson 2013).

Three main rivers, together with several small ones, traverse the ranch: the Shangani River forms the eastern boundary of the ranch and is near perennial, and the Munyati and Nsangu Rivers which flow across the ranch at various points are an important source of water on the ranch. Most of the rivers and streams dry up outside of the rainy season and many animals, including leopards, use the riverbeds as pathways (Bothma and le Riche 1984). Several granite kopjes (small hills rising from a generally flat veld) (Fig 2.5) are scattered across the ranch, especially alongside the Shangani river and the northwestern boundary, which borders the culturally important mountain ranges ‘IntabazikaMambo’. These kopjes are presumed to be important habitats for leopards in the area together with dry riverbeds and riverine vegetation (Mills 1984).

**Fig 2.5**: Images of the typical granite kopjes found on Debshan ranch, Shangani, Zimbabwe.

Zimbabwe falls within the Savanna Biome (van Wyk *et al*. 2000). Debshan ranch comprises woodlands, bushlands, grasslands and vleis (grassy and marshy wetland covered with water mostly during the rain season). The major woodland types are Miombo, *Acacia*, *Mopane* and *Terminalia – Combretum* (Dunham *et al*. 2003). No extensive work has been done on the vegetation of Debshan ranch. However, Dunham *et al*. (2003) and Robertson (2013) provide a description of the vegetation of Debshan.

On medium to coarse - grained loamy sands, the major vegetation type is Miombo woodland and the dominant species are *Brachystegia spiciformis* and *Julbernadia globiflora* (Robertson 2013). In this woodland, unpalatable *Stereochlaena cameronii* grass occurs while a mixed bushland occupies the shallow soils. The dominant species are *Combretum hereronse* and *Acacia* species. Patches of heavy-textured soils, known as sodic soils, support *Colophospermum mopane* woodland and shrubland, and these areas are characterised by the occurrence of a palatable grasses such as *Sporobolus ioclados* and *Chloris virgata.* On the south- western boundary of the Mahwe section (Fig 2.5), small kopjes support a diversity of tree and shrub species. *Terminalia sericea* dominates bushland and wooded grassland which occurs within this mostly granite landscape (Robertson 2013).

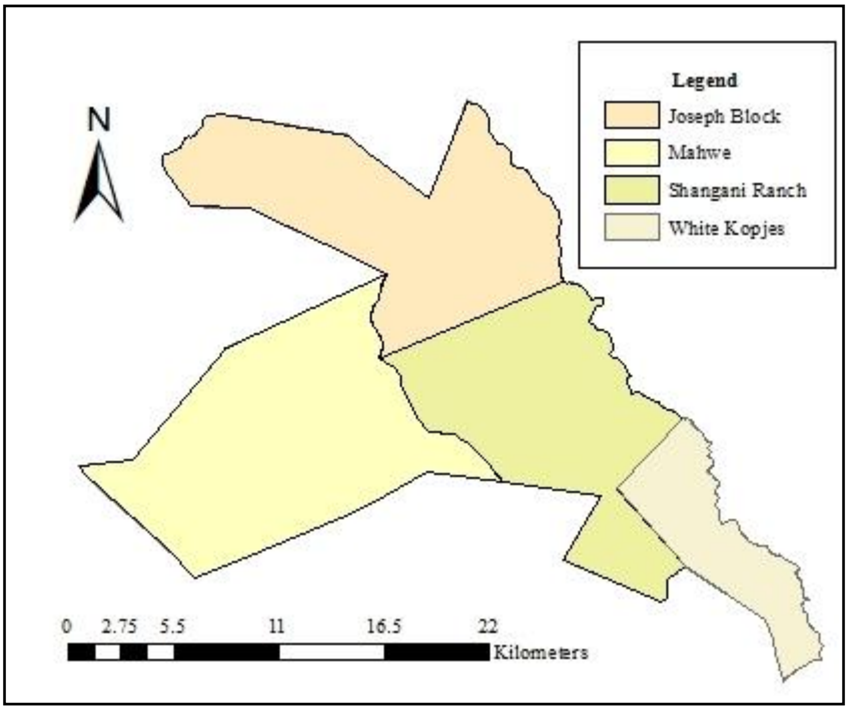


**Fig 2.6:** A map showing the four administrative sections within Debshan ranch, Shangani, Zimbabwe.

From Mafic and Ultramafic rocks, sandy clay loamy soils are derived. These soils support *Acacia* bushland which includes *Acacia karroo, Acacia gerrardii* and *Acacia nilotica,* together with several *Combretum* species that predominate in a dense bushland (Robertson 2013). Perennial grasses such as *Heteropogon contortus, Bothriochloa insculpta* and *Cymbopogon pospischilii* are moderately abundant. On fertile, fine red clay soils there is *Bolusanthus* bushland, *Bolusanthus speciosus* being the dominant species, there is also a variety of other *Acacia* and *Combretum* species (Robertson 2013). On alluvial soils, *A.*

*karroo* is dominant and often in association with *Rhus lancea*. Throughout the ranch, there are small depressions that were once vleis which, although most have been invaded by small shrubs, they still support robust perennial grasses such as *Hyparrhenia* species, *Hyperthelia dissoluta* and *Andropogon* species (Dunham *et al*. 2003).

**Mammalian fauna**

Debshan ranch supports a variety of wild animals (Dunham *et al*. 2003). More than 34 wildlife species have been recorded in aerial surveys which are conducted annually in July when vegetation cover is sparse and hence visibility for the observers is at a maximum (Berry and Macfadyen 2014). Lions were historically present (Dunham *et al*. 2003) in the region but were extirpated as the human population increased around Debshan, owing to persecution for livestock depredation (Livestock Mortality record sheet, September 2012). Buffalo (*Syncerus caffer*) is another species absent from the ranch. The species is actively eradicated because it carries Foot and Mouth Disease (FMD) (Steve Collins, Section Manager, pers. comm.). Without lions, leopards have become one of the apex predators in the area, together with the spotted hyena (*Crocuta crocuta*).

Elephant sightings were first confirmed on Debshan ranch in 1995 during an aerial survey (Shangani game count report 2013) when 17 individuals were counted. Since then, the number of elephants has increased significantly with the highest number of individuals (264) recorded in 2012. In 2014, 174 individuals were counted. The increase in the elephant population has negatively impacted the vegetation and requires monitoring (Shangani game count report 2013). Dunham *et al*.'s (2003) study on the tsessebe (*Damaliscus lunatus lunatus*) recorded a substantial decline of tsessebe population from 2209 to 435 between the years 1995 to 1999. A long-term reduction in the dry-season availability of green grass leaf (the preferred food of tsessebe) was identified as the cause of the tsessebe population decline (Dunham *et al*. 2003). The population continued to decline with only 12 individuals detected during the aerial survey (Shangani game count report 2013). In 2012 and 2013, a total of 140 bushbuck (*Tragelaphus scriptus*) were translocated into the ranch to augment the population (Steve Collins, Section Manager, pers. comm.). An inventory of the wildlife species found on Debshan was compiled from the results of the aerial surveys (Appendix I) and also from the camera trapping survey (Appendix II).

**History of trophy hunting on Debshan ranch**

Trophy hunting on Debshan ranch started in 1987 (Colin Edwards, General Manager, pers. comm.). Most of the currently hunted species were on quota from that year, with the main addition to the list being elephants in 1998 (Colin Edwards, General Manager, pers. comm.). Numbers of the other species hunted are provided in Appendix III.

The ranch was only allocated one leopard on quota for many years (1987 - 2007) and even at one animal, the tag was hardly ever filled (Sean Grant, Professional Hunter, pers. comm.; Colin Edwards, General Manager, pers. comm.). The leopard quota was increased in about 2008/2009 from one animal to six due to excessive cattle losses to leopard predation (Colin Edwards, General Manager, pers. comm.). However, rarely more than three leopards have been hunted in any given year. In some years, no leopards were hunted at all, probably due to poor hunting success rather than absence of leopards (Colin Edwards, General Manager, pers. comm.). Some of the leopards allocated on quota are sometimes taken from the adjacent properties.

While the quota allocations indicate what the ranch is allowed to hunt for export as trophies, it does not reflect what is actually hunted as the total number of animals listed for each species in most cases will not be hunted in any given year (Colin Edwards, General Manager, pers. comm.). However, for species such as the elephant, sable (*Hippotragus niger*) and zebra (*Equus burchelli*), the quota is normally exhausted (Sean Grant, Professional Hunter, pers. comm.; Colin Edwards, General Manager, pers. comm.).

**Background to National Land Reform Programme: Changes around Debshan ranch**

The National Land Reform Programme (NLRP) was initiated by the government of Zimbabwe in 2000 to redress the imbalances in land ownership from the previous colonial era (Scoones *et al*. 2010). Land was acquired on the basis of multiple ownership, or absenteeism or land underutilization (Griffin *et al*. 2001). The identified beneficiaries were resettled on the acquired land based on two models; subsistence farming with villages as A1 model, while the A2 was based on small scale commercial farming with individual units (Pazvakavambwa and Hungwe 2009). Farms were pegged out and formally designated as new resettlements with occupants provided offer letters and permits (Scoones *et al*. 2010). The occupants were promised 99 year leases which they never received. In addition to the legal settlers, informal settlers also took over other farms even without offer letters. Security of tenure is lacking in these circumstances and these areas have therefore been identified as highly politicised with much tension among stakeholders (Alexander 2006; Charumba *et al*. 2003a). This lack of security is detrimental to the survival of natural resources as abuse is rife due to a lack of accountability (Charumba *et al.* 2003a; Williams 2012). The NLRP is still ongoing (Sithole 2011) with at least 8.3 million hectares (71 %) of large scale commercial farmlands being resettled by 2010, plus a further16 % occupied by informal settlements.

Owing to their high human and livestock densities, resettlement areas are highly fragmented (Williams 2012) and have a high prevalence of Human – Wildlife Conflict (HWC). Also, the diversity of conflicting interests exposes leopards and other carnivores to increased persecution due to perceived and real livestock losses. Debshan, as one of the only and largest of the few remaining private ranches in the area, is not sufficiently large enough to maintain viable populations of leopards in the region. However, Debshan is also viewed as a source or refuge for predators by many of its neighbours, potentially exacerbating conflict.

Before the NLRP, Debshan was surrounded by at least 61 large commercial properties (Fig 2.6) mostly for cattle ranching. Wildlife ranching was also an important supplementary venture due to the natural occurrence of wildlife in the area (Steve Collins, Section Manager, pers. comm.). Despite the high prevalence of livestock depredation (Debshan livestock losses records) and the presumably negative attitudes of the ranchers towards the leopard and other carnivores (Colin Edwards, General Manager, pers. comm.), these properties had the distinct advantage of intact habitats coupled with low human densities. However, with the onset of the NLRP in the year 2000, these properties were subdivided into smaller units either individually owned (A2 model schemes) or as villages (A1 model) (Scoones *et al.* 2010). A few private properties were spared but some were also informally settled within their boundaries (Private property owners, pers. comm.) leaving uncertainty as to the actual property sizes. From approximately 61 private properties (1:50 000 maps, Surveyor General) within 10 km of the Debshan ranch pre-2000, Debshan is now surrounded by at least 500 small scale resettlement properties and about 10 private ranches.

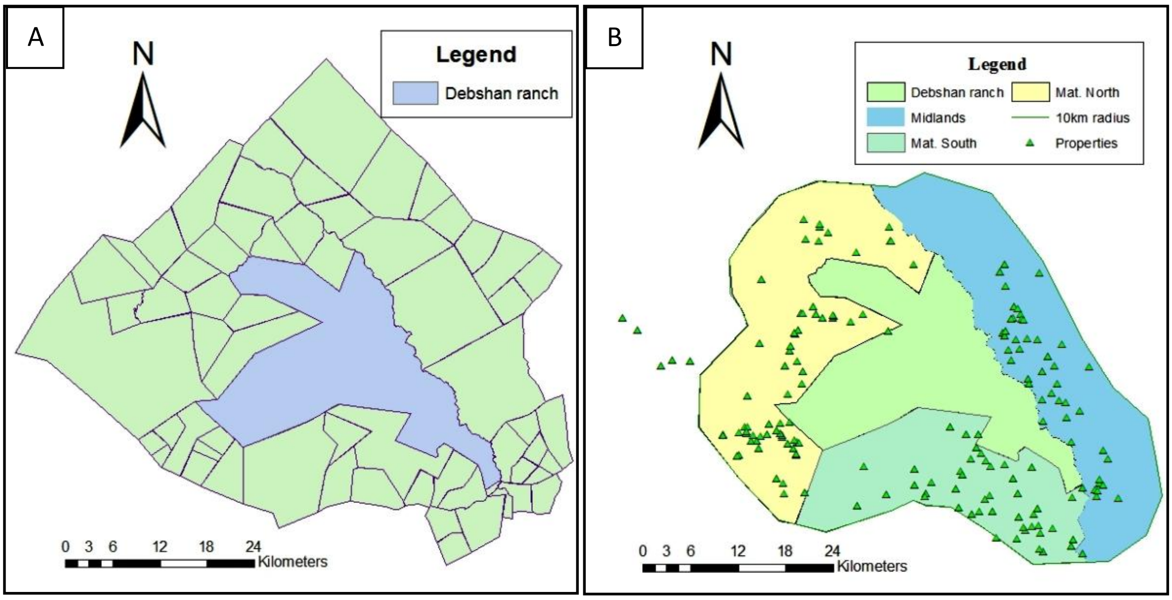


**Fig 2.7:** A map of the communities surrounding Debshan ranch: (A) the small and large private properties that surrounded Debshan ranch before the year 2000 and, (B) the many but small sized properties that were built after the NLRP starting from the year 2000.

The proliferation of these small scale properties gave rise to a substantial increase in the human and livestock densities around the ranch. This 'sea' of a changing landscape renders Debshan ranch an island and thus potentially the only intact habitat for wildlife.

# CHAPTER 3

## POPULATION DENSITY ESTIMATES OF THE LEOPARD (*Panthera pardus*) AT DEBSHAN RANCH, SHANGANI, ZIMBABWE

### INTRODUCTION

Reliable population estimates are very important to both managers and conservationists (Caughley and Sinclair 1994; Stander 1998) as they aid decision-making in conservation programmes (Barea-azco *et al*. 2007). In the absence of reliable population estimates, management decisions are often based on crude estimates which may be detrimental for conservation (Blake and Hedges 2004; Jhala *et al.* 2010). For example, most national export quotas for leopards (*Panthera pardus*) in sub-Saharan Africa were based on the regional and national leopard population estimates provided by Martin and de Meulenaer (1988). Besides the estimates being criticised as an overestimate (Norton 1990), lack of any other better estimates, led to overexploitation of the population (Nowell and Jackson 1996) until recently the leopard was up listed from Least Concern to Near Threatened in the International Union for Conservation of Nature (IUCN) Red List (Henschel *et al*. 2008). Also, the fur trade subjected leopard populations to immense pressure in Uganda and Kenya due to lack of an understanding of the population dynamics (Myers 1976; Martin and de Meulenaer 1988) enforcing the ranking of the leopard as an Appendix I species in the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) in 1973 (Myers 1976).The need for reliable population estimates has also been accentuated by the accelerated rate of biodiversity loss in recent decades ( Nowell and Jackson 1996; Weber and Rabinowitz 1996; Woodroffe and Ginsberg 1998).

However, due to the nature of leopards; scarce, elusive, nocturnal and occurring at low densities (Bailey 1993; Skinner and Chimimba 2005), methods involving direct censuses are not viable (Bailey 1993; Pitman 2012). Also, as the survey areas become larger (national or regional scale e.g. Martin and de Meulenaer 1988), challenges get more complex as high economic costs and intensive field efforts are necessary to achieve reliable abundance estimates (Jhala *et al.* 2010). Therefore, most studies on carnivores have focused on smaller areas e.g. protected areas (PAs), private land or communal lands (Karanth and Sunquist 1995;

Balme and Hunter 2004; Silver *et al*. 2004; du Preez *et al.* 2014). These studies provide detailed abundance and density estimates on a variety of habitats which, together with others, ultimately cover up large scales (Silver *et al.* 2004; Odden *et al.* 2014). In line with the need for large scale studies (Simberloff 1998) is the focus on single species studies, or umbrella species (Simberloff 1998) which however, have been criticised (Andelman and Fagan 2000). Andelman and Fagan (2000) recommended that for any species to adequately qualify as an umbrella species, it must coexist spatially with many other species of interest and also be highly persistent. The leopard satisfactorily satisfies these assumptions as it has been shown to co-occur with a wide range of other carnivores (Lindsey *et al.* 2005; Breintenmoser *et al*. 2011; Odden *et al*. 2014) while also being highly persistent in a wide variety of conditions including human presence (Turn-Bull Kemp 1967; Hamilton 1986) and varied habitats (Myers 1976; Bailey 1993; Skinner and Chimimba 2005). Thus, the protection of the leopard will undeniably secure biodiversity protection at a large ecosystem scale (Bothma and Bothma 2012). Although protecting multiple species can shelter a higher percentage of the region’s biota (Simberloff 1998), it comes with unrealistically high costs (Seddon and Leech 2008). Friedmann and Traylor-Holzer (2008) also mentioned the importance of leopards as an indicator of human attitudes and extent of persecution which also mirrors on the challenges suffered by the less visible animals or the less important e.g. hyena and jackal species (Lindsey *et al*. 2005).

Conservation needs for carnivores have been identified worldwide (Zielinski and Kucera 1995; Gese 2001; Balme *et al.* 2010) largely because of their wide ranging behaviour (Garshelis 1992) which exposes them to a variety of potentially fatal conditions (Zimmermann and Walpole 2005; Balme *et al*. 2010). Because they are apex predators (at the top of the food chain) in terrestrial ecosystems (Bailey 1993; Skinner and Chimimba 2005; Bothma and Bothma 2012; Pitman 2012), carnivores naturally occur at low densities (Skinner and Smither 1990) which, when coupled with their large potential impact on different human activities (e.g livestock depredation) (Butler 2000; MacDonald and Sillero-Zubiri 2002; Marker and Dickman 2005; Gandiwa et al. 2013), carnivores become highly susceptible to extinction (Nowell and Jackson 1996; Gittleman *et al*. 2001).

Assessments of animal abundance are achieved through either relative or absolute abundance (Gese 2001). Relative abundance uses indices of animal abundance through indirect approach methods (Gese 2001). These indices can be compared over time or across different areas though they do not estimate animal numbers but have a constant ratio to the actual population size (Henschel and Ray 2003). Examples of the methods used to calculate relative abundance include presence of animal signs e.g. spoor or scat along a fixed transect (Hayward *et al*. 2002; Balme *et al*. 2009), kill sites (Karanth and Sunquist 1995; Marker *et al*. 2003; Ott *et al*. 2007), habitat assessments (Daly *et al*. 2005; Balme *et al.* 2007) and prey availability assessments (Bailey 1993; Carbone and Gittleman 2002). Sometimes researchers conduct interviews with local people to carry out inventories of mammal species (Tobler et al. 2008) as well as the number of breeding den sites (Heydon *et al.* 2000).

Absolute abundance approaches, on the other hand, involve more direct methods that actually count animals and then provide a population estimate expressed as number of individuals per unit area (Gese 2001; Nichols *et al*. 2008). Absolute abundance requires species-specific detection coefficients or probability functions obtained from the relationship between number of detections and distance from observer (Gregory *et al*. 2004). Since differences in species-specific detectability are accounted for in the statistical analyses, absolute abundance estimates may be compared among species within the same or different habitats (Carey *et al*. 1991). Examples of direct methods include call up stations (Maputla *et al.* 2013) where carnivores are attracted by artificially played sounds of a prey species in distress (Ferreira and Funston 2010) and camera trapping (Karanth and Nichols 1998; Balme *et al.* 2009). Absolute abundance can be achieved through total counts or by sub-sampling an area and then extrapolating the resulting density estimates to the rest of the area ( Gese 2001; Foster and Harmsen 2012). However, in most free-roaming carnivore populations, the probability of detecting an individual is less than one (Royle and Young 2008) because it is impossible to count with certainty all the individuals (Henschel and Ray 2003) making total counts unfeasible.

Because cost is one of the constraining factors in many studies of carnivore population estimates, often restricting repeatability of some methods (McKelvey and Pearson 2001; Engeman 2005; Bengsen *et al*. 2011) or extending the time between surveys, most studies have sacrificed the need to know absolute numbers and settled for monitoring population trends and their changes over time (Engeman 2005). Detecting changes in population trends therefore becomes more important than precision of estimates as it allows for timely detection of changes to the population (Gerrodette 1987). The few studies that have overcome these cost constraints have relied on intensive observations of the populations over long periods (Kissui and Packer 2004; Packer *et al*. 2005). More commonly, however, only a once-off survey is feasible to benchmark a population (Myers 1976; Smuts 1977; Martin and de Meulenaer 1988; Stander 1991; Creel and Creel 1996; Gros 2002) mainly due to the high costs involved in large scale coverage of the surveys.

The management of large carnivores could, however, benefit by using indices of the population size. Population indices are advantageous as they are generally cost effective and can be easily repeated (Stander 1998) and can provide reliable estimates of the population size together with a measure of precision (Houser *et al.* 2009; Funston et al. 2010). However, precision in population estimates can only be achieved through the application of a quantifying technique to get a population density (Houser *et al*. 2009), either by using spoor measurements to identify and count individuals within a population (Sharma *et al*. 2005) or double sampling and calibrating data between spoor surveys and camera-trapping (Wilson and Delahay 2001). The use of track counts which relies on the relationship between frequencies with which tracks (spoor) are detected and a subsequent estimation of the actual population density has been widely applied to create population indices (Van Dyke *et al*. 1986; Smallwood and Fitzhugh 1995; Houser *et al*. 2009). Such indices may be species- or site- specific and the type of substrate plays a key role through influencing spoor detectability, identification and measurement (Dirzo and Miranda 1990; Norris *et al*. 2008; Dias *et al*. 2011; Stander 1998). Several researchers have recommended the use of sign surveys, such as spoor counts, as the main element in national monitoring programmes or large-scale studies (Toms *et al*. 1999; Baker *et al*. 2002; Webbon *et al*. 2004) mainly due to their repeatability and cost effectiveness (Stander 1998).

Closed population capture-recapture analysis of camera-trap data has become the conventional method for estimating the abundance of individually distinguishable, enigmatic species occurring at low densities, especially large felids (Karanth 1995; Karanth and Nichols 1998; Silver *et al*. 2004; Soisalo and Cavalcanti 2006; Dillon and Kelly 2008; Balme *et al*. 2009). Most times, these estimates are the only information available to guide wildlife managers and conservation policy in decision making regarding management actions for carnivore populations. However, while closed population capture-recapture procedures of camera-trapping have been employed in many other studies, few have tested its validity (Dillon and Kelly 2008; Balme *et al*. 2009). Camera-trapping has been used for most estimates of felid abundance, including tigers (*Panthera tigris*: Karanth and Nichols 1998; O'Brien *et al.* 2003; Karanth *et al*. 2004; Kawanishi and Sunquist 2004; Lynam *et al*. 2009; Rayan and Mohamad 2009), jaguars (*Panthera onca*: Wallace *et al*. 2003; Maffei *et al.* 2004; Silver et al. 2004; Miller 2005, 2006; Miller and Miller 2005; Soisalo and Cavalcanti 2006; Salom-Pe´rez *et al*. 2007), pumas (*Puma concolor*: Kelly *et al*. 2008), ocelots (*Leopardus pardalis*: Trolle and Kerrry 2003, 2005; Maffei *et al*. 2005; Di Bitetti *et al*. 2006; Haines *et al.* 2006; Dillon and Kelly 2007), Geoffroy's cat (*Oncifelis geoffroyi*: Cuellar *et al*. 2006), snow leopards (*Uncia uncia*: Jackson *et al.* 2006; McCarthy *et al*. 2008), bobcats (*Lynx rufus*: Heilbrun *et al*. 2006), cheetahs (*Acinonyx jubatus*: Marnewick *et al.* 2008) and African leopards (Balme *et al*. 2009; Chapman and Balme 2010; Gray and Prum 2012; du Preez *et al.* 2014) where individuals can be individually identifiable using unique markings such as stripe, rosette or spot patterns. Also, camera traps can be deployed in areas that are relatively inaccessible (especially in challenging landscapes) (Tobler *et al*. 2008; Bengsen *et al.* 2011) where other methods are inappropriate.

Capture-recapture models are underlined by three basic assumptions that should be met during any camera-trapping study (Otis *et al*. 1978; White *et al.* 1982). The first assumption pertains to population closure. Closure means that the size of the population is constant throughout the study duration both geographically and demographically i.e. without recruitment (birth or recruitment) or losses (deaths or emigration) (White *et al.* 1982). To satisfy this assumption, camera-trapping surveys for large felids are generally carried out within three months (Karanth and Nichols 1998; Silver *et al*. 2004; Jackson *et al.* 2005). However, because this is a very strong assumption which is seldom true for any biological population, closure is usually taken to mean that no unknown changes to the initial population exist or those known changes do not significantly influence the population (White *et al*. 1982; Karanth and Nichols 1998). The second assumption is that all individuals in the population have a greater than zero chance of being captured (Nichols 1992; Karanth and Nichols 1998; Gerber *et al*. 2010). This second assumption requires that there be at least one trapping site in each individual's home range (Tobler and Powell 2013). Thus, a species' smallest home range from previous studies is used in the determination of the radius between adjacent trapping sites (Silver *et al.* 2004; Silveira *et al.* 2010). However, this assumption is only more relevant to traditional (non-spatial) capture-recapture and more relaxed for spatial capture-recapture analyses (Royle *et al.* 2013). More recently, telemetry data has also been used to determine the minimum spacing of cameras (Dillon and Kelly 2008; Balme *et al*. 2009; du Preez *et al*. 2014). The third assumption is that each individual should be uniquely identifiable (Otis *et al.* 1978) through spots, rosettes or stripes (Karanth and Nichols 1998; Royle *et al*. 2009). Care should be taken that these markings are permanent for the duration of the study to help determine recapture from first captures (White *et al*. 1982, Silver *et al*. 2004).

Recent statistical advances and development of spatially explicit capture–recapture (SECR) software greatly reduce the difficulties in estimating effective survey area, and hence density, from capture–recapture data (Gray and Prum 2012). However, conventional capture–recapture techniques estimate abundance and not density, increasing the likelihood of overestimating the number of animals with only part of their home range within the sampling area (Parmenter *et al.* 2003). Traditional density estimation methods account for this by adding a boundary strip width around the sampling area to determine the effective trapping area (Wilson and Anderson 1985). This strip estimates the distance animals available for capture move away from the sampling area during normal movements (White *et al*. 1982; Parmenter *et al.* 2003). The most widely used boundary strip width in capture–recapture camera-trap studies is half the mean maximum distance moved (HMMDM: Karanth and Nichols 1998). However, this essentially ad hoc manner for estimating effective survey area has been widely criticised as it underestimates home ranges and subsequently overestimates densities (Borchers and Efford 2008; Dillon and Kelly 2008). A recently developed alternative approach, which does not assume geographic closure or estimate the area sampled, is likelihood-based spatially explicit capture–recapture (SECR; Borchers and Efford 2008). SECR models use the locations at which each animal is detected within a likelihood-based framework to fit a spatial model of the detection process. These models combine capture–recapture with distance sampling methods to estimate each animal's range and centre of activity and model the probability density functions for detections of animals based on distance from activity centres (Borchers and Efford 2008).

Density estimates from multiple sites and habitat types will provide better estimates of national and global leopard populations (Silver *et al*. 2004) and enough scientific evidence to validate support for existing conservation areas and facilitate lobbying for more areas for the protection of leopards. Repeated spoor and camera trap density estimates over long periods of time will facilitate population assessment and monitoring through development of population model programmes that are species- and site- specific. My study, therefore, will provide leopard density estimates which will guide the management of a leopard population on a large, commercial cattle (*Bos indicus*) ranch in Central Zimbabwe. These data can also feed into the national survey which so far has a patchy but growing understanding of the national leopard population (Matopo National Park: Smith 1977; Gonarezhou National Park: Groom 2009; Mangwe area: Grant 2012; Bubye Valley Conservancy: du Preez *et al*. 2014; most protected areas: The Zambezi Society/ZPWMA; Save Valley Conservancy: Groom *ongoing monitoring*).

## OBJECTIVES

The objective of this chapter was to provide a preliminary estimate of the leopard density of Debshan Ranch using a spoor survey and camera-trapping.

## METHODS

Two methods were employed to assess the leopard population density of Debshan Ranch; spoor counts (indirect) and camera trapping (direct). The spoor count survey was conducted between 14 May and 28 June 2013 and the camera trapping survey was done from 20 May to 28 July 2014.

### Spoor survey

All of the roads of the ranch were mapped using Google Earth (2013 Google Inc.). The roads selected for spoor transects were at least 5 km apart (Funston *et al*. 2010); this reduced the potential for double counting individuals on the same day (Houser *et al.* 2009). Twelve transects were selected altogether across the ranch (Fig 3.2) and mapped using ARCMAP 10.2 (ESRI Inc. Carlifonia), in order to provide even coverage (Stander 1998; Balme *et al.* 2009a). The total transect distance was 163.35 km, giving a ratio of 1 km of transect for every 2.75 $km^2$ of the study area. This is referred to as the penetration rate i.e. the sum of the distance surveyed expressed as a ratio of the sample area, that is 1 km surveyed: $xkm^2$ survey area (Stander 1998). Thus, a low value reflects a high penetration rate (Houser *et al.* 2009).

The twelve transects were driven to assess their suitability prior to the start of the survey. Eighty three percent of potential transect roads (n = 10) consisted of soft Kalahari sand (Fig 3.1 a) and the rest (n = 2) gravelly sand (Fig 3.1 b) but with good spoor visibility. Each transect was then surveyed twice (48 hours apart, Houser *et al.* 2009) to allow previously recorded tracks to be removed and to minimize double counting the same track incidence (Funston *et al*. 2010). Smallwood and Fitzhugh (1995) showed that clearing the road before survey did not necessarily improve spoor detectability; hence it was not done for this survey. Also, because the ranch has over 4000 head of cattle, the likelihood of tracks persisting for more than a day was low.


**Fig 3.1**: Images showing the different transect roads' soil surfaces; soft Kalahari sands (A) and gravelly sand (B).

Each survey started at sunrise (~0630 hrs ± 7 mins) while spoor from the previous night was still fresh, and also before human, cattle and diurnal wildlife movement increased. In addition, spoor counts were finished before midday so that the angle of the sun's rays highlighted the concave nature of spoor in the road, making tracks easier to detect (Beier and Cunningham 1996).

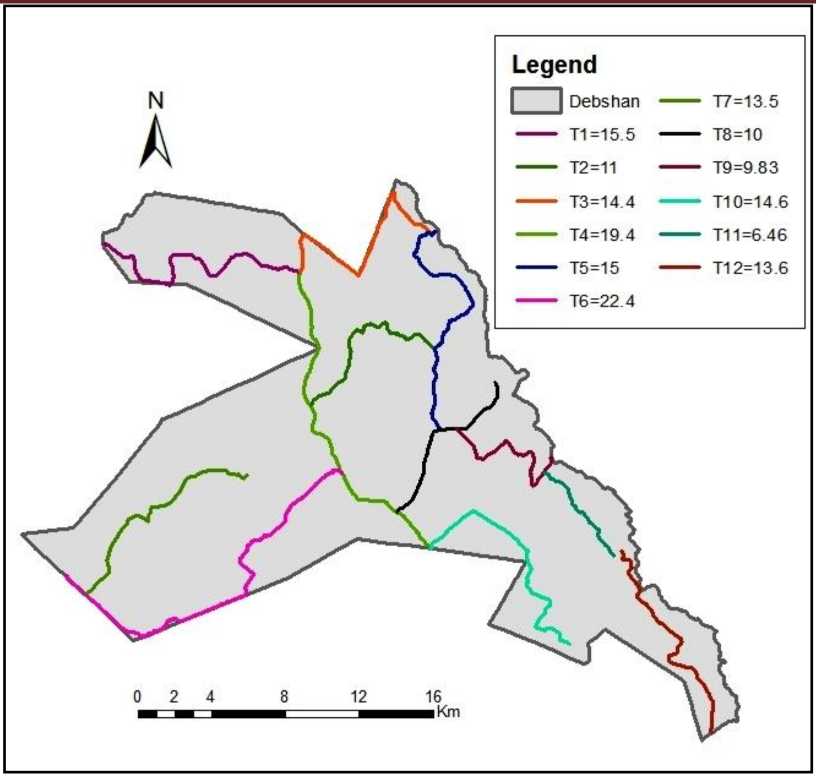


**Fig 3.2**: A map of Debshan ranch (450 km$^2$) showing the 12 transects selected for the spoor survey conducted from 14 May to 28 June 2013 (All measurements are in kilometres).

The survey team comprised three people; a driver, a recorder and an experienced tracker sitting on the car bonnet to scan for spoor ahead. The car, a Nissan 4-Wheel drive pick-up truck, was driven at < 20 km/hr (Stander 1998) to increase spoor detectability by the tracker. All mammalian spoor were recorded but when the spoor of any large carnivore was detected; a GPS coordinate was also recorded. For leopard spoor, the length and width of five separate tracks were measured in millimetres (Stuart and Stuart 2000), three stride lengths were also measured in centimetres, and the type of road substrate, the direction of travel and the age (in hours; determined by the tracker) was also estimated. Tracks likely belonging to the same individual were recorded only once (Stander 1998; Houser *et al.* 2009), using the following guidelines; size, proximity (<500 m) to any previous spoor and the direction of travel (Funston *et al.* 2010). The GPS co-ordinates for leopard tracks were used to create a leopard spoor distribution map in ARGIS 10.2.

**Data analysis**

Spoor density and spoor frequency were calculated as proposed by Stander (1998). Spoor density is defined as the number of individual leopard spoor/100km (Stander 1998) where an individual's spoor is only counted once a day. Spoor frequency is the number of kilometres/spoor (Stander 1998) i.e. the average distance driven to encounter a single spoor. A bootstrap analysis (Sokal and Rohlf 1995) was used to determine sampling precision. Two samples were randomly chosen and their mean and coefficients of variation (CV) calculated. The number of samples was then increased progressively to 3, 4, 5, 6 . . . up to 24, all the time calculating new means and CVs (Grieg-Smith 1957). These data were then plotted against sampling effort (i.e. number of spoor and distance driven) and the desired sampling intensity was achieved at 20 % CV (Funston *et al.* 2010). Leopard densities for the ranch were then calculated using three published calibration equations (Stander 1998, Balme *et al.* 2009a, Funston *et al.* 2010). The calibration equations were derived from linear relationships between track density and true density. Population abundance estimates, sex and age compositions were extrapolated for the entire ranch using these density estimates.

