The Status and Conservation Potential of Carnivores in Semi-Arid Rangelands, Botswana The Ghanzi Farmlands: A Case Study

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Vivien T. Kent

Abstract

The persistence of many species of carnivore may depend on their survival outside protected areas where they come into conflict with humans and their livestock. Knowledge of these wildlife populations and of the perceptions and attitudes of the stakeholders in the areas in which they live is of critical importance in the quest for coexistence.

The Ghanzi farmlands in western Botswana are a prime example of semi-arid rangeland where humans, domestic livestock and wildlife live side by side with varying degrees of success. But little research has been conducted in the area into either the wildlife or the white Afrikaner minority who own the majority of the land. This study aimed to fill some of these gaps in knowledge by adopting an interdisciplinary approach, and employing methodologies from both the biological and social sciences, to determine the potential for conservation of carnivores in the area.

The farm block was found to contain good carnivore species diversity and a reduced, but healthy, naturally occurring prey base. Densities of cheetah and leopard were low, but comparable to, or better than, those reported for other similar environments. A good population of brown hyaena was found to exist in the area which could be of importance to the conservation of the species as a whole. The farming community were supportive of conservation in principle, but generally intolerant of predators that killed their livestock. A wide variety of land management and livestock husbandry practices were apparent, with some farmers prepared to do more than others to actively protect their livestock. Farmers with small stock suffered from greater levels of depredation than those who farmed only cattle, while some species of predator elicited greater feelings of antipathy than others. Some farmers professed a distrust of government interference in their affairs which served to hamper efforts to obtain reliable data on livestock depredation and monitor the lethal control of predators.

The status and conservation potential of carnivores in semi-arid rangelands, Botswana

The Ghanzi Farmlands: A Case Study

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

AIC	Akaike Information Criteria
BMC	Botswana Meat Commission
BPCT	Botswana Predator Conservation Trust
BWPA	Botswana Wildlife Producers Association
CCB	Cheetah Conservation Botswana
CCF	Cheetah Conservation Fund
CCM	Cultural Consensus Model
CITES	Convention on International Trade in Endangered Species
CKGR	Central Kalahari Game Reserve
CS	Camera Survey
DWNP	Department of Wildlife and National Parks
HRM	Holistic Resource Management
IUCN	International Union for Conservation of Nature
KTP	Kgalagadi Transfrontier Park
MCP	Minimum Convex Polygon
NGO	Non-Governmental Organisation
PAC	Problem Animal Control (DWNP)
RAI	Relative Abundance Index
RN	Royle-Nichols Model
SS	Spoor Survey
WCS	Wildlife Conservation Society
WMA	Wildlife Management Area

Statement of Copyright

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When you have caught the rhythm of Africa, you find that it is the same in all her music

Karen Blixen, Out of Africa

Man cannot discover new oceans unless he has the courage to lose sight of the shore

André Gide

Chapter 1 – General Introduction

1.1 Background

Human-carnivore conflict is a global and challenging problem, but is particularly severe in southern Africa where many carnivores have populations located outside the national parks and reserves. In some cases these are considered to be essential to the conservation of the species as a whole (Woodroffe & Ginsberg 1998, 2000) and it has been postulated that if such species cannot be conserved in multi-use landscapes then they probably cannot, in the end, be conserved at all (Woodroffe *et al.* 2005b).

The demarcated concept of separation between human populations and wildlife, also called zoning (Linnell *et al.* 2005), that prevailed in Africa throughout much of the 20th century, has serious practical limitations. The difficulties involved in containing viable populations of wide-ranging, territorial animals within the boundaries of, sometimes very small and isolated, patches of land designated for this purpose are all too apparent (Woodroffe & Ginsberg 1999, 2000). Compounding these problems is that of loss of habitat, which is widely considered to be one of the major factors affecting the survival of mammalian predators. As human populations increase more and more land is appropriated for agriculture resulting in conflict between land owners and the wildlife that exists on that land (Nowell & Jackson 1996; Sunquist & Sunquist 2001).

Many of the areas where livestock and wildlife now live side by side are semi-arid rangelands. Examples can be found across the world such as those in South America, Mongolia and Australia, but the largest expanses occur on the African continent (Wrobel & Redford 2010). Historically, these ecosystems have often supported large accumulations of grazing and browsing species that have evolved in, and are adapted to, such an environment. As human societies developed, pastoralists learned to manage their livestock by moving with their herds to take advantage of the seasonal availability of good grazing. Increasingly over the past century such communal grazing practices have been subsumed and replaced by more sedentary methods of raising livestock. The introduction of fencing to enclose farms and prevent transmission of disease between wildlife and domestic livestock has transformed, and often degraded, these fragile grasslands through overgrazing and disruption of the nutrient cycle (Wrobel & Redford 2010). However, even within those fences domestic livestock are often permitted to range relatively freely to maximise grazing opportunities and, as a result, are particularly vulnerable to depredation (Zimmermann *et al.* 2010).

As predators, carnivores frequently interfere with other animals, including livestock, and it is clear that the greatest source of human-carnivore conflict arises from competition for resources, whether that is land, domestic animals or prey species (Sillero-Zubiri & Laurenson 2001). Such problems may be particularly acute where areas of livestock production are situated close to, or on the borders of, protected areas. The occurrence of dispersing individuals of territorial species in these areas is inevitable, and the depletion of natural prey resources in such areas may also increase the likelihood of livestock depredation (Woodroffe & Ginsberg 1998).

Knowledge of the status of large- and medium-sized carnivore populations in such areas is relatively scarce as research into such species has historically been concentrated on populations inside parks and reserves. More than a decade ago it was recommended that research on wild felids be extended to populations outside protected areas in order for the ways in which behaviour may be modified by human disturbance and changes in habitat to be assessed, and for more accurate estimations of species status to be determined (Nowell & Jackson 1996). This principle applies equally to carnivore species in other Orders as well.

While the strengthening of the conservation principle which took hold during the last century saw a shift towards viewing carnivores as an integral and valued part of the ecosystem, this change in attitude cannot be said to be true of communities that live alongside these species, where the traditional view of predators as 'vermin' or 'pests' remains intact (Thomson 1992; Sillero-Zubiri & Laurenson 2001). The drivers behind these attitudes are often cited by stakeholders as being economic, and there is no doubt that livestock depredation can have catastrophic financial consequences for farmers. However, there is also evidence to suggest that such negative attitudes towards predators may be deeply imbedded in the culture of the community concerned (Naughton-Treves *et al.* 2003; Zimmermann *et al.* 2005), and that livestock losses to other causes that are equal to, or greater than, those recorded to depredation may receive less attention (Dickman 2010).

These and other factors mean that indiscriminate persecution of carnivores is widespread (Marker *et al.* 2003a; Hodkinson *et al.* 2007), but the traditional scatter-gun approach to predator control has been largely ineffective, both in minimising stock losses and in controlling predator populations (Marker *et al.* 2003b; Avenant *et al.* 2006). A sea-change in attitudes has been called for (Sillero-Zubiri & Laurenson 2001) that would result in more holistic management practices enabling farmers and land owners to work with the environment rather than against it (Hodkinson *et al.* 2007). Improvements in livestock husbandry, such as the employment of herders and the kraaling of stock, have been shown to considerably reduce the rates of depredation by carnivores (Ogada *et al.* 2003), the use of livestock guarding animals such as dogs or donkeys has also been shown to be effective (Smith *et al.* 2000; Marker *et al.* 2005; Hodkinson *et al.* 2007).

However, one of the most important issues surrounding the mitigation of human-wildlife conflicts is the need to address the human-human relationships that are involved. Increases in tension between different groups of stakeholders can often be traced back to a failure to listen and engage with the people who actually have to live with the wildlife on their land (Madden 2004). Opinions about which species pose the greatest problem may also differ between groups. This was demonstrated in a study conducted by McIvor & Conover (1994) into the perceptions of farmers and non-farmers toward the management of problem wildlife in Utah and Wyoming, USA. They also found evidence that the farmers may have been more sensitive to new threats and consequently overestimated the amount of damage done by a species with which there was a relatively short history of conflict (McIvor & Conover 1994).

It is also true that while different carnivores may have a range of impacts on farmers not all types of livestock are equal in terms of their vulnerability to predation (Linnell *et al.* 2005). Doubts may also exist as to the actual, as opposed to the perceived, level of livestock predation that occurs. Rasmussen (1999) conducted a case study to determine numbers and movements of African wild dogs (*Lycaon pictus*) in regions of Zimbabwe where they were likely to come into contact with domestic cattle, and to accurately assess losses that could be attributed to predation. There was considerable prejudice amongst farmers, who only started to attribute their stock losses to wild dogs once it was known that they had been seen in the area. Prior to this leopards (*Panthera pardus*) and hyaenas (*Crocuta crocuta*) had been blamed. There was also evidence that a large proportion of the stock losses attributed to predators were more likely to have been poached and/or rustled. As Rasmussen (1999) points out however, prejudice is rarely swayed by statistics, a fact illustrated elsewhere in studies of human perceptions of predators (Kellert *et al.* 1996; Marker & Dickman 2004).

In some situations there may be a reluctance by farmers to engage with government- and NGO-led initiatives to mitigate human-wildlife conflict outside protected areas. This may have many causes. In South America, where conflict between cattle ranchers and the jaguar (*Panthera onca*) has a long history, the ranchers indicated that they felt as though they were being treated as part of the problem rather than the solution (Rabinowitz 2005); there were also consistent mismatches between the beliefs of ranchers and those of conservationists as to whether a particular predator was plentiful or scarce (Rabinowitz 2005).

Solutions to these problems have traditionally been sought by either conservation biologists or social scientists working in isolation and often with contrasting and conflicting agendas. However, the move away from the 'fortress conservation' model in recent years has led to attempts being made to include local communities in conservation policy and practice and acknowledging that solutions to human-carnivore conflict must be sought that involve the human side of the equation as well (Sillero-Zubiri & Laurenson 2001; Mascia *et al.* 2003; Campbell 2005; Chan *et al.* 2007; Treves *et al.* 2009; Dickman 2010; White & Ward 2010; Drury *et al.* 2011). Until recently a lack of attention to the human side of this issue has been a consistent failing of carnivore conservation programmes (Clark *et al.* 2001). The situation is concisely encapsulated by Clark *et al.* (2001):

> *A more comprehensive, contextual, and rational approach to carnivore conservation is urgently needed. Concerned people must conceive of conservation as a process of human decision-making, upgrade this process to achieve better outcomes, and by this means change the human practices that threaten carnivores* (Clark *et al.* 2001 p. 223).

Many so-called community based conservation programmes however, have tended to pay lip-service to community engagement. If the economic benefit to the community derived from the protection of wildlife or the environment is less than could be achieved from alternative activities, then the initiative will fail to achieve the commitment required to make it succeed. The result may be minor infringements of rules or even outright sabotage (Tisdell 1995). Research has shown that rules and regulations surrounding protection of biodiversity must be meaningful to the local community if they are to be implemented successfully (Hampshire *et al.* 2004) and addressing the human and social dimensions of a conflict situation are as important as understanding the ecological factors involved (Madden 2004; Dickman 2010). As Dickman (2010) summarises:

> *Ultimately, effective conflict resolution will require a broad, multifaceted and truly interdisciplinary approach, and conservation biologists must move beyond examining species-based conflicts towards considering the wider socio-economic, ecological and cultural conditions under which intense conflicts arise* (Dickman 2010 p. 464).

The Ghanzi farmland area in the Kalahari of western Botswana is a prime example of all that has been described above. An area of semi-arid rangeland situated in close proximity to the Central Kalahari Game Reserve, it was historically home to large populations of ungulates, both migratory and sedentary, and to a wide range of carnivore species of all sizes. But the arrival of Afrikaner trekkers and their livestock at the end of the 19th century heralded the beginning of a dramatic change in the nature of this vast open landscape and the most common mammal to be found in the area today is the cow (Thomas 2002). As a result of this habitat degradation has also occurred. However, some wild game species do remain and carnivores are also still present but little is known about their diversity or abundance. What is known is that livestock depredation and retaliatory killing of predators is commonplace, and that there is a tension between the stated aims of the Government to protect and conserve the country's natural resources and the need to provide an environment which allows for the economic production of domestic livestock.

The amount of research that has been conducted on commercial farmland in Botswana is limited and therefore many questions with respect to the status of the wildlife in such areas and the views of the farmers on whose land they live remain unanswered. Socio-cultural questions surrounding the perceptions and attitudes of the minority group that owns and manages these large areas of land have also been neglected. As a result, the potential of these wildlife populations as a component of Botswana's biodiversity is unknown. The overarching question is, is coexistence possible and if so at what scale? What conditions need to exist to facilitate it? The understanding of both sides of the equation is vital to any strategy or management plan. To this end, the lack of knowledge regarding carnivores outside protected areas needs to be addressed and the attitudes and opinions of the human population accorded a higher priority than has historically been the case. The aims of this study were to fill in some of these gaps in understanding to facilitate the formation of a more complete strategy for the management and conservation of the wildlife in this, and similar, areas.

1.2 Project aims

The project aimed to bridge the divide between biology and anthropology by addressing both issues within one study. From the biological perspective the aim was to address those gaps in knowledge that exist with regard to the populations of carnivores that currently live on farmland in Botswana and the human-wildlife conflict they engender. The anthropological side of the equation was concerned with ethnic identity, livelihoods and economics. For that reason the people were questioned to determine how they feel and what they know about the animals on their land. Their attitudes and the strategies they employ to protect themselves and their livestock could make the difference between survival and extinction (at least at a local level) for some carnivore species.

In order to achieve these aims the following questions were addressed:

1. What is the population status of carnivores on farmland and does their distribution vary with land use and management?
2. Does the behaviour of carnivores in farmland differ from that documented for protected areas, and are any differences equivalent for all species?
3. What is the availability of naturally occurring prey species and does their distribution vary with land use and management?
4. Does the behaviour of prey species in farmland differ from that documented for protected areas?
5. What are the attitudes of local farmers and landowners to specific carnivore species and their conservation, and how are those attitudes informed by their ethnic identity?
6. What is the potential for carnivore conservation in the Ghanzi farmlands?

1.3 Thesis structure

The thesis has been divided into eight chapters which are broadly outlined below:

1. **General introduction.** The first chapter of the thesis outlined the context of human-carnivore conflict in semi-arid rangelands and its relevance and application to the current study. The aims of the project were also outlined.
2. **Study area and methodology.** This chapter provides an introduction to the study area describing the human and animal populations of the Ghanzi farmlands. An overview of the methods and analyses used in the study is presented.
3. **Historical perspective of wildlife in the Ghanzi farmlands.** In the introduction to the study area it is made clear that the environment in the area has undergone many changes in the past c. 100 years due to the expansion of human populations and livestock production. This chapter describes the ecosystem as it was and how it is remembered. It then expands on the reasons for the subsequent changes.
4. **Prey populations in the Ghanzi farmlands.** Having established the historical picture of the area attention turns to the situation as it is today. Chapter 4 addresses Question 3 and analyses data obtained from biological methodologies to assess the occurrence of naturally occurring prey species in the area today.
5. **Ecological aspects of carnivore populations in the Ghanzi farmlands today.** Completing the investigation of the status of the wildlife population in the area Chapter Five sets out to answer Question 1. Data from two biological methodologies are analysed to determine the population status of five different carnivore species in the Ghanzi farmlands today.
6. **Social and cultural attitudes towards wildlife.** Having gained a picture of the biological status of the wildlife in the Ghanzi farmlands this chapter addresses Question 5, and examines the prevailing attitudes of the farmers and other stakeholders to that wildlife and its conservation. The possible influence of ethnic identity on those views is also investigated.
7. **Carnivore and prey activity patterns in the Ghanzi farmlands.** The final data chapter addresses Questions 2 and 4 by examining patterns of activity of carnivores and prey in this area of high human activity in order to determine how and if they differ from those in protected areas. The influence of the activity pattern of a species on its perception by farmers is also explored.
8. **Final discussion and conclusions.** The final chapter provides a summary and synthesis of the results from Chapters 3 to 7 and also addresses Question 6 in assessing the current status and future prospects of carnivores in the Ghanzi

farmlands. Recommendations are made for measures that could reduce conflict, and increase community involvement in the development and implementation of management strategies. Areas where further work is thought necessary are also highlighted.