**Camera trapping survey**

**Equipment**

Two models of trail cameras were used in the study; six passively triggered Cuddeback Attack (Non Typical Inc., Greenbay, Winsconsin) and four active infrared-triggered Moultrie Game Spy I-40 Classic Digital Infrared Trail Camera (Moultrie Products, LLC, Birmingham, Alabama). Passive camera traps are triggered by temperature changes and animal movement to capture an image (Swann *et al*. 2004) while active infrared-triggered cameras record an image when the continuous infrared beam is broken by a passing animal (Swan *et al*. 2010). The Cuddeback Attack cameras have a strobe flash and recorded colour images both during the day and at night. They have a trigger speed of ¼ second, which if the camera is not correctly set up, results in the classic 'head and tail pictures'. These cameras have 5 MP resolution/image quality and a strobe flash range > 30.5 m. Captured images were saved onto 8 GB SD cards prior to being downloaded.

The Moultrie cameras have a laser beam for aiming at the target view which makes it very much easier to set up. They record colour images during the day and black/white images at night. Trigger speed is > 2.5 seconds, increasing its probability of missing passing animals because animals are either in the centre or towards the end of the detection zone. Moutrie's image resolution is 4.0 MP; detection range of 12 ± 1.5 m and despite the model having an inbuilt memory of 32 MB, a 4 GB SD card was used to save images because of the long lapses between downloads. Both camera models take D-cell batteries (Cuddeback (4) and Moultrie (6)) which last approximately 100 days. Within the first fortnight of the survey, two Cuddeback cameras were stolen by poachers and one was destroyed by elephants prompting the sourcing of the four Moultrie cameras. Nevertheless, for the duration of the survey, five pairs of cameras were used and one extra Cuddeback was on standby as recommended by Silver (2004). Images of both the cameras are shown below (Fig 3.3).

**Fig 3.3**: Images of the two models of cameras used in the camera trapping survey at Debshan ranch from 20 May to 28 July 2014, Moultrie (left) and Cuddeback (right).

**Site selection**

It is imperative that cameras are sited in such a way that every individual of the focal species in the study area has a greater than zero chance of being captured at any one of the cameras (Karanth and Nichols 1998; Silver 2004; Dillon and Kelly 2007; Balme *et al*. 2009a). Thus, the spatial layout of the cameras must ensure that at least one camera site is situated within the home range of every individual in the study area (Tobler and Powell 2013). This normally is done by using the smallest known home range of the target species to determine adequate camera spacing. For felids, female home range estimates are normally used to do this because they are smaller than those for males and transient individuals (Rabinowitz and Nottingham 1986; Smith 1993). Some studies have used home ranges of animals from previously published studies (Kelly 2003; Silver *et al*. 2004; Silveira *et al*. 2010). However, for this study, the minimum home range used to calculate camera spacing was based on data collected from a collared adult female leopard. The female, DF1, was fitted with an iridium satellite collar (Tellus Medium, Followit, Lindesberg, Sweden) on 24 January 2014 to provide home range and diet data (Appendix IV). Locations from the GPS radio collar (8 location fixes/day) from 24 January to 22 March 2014(onset of camera trapping design planning) were thus used to estimate the female's home range. Using Biotas 2.0 Alpha (1998-2013 Ecological Software Solutions LLC), a home range of 53.6 $km^2$ was estimated, resulting in a radius of 4 km. This radius (4 km) was then used as the maximum distance between adjacent camera sites.

In ArcGIS 10.0, Debshan was subdivided into 16 $km^2$ grids and potential camera sites provisionally selected in the centre of each grid cell. These points were then loaded onto a handheld GPS Garmin eTrex VISTA HCx (Garmin International Inc., Kansas) and ground truthing was done to ascertain their specific locations on the ranch. All the initial 15 points were located in unsuitable sites (i.e. in dense vegetation with very low expected leopard activity/movement). Thus, to increase leopard capture probability, alternate camera sites were selected < 1 km away at more suitable sites like along roads, dry river beds and game trails with high leopard and other animal activity (Bailey 1993; Stander 1998; Funston *et al*. 2010). The selected camera sites (Fig 3.4) were all positioned in the centre of the ranch to minimize theft and damage (Karanth *et al*. 2004; Silver *et al*. 2004).

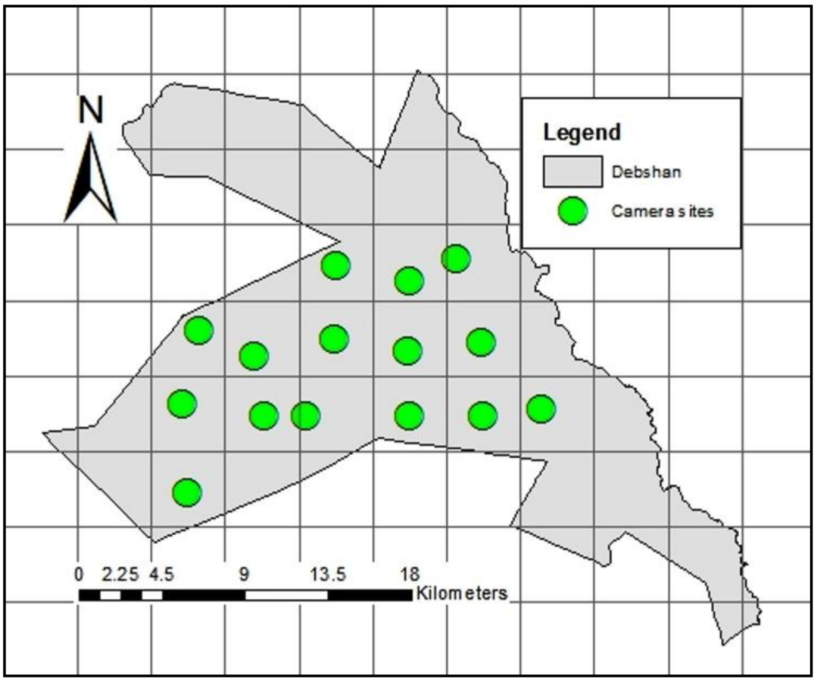


**Fig 3.4:** A map of Debshan ranch showing the 15 camera sites used for the camera trapping survey from 20 May to 28 July 2014. The square grids are 16 $km^2$ in size.

**Camera placement**

At each camera site, two cameras were placed on either side of a road, riverbed or game trail to capture both flanks of any passing leopard (du Preez *et al.* 2014). Capturing both sides of animals that have unique patterns on either flank aids in individual identification from both left and right side capture images (Soisalo and Cavalcanti 2006; Efford *et al.* 2009; du Preez *et al.* 2014).

The cameras were placed within 2 m from where the leopards were expected to pass and faced each other. The cameras were slightly offset from each other to avoid flash interference (Karanth and Nichols 1998; Silver *et al.* 2004; du Preez *et al.* 2014) which blurs the images and deems them unusable for analysis. Also, the slight offset allowed the Moultrie cameras enough time to detect and capture object while still within the detection zone (due to their slow trigger speed). On relatively flat areas, cameras were fastened to trees using their provided straps at a height of 60 cm off the ground (Silver 2004) (average leopard shoulder height) to maximise the range of capture for all leopard sizes. On cambered road surfaces, the camber interfered with the detection view, so cameras were set ~1 m on a tree and angled slightly downwards. When setting up the camera, a crawl test was done in front to test the cameras' focus on the target detection zone.

**Survey design**

To satisfy the assumption of population closure (Karanth & Nichols 1998, 2000, 2002), the camera survey was conducted over a period of 69 days. Over this period, the available cameras (n = 10 - 12) were rotated six times across the 15 sampling sites (Table 3.1). I had initially planned to only have three rotations, each lasting approximately 30 days. However, the theft of cameras, damage from elephants and the non-arrival of a camera order from the USA, meant that this approach had to be adjusted. Significantly, after the third rotation, I decided to rotate the cameras across each of the 15 grid cells for an additional seven days at each site (Table 3.1). When I returned the cameras to these grid cells (rotations 4, 5 and 6), I chose slightly different locations (< 800 m from original location) to improve the chances of leopard captures. Because of this approach, camera grid cells 1-4 were effectively sampled for 38 days, grid cells 5 and 11 for 19 days, grid cells 7-10 for 18 days, grid cells 13-15 for 14 days, and grid cell 12 for 13 days. Cameras were checked every 3 – 4 days to download images to avoid losing data in case of theft or damage.

**Table 3.1**: Summary of sampling rotations for the camera trapping survey conducted at Debshan ranch from 20 May to 28 July 2014. [a]two cameras were only out for five days before being stolen by poachers, [b]two cameras only out for four days but were moved to camera site 12 to make it easy to check the sites because they were closer together, [c]cameras out for six days then moved for the third rotation.*A trap night was defined as a 24 hour period when each individual camera was active.

| ROTATION | SAMPLING PERIOD | CAMERA GRID CELL | DAYS ACTIVE | *TRAP NIGHTS |
|---|---|---|---|---|
| 1 | 20 May - 19 June | 1; 2; 3; 4; 5[a] | 31 | 250 |
| 2 | 20 June - 30 June | 6; 7; 8; 9; 10; 11[b]; 12[c] | 10 | 110 |
| 3 | 1 July - 7 July | 5; 11; 13; 14; 15 | 7 | 70 |
| 4 | 8 July - 14 July | 3; 4; 8; 9; 10 | 7 | 70 |
| 5 | 15 July - 21 July | 1; 2; 6; 7; 12 | 7 | 70 |
| 6 | 22 July - 28 July | 5; 11; 13; 14; 15 | 7 | 70 |

**Data analysis**

Firstly, all the images from the survey were tagged, renamed and sorted using PhotoGofer software (Rapid Imaging Software Inc.). A summary table of all the species captured was created. All the leopard images were separated into left and right side images and individual leopards were identified from the images using each animal's unique rosette patterns (Miththapala *et al.* 1989; Karanth & Nichols 1998). Images taken within 30 minutes were considered as a single event of the same leopard (Gray *et al.* 2014). Poor quality images were not used in the identification (Fig 3.5 A and B). A unique feature (primary feature) was identified on each individual leopard image and this feature was used to compare with others. One or two secondary features were also identified (Fig 3.5 C-F). Only the left side images identification were used for the analyses. The right side images were not used because there was a high variability in body section captured, thus the images were not comparable against each other and there were also too few (n = 9).

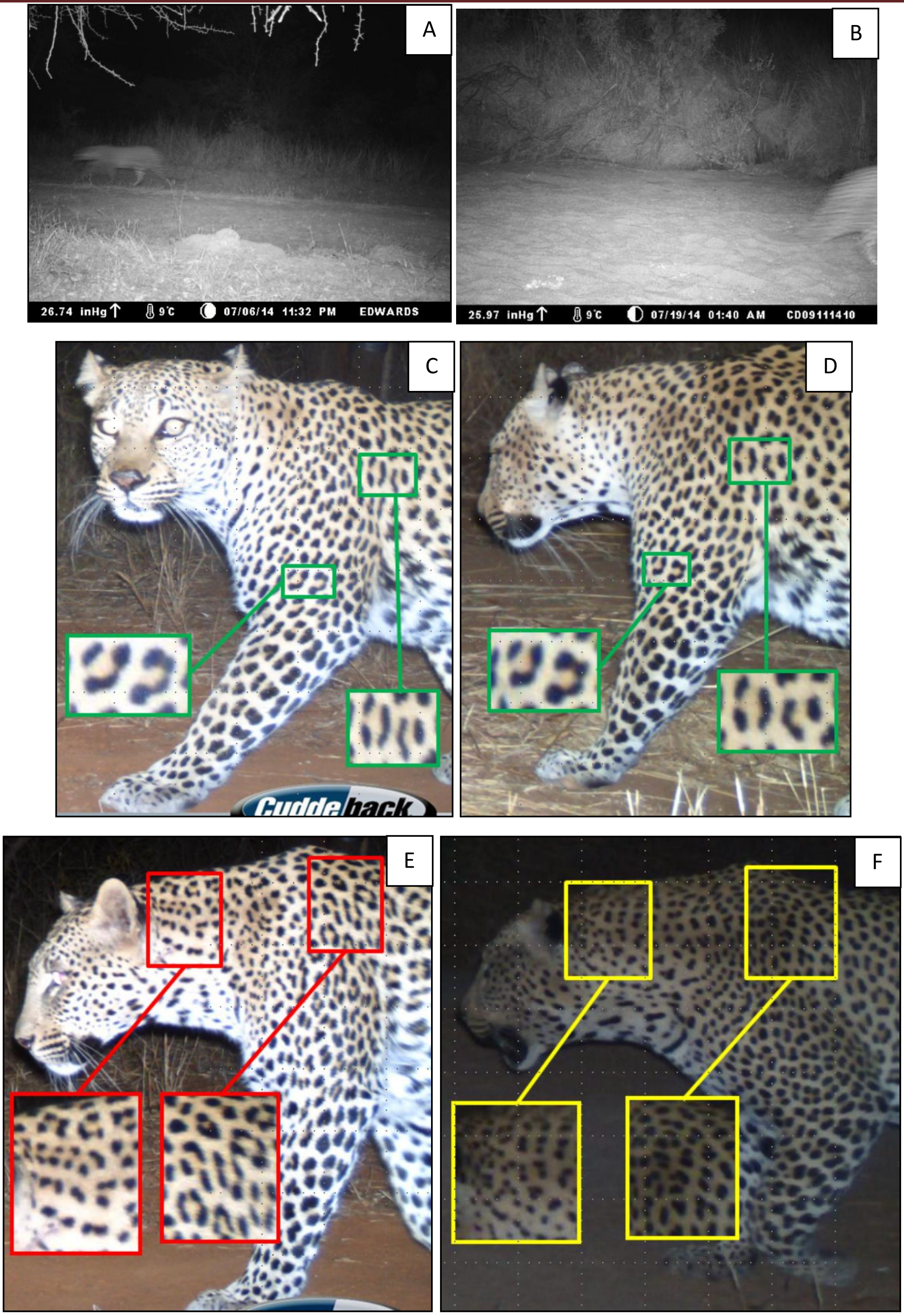


**Fig 3.5**: Examples of images from the camera trapping survey conducted at Debshan ranch from 20 May to 28 July 2014; A and B are the unclear images, C and D are different images of the same individual showing the similar features while E and F highlight the different features on different individuals.

**CAPTURE**

The program CAPTURE (Otis *et al.* 1978; White *et al*. 1982; Rexstad and Burnham 1991) was used to analyse the leopard capture matrix generated from the camera trapping data (Appendix V). Each sampling occasion was defined as the 24 hour period beginning and ending at 1500 hours. Because leopards are nocturnal (Karanth and Sunquist 2000; Balme *et al*. 2009a; du Preez *et al.* 2014), this eliminated occurrences of an individual photographed either side of 0000 hours and being regarded as two separate events. Due to the rotation of the cameras, data were pooled so that sampling occasions were regarded as the time a camera site was active only, though this was not entirely so in this study due to the uneven number of trapping days per site. Total number of captures for occasion 1 was the sum of captures occurring on the first day of trapping in each rotation at each camera site, number of captures or recaptures for capture occasion 2 was the sum of captures or recaptures for the second day of each rotation and each camera site, and so on (Karanth and Nichols 2002).

CAPTURE computes a population closure test and also selects the best model that estimates population abundance and capture probability from seven probabilistic models that differ in their assumed sources of variation in capture probability (Rexstad and Burnham 1991). Sources of variation in capture probability that are considered in the models of CAPTURE are individual heterogeneity, behavioural response, and time (White *et al*. 1982). Several estimators of population size are offered by program CAPTURE. The simplest is the null model ($M_0$), which assumes that the time of capture, heterogeneity among individuals, or trap-response (behaviour) do not affect capture probabilities of animals in the population being sampled. The $M_h$ (Jackknife) model assumes that capture probability will differ between individuals (Otis *et al*. 1978; White *et al*. 1982; Rexstad and Burnham 1991; Karanth 1995). White *et al. (*1982) recommended that closed capture-recapture models should ideally not be used to estimate the size of small populations ($n < 20$) because they do not provide enough information for any procedure to perform well.

**DENSITY**

The leopard density estimates were calculated using the program DENSITY 5.0 (Efford *et al.* 2004; http://www.landcareresearch.co.nz/services/software/density; University of Otago, New Zealand) to carry out the Spatially Explicit Capture Recapture (SECR) analyses. SECR aims to estimate population density of free-ranging animals (Efford 2004; Efford *et al.* 2004; Borchers and Efford 2008; Efford *et al.* 2009), unlike non-spatial analyses which compute population abundance (White *et al*. 1982; Rexstad and Burnham 1991, Karanth 1995).

Animals are assumed to be independently distributed in space and occupying home ranges. Similarly, as with all conventional capture-recapture (Williams *et al.* 2002), the SECR fits a model that includes both population parameters and parameters for the detection process. Two input files are used and need careful formatting (Appendix VI).

A trap deployment file gives the locations of detectors (camera sites) in the Universal Transverse Mercator (UTM) format and has the binary matrix for the sampling occasions where a '1' represents active days and a '0' when the detectors were not active either out of rotation or due to damage or theft. Sollmann *et al*. (2011) showed that it is important to account for capture probability differences as a result of camera placement, either on or off roads; hence a 'roads' covariate was also included. However, Sollmann *et al.* (2011) and Tobler and Powell (2013) further advise that including covariates fragments the data into smaller groups, therefore larger samples are required to get more precise estimates with smaller confidence intervals. The second input file was a leopard capture file which showed animal identities with their corresponding detectors and the occasions on which they were captured; session shows that the data was collected during one survey. A sex covariate was also included (Sollmann *et al.* 2011).

For the SECR analysis, analyses were conducted on both the pooled and un-pooled sampling occasions and with different buffer widths (Soisalo and Cavalcanti 2006; Balme *et al.* 2009). These were run 24 times under different conditions including with and without road and sex covariates and also under full and conditional maximum likelihoods (Pledger 2000; Borchers and Efford 2008; Marques *et al.* 2010). The incomplete trap layout was chosen as cameras were not at all the stations all the time but were being rotated. Thus, a 1 indicated camera presence and a 0 showed absence. Different buffer widths were used, the Half Mean Maximum distance Moved (HMMDM) which is simply half the Mean Maximum Distance Moved (MMDM) by leopards between the camera stations during the survey (Karanth and Nichols 1998; Silver *et al.* 2004). The full MMDM was also used as the second buffer width.

Parmenter *et al*.(2003), Soisalo and Cavalcanti (2006) and Balme *et al*. (2009) used as an extra buffer width, the Mean Maximum Distance Moved Outside Of Study Area (MMDMOSA) using data from locally GPS radio collared animals. The three buffer widths I used were therefore; HMMDM (3 147 m), MMDM (6 294 m) and MMDMOSA (12 679 m).

MMDMOSA was calculated, using the mean home range estimates of the two collared leopards, DF1 and DM1, using Biotas 2.0 Alpha. The Poisson distribution and half normal detection models were used (Efford 2004; Gray and Prum 2012). Densities were ranked using their weighted corrected Akaike's Information Criterion (AICc) values ( AIC; Akaike 1974; Burnham and Anderson 2002; Winchester *et al*. 2009; Symonds and Moussalli 2011). Non spatial analyses were also done in DENSITY 5.0 where the best model was also selected and abundance estimates computed.

# RESULTS

## Spoor survey

Twelve transects, totaling 163.35km (average transect length = 13.6 km; range = 6.46 – 22 km), were each driven twice, giving a total distance driven of 326.7km (Table 3.2). A penetration rate of 2.75 resulted, meaning that for every kilometre driven, ~2.75km$^2$ of the study area was effectively surveyed. A total of 59 individual leopard spoor were encountered (Fig 3.6). The spoor were highly concentrated in the centre of the ranch and also along the eastern boundary which is the Shangani River.

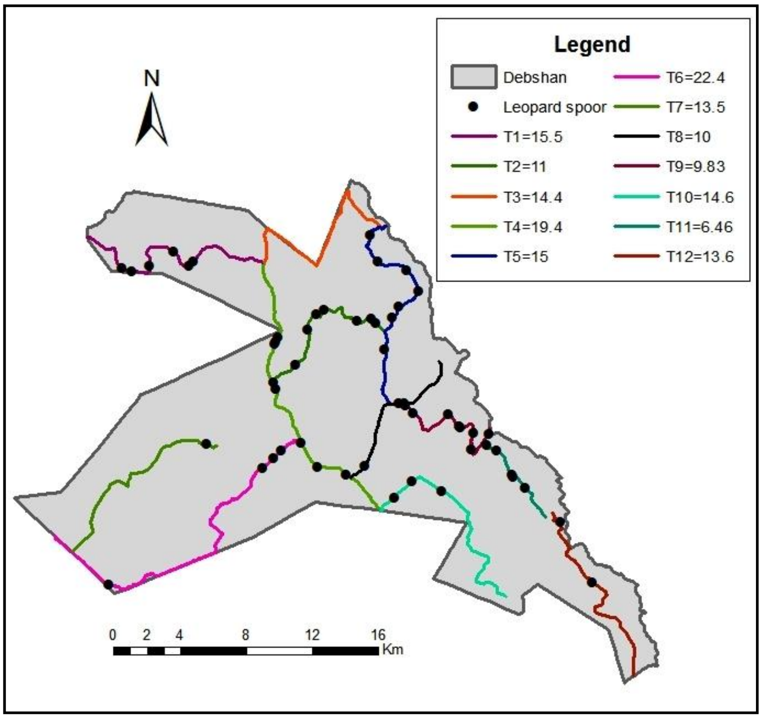


**Fig 3.6**: A map of Debshan ranch showing the distribution of leopard spoor from the spoor survey conducted from 14 May to 28 June 2013.

Of the 59 spoor; 22 were from adult males, 23 from adult females, eight and six from sub-adult males and females, respectively (Table 3.2). The spoor survey resulted in a leopard spoor frequency of 5.54 km/spoor and a leopard spoor density of 18.1 spoor/100km.

**Table 3.2:** Summary of results for the leopard spoor survey conducted at Debshan ranch, Shangani, Zimbabwe, from 14 May to 28 June 2013. *Penetration rate is the sum of the distance of all transects expressed as a ratio of 1km of road to *x*km$^2$ surface area of the study area.

| | |
|---|---|
| Survey area size | 450 km² |
| Total transect length | 163.35 km |
| Total distance driven | 326.7 km |
| *Penetration | 2.75 |
| Total number of leopard spoor counted | 59 |
| Spoor frequency (km/spoor) | 5.54 |
| Spoor density (spoor/100km) | 18.1 |
| Number of male leopard tracks counted | 22 |
| Number of female leopard tracks counted | 23 |
| Number of sub-adult male tracks counted | 8 |
| Number of sub-adult female tracks counted | 6 |

Sampling precision, as measured by the coefficient of variation (CV), increased with increasing sample size (Fig. 3.7a). However, a CV of 20% was only reached once 35.35 spoor had been encountered (Fig. 3.7a). At the end of the survey, the CV had decreased to 16.63%. When 35.35 leopard spoor had been encountered, a total transect distance of 192km had been driven (Fig. 3.7b) and the CV was 23%.

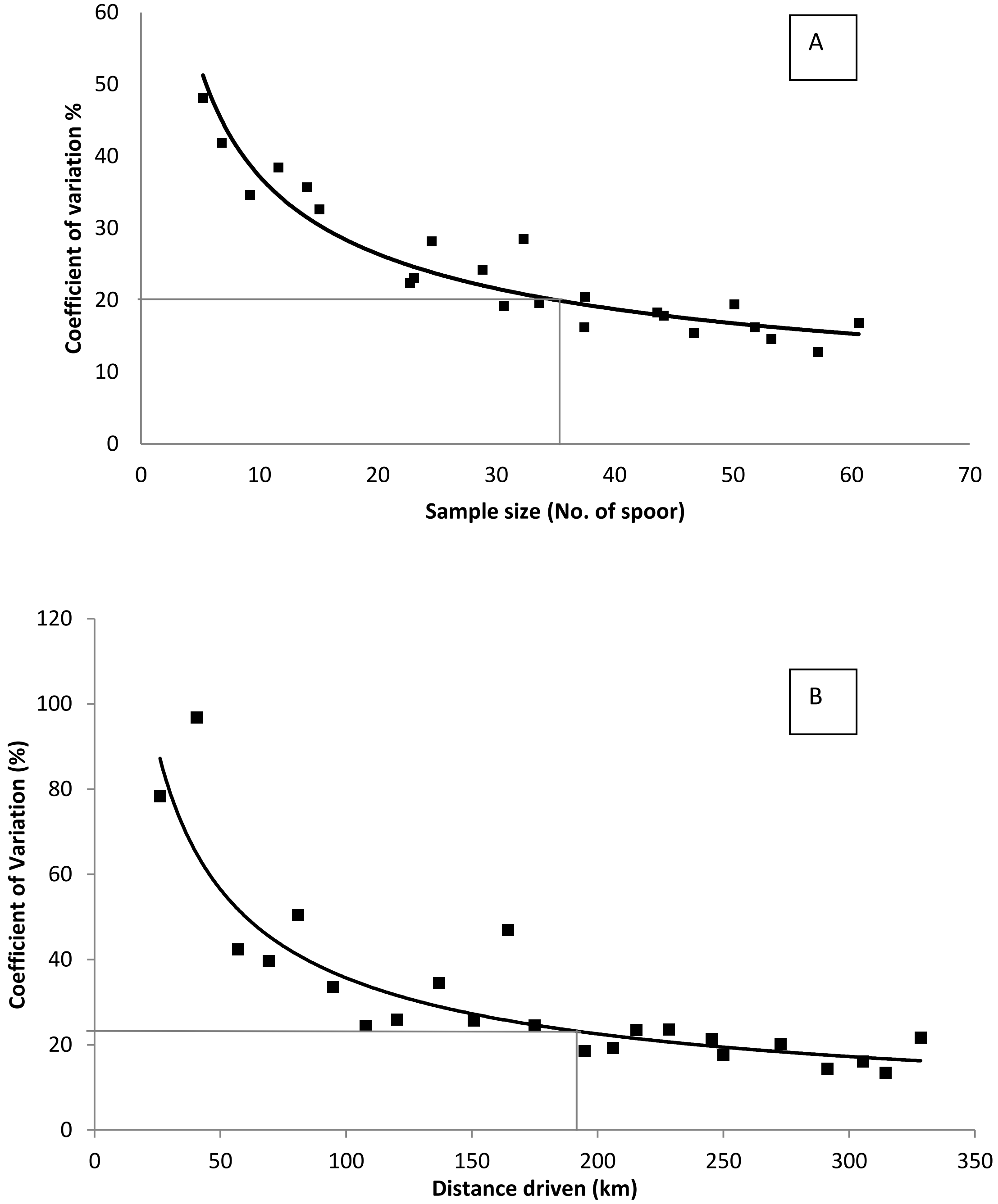


**Fig. 3.7**: The relationship between sampling precision (coefficient of variation) and A) the number of spoor encountered; and B) the distance driven during the spoor survey at Debshan ranch, Shangani, Zimbabwe from 14 May to 28 June 2013. A CV of 20% was reached at 35.35 spoor and at 35.35 spoor counted, a distance of 192km was driven giving a CV of 23.2%.

The estimated leopard density of Debshan varied, depending on which calibration equation was used to calculate density (Table 3.3). The leopard spoor density of 18.1spoor/100km derived from the spoor survey was used in the equations to generate the density estimates. The lowest density of 5.6 leopards/100km$^2$ resulted from Funston *et al.* (2010)'s combined model for all carnivores on sandy soils, followed by Stander's (1998) equation which estimated the density of leopards to be 9.5 leopards/100km$^2$. Balme *et al.* (2009)'s equation gave the highest population estimate of 13.6 leopards/100km$^2$. Thus, taking all three estimates into consideration, the mean and median leopard density on Debshan was estimated to be 10 ± 4 leopards/100km$^2$.

By extrapolating the density estimate to the entire property, ~45 leopards (range: 25 – 61) may be present on Debshan. By using the approximate age and sex breakdown of the leopard spoor observed (Table 3.2), it is therefore possible that there could be ~17 adult males (range: 10 – 23), ~18 adult females (range: 11 – 25), and ~11 sub-adult individuals (range: 7 – 15). However, these estimates must be interpreted with caution as spoor surveys do not necessarily differentiate between individual animals during repeat counts.

**Table 3.3:** Estimated population densities of leopards (no. of leopards/100km$^2$) for Debshan ranch derived from the spoor density results using three published equations.

| METHOD | EQUATION | DENSITY(leopards/100km$^2$) |
|---|---|---|
| Stander (1998) leopard equation | y=1.9x | 9.53 |
| Balme *et al.(*2009a) Phinda calibration | y=1.33x + 0.05 | 13.57 |
| Funston *et al*. (2010) Combined model (all carnivores) on sandy soils | y = 3.15x+0.40 | 5.62 |

**Camera trapping survey**

The camera trapping survey ran for 69 days, giving a total of 646 trapping nights across all 15 camera sites (Table 3.4). A total of 749 images were recorded with 118 being of cattle. Domestic dogs (n = 3 with > 6 dogs in each) were also recorded. Five of the six human pictures were of poachers from two separate events.

There were a total of 26 leopard images (Table 3.4); two were not clear enough to be used for any further analyses, three were separated by a 2-minute interval and were considered to be a single event (images confirmed it was the same individual). Of the 22 remaining images; 13 were of left-side and nine were right-side images.

Of the 13 left-side images, 15 individual leopard images (because one female had two cubs in one image) were used for individual leopard identification. Ten individuals were identified with seven single captures, two double captures and one triple capture.

**Table 3.4**: Summary data from the camera trapping survey conducted at Debshan ranch, Shangani, Zimbabwe, from 20 May to 28 July 2014.

| | **Number** | **%** |
|---|---|---|
| No. of camera-trapping days | 646 | 100 |
| Total number of images | 749 | 100 |
| Cattle | 118 | 16 |
| Poachers | 5 | 0.7 |
| Domestic dogs | 3 | 0.4 |
| Total leopard photo events | 26 | 3.5 |
| Individual leopards identified (left-side only) | 10 | - |
| Total mammal species | 28 | - |
| Total carnivore species | 12 | - |
| Total carnivore photo events | 116 | 15.5 |
| Total bird species | 7 | - |
| Total bird photo events | 64 | 8.5 |
| Total wildlife species | 35 | - |

**CAPTURE**

The program CAPTURE was used to analyse the leopard capture matrix generated from the camera trapping data (Appendix V). The Null ($M_0$) model was selected as the most appropriate model with a criterion score of 1.00 followed by the Jackknife ($M_h$) model with a score of 0.93 (Table 3.5). The test for population closure revealed that the population was closed after the survey ($z = 0.196$; $p = 0.578$). The Null model estimated the leopard population abundance to be 9 ± 3.35 animals (range = 7 – 23) with a constant capture probability of 0.0271.

**Table 3.5**: CAPTURE model selection criterion score for the left-side images of leopards from the camera survey at Debshan between May and July 2014.

| MODEL | CRITERION SCORE |
|---|---|
| $M_0$ | 1.00 |
| $M_h$ | 0.93 |
| $M_{tbh}$ | 0.86 |
| $M_{bh}$ | 0.85 |
| $M_b$ | 0.58 |
| $M_{tb}$ | 0.50 |
| $M_{th}$ | 0.43 |
| $M_t$ | 0.0 |

**DENSITY 5.0**

Twenty-four analyses were done in the program DENSITY 5.0 using two sets of paired data for camera sites and leopard capture data files, an example is given in Appendix VI (a and b). The Null ($M_0$) model was again selected as the best approximating model with an abundance estimate of 18.0 ± 6.7 (range = 10.3 – 48.2) and a per occasion capture probability of 0.0210. The second best model was still the Jackknife ($M_h$) model with an abundance estimate of 16.6 ± 5.5 animals (range = 11.6 – 37.4) and a per occasion capture probability of 0.0227 (Table 3.6).

**Table 3.6:** Leopard population abundance estimates from the closed population estimators calculated using DENSITY 5.0 from the 10 individuals identified from the camera survey at Debshan ranch, Shangani, Zimbabwe from 20 May to 28 July 2014.

| MODEL | ABUNDANCE ESTIMATE | STANDARD ERROR | CONFIDENCE LIMITS | PROBABILITY |
|---|---|---|---|---|
| $M_0$ | 18.0 | 6.7 | 10.3 - 48.2 | 0.021 |
| $M_h$ | 16.6 | 5.5 | 11.6 - 37.4 | 0.0227 |

Density estimates varied greatly according to the buffer width used (Fig 3.8). The HMMDM estimated density to be 6.9 leopards/100km$^2$, MMDM at 3.9 leopards/100km$^2$ and MMDMOSA gave the lowest estimate of 2.0 leopards/100km$^2$ (Table 3.7). Un-pooled sampling occasions analysed under a conditional maximum likelihood without a road and sex covariate gave the best estimates.

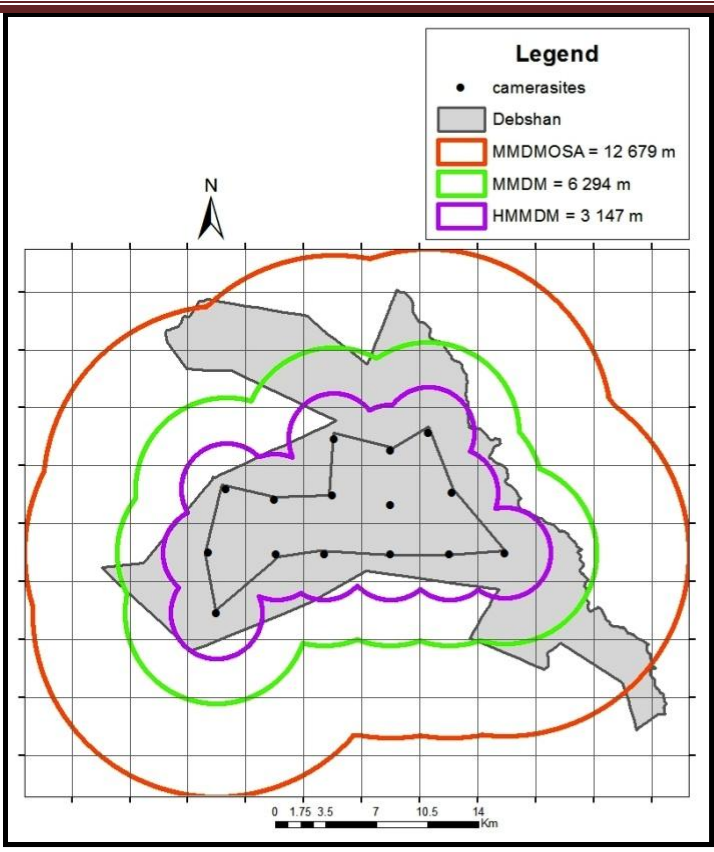


**Fig 3.8**: A map of Debshan ranch showing the three buffer widths (HMMDM, MMDM and MMDMOSA) used in the calculation of density estimates in DENSITY 5.0.