Chapter 2 - Study area and methodology

2.1 Study area

Botswana is a landlocked country located in southern Africa (Figure 2.1). It is bordered by South Africa, Namibia, Zambia and Zimbabwe. The population at the census of 2001 was around 1.7 million and the economy is based on diamond mining (Botswana is the largest exporter of gemstone diamonds in the world), cattle/beef production and tourism (Government of Botswana 2005).

Figure 2.1 Map of southern Africa

The study area of Ghanzi is located in Ghanzi District in western Botswana. One of ten administrative districts in the country (Figure 2.2), Ghanzi District covers an area of 117,910 km^2 and at the 2001 census had a population of just over 33,000. The ethnic make-up of the area comprises four main groups. The Batswana (the largest ethnic group in Botswana comprising eight different clans), the Bushmen (Basarwa or San), who are numerically the largest group in the area, the Baherero and those of European origin – mainly the Boers or Afrikaners (Twyman 2001). The vast majority of the farmland is owned by the latter.

The first white European to settle in the area was a Boer named Hendrik Van Zyl who built an ostentatious house at Ghanzi Pan (one of the few permanent surface water points in the area) in the 1870's (Russell & Russell 1979; Thomas & Shaw 1991). Little is known about this individual other than that he was a hunter of apparently insatiable appetites accounting for 400 elephant in the Ghanzi area in 1877 and a year later, when in a six-man hunting party, 103 in a

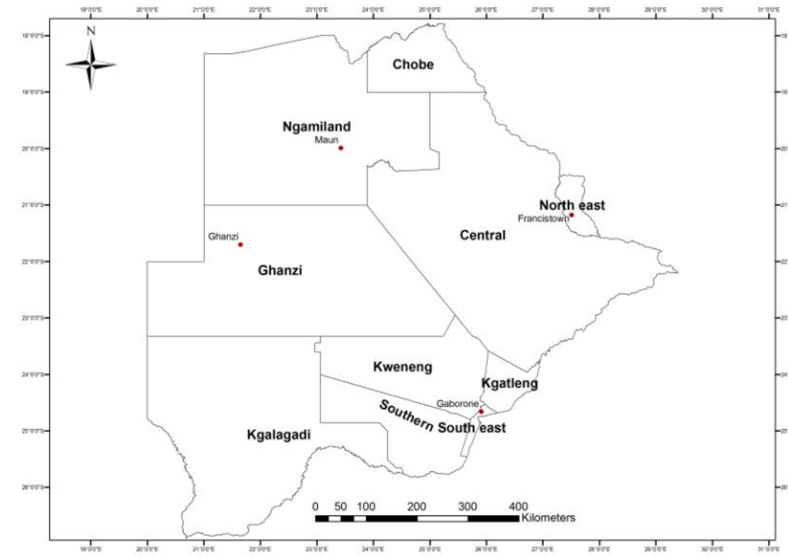

Figure 2.2 Map of Botswana showing the ten administrative Districts

single afternoon (Thomas & Shaw 1991). Van Zyl did not remain in the area however and it was in 1898 that the first eleven Afrikaner families arrived in Ghanzi from the Cape having been allocated farms by the British South Africa Company. By February 1899 the number of families had swelled to 41 and each was allotted 5000 morgen (about 4,500 hectares). This initial settlement was not successful and by 1902 only one of the original families remained (Russell & Russell 1979). But the lure of Ghanzi had taken hold and others followed forging a mutually dependent relationship between themselves and the Bushmen, with the trekkers relying on Bushman veld-knowledge and labour and the Bushmen benefiting from Afrikaner skills and protection from slave traders (Russell & Russell 1979; Dekker 2008).

Today the Bushmen people in the area no longer follow their traditional hunter/gatherer lifestyle but are almost totally dependent for employment on the farm owners. As a result, unemployment among this group is extremely high (pers. obs.). The Batswana population are predominantly government workers (e.g. teachers, health-care professionals and officials of the Department of Wildlife and National Parks (DWNP)). There is limited history of Batswana settlement of the area and many of the aforementioned officials hail from the larger urban centres in the east and south of the country. Russell & Russell (1979) described the arrival of such officials at Ghanzi air strip in the 1970s as having:

> *…….an air of authority and a casual, self-conscious sophistication. This is their territory, yet they are outsiders; a term of duty in Ghanzi is a term of exile from the east, from one's own kind; it is to be plunged into a curious rural cosmopolitanism, administering*

> *the affairs of a host of Botswana's ethnic and cultural minorities.* (Russell & Russell 1979 p. 3)

Ghanzi District is an area of semi-arid bush with a wet season that extends from October to April with a mean annual rainfall of 400 mm. Temperatures range from -5^{o} C in winter to 43°C in summer. The area comprises a multi-use landscape with commercial farms of both livestock (cattle, sheep and goats) and game, communal farms and Wildlife Management Areas (WMA's) (Law). WMA's are areas designated by the government as multiple-use land designed to combine wildlife conservation with the establishment of self-sufficient, sustainable rural economies (Twyman 2001).

The District is bordered on the west by Namibia, while most of the eastern half is made up of the Central Kalahari Game Reserve (CKGR), which at 52,800 km^2 is the second largest game reserve in the world (larger than Denmark or Switzerland). The CKGR was established in 1961 to protect wildlife resources and provide sufficient land for traditional use by the Bushmen communities of the central Kalahari. The Bushmen were subsequently relocated in three big clearances in 1997, 2002 and 2005 as their increasingly pastoral lifestyles were considered to be incompatible with the preservation of wildlife populations (http://www.gov.bw/index). There are potentially 21 species of carnivore that may occur in the area (Table 2.1) (Mills & Hes 1997); although today lions (*Panthera leo*) are rarely seen except on the farms on the eastern side of the farm block which functions as a sink for those dispersing from the CKGR (pers. obs.). Naturally occurring mammalian prey species in the area range in size from kudu (*Tragelaphus strepsiceros)* to various species of rodent (Mills & Hes 1997).

Ghanzi farm block is centred around the town of Ghanzi (Figure 2.3) the administrative centre of Ghanzi District. Ghanzi town, originally called Ghanzi Camp (Russell & Russell 1979), and the farm block were initially located on the limestone ridge which extends north east from the town of Gobabis in Namibia to just below Lake Ngami in Botswana (Figure 2.4), this being the most fertile area with good, easily accessible underground water supplies. Over time the farm block has expanded out into the sandveld. The farm block consists of over 200 farms holding around six per cent of the national cattle stock (national herd). Most of these farms are commercial cattle operations, but in recent years several farmers have converted, either in part or completely, to game for tourism/hunting (Figure 2.5). Many farmers also keep some small-stock and there are a few that farm small-stock exclusively.