**Table 3.7**: Results from the SECR analyses in DENSITY5.0. Data were analysed for pooled and unpooled sampling occasions, different buffer widths (HMMDM = 3147 m, MMDM = 6 294 m, MMDMOSA = 12 679 m), full and conditional maximum likelihood and with/without road and gender covariates.

| SAMPLING OCCASION | BUFFER WIDTH | MAXIMUM LIKELIHOOD | ROAD AND GENDER COVARIATES | DENSITY/100km2 | SE | 95% CI | AIC | AICc | ∆AICc | AICc WEIGHT |
|---|---|---|---|---|---|---|---|---|---|---|
| Unpooled | HMMDM | Conditional | No | 6.9 | 3.29 | 0.47 - 13.36 | 145.00 | 146.71 | 0.00 | 0.25 |
| Unpooled | MMDM | Conditional | No | 3.9 | 2.10 | 0.20 - 8.20 | 145.40 | 147.12 | 0.41 | 0.20 |
| Pooled | HMMDM | Conditional | No | 6.9 | 3.30 | 0.50 - 13.40 | 145.66 | 147.38 | 0.67 | 0.18 |
| Unpooled | MMDMOSA | Conditional | No | 2.0 | 2.00 | -1.83 - 5.80 | 146.06 | 147.77 | 1.06 | 0.14 |
| Pooled | MMDM | Conditional | No | 3.9 | 2.20 | -0.30 - 8.20 | 146.46 | 148.17 | 1.46 | 0.12 |
| Pooled | MMDMOSA | Conditional | No | 2.0 | 1.90 | -1.70 - 5.60 | 146.80 | 148.52 | 1.81 | 0.10 |
| Unpooled | HMMDM | Full | No | 6.9 | 3.51 | 2.71 - 17.67 | 151.15 | 155.15 | 8.44 | $3.62 \times 10^{-3}$ |
| Unpooled | MMDM | Full | No | 3.9 | 2.30 | 1.30 - 11.60 | 151.56 | 155.56 | 8.85 | $2.94 \times 10^{-3}$ |
| Pooled | HMMDM | Full | No | 6.9 | 3.50 | 2.70 - 17.70 | 151.82 | 155.82 | 9.11 | $2.59 \times 10^{-3}$ |
| Unpooled | MMDMOSA | Full | No | 2.0 | 2.70 | 2.70 - 14.70 | 152.21 | 156.21 | 9.50 | $2.13 \times 10^{-3}$ |
| Pooled | MMDM | Full | No | 3.9 | 2.40 | 1.30 - 11.60 | 152.61 | 156.61 | 9.90 | $1.74 \times 10^{-3}$ |
| Pooled | MMDMOSA | Full | No | 2.0 | 2.50 | 0.30 - 13.30 | 152.96 | 156.96 | 10.25 | $1.46 \times 10^{-3}$ |
| Pooled | MMDM | Conditional | Yes | 3.5 | 1.60 | 0.30 - 6.70 | 150.92 | 206.92 | 60.21 | $2.07 \times 10^{-14}$ |
| Unpooled | HMMDM | Conditional | Yes | 7.5 | 3.78 | 0.10 - 14.94 | 152.06 | 208.06 | 61.35 | $1.17 \times 10^{-14}$ |
| Pooled | MMDMOSA | Conditional | Yes | 1.5 | 9906 | 19414 - 19417 | 152.71 | 208.71 | 62.00 | $8.47 \times 10^{-15}$ |
| Unpooled | MMDMOSA | Conditional | Yes | 1.5 | 0.70 | 0.20 - 2.80 | 156.35 | 212.35 | 65.64 | $1.37 \times 10^{-15}$ |
| Unpooled | MMDM | Conditional | Yes | 3.3 | 1.50 | 0.30 - 6.30 | 156.37 | 212.37 | 65.66 | $1.36 \times 10^{-15}$ |
| Unpooled | HMMDM | Full | Yes | 7.5 | 4.12 | 2.74 - 20.52 | 158.12 | 302.12 | 155.41 | $4.41 \times 10^{-35}$ |
| Unpooled | MMDM | Full | Yes | 4.8 | 2.90 | 1.60 - 14.30 | 154.34 | 302.34 | 155.63 | $3.95 \times 10^{-35}$ |
| Pooled | MMDMOSA | Full | Yes | 1.3 | 0.60 | 0.60 - 3.00 | 157.96 | 301.96 | 155.25 | $4.77 \times 10^{-35}$ |
| Pooled | HMMDM | Full | Yes | 6.3 | 3.04 | 2.60 -15.50 | 158.91 | 302.91 | 156.20 | $2.97 \times 10^{-35}$ |
| Pooled | HMMDM | Conditional | Yes | 6.3 | 0.00 | 6.33 | 158.91 | 302.91 | 156.20 | $2.97 \times 10^{-35}$ |
| Unpooled | MMDMOSA | Full | Yes | 1.5 | 0.70 | 0.60 - 3.60 | 162.51 | 306.51 | 159.80 | $4.91 \times 10^{-36}$ |
| Pooled | MMDM | Full | Yes | 3.3 | 1.60 | 1.20 - 8.20 | 163.77 | 307.77 | 161.06 | $2.61 \times 10^{-36}$ |

## DISCUSSION

### Spoor survey

Successful monitoring of carnivore densities or presence from spoor counts is dependent on thorough sampling design (Stander 1998). An increase in transect numbers or length has an increased effect on data precision. Penetration rates $< 7$ were deemed appropriate (Stander 1998; Davidson 2009, du Preez *et al*. 2011) thus the penetration rate of 2.75 in my study is very high thus appropriate for increasing both accuracy and precision (Stander 1998) of spoor frequency estimates. Habitat utilisation by carnivores is also an important variable influencing leopard distribution (Bailey 1993) thus variations in habitat may influence leopard spoor distribution in an area and consequently bias density estimates. Habitat assessments are, therefore, also crucial to the interpretation of spoor survey results.

Spoor counts which involve the counting of tracks provide useful information for monitoring populations over time. Because distinguishing between sexes is important, García *et al*. (2010) used linear, angular, area and geometric measurements to determine the sex of pumas (*Puma concolor*). However to obtain tracks that will yield accurate measurements, they must be from a hard substrate covered by dust or sand (muddy or loose soil distorts shape) (Henschel and Ray 2003; Karanth *et al.* 2003). This study was done during the dry season (May/June) so tracks were usable for the determination of sex and identification of individuals, however, the survey duration was too short to get sufficient data. Nevertheless, I recorded all track measurements as they have the potential to supplement other surveys or be useful once a program to handle them becomes available (Henschel and Ray 2003). Despite tracks being very important sources of information, they should not be used as an only means of deriving populations unless if the soil surfaces are favourable and the sample is large enough to represent all individuals in the area e.g. Smallwood and Fitzhugh (1995) derived good mountain lion (*Felis concolor californica*) data in logging roads.

Leopard spoor distribution was highly concentrated in the core area of the ranch and along the eastern boundary which is along a nearly perennial river, Shangani. Absence of signs does not necessarily mean leopard absence (Henschel and Ray 2003) but because equal sampling effort was invested throughout the ranch, I can safely conclude that leopard spoor were unevenly distributed. This is an important result as Balme *et al*.'s (2010) study of edge impacts on the PA showed a substantial decline in leopard density from the core (11.11 ±

1.31 leopards/100km$^2$) to the border (7.17 ± 1.12 leopards/100km$^2$) in the Phinda-Mkhuze Complex (PMC), South Africa. The leopard densities were even lower in the non-protected areas adjoining the PMC (2.49 ± 0.87 leopards/100km$^2$). Their study revealed that low densities were not related to prey abundance or interspecific competition as radio telemetry showed that leopards near the border spent a greater proportion of their time outside the reserve and suffered higher annual mortality rates (0.358±0.075) than those closer to the core (0.122±0.065). Due to its shape, Debshan has a high perimeter ratio which increases exposure to edge effects which have a potentially devastating effect on the population. Therefore, absence of leopard signs e.g. spoor around the edges of the ranch might signify impacts of the negative interactions with humans on the boundary.

Or it could be this: Since previous studies have shown that leopards adjust their behaviour and become more secretive in the presence of humans (Odden *et al*. 2014), the leopards closer to the boundaries of the ranch may have resorted to avoiding areas of high human activity such as roads which were our sample zones. Also, females have been seen to generally avoid roads as they are frequented more by males (Ngoprasert *et al.* 2007; Balme *et al*. 2009). Bailey (1993) observed that males used roads more often than females in the Kruger national park. Therefore, because only males are hunted for trophy (Balme and Hunter 2004; Lindsey and Mandisodza-Chikerema 2012), the remaining population majority comprises females which tend to avoid roads. Thus, the additive effects of these two factors; males hunted only and females' avoidance of roads might affect leopard spoor distribution closer to the ranch borders.

The preference of leopards for areas of rocky hills, mountain ranges and riverine forests is widely documented (Skinner and Chimimba 2005; Daly *et al*. 2005). Bailey (1993) also found that radio-collared leopards used riparian habitats significantly more than the open sites in the Kruger national park. Debshan ranch has a highly heterogenous vegetation. Heterogeneous habitats pose a problem as carnivores frequent particular vegetation or geological types and spoor frequencies on roads associated with their preferred habitats are higher than expected (Van Dyke *et al*. 1986, Smallwood and Fitzhugh 1995). Taking this into consideration, leopards possibly preferred the *Brachystegia spiciformis* vegetation which is dominant in the centre of the ranch and also in the north-western wing of the ranch. Myers (1976) estimated that the Ruaha Park of Tanzania which lies entirely in the miombo biome was capable of supporting one leopard for every 10 $km^2$. *Colophospermum mopane* woodlands dominated the western wing of and the northern end of the ranch and spoor density was least in those areas. Density of stalking cover is a very important factor as it determines hunting success through concealment (Bailey 1993), a factor which may have increased leopard presence in the middle of the ranch and along the river.

Also, levels of human interaction and subsequent persecution (Balme *et al*. 2009) have an effect on leopard distribution as observed from spoor surveys. On the western and northern boundaries, the ranch borders immediately with resettlement plots without any buffer zone. These areas have large livestock numbers hence conflicts due to livestock depredation might arise leading to persecution. Whilst on the eastern side, the Shangani River creates a buffer between the ranch and the village resettlements hence reduced conflict.

Harmsen *et al*. (2011) explained how the use of biased abundance estimates could have serious conservation management implications/consequences. Therefore the abundance and density estimates generated from the spoor survey calibration equations will be used with great caution. Because these equations were generated for specific area with specific conditions (Stander 1998; Balme *et al.* 2009) e.g. habitat, prey abundance and persecution levels, they may not adequately cater for local conditions in my study area. Leopards are not equally distributed throughout their range; different habitats will determine their varying spatial requirements (Ray *et al*. 2005). Houser *et al*. (2009) recommended how the differences in lion, leopard, wild dog and cheetah's range, daily movements and road usage will affect the universal applicability of one general equation emphasising the need to quantify the correlations. Funston *et al*.'s (2010) equation gave the lowest density estimate of 5.62 leopards/100$km^2$. Indices of population sizes can be used to estimate large carnivore abundances, but are often case-, species- and site specific, Funston *et al.*'s (2010) study combined different species in different habitats (though) the substrate was all sand, extensive assumptions were made and also, because leopards occurred at low densities, their equation may not adequately represent the leopards at Debshan ranch. Bias according to tracker differences can also influence results and cannot be controlled for however, Stander *et al.* (1997) confirmed that observer bias does not confound the resulting spoor indices. Due to the large differences socially and all of these species, the imposition of lion (majority) data onto other species may not be ideal especially as species behaviour will vary widely as a result of interspecific competition (which is absent in my study because lions are not present). Previous studies have found that leopards show some behavioural differences in habitats where they are not competing with larger carnivores (Eisenberg & Lockhart 1972).

Stander's (1998) calibration equation gave the second highest density estimate of 9.57 leopards/100km$^2$. His study was carried out in an area of very low leopard density and in a semi-arid climate. However preliminary results from the two GPS collared leopards in the ranch revealed smaller home ranges 53.3 km$^2$ and 112 km$^2$ respectively for the female and male. Stander *et al*.'s (1997) home ranges were on average 188 km$^2$ and 451 km$^2$ for females and males respectively. Stander *et al*.'s (1997) home ranges are too large compared to these from the current study and renders the calibration equation unsuitable due to its specificity to low leopard densities.

Balme *et al.* (2009a) calibration for Phinda Game Reserve gave the highest density estimate for my area (13.57 leopards/100km$^2$). Balme *et al.*'s (2009a) Phinda calibration was based on a linear, but insignificant, relationship between spoor density and true density, and (Balme *et al.* 2009a) claims that it underestimated the density of leopards at Phinda. The Phinda area is protected as a game reserve, without any trophy hunting though the reserve serves as a source population for trophy hunting areas on the reserve's surrounding areas (Balme *et al*. 2010). Because Debshan is adequately protected as a private ranch, but also practises trophy hunting and is affected by poaching and trophy hunting inside its boundaries as well as beyond, this equation might be the most suitable to consider. And, as the apex predators in the areas, due to absence of lions and low density of spotted hyenas (*Crocuta crocuta*) (from camera-trapping), leopards can potentially reach these high densities.

In my study, the leopard spoor density was 18.1 spoor/100km. which was very high compared to the spoor densities from other previous studies (Table 3.8). Spoor density estimates serve as a quick surrogate for confirming carnivore presence/absence and abundance in an area (Henschel and Ray 2003; Garcia *et al*. 2010), monitoring trends over time and also for comparison with other areas (Caughley and Sinclair 1994; Stander 1998). Spoor surveys, however, on their own do not reveal any meaningful information (Stander 1998) as they do not give population size but because they are quick to perform and relatively cheaper (Smallwood and Fitzhugh 1995; Stander 1998), they can be used to generate indices using true densities from either telemetry or camera trapping data (Stander 1998; Balme *et al*. 2009; Houser *et al.* 2009; Funston *et al*. 2010). However, to create a strong calibration index, spoor counts have to be done for a long time and with adequate precision (Grigione *et al*. 1999; García *et al*. 2010) making my current results insufficient to create a calibration index for this particular area, hence, calibration equations from other previous studies were used to determine/estimate population densities (Stander 1998; Balme *et al.* 2009; Funston *et al*. 2010).

**Table 3.8**: Summary of literature on leopard spoor densities from different spoor surveys in sub-Saharan Africa.

| **Author** | **Location** | **Habitat** | **Spoor density(Spoor/100km)** |
|---|---|---|---|
| Houser *et al*. (2009) (cheetah) | Jwana Game Reserve, Jwaneng, Botswana | Open semi-wooded savannah mixed with a moderate to thick bush | 2.32 |
| Balme *et al*.(2009a) | Phinda Private Game Reserve, KwaZulu-Natal, South Africa | Lowveld bushveld and bushveld grassland | 6.07 ± 0.24 |
| Stander (1998) | Tsumkwe District Communal Area, Namibia | Semi-arid savanna woodland | 2.6 |
| du Preez (2010) | Bubye Valley Conservancy, Zimbabwe | Closed woodland | 9.1 |
| Funston *et al*. (2010) | Hwange National Park, Zimbabwe | Closed woodland with dense shrubs | 0.29 |
| Funston *et al*. (2010) | Kgalagadi Transfrontier Park, SA/Botswana | Sparse to open tree savanna | 0.8 |
| Grant (2012) | Mangwe area, Zimbabwe | Deciduous tree savanna | 4.3 |

The spoor density from my study should be interpreted with caution as double counting of the same individual's spoor may have been likely. Stander (1998) cautioned against using calibration indices (equations) from other studies as some field variables are important to consider (Grigione *et al*. 1999) such as the soil substrate which influences spoor detectability and size measurements, habitats and prey which influence leopard distribution (Van Dyke *et al.* 1986; Smallwood and Fitzhugh 1995; Balme *et al*. 2007).

**CAMERA TRAPPING**

Ten individually identifiable leopards were captured during the camera trapping survey. In addition to leopards, the survey showed a number of species and confirmed long standing questions for the ranch personnel e.g. both the spotted hyena and brown hyena (*Hyaena brunnaea*) were captured at the same camera station in one night. An inventory of the wildlife and bird species was also confirmed for the less obvious species. This inventory adequately serves as an indication of available prey diversity (Stein *et al.* 2008, Tobler *et al.* 2008). Poaching activities were also confirmed, revealing the power of the method and its broad usefulness (O'Conell *et al*. 2011). However, challenges in terms of theft (by poachers) and damage (by elephants: *Loxodonta Africana*) were also experienced proving the high maintenance and running costs associated with camera-trapping.

The program CAPTURE confirmed population closure meaning that the survey satisfied the underlying assumptions. The survey was 69 days long and thus was sufficiently within the recommended three months for large carnivores (Karanth and Nichols 2000) and was consistent with other previous studies on large felids (Silver *et al*. 2004; Jackson *et al*. 2006; Wang and Macdonald 2009). However, one collared female was caught and killed in a wire snare within the survey period which may violate demographic closure. Also, the population was not purely geographically closed as there was no hard physical boundary to restrict movement into and out of the trapping grid. But, because this is a very powerful assumption which can be rarely met by a free roaming population (White *et al.* 1982). Otis *et al.* (1978) and White *et al.* (1982) generalised that any losses or movement do not significantly violate this assumption.

CAPTURE selected the Null ($M_0$) model as the best approximating model followed by the Jackknife ($M_h$) model. The $M_0$ model assumes constant capture for all individuals (Otis et al. 1978). Burnham and Overton (1978) and Chao and Huggins (2005) stated that models assuming equal capture probability are likely to underestimate abundance. Because capture heterogeneity is expected due to sex, age, social status, individual preferences and territoriality (Karanth 1995; Harmsen *et al*. 2010), Karanth and Nichols (1998) recommended the use of $M_h$ which considers heterogeneity of captures. Jackson *et al.* (2005) also criticised the $M_0$ as too simplistic for assuming constant capture in a free roaming animal population. Tobler and Powell (2013) posited that $M_0$ underestimates abundances but the $M_h$ also has poor precision in small capture probability ($p < 0.1$) conditions even given large samples (N=50). Adequate sample sizes of individuals and recaptures greatly influence reliability of capture-recapture models (White *et al*. 1982). Therefore, in my study, the 22 usable images captured for only 10 individuals with only four recaptures were too low to give reliable estimates. Also, my capture probability of $p<0.1$ (White *et al*. 1982; Tobler and Powell 2013) was insufficient for reliability. Many other studies (O'Brien *et al*. 2003; Maffei *et al.* 2004, 2005; Silver *et al*. 2004; Miller 2005, 2006; Miller and Miller 2005; Soisalo and Cavalcanti 2006) all reported capture probabilities less than the recommended 0.1. Pooling the sampling occasions in a capture matrix has improved results (Harmsen 2006; Foster 2008) but it did not influence my results. From the above explanations, the abundance estimates of 9 ± 3.35 (range: 7 – 23) may be an underestimate of the leopards at Debshan, however the effective trapping area in unknown. Other studies which had $M_0$ as the best approximating model include (Karanth 1995; Chapman and Balme 2010; Tobler and Powell 2013) even though Karanth (1995) selected the second model $M_h$ after considering the heterogeneity of tigers (*Panthera tigris*). For my study, however, other factors like a small capture probability (White *et al.* 1982) and small sample size (Harmsen *et al*. 2012) also render $M_h$ as unsuitable.

The program DENSITY 5.0 executed both conventional capture-recapture as well as Spatially-Explicit Capture-Recapture (SECR). Conventional capture-recapture also selected $M_0$ as the best approximating model. However, the estimated abundances were slightly higher than for those resulting from CAPTURE with a small overlap in the ranges. $M_0$ had an estimated abundance of 18 ± 6.7 (range: 10.3 – 48.2) leopards while the $M_h$ had a slightly smaller average (16.6), a smaller margin of error (5.5) and a tighter range limit (11.6 – 37.4) indicating its vigour.

SECR in DENSITY incorporated different buffer widths into the analyses which represent the Effective Trapping Area (ETA) as not all the animals captured by the cameras possibly live within the trapping grid as defined by the Minimum Convex Polygon (MCP) demarcated by the perimeter of the camera grid (Otis *et al.* 1978, Balme *et al.* 2009a). The top four models with the ΔAICc < 2 (Burnham and Anderson 2002) included unpooled sampling occasions without road and gender covariates. The HMMDM with pooled sampling occasions was also selected as the third best model. These top models also had Conditional Maximum Likelihood (CML) over Full Maximum Likelihood (FML). CME simplifies the maximisation problem by treating some of the parameters as known and though it produces consistent estimates (Palmer 2004); the estimates are generally considered less efficient.

Density estimates decreased with an increase in the buffer width used. Gender and road covariates were not considered in the analyses probably due to the small sample size of captures as including the covariates further fragments the sample and weakens the analyses. However, because recommendations by (Gray and Prum 2012; Salom-Peréz *et al*. 2007) of how females avoid human-made trails like roads were taken into consideration in the planning of this survey, seven roads; six rivers and game trails were used as trapping sites in this study. Gender covariates likely became unreliable because only a small number (one female and two males) could be classified with certainty due to the difficulties in telling the different sexes apart (Grant 2008). Gray and Prum (2012) advised that the use of SECR on smaller and isolated areas should be locally tested as they may not strongly conform to the underlying assumptions of closure as the immediate buffers are highly likely to be patchy (Dillon 2005).

The HMMDM buffer width resulted in the highest leopard density estimate of 6.9 leopards/100km$^2$. The HMMDM has been highly criticised for overestimating densities through the underestimation of the home range radii (Soisalo and Cavalcaanti 2006; Dillon and Kelly 2008; Tobler and Powell 2013). The MMDMOSA has been considered as the most convenient buffer width as it uses the average home ranges of individual animals from the area of study (Dillon and Kelly 2008). The number of collared individuals whose data is used to calculate the MMDMOSA value is also vital as it increases accuracy e.g. the MMDMOSA used by Balme *et al*. (2009) was efficient due to the large sample size (n = 12) of collared leopards used to create the MMDMOSA value. In my study, only two collared leopards' data were used which may not truly reflect the average home range for leopards in the area. The MMDM, which gave the same density estimate as the MMDMOSA for Dillon and Kelly (2008), gave a density estimate of 3.9 leopards/100km$^2$ in my study.

Because this is an initial study for this area, a cautionary estimate has to be used. Therefore, the MMDMOSA leopard density estimates of 2.0 leopards/100km$^2$ will be considered as the likely reflection of the population. This is also chosen because a number of other field studies (Soisalo and Cavalcanti 2006; Dillon and Kelly 2008; Balme et al. 2009) have chosen it as the most reliable. In an unknown situation, it is always advisable to use the lower limit as it has less detrimental consequences on the population. Also, the MMDMOSA is the only of the three buffer widths which is derived from a real and local environment (Dillon 2005; Gray and Prum 2012).

**CONCLUSION**

A number of leopard density estimates resulted from this study giving a very wide range of population abundance estimates (9 – 62 individual leopards). From both the methodologies employed (spoor and camera-trapping), crucial population parameters like age and sex composition could not be deduced due to the limited survey duration and difficulty in identifying the different sexes from either spoor or camera images. Tobler and Powell (2013) advised that the best way to improve density estimates if capture probabilities are low are to either add more cameras or extend the survey duration or to use bait to increase the chance of capturing more individuals (Trolle 2003; Michalski *et al*. 2007; Norris *et al*. 2008). The home range estimation has been discovered to be the main source of imprecision for the $M_h$, MMDM and SECR models, thus using data from telemetry becomes an invaluable solution. Great care is needed when extrapolating densities from core areas to the whole complex (Gray et al. 2012) as potentially population limiting edge effects (Balme *et al*. 2010) may increase closer to the perimeter of the ranch e.g. human induced mortality, habitat destruction and prey depletion (Balme *et al*. 2007). Additional camera trapping in the neighbouring communities will be necessary to better understand the value of the landscape for leopard conservation (Gray *et al.* 2012) and the effective size of the protected areas. Harmsen *et al*. (2010) recommended that studies present capture frequencies of all sampled individuals so that policy makers can assess the reliability of the abundance estimates. Though many studies acknowledge the male bias in captures (Karanth 1995; Wallace *et al*. 2003; Maffei *et al*. 2004; Silver *et al*. 2004; Miller and Miller 2005; Miller 2006; Soisalo and Cavalcanti 2006; Harmsen *et al.* 2009), for leopards a challenge in differentiating males and females from camera images becomes a limiting factor. Harmsen *et al*. (2010) argued that disentangling the different sources of heterogeneity and their effect upon final estimates is extremely difficult since they stem from spatial aspects of sampling (closure), sampling (camera placement) and behaviour (natural differences). A study by Barea-Azcón *et al*. (2007) comparing applicability of four methods (sign surveys, scent stations lines, camera trapping with a live bait and box-traps with a live bait) to test their relative efficiencies revealed that only a combination of several methods can reveal the true representation of a carnivore community in a location or region. Therefore, future research in the area will focus on carrying out thorough spoor, radio telemetry and camera-trapping surveys so as to create a calibration index specific for Debshan ranch, and which can be used in future repeatedly and cheaply to assess and monitor the population trends.

# CHAPTER 4

# COMMUNITY ATTITUDES TOWARDS LEOPARDS AND OTHER CARNIVORES AROUND DEBSHAN RANCH, ZIMBABWE

## INTRODUCTION

Our generation is witnessing the greatest ever increase in the human population and at the same time, a major decrease in biodiversity (Chardonnet *et al.* 2010). As the human population continues to increase, it expands further and further into previously intact natural habitats thereby increasing the potential for human-wildlife conflict (HWC) (Mills 1991; Woodroffe 2000; Treves and Karanth 2003). HWC occurs when the needs and behaviour of wildlife impact negatively on the goals of humans or when the goals of humans negatively impact the needs of wildlife (IUCN 2005).

HWC can take various forms (Gandiwa et al. 2013), including carnivores attacking and killing humans and /or their livestock or, wildlife species raiding crops, competition between humans and wildlife for game and/or other natural resources, and disease exchange between livestock and wildlife (Thirgood *et al.* 2005, Madden 2008). This conflict often leads to the persecution of the wildlife by humans and Woodroffe and Ginsberg (1998) ranked persecution by humans as the greatest cause of mortality for many large carnivores both inside and outside protected areas worldwide.

Chardonnet *et al.* (2010) blame much of the HWC which we observe today on 20$^{th}$ century wildlife management in Africa, where wildlife and people and livestock were kept separately – known as the protectionist or fortress approach (Oates 1999; Terborgh 1999). National parks were set aside and people and their livestock excluded (Oates 1999, Terborgh 1999, Hutton et al. 2005). However, wildlife continued to be extensively hunted outside protected areas on the pretext that wildlife outside of protected areas impeded human development (Hutton *et al*. 2005). Significantly, large (> 5kg) carnivores were all but exterminated in most parts of Africa (outside of protected areas) because they prey on livestock (Chardonnet 2002; Bauer and van der Merwe 2004; Woodroffe et al. 2005). As such, large carnivore populations have and continue to decline in Africa because few parks can support viable large carnivore populations (Frank *et al.* 2006, Chardonnet *et al.* 2010).

The protectionist approach, which advocated for protected areas with the use of fences and fines, exclusion of livestock and people, non consumptive use and retention of "pristine environments" (Oates 1999, Terborgh 1999, Hutton *et al*. 2005) is fast becoming unpopular among governments (Fletcher 2010) and conservationists, and community-based wildlife management is believed to be more appropriate (Bond et al. 2005; Gandiwa et al. 2013; Zimmermann and Walpole 2005). Thus, strategies have been developed to foster coexistence of humans with large carnivores and other wildlife. For example, the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) in Zimbabwe (Martin 1986), Community-Based Natural Resource Management (CBNRM) programmes in Botswana (Rihoy and Maguranyanga 2010), Zambia (Lubilo and Child 2010), and Mozambique (Monjane 2010). Conservancies (a collection of multiple properties without internal fences for the protection of natural resources at a larger scale (Bond et al. 2005) have also been formed in many areas that seek to devolve rights over natural resources to local communities (NACSO 2009; Murombedzi 2010, Gandiwa *et al.* 2013). However, the movement of livestock and wildlife across protected area boundaries increases the likelihood of HWC (Chardonnet *et al.* 2010) and novel strategies to mitigate such conflict need to be developed to promote coexistence between humans and wildlife.

In the absence of intense persecution, leopards (*Panthera pardus*) are able to adapt to altered natural habitat together with settled environments (Turnbull-Kemp 1967; Guggisberg 1975, Tello 1986a; Martin and de Meulenaer 1988). For example, Hamilton (1986b) reported leopard occurrence in western Kenya in extensively cultivated districts with more than 150 people/km$^2$, large livestock populations, little natural habitat and prey and where 20 years ago they had been considered extirpated. In addition, a recent study by Odden *et al*. (2014) in the Indian states of Maharashtra and Himachal Pradesh showed that GPS collared leopards visited houses regularly to prey on domestic livestock and pets, especially at night, with 20 % of all locations less than 25 m from houses. However, such close interaction between humans and leopards is highly volatile and can threaten both parties. Therefore, understanding the nature of the interactions between humans and leopards, and how humans view and respond to such interactions is of vital importance for conflict mitigation (Odden et al. 2014).

In addition, understanding and addressing local people's attitudes and behaviours toward HWC is imperative to the successful conservation of many wildlife species (Wang *et al*. 2006; Palmeira *et al*. 2008). Conservationists have increasingly realised that effective wildlife management policy must be based on an understanding of public attitudes toward wildlife and conservation programs (Kellert and Berry 1987; Naughton-Treves *et al*. 2003). Understanding the drivers of human-carnivore conflict is a fundamental prerequisite for developing strategies to achieve conservation goals. People are undeniably a part of all HWC problems, rendering social research methods essential for finding solutions (Kansky and Knight 2014). Significantly, livestock predation has been identified as a very important factor driving attitudes (Mishra 1997; Sillero-Zubiri and Laurenson 2001; Ogada *et al.* 2003; Dickman 2008), however some studies revealed that perceptions of predators are not always linked with predation history (Conforti and de Azevedo 2003; Marker *et al.* 2003c). In addition to past encounters with animals, attitudes towards wildlife have also been shown to be influenced by belief systems (Spash 1997; Zimmermann *et al.* 2005). Consequently, these attitudes and subjective norms affect people's behavioural responses (Kotchen and Reiling 2000).

In addition to attitudes, assessing people's level of tolerance of livestock predation is another valuable technique used to determine how people perceive carnivores and to predict their behaviour towards them (Romañach *et al.* 2007). Liu *et al.* (2011) showed that, as a general rule, the more favourable the attitude and subjective norm, the stronger should be the person's intention to perform the behaviour (Kotchen and Reiling 2000). Attitudes are therefore considered important predictors of behaviour or intentions, and can be considered explanatory factors for individual behaviour (Ajzen 1991; Ajzen and Fishbein 1980).

In Zimbabwe, relatively few studies have been conducted on the attitudes of humans towards carnivores (Gandiwa et al. 2013; Butler 2000; Williams 2012). Thus, my study site around Debshan ranch, Shangani in central Zimbabwe, becomes an important addition. Besides being in a previously unstudied area, it also adds a very important dimension to human-carnivore conflict. Most importantly because it includes a mosaic of land-tenure, including recently resettled areas. The Fast-Track Land Reform Programme (FTLRP) initiated in Zimbabwe in the year 2000 resulted in the resettlement of many subsistence farmers onto private land (Kwashirai 2009b) which previously supported significant populations of carnivores (Stuart and Wilson 1988). The FTLRP is therefore likely to have had a huge impact on the levels of HWC in this part of Zimbabwe. However, the attitudes and tolerance of resettlement farmers in Zimbabwe towards wildlife has not yet been comprehensively assessed (Williams 2012).

The goals of this study were therefore 1) to begin to understand the attitudes of the communities surrounding Debshan ranch towards leopards and other carnivores in an effort to plan for, reduce and ultimately prevent human-carnivore conflict; 2) to obtain baseline data on the attitudes for the area and; 3) to begin to understand local reactions to livestock losses caused by carnivores.

## OBJECTIVES

The objective of this chapter was to assess the attitudes of the communities surrounding Debshan ranch towards leopards and other carnivores. I also wanted to gain an understanding of the levels of human-carnivore conflict within and across the different administrative provinces and land use types which surround Debshan ranch.

## METHODS

### Study area

The study was conducted in the areas surrounding Debshan ranch (Fig 4.1). These areas included three administrative provinces; Matabeleland North, Matabeleland South and Midlands. Debshan ranch falls within Matabeleland South but is bordered to the east by the Midlands province and by Matabeleland North to the north. The provinces derive their names from the ethnic group (or tribe) which dominates the area (http://www.statoids.com/uzw.html) and their geographical position in relation to one another. Midlands, however, derives its name from the fact that it is in the middle of the country and thus includes mixture of all the tribes.

Matabeleland South is predominantly a cattle (*Bos indicus*) farming province because it falls within Zimbabwe's agro-ecological region V which receives low (< 460 mm/year) and erratic rainfall and also experiences high temperatures of above 30˚C during the hot-dry season

(September – November) (Trapnell and Clothier 1957; Vincent and Thomas 1961). This renders the province unsuitable for crop production except for drought resistance crops like sorghum (*Sorghum bicolor*) and finger millet (*Eleusine coracana*). Cattle and wildlife ranching are the only viable agricultural enterprises. However, many people still practice crop cultivation, mainly for subsistence, but also commercially using intensive irrigation in places. Matabeleland North falls within agro-ecological region IV and receives a slightly higher and more reliable rainfall than Matabeleland South. It receives 400 – 600 mm of rainfall per year (Trapnell and Clothier 1957; Vincent and Thomas 1960). This province has high wildlife populations, hence wildlife ranching is a popular venture. National parks, safari areas and community managed wildlife (CAMPFIRE) are also common (Child 1995). However, cropping and livestock pastoralism is also widespread. Midlands falls within agro-ecological region III, with rainfall between 600 – 800 mm/year. Midlands has highly mixed and varied land uses but is mostly industry oriented. Manufacturing industries, mining and production companies are mostly found in this province.

For the purposes of this study, only properties within a maximum radius of 10 km from the Debshan ranch boundary were surveyed. This particular distance was chosen to minimise the potential interference of other large, neighbouring protected areas on community attitudes (Whittington-Jones 2011). In addition, previous research has found that landowners closer to protected areas (or areas that are perceived to act as refugia for predators, such as Debshan ranch) are generally more likely to come into conflict with carnivores (Bond *et al.* 2004; Lagendijk and Gusset 2008; Balme *et al.* 2009; Carter *et al.* 2013, 2014). The properties within this area mainly fall into one of the two categories; private property or resettled land. The resettled land can be divided into three categories; A1 villages, A2 plots, and A2 single properties. The main difference between the private properties and the resettled land is that the private properties are those dating beyond the year 2000, while the resettled land only came into existence after the FTLRP which began in the year 2000.

Under the FTLRP, former commercial farms were divided into small-holder production units called A1 schemes, and commercial farms called A2 schemes. In the A1 scheme, beneficiary households were allocated 0.5 – 2.0 hectares for residential buildings and arable land for cropping in a village of 20 – 25 households (Pazvakavambwa and Hungwe 2009). The villages have shared woodlots, water points and grazing land. The A1 scheme was designed to target landless and poor households from overcrowded areas and also any farm workers that were retrenched (Scoones *et al*. 2011).