Table 2.1. Carnivore species potentially occurring in the Ghanzi farmlands ((Mills & Hes 1997))

Common name	**Scientific name**	**IUCN Red List status** ((IUCN 2010)) (as at 01/01/2011)
Aardwolf	*Proteles cristatus*	LC
African wild cat	*Felis silvestris lybica*	LC
African wild dog	*Lycaon pictus*	EN
Banded mongoose	*Mungos mungo*	LC
Bat-eared fox	*Otocyon megalotis*	LC
Black-backed jackal	*Canis mesomelas*	LC
Black-footed cat	*Felis nigripes*	VU
Brown hyaena	*Parahyaena brunnea*	NT
Cape fox	*Vulpes chama*	LC
Caracal	*Caracal caracal*	LC
Cheetah	*Acinonyx jubatus*	VU
Dwarf mongoose	*Helogale parvula*	LC
Honey badger	*Mellivora capensis*	LC
Leopard	*Panthera pardus*	NT
Lion	*Panthera leo*	VU
Slender mongoose	*Galerella sanguinea*	LC
Small-spotted genet	*Genetta genetta*	LC
Spotted hyaena	*Crocuta crocuta*	LC
Striped polecat	*Ictonyx striatus*	LC
Suricate	*Suricata suricatta*	LC
Yellow mongoose	*Cynictis pencillata*	LC

Red List key: LC = least concern; NT = near threatened; VU = vulnerable; EN = endangered; CR = critically endangered; EW = extinct in the wild; EX = extinct

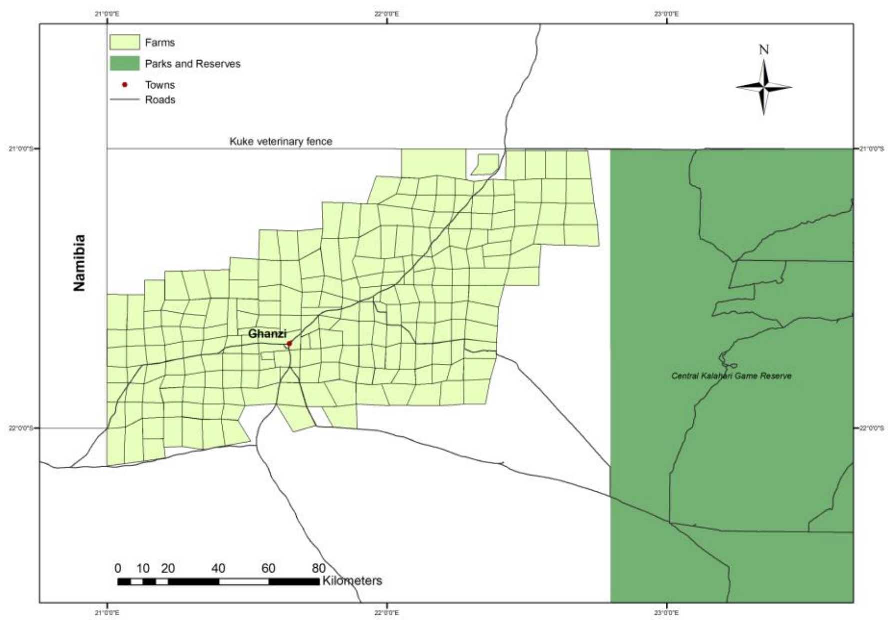

Figure 2.3 Ghanzi farm block

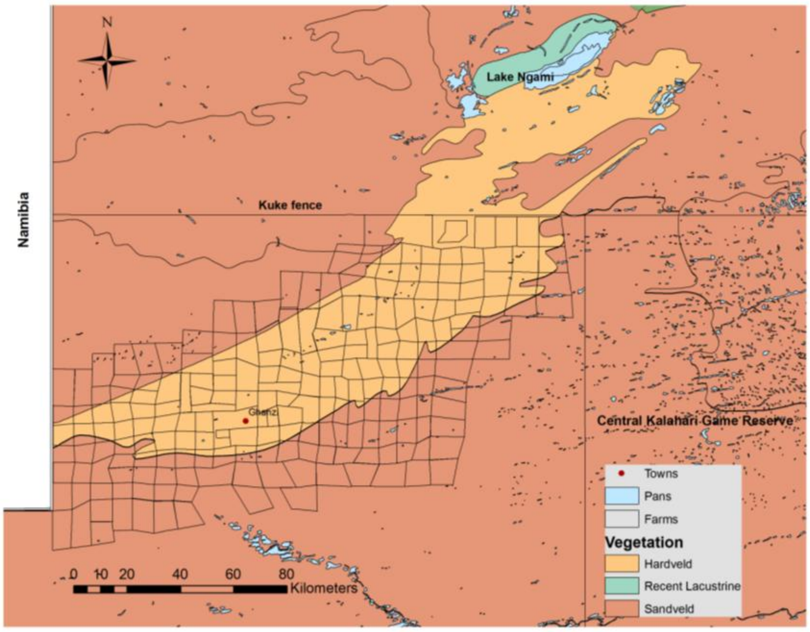

Figure 2.4 Map of Ghanzi area showing geology/vegetation zones

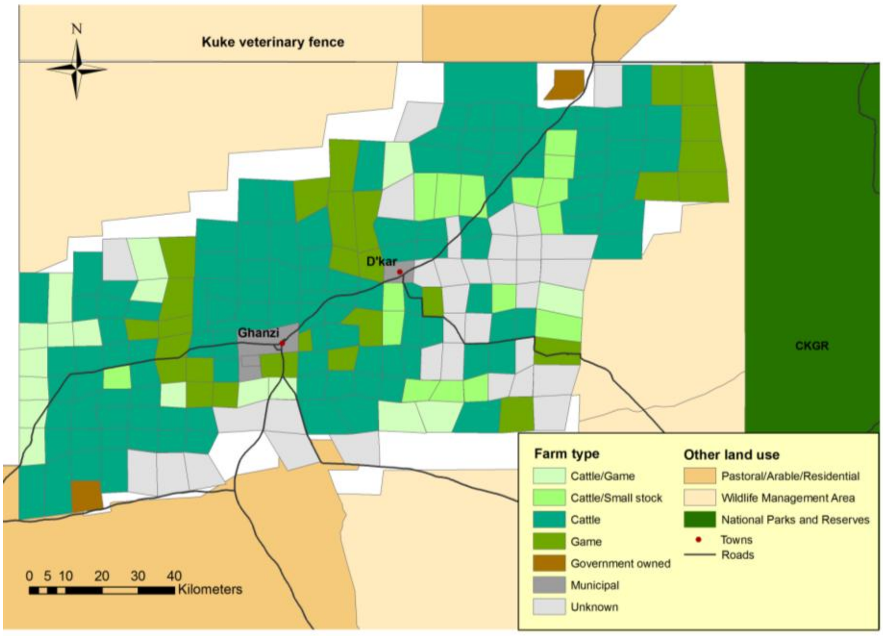

Figure 2.5 Ghanzi farm block showing land use in 2009

Farm management practices vary considerably in the area and range from the historically traditional Afrikaner practice of allowing cattle to range freely with minimal management or supervision, to the intensive management framework of the Holistic Resource Management (HRM) model developed by Allan Savory (Savory 1991). The HRM model was developed to address the problems of farming in brittle environments (landscapes with erratic annual moisture distributions) in a period of global climate change and desertification and seeks to provide a means of farming that allows for increased production while promoting and protecting biodiversity, reducing invasive species and preventing soil erosion (Savory 1991). In practice very few farmers in the Ghanzi farm block have embraced all of the principles associated with this system but many have incorporated elements of it such as rotational grazing, calving seasons and improved record-keeping systems.

The farms are large and fenced, sometimes they are also fenced internally into camps to allow for rotational grazing, but the livestock are generally free-ranging within those fenced areas. Two main types of fencing are utilised. The first is a five-strand circa 1.5 metre high cattle fence (Figure 2.6); this is a barrier only to cattle, horses and donkeys. Kudu can jump these fences with ease (Figure 2.7) and smaller naturally occurring game species such as common duiker (*Sylvicapra grimmia*), steenbok (*Raphicerus campestris*) and warthog (*Phacochoerus africanus*), as well as all predator species, either go through or under them. The second type is the game fence which is designed to enclose all large game species including kudu. The smaller game species and predators still go through or under them. When game fences are newly erected it is not uncommon for kudu, that are accustomed to free movement across the land, to become entangled whilst trying to get through (Figure 2.8), usually with fatal results.