The A2 plots were introduced in the late 1990s and the beneficiaries were allocated self contained farm units for cropping, residential buildings, grazing and woodlot use (Pazvakavambwa and Hungwe 2009). The size of the A2 plots varied depending on the agro-ecological region, with recipients in the drier regions receiving larger units than the more mesic areas (Table 4.1). Besides being formed under the FTLRP, the A2 plots were recognised as the new small to medium scale commercial scheme rather than a settlement. To create the A2 plots, former commercial farms were subdivided into three to seven units (Scoones *et al.* 2010; Hanlon *et al.* 2012).

**Table 4.1**: The official sizes of the A2 plots for each of the agro-ecological regions of Zimbabwe (taken from Pazvakavambwa and Hungwe 2009).

| Agro ecological region | Plot size (ha) |
|---|---|
| **II** | 50 |
| **III** | 150 |
| **IV & V** | 300 |

The third category under the resettlement models is the A2 single farms. Although similar to the A2 plots, the A2 single farms are much larger than the A2 plots because either a former commercial farm was allocated to a new household as a whole or it was divided into two units. The average size of A2 single properties was 555 ± 171.6 ha (range: 400 – 800), much larger than the largest official size of the A2 plots in agro-ecological regions IV and V. Private farms included small commercial farms up to 1000 ha in size and large private farms (>1000 ha). However, due to the resettlement programme, most farmers were not aware of their current farm sizes as some settlers have expanded beyond the gazetted plot sizes (Scoones *et al.* 2010*;* Bell 2011; Sithole 2011).

### Data collection

#### Survey instrument

A structured questionnaire (Appendix VII) was used to collect the data on the attitudes of the communities surrounding Debshan ranch towards leopards and other carnivores. Questionnaires are important because they allow people to express their feelings and opinons freely and accurately (Dwyer and Scampion 1995). The questionnaire structure was adapted from Whittington-Jones (2011). It is acknowledged that a community has people with different backgrounds; cultures, levels of education, beliefs etc. Thus, the questionnaire was structured in such a way to try and accomodate all potential respondents. The questionnaire was subdivided into nine sections and had a total of 94 questions (Table 4.2). Section A sought general information; date and time of survey, name of interviewer, interview location (general), the position of the respondent (interviewee) and GPS location. The GPS location was very important for the spatial representation of the properties to understand their distribution. Section B requested detailed property characteristics including the type of land tenure ( i.e. private or resettled). Property size was also an important variable especially in the understanding of whether the property could independently sustain a viable leopard population or not.

The livestock predation and protection section (Section C) was used to elicit information pertaining to the number of livestock lost to all causes including predation, disease, accidents, theft, snares, and others categorized into two periods; last 12 months (August 2012 – August 2013) and "over a year ago" (since arrival to August 2012). Information on livestock losses provided a platform to compare and rank the severity of problems within and across the different provinces. Livestock management techniques employed as well as action taken in cases of livestock loss were also sought to understand how the respondents reacted to losses. Because predation was likely to be one of the main problems faced, a predator identification section was also included for gauging the respondents' understanding of the predators in question. Posters of the different carnivores known to occur in the area; lion (*Panthera leo*), leopard, cheetah (*Acinonyx jubatus*), spotted hyena (*Crocuta crocuta*), brown hyena (*Hyaena brunnea*), black-backed jackal (*Canis mesomelas*), wild dog (*Lycaon pictus*) were shown individually to respondents and they were asked to identify each species. An aardwolf (*Proteles cristatus*), although an insectivorous carnivore (Henschel and Skinner 1990), was also included in this section because of its physical resemblance to a hyena. Previous studies have shown that respondents are prone to misidentifying predators, thus all respondents in my study were shown these identification pages to assess their knowledge of the predators (Dickman *et al.* 2011).

The main focus of this study was to establish the attitudes of the communities surrounding Debshan ranch towards leopards and other carnivores. Eleven questions were asked which were used to establish an attitude index reflecting the general feelings of the respondents towards predators (Section E). Questions concerning the personal information of the respondents (Section G) were asked towards the end of the interview when the respondents had become more comfortable with the interviewer (Schüttler *et al*. 2011; Delibes-Mateos *et al*. 2013) and also to reduce the amount of bias which might be brought in by the respondent knowing they will be quoted afterwards. This is known as social desirability (Maccoby and Maccoby 1954) and may lead to respondents only saying what they believe the interviewer would like to hear.

In addition, questions concerning snaring (Section H) and elephants (Section I) were also asked in order to inform ranch management. These sections were not directly related to my work on leopards, but were included to assist ranch management as a separate study. None of these data are presented in the current chapter.

**Table 4.2:** Summary table of the structure of the questionnaire, showing the breakdown of the sections and the number of questions per section for the questionnaire survey conducted in the communities surrounding Debshan ranch from 14 August to 4 December 2013.

| **Section** | **Title** | **Number of questions** |
|---|---|---:|
| A | General information | 7 |
| B | Property, livestock/game information | 17 |
| C | Livestock predation and protection | 19 |
| D | Predator identification | 8 |
| E | Community attitudes | 24 |
| F | General knowledge of species | 5 |
| G | Personal information | 7 |
| H | Snaring | 2 |
| I | Elephant survey | 5 |
| Total | | 94 |

**Survey design**

The questionnaire survey was conducted across the three provinces from 14 August to 4 December 2013. Each province was surveyed separately before moving onto the next one. Matabeleland South was surveyed first because it is the same province Debshan ranch falls within. Permission to conduct the survey was sought from the local Councillors who then directed me to consult the local Headman before I began the survey. Initially, the Debshan ranch security officer (Douglas Mpofu) would accompany me to the local authorities to introduce me to the community leaders.

In Matabeleland North and South, all properties encountered within the 10km radius were surveyed. In Midlands, the survey area was a maximum of 10km from the boundary of Debshan ranch. However, the majority of respondents interviewed were those that fell within 5km of the boundary of Debshan ranch. Due to the large number of small holder properties (45, 50 and 55 ha each) in the Midlands, stratified random sampling (Sokal and Rohlf 1995) had to be employed to select properties for the survey. The properties were first subdivided under the individual Headmen (four in total) and then within each Headman. All the property names were acquired, printed onto tiny pieces of paper then randomly picked from a hat. Ten percent of the total population under each headman was selected for interview to get a sample size that was comparable with the other provinces (Matabeleland North and South; 50 and 47 respectively). If the property selected was beyond 10km, it was discarded and another one chosen. The shortlisted properties were then visited and respondents interviewed. Stratification was done to make the survey easier to administer operationally and also for every local authority to be fairly represented in the study design.

Individual interviews were conducted for single property respondents' whilst in villages, group meeting were conducted. Group meetings were chosen for villages because within each village, the individual dwellers share resources e.g. grazing land, water and communal woodlots which likely created similarities in experiences with wildlife and potentially attitudes towards predators (Romañach *et al.* 2011). Property owners, managers, herders, farmers, relatives were interviewed on all the properties (Dickman 2008).

**Attitude and knowledge indices**

Attitude is defined as "a psychological tendency that is expressed by evaluating a particular entity with some degree of favour or disfavour" (Eagly and Chaiken 1993). An attitude index was created in order to measure the overall attitude of each respondent towards predators (Walpole & Goodwin 2001). A knowledge index was also created to gauge how much knowledge each respondent had pertaining to leopards and other carnivores (Marker *et al.* 2003; Zimmerman *et al.* 2005). The scores for the indices were calculated by assigning a +1, 0, or -1 to the particular questions that were asked. Generally, a +1 was allocated to positive responses, 0 to neutral and -1 to negative responses (Foddy 1993; Walpole & Goodwin 2001, Parker *et al.* 2014). The sum of the scores for each question were used to generate each respondent's overall score. This was done for both the attitude and knowledge indices. The higher the index score, the more positive or more knowledgeable the individual was towards predators.

A total of eleven questions were used to generate the attitude index hence there was a possible minimum and maximum score of -11 and +11, respectively. For the knowledge index, 13 questions were used, including six which were for the identification of carnivores. A Cronbach α test was used to test for internal consistency within the attitude and knowledge indices (Cronbach 1951; Gliem and Gliem 2003). Acceptable values of α lie between 0.6 and 0.7, lower values reflect departure from internal consistency or may be because a low number of questions were used, while higher values reflect redundancy in the questions used (Zaiontz 2014). The α value was calculated using the formula below (Cronbach 1951):

$$\alpha = \left(\frac{k}{k-1}\right)(1 - \sum_{i=1}^{k} \sigma_i^2 / \sigma_s^2)$$

Where, k indicates the number of items on the scale, $\sigma_i^2$ is the variance of an item within the Likert scale, and $\sigma_s^2$ is the variance within the scale (Cronbach 1951).

## Data analysis

### Descriptive analysis

Descriptive statistics were used where statistical tests were inappropriate. Data collected from the village group meetings were only included in the overall summary but excluded from all other analyses because of multiple responses for any one question. Data were presented either as actual numbers or as percentages. Means, standard deviations and ranges were used to explain the results. A property distribution map for all the properties surveyed across the three provinces was constructed using ARCGIS 10.2 (ESRI, Redlands, California).

### Statistical analysis

The analyses were carried out using R 3.1.1 Software (R Development Core Team 2014). A total of 11 predictor variables were used to assess their relationship with the attitude index.

Six continuous variables used included; knowledge index, distance from Debshan ranch boundary (km), length of tenure in the area (years), number of cattle on the property, age of respondent and the number of cattle killed by predators (per year). Categorical variables included; province (three levels), gender (two levels), highest level of education attained (four levels), type of property (four levels) and leopard movement (Yes/No). Two respondents were removed from the analyses because they did not answer all questions.

Normality was tested using the Shapiro-Wilk's test and generalised variance inflation factors were calculated (Freckleton 2011). The variance inflation factor (VIF) quantifies the severity of multi-colinearity by providing an index measuring how much the variance of an estimated regression coefficient is increased because of colinearity (Kutner *et al.* 2004; Hair *et al.* 2006). A VIF > 5 reflects multi-colinearity (Freckleton 2011) thus any predictor variables with a VIF > 5 were removed from the analyses. Stepwise generalised variance inflation factor tests were carried out until all predictor variables that had a VIF > 5 were eliminated. Model building (using Akaike's Information Criterion – AIC) was then conducted using the MuMiN and car packages and the *dredge* function to select the models that best predicted the attitude index of respondents. Delta AICc (ΔAICc) and Akaike's weights ($_{wi}$) were used to select the best approximating models because AIC values in their raw form are inappropriate (Burnham and Anderson 2002).The model with the lowest ΔAICc is considered the best but all models with ΔAICc < 2 may also be appropriate (Burnham and Anderson 2002). Thus, for the purposes of this study, all predictor variables contained in the top models with ΔAICc < 2 were used in a cross validation generalised linear model to assess their relationship with the attitude index (Burnham and Anderson 2002; Archibald *et al.* 2005; Symonds and Moussalli 2011).

# RESULTS

## Geographical distribution of properties surveyed

The geographic distribution of the three provinces and the properties surveyed in relation to Debshan ranch is portrayed in Fig 4.1. The total land area surveyed was 1528 km$^2$ which is split into Matebeland South (394 km$^2$), Matebeleland North (587 km$^2$) and Midlands (547 km$^2$) though practically, the entire area was not surveyed. A2 plots were evenly distributed across all provinces while villages were only found in the Matebeleland provinces.

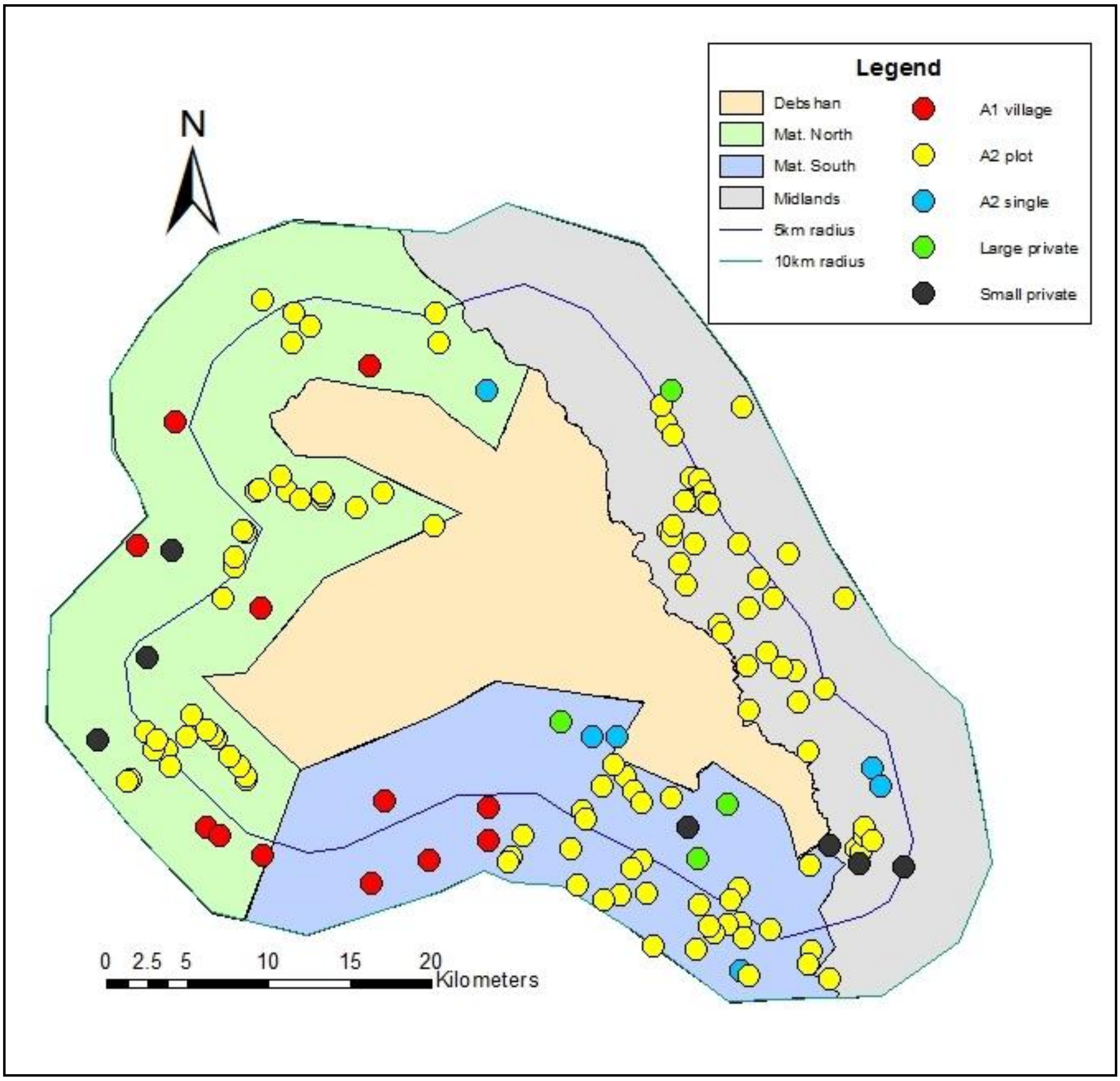


**Fig 4.1:** A map showing Debshan ranch (orange) and the surrounding provinces Matabeleland North (Mat. North), Matabeleland South (Mat. South) and Midlands. All the properties that were surveyed are also highlighted i.e. village, A2 plot, A2 single, small private and large private.

**General results**

A total of 140 independent questionnaire interviews were conducted; 43 in Midlands, 47 in Matabeleland South and 50 in Matabeleland North provinces (Table 4.1). Of these, 128 were single holder properties and 12 were villages. The A2 plot was the most common property in all provinces and there were no villages in Midlands (Table 4.1).

**Table 4.1:** Summary data of the number of questionnaire interviews conducted per province and per property type for the questionnaire survey conducted in the communities surrounding Debshan ranch from 14 August to 4 December 2013.

| | NUMBER OF RESPONDENTS INTERVIEWED | | | | | |
|---|---|---|---|---|---|---|
| **PROVINCE** | **A2 Plot** | **A2 Single** | **A1 Village** | **Private Small Farm** | **Private Large Farm** | **Total** |
| Matabeleland South | 34 | 3 | 5 | 2 | 3 | 47 |
| Matabeleland North | 39 | 1 | 7 | 3 | 0 | 50 |
| Midlands | 38 | 2 | 0 | 2 | 1 | 43 |
| **Total** | **111** | **6** | **12** | **7** | **4** | **140** |

**Demography of respondents**

Eighty three percent of single holder property respondents were males (n = 106) and 17 % were females (n = 22). The majority of females interviewed (n = 15) were landowners from the Midlands province. The majority of respondents (67 %) were Ndebele speaking followed by the Shona speaking group (Table 4.2). The English speaking respondents were from both the small and large private ranches and had all obtained a tertiary education. Primary and secondary levels of education were the most common at 48 % and 42 %, respectively with only 3 % of all respondents not having any formal education. Forty-five percent of the properties were under the curatorship of a manager while the rest had the landowner or a relative present at all times.

The position of people interviewed fell into two categories; landowners and managers. Managers (n = 60) included all the respondents that were employed to look after the property or livestock and these included farm managers, foremen, herders and their partners. Landowners, on the other hand, encompassed the property owners and anyone who was related to the landowner.

**Table 4.2:** Summary of language and education of the respondents interviewed during the questionnaire survey conducted around Debshan ranch from 14 August to 4 December 2013.

| LANGUAGE | % | EDUCATION | % |
|---|---|---|---|
| Ndebele | 67 | Primary | 48 |
| Shona | 20 | Secondary | 42 |
| Other | 6 | Tertiary | 7 |
| English | 5 | None | 3 |

Respondents spanned a very wide age range with a mean of 44 ± 16.7 years (range: 16 - 95). A total of 30 respondents (23 %) were under the age of 30 years, 51 were aged between 30 and 50 years (40 %) and 47 (37 %) were over 50 years of age (Table 4.3). The majority of respondents (95 %) came to live and work around Debshan ranch as result of the government sanctioned land resettlement programme in 2000 which is why most of them had only been present in the area for 13 years or less (Table 4.3). The 5 % which has been in the area for over 13 years were either owners of or workers on the private properties (Table 4.3).

**Table 4.3:** Summary of the ages of respondents and the length of time they have been living around Debshan ranch.

| Age (years) | Number | % | Time in the study area (years) | Number | % |
|---|---|---|---|---|---|
| <30 | 30 | 23% | >13 | 7 | 5% |
| 30-50 | 51 | 40% | 9 – 13 | 42 | 33% |
| >50 | 47 | 37% | 3 – 9 | 35 | 27% |
| | | | <3 | 44 | 34% |

**Property attributes**

Property size was highly variable both within and across provinces and 32 % (n = 41) of respondents did not know the size of their properties. Matabeleland North had 31 respondents who could not give the size of their properties. In Matabeleland South, 26 respondents knew their plot sizes. All the property sizes in Midlands were acquired, either from the owner or simply because they all fell into one of the three sizes (45, 50 and 55 hectares) according to which headman they came under.

For the A2 single properties, four of the six surveyed had an average size of 555 ± 171.6 ha (range: 400 – 800). The small private properties (n = 3) had an average size of 767± 104.1 ha (range: 650 – 850). For the large private properties, the average property size was 4975 ± 5073.1 ha (range: 1400 – 12500). All the villages in Matabeleland South shared a 13000 ha former commercial ranch equally amongst themselves resulting in 2600 ha of land available per village. Five of the seven villages in Matabeleland North had an average size of 1885 ± 392 ha (range: 1500 – 2500). A2 plot sizes were highly variable in size within and across the three provinces. The plots in Midlands only had three possible sizes averaging 47.7 ± 3.3 ha. Matabeleland South had an average plot size of 137.7 ± 83.3 (range: 60 – 400) while Matabeleland North had an average of 225.1 ± 113.4 (range: 123 – 430) (only 10 respondents could give the plot size).

Fencing off of properties was relatively common in the Matabeleland North and South provinces with 42 % and 50 % respectively of properties fenced. However, only 21 % of respondents in Midlands had fences surrounding their land (Table 4.4). Of the 49 respondents that had fenced properties, all had cattle fences while only one respondent (large private rancher in Midlands) had a game fence.

**Leopard movement**

The spatial distribution of leopard presence is shown in Fig 4.2. The large private property in Midlands covers all the area from the Matabeleland North eastern boundary. The four villages in Matabeleland border with the Debshan boundary. About 50 % of respondents in Matabeleland South reported leopard movement on their properties, while an overwhelming 95 % confirmed leopard movement on their properties in Matabeleland North. Comparatively less leopard movement was reported in Midlands (35 % of respondents) and this movement was confined to a smaller section of the province. Only the properties immediately adjacent to the large private ranch reported leopard movement.

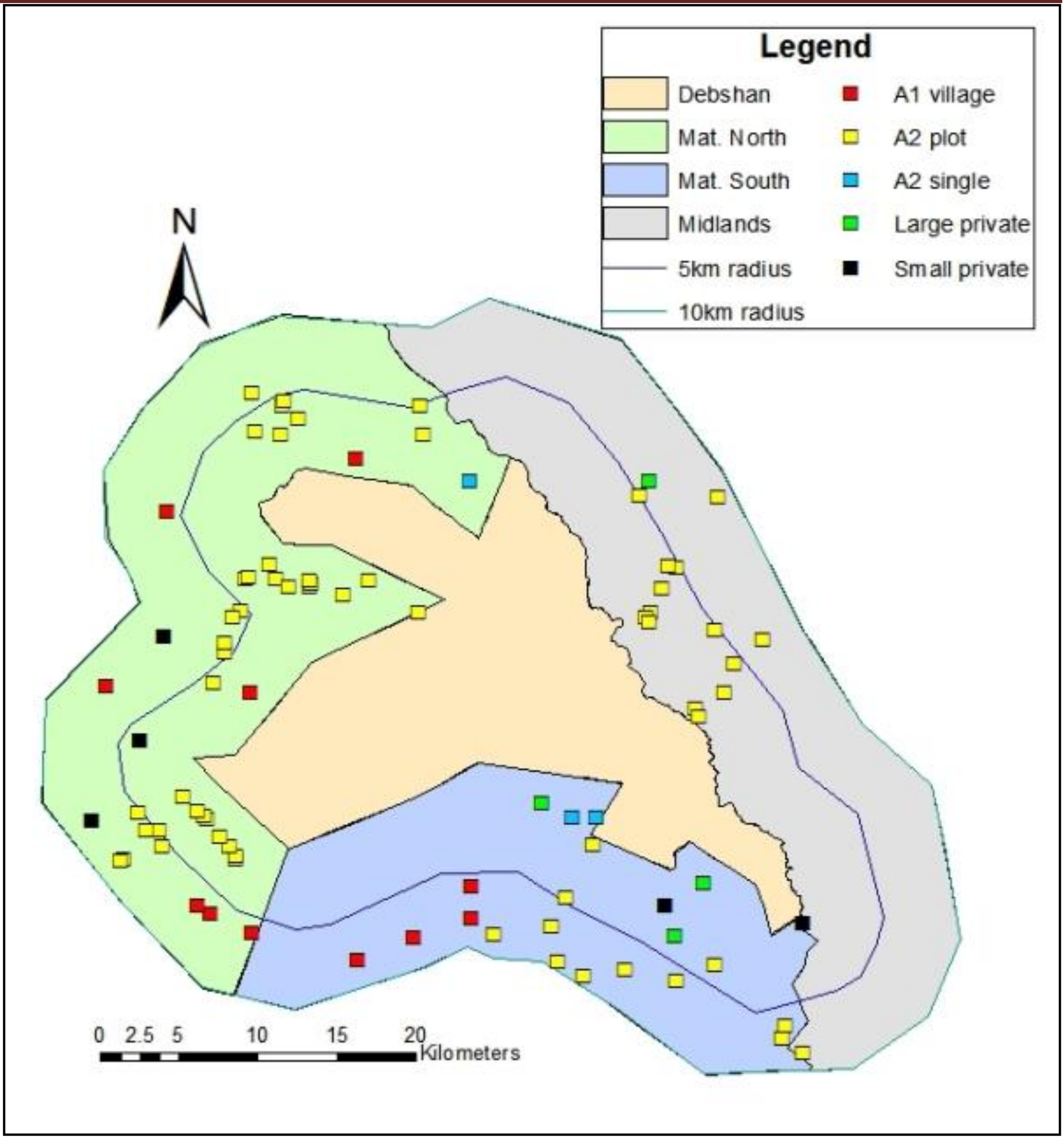


**Fig 4.2:** A map showing all the properties from which the respondents reported leopard movement in the communities surrounding Debshan ranch.

**Livestock numbers and losses**

Livestock kept by most of the respondents included; cattle, donkeys (*Equus asinus*), goats (*Capra hircus*), sheep (*Ovis aries*), pigs (*Sus scrofa*) and domestic chickens (*Gallus gallus domesticus*). Cats (*Felis catus*) and dogs (*Canis familiaris*) were also kept but mainly as pets or for security. There was a general decline in livestock losses from "over a year ago" to within the past year except for Matabeleland North (see Table 4.4). However, the time scales were not equal as "over a year ago" referred to the period from arrival in the area until August 2012. This ranged from one year to 13 years for resettled properties and could be up to 64 years for private property holders. Despite Matabeleland South traditionally being a cattle rearing province, total cattle numbers were highest in Matabeleland North, followed by Midlands (see Table 4.5). Donkeys were most common in Matabeleland North and Midlands, but Matabeleland South had substantially larger numbers of sheep, goats and poultry (Table 4.5).

A number of causes of livestock loss were reported by the respondents, the most prominent were disease, theft, predation, snaring and rail/road accidents (Table 4.5). Other causes of livestock losses included falling into open mine pits, attacks by domestic dogs and cats, drowning during dipping, fire, over-eating, straying, death while giving birth, poison, drought and unknown causes. The severity of each cause differed across provinces and also among different livestock species. Disease caused many deaths in cattle and poultry in Midlands, while in Matabeleland South disease affected sheep and goats the most (Table 4.5). Theft was a problem for owners of cattle, sheep and goats in Matabeleland North. Predation was perceived to be highest in Matabeleland North and Midlands especially for poultry, cattle, sheep and goats (Table 4.5). Respondents from Midlands never reported snaring as a problem but it was believed to have killed cattle in both Matabeleland South and North. Respondents from Matabeleland South and Midlands suffered cattle losses as a result of being hit by trains and vehicles probably due to their proximity to the Bulawayo-Harare road (Table 4.5).

Further investigation into the losses caused specifically by predators revealed that leopards killed mostly cattle across the three provinces, with the highest loss of 55 cattle in Matabeleland North and only 11 and six for Midlands and Matabeleland South respectively (Table 4.5). Leopards and hyenas also killed sheep and goats in Matabeleland North and Midlands. Black-backed jackals were believed to predate upon goats, sheep and poultry across all the provinces, with the greatest losses of sheep and goats experienced in Matabeleland North (Table 4.6). Matabeleland North and Midlands suffered poultry losses to other predators like the slender mongoose (*Galerella sanguinea*), Martial Eagles (*Polemaetus bellicosus*) and the chacma baboon (*Papio ursinus griseipes*) (Table 4.5).

Expressed as a percentage of the total losses incurred per province, cattle losses to predation were highest in Matabeleland North (40 %) and were substantially lower for Matabeleland South (6 %) and Midlands (8 %) (Table 4.5). Matabeleland North lost relatively higher percentages of sheep, goats and poultry to predators despite Midlands losing more in absolute numbers (Table 4.5).

**Table 4.4:** Summary of the number of respondents who reported that they had lost livestock within the past year (August 2012 – August 2013) and also more than a year ago (since arrival to August 2012) from the communities surrounding Debshan ranch, Zimbabwe.

| **Province** | **Lost livestock within the past year** | | **Lost livestock more than a year ago** | |
|---|---|---|---|---|
| | **Yes** | **No** | **Yes** | **No** |
| Matabeleland South | 27 | 15 | 36 | 6 |
| Matabeleland North | 39 | 4 | 38 | 5 |
| Midlands | 33 | 10 | 39 | 4 |
| **Total** | **99** | **29** | **113** | **15** |

Table 4.5: Detailed summary of livestock numbers owned, total livestock lost to all causes, and the number of livestock lost to predators summarised for the three provinces around Debshan ranch, Zimbabwe.

| | **Matabeleland South** | | | | **Matabeleland North** | | | | **Midlands** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cattle | Donkey | Sheep + goats | Poultry | Cattle | Donkey | Sheep + goats | Poultry | Cattle | Donkey | Sheep + goats | Poultry |
| **Total owned** | 2181 | 30 | 805 | 2213 | 3620 | 61 | 345 | 590 | 2379 | 63 | 249 | 845 |
| **Losses to** | | | | | | | | | | | | |
| Disease | 43 | 0 | 87 | 0 | 80 | 0 | 17 | 64 | 154 | 1 | 19 | 325 |
| Theft | 5 | 0 | 5 | 0 | 13 | 0 | 16 | 0 | 3 | 0 | 3 | 0 |
| Predators | 6 | 0 | 30 | 3 | 80 | 3 | 89 | 82 | 11 | 0 | 39 | 227 |
| Snares | 25 | 0 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rail/road accidents | 20 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 |
| Others | 4 | 0 | 5 | 0 | 13 | 0 | 6 | 0 | 6 | 2 | 4 | 50 |
| **Total losses** | 103 | 0 | 128 | 3 | 199 | 3 | 128 | 146 | 189 | 3 | 65 | 602 |
| **Losses to** | | | | | | | | | | | | |
| Hyena | 0 | 0 | 0 | 0 | 25 | 3 | 10 | 0 | 4 | 0 | 11 | 0 |
| Leopard | 6 | 0 | 0 | 0 | 55 | 0 | 21 | 0 | 11 | 0 | 4 | 0 |
| Jackal | 0 | 0 | 30 | 3 | 0 | 0 | 58 | 16 | 0 | 0 | 24 | 56 |
| Others | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 66 | 0 | 0 | 0 | 171 |
| **Total losses to predators** | 6 | 0 | 30 | 3 | 80 | 3 | 89 | 82 | 15 | 0 | 39 | 227 |

**Table 4.6**: Summary of the number of respondents from the communities surrounding Debshan ranch, Zimbabwe who employed one (or more) of five livestock management techniques to manage their livestock.

| **Province** | **Herding** | | | **Paddock** | **Night kraals** | | **Bell collars** | | **Day/night kraals** |
|---|---|---|---|---|---|---|---|---|---|
| | Yes | No | Seasonal | Yes | Yes | No | Yes | No | Yes |
| Matabeleland South | 19 | 19 | 1 | 1 | 37 | 3 | 38 | 2 | 4 |
| Matabeleland North | 13 | 19 | 6 | 5 | 40 | 3 | 38 | 5 | 7 |
| Midlands | 9 | 13 | 20 | 1 | 40 | 3 | 34 | 9 | 3 |
| **Total numbers** | 41 | 51 | 27 | 7 | 117 | 9 | 110 | 16 | 14 |
| **Percentage** | 33 | 40 | 21 | 6 | 93 | 7 | 87 | 13 | 11 |

**Livestock management techniques**

Most livestock management techniques were used in combination to reinforce one another (Table 4.6) and also because some were believed to have spatial or temporal limitations (e.g. herding is feasible during the day and also allows constant monitoring, but kraaling is believed to be best at night when mobility is restricted). The most common practice amongst respondents was the kraaling of livestock at night (93 %) followed by the use of bell collars (87 %) to scare away predators and also to inform the owner of the whereabouts of his herds (Table 4.6). Herding of livestock was done for a variety of reasons, but the main reason was to prevent cattle from eating crops (Table 4.6). Paddocking, mainly practised on private properties and was done by only 6 % of the respondents (Table 4.6). Both day and night kraals were used mainly for young stock and also by those doing supplementary feeding and were reported by 11 % of the respondents.

**Identification of predators responsible for killing livestock**

A number of ways were used to identify the predators believed to be responsible for killing livestock, the most common being carcass remains (Table 4.7). Twenty-six percent of respondents claimed that they identified which predator had killed their livestock through the state of the remaining carcass. The second most common form of identification was spoor identification and was used by 20 % of respondents (Table 4.7). Drag marks and cached carcasses were also identified and were attributed to leopards (n = 2 respondents). Suspicions and assumptions were used by respondents when no tangible evidence could be found hence the most commonly seen or heard predator was incriminated (e.g. if the territory was assumed to belong to a jackal or leopard then it was the suspected culprit).

**Table 4.7**: The percentage of respondents from the communities surrounding Debshan ranch, Zimbabwe who used a particular method(s) for identifying predators believed to be responsible for killing their livestock.

| Identification of the predator | % |
|---|---|
| Carcass remains | 26 |
| Spoor | 20 |
| Actual sighting | 18 |
| Suspicion | 18 |
| Call sounds at night | 6 |
| Assumption | 4 |
| Drag marks | 4 |
| Carcass put up a tree | 4 |

**Action taken by respondents after losing livestock**

The actions taken by respondents after losing livestock reflects both the availability of options as well as the level of faith the respondents have in a particular action. Losses to disease were reported to the local veterinary authority by eight respondents in Matabeleland South (Table 4.8). However, despite many losses to diseases experienced in Matabeleland North and Midlands (see Table 4.5); only two respondents from each province made reports to the veterinary authorities in those provinces. Matabeleland South respondents also made reports to the police or to the property owner (Table 4.8). Midlands respondents utilised a wide range of options, the most common being reports to the Rural District Council and the improvement of livestock management through the employment of better herders and the adoption of night kraaling (Table 4.6). However, one respondent from Midlands described how she killed a jackal’s puppies using hot water down the hole.

**Table 4.8:**The number of respondents who took a particular action when they had lost livestock (all losses included) as revealed by the questionnaire survey conducted in the communities surrounding Debshan ranch from 14 August to 4 December 2013.*RDC stands for Rural District Council.

| | Report to *RDC | Report to chief/head | Kill the predator | Report to police | Report to vet | Report to owner | Improve livestock management |
|---|---|---|---|---|---|---|---|
| Matabeleland South | 0 | 0 | 0 | 6 | 8 | 4 | 0 |
| Matabeleland North | 7 | 2 | 0 | 5 | 2 | 7 | 7 |
| Midlands | 4 | 1 | 1 | 2 | 2 | 1 | 4 |
| **Total** | **11** | **3** | **1** | **13** | **12** | **12** | **11** |

**General knowledge about predators**

Only one respondent could not identify a lion, whereas 65 % of respondents could correctly identify a leopard and 52 % could identify a cheetah (Table 4.9). Most of the other respondents confused the latter two animals and about an equal proportion (nine and 10) admitted to not knowing which animals they were. Leopards had a cultural importance to 49 % of the respondents. A total of 68 respondents believed leopards preferred livestock to wild prey and attributed this to the fact that the leopard will expend more effort in hunting down wild prey than 'naive' livestock. Only 11 respondents believed that lions do not live in social groups because, in their experience, they only ever saw male lions on their own. A high of 52 respondents admitted not knowing about the lions' sociality (Table 4.9). Most people only knew lions either from pictures from school or television. Jackals were believed to be a common menace to many people and even though many had either lost livestock to them or heard them call at night, only 57 % (n = 72) could identify a black-backed jackal. Despite confusion between weight and height as a measure of size, 58 respondents believed that a leopard is bigger than a cheetah while 30 believed otherwise and 38 respondents had no idea on which one was larger. Ninety-two respondents believed that the leopard is dangerous to humans but the 26 who thought otherwise argued that it is only dangerous when cornered (Table 4.9).