Figure 2.6 Typical five-strand cattle fence

Figure 2.7 Female kudu jumping cattle fence

Figure 2.8 Young male kudu caught in game fence

Land ownership is to a large degree concentrated in the hands of a few individuals. Each individual farm plot covers an area of around 5000 hectares, but many farms are made up of several of these plots to the extent that some farmers now own, lease or manage huge tracts of land. The vast majority of land in the farm block is owned and/or managed by as few as 50 families. Bushmen are often employed to live at cattle posts located out in the bush where the stock may be watched, herded and/or kraaled to varying degrees (Figure 2.9).

An increasingly common phenomenon is that of the absentee farmer. Families who historically owned large tracts of land have, in some instances, started to sell off some of these individual farms, many of which are being bought by South Africans who live outside of Botswana. These farms are often left in the hands of foremen and Bushmen at cattle posts and only occasionally visited by the owners. The terms and conditions on which these workers are employed vary considerably and there are instances where they are largely left to fend for themselves, with insufficient money to buy food, diesel for water pumps or other essentials (pers. obs.). This often results in the poaching of game on neighbouring farms and neighbours being asked to supply diesel to run the pumps for the cattle (pers. obs.).

Figure 2.9 Cattle post on commercial farm in Ghanzi farmlands

The vegetation in the area used to be classed as open bush savanna, a habitat which was partially maintained by bush fires, both naturally occurring and deliberately set by the Bushmen who, at the time of settlement, still lived traditional hunter-gatherer lifestyles. However, overgrazing and the cessation of controlled burning have, in the past 50 years or so, been two of the factors considered likely to have caused the severe bush encroachment which is now apparent in most of the area. This has resulted in impoverished grazing for both cattle and game (Ringrose *et al.* 2002). The increase in woody plants, at the expense of grasses, in semi-arid rangelands can be viewed as a type of desertification (Archer 2010) and is characterised by dense thickets of aggressive species such as *Acacia mellifera*.

The Ghanzi farmlands are comprised of two distinct vegetation types, hardveld and sandveld. The hardveld, situated along the limestone of the Ghanzi ridge (Figure 2.4), has a complex vegetation structure which was thought sufficiently different to warrant it being given its own classification, namely Ghanzi bush savanna, in 1971 (Weare & Yalala 1971 cited in Ringrose *et al.* 2002), and is dominated by *Acacia mellifera*, *Acacia erioloba*, *Terminalia prunioides* and *Catophractes alexandri.* Because of its geological structure it is also characterised by a shallower water table providing easier access to much needed water resources (Thomas & Sporton 2002). Small (up to 50m diameter) pans, or depressions, commonly occur on the hardveld of the Ridge which fill with rain water in the wet season as well as occasional larger ones (Cole & Brown 1976). (Hardveld mostly occurs in the eastern part of Botswana and the Ghanzi Ridge therefore represents an unusual habitat situated as it is in the middle of the Kalahari sandveld.) The sandveld that lies away from the ridge is covered with Arenosols which have a low capacity to hold water and poor organic matter content (Botswana Government 2006). The water table underlying the sandveld is also much deeper than the hardveld (Cole & Brown 1976). Sandveld tree and shrub vegetation is characterised by *Terminalia sericea*, *Lonchocarpus nelsii* and *Acacia erioloba* with *Acacia erubescens* becoming more prevalent in the north. Grasses in the two vegetation types are also quite different with species characteristic to the hardveld, such as *Panicum maximum, Urochloa trichops* and *Bothriochloa insculpta*, providing higher crude protein content, especially in the dry season, than those found on the sandveld such as *Digitaria milanjiana* and *Anthephora pubescens* (Burgess 2003).

2.2 Data Collection

Data collection had two components. The first focused on the gathering of information on density, abundance and activity patterns of both predators and naturally occurring prey species. This was achieved by carrying out spoor surveys and camera trapping surveys. The second component involved ascertaining the knowledge, opinions and perceptions of farmers and other stakeholders, towards wildlife, by means of interviews and researcher administered questionnaires.

2.2i Ecological methods

Spoor and camera trapping surveys were undertaken on several farms of different land usage types and with varying management practices within a 70 kilometre radius of Ghanzi town (Figure 2.10).

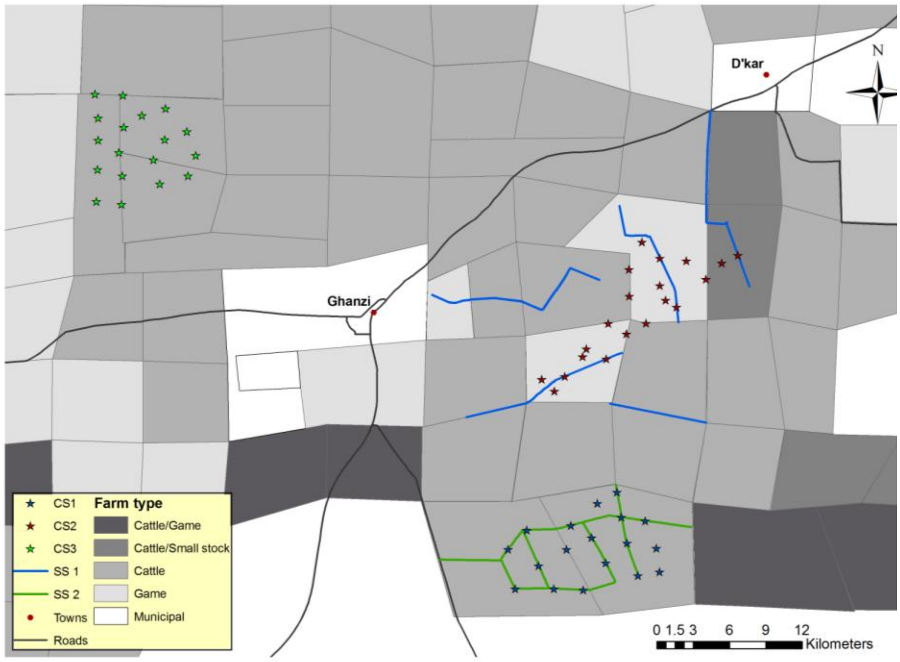

Figure 2.10 Map of study area showing locations of spoor and camera surveys
Spoor surveys – SS1 and SS2; Camera surveys – CS1, CS2 and CS3

Spoor surveys

Spoor surveys aimed at establishing the density of leopard, cheetah (*Acinonyx jubatus*), brown hyaena (*Parahyaena brunnea*), caracal (*Caracal caracal*) and black-backed jackal (*Canis mesomelas*) were conducted in two areas on the eastern side of the farm block.

Spoor Survey 1 (SS1) was carried out during the wet season on a group of farms that comprised a range of land uses - cattle farming, small stock farming, game farming and one farm that had been unused for several years but was in the process of being prepared for cattle (Figure 2.11).