The knowledge index had a mean of 2.4 ± 3.3 (range: -7 – 12). This low, but positive value for the knowledge index probably reflects a reasonable knowledge about predators and their behaviour in the communities surrounding Debshan ranch. However, it is clear that some respondents (n = 25) did not possess a particularly good knowledge of predators, as reflected in their negative scores for the knowledge index. The knowledge index had a low Cronbach reliability with $\alpha = 0.27$ (range: 0.18 – 0.35 for individual questions). Lower Cronbach alpha values may reflect departure from internal consistency but Ritter (2010) propounds that they can also be found in perfectly valid tests and may be as a result of reverse coding or multiple factors. The most likely reason for such a low α-value could be that few questions were used (n = 13) as there was no evidence of reverse coding or multiple factors (Gliem & Gliem 2003) however, lower α-values have been used before (Santos 1999) .

**Table 4.9**: Questions used to gauge the general knowledge of the respondents about leopards and other carnivores. The total numbers of respondents per response type are given.

| Question | Yes | No | Don't know |
|---|---|---|---|
| 1. Identification of predators: | | | |
| a. Lion | 125 | 1 | 0 |
| b. Leopard | 82 | 35 | 9 |
| c. Cheetah | 66 | 50 | 10 |
| d. Spotted hyena | 47 | 37 | 42 |
| e. Brown hyena | 21 | 53 | 52 |
| f. Wild dog | 30 | 74 | 22 |
| g. Jackal | 72 | 17 | 36 |
| h. Aardwolf | 18 | 72 | 36 |
| 2. Do leopards have a cultural importance to you? | 62 | 55 | 9 |
| 3. Do leopards prefer livestock to wild prey? | 68 | 35 | 23 |
| 4. Do lions live in social families? | 63 | 11 | 52 |
| 5. Are cheetahs smaller than leopards? | 58 | 30 | 38 |
| 6. Are leopards dangerous to humans? | 92 | 26 | 8 |

**Attitudes towards leopards and other carnivores**

The specific emotions respondents expressed towards leopards varied (Table 4.10). In Matabeleland South and Midlands provinces, 26 and 25 respondents respectively held neutral emotions towards leopards (Table 4.10). The high prevalence of neutrality from these two provinces is in line with the number of respondents who had not observed any leopard movement on their properties. Despite Matabeleland North having more respondents with negative emotions towards leopards, it also had the highest number of positive responses (Table 4.10).

**Table 4.10**: Specific emotions expressed by respondents towards leopards during the questionnaire survey conducted between 14 August and 4 December 2013. Actual numbers of respondents are given.

| | **Emotions towards leopards** | | |
|---|---|---|---|
| | Positive | Negative | Neutral |
| Matabeleland South | 1 | 13 | 26 |
| Matabeleland North | 6 | 28 | 6 |
| Midlands | 5 | 10 | 25 |
| **Total** | **12** | **51** | **57** |

Despite a high number of respondents (n = 94) confirming the importance of leopards to the environment, 117 recognising the need for leopard conservation, and 91 wanting to see leopards in the bush (Table 4.11), commonly echoed sentiments by respondents were that leopards are dangerous to humans, have a potential to kill livestock, and should be put in parks. However, 72 respondents (57 %) said that they would love leopards to stay on their properties. Sixty-three percent of the respondents (n = 80) understood leopards to have a business potential for them in the form of tourism, but most were unaware of how to tap into such a resource. A high percentage of respondents (94 %) expressed interests in learning more about leopards mainly on how to prevent livestock depredation, self defence and about the leopard as a species (Table 4.11).

The attitude index had a mean score of 1.7 ± 3.8 (range: -7 – 10). A mean of 1.7 indicates that respondents were neither too negative nor too positive towards leopards and other carnivores. However, some respondents (n = 34) clearly expressed extremely negative attitudes towards leopards and other carnivores. The attitude index had a Cronbach reliability α = 0.69 showing an acceptable internal consistency of the questions used. Individual questions used also had acceptable consistency (0.62 – 0.74).

**Table 4.11**: Questions used to gauge the attitudes of respondents towards leopards and other carnivores in the communities surrounding Debshan ranch. Actual numbers of respondents are given.

| Question | Yes | No | Don't know |
|---|---|---|---|
| 1. Positive emotions towards | | | |
| a. Leopards | 12 | 51 | 63 |
| b. Hyenas | 5 | 38 | 83 |
| c. Cheetahs | 7 | 11 | 108 |
| d. Jackal | 9 | 59 | 57 |
| 2. Are you more tolerant of leopards than your neighbour? | 32 | 76 | 18 |
| 3. Leopards are an important part of the environment | 94 | 23 | 9 |
| 4. Would you be happier if leopards were absent from your property? | 48 | 72 | 6 |
| 5. Should leopards be protected? | 117 | 6 | 3 |
| 6. Do leopards have tourism potential? | 80 | 23 | 23 |
| 7. Would you like to see leopards in the bush? | 91 | 32 | 3 |
| 8. Do you want to learn more about leopards? | 118 | 6 | 2 |

**Effects of leopards on livelihoods**

How people perceive leopards and other carnivores to affect their livelihoods is very important in the understanding of attitudes. Respondents who cited the killing of livestock and subsequent loss of financial income blamed the leopards for affecting their livelihoods. Sixty-seven percent of respondents did not experience any negative effects from leopards, while 30 % of the respondents were believed to be negatively affected by leopards through loss of livestock. Only 3 % could not ascertain the effects of leopards on their business and livelihoods.

**Table 4.12**: Summary of the number of respondents citing perceived impacts of leopards on their livelihoods.

| | **Negative impact on livelihoods** | | |
|---|---|---|---|
| | Yes | No | Don’t know |
| Matabeleland South | 11 | 28 | 1 |
| Matabeleland North | 15 | 25 | 3 |
| Midlands | 12 | 31 | 0 |
| **Total** | 38 (30 %) | 84 (67 %) | 4 (3 %) |

**Factors influencing attitudes towards leopards and other carnivores**

Eleven predictor variables were initially used in the generalised linear model to determine whether or not they had any significant influence on the attitudes of respondents towards leopards and other carnivores. The four predictor variables which were removed because they were co-linear (VIF's > 5) were province, gender, education and property type (land tenure). Ten models were selected as the best predictors of the attitude index ($\Delta$AICc < 2). These models contained seven predictor variables and included the knowledge index, time spent living in the property (years), leopard movement on property (Yes/No), number of cattle killed by predators, distance from boundary (km), age of respondents and number of cattle owned. A cross validation generalised linear model using all seven predictor variables revealed that none of the individual variables had a significant probability of influencing the attitudes of the respondents surrounding Debshan ranch (Table 4.13). However, the knowledge index approached significance (Table 4.14) indicating that as respondent knowledge increased, so attitudes towards predators increased.

**Table 4.13:** The cross validation generalised linear model output including the top seven predictor variables on attitudes of respondents. None of the variables had a significant relationship with the attitude index (all p > 0.05).

| | **Estimate** | **Std. Error** | **t - value** | **p - value** |
|---|---|---|---|---|
| (Intercept) | 0.3709 | 1.1200 | 0.3310 | 0.7409 |
| Knowledge index | 0.1980 | 0.1054 | 1.8790 | 0.0628 |
| Number of cattle killed by predators | -0.1730 | 0.1445 | -1.1980 | 0.2334 |
| Distance from Debshan boundary (km) | 0.0757 | 0.1441 | 0.5250 | 0.6006 |
| Time spent living in the property (years) | 0.0614 | 0.0404 | 1.5200 | 0.1312 |
| Number of cattle owned | 0.0026 | 0.0032 | 0.8220 | 0.4126 |
| Age of respondent in years | -0.0124 | 0.0216 | -0.5750 | 0.5661 |
| (Leopard movement): Yes | 0.9351 | 0.6873 | 1.3610 | 0.1762 |

**DISCUSSION**

A total of 140 interviews were conducted across an area of about 1528 $km^2$ in my study. This area alone is greater than Matusadona National Park, Zimbabwe (1367 $km^2$) and, together with Debshan ranch, is nearly as large as Matopos National Park, Zimbabwe (2000 $km^2$). However, 140 is the minimum number of properties in the area as not all properties were surveyed, especially in Midlands where only 10 % was sampled. The high levels of habitat fragmentation as a result of cropping fields, settlements and infrastructure may have a negative effect on the growth and sustainability of the leopard population (Murphree and Metcalfe 1997; Dickman 2008). The impacts of infrastructure can be felt over extensive areas (Theuerkauf *et al.* 2001) as they limit the dispersal of individuals thus affecting the survival of small and isolated population segments (Brown 1989; Ntinda 2007). An increase in the human and livestock densities may also suppress the wildlife populations due to competition for resources such as space and food. Evensen Gangås (2014) posited in her PhD thesis that biological sustainability increases with increasing area and eventually reaches an asymptote as the area becomes large enough to be inhabited by a sizeable population that can avoid extinction due to environmental and genetic disturbances. However, despite being tolerable of predictable human activities, human presence also upsets carnivores through displacement from preferred feeding and denning sites (Naves *et al*. 2001; Kaartinen *et al*. 2010).

The single holder properties surveyed in my study are all incapable of supporting a viable leopard population as, according Bailey (1993), maintaining viable populations in areas smaller than 500$km^2$ will be difficult in the long run due to genetic instability. Again, because leopards are territorial, an area of a given size can only support a certain number of individuals at any given time. Also, using data from the GPS collared leopards inside Debshan ranch; the smallest home range recorded for a female was 53.3 $km^2$ (P. Nyoni, unpublished data), a size larger than individual properties in Midlands. Thus, it is imperative for leopard conservation in the region that wildlife management authorities consider the establishment of conservancies (Lindsey *et al*. 2005). Essentially, a conservancy is created when a number of land owners work together to manage their properties as a joint wildlife unit (Murphree and Metcalfe 1997) and agree on collective wildlife operations, including the sharing of benefits and responsibilities. The most important value of a conservancy is the removal of internal fences (Child 1995; Fitzgerald 2012) which could facilitate leopard dispersal into larger areas, and offtakes can be cushioned by the large size of the population from which individual animals are drawn (Balme *et al*. 2010). The establishment of conservancies is likely to be even more important considering that leopards are hunted as trophy animals in the area (Bond and Frost 2005) and there does not appear to be any concerted management or control of this hunting. For example, leopard trophy hunting occurs in the CAMPFIRE area in Midlands (with a quota of two male leopards/year) and Matabeleland North has individual property hunting rights for leopards (at least one leopard/year per property). This leads to annual offtakes of ± 20 leopards over approximately 600 $km^2$ which is clearly unsustainable (Purchase 2006; Lindsey and Mandisodza-Chikerema 2012 ), especially considering that the population size is unknown. These trophy hunting practices increase pressure on leopards through multiple offtakes from a single population (Balme *et al*. 2010). For territorial species such as leopards, concentrated offtakes through hunting can generate localised population sinks with an unbalanced impact on metapopulation viability (Cooley et al. 2009; Balme *et al*. 2012). Therefore, leopard hunting units (Balme *et al*. 2010) within conservancies (at least 500 $km^2$ according to Bailey 1993) and benefit sharing by all members should be explored.

Deodatus (2000); Woodroffe *et al*. (2005) and Gandiwa *et al*. (2013) all asserted that living in close proximity to protected areas (PAs) imposes costs on the surrounding human communities. Such costs include damage to or loss of crops and livestock and occasionally injury or death to people (Woodroffe *et al*. 2005; Dickman 2008). The costs are likely to increase as conservation efforts lead to the recovery of wildlife populations and human population growth leads to increased proportions of land outside of PAs used for agriculture (Richardson *et al*. 2012). Human settlements that were surveyed in my study went up to the boundary fence of Debshan ranch. Thus, there was no buffer zone to accommodate dispersing wildlife, potentially increasing the chances of encounters between people and the carnivores moving out of Debshan ranch. However, in my study, an analysis of attitudes in relation to distance from Debshan boundary did not reveal any significant relationship between attitudes and distance from the Debshan boundary. This may be because the communities do not view Debshan as the source of leopards in the area. Also, the relatively lower levels of livestock depredation compared to other losses e.g. to disease, accidents and theft may be neutralising attitudes towards leopards.

Sixty percent of respondents in my study admitted being as equally intolerant as their neighbours of leopard presence on their properties. However, only 38 % said they would be happier if leopards were absent from their properties. These seemingly contradictory feelings echo the sentiments that leopards potentially pose a threat to livestock and personal security while still valuing the cultural economic role of leopards. An overwhelming 83 % of respondents believed leopards should be protected and 72 % would like to see them in the bush. However, they all believed that the protection should be achieved through putting the leopards in national parks. The protectionist approach (Gandiwa *et al.* 2013) is clearly still deeply ingrained in people's minds in this area. The long standing "not in my backyard" (NIMBY) syndrome (Eriksson 2013) is clearly evident in the communities surrounding Debshan ranch. Like cattle ranchers in the Brazilian Pantanal, respondents mostly agree that leopards deserve protection, but not on that individual's property (Zimmerman *et al*. 2005). However, leopards and other large carnivores can best be conserved if communities value their presence and are willing to share space with them (Williams 2012). The challenge is therefore to get communities to value leopards (Liu *et al*. 2011) through improving their attitudes and tolerance (Errikson 2013). Community education and awareness programmes can be used to highlight the importance and benefits of coexisting with the large carnivores. For example, leopards could be valued more by highlighting the potential benefits accrued through trophy hunting (if managed sustainably), ecotourism, mesopredator (small-medium sized carnivores) control (Crooks & Soulé 1999; Prugh *et al*. 2009) and ecosystem stability (Elliot 2004).

It was pleasing to note, however, that the majority of respondents (94 %) were willing to learn more about leopards especially concerning their reproduction and how to prevent livestock depredation. Such a display of interest is a positive step towards improved coexistence. According to Mamimine (2003), conflict is perceived to come about as a result of forced relocation of communities among other things. In this context, however, people moved into the area willingly and most of them were well aware of the nature of the area. Therefore, there is a great opportunity to convince these communities to continue conserving wildlife in the area. The FTLRP has a Wildlife Based Land Reform Policy (WBLRP) which advocates for coexistence with and the conservation of wildlife (Fitzgerald 2012). Incorporation of this instrument into the planning of the resettlement and making the settlers aware of its requirements and guidelines is vital to the smooth transaction from former to current settlers. In addition, collaboration of the different stakeholder institutions such as Rural District Councils (RDCs), Parks and Wildlife Management Authority (PWMA), Non-Governmental Organisations (NGOs) and the community authorities (chiefs and headmen) to spearhead the enactment of the policy will undoubtedly assist this process.

There are likely to be a number of reasons for the low (though positive) respondent attitudes towards leopards and other carnivores in my study area. Williams (2012) suggested that conflicts are usually latent in their initial stages and this might suggest that the communities in my study area have not yet reached climax, hence their interactions with leopards are still regarded as minor. Nzongola-Ntalaja (1999) further states that group conflict eventually comes to light when an individual or group faces a threat (real or imagined) to its interests, security or its very existence and solidarity is mobilised from those in similar positions. These conflicts generally worsen during economic and political crises (Williams 2012). Five percent of respondents have been in the area for over 13 years under the private sector while 33 % had only been resident for between 9- 13 years under the FTLRP. The human population is therefore still steadily increasing hence the community members are probably still establishing themselves and building trust amongst one another (*pers. obs.*). Also, the survey revealed that the settlers come from a very wide range of backgrounds economically, socially, religiously, culturally and geographically. Community amalgamation is probably still underway and dealing with wildlife is a secondary issue. For example, in one village, they were still fighting as to who should be the Headman and arguments interrupted our interview proceedings. There are also studies which show that negative attitudes towards wildlife are mostly secondary, appearing with the initial encounter with animals but decreasing over time with increasing experience of large carnivores (Zimmerman *et al*. 2001). Such a change in attitude could be an effect of education/awareness campaigns coupled with the implementation of predator-livestock damage control programmes or simply a result of acclimatisation to coexistence with the large carnivores (Majic and Bath 2010). As none of the predictor variables I used could adequately explain the attitudes, no conclusive projections can be drawn as to what will happen in these communities. However, active steps should be taken to effectively mitigate conflict (IUCN 2006; Ray et al. 2005) through engaging the communities in pro-conservation activities e.g. improved livestock husbandry and receiving benefits from trophy hunting ventures (Child 1995; Bond and Frost 2005) and extensive involvement of the communities in decision-making (Eriksson 2013).

Though not significant, respondents with leopard movement on their properties had slightly more positive attitudes than those who did not have leopards moving on their properties. A study by Lindsey *et al*. (2005) on private lands in South Africa and Zimbabwe revealed that leopards are popular among ranchers due to their economic value through ecotourism and hunting. Therefore, despite experiencing livestock losses, respondents with leopards on their properties may be aware of the greater potential for financial returns through hunting and tourism and were thus more positive. Williams (2012) studied cheetahs in the Save Valley Conservancy (SVC) in Masvingo, Zimbabwe, and also found that respondents who had cheetah movement on their properties were positive towards cheetahs than those who did not have cheetah movement in their properties. Williams (2012) concluded that the reality of living with carnivores might not be as problematic as perceived by those that do not coexist with them. Similarly, Gandiwa *et al*. (2013) demonstrated that in communities surrounding Gonarezhou national park, more positive attitudes were found where communities were living with predators than where predators were absent. These findings suggest that communities surveyed in my study might become more tolerant of leopards as they become more accustomed to leopard presence.

However, the belief that carnivores are dangerous to livestock still remains an important determinant of attitudes (Maddox 2002; Dickman 2008). Williams' (2012) attitude to behaviour process models suggested that people may attempt to kill cheetahs in resettlements and communal areas while hunting continues as part of trophy hunting activities in the commercial areas. This was attributed to the fact that commercial farmers are generally wealthier than communal farmers, so are in a better position to absorb the costs of predation and are less likely to develop negative perceptions (Romañach *et al.* 2007). With the continued FTLRP, the resettlement model setup is fast becoming common, hence there is a need to create awareness about the threats faced by large carnivores and involve the communities in the decision-making process towards sustainable wildlife management. On top of economic losses, carnivores often cause emotional losses for producers (Hafer and Hygnstrom 1991) as livestock can be a symbol of social standing, wealth and can be used in non-financial transactions like paying the bride price (lobola), and food provision (e.g. meat and milk) as well as manure.

Out of a total of 99 respondents who reported livestock losses to whichever cause, very few made reports to the RDC, vet, police and/or chief/headman. Low levels of reporting to the local authorities may be a sign of a lack of faith/ or a non-existent relationship between these institutions and the settlers. Conflict between humans and wildlife has been shown to create friction between managers of PAs and communities adjacent to them (De Boers and Baquette 1998) which often undermines local support for conservation (Gusset *et al*. 2009). Matabeleland South understandably has low levels of reporting because the RDC offices are hundreds of kilometres away in a non-wildlife area hence access is a challenge. In Matabeleland North, however, despite partaking in trophy hunting, somehow settlers and the council have failed to establish the link between wildlife losses and predators. One would expect that communities in Matabeleland North would be more aware of better livestock husbandry judging from that they are already tapping into the wildlife resource base through trophy hunting. Matabeleland North has only engaged with one aspect of human-wildlife relationship which is exploiting benefits but failed to adequately inform the communities on better livestock husbandry techniques. Resentment towards leopards in Midlands is most probably due to the centralisation of the CAMPFIRE programme by the local rancher. Benefits from the trophy hunting ventures have not reached the intended communities yet. Community-based management programmes should thus have the communities adequately involved in decision making and benefit realisation (Barrett and Arcese 1995; Balint and Mashinya 2006).

A majority of livestock were predated while spending the night in the bush or when lost or left unattended even during the day except for one case in Midlands where a leopard supposedly dragged goats from inside a kraal at night. These results suggest that leaving livestock unattended, especially goats, during daylight increases predation likelihood regardless of the predator implicated or livestock predated. Kraaling livestock at night has been shown to reduce predation (Ogada *et al*. 2003) and the kraals should be conveniently/adequately adapted for the type of livestock and likely predator. For example, in Zimbabwe, the traditional cattle kraals are made either of fences or wood which is spaced widely enough to prevent cattle from moving out while predator may easily get inside (*pers. obs*.). Schiess-Meier *et al*. (2007) advised that owners should take greater responsibility of livestock by tending them during the day, kraaling at night and keeping records of numbers owned and losses.

Two respondents admitted to killing carnivores; a group of villagers who killed a spotted hyena and an individual who killed a jackal. The low level of killings reported might also be an indication that predation levels may not yet be viewed as a serious threat while it may also explain inability or fear to kill. St John *et al*. (2012) however, was suspicious of the low levels of killings reported, suggesting instead people may not readily divulge such information to a stranger. Trust therefore should be built with communities to get a grasp of actual predator removals.

**CONCLUSION**

Attitudes are a strong predictor of a person or group's intention to behave in a particular manner (e.g. compliance with wildlife protection regulations; Fulton et al. 1996). As such, an assessment of attitudes towards wildlife provides insights on the extent to which people are willing to coexist with wildlife (Carter *et al*. 2013). Because attitudes are rarely uniform across space (Sitati *et al*. 2003; Naughton-Treves and Treves 2005), my study was conducted within distinct categories such as province and property type. As a result, patterns and information that exist on the spatial distribution of attitudes will serve to inform managers and conservation agencies on where to channel their interventions for alleviating HWC. Such information will be increasingly important as the world is expected to add approximately 1400 million people over the next 20 years (United Nations 2010).

The support and involvement of people living in and close to leopard habitats are vital in such efforts because they might not only affect the conservation of the leopard but also because they depend on their livestock which could be killed occasionally by leopards. Although it is not always practical, compensation for lost livestock from leopard predation should be considered (Anderson and Grove 1989) with benefits reaching down to the affected individual. However, basic requirements should include concrete livestock management schemes before compensation is given. An important way to gain support of local inhabitants is to have them experience an economic benefit from protecting such a species (Bailey 1993) through revenue from sources such as hunting rights and ecotourism, services such as roads and school and employment in PAs which would encourage local residents to participate in leopard conservation. Additionally, a detailed study of leopard distribution and habitat requirement is needed within the communities (Al-Johany 2007) for the management of the species. The ecological information needed includes data on feeding behaviour, range use and reproduction (Balme *et al.* 2007) to complement the local knowledge which, despite its potential to provide reliable, quick, and low cost data, is limited due to the lack of understanding of the accuracy and biases (Shepperson *et al*. 2014).

# CHAPTER 5

## SYNTHESIS AND MANAGEMENT RECOMMENDATIONS

This chapter synthesises the data presented in Chapter 3 (spoor counts and camera trapping) and Chapter 4 (community attitudes towards leopards). The outcomes of the research are then summarised. Management recommendations and suggestions for future research are also presented.

## SYNTHESIS

### Leopard density estimates

### Spoor counts

Leopard density estimates for Debshan ranch varied depending on the method used. The spoor calibration equation which was regarded as the most appropriate for the study site (Balme *et al*. 2009) gave a leopard density of 13.57 leopards/100km$^2$ which, when extrapolated to the whole property, gave a total of 61 individuals. However, this estimate is likely to be an overestimate given the likelihood of double counting spoor. Nevertheless, the spoor survey did provide important information on the distribution of leopards across the ranch as well as spoor densities which are comparable with other areas. To consolidate the validity and applicability of the method though, the spoor densities should be calibrated against true densities so that, in future, the leopard population of Debshan can be quickly and affordably assessed through spoor counts.

### Camera trapping

The camera trapping survey, completed over a period of 69 days, yielded 26 leopard images and 10 individually identifiable animals. Appreciating that a maximum of six camera pairs were available at any given time, and the limitations of an un-baited camera trapping survey over an area of 240 km$^2$, these results provided a solid estimate of leopard densities on Debshan ranch. However, as a precautionary measure, the density estimate of 2.0 leopards/100km$^2$ resulting from the program DENSITY's Mean Maximum Distance Moved Outside of Study Area (MMDMOSA) buffer width of 12. 68 km should be regarded as the most appropriate. This buffer width was chosen because it uses the home range sizes of leopards collared at the study site (Dillon and Kelly 2008) and also assumes the 'worst case scenario'. For example, if the calculated density for Debshan is an overestimate, the leopard population will still be cushioned from the effects of any management decisions e.g. trophy offtake quotas based on the density estimate (Caro *et al.* 2009; Chase-Grey 2011).

The two leopard density methods which I employed resulted in different density estimates. My estimates should be interpreted with caution as they do not reflect vital population parameters like age and sex ratios, recruitment and reproduction capacity (Balme *et al*. 2012; Mondal *et al.* 2012). Although the camera survey may have been more robust as it used individual leopard identification, spoor counts have the advantage of being relatively cheaper and repeatable (Smallwood and Fitzhugh 1995; Stander 1998).

**Community attitudes towards leopards**

Although my interviews were done across three different provinces (Matabeleland North, Matabeleland South, Midlands) and within different land use types (small and large private farms, A1 villages, A2 plots and single-owned), there were no significant differences in attitudes across these variables, nor for any of my selected predictor variables. However, the overall attitudes towards leopards and other carnivores were generally low (1.7 ± 3.8; range: -11 - +11). Because attitudes are not static (Kansky and Knight 2014), positive steps to promote tolerance should be taken to counter any future problems and to perhaps improve overall attitudes towards predators in the area. Tolerance can be boosted through the realisation of financial benefits such as through trophy hunting or ecotourism and also improving general knowledge about carnivores throughout the communities. Woodroffe (2000) highlighted the strong negative association between high human densities with the loss of carnivore populations. However, Linnell *et al*. (2001) identified an increase in carnivore populations despite increasing human densities when legislation is favourable and wildlife management policies are effective. Therefore, even with the obvious increase in the human densities around Debshan, establishing awareness amongst the current settlers may lay the foundation for a shift in attitudes towards carnivores.

Respondents expressed a keen interest in learning more about leopards so as to improve their levels of understanding of the species. However, livestock losses (both real and perceived) appeared to negatively affect community attitudes towards carnivores. Such losses could be offset through the adoption of improved livestock management techniques (such as night kraaling, use of livestock-guarding dogs and employing herders) which have been shown to significantly reduce livestock losses.

**MANAGEMENT RECOMMENDATIONS**

Leopard trophy hunting offtakes were not explicitly investigated in this study, but I appreciate that hunting also contributes directly to the reduction in the population, especially if done excessively (Henschel *et al*. 2008). When extrapolated to the entire property, a density of 2 leopards/100km$^2$ translates to nine (range: 0 - 26) leopards in total. An annual leopard hunting quota of five leopards for Debshan ranch may be excessive and therefore detrimental to population viability. Caro *et al*. (2009) recommended that trophy hunting should not exceed 3.6 % of the total population, especially if females are also incidentally taken. A further investigation is required on trophy hunted leopards in the area to determine if females are also killed. However, despite the ranch being allocated an annual quota of six leopards from 2008 to date, no more than three leopards have been hunted in any given year (Colin Edwards, General Manager, pers. comm.; Sean Grant, Professional Hunter, pers. comm.). Applying the 3.6 % to the minimum population estimate (Caro *et al*. 2009) gives an offtake of 0.3 leopards/year. In practical terms, this means that only one leopard should be hunted every three years. However, because I used a conservative density estimate, using its upper limit (26 leopards) woul translate to one trophy leopard per year.

Another recommendation to put forward pertains to leopard hunting units (Balme *et al*. 2010). For a long time in Zimbabwe, quotas have been allocated using human demarcated boundaries instead of ecological boundaries. These human boundaries, however, do not reflect the ranging behaviour of leopards. Thus, quota estimations are probably compromised (Grant 2012; Lindsey and Mandisodza-Chikerema 2012). To reduce hunting hotspots, Bailey (1993) suggested that no two males should be removed from the same home range within two consecutive years to reduce infanticide and encourage recruitment into adulthood. The effect of hunting hotspots on leopard populations has been shown elsewhere and was linked to a significant decline in trophy skull size across Zimbabwe (Sibanda 2010). Therefore, Balme *et al*. (2010a) recommended employing leopard hunting units of 600 km$^2$ from which only one leopard can be hunted per year but not from the same locality. However, leopard hunting units of 600 km$^2$ may not be appropriate for all parts of southern Africa as other factors also influence male home range sizes e.g. prey and habitat availability (Bothma and Bothma 2012) and human densities. When prey is abundant, leopard home ranges are smaller as compared to low prey densities when leopards have to range more widely to fulfil their food requirements (Smith 1977; Henschel *et al*. 2011; Pitman 2012). Also closely linked to prey availability, are human densities, high human densities mostly correlate with low leopard densities due to competition over resources (Martin and de Meulenaer 1988; Lindsey and Mandisodza-Chikerema 2012). Based on my results, I would recommend that the size of Debshan ranch (450 $km^2$) be considered a single hunting unit, taking one trophy leopard a year.

Woodroffe and Ginsberg (1998) recommended that priority be given to measures that seek to maximise reserve size or mitigating carnivore persecution on reserve borders and in buffer zones. In order to promote a healthy coexistence between communities and wildlife, management interventions should aim to reduce livestock depredation, improve people's attitudes to wildlife and ensure that communities actively partake in, and receive benefits from wildlife management (Hemson 2003). To achieve this healthy balance, I recommend that the communities surrounding Debshan ranch are actively included in decision-making regarding wildlife management in the area. The lack of decision-making authority and control over one's environment may be one of the key factors influencing attitudes toward leopards (Zinn *et al*. 2000; Carter *et al*. 2012a). Authorities like the Rural District Councils (RDCs) and community elders (chiefs and headmen) should reach out to the ordinary members who bear the costs of living with carnivores and find out about their concerns so as to make informed decisions. Debshan could therefore serve as education centre, disseminating information and doing community outreach on the importance of wildlife and promoting awareness of healthy coexistence (Ogada *et al.* 2003).

Properly addressing livestock losses may substantially improve community attitudes to and tolerance of carnivores. Having realised that most livestock losses took place in the absence of appropriate livestock management methods, there is a huge opportunity for the communities to implement different livestock management practices. Improved livestock husbandry should include the use of techniques such as herders, the use of guardian dogs, synchronisation of birthing times within the herd, the use of maternal kraals among others (Schumann 2004; Nyoni and Williams 2008). Programmes such as the training of guardian dogs can be carried out by independent Non-Governmental Organisations (NGOs) or the local authorities like RDCs using prepared manuals. The Veterinary department can also be involved in educating communities on maternal kraals and birthing synchronisation with wild prey.

The adoption of holistic livestock management on Debshan ranch has had many advantages. The pooling of livestock into herds and monitoring them throughout the day has significantly reduced livestock depredation rates while also enabling early detection of other factors like disease. Therefore, I would recommend that the communities surrounding Debshan ranch adopt a similar form of holistic management. This will involve several property owners pooling their cattle together and routinely herding them to prevent overgrazing and allowing grasses enough time to regenerate (Neely and Butterfield 2004).

**RECOMMENDATIONS FOR FUTURE RESEARCH**

The present study has revealed interesting information about the densities of leopards on Debshan ranch as well as the attitudes of communities beyond Debshan's boundary, but it has also raised a number of questions that need to be answered to fully understand the leopard population in the Shangani ecosystem. A study by Woodroffe and Ginsberg (1998) on the edge effects and extinction of populations in protected areas (PAs) revealed that wide ranging carnivores are more likely to become extinct than those with smaller home ranges in a reserve of whatever size, regardless of population density rendering population size a relatively poor predictor of extinction. Hence, while population density is very important in guiding decision making, understanding ranging behaviour is crucial for long term goals as it mediates contact with human activity subjecting the population to human induced mortality (Dar *et al*. 2009; Nori *et al*. 2013). Significantly, the need to secure the leopard population across a broader landscape (larger than Debshan alone) is vital to the long term sustainability of the leopard and other wildlife species. Therefore, the first recommendation is that research activities be extended beyond the Debshan boundary.

To reconcile the differences in leopard density estimates provided by the different methods and analyses which I used, calibration over time should be done between the two methods. Intensive spoor counts should be done across the different seasons and also opportunistically to eventually have a record of almost all the leopards within Debshan ranch. While camera trapping in the present study only covered 240 $km^2$ in the centre of the ranch, in future, it should cover the whole ranch so as to effectively reveal crucial information such as whether the leopard density declines towards the edges as recorded in other studies (Woodroffe and Ginsberg 1998; Balme *et al.* 2010). Also, to maximise the probability of leopard captures as well as improve image quality for identifying the sex and ages of individuals so as to identify crucial population elements vital for population survival (age and sex ratios), future research should consider the use of baits (Lopéz-Bao *et al.* 2010) or commercially available perfumes and colognes (e.g. Thomas *et al*. 2005) as attractants.

Baseline density estimates for large carnivores are essential for monitoring effectiveness of conservation activities (Gray and Prunn 2012). Understanding the ranging behaviour of leopards is important so as to better understand the value of the landscape for leopard conservation as well as the effective size of the conservation area (Gray *et al*. 2012). To achieve this objective, it will be ideal to collar a minimum of 20 leopards over at least five years (Balme *et al*. 2009, 2010) within and beyond the ranch and monitor their ranging behaviour and movement patterns. This will provide information on home range sizes, home range overlaps thus how many adult leopards the area can support at any given time which will also aid in trophy offtake decision making. Implementing spoor counts, camera trapping and telemetry simultaneously and over sufficient periods of time (at least six years) may provide adequate information to create a calibration index (Stander 1998; Balme *et al*. 2009). Thereafter, spoor counts can be done to estimate leopard population density and abundance because they are relatively cheaper and quick compared to other methods (Stander 1998).

Telemetry data can also be used to gather information on livestock depredation and leopard diet. Moreover, the data from collared leopards can be used in mapping habitat preferences by leopards as well as how leopards overlap with humans in their space use. This will provide a clearer understanding of how leopards manage to coexist in close proximity with humans in the Shangani landscape as portrayed by Odden *et al.* (2014) for Maharashtra and Himachal Pradesh in India. Spatial and temporal avoidance strategies can be investigated to further help determine the survival potential of leopards in this human dominated landscape.

Because food availability ranks high as one of the most important factors influencing leopard distribution, home range sizes and densities (Sharma 2004; Wang and MacDonald 2009;

Wegge *et al*. 2009; Bothma and Bothma 2012), it is crucial to understand the diet composition of leopards in the Shangani ecosystem. With the preliminary leopard diet analysis underway (Buhlebenkosi Ngwenya, BSc thesis), future research should seek to comprehensively document the diet of leopards. Methods should include scat analysis with scats being opportunistically collected while carrying out other methods as well as using telemetry data to track and identify leopard kills.