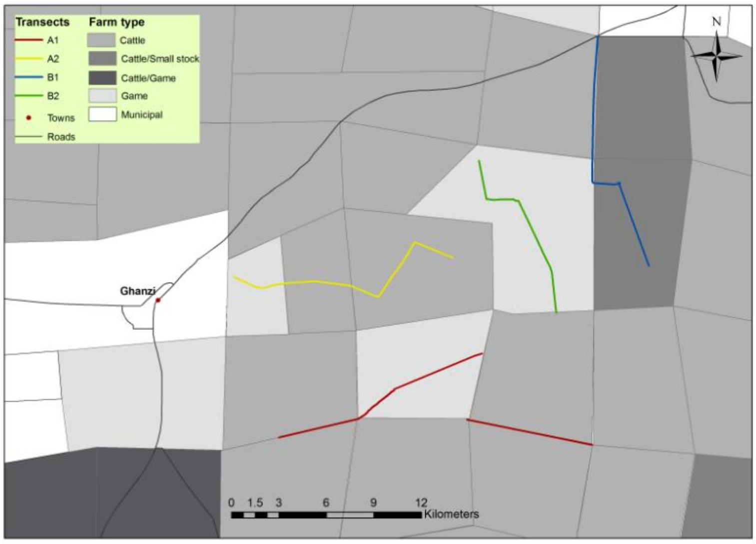

Figure 2.11 Spoor survey 1 transects
Conducted in 2008/9

All these farms were situated on the hardveld of the limestone ridge and were therefore characterised by a substrate of Kalahari sand interspersed with occasional outcrops of calcrete or rock. SS1 had six transect routes ($\bar{x}$ distance = 10.74 km $\pm$ 1.87 S.E.) (Figure 2.11) and was undertaken between November 2008 and March 2009. Transects were not driven when rain had fallen in the past 24 hours or when there was evidence of the track having been driven by another vehicle in the previous 12 hours.

Spoor Survey 2 (SS2) was conducted on a 20,000 hectare cattle farm during the dry season. The farm was located on the sandveld with a substrate comprised entirely of soft loose Kalahari sand. SS2 had five transect routes ($\bar{x}$ distance = 9.9 km $\pm$ 2.91 S.E.) (Figure 2.12) and was undertaken between May and September 2009. Although the months during which this spoor survey was carried out were nominally the dry season, winter rain occurred during May and over a two week period in June when, as for Survey 1, transects were not driven if rain had fallen in the previous 24 hours.

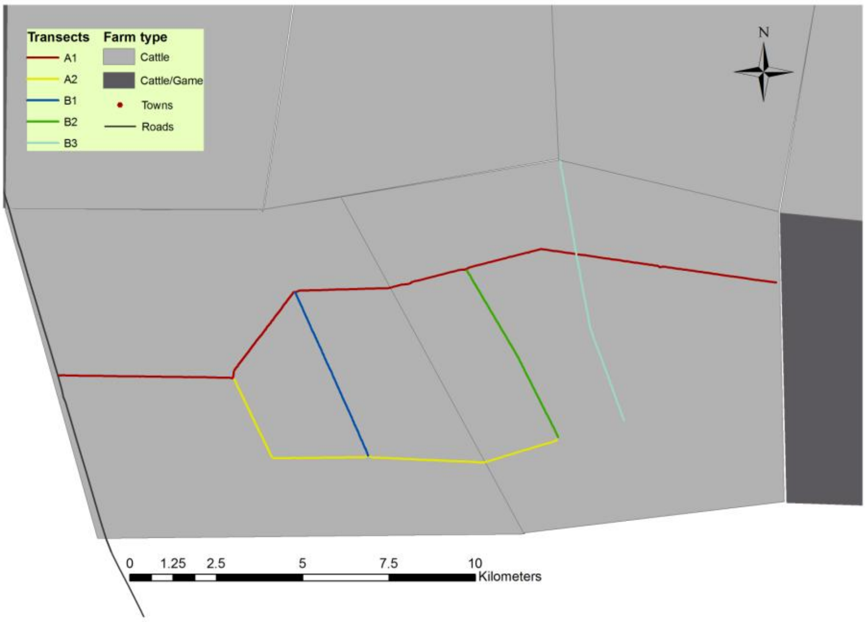

Figure 2.12 Spoor survey 2 transects
Conducted in 2009

In both surveys, transects used were existing farm tracks and were selected on the basis of their being as linear as possible. Transects were also selected to ensure that tracks with both east-west and north-south orientations were surveyed, with only one direction being driven on any given day. All transects within a survey were driven with equal frequency, between the hours of sunrise and no later than 11:00, and at a constant speed of between 12-20 km/hour, until a total $\cong$ 1000 km of transect had been accumulated. This is thought to be the minimum surveyed distance needed to reach an asymptote of spoor frequency (number of kilometres per spoor) where carnivores exist at low density (J. W. McNutt pers. comm.). A skilled Bushman tracker sat on the front of the vehicle and all fresh ($\leq$24 hr old) spoor of black-backed jackal, caracal, brown hyaena, cheetah and leopard were recorded. Bushmen are renowned for the accuracy of their tracking skills which, when tested, have been found to be highly reliable (Stander *et al.* 1997a) and have been used in several spoor survey counts in southern Africa (cf. Stander 1998; Funston *et al.* 2001; Melville & Bothma 2006). The same tracker was used for both surveys. In addition to recording the occurrence of a species' track, the group size and distance travelled along the road was also noted. Additionally, where possible, the age and sex of the animal(s) was determined. Spoor was identified using the tracker's experience and, when necessary, by referring to a field guide for tracks and signs of the area (Stuart & Stuart 1999).

Camera trapping

Three camera-trapping surveys were carried out using 26 x Cuddeback© Digital Expert cameras (Non Typical Inc. Wisconsin, USA). The data gathered in these surveys were used to provide density and/or abundance estimates of the same species of predators targeted in the spoor surveys, plus naturally occurring prey species.

Camera Survey 1 (CS1) was carried out on the same cattle farm as Spoor Survey 2, Camera Survey 2 (CS2) was located primarily on two adjoining game farms in the centre of the group of farms surveyed in SS1 and Camera Survey 3 (CS3) was undertaken on two cattle farms on the western side of the farm block. Camera trapping protocols were based on methods developed for surveying tigers (*Panthera tigris*) (Karanth & Nichols 1998; Karanth & Nichols 2002), leopards (Henschel & Ray 2003) and jaguars (Silver 2004).

All surveys ran for a period of 62 days with cameras operating 24 hours per day. Sixty-two days was selected as an appropriate period that would ensure that at least 1000 camera trap nights were achieved, in a period of time that would not compromise population closure assumptions. Cameras were attached to trees or fence posts where possible. Where neither of these was available a stake was driven into the ground to which the camera was attached. Camera height was set at between 25 and 40 cm above the ground which was optimal for capturing all predators. Delay between consecutive exposures was set at 1 minute and sensitivity set to high. Cameras were checked weekly, when memory cards were changed and pictures then downloaded and entered into Camera Base (Tobler 2007), a tool designed to be used with Microsoft® Access for the management of camera trap survey data. Each 62-day survey was preceded by a pilot period of between two and three weeks when camera positions and spacing were refined and adjusted. Data gathered during the pilot periods were sometimes included in analysis and where this was the case it is indicated in the relevant section.

CS 1 was undertaken during the wet season between January 18th and March 20th 2009. A three week pilot survey was carried out prior to the commencement of the survey proper. Eighteen camera stations were laid out in a roughly rectangular grid (Figure 2.13).

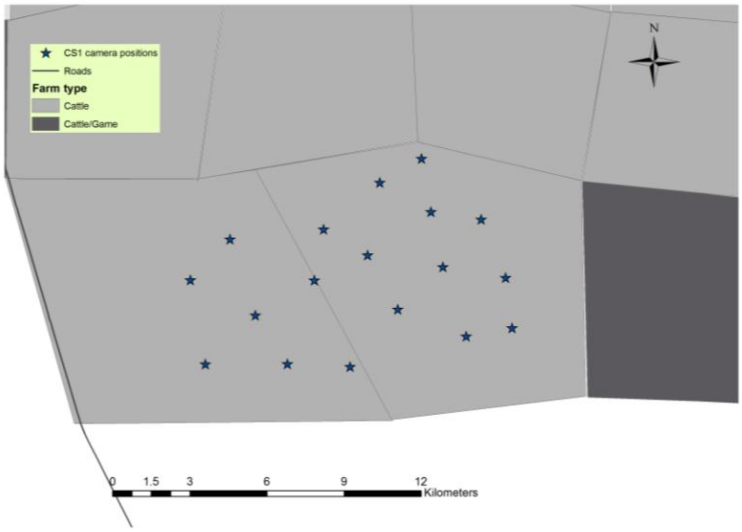

Figure 2.13 Camera positions for Camera Survey 1

Design and spacing ($\bar{x}$ distance = 2.49 km) was initially aimed at capturing caracal and stations were positioned where it was thought most likely that predators in general, and caracal in particular, would be seen based on previous sightings, spoor and/or availability of water. Gaps were then filled to ensure that no holes existed in the grid large enough to encompass the entire home range of a female animal with young (Karanth & Nichols 1998). This ensures that no animal within the survey area has a zero probability of capture. Caracal home range size was determined from previous studies carried out in South Africa with radio-collared animals (Stuart 1984; Norton & Lawson 1985; Moolman 1986; Avenant 1993; Avenant & Nel 1998) in which the smallest home range recorded of 2.97 km^2 was that of a female with kittens <4 months old (Avenant & Nel 1998). A camera spacing distance of $\leq$2.5 km was therefore selected as being appropriate to fulfil that requirement.