Henschel *et al*. (2008) acknowledged that the impacts of trophy hunting on leopard populations is unclear but may have impacts at the demographic and population levels, especially when females are shot. To dovetail the contribution of trophy hunting into the overall understanding of leopard populations, future research should collate all the historical information pertaining to hunting offtakes in the region, including numbers, locality of hunting, year and trophy size and quality for assessment (Sibanda 2010; Lindsey and Mandisodza-Chikerema 2012). This information will feed into the National Leopard Management Programme (NLMP) and also assist in revising the applicability of the annual leopard export quota of 500 individuals in Zimbabwe.

Once baseline biological data are available, it is essential to expand the conservation equation to include relevant cultural, economic, and political factors (Weber 1995). Appreciating that conservation does not occur in a vacuum, and understanding that the broader context is essential to long-term success (Weber and Rabinowitz 1996), I strongly recommend that any future research incorporates the communities surrounding Debshan ranch. Recognising and acknowledging different interests and concerns can go a long way towards reducing possible conflicts and tensions and help design and implement more comprehensive approaches to conservation. To this end, a deeper understanding of the determinants of community attitudes should be sought. Building a healthy relationship of trust with the communities will help in the sourcing out of information such as whether leopards and other carnivores have been killed in the area and financial losses caused by the carnivores. Community buy-in into conservations strategies will go a long way in securing long term sustainability of all carnivores.

## REFERENCES

1. Ajzen, I. and Fishbein, M. 1980. Understanding Attitudes and Predicting Social Behaviour. Prentice Hall, New Jersey.
2. Ajzen, I., 1991. The theory of planned behaviour. *Organizational behaviour and human decision processes* **50:** 179–211.
3. Akaike, H. 1974. A new look at statistical model identification. *IEEE Transactions on Automatic Control* **19**: 716-723.
4. Alexander, J. 2006. *The unsettled land: state-making and the politics of land in Zimbabwe, 1893-2003.* James Currey, Oxford.
5. Al-Johany, A. M. H. 2007. Distribution and conservation of the Arabian Leopard *Panthera pardus nimr* in Saudi Arabia. *Journal of Arid Environments* **68**: 20-30.
6. Andelman, S. J. and Fagan, W. F. 2000. Umbrellas and flagships: efficient conservation surrogates or expensive mistakes? *Proceedings of the National Academy of Sciences of the United States of America* **97**: 5954–5959.
7. Anderson, D. and Grove, R. 1989. *Conservation in Africa: People, policies and practice*. Cambridge University Press, Cambridge.
8. Anderson, I. P., Brinn, P. J., Moyo, M. and Nyamanzwa, B. 1993. *Physical Resource Inventory of the Communal Lands of Zimbabwe- An Overview*, NRI Bulletin 60. Chatham, UK: Natural Resources Institute.
9. Archibald, A. S., Bond, W. J., Stock, W. D. and Fairbanks, D. H. K. 2005. Shaping the landscape: Fire-grazer interactions in an African Savanna. *Ecological Applications* **15**: 96-109.
10. Bailey, T. N. 1993. *The African leopard: a study of the ecology and behaviour of a solitary felid.* Columbia University Press, New York.
11. Baker, P.J., Harris, S. and Webbon, C. C. 2002. Effect of British hunting ban on fox numbers. *Nature* **419:** 34.
12. Balakrishnan, M. and Easa, P. S. 1986. Habitat preferences of the larger mammals in the Parambikulam Wildlife Sanctuary, Kerala. *Biological Conservation* **37**: 191-200.
13. Balint, P. and Mashinya. J. 2006. The decline of a model community-based conservation project: governance, capacity, and devolution in Mahenye, Zimbabwe. *Geoforum* **37**:805-815. http://dx.doi.org/10.1016/j.geoforum.2005.01.011.
14. Balme, G., Hunter, L. and Slotow. R. 2009a. Evaluating methods for counting cryptic carnivores. *The Journal of Wildlife Management* **73**(3): 433-441.

15. Balme G, Hunter L. T., Goodman, P., Ferguson, H., Craigie, J. and Slotow, R. 2010a. An adaptive management approach to trophy hunting of leopards (*Panthera pardus*): a case study from KwaZulu-Natal, South Africa. In: DW Macdonald & AJ Loveridge (Eds.). *Biology and Conservation of Wild Felids*. Pp: 341-352.Oxford University Press, Oxford.
16. Balme, G. A., Hunter, L. and Braczkowski, A. R. 2012. Applicability of age-based hunting regulations for African leopards. *PloS one* **7**: e35209.
17. Balme, G. A., Lindsey, P. A., Swanepoel, L. H. and Hunter, L. T. B. 2013. Failure of research to address the rangewide conservation needs of large carnivores: leopards in South Africa as a case study. *Conservation Letters* **7**: 3-11.
18. Balme, G. A., Slotow, R. and Hunter, L. T. B. 2009. Impact of conservation interventions on the dynamics and persistence of a persecuted leopard (*Panthera pardus*) population. *Biological Conservation* **142**: 2681-2690.
19. Balme, G. A., Slotow, R. and Hunter, L. T. B. 2010. Edge effects and the impact of non-protected areas in carnivore conservation : Leopards in the Phinda – Mkhuze Complex, South Africa. *Animal Conservation* **13**:315–23.
20. Balme, G., Hunter, L. T. B. and Slotow, R. 2007. Feeding habitat selection by hunting leopards (*Panthera pardus*) in a woodland savanna: prey catchability versus abundance. *Animal Behaviour* **74**:589–98.
21. Barea-Azcón J, Virgos E, Ballesteros-Duperon E, Moleon M & Chirosa M. 2007. Surveying carnivores at large spatial scales: a comparison of four broad-supplied methods. *Biodiversity and Conservation* **16**(4): 1213–1230.
22. Barrett, C. B. and Arcese. P. 1995. Are integrated conservation-development projects (ICDPs) sustainable? On the conservation of large mammals in Sub-Saharan Africa. *World Development* **23**:1073–1084. http://dx.doi.org/10.1016/0305-750X(95)00031-7
23. Bauer, H. and Van Der Merwe, S. 2004. Inventory of free-ranging lions *Panthera leo* in Africa. *Oryx* **38**: 26-31.
24. Beetz, A. E. and Rinehart, L. 2010. Rotational grazing. NCAT Agriculture Specialists, Minneapolis.
25. Beier, P. and Cunningham, S. C. 1996. Power of track surveys to detect changes in cougar populations. *Wildlife Society Bulletin* **24**(3): 540-546.
26. Bell, A. 2011 Farm invasions continue across Zimbabwe. http://www.swradioafrica.com/news180811/farm180811.htm

27. Bengsen, A. J., Leung, L. K. P., Lapidge, S. J. and Gordon, I. J. 2011. Using a general index approach to Analyze analyse camera-trap abundance indices. *Journal of Wildlife Management 9999*(xx):1–6; 2011; DOI: 10.1002/jwmg.132.
28. Berry, M. and Macfadyen, D. 2014. *Counting wildlife: The annual helicopter census on the Oppenheimer and De Beers consolidated mines properties (1997 – 2013*. E. Oppenheimer and Sons, Johannesburg.
29. Bertram, B. C. R. 1982. Leopard ecology as studied by radio tracking. *Symposia of the Zoological Society of London* **49**: 341-352.
30. Blake, S. and Hedges, S. 2004. Sinking the flagship: the case of forest elephants in Asia and Africa.*Conservation Biology* **18**: 1191–1202;
31. Bond, I. and Frost, P. G. H. 2005. CAMPFIRE and the payment for environmental services. Paper prepared for the workshop *Payments for Environmental Services (PES) – Methods and Design in Developed and Developing Countries.* Titisee, Germany, 15 – 18 June 2005. Organised by the Center for Development Research (ZEF), University of Bonn, Germany and the Center for International Forestry Research (CIFOR), Bogor, Indonesia.
32. Bond, I., Child, B., de la Harpe, D., Jones, B., Barnes, J. and Anderson, H. 2004. Private land contribution to conservation in South Africa. In: Child, B. (Ed.). 2004. *Parks in transition: biodiveristy, rural development, and the bottom line*. Earthscan, London. pp: 29-61.
33. Borchers, D. L. and Efford, M. G. 2008. Spatially explicit maximum likelihood methods for Capture – Recapture Studies. *Biometrics*, **64**(June): 377-385.
34. Bothma, J. du P. and Bothma, M. D. 2012**.** Leopard range size and conservation area size in the southern Kalahari. *Koedoe* **54**(1): 4 pages.
35. Bothma, J. du P. and le Riche, E. A. N. 1984. Aspects of the ecology and the behaviour of the leopard *Panthera pardus* in the Kalahari Desert. *Koedoe*: 259-279.
36. Breintenmoser, C., Breintenmoser, U., Hofer, E. and Vogt, K. (Eds.). 2011. Cat News: Cats of the world- snapshots. Cat News. IUCN/SSC Cat Specialist Group **6.**
37. Breitenmoser, C., Breintenmmoser, U., Richmond, K., Bertram, B., Bashir, S. and Pereira, J. (Eds.). 2013. Cat News. IUCN/SSC Cat Specialist Group **58.**
38. Brown, A.H.D. 1989. Genetic characterization of plant mating systems. In: Brown, A.H.D., Clegg, M.T., Kahler, A.L. and Weir, B.S. (Eds.). 1989. Plant Population

Genetics, Breeding and Genetic Resources. Sinauer Associates, Sunderland. pp: 145-162.

39. Burnham, K. P. and Anderson, D. R. 2002. *Model selection and multimodel inference* 2nd edition. Springer, New York.
40. Burnham, K. P. and Overton, W. S. 1978. Estimation of the size of a closed population when capture probabilities vary among animals. *Biometrika* **65**: 625-633.
41. Burnham, K.P. and Anderson, D.R. 2002. *Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach*. 2nd Edition. Springer Science, New York.
42. Butler, J. R. A. 2000. The economic costs of wildlife predation on livestock in Gokwe communal land, Zimbabwe. *African Journal of Ecology* **38**: 23-30.
43. Carbone, C. and Gittleman, J. 2002. A common rule for the scaling of carnivore density. *Science* **295**: 2273–2276.
44. Carey, A.B., Hardt, M.M., Horton, S.P. and Biswell, B. L. 1991. Spring bird communities in the Oregon coast range. Pp 123-144 In: Wildlife and Vegetation of Unmanaged Douglas-fir Forests. U.S. Dep. Agric., For. Serv., Gen. Tech. Rep. PNW-GTR-285. Pac. N.W. Res. Sta.
45. Caro, T., Young, C., Cauldwell, A. and Brown, D. 2009. Animal breeding systems and big game hunting: Models and application. *Biological Conservation* **142**(4): 909-929.
46. Carter, N. H., Riley, S. J. and Liu, J. 2012. Utility of a psychological framework for carnivore conservation. *Oryx* **46** (4):525-535.
47. Carter, N. H., Riley, S. J., Shortridge, A., Shrestha, B. J. and Liu, J. 2013. Spatial assessment of attitudes toward tigers in Nepal AMBIO DOI 10.1007/s13280-013-0421-7.
48. Carter, N., Jasny, M., Gurung, B. and Liu, J. 2014. Impacts of people and tigers on leopard spatiotemporal activity patterns in a global biodiversity hotspot. *Global Ecology and Conservation* **3** (2015): 149-162.
49. Caughley, G and Sinclair, A. R. E. 1994. *Wildlife ecology and management*. Blackwell Scientific Publications, Oxford..
50. Chao, A. and Huggins, R. M. 2005. Classical closed-populations capture–recapture models. In: Amstrup, S. C., McDonald, T. L. and Manly, B. F. J. (Eds.). *Handbook of*

*capture–recapture analysis*. Pp 22–35. Princeton University Press, Princeton, New Jersey.

51. Chapman S & Balme G. 2010. An estimate of leopard population density in a private reserve in KwaZulu-Natal, South Africa, using camera-traps and capture-recapture models. *South African Journal of Wildlife Research* **40**(October): 114-120.
52. Chardonnet, P. 2002. *Conservation of the African lion: Contribution to a status survey*. International Foundation for the Conservation of Wildlife, France and Conservation Force, USA.
53. Chardonnet, P., Soto, B., Fritz, H., Crosmary, W., Drouet-Hoguet, N., Me´sochina, P., Pellerin, M., Mallon, D., Bakker, L. and Boulet, H. 2010. Managing the conflicts between people and lion: Review and insights from the literature and field experience. Food and Agriculture Organization of the United Nations. Wildlife Management Working Paper 13.
54. Chase-Grey, J. N. 2011. Leopard population dynamics, trophy hunting and conservation in the Soutpansberg Mountains, South Africa. PhD thesis, Durham University, Durham, UK.
55. Chaumba, J., Scoones, I. and Wolmer, W. 2003. From jambanja to planning: the reassertion of technocracy in land reform in south-eastern Zimbabwe? *Journal of Modern African Studies* **41:**533-554.
56. Child G. 1984. Resolution 4.13: Leopards. Letter from the Director of National Parks and Wildlife Management to the Secretary-General of the CITES Secretariat, C/98/1, 3 December 1984.
57. Child, G.F.T. 1995. *Wildlife and People: The Zimbabwean Success. How the Conflict Between Animals and People Became Progress for Both*. WISDOM Foundation, Harare and New York.
58. Chloe Inskip, C., Fahad, Z., Tully, R., Roberts, T. and MacMillan, D. 2014. Understanding carnivore killing behaviour: Exploring the motivations for tiger killing in the Sundarbans, Bangladesh. *Biological Conservation* **180**: 42–50.
59. CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora). 1985. Interpretation and Implementation of the Convention: Trade in leopard skins. 5th Meeting of the Conference of the Parties .Buenos Aires (Argentina), 22 April to 3 May 1985**. Doc. 5.23**

60. CITES. 1989. Interpretation and Implementation of the Convention: Trade in Leopard Skins. Secretariat report on leopard quotas. 7th Meeting of the Conference of the Parties Lausanne (Switzerland), 9 to 20 October 1989. Doc. 7.27.
61. CITES. 2006. Interpretation and implementation of the Convention: General compliance issues: Economic incentives. 54th meeting of the Standing Committee Geneva (Switzerland), 2-6 October 2006. SC54 Doc. 41.
62. CITES. 2011. Appendices I, II and III. CITES, Geneva.
63. Conforti, V.A. and de Azevedo, F.C.C. 2003. Local perceptions of jaguars (*Panthera onca*) and pumas (*Puma concolor*) in the Iguacu National Park area, south Brazil. *Biological Conservation* **111**: 215-221.
64. Cooley, H. S., Wielgus, R. B., Koehler, G. M., Robinson, H. S. and Maletzke, B. T. 2009. Does Hunting Regulate Cougar Populations? A Test of the Compensatory Mortality Hypothesis. *Ecology* **90**: 2913-2921.
65. Cougar Management Guidelines Working Group (CMGWG). 2005. Cougar management guidelines.First edition. Wild Futures, Bainbridge Island, Washington, USA
66. Creel, S. and Creel, N. M. 1996. Limitation of African wild dogs by competition with larger carnivores. *Conservation Biology* **10**:526–538.
67. Cronbach, L. 1951. Coefficient alpha and the internal structure of tests. *Psychometrika* **16**: 297-334.
68. Crooks, K. R. and Soulé, M. E. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. *Nature* **400**: 563–566.
69. Cuéllar, E., Maffei, L., Arispe, R. and Noss, A. J. 2006. Geoffroy's cats at the northern limit of their range: activity patterns and density estimates from camera trapping in Bolivian dry forests. *Studies on Neotropical Fauna and Environment* **41**:169–177.
70. Daly, B., Power, J., Camacho, G., Traylor-Holzer, K., Barber, S., Catterall, S., Fletcher, P., Martins, Q., Martins, N., Owen, C., Thal, T. and Friedmann, Y. (Eds.). 2005. Leopard (*Panthera pardus*) PHVA. Workshop report. Conservation Breeding Specialist Group (SSC/IUCN)/CBSG South Africa. Endangered Wildlife Trust.
71. Dar, N. I., Minhas, R. A., Zaman, Q. and Linkie, M. 2009. Predicting the patterns, perceptions and causes of human–carnivore conflict in and around Machiara National Park, Pakistan. *Biological Conservation* xxx (2009) xxx–xxx.

72. Davidson, Z. 2009. Lion ecology and socio-spatial impacts of trophy hunting in Zimbabwe. PhD Thesis, Oxford University, UK.

73. De Boer, W. F. and D. S. Baquete. 1998. Natural resource use, crop damage and attitudes of rural people in the vicinity of Maputo Elephant Reserve, Mozambique. *Environmental Conservation* **25**:208-218. http://dx.doi.org/10.1017/S0376892998000265

74. Debshan rainfall record sheet (1992-2014), unpublished data.

75. Delibes-Mateos, M., Diaz-Fernandez, S., Ferreras, P., Vinuela, J. and Arroyo, B. 2013. The Role of Economic and Social Factors Driving Predator Control in Small-Game Estates in Central Spain. *Ecology and Society* **18**: 1-14.

76. Deodatus, F. 2000. Wildlife damage in rural areas with emphasis on Malawi. In: Prins, H. H. T., Grootenhuis, J. G. and Dolan, T. T. (Eds.) 2000. *Wildlife conservation by sustainable use*. Kluwer Academic Publishers, Boston, Massachusetts. pp: 115–140. http://dx.doi.org/10.1007/978-94-011-4012-6_7

77. Di Bitetti, M. S., Paviolo, A. and Di Angelo, C. 2006. Density, habitat use and activity patterns of ocelots (*Leopardus pardalis*) in the Atlantic Forest of Misiones, Argentina. *Journal of Zoology* **270**: 153-163.

78. Dickman A. J., Hazzah, L., Carbone, C.,and Durant, S. M. 2014 Carnivores, culture and ‘contagious conflict’: Multiple factors influence perceived problems with carnivores in Tanzania’s Ruaha landscape. *Biological Conservation* **178**: 19–27

79. Dickman, A. 2008. Key determinants of conflict between people and wildlife, particularly large carnivores, around Ruaha National Park, Tanzania. PhD Thesis, University College, London.

80. Dickman, A. J. 2010. Complexities of conflict: the importance of considering social factors for effectively resolving human-wildlife conflict. *Animal Conservation* **13**(5): 458-466.

81. Dickman, A.J., Macdonald, E.A. and Macdonald, D.W. 2011. A review of financial instruments to pay for predator conservation and encourage human–carnivore coexistence. Proceedings of the National Academy of Sciences.

82. Dillon, A. and Kelly, M. J. 2007. Ocelot *Leopardus pardalis* in Belize: the impact of trap spacing and distance moved on density estimates. *Oryx* **41**: 469–477.

83. Dillon, A. and Kelly, M. J. 2008. Ocelot home range, overlap and density: comparing radio telemetry with camera trapping. *Journal of Zoology* **275**(4): 391-398.

84. Dirzo, R. and Miranda, A. 1990. Contemporary Neotropical defaunation and the forest structure, function, and diversity—a sequel to John Terborgh. *Conservation Biology* **4**:444–447.
85. du Preez, B., Groom, R., Mundy, M. and Loveridge, A. 2011. Results of the Bubye Valley Conservancy spoor survey. WildCRU, Unpublished Report. 16pp
86. Dunham, K. M., Robertson, E. F. and Swanepoel, C. M. 2003. Population decline of tsessebe antelope (*Damaliscus lunatus lunatus*) on a mixed cattle and wildlife ranch in Zimbabwe. *Biological Conservation* **113**: 111–124.
87. Dwyer, D. and Scampion, J. 1995. *Work out psychology: Advanced Level*. Palgrave, Macmillan.
88. Eagly, A.H. and Chaiken, S. 1993. *The psychology of attitudes*. Harcourt Brace Jovanovich College Publishers, Fort Worth, Texas.
89. Eaton, R. L. 1978. The conservation of the leopard in Africa: towards an authentic philosophy of conservation. *Carnivore* **1**(3/4): 82- 149.
90. Efford, M. 2004. Density estimation in live-trapping studies. *Oikos* **106**: 598-610.
91. Efford, M. G., Dawson, D. K. and Borchers, D. L. 2009. Population density estimated from locations of individuals on a passive detector array. *Ecology* **90**: 2676-2682.
92. Efford, M. G., Dawson, D. K. and Robbins, C. S. 2004. DENSITY: software for analysing capture-recapture data from passive detector arrays. *Animal Biodiversity and Conservation* **27**: 217-228.
93. Eisenberg, J.F. and Lockhart, M. 1972. An ecological reconnaissance of Wilpattu National Park, Ceylon. *Smithson. Contrib. Zool*. **101**: 1–118.
94. Elliot, W. 2004. Solving conflicts between Asian big cats and humans: A portfolio of conservation action. Global species programme, WWF International.
95. Engeman, R. M. 2005. Indexing principles and a widely applicable paradigm for indexing animal populations. *Wildlife Research* **32**:203– 210.
96. Eriksson, M. 2013. Attitude stability in a changing carnivore context: The foundations of attitudes towards the Swedish wolf policy. In: Lundmark, L. and Sandström, C. (Eds.). *Natural resources and regional development theory*. pp: 98-123. Umeå: Institutionen för geografi och ekonomisk historia, Umeå universitet GERUM Kulturgeografisk arbetsrapport

97. Espartosa, K. D., Pinotti, B. T. and Pardini, R. 2011. Performance of camera trapping and track counts for surveying large mammals in rainforest remnants. *Biodiversity and Conservation* **20**(12): 2815–29.
98. FAO (Food and Agriculture Organisation of the United Nations). 2006. Fertiliser use by crop in Zimbabwe. FAO Report, Rome.
99. Ferreira, S.M. and Funston, P.J. 2010. Estimating lion population variables: prey and disease effects in Kruger National Park, South Africa. *Wildlife Research* **37:** 194–206.
100. Fitzgerald, K. 2012. Understanding the Ecological, Economic and Social Context of Conservancies in Zimbabwe. African Wildlife Foundation, Harare.
101. Fletcher, R. 2010. Neoliberal Environmentality: Towards a Poststructuralist Political Ecology of the Conservation Debate. *Conservation and Society* **8**(3): 171-181.
102. Foddy, W. 1993. *Constructing questions for interviews and questionnaires: Theory and practice in social research*. Cambridge University Press, Cambridge.
103. Foster, R. J. 2008. The ecology of jaguars (*Panthera onca*) in a human-influenced landscape. PhD thesis, University of Southampton, Southampton, UK.
104. Foster, R. J. and Harmsen, B. J. 2012. A Critique of Density Estimation from Camera-Trap Data. *The Journal of Wildlife Management* **76**: 224-236.
105. Frank, L., Hemson, G., Kushnir, H. and Packer, C. 2006. Lions, conflict and conservation in Eastern and Southern Africa. In: Eastern and Southern African Lion Conservation Workshop. Johannesburg, South Africa.
106. Frank, L., Simpson, D. and Woodroffe, R. 2003. Foot snares: an effective method for capturing african lions. *Wildlife Society Bulletin* **31**(1): 309-314
107. Freckleton, R. P. 2011. Dealing with collinearity in behavioural and ecological data: Model averaging and the problems of measurement error. *Behavioral Ecology and Sociobiology* **65:** 91–101.
108. Friedmann, Y. and Daly, B. (Eds.). 2004. *Distribution of the Leopard in South Africa*. Red Data Book of the Mammals of South Africa
109. Friedmann, Y. and Traylor-Holzer, K. 2008. Leopard (*Panthera pardus*) case study. NDF workshop case studies, WG 5 – Mammals, CASE STUDY 4, Panthera pardus, SOUTH AFRICA.

110. Fulton, D. C., Manfredo, M.J. and Lipscomb, J. 1996. Wildlife value orientations: A conceptual and measurement approach. *Human Dimensions of Wildlife* **1**: 24-47.

111. Funston, P. J., Frank, L., Stephens, T., Davidson, Z., Loveridge, A., Macdonald, D. M., Durant, S., Packer, C., Mosser, A. and Ferreira, S. M. 2010. Substrate and species constraints on the use of track incidences to estimate African large carnivore abundance. *Journal of Zoology* **281**: 56-65

112. Gandiwa, E., Heitkönig, I. M. A., Lokhorst, A. M., Prins, H. H. T. and Leeuwis, C. 2013. CAMPFIRE and human-wildlife conflicts in local communities bordering northern Gonarezhou National Park, Zimbabwe. *Ecology and Society* **18**(4):7. http://dx.doi.org/10.5751/ES-05817-180407.

113. Gangås, K. E. 2014. Attitudes towards large carnivores and acceptance of illegal hunting- The importance of social attitudes and scales in large carnivore management. PhD thesis. HedMark University College, -

114. García, K. P., Ortiz, J. C., Vidal, M. and Rau, J. M. 2010. Morphometrics of the tracks of Puma concolor: Is it possible to differentiate the sexes using measurements from captive animals? *Zoological Studies* **49**(4): 577-582

115. Garshelis, D.L. 1992. Mark-recapture density estimation for animals with large home ranges. In: McCullough, D. R. and Barrett, R. H. (Eds.). *Wildlife 2001: Populations*. pp. 1098–1111. Elsevier Applied Science, New York

116. Gerber, B., Karpanty, S. M., Crawford, C., Kotschwar, M. and Randrianantenaina, J. 2010. An assessment of carnivore relative abundance and density in the eastern rainforests of Madagascar using remotely-triggered camera traps. *Oryx* **44**: 219-222.

117. Gerrodette T. 1987. A power analysis for detecting trends. *Ecology* **68**:1364–1372.

118. Gese, E. M. 2001. Monitoring of terrestrial carnivore populations. In: Gittleman, J. L., Funk, S. M., Macdonald, D. and Wayne, R. K. (Eds.). *Carnivore conservation*. . pp: 372-396 Cambridge University Press, Cambridge.

119. Gittleman, J. L., Funk, S. M., MacDonald, D. and Wayne, R. K. 2001. Why ‘carnivore conservation’? In: Gittleman, J. L., Funk, S. M., MacDonald, D. and Wayne, R. K. 2001. (Eds). 2001. *Carnivore conservation*, pp. 1-7. Cambridge University Press, Cambridge

120. Gliem, J. A. and Gliem, R. R. 2003. Calculating, Interpreting, and Reporting Cronbach's Alpha Reliability Coefficient for Likert-Type Scales.

121. Government of Zimbabwe. 2002. Wildlife-based land reform policy. Government of Zimbabwe, Harare.

122. Grant, T. 2012. Leopard population density, home range size and movement patterns in a mixed land use area of the Mangwe district of Zimbabwe. MSc Thesis. Rhodes University, Grahamstown, South Africa.

123. Grant, W. M. 2008. *Into the Thorns: Hunting the cattle-killing leopard of the Matobo Hills*. African Hunter, Harare, Zimbabwe

124. Gray, T. N. E. and Prum, S. 2012. Leopard density in post-conflict landscape, Cambodia: evidence from spatially explicit capture-recapture. *Journal of Wildlife Management* **76**: 163-169.

125. Gray, T. N. E., Pin, C., Phan, C., Crouthers, R., Kamler, J. F. and Prum, S. 2014. Camera-trap records of small carnivores from eastern Cambodia, 1999–2013. *Small Carnivore Conservation* **50**: 20–24.

126. Gregory, R. D., Gibbons, D. W. and Donaldson, R. 2004. Bird census and survey techniques. In: Sutherland, W. J., Newton, I. and Green, R. E. (Eds.). *Bird ecology and conservation*: *a handbook of techniques*. pp. 17-56. Oxford University Press. Oxford.

127. Grieg-Smith, P. 1957. *Quantitative plant ecology*. Butterworths, London.

128. Griffin, K., Khan, A. R. and Ickowitz, A. 2001. *Poverty and the Distribution of Land.* Department of Economics, University of California, Riverside.

129. Grigione, M. M., Burman, P. and Bleich, V. C. 1999. Identifying individual mountain lions *Felis concolor* by their tracks: refinement of an innovative technique. *Biological Conservation* **88**:25–32.

130. Groom, R. 2009. Carnivore Densities in Gonarezhou National Park: Results of the May/June 2009 Spoor Survey, Lowveld Wild Dog Project, Zimbabwe.

131. Groom, R. 2013. Carnivore densities in the Savé Valley Conservancy: Results of the 2012 spoor survey & wild dog monitoring project. African Wildlife Conservation Fund.

132. Gros, P.M. 2002. The status and conservation of the cheetah *Acinonyx jubatus* in Tanzania. *Biological Conservation* **106:** 177-185.

133. Gusset, M., Swarner, M.J., Mponwane, L., Keletile, K. and McNutt, J.W. 2009. Human-wildlife conflict in northern Botswana: livestock predation by endangered African wild dog *Lycaon pictus* and other carnivores. *Oryx* **43:** 67-72.

134. Hafer, D. J. and Hygnstrom, S. E. 1991. "Attitudes of Nebraska sheep producers towards predators" Great Plains Wildlife Damage Control Workshop Proceedings. Paper 19. http://digitalcommons.unl.edu/gpwdcwp/19.

135. Haines, A. M., Janecka, J. E., Tewes, M. E., Grassman, L. I. Jr. and Morton, P. 2006. The importance of private lands for ocelot *Leopardus pardalis* conservation in the United States. *Oryx* **40**:1–5.

136. Hair, J. F., Anderson, R., Tatham, R. L. and Black, W. C. 2006. *Multivariate Data Analysis*. Upper Saddle River, New Jersey.

137. Hamilton, P. H. 1986b. Status of the leopard in Kenya, with reference to sub-Saharan Africa. Pp. 447-459 in S.D. Miller and D.D. Everett, eds. Cats of the world: biology, conservation and management National Wildlife Federation, Washington, D.C.

138. Hamilton, P. H. 1981. The leopard (*Panthera pardus*) and the cheetah (*Acinonyx jubatus*) in Kenya. Unpubl. report to the U.S. Fish and Wildlife Service.

139. Hamilton, P. H. 1986a. Status of the leopard in Kenya, with reference to sub-Saharan Africa. In: Miller, S. D. and Everett, D. D. (Eds.) 1986. *Cats of the world: biology, conservation and management*. pp: 447-459. National Wildlife Federation, Washington, D.C.

140. Hanlon, J., Manjengwa, J. and Smart, T. 2012. *Zimbabwe Takes Back its Land*. Kumarian Press, Sterling.

141. Harmsen, B. J. 2006. The use of camera traps for estimating abundance and studying the ecology of jaguars (*Panthera onca*). PhD thesis, University of Southampton, Southampton, UK.

142. Harmsen, B. J., Foster, R. J. and Doncaster, C. P. 2011. Heterogeneous capture rates in low density populations and consequences for capture–recapture analysis of camera-trap data. *Population Ecology* **53**: 253-259

143. Hayward, G. D., Miquelle, D. G., Smirnov, E. N. and Nations, C. 2002. Monitoring Amur tiger populations: characteristics of track surveys in snow. *Wildlife Society Bulletin* **34**: 67-73

144. Heilbrun, R. D., Silvy, L. J., Peterson, M. J. and Tewes, M. E. 2006. Estimating bobcat abundance using automatically triggered cameras. *Wildlife Society Bulletin* **34**:69–73.

145. Hemson, G. 2003. The Ecology and conservation of lions: Human-wildlife conflict in semi-arid Botswana. Ph.D. Thesis, University of Oxford, Oxford, U. K., 213pp.

146. Henschel, J.R. and Skinner, J.D. 1990. The diet of the spotted hyaenas *Crocuta crocuta* in The Kruger National Park. *African Journal of Ecology* **28**: 69-82.

147. Henschel, P. and Ray, J. 2003. Leopards in African rainforests: survey and monitoring techniques. Wildlife Conservation Society Report, Global Carnivore Program, New York, USA.

148. Henschel, P., Hunter, L., Breitenmoser, U., Purchase, N., Packer, C., Khorozyan, I., Bauer, H., Marker, L., Sogbohossou, E. & Breitenmoser-Wursten, C. 2008. *Panthera pardus*. The IUCN Red List of Threatened Species. Version 2014.3. <www.iucnredlist.org>.

149. Heydon, M. J., Reynolds, J. C. and Short, M. J. 2000. Variation in abundance of foxes (*Vulpes vulpes*) between three regions of rural Britain, in relation to landscape and other variables. *Journal of Zoology* **251**: 253-264.

150. Houser, A. M., Somers, M. J. and Boast, L. K. 2009. Spoor density as a measure of true density of a known population of free-ranging wild cheetah in Botswana. *Journal of Zoology* **278**(2): 108-115.

151. http://esa.un.org/wpp/unpp/panel_population.htm.

152. http://www.statoids.com/uzw.html

153. Hunter, L. and Balme, G. 2004. The leopard: The world's most persecuted big cat. In: Endangered Wildlife: Business, ectourism and the environment, Twelfth Vision Annual. Endangered Wildlife Trust. pp: 88-94.

154. Hutton, J., Adams, W. M. and Murombedzi, J. C. 2005. Back to the barriers? Changing narratives in biodiversity conservation. *Forum for Development Studies* **32**:341–370. http://dx.doi.org/10.1080/08039410.2005.9666319.

155. IUCN (International Union for Conservation of Nature). 2004. A global species assessment. IUCN Red List of Threatened Species.

156. IUCN. 2005. Benefits beyond boundaries. *Proceedings of the V$^{th}$ IUCN World Parks Congress.* IUCN, Gland, Switzerland and Cambridge.

157. IUCN. 2006. Regional conservation strategy for the lion Panthera leo in Eastern and Southern Africa. IUCN SSC Cat Specialist Group, Gland, Switzerland, p. 60.

158. Jackson, R. 1989. Snow leopards (Panthera uncia) in Nepal: home range and movements. *Nat. Geogr. Research* **5**(2): 161- 175.

159. Jackson, R. M., Roe, J. D., Wangchuk, R. and Hunter, D. O. 2006. Estimating snow leopard population abundance using photography and capture-recapture techniques. *Wildlife Society Bulletin* **34**(3): 772-781.

160. Jackson, R., Roe, J., Wangchuk. R. and Hunter, D. 2005. *Surveying snow leopard population with emphasis on camera trapping: A handbook*. The Snow Leopard Conservancy, Sonoma, California. Available at: www.snowleopardconservancy.org

161. Jhala, Y., Qureshi, Q. and Gopal, R. 2011. Can the abundance of tigers be assessed from their signs? *Journal of Applied Ecology* **48**(1): 1-11.

162. Kaartinen, S., M. Luoto, and I. Kojola. 2010. Selection of den sites by wolves in boreal forests in Finland. *Journal of Zoology* **281**(2): 99-104.

**163.** Kansky, R., Kidd, M. and Knight, A. T. 2014. Meta-Analysis of Attitudes toward Damage-Causing Mammalian Wildlife *Conservation Biology* **28** (4): 924–938.

164. Karanth, K. U. 1995. Estimating tiger Panthera tigris populations from camera-trap data using capture-recapture models. *Biological Conservation* **71**: 333-338.