A mixture of paired and single camera stations was used in order to maximise the number of stations employed and area covered with the available cameras. The logic underlying this strategy was that it would only require one photographic capture of an animal with unique pelage markings at a paired station to provide images of both flanks. Subsequent captures of the same individual at a station with only a single camera would then make identification possible, regardless of which flank the photograph showed.

CS 2 was carried out between April 19^{th} and June 19^{th} at the beginning of the dry season although, as previously mentioned in the methods for SS2, late rain fell in both May and June 2009. In this survey the two game farms being surveyed were connected diagonally at their north-east and south-west corners. The layout and spacing for the cameras was determined as for CS1 except that 20 camera stations were deployed ($\bar{x}$ distance = 2.2 km), but due to the geography of the farms this resulted in a much more elongated grid (Figure 2.14). A two week pilot survey was again carried out in order to refine and adjust camera station positions.

CS3 was undertaken between 15th July and 14th September during the dry season. The farms in this survey were adjoining cattle farms both of which had, until recently, been managed using traditional methods (see section 2.1). Eighteen stations were deployed, with positions and spacing again determined as for CS 1 ($\bar{x}$ distance = 2.5 km) and refined and adjusted during a two week pilot period (Figure 2.15).

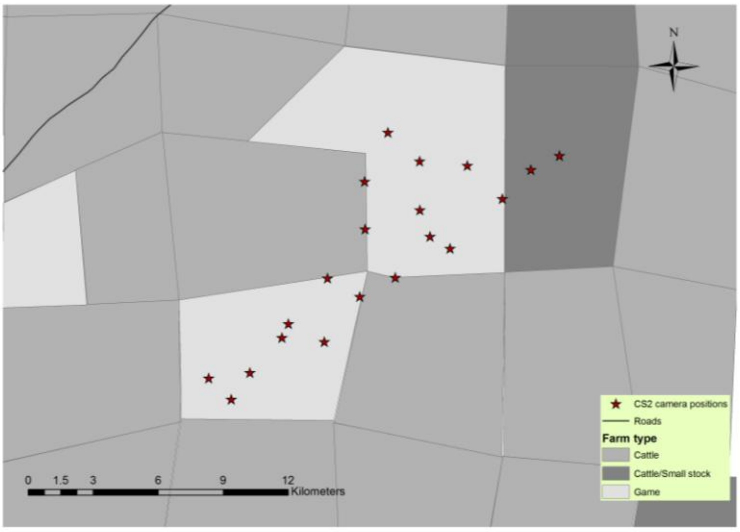

Figure 2.14 Camera positions for Camera Survey 2

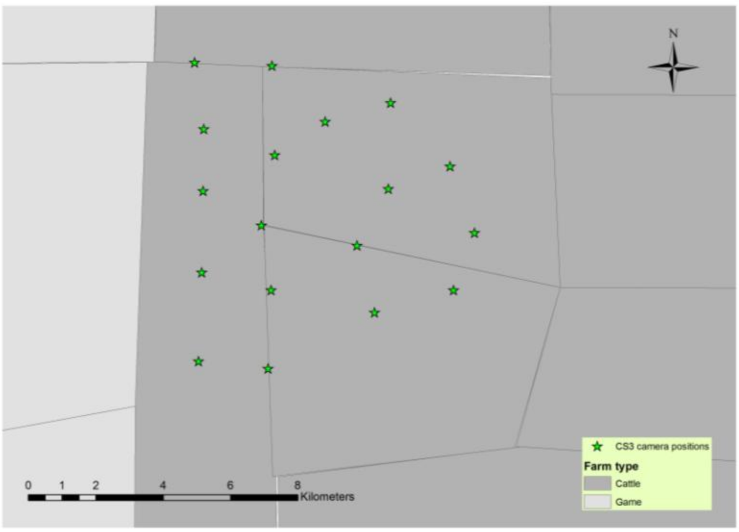

Figure 2.15 Camera positions for Camera Survey 3

2.2ii Socio-cultural methods

Interviews

In depth interviews were conducted with five older generation farmers in order to gain an insight into their memories of wildlife populations as they existed in the past, and how they have changed in the intervening years. Sample size was governed by the limited number of individuals of this generation still living in the area. The interviewee sample comprised two farmers of Afrikaner and three of African/European descent. Four were male and one female. Interviews were semi-structured in that initial questions were predefined for all interviews, but the interview was then allowed to develop according to the train of thought of the interviewee in accordance with methods outlined by Bernard (2002). They were conducted in informal situations and were recorded on a digital recording device with the permission of the interviewee. Interviews were transcribed and coded at a variety of categories and subjects for subsequent analysis in QSR NVivo 8 (QSR International 2008).

Questionnaires

Twenty questionnaires were administered by the researcher towards the end of the fieldwork period, to both domestic livestock and game farmers, in order to gain information on livestock management practices, occurrence and status of predators and prey species on respondents land, levels of livestock predation (both numeric and economic) and attitudes towards them. In the first instance, approaches were made to farmers who were known to the researcher and contacts obtained from these individuals to widen the sampling base. The aim was to sample a mix of game, cattle and cattle/small stock farmers from both Afrikaner and non-Afrikaner backgrounds. As mentioned in section 2.1, the total number of farming families in the area is only around 50 and no farmer who was approached refused to participate. However, sample size was to some degree governed by time and travel constraints (further information on time constraints is provided in the section on Participant Observation below). Due to the large size of the study area, and the long travel times involved in reaching many farms, most participants were located within a two hour drive of Ghanzi; although meetings were arranged in town with some who lived further out. The total area of farmland owned and/or managed by the questionnaire respondents amounted to nearly 4,000 km^2.

As for the interviews, most of the meetings at which the questionnaires were administered were recorded on a digital recording device with the permission of the participant. This allowed for additional information to be gathered which, if not covered in the questionnaire, might otherwise have been lost.

The questionnaire was trialled, after which questions were modified, and added and/or removed where necessary, in order to ensure that the questionnaire was appropriate in both biological and anthropological contexts before the implementation of the survey proper (Bernard 2002). For this, and other reasons, (see the Participant Observation methods section), implementation of the questionnaire survey was the last component of data collection to be undertaken during the fieldwork period.

An undertaking was given to all participants, of both questionnaires and interviews, that anonymity and confidentiality would be preserved. This was necessary to allow them the freedom to speak their minds without fear of repercussions. In order to honour that commitment quotations used from interviews and questionnaires are not attributed or identified by a code.

Cultural Consensus Analysis

In addition to the questionnaire described above, a separate set of 33 questions/statements was administered at the same time which was designed to test for cultural consensus on knowledge and beliefs about carnivores using the informal Cultural Consensus Model (Weller 2007). The theory behind this method has been outlined and elaborated by several authors (cf. Romney *et al.* 1986; Ross 2004; Weller 2007) and in recent years has been used in an environmental anthropology context by Miller *et al*. (2004) to compare knowledge about fish stocks, structure and movement of hand-line fishermen and fishery scientists in Hawaii and by Johnson & Griffith (2010) to investigate differences in perceptions of coastal resource problems between recreational and commercial fishers.