165. Karanth, K. U. and Nichols, J. D. 1998. Estimation of Tiger Densities in India Using Photographic Captures and Recaptures. *Ecology* **79**(8): 2852-2862

166. Karanth, K. U. and Nichols, J. D. 2000. Camera trapping big cats: some questions that should be asked frequently. Wildlife Conservation Society and US Geological Survey. Unpublished notes, (October): 1-17. Available at: http://www.savethejaguar.com/media/file/FINAL

167. Karanth, K. U. and Nichols, J. D. 2002. Monitoring tigers and their prey: a manual for researchers, managers and conservationists in tropical Asia. Centre for Wildlife Studies, Karnataka, India

168. Karanth, K. U. and Sunquist, M. E. 2000. Behavioural correlates of predation by tiger (*Panthera tigris*), leopard (*Panthera pardus*) and dhole (*Cuon alpinus*) in Nagarahole, India. *Journal of Zoology* **250**: 255-265.

169. Karanth, K. U., and Sunquist, M. E. 1995. Prey selection by tiger, leopard and dhole in tropical forests. *Journal of Animal Ecology* **64**: 439-450.

170. Karanth, K. U., Chundawat, R. S., Nichols, J. D. and Kumar, N. S. 2004. Estimation of tiger densities in the tropical dry forests of Panna, Central India, using photographic capture–recapture sampling. *Animal Conservation* **7**: 285-290.

171. Karanth, K. U., Nichols, J. D., Seidensticker, J., Dinerstein, E., David Smith, J. L., McDougal, C., Johnsingh, A. J. T., Chundawat, R. S. and Thapar, V. 2003. Science deficiency in conservation practice: the monitoring of tiger populations in India. *Animal Conservation* **6**: 141-146.

172. Kawanishi, K. and Sunquist, M. E. 2004. Conservation status of tigers in a primary rainforest of Peninsular Malaysia. *Biological Conservation* **120**: 329-344.

173. Kellert, S.R. and Berry, J.K. 1987. Attitudes, knowledge and behaviours toward wildlife as affected by gender. *Wildlife Society Bulletin* **15**: 363-371.

174. Kelly, M. J. 2003. Jaguar monitoring in the Chiquibul Forest, Belize. *Caribbean Geography* **13**: 19-32.

175. Kelly, M. J., Noss, A. J., Di Bitetti, M. S., Maffei, L., Arispe, R. L., Paviolo, A., De Angelo, C. D. and Di Blanco, Y. E. 2008. estimating puma densities from camera trapping across three study sites: Bolivia, Argentina, and Belize. *Journal of Mammalogy* **89**: 408-418.

176. Kissui, B.M. and Packer, C. 2004. Top down regulation of a top predator: lions in Ngorongoro Crater. *Proc. Roy. Soc. Lond*. **24**: 200–210.

177. Kotchen, M.J. and Reiling, S.D. 2000. Environmental attitudes, motivations, and contingent valuation of non use values: a case study involving endangered species. *Ecological Economics* **32**: 93-107.

178. Kucera, T. E. and Zielinski, W. J. 1995. The case of forest carnivores: small packages, big worries. *Endangered Species Update* **12**: 1-6.

179. Kutner, M. H., Nachtsheim, C. J. and Neter, J. 2004. *Applied Linear Regression Models*. 4th Edition. McGraw-Hill, Irwin.

180. Kwashirai, V.C. 2009. Ecological and poverty impacts of Zimbabwe's land struggles: 1980 to present. *Global Environment* **2**: 222-253.

181. Lagendijk, D. D. G. and Gusset, M. 2008. Human-carnivore coexistence on communal land bordering the greater Kruger area, South Africa. *Environmental Management* **42**: 971–976.

182. Lindsey, P. A. and Mandisodza-Chikerema, R. 2012. Preliminary Non-Detriment Finding Assessment: Preliminary report for leopards in Zimbabwe Preliminary NDF Workshop Report December 2012. Workshop facilitated by Newton, D. J.

183. Lindsey, P.A., du Toit, J.T. and Mills, M.G.L. 2005. Attitudes of ranchers towards African wild dogs *Lycaon pictus*: conservation implications on private land. *Biological Conservation* **125**: 113-121.

184. Lindsey, P.A., Romañach, S.S., Tambling, C.J., Chartier, K. and Groom, R. 2011. Ecological and financial impacts of illegal bushmeat trade in Zimbabwe. *Oryx* **45:** 96-111.

185. Linnell, J. D. C., Swenson, J. E., and Anderson, R. 2001. Predators and people: Conservation of large carnivores is possible at high human densities if management policy is favourable. *Animal Conservation* **4:** 345-349.

186. Liu, F., McShea, W.J., Garshelis, D.L., Zhu, X., Wanga, D. and Shao, L., 2011. Human-wildlife conflicts influence attitudes but not necessarily behaviors: Factors driving the poaching of bears in China. *Biological Conservation* **144**(2011): 538-547.

187. López-bao, J. V., Rodríguez, A. and Palomares, F. 2010. Abundance of wild prey modulates consumption of supplementary food in the Iberian lynx. *Biological Conservation* **143**(5): 1245-1249.

188. Lubilo, R. and Child, B. 2010. The rise and fall of Community-Based Natural Resource Management in Zambia's Luangwa Valley: An Illustration of Micro- and Macro- Government Issues. In: Nelson, F. (Ed). 2010. *Community Rights, Conservation and Contested Land: The politics of Natural Resource Governance in Africa*. Earthscan Ltd, London. pp: 202-226.

189. Maccoby, E. E. and Maccoby, N. 1954. The interview: A tool of social science. In: Lindzey, G. (Ed.). 1954. *Handbook of social psychology*. Addison-Wesley, Cambridge. pp: 449-487.

190. Macdonald, D.W. and Sillero-Zubiri, C. 2002. Dimensions of the problem. In: Loveridge, A.J., Lynam, T. and Macdonald, D.W. (Eds). Lion conservation research, Workshop 2: Modeling conflict. Wildlife Conservation Research Unit, University of Oxford, Oxford, UK:

191. MacFadyen, D. 2013. Shangani game count report 2013. Unpublished data.

192. Madden, F. M. 2008. The growing conflict between humans and wildlife: law and policy as contributing and mitigating factors. *Journal of International Wildlife Law & Policy* **11**:189–206. http://dx.doi.org/10.1080/13880-290802470281.

193. Maddox, T. 2002. *The ecology of cheetahs and other large carnivores in a pastoralist-dominated buffer zone*. University of London, London.

194. Maffei, L., Cuellar, E. and Noss, A. 2004. One thousand jaguars (*Panthera onca*) in Bolivia's Chaco? Camera trapping in the Kaa-Iya National Park. *Journal of Zoology* **262**: 295–304.

195. Maffei, L., Noss, A. J., Cuéllar, E. and Rumiz, D. I. 2005. Ocelot (*Felis pardalis*) population densities, activity, and ranging behaviour in the dry forests of eastern Bolivia: data from camera trapping. *Journal of Tropical Ecology* **21**: 349–353.

196. Majic, A. and Bath, A. J. 2010. "Changes in attitudes toward wolves in Croatia." *Biological conservation* **143**(1): 255-260.

197. Mamimine P.W. 2003. "Administration by Consensus: A Quest for Client-Centred Institutional Structures for Land Administration in Zimbabwe". In: Roth, M and Gonese, F. (Eds.). 2003. *Delivering Land and Securing Rural Livelihoods: Post-Independence Land Reform and Resettlement in Zimbabwe*. CASS, University of Zimbabwe and the Land Tenure Center, University of Wisconsin-Madison

198. Maputla, N. W., Chimimba, C. T. and Ferreira, S. M. 2013. Calibrating a camera trap-biased mark-recture sampling design to survey the leopard population in the N'wanetsi Concession, Kruger National Park, South Africa. *African Journal of Ecology* **51**:422–30.

199. Marker, L. L. and A. J. Dickman. 2005. Factors affecting leopard (Panthera pardus) spatial ecology with particular reference to Namibian farmlands. *South African Journal of Wildlife Research* **35**(October):105–15.

200. Marker, L. L., Muntifering, J. R., Dickman, A. J., Mills, M. G. L. and MacDonald, D. W. 2003. Quantifying prey preferences of free-ranging Namibian cheetahs. *South African Journal of Wildlife Research* **33**: 43–53.

201. Marker, L.L., Mills, M.G.L. and Macdonald, D.W. 2003. Factors influencing perceptions of conflict and tolerance toward cheetahs on Namibian farmlands. *Conservation Biology* **17**: 1290-1298.

202. Marnewick, K., Funston, P. J. and Karanth, K. U. 2008. Evaluating camera trapping as a method for estimating cheetah abundance in ranching areas. *South African Journal of Wildlife Research* **38**(1): 59-65.

203. Marques, T. A., Thomas, L., Martin, S. W., Mellinger, D. K., Jarvis, S., Morrissey, R. P., Ciminello, C.-A. and Dimarzio, N. 2010. Spatially explicit capture–recapture methods to estimate minke whale density from data collected at bottom-mounted hydrophones. *Journal of Ornithology* **152**: 445-455.

204. Martin, R. B. 1986. Communal Areas Management Programme for Indigenous Resources (CAMPFIRE*)*. Revised version. CAMPFIRE Working Document No. 1/86. Branch of Terrestrial Ecology, Department of National Parks and WildLife Management, Harare, Zimbabwe.

205. Martin, R.B. and de Meulenaer, T. 1988. Survey of the status of the leopard (*Panthera pardus*) in sub-Saharan Africa. Secretariat of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, Lausanne.

206. Mberi, M. 2013. Debshan ranch and the holistic alternative- an overview. Presentation at the 4$^{th}$ annual Diamond Route Research Conference 2013. 29 October 2013. De Beers campus, Johannesburg.

207. McCarthy, K. P., Fuller, T. K., Ming, M., McCarthy, T. M., Waits, L. & Jumabaev, K. 2008. Assessing estimators of snow leopard abundance. *Journal of Wildlife Management* **72**: 1826–1833.

208. McKelvey, K. S., and Pearson, D. E. 2001. Population estimation with sparse data: the role of estimators versus indices revisited. *Canadian Journal of Zoology* **79**:1754–1765.

209. Michalski, F., Crawshaw, P. G. Jr., Oliveira, T. G. and Fábian, M. T. 2007. Efficiency of box-traps and leg-hold traps with several bait types for capturing small carnivores (Mammalia) in a disturbed area of Southeastern Brazil. *Revista de Biologí Tropical* **55**:315–320.

210. Miller, B., Dugelby, B., Foreman, D., Martinez Del Rio, C., Noss, R., Phillips, M., Reading, R., Soulé, M. E., Terborgh, J. and Willcox, L. 2001. The importance of large carnivores to healthy ecosystems. *Endangered Species Update* **18**: 202–210.

211. Miller, C. M. 2005. Jaguar density in Gallon Jug Estate, Belize. Unpublished report. Wildlife Conservation Society, Gallon Jug, Belize.

212. Miller, C. M. 2006. Jaguar density in Fireburn, Belize. Unpublished report. Wildlife Conservation Society, Gallon Jug, Belize

213. Miller, C. M. and B. Miller. 2005. Jaguar density in La Selva Maya. Unpublished report. Wildlife Conservation Society, Gallon Jug, Belize

214. Mills, M. G. L. 1984. Prey selection and feeding habits of the large carnivores in the southern Kalahari. *Koedoe*: 281-294.

215. Mills, M.G.L. 1991. Conservation management of large carnivores in Africa. *Koedoe* **34**: 81-90.

216. Mishra, C. 1997. Livestock depredation by large carnivores in the Indian trans-Himalaya: conflict perceptions and conservation prospect. *Environmental Conservation* **24:** 338-343.

217. Miththapala, S., Seidensticker, J., Phillips, L. G., Fernando, S. B. U. and Smallwood, J. A. 1989. Identification of individual leopards (*Panthera pardus kotiya*) using spot pattern variation. *Zoological Society of London* **218**: 527-536.

218. Mondal, K., Sankar, K., Qureshi, Q., Gupta, S. and Churasia, P. 2012. Estimation of population and survivorship of leopard *Panthera pardus* (Carnivora: Felidae) through photographic capture-recapture sampling in western India. *World Journal of Zoology* **7** (1): 30 – 39.

219. Monod, T. 1965. Comment-Discussion Section. In: Howell, F.C. and Bourliere, F. (Eds.). African ecology and human evolution. Pp. 547- 654. Methuen, London.

220. Moyo, S. (Ed.). 2000. *Zimbabwe environmental dilemma: balancing resource inequities*. Zimbabwe Environmental Research Organization Report, Harare.

221. Moyo, S., Robinson, P., Katerere, Y., Stevenson, S and Gumbo, D. 1991. *Zimbabwe's dilemma: Balancing Resource Inequality*. ZERO. Harare. Zimbabwe

222. Mugandani, R, Wuta, M, Makarau, A and Chipindu, B. 2012. Re-classification of Agro-ecological Regions of Zimbabwe inconformity with climate variability and change. *African Crop Science Journal* **20**(2): 361 – 369.

223. Murindagomo, F. 1989. The Administration and Management of Wildlife in the Communal Lands: The Case of Dande. *Zimbabwe Science News* **23**: 71-74.

224. Murombedzi, J. C. 2010. Agrarian social change and Post-Colocial Natural Resource Management Interventions in Southern Africa's 'Communal Tenure' Regimes. In: Nelson, F. (Ed). 2010. *Community Rights, Conservation and Contested*

*Land: The politics of Natural Resource Governance in Africa*. Earthscan Ltd, London. pp: 32-55.

225. Murphree, M.W. and Metcalfe, S. C. 1997. Conservancy Policy and the CAMPFIRE Programme in Zimbabwe Centre for Applied Social Sciences Technical Paper Series 1/97. University of Zimbabwe.

226. Myers, N. 1976. *The Leopard Panthera pardus in Africa*. IUCN Monograph no. 5

227. NACSO. 2009. Namibia's communal conservancies: a review of progress 2008. NACSO, Windhoek.

228. Naughton-Treves, L., Grossberg, R. and Treves, A. 2003. Paying for tolerance: rural citizens' attitudes toward wolf depredation and compensation. *Conservation Biology* **17**: 1500-1511.

229. Naves, J., Fernandez-Gil, A. and Delibes, M. 2001. Effects of recreation activities on a brown bear family group in Spain. *Ursus* **12**: 135-140.

230. Ndebele, N., Mtimuni, J. P., Mpofu, I. D. T., Makuza, S. and Mumba, P. 2005. The status of selected minerals in soil, forage and beef cattle tissues in a semi-arid region of Zimbabwe. *Tropical Animal Health and Production* **37**: 381-393.

231. Neely, C. L. and Butterfield, J. 2004. Holistic management of African rangelands. *Leisa Magazine* **20**(4): 26-28.

232. Ngoprasert, D., Lynam, A. J. and Gale, G. A. 2007. Human disturbance affects habitat use and behaviour of Asiatic leopard Panthera pardus in Kaeng Krachan National Park, Thailand. *Oryx* **41**(3):343–51.

233. Ngwenya, B. T. N. 2015. Diet composition and prey preferences of leopards (*Panthera pardus*) across season at Debshan ranch. BSc thesis, *in prep.* National University of Science and Technology, Bulawayo, Zimbabwe.

234. Nichols, J. D. 1992. Capture-recapture models: using marked animals to study population dynamics. *Bioscience* **42**: 94-102.

235. Nichols, J. D., Bailey, L. L., O'Connell, A. F. Jr., Talancy, N. W., Grant, E. H. C. . Gilbert, A. T., Annand, E., Husband, T. and Hines, J. 2008. Occupancy estimation using multiple detection devices. *Journal of Applied Ecology* **45**:1321–1329.

236. Nichols, J. D., Thomas, L. and Conn, P. B. 2009. Inferences about landbird abundance from count data: recent advances and future directions. In: Thomson, D.

L., Cooch, E. G. and Conroy, M. J. (Eds). *Modeling demographic processes in marked populations*. Pp 201–235. Springer, New York, USA.

237. NLMP (National Leopard Management Programme). 2008. Towards sustainable utilization of leopard in Zimbabwe: Determining the status and distribution of leopard in Zimbabwe, and assessing the population dynamics of leopard populations under five different utilisation systems in Zimbabwe. Zambezi Society,Unpublished Project Proposal.

238. Nori, J., Lescano, J. N., Illoldi-Rangel, P., Frutos, N., Cabrera, M. R. and Leynaud, G. C. 2013. The conflict between agricultural expansion and priority conservation areas: Making the right decisions before it is too late. *Biological Conservation* **159**: 507–513.

239. Norris, D., Peres, C. A. and Michalski, F. 2008. Terrestrial mammal responses to edges in Amazonian forest patches: a study based on track stations. *Mammalia* **72**:15–23.

240. Norton, P. 1990. How many leopards? A criticism of Martin & de Meulenaer's population estimates for Africa. *South African Journal of Science* **86**: 218-220

241. Nowell, K. and Jackson, P. 1996. *Wild cats: status survey and conservation action plan.* IUCN/SSC Cat Specialist Group, Gland.

242. Ntinda, M. N. 2007. A Review of A DNA Dataset of Mangrove Populations from Las Perlas Archipelago, Panama. Submitted as part assessment for the degree of Master of Science in Marine Resource Development and Protection Centre for Marine Biodiversity and Biotechnology School of Life Sciences, Heriot-Watt University, Edinburgh.

243. Nyoni, W. and Williams, S. 2008. *Living with Predators: A farmer's guide*. Marwell Zimbabwe Trust, Bulawayo.

244. Nzongola-Ntalaja, G. 1999. Ethnicity and state politics in Africa. *African journal of international affairs* **2**(1).

245. O'Connell, A. F., Nichols, J. D. and Karanth, K. U. (eds). 2011. *Camera traps in Animal Ecology Methods and Analyses*. Springer, Tokyo.

246. Oates, J. F. 1999. *Myth and reality in the rainforest: how conservation strategies are failing in West Africa*. University of California Press, Berkeley, California.

247. Odden, M., Athreya, V., Rattan, S., and Linnell, J. D. C. 2014. Adaptable neighbours: Movement patterns of GPS-Collared leopards in human dominated landscapes in India. *PLoS ONE* **9**(11): e112044. doi:10.1371/journal.pone.0112044.

248. Ogada, M. O., Woodroffe, R., Oguge, N. O. and Frank, L. G. 2003. Limiting depredation by African carnivores: the role of livestock husbandry. *Conservation Biology* **17**: 1521–1530.

249. Ogada, M.O., Woodroffe, R., Oguge, N. and Frank, L.G. 2003. Limiting depredation by African carnivores: The role of livestock husbandry. *Conservation Biology* **17**: 1521-1530.

250. Otis, D., Burnham, K., White, G. and Anderson, D. 1978. Statistical inference from capture data on closed animal populations. *Wildlife Monographs* **62**: 1-135

251. Ott, T., Kerley, G. I. H. and Boshoff, A. F. 2007. Preliminary observations on the diet of leopards (*Panthera pardus*) from a conservation area and adjacent rangelands in the Baviaanskloof region, South Africa. *African Zoology* **42**: 31–37.

252. Packer, C., Brink, H., Kissui, B. M., Maliti, H., Kushnir, H. and Caro, T. 2011. Effects of trophy hunting on lion and leopard populations in Tanzania. *Conservation Biology* **25**(1): 142-153.

253. Packer, C., Ikanda, D., Kissui, B. and Kushnir, H. 2005. Lion attacks on humans in Tanzania. *Nature* **436:** 927–928.

254. Palmeira, F.B.L., Crawshaw Jr, P.G., Haddad, C.M., Ferraz, K.M.P.M.B. and Verdade, L.M. 2008. Cattle depredation by puma *Puma concolor* and jaguar *Panthera onca* in central-western Brazil. *Biological Conservation* **141**: 118-125.

255. Palmer, H. 2004. Conditional Maximum Likelihood Estimation. In Lewis-Beck, M. S., Bryman, A. and Liao, T. F. (Eds.). *The SAGE Encyclopedia of Social Science Research Methods.* pp. 168-169. Thousand Oaks, CA: Sage Publications, Inc. doi: http://dx.doi.org/10.4135/9781412950589.n153

256. Parker, D. M., Whittington-Jones, B. M., Bernard, R. T. F. and Davies-Mostert, H. T. (2014) Attitudes of Rural Communities Toward Dispersing African Wild Dogs in South Africa. *Human Dimensions of Wildlife*: *An International Journal* **19**(6): 512-522. DOI:10.1080/10871209.2014.926575.

257. Parks and Wild Life Act [Chapter 20: 14]. Part 1. (1975) and Revised Edition (1996).

258. Parmenter, R. R., Yates, T. L., Anderson, D. R., Burnham, K. P., Dunnum, J. L., Franklin, A. B., Friggens, M. T., Lubow, B. C., Miller, M., Olson, G. S., Parmenter, C. A., Pollard, J., Rexstad, E., Shenk, T. M., Stanley, T. R. and White, G. C. 2003. Small-mammal density estimation: A field comparison of grid-based vs. web-based density estimators. *Ecological Monographs* **73**:1–26.

259. Pazvakavambwa, S. and Hungwe, V. 2009. Land redistribution in Zimbabwe. In: Binswanger-Mkhize, H. P., Bourguignon, C. and van den Brink, R. J. E. (Eds.). 2009. *Agricultural land redistribution: Towards greater concensus*. World Bank, Washington, D. C. pp: -

260. Peel, M. C., Finlayson, B. L. and McMahon, T. A. 2007. Updated world map of the Köppen-Geiger climate classification. *Hydrology and Earth System Sciences* **11**: 1633-1644.

261. Pitman, R. T. 2012. The Conservation biology and ecology of the African leopard Panthera pardus pardus. *The Plymouth Student Scientist* **5**(2):581–600.

262. Pledger, S. 2000. Unified maximum likelihood estimates for closed capture–recapture populations using mixtures. *Biometrics* **56**:434–442.

263. Policy brief. 2012. Equitable benefit sharing of natural resources in Mara River Basin. **CIANEA** (Community-Based Impact Assessment Network for Eastern Africa) (U) Ltd. Kenya and Tanzania.

264. Prugh, L. R., Stoner, C. J., Epps, C. W., Bean, W. T., Ripple, W. J., Laliberte, A. S. and Brashares, J. S. 2009. The Rise of the Mesopredator. *BioScience* **59**: 779-791.

265. Purchase, G. K. 2006. An assessment of the trophy hunting of leopard (*Panthera pardus*) in Marula ICA (Local level) and Matabeleland South (Provincial level) in Zimbabwe: Is the current system sustainable? Unpublished report, commissioned by the Zimbabwe Parks and Wildlife Management Authority.

266. Purchase, G. K. 2012. Impacts of holistic management on depredation rates: A case study of Debshan Ranch, Zimbabwe. Presentation at the 3rd annual Diamond Route Research Conference 2013. 30 October 2012. De Beers campus, Johannesburg**.**

267. Rabinowitz, A. and Nottingham, B. 1986. Ecology and behavior of the jaguar *(Panthera onca)* in Belize, Central America. *Journal of Zoology, London* **210**:149-159.

268. Ray J. C., Hunter, L. T. B. and Zigouris, J. 2005. Setting conservation and research priorities for larger African carnivores. New York: Wildlife Conservation Society. 203 p

269. Real statistics using excel: © 2014, Charles Zaiontz, All rights reserved.

270. Reason, C. J. C. and Keibel, A. 2004. Tropical Cyclone Eline and Its Unusual Penetration and Impacts over the Southern African Mainland. American Meteorological Society 19: 789-805.

271. Rexstad, E. A. and Burnham, K. P. 1992. *User's Guide for Interactive Program CAPTURE: Abundance Estimation of Closed Animal Populations*. Colorado Cooperative Fish and Wildlife Research Unit, Colorado.

272. Richardson, R. B., Fernandez, A.. Tschirley, D. and Tembo. G. 2012. Wildlife conservation in Zambia: impacts on rural household welfare. *World Development* **40**:1068-1081. http://dx.doi.org/10.1016/j.worlddev.2011.09.019

273. Rihoy, L. and Maguranyanga, B. 2010. The Politics of Community-Based Natural Resource Management in Botswana. In: Nelson, F. (Ed). 2010. *Community Rights, Conservation and Contested Land: The politics of Natural Resource Governance in Africa*. Earthscan Ltd, London. pp: 55-78.

274. Ripple, W. J., Estes, J. A., Beschta, R. L., Wilmers, C. C., Ritchie, E. G., Hebblewhite, M., Berger, J., Elmhagen, B., Letnic, M., Nelson, M. P., Schmitz, O. J., Smith, D. W., Wallach, A. D. and Wirsing, A. J. 2014. Status and ecological effects of the world's largest carnivores. *Science* **343**: 1241484–1–1241484–11.

275. Ritter, N. 2010. "Understanding a widely misunderstood statistic: Cronbach's alpha". Paper presented at Southwestern Educational Research Association (SERA) Conference 2010: New Orleans, Los Angeles ED526237.

276. Roberge, J.-M. and Angelstam, P. 2004. Usefulness of the umbrella species concept as a conservation tool. *Conservation Biology* **18**: 76–85. doi: 10.1111/j.1523-1739.2004.00450.x

277. Robertson, E. F. 2013. Geology, soils and vegetation of Shangani Ranch**.** unpublished data.

278. Romañach, S., Lindsey, P.A. and Woodroffe, R. 2007. Determinants of attitudes towards predators in central Kenya and suggestions for increasing tolerance in livestock dominated landscapes. *Oryx* **41:** 185-195.

279. Romanach, S.S., Lindsey, P.A. and Woodroffe, R. 2007. Determinants of attitudes towards predators in central Kenya and suggestions for increasing tolerance in livestock dominated landscapes. *Oryx* **41**: 185-195.

280. Royle, J. A. and Young, K. V. 2008. A hierarchical model for spatial capture–recapture data. *Ecology* **89**: 2281–2289.

281. Royle, J. A., Nichols, J. D., Karanth, K. U. and Gopalaswamy, A. M. 2009. A hierarchical model for estimating density in camera-trap studies. *Journal of Applied Ecology* **46**: 118- 127

282. Salom-Pérez, R., Carrillo, E. Sáenz, J. C. and Mora, J. M. 2007. Critical condition of the jaguar *Panthera onca* in Corcovado National Park, Costa Rica. *Oryx* **41**(1):1–7.

283. Santos, J. 1999. Cronbach's alpha: A tool for assessing the reliability of scales. *Journal of Extension* **37**(2): 34-36.

284. Savory, A. 1978. A holistic approach to ranch management using short duration grazing. Pp 555-557. In Hyder, D. N. (Ed.). Proceedings of 1st international range congress. Denver, colo. Soc. Range management publ.

285. ScheepersJ, .L. and Gilchrist, D. 1991. Leopard predation on giraffe calves in the Etosha National Park. *Madoqua* **18**(l): 49.

286. Schiess-Meier, M., Ramsauer, S., Gabanapelo, T. and König, B. 2007. Livestock Predation-Insights From Problem Animal Control Registers in Botswana. *Journal of Wildlife Management* **71**: 1267-1274.

287. Schumann, M. (Ed.) 2004. *Guide to integrated livestock and predator management*, CCF / RISE Namibia, Cheetah Conservation Fund, Windhoek, Namibia.

288. Schüttler, E., Rozzi, R. and Jax, K. 2011. Towards a societal discourse on invasive species management: A case study of public perceptions of mink and beavers in Cape Horn. *Journal for Nature Conservation* 19: 175-184.

289. Scoones, I., Marongwe, N., Mavedzenge, B., Mahenehene, J., Murimbarimba, F. and Sekume, C. 2010. *Zimbabwe's land reform: myths and realities*. James Currey, Woodbridge.

290. Seddon, P. J. and Leech, T. 2008. Conservation short cut, or long and winding road? a critique of umbrella species criteria. *Oryx* **42**(2):240–45.

291. Sharma, D. C. 2004. Disappearing Prey Spurs Leopard Attacks. *Frontiers in Ecology and the Environment* **2**(6) p. 288

292. Sharma, S., Jhala, Y. and Sawarkar, V.B. 2005. Identificationof individual tigers (*Panthera tigris*) from their pugmarks.*Journal of Zoology*. (Lond.) **267:** 9–18.

293. Shepperson, J., Murray, L. G., Cook, S., Whiteley, H. and Kaiser, M. J. 2014. Methodological considerations when using local knowledge to infer spatial patterns of resource exploitation in an Irish Sea fishery. *Biological Conservation* **180** (2014): 214-223.

*294.* Sibanda P. 2010. Comparison of skull sizes from trophy hunted leopards in Zimbabwe. Bsc thesis. National University of Science and Technology, Bulawayo.

295. Sillero-Zubiri, C. and Laurenson, M. K. 2001. Interactions between carnivores and local communities: Conflict or co-existence? In: Gittleman, J.L., Funk, S.M., Macdonald, D.W. and Wayne, R.K. (Eds.). 2001. *Carnivore conservation*. University of Cambridge, Cambridge.

296. Silveira, L., Jácomo, A. T. A., Astete, S., Sollmann, R., Tôrres, N. M., Furtado, M. M. and Marinho-Filho, J. 2010. Density of the Near Threatened jaguar *Panthera onca* in the caatinga of north-eastern Brazil. *Oryx* **44**: 104-109.

297. Silver, S. 2004. Assessing Jaguar Abundance Using Remotely Triggered Cameras. Wildlife Conservation Society.

298. Silver, S. C., Ostro, L. E., Marsh, L. K., Maffei, L., Noss, A. J., Kelly, M. J., Wallace, R. B., Gomez, H. and Ayala, G. 2004. The use of camera traps for estimating jaguar Panthera onca abundance and density using capture-recapture analysis. *Oryx* **38**(2): 148-154.

299. Simberloff, D. 1998. Flagships, umbrellas, and keystones: is single-species management passe in the landscape era? *Biological Conservation* **83**(3):247–57.

300. Sitati, N.W., Walpole, M.J. Smith, R.J. and Leader Williams, N. 2003. Predicting spatial aspects of human–elephant conflict. *Journal of Applied Ecology* **40**: 667-677.

301. Sithole, Z. 2011. Fresh wave of farm invasions. The Zimbabwean, 17 May 2011.

302. Skinner, J. D. and Smithers, R. H. N. (1990). *The mammals of the southern African subregion. 3rd Edition.* University of Pretoria.

303. Smallwood, K. S. and Fitzhugh, E. L. 1995. A track count for estimating mountain lion *Felis concolor californica* population trend. *Biological Conservation* **71**: 251-259.

304. Smith, J. L. D. 1993. The role of dispersal in structuring the Chitwan tiger population. *Behavior* **124**(3-4):165-195.

305. Smith, R. M. 1977. Movement patterns and feeding behaviour of leopard in the Rhodes Matopos National Park, Rhodesia. *Arnoldia Rhodesia* **8** (13): 1-15.

306. Smuts, G. L., White, I. J. and Dearlove, T. W. 1977. A mass capture technique for lions. *East African Wildlife Journal* **15**: 81- 87

307. Soisalo, M. K. & Cavalcanti, S. M. C. 2006. Estimating the density of a jaguar population in the Brazilian Pantanal using camera-traps and capture-recapture sampling in combination with GPS radio- telemetry. *Biological Conservation* **129**:487-496

308. Sokal, R. R. and Rohlf, F. J. 1995. *Biometry: the principles and practice of statistics in biological research* 3rd Edition. WH Freeman, New York.

309. Sollmann, R., Furtado, M. M., Gardner, B., Hofer, H., Jácomo, A. T., Torres, N. and Silveira, L. 2011. Improving density estimates for elusive carnivores: Accounting for sex-specific detection and movements using spatial capture – recapture models for jaguars in central Brazil. *Biological Conservation*, **144**: 1017-1024.

310. Spash, C.L. 1997. Ethics and environmental attitudes with implications for economic valuation. *Journal of Environmental Management* **50**: 403-416.

311. Spong, G., Hellborg, L. and Creel, S. 2000. Sex ratio of leopards taken in trophy hunting: genetic data from Tanzania. *Conservation Genetics* **1**: 169–171.

312. St John, F., Keane, A., Edwards-Jones, G., Jones, L., Yarnell, R. and Jones, J. 2012. Identifying indicators of illegal behaviour: carnivore killing in human-managed landscapes. Proceedings of the Royal Society. *Biological Sciences* **279**: 804-812.

313. Stander, P. E. and Morkel, P. vd B. 1991. Field immobilization of lions using disassociative anaesthetics in combination with sedatives. *African Journal of Ecology* **29**: 138- 148.

314. Stander P. E. 1998. Spoor counts as indices of large carnivore populations: the relationship between spoor frequency, sampling effort and true density. *Journal of Applied Ecology* **35**: 378-385.

315. Stander, P. E., Ghau, H., Tsisaba, D. and X. UI. 1997. Tracking and the interpretation of spoor: a scientifically sound method in ecology. *Journal of Zoology* **242:** 329-341.

316. Stander, P. E., Haden, P. J. Kaqece, H. and Ghau, H. 1997. The ecology of asociality in Namibian leopards.*Journal of Zoology* **242**:343–364

317. Stuart, C. T. 1986. The incidence of surplus killing by *Panthera pardus* and *Felis caracal* in Cape Province, South Africa. *Mammalia* **50**(4): 556-558.

318. Stuart, C. T. and Stuart Stuart, T. 1989. Leopard in the lower Orange River basin-a survey of their conservation status. Unpubl. Report, African Carnivore Survey, Nieuwoudtville, South Africa.

319. Stuart, C. T. and Stuart, T. 1991. A leopard in the wilderness. *African Wildlife* **45**: 251-254.

320. Stuart, C. T. and Stuart, T. 2000. A field guide to the tracks & signs of southern and east African wildlife (3rd edition). Struik Publishers, Cape Town.

321. Stuart, C.T. and Wilson, V.J. 1988. The cats of southern Africa. Chipangali Wildlife Trust, Bulawayo.

322. Swann, D. E., Hass, C. C., Dalton, D. C., and Wolf, S. A. 2004. Infrared-triggered cameras for detecting wildlife: an evaluation and review. *Wildlife Society Bulletin* **32**:357–365.

323. Swann, D. E., Kawanishi, K. and Palmer, J. 2010. Evaluating types and features of camera traps in ecological studies: a guide for researchers. In. O'Conell, A. F., Nichols, J. D. and Karanth, K. U. (Eds.). 2011. *Camera Traps in Animal Ecology*: *Methods and Analyses*. Pp: 27-44. Springer, Tokyo.

324. Symonds, M. R. E. and Moussalli, A. 2011. A brief guide to model selection, multimodel inference and model averaging in behavioural ecology using Akaike's information criterion. *Behavioural Ecology and Sociobiology* **65**: 13-21.

325. Tello, J. 1986. Survey of protected areas and wildlife areas in Mozambique, with recommendations for their conservation. *Unpublished report.* WWF International, Gland, Switzerland.

326. Terborgh, J. 1999. *Requiem for nature*. Island Press/ Shearwater Books, Washington, D.C.

327. The Zambezi Society, 2013. The Bulletin, December 2013. http://www.zamsoc.org/wp-content/uploads/2014/07/BULLETIN-Dec-2013.pdf

328. Theuerkauf, J., Jędrzejewski, W., Schmidt, K. and Gula, R. 2001. Impact of human activity on daily movement patterns of wolves (*Canis lupus*) in the Białowieża Forest, Poland. In: Field, R., Warren, R. J., Okarma, H. and Sievert, P. R. (Eds.). 2001. *Wildlife, land and people: priorities for the 21st Century. Proceedings of the Second International Wildlife Management Congress*: The Wildlife Society, Bethesda, Maryland, USA. pp: 206-208.

329. Thirgood, S., Woodroffe, R. and Rabinowitz, A.R. 2005. The impact of human-wildlife conflict on human lives and livelihoods. In: Woodroffe, R., Thirgood, S. and Rabinowitz, A. R. (Eds) *People and wildlife: conflict or coexistence*? pp. 13-26. Cambridge University Press, Cambridge.

330. Thomas, P., Balme, G., Hunter, L., and McCabe-Parodi, J. (2005). Using scent attractants to noninvasively collect hair samples from cheetahs, leopards and lions. *Animal Keeper's Forum* **7/8**: 342-384.

331. Tiedeman, J. A. 1986. Short duration grazing, proceedings of the short duration grazing and current issues in grazing management short course held January 21 – 23, 1986, at Kennewick, Washington.

332. Tjibae, M. 2001. Overview of problem animal control. In: *National Technical Predator Management and Conservation Workshop in Botswana*, pp. 25–34. Department of Wildlife and National Parks, Gaborone, Botswana.

333. Tobler, M. W. and Powell, G. V. N. 2013. Estimating jaguar densities with camera traps: Problems with current designs and recommendations for future studies. *Biological Conservation* **159**: 109-118.

334. Tobler, M. W., Pitman, R. L., Mares, R. and Powell, G. 2008. An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. *Animal Conservation* **11**: 169-178.

335. Toms, M.P., Siriwardena, G.M. and Greenwood, J.J.D. 1999. Developing a mammal monitoring programme for the UK. British Trust for Ornithology, Thetford, UK

336. Trapnell, C. G. and Clothier, J. N. 1957. *The soils, vegetation, and agricultural systems of northwestern Rhodesia. Report of the ecological survey*. 2$^{nd}$ Edition. Lusaka: Govt. printer.

337. Treves, A. and Karanth, K. U. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. *Conservation Biology* **17**: 1491-1499.

338. Treves, A. and Naughton-Treves, L. 2005. Evaluating lethal control in the management of human – wildlife conflict. In: Woodroffe, R., Thirgood, S. and Rabinowitz, A. (Eds.). 2005. *People and Wildlife: Conflict or Coexistence*? Cambridge University Press. pp. 86-106.

339. Trolle, M. 2003a. Mammal survey in the Rio Jauaperi region, Rio Negro Basin, the Amazon, Brazil. *Mammalia* **67**:75–83.

340. Trolle, M. 2003b. Mammal survey in the southeastern Pantanal, Brazil. *Biodiversity and Conservation* **12**:823–836.

341. Trolle, M. and Kéry, M. 2003. Density estimation of ocelot (*Leopardus pardalis*) in the Brazilian Pantanal using capture-recapture analysis of camera-trapping data. *Journal of Mammalogy* **66**:13–21.

342. Trolle, M. and Kéry, M. 2003. Estimation of ocelot density in the Pantanal using capture-recapture analysis of camera-trapping data. *Journal of Mammalogy* **84**(2): 607-614.

343. Trolle, M. and Kéry, M. 2005. Camera-trap study of ocelot and other secretive mammals in the northern Pantanal. *Mammalia* **69**: 409–416.

344. Turnbull-Kemp, P. 1967. *The leopard.* Timmins, Cape Town.

345. United Nations Country Team. 2000. Flood disaster in Zimbabwe. UN Inter-Agency Appeal for Emergency Relief As of 8 March 2000 15H00 Contact DMT c/o D. Nkala, tel 792681-6, ext.240 Fax 792978, dennis.nkala@undp.org, Harare, Zimbabwe.

346. United Nations. 2010. World population prospects: The 2010 revision.

347. Van Dyke, F., Brocke, R. and Shaw, H. 1986. Use of road track counts as indices of mountain lion presence. *The Journal of Wildlife Management* **50**(1): 102–109.

348. Van Wyk B., Van Wyk, P. and Van Wyk, B-E. 2000. Photographic guide to trees of southern Africa. Briza Publications, Pretoria. (360 pages). (Revised edition 2008).

349. van Wyk, B. and van Wyk, P. 1997. *Field guide to trees of Southern Africa*. Struik, Cape Town.

350. Vincent, V. and Thomas, R. G. 1961. Agro-ecological Survey of Southern Rhodesia: Natural Regions and Areas and Related Farming Systems 1:1 000 000. Federal Ministry of Agriculture.

351. Wallace, R. B., Gomez, H., Ayala, G. and Espinoza, F. 2003. Camera trapping for Jaguar (*Panthera onca*) in the Tuichi Valley, Bolivia. *Journal of Neotropical Mammalogy* **10**: 133–139.

352. Walpole, M.J. and Goodwin, H.J. 2001. Local attitudes towards conservation and tourism around Komodo National Park, Indonesia. *Environmental Conservation* **28**: 160-166.

353. Wang, S. and Macdonald, D. 2009. The use of camera traps for estimating tiger and leopard populations in the high altitude mountains of Bhutan. *Biological Conservation* **142**(3): 606-613.

354. Wang, S.W. and Macdonald, D.W. 2006. Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. *Biological Conservation* **129**: 558-565.

355. Wang, S.W. and Macdonald, D.W. 2009. Feeding habits and niche partitioning in a predator guild composed of tigers, leopards and dholes in a temperate ecosystem in central Bhutan. *Journal of Zoology* **277**: 275–283.

356. Webbon, C. C., Baker, P. J. and Harris, S. 2004. Faecal density counts for monitoring changes in red fox numbers in rural Britain. *Journal of Applied Ecology* **41**: 768-779.

357. Weber, W. 1995. Monitoring awareness and attitudes in conservation education programs. In: Jacobson, S. K. (Ed.). Conserving wildlife: international education and communication approaches. Pp 28-48. Columbia University, Columbia.

358. Weber, W. and Rabinowitz, A. 1996. A global perspective on large carnivore conservation. *Conservation Biology* **10**: 1046-1054.

359. Wegge, P., Odden, M., Pokharel, C. P. and Storass, T. 2009. Predator–prey relationships and responses of ungulates and their predators to the establishment of protected areas: A case study of tigers, leopards and their prey in Bardia National Park, Nepal. *Biological Conservation* **142**: 189 –202.

360. White, G. C., Anderson, D. R., Burnham, K. P. and Otis, D. L. 1982. *Capture-recapture and removal methods for sampling closed populations*. Los Alamos National Laboratory Publication LA- 8787-NERP. Los Alamos, New Mexico, USA

361. Whittington-Jones, B. M. 2011. The dispersal of African wild dogs (*Lycaon pictus*) from protected areas in the northern KwaZulu-Natal Province, South Africa. MSc Thesis. Rhodes University, Grahamstown.

362. Williams, B. K., Nichols, J. D. and Conroy, M. J. 2002. Analysis and Management of animal populations: modeling, estimation, and decision making. Academic Press, London, UK.

363. Williams, S. T. 2012. The impact of land reform in Zimbabwe on the conservation of cheetahs and other large carnivores. PhD thesis, Durham University, Durham, UK.

364. Wilson, G.J. and Delahay, R.J. 2001. A review of methods to estimate the abundance of terrestrial carnivores using field signs and observation. *Wildlife Research* **28:** 151–164.

365. Wilson, K. R. and Anderson, D. R. 1985. Evaluation of two density estimators of small mammal population size. *Journal of Mammalogy* **66:**13-21.

366. Winchester, C., Castleberry, S. B. and Mengak, M. T. 2009. Comparison of methods for estimating key large woodrat abundance. *Natural Resources*: 35–40.

367. Woodroffe, R. 2000. Predators and people: using human densities to interpret declines of large carnivores. *Animal Conservation* **3**: 165-173.

368. Woodroffe, R. and Ginsberg, J. R. 1998. Edge effects and the extinction of populations inside protected areas. *Science* **280**: 2126–2128.

*369.* Woodroffe, R., Lindsey, P., Romanach, S., Stein, A. and Ranah, S. M. K. O. 2005. Livestock predation by endangered African wild dogs *Lycaon pictus* in northern Kenya. *Biological Conservation* **124**: 225-234.

370. Woodroffe, R., Thirgood, S. and Rabinowitz, A. (Eds.). 2005. *People and wildlife: conflict or coexistence?* Cambridge University Press, Cambridge. http://dx.doi.org/http://dx.doi.org/10.1017/CBO9780511614774

371. Zielinski, W. J. and Kucera, T. E. 1995. American marten, fisher, lynx and wolverine: survey methods for their detection. General Technical Report PSW-157. US Department of Agriculture Forest Service, Pacific Southwest Research Station, Berkeley, CA, USA.

372. Zimmermann, A., Walpole, M. J. and Leader-Williams, N. 2005. Cattle ranchers' attitudes to conflicts with jaguar *Panthera onca* in the pantanal of Brazil. *Oryx* **39**(4):406–12.

373. Zimmermann, B., Wabakken, P. and Dotterer, M. 2001. Human-carnivore interactions in Norway: How does the re-appearance of large carnivores affect people's attitudes and levels of fear? *Forest Snow and Landscape Research* **76**: 137-153.

374. Zinn, H. C., Manfredo, M. J., Vaske, J. J. 2000. Social psychological bases for stakeholder acceptance capacity. *Human Dimensions of Wildlife* **5**: 20–33.

# APPENDICES

## Appendix I: Historical aerial survey results for Debshan ranch from 1993 to 2014.

| Common name | Latin name | 1993 | 1995 | 1997 | 1999 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Aardvark | *Orycteropus afer* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| Aardwolf | *Proteles cristatus* | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chacma baboon | *Papio ursinus* | 8 | 12 | 19 | 15 | 15 | 8 | 13 | 10 | 22 | 13 | 12 | 10 | 12 | 10 | 6 |
| Brown hyena | *Hyaena brunnea* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Bushbuck | *Tragelaphus scriptus* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 0 | 6 | 12 | 5 | 9 | 6 | 5 |
| Bushpig | *Potamochoerus porcus* | 35 | 32 | 55 | 29 | 20 | 4 | 47 | 44 | 17 | 42 | 47 | 21 | 18 | 10 | 40 |
| Caracal | *Caracal caracal* | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cheetah | *Acinonyx jubatus* | 1 | 6 | 0 | 11 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Common duiker | *Sylvicapra grimmia* | 232 | 169 | 129 | 96 | 109 | 100 | 137 | 232 | 209 | 171 | 330 | 271 | 275 | 226 | 158 |
| Eland | *Taurotragus oryx* | 0 | 0 | 18 | 39 | 124 | 62 | 81 | 100 | 47 | 73 | 107 | 74 | 147 | 94 | 79 |
| Elephant | *Loxodonta africana* | 0 | 17 | 4 | 20 | 112 | 157 | 174 | 115 | 144 | 151 | 254 | 139 | 264 | 231 | 174 |
| Giraffe | *Giraffa camelopardalis* | 1 | 2 | 1 | 1 | 43 | 50 | 45 | 50 | 83 | 127 | 80 | 91 | 88 | 108 | 84 |
| Southern Ground Hornbill | *Burcovus leadbeateri* | 8 | 11 | 11 | 30 | 25 | 15 | 9 | 13 | 7 | 16 | 6 | 18 | 5 | 25 | 6 |
| Helmeted Guinea Fowl | *Numida meleagris* | 42 | 20 | 36 | 44 | 46 | 9 | 26 | 24 | 27 | 25 | 9 | 24 | 12 | 7 | 18 |
| Hippopotamus | *Hippopotamus amphibius* | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Honey Badger | *Mellivora capensis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Impala | *Aepyceros melampus* | 2541 | 1767 | 2383 | 2042 | 1746 | 1578 | 1545 | 2517 | 1859 | 1894 | 2047 | 1852 | 2301 | 2514 | 2457 |
| Black-backed jackal | *Canis mesomelas* | 31 | 32 | 30 | 19 | 14 | 7 | 7 | 35 | 11 | 10 | 7 | 5 | 6 | 1 | 2 |
| Kori Bustard | *Ardeotis kori* | 0 | 8 | 10 | 5 | 4 | 0 | 0 | 3 | 8 | 1 | 3 | 2 | 5 | 1 | 0 |
| Greater kudu | *Tragelaphus strepsiceros* | 906 | 661 | 847 | 613 | 466 | 463 | 466 | 521 | 586 | 459 | 547 | 469 | 535 | 415 | 363 |
| Leopard | *Panthera pardus* | 1 | 2 | 4 | 1 | 3 | 2 | 2 | 7 | 9 | 0 | 4 | 2 | 1 | 4 | 1 |
| Ostrich | *Struthio camelus* | 79 | 80 | 66 | 58 | 30 | 26 | 12 | 10 | 10 | 8 | 13 | 5 | 12 | 11 | 9 |
| Southern reedbuck | *Redunca arindunum* | 152 | 71 | 37 | 17 | 19 | 18 | 9 | 14 | 3 | 21 | 15 | 13 | 20 | 18 | 21 |
| Sable | *Hippotragus niger* | 105 | 98 | 82 | 24 | 39 | 35 | 66 | 84 | 65 | 33 | 81 | 84 | 76 | 114 | 131 |
| Serval | *Leptailurus serval* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Steenbuck | *Raphicerus campestris* | 106 | 63 | 71 | 29 | 52 | 42 | 55 | 103 | 115 | 89 | 138 | 133 | 87 | 105 | 88 |
| Tsessebe | *Damaliscus lunatus lunatus* | 1701 | 1167 | 903 | 337 | 75 | 40 | 20 | 33 | 14 | 15 | 12 | 8 | 3 | 7 | 12 |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blue wildebeest | *Connochaetes taurinus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 |
| Warthog | *Phacochoerus aethiopicus* | 1131 | 821 | 1408 | 775 | 388 | 227 | 240 | 363 | 275 | 215 | 320 | 312 | 296 | 208 | 185 |
| Waterbuck | *Kobus ellipsiprymnus* | 6 | 0 | 2 | 6 | 0 | 4 | 13 | 0 | 1 | 12 | 16 | 9 | 6 | 6 | 11 |
| Burchell's zebra | *Equus burchelli* | 69 | 82 | 111 | 121 | 273 | 192 | 244 | 385 | 341 | 419 | 374 | 343 | 448 | 615 | 661 |

## Appendix II: An inventory of species recorded during the camera trapping survey from May – July 2014.

| Family | Latin Name | Common Name | n |
|---|---|---|---|
| Anthropogenic | *Bos domesticus* | cow | 118 |
| | *Canis lupus familiaris* | domestic dog | 3 |
| | *Homo sapiens sapiens* | person + poachers | 6 |
| Bovidae | *Tragelaphus scriptus* | Bushbuck | 4 |
| | *Sylvicapra grimmia* | Common duiker | 69 |
| | *Taurotragus oryx* | Eland | 1 |
| | *Tragelaphus strepsiceros* | Greater kudu | 17 |
| | *Aepyceros melampus* | Impala | 75 |
| | *Hippotragus niger* | Sable | 3 |
| | *Raphicerus campestris* | Steenbok | 11 |
| Canidae | *Canis mesomelas* | Black backed jackal | 2 |
| Cercopithecidae | *Papio hamadryas ursinus* | Chacma baboon | 46 |
| | *Cercopithecus pygerythrus* | Vervet monkey | 13 |
| Elephantidae | *Loxodonta africana* | elephant | 60 |
| Equidae | *Equus burchelli* | Burchell's zebra | 6 |
| Felidae | *Felis slyvestris lybica* | African wild cat | 9 |
| | *Panthera pardus* | Leopard | 26 |
| | *Felis serval* | serval | 3 |
| Giraffidae | *Giraffa camelopardalis* | girrafe | 31 |
| Herpestidae | *Mungos mungo* | banded mongoose | 3 |
| | *Galerella nigrata* | slender mongoose | 9 |
| | *Ichneumia albicauda* | white tailed mongoose | 12 |
| Hyaenidae | *Hyaena brunnea* | brown hyena | 21 |
| | *Crocuta crocuta* | spotted hyena | 8 |
| Leporidae | *All species* | scrub hare | 22 |
| Mustelidae | *Mellivora capensis* | honeybadger | 4 |
| Orycteropodidae | *Orycteropus afer* | aardvark | 8 |
| Suidae | *Potamochoerus porcus* | bushpig | 11 |
| | *Phacochoerus aethiopicus* | warthog | 52 |
| Viverridae | *Civettictis civetta* | african civet | 1 |
| | *Genetta tigrina* | large spotted genet | 18 |
| Birds | *Peliperdix sephaena* | crested francolin | 21 |
| | *Numida meleagris* | helmeted guineafowl | 20 |
| | *Lophotis ruficrista* | red crested korhaan | 10 |
| | *Streptopelia semitorquata* | red eyed dove | 1 |
| | *Tockus leucomelas* | southern yellowbilled hornbill | 4 |
| | *Pternistes swainsonii* | swainson's francolin | 7 |
| Unidentifiable | | | 14 |
| Total | | | 749 |

## Appendix III: Quota allocations for trophy hunted wildlife species on Debshan ranch from 2004 to 2015.

2015 OFFTAKE QUOTAS FOR ALIENATED LAND

NAME OF PROPERTY: Debshan Ranch
LANDOWNER: OPPENHEIMER

SIZE OF PROPERTY (ha) 65000
PROVINCE Mat South

DISTRICT Shangani/Insiza
NRCC

| Species | Owner's population estimate | ZPWMA population estimate | Sport-hunting | | | | Recommended 2015 quota | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 Quota |
| Baboon | 300 | 200 | 10 | 10 | 10 | 10 | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) |
| Bushbuck | 100 | 100 | 0 | 0 | 0 | 0 | 0(zero) | 0(zero) | 0(zero) | 0(zero) | 1(One) | 2(two) | 2(two) | 2(two) |
| Bushpig(m) | 100 | 70 | 6 | 6 | 6 | 6 | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) |
| Civet | 50 | 40 | 2 | 2 | 2 | 2 | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) |
| Cheetah | 25 | 0 | 0 | 0 | 0 | 0 | 0(zero) | 1(One) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 1(one) |
| Crocodile | 30 | 0 | 1 | 1 | 1 | 1 | 1(one) | 1(One) | 1(One) | 1(One) | 1(One) | 1(One) | 1(One) | 1(One) |
| Duiker | 250 | 120 | 9 | 6 | 6 | 6 | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) |
| Eland(m) | 150 | 60 | 3 | 3 | 3 | 3 | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) |
| Elephant(M) | | | 0 | 0 | 2 | 2 | 1(one) | 3(three) | 5(five) | 5(five) | 5(five) | 7(seven) | 7(seven) | 6(six) |
| Elephant(TL) | 160 | migratory | 8 | 1 | 1 | 1 | 1(one) | 0(zero) | 0(zero) | 0(zero) | 0(zero) | 0(zero) | 0(zero) | 0(zero) |
| Genet | 50 | 20 | 0 | 2 | 2 | 2 | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) |
| Giraffe(m) | 110 | 100 | 0 | 2 | 2 | 2 | 2(two) | 2(two) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) |
| Honey badger | 50 | 40 | 2 | 2 | 2 | 2 | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) |
| Spotted hyena(m) | 20 | 10 | 3 | 3 | 3 | 3 | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) |
| Impala bait | 2500 | 2000 | 30 | 30 | 30 | 30 | 30(thirty) | 40(forty) | 20(Twenty) | 20(Twenty) | 20(Twenty) | 20(Twenty) | 20(Twenty) | 20(Twenty) |
| Impala trophy | | | 30 | 40 | 40 | 40 | 40(forty) | 30(thirty) | 30(thirty) | 30(thirty) | 30(thirty) | 30(thirty) | 30(thirty) | 30(thirty) |
| Jackal(M) | 100 | 100 | 10 | 10 | 10 | 10 | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) |
| Kudu(M) | 500 | 400 | 15 | 12 | 12 | 12 | 12(twelve) | 12(twelve) | 12(twelve) | 12(twelve) | 12(twelve) | 12(twelve) | 12(twelve) | 12(twelve) |
| Leopard(M) | 30 | migratory | 4 | 1 | 1 | 1 | 2(two) | 4(four) | 6(six) | 6(six) | 5(five) | 5(five) | 5(five) | 5(five) |
| Lion(m) | 3 | migratory | 3 | 0 | 1 | 1 | 0(zero) | 1(One) | 1(One) | 1(One) | 1(One) | 0(zero) | 0(zero) | 0(zero) |
| Monkey | 300 | 200 | 2 | 1 | 10 | 10 | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) | 10(ten) |
| Reedbuck | 75 | 50 | 0 | 0 | 0 | 0 | 0(zero) | 0(zero) | 0(zero) | 0(zero) | 0(zero) | 1(One) | 1(One) | 1(One) |
| Sable(m) | 150 | 150 | 3 | 3 | 3 | 3 | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) | 3(three) |
| Steenbok(M) | 200 | 200 | 9 | 6 | 6 | 6 | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) | 6(six) |
| Tsessebe(m) | 200 | 200 | 12 | 2 | 2 | 2 | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) |
| Waterbuck(m) | 50 | 50 | 0 | 0 | 2 | 2 | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) | 2(two) |
| Warthog(m) | 300 | 300 | 14 | 5 | 5 | 5 | 5(five) | 5(five) | 5(five) | 5(five) | 5(five) | 5(five) | 5(five) | 5(five) |
| Wildebeest(m) | 300 | 300 | 0 | 3 | 3 | 3 | 3(three) | 2(two) | 3(three) | 3(three) | 3(three) | 10(ten) | 10(ten) | 10(ten) |
| Zebra(m) | 1200 | 500 | 6 | 6 | 6 | 6 | 6(six) | 3(three) | 8(eight) | 8(eight) | 8(eight) | 15(fifteen | 15(fifteen | 15(fifteen |

Signed: 03/11/14

Scientific Services
Parks & Wildlife Management Authority

Date: 11/11/14
08/12/14

MINISTER'S OFFICE
MINISTRY OF ENVIRONMENT WATER & CLIMATE
19 JAN 2015
P. BAG 7753, CAUSEWAY, HARARE
ZIMBABWE
TEL: +263 4 701681-3

2

## Appendix IV: Leopard capture and collaring at Debshan ranch (7 – 29 January 2014). Rhodes University ethical clearance number (ZOOL-01-2014)

Two leopards, a male (DM1, captured 16/01/2014) and a female (DF1, captured 24/01/2014) were captured and fitted with Iridium satellite collars on the ranch from 7 – 29 January 2014. This was done and sanctioned by ranch management to provide information on the home range and diet analysis for the species on the ranch. Foot-loop traps were used inside baited cubby sets to capture the leopards (Smuts *et al.* 1977, Mills 1996; Frank *et al*. 2003). Impala (*Aepyceros melampus*) and Zebra (*Equus burchelli*) meat was used for baiting. The cubby sets were constructed using fresh vegetation to create a solid wall around the bait and the loop, leaving only one opening. The bait was tied farthest inside the set as an attractant for the leopards. Four stepping clearances were created by placing thorns and vegetation around the clearances to encourage the leopard to only step in certain positions. On the third clearance, the foot-loop trap was positioned.

**Appendix 4.1**: Right-side images of the collared leopards, DM1 (top) and DF1 (bottom).

**Appendix 4.2**: Images of the 'cubby sets' built of tree brushes and housing the bait and the foot-loop trap, close-up image (left) and how it appears from a distance (right).

Seven cubby sets were built within a 15 $km^2$ area to allow for easy and rapid checking by the capture team. To reduce capture of non-target species, the traps were checked and closed every morning as from 0500 hours and then opened again every evening as from 1730 hours to coincide with the leopard's nocturnal activity while Frank *et al*. (2003) closed their traps early in the morning as lions are diurnal. When there was a capture, the crew immediately carried out the collaring while one member quickly went around closing all the other traps to reduce chances of multiple captures (Logan *et al*. 1999). A qualified veterinarian darted and immobilized each leopard with a zoletil/medetomidine drug combination using a $CO_2$ charged dart gun, DanInject Rifle (Daninject, Børkop, Denmark), dosage dependent on estimated body weight before darting (Goodrich *et al.* 2001). The iridium satellite collars (Tellus Medium, Followit, Lindesberg, Sweden) was then securely fitted around the neck allowing for an increase in neck growth while also making sure the collar does not slip off over the ears (Logan *et al.* 1999). Several morphometric measurements were then taken, including total body length, tail length, neck circumference, head and pad length and width, weight and also photographs of the pelage for unique identification (Stander 1997). When all activities were completed yohimbine (1.2 ml * 6.25 mg) was administered by a hand injection (1/3 Intra-venous, 2/3 Intra-muscular).

The collars were set to record and transmit eight GPS location fixes per day every 2 hours from 0100 - 0700 hours, one at 1200 hours, then one every 2 hours again from 1900 - 2300 hours. More fixes are sent during the night to record maximum activity of a nocturnal species (Bailey 1993). Each collar was also equipped with a remote "drop-off" mechanism, set to drop-off the animals after twelve months. Thus, the collared individuals would not need to be recaptured to remove the collars.

**Appendix V: Capture matrix of leopards captured during the camera trapping survey at Debshan ranch, Shangani, Zimbabwe from 20 May to 28 July. The numbers on the columns represent the pooled sampling occasions and the rows contain the individual leopards identified from the survey. A 1 represents a capture and a 0 a non-capture.**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **BEAU** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **BIGP** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **BIGG** | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **CUT1** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **CUT2** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **DM11** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **EARS** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **MOUN** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **MUGW** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **MUNY** | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Appendix VI (a and b): Examples of trap deployment file (a) and leopard capture file (b) used in DENSITY 5.0.**

a) Trap deployment file for non-pooled sampling occasions showing which camera sites were active at what time during the Debshan camera survey from 20 May to 28 July 2014.

| DETECTOR | X | Y | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | . | . | . | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | ROAD/NOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | 722665 | 7830386 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | . | . | . | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /1 |
| P2 | 726005 | 7829683 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | . | . | . | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /0 |
| P3 | 729972 | 7829946 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | . | . | . | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /0 |
| P4 | 733961 | 7829324 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | . | . | . | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /1 |
| P5 | 737941 | 7829762 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | /0 |
| P6 | 721413 | 7825992 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /0 |
| P7 | 726122 | 7825888 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /0 |
| P8 | 728447 | 7825893 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /1 |
| P9 | 733978 | 7825873 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /0 |
| P10 | 738040 | 7825894 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /1 |
| P11 | 741205 | 7826223 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | /1 |
| P12 | 721962 | 7821846 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | /1 |
| P13 | 730083 | 7833879 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | /0 |
| P14 | 734010 | 7833064 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | /1 |
| P15 | 736584 | 7834264 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | . | . | . | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | /1 |

b) Leopard capture file for non-pooled sampling occasions showing which leopard was caught at which camera site on which day and its sex. Session stands for the separate camera trapping surveys (only one for this study)

| SESSION | ID | OCCASION | DETECTOR | GENDER |
|---|---|---|---|---|
| 1 | BEAU | 58 | P7 | U |
| 1 | BIGP | 33 | P9 | U |
| 1 | BIGG | 36 | P7 | M |
| 1 | BIGG | 56 | P8 | M |
| 1 | CUT1 | 31 | P9 | U |
| 1 | CUT2 | 31 | P9 | U |
| 1 | DM11 | 7 | P2 | M |
| 1 | DM11 | 67 | P15 | M |
| 1 | EARS | 56 | P3 | U |
| 1 | MOUN | 52 | P4 | U |
| 1 | MUGW | 9 | P1 | U |
| 1 | MUNY | 31 | P9 | F |
| 1 | MUNY | 38 | P10 | F |
| 1 | MUNY | 50 | P10 | F |

**APPENDIX V11: The questionnaire used to assess community attitudes towards leopards and other carnivores around Debshan ranch.**

**Section A: General information**

1.Date…………………… 2.Time…………………………

3.Interviewer………………………………… 4.Interview location……………………

5.Position of Interviewee……………… 6.Property name……………………………………………..

7.GPS coordinates of property/area…………………………………………………………

**Section B: Property characteristics and livestock/game information**

10.Land Tenure (tick applicable)

Private communal leasehold resettlement stateland

11.Land Use (tick applicable)

| | | |
|---|---|---|
| Livestock ranching | Crop farming | Wildlife ranching |
| Small stock | | Trophy hunting |
| Large stock | | ecotourism |

12.Size of property (hectares)…………………………………………………..

13.Is property fenced around (tick applicable) YES NO DON'T KNOW

14.If fenced, indicate the type of fence (tick applicable)

| | | | | | |
|---|---|---|---|---|---|
| Cattle fence | Wood fence | Game fence | Electric fence | Mesh fence | other |

15.Have you ever had leopards moving in or out of your land? YES NO DON'T KNOW

16.Please specify what kind of livestock and or game are found in this area and how many. If you do not know the numbers, just tick

a) Livestock

| Stock | Cattle | Sheep | Goats | Donkeys | Poultry | Pigs | Dogs | Cats | other | Don't know | None |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Numbers | | | | | | | | | | | |

b) Game

| Game | Impala | Kudu | Elephant | Warthog | Baboon | Zebra | Eland | Ostrich | Sable | Other | None |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Numbers | | | | | | | | | | | |

17.Please indicate how frequently the following predators are seen on this property (tick applicable)

| | Never | >once/year | Every few months | Once/month | >once/month | Don't know |
|---|---|---|---|---|---|---|
| Lion | | | | | | |
| Leopard | | | | | | |
| Cheetah | | | | | | |
| Spotted hyena | | | | | | |
| Brown hyaena | | | | | | |
| Wild dog | | | | | | |
| Caracal | | | | | | |
| Jackal | | | | | | |

**Section C: Livestock protection and predation**

18.Please indicate which livestock management technique (s) are used on this property (tick applicable)

| Herding | Kraaling | | Collars | | Guard animals | | Other |
|---|---|---|---|---|---|---|---|
| | Day and night | Night | Bell or scent | Protective | Dogs | Donkeys | |

19.Have you ever lost your livestock to the following ? YES NO NOT SURE

20.If yes, please indicate in what way. (put numbers or tick applicable)

| | Never | >once/year | Every few months | Once/month | >once/month | Don't know |
|---|---|---|---|---|---|---|
| Disease | | | | | | |
| Theft | | | | | | |
| Domestic dogs | | | | | | |
| Predators | | | | | | |
| Other | | | | | | |
| None | | | | | | |

21.Please indicate the number of livestock lost to each cause (put numbers or tick)

| | Cattle | Sheep | Goats | Donkeys | Pigs | Poultry | Other |
|---|---|---|---|---|---|---|---|
| Disease | | | | | | | |
| Theft | | | | | | | |
| Domestic dogs | | | | | | | |
| Predators | | | | | | | |
| Other | | | | | | | |
| None | | | | | | | |

22. If you suffered losses to any predators, please indicate to which (put numbers or tick)

| | Cattle | Sheep | Goats | Donkeys | Pigs | Poultry | Other |
|---|---|---|---|---|---|---|---|
| Lion | | | | | | | |
| Leopard | | | | | | | |
| Spotted hyena | | | | | | | |
| Brown hyena | | | | | | | |
| Wild dog | | | | | | | |
| Cheetah | | | | | | | |
| Jackal | | | | | | | |
| Caracal | | | | | | | |
| Other | | | | | | | |

23.How did you identify the predator that killed your livestock? (tick applicable)

Actual sighting Nature of remains of carcass Spoor Reports Other

24.Rank form of identification by showing photographs (tick)

Positive Wrong (redirect to correct) Unclear

25. What did you do? (tick applicable) report to RDC Report to chief/headman

Kill the predator Snare it/poison it Other Nothing

**Section D: Predators**

26.Identification of predators (show photographs)
Rank identification (tick)
Correct Wrong (redirect to correct) Unclear

**Section E: Community attitudes**

27.How do you feel about the presence of the following predators on your property (Please tick applicable)?

| | Positive | Neutral | Negative | Not applicable | |
|---|---|---|---|---|---|
| Lion | | | | | |
| Leopard | | | | | |
| Cheetah | | | | | |
| Wild dog | | | | | |
| Spotted hyena | | | | | |
| Caracal | | | | | |
| Jackal | | | | | |

28.What is the general feeling towards the following predators in the district (Please tick applicable)?

| | Positive | Neutral | Negative | Not applicable | |
|---|---|---|---|---|---|
| Lion | | | | | |
| Leopard | | | | | |
| Cheetah | | | | | |
| Wild dog | | | | | |
| Spotted hyena | | | | | |
| Caracal | | | | | |
| Jackal | | | | | |

29.Do you know if any of your neighbours have ever successfully removed predators from their property? If yes, please specify the preferred method of removal (Please tick applicable).

| | Yes | No | Don't know | Method of removal (select from list below; if other specify) |
|---|---|---|---|---|
| Lion | | | | |
| Leopard | | | | |
| Cheetah | | | | |
| Wild dog | | | | |
| Spotted hyena | | | | |
| Caracal | | | | |
| Jackal | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Firearm | Snare | Poison | Dogs | Gin traps | Cage traps | Other |

30.Please indicate your disagreement/agreement with each of the following statements (Please tick applicable).

| | | | |
|---|---|---|---|
| You are more tolerant of leopards than your neighbours. | Yes | No | Don't know |
| Leopards negatively impact your business/livelihood/profit. | Yes | No | Don't know |
| Leopards form an important part of the environment. | Yes | No | Don't know |
| You would be happier if leopards were absent from your property. | Yes | No | Don't know |
| Please explain your responses to the question above: | | | |
| Leopards should be protected. | Yes | No | Don't know |
| Leopards could produce tourism benefits for you/your business. | Yes | No | Don't know |
| You would like to see leopards in the bush. | Yes | No | Don't know |
| Leopards are culturally important to you. | Yes | No | Don't know |
| You would like to learn more about leopards. | Yes | No | Don't know |

**Section F: Knowledge of the species and conservation in general**

31. Respondent could correctly identify a leopard. YES NO DON'T KNOW

32. Leopards are dangerous to humans YES NO DON'T KNOW

33. Leopards prefer livestock to wild prey YES NO DON'T KNOW

34. Lions live in social families YES NO DON'T KNOW

35. Cheetahs are smaller than leopards YES NO DON'T KNOW

**Section G: Personal information about respondent**
36.Name………………………… 37. Age…………
33.Gender……………………. 34. Contact number…………………
38. Level of education (tick applicable)

| None | Primary school | Secondary school | High school | College | University | N/A |
|---|---|---|---|---|---|---|

39. Languages (in order from first)………………………………… ……………..

40. Occupation……………………………………

**Section H: Snaring on the property**
41. Please indicate whether snaring is a problem on the property or not?.........................

42. Please indicate the number of snares cleared monthly………………………

**Section I: Elephant survey**
43. Do you ever see elephants here? YES NO

44. Around which time of year?..............................................

45. Which direction do they come from?.......................................................

46. Are they giving problems (Tick applicable) YES NO

47. Explain your answer above……………………………………………