Cultural Consensus Theory requires participants to answer a number of questions pertaining to the same topic or domain. The interview should be conducted independently of other participants so that no consultation between individuals occurs. In this study, the additional set of questions was also administered as a stand-alone questionnaire to several members of other ethnic groups in the area (namely Bushmen and Batswana) with the intention of performing a cross-cultural analysis. The development of the questions/statements was based on conversations with farmers, officials of DWNP and farm workers over a period of several months of fieldwork and designed, like that of Miller *et al*. (2004), to elicit from people who could be classed as experts in the domain of carnivores on farmland, an answer to the question "What do you know?"

Participant observation

The practice of participant observation is frequently employed in social anthropology in order to gain a more complete understanding of attitudes, beliefs, value systems and behaviour of the community of interest (Bernard 2002). The perspective this provides being more readily applicable to practical situations (Glaser & Strauss 1999).

I was familiar with the area and many of the farmers as I had worked for a year as a researcher in the area for Cheetah Conservation Botswana (CCB) in 2006/7. This previous experience accorded both advantages and disadvantages. My knowledge of the area and many of the people allowed me to integrate into the community more quickly than might otherwise have been possible. However, my previous association with CCB meant that it took some time for me to establish myself in the minds of some farmers as an independent researcher, and for them to trust me as such, rather than as a representative of an NGO which, in the eyes of some, is a branch of officialdom. This was an important factor in the decision to leave the implementation of the questionnaires until the end of the fieldwork period. My experience of talking to the farmers was generally a rewarding one. I found them to be open, friendly, hospitable and eager to talk to someone who wanted to hear what they had to say without judging or condemning them.

The fieldwork was conducted over a period of 15 months and throughout this time I rented a cottage on a game farm approximately five kilometres from Ghanzi Town. The farm operated as a safari camp destination for tourists and the bar/restaurant was a regular haunt of the farming community. I regularly participated in social activities there as well as attending farmer's meetings and other events integral to the Ghanzi farming community such as the Ghanzi Show. In addition, encounters in the supermarket car park (a common meeting place) when undertaking daily shopping trips and the conducting of ecological fieldwork all provided opportunities for interaction with farmers, farm workers, NGO's and officials. These events, conversations and encounters, along with any other relevant information that occurred during daily life in the community, were recorded in an ethnographic diary. This was then coded for topics which, as for the interviews, was facilitated by the use of the qualitative data analysis software program NVivo 8 (QSR International 2008). Codes may be generated from simple subject matter or from more abstract concepts derived from identifying passages of interest and asking why they are interesting (Richards 2005). Recurring themes and ideas are likely to signify that they are of importance to the people expressing them (Ryan & Bernard 2003) and are therefore useful in the coding of data (Richards 2005).

Qualitative analysis of this kind, using established principles in which theories are generated from the data rather than imposed upon them (grounded theory) (Glaser & Strauss 1999), enables the discovery of emergent patterns and themes in the data. Some of the information gained in this way was used to inform the development of the Cultural Consensus questionnaire described above.

Chapter 3 – Historical perspective of wildlife in the Ghanzi farmlands

3.1 The history of wildlife conservation in southern Africa

Before attempting to describe the wildlife populations as they exist in the Ghanzi farm block today it is of value to put this into context by examining the past. Patterns of land and wildlife management in the southern African region as a whole, Botswana and the Ghanzi District have all contributed to the situation that exists today. This section therefore looks at the events and factors that have played a part in the creation of today's environment through historical records and the recollections of those that witnessed them.

Historically, the pattern of African wildlife conservation involved the setting aside of large areas reserved exclusively for nature, which in this context did not include humans (Adams & Hulme 2001). This was in fact rather different from the principle expounded in the 'Yellowstone Model' of National Parks, named after the creation of the Yellowstone National Park in the US in 1872, which was designed for the benefit and enjoyment of the people (Child 2004; Carruthers 2009). Rather, the policy on protected areas in Africa emerged out of European notions of how Africa and its wildlife 'should be' and a desire for it to remain as such, in order that traditional hunting rituals pertaining to European culture could continue to be played out (Adams & Hulme 2001). The exploitation of wild animals as a motivating force behind European colonial expansion being an acknowledged phenomenon (MacKenzie 1988). There was also a strong undercurrent of the mores of the British social class system in the way in which hunting for reasons other than 'sport', i.e. for meat, was considered to be unacceptable (MacKenzie 1987). When this was combined with the attitudes of Boer trekkers, who considered it their moral duty to remove wildlife in order to promote progress in general and agriculture in particular (Carruthers 1995), it led to widespread reductions in wild populations of many species.

The Convention Relative to the Preservation of Fauna and Flora in their Natural State (London Convention 1933) involved the governments of South Africa, Belgium, the UK, Egypt, Spain, France, Italy, Portugal and the Anglo-Egyptian Sudan. It was convened by these African colonial powers with the stated aim of protecting the vanishing wildlife of the world, and Africa in particular, by the institution of 'a special regime for the preservation of fauna and flora.' It considered the best means of achieving this aim were:

- *(i) (by) the constitution of national parks, strict natural reserves, and other reserves within which the hunting, killing or capturing of fauna, and the collection or destruction of flora shall be limited or prohibited*
- *(ii) (by) the institution of regulations concerning the hunting, killing and capturing of fauna outside such areas*
- *(iii) (by) the regulation of the traffic in trophies, and*

(iv) *(by) the prohibition of certain methods of and weapons for the hunting, killing and capturing of fauna.* (London Convention, 1933)

Unfortunately, the policy effectively nationalised wildlife, thereby removing any economic incentive for landowners to manage and/or conserve the wild animals on their land (Child 2009a). It also presented a highly formalised view of conservation, existing within the boundaries of parks and reserves specifically created for such purposes, which led to a view that all wildlife existing outside such areas should be controlled and/or exterminated as it infringed on and compromised areas of human activity and commerce. In Botswana, the protected areas are large and include buffer zones - Wildlife Management Areas (WMAs) – which have been designated to combine conservation with wildlife utilisation by local communities (subject to government regulations) (Twyman 2001). It is hoped that the WMAs thereby offer a degree of protection to agricultural land from the worst impacts inherent in being situated close to a protected area. However, conflict still occurs (see Chapter 6). Botswana may also present a special case as, from a biological and ecological point of view, it has been argued that due to the unique nature of its environment and its unpredictable rainfall, the Kalahari is 'different' and that the survival of wildlife populations there is dependent on their having access to surrounding areas (Crowe 1995).

3.2 The history of wildlife conservation in Botswana

Botswana as a country occupies a land mass of just under 570,000 km^2 (roughly equal to the size of France) and lies on the Southern African plateau at an elevation of around 1,000 metres, Kalahari sand covers 60 per cent of country (Figure 3.1). It has a small human population (1.7 million at the 2001 census) and, despite its semi-arid environment, large populations of wildlife. The diversity of species is also impressive with 147 described species of mammal (Botswana Government, 2009), 46 of which are medium to large mammals ≥ 6kg in weight. Many are uniquely adapted to survive for long periods without access to surface water (Child 1970) and for carnivores Botswana is a hotspot of diversity with 28 species (Mills *et al.* 2001). From a wildlife perspective there are now two distinct functional systems within Botswana, which have been created by the erection of fences. The Northeast system is made up of the districts of Ngamiland, Chobe and Central while the Southwestern system comprises the Ghanzi, Kgalagadi, Southern and Kweneng Districts (Crowe 1995)(Figure 3.2).

Botswana (or the Bechuanaland Protectorate as it was until Independence in 1966), formalised its nature conservation efforts late in comparison to the rest of southern Africa, with the creation of the Game Department in 1956. At the time this body consisted of just one officer and a few scouts, whose primary role was that of elephant control (Campbell 1973). Prior to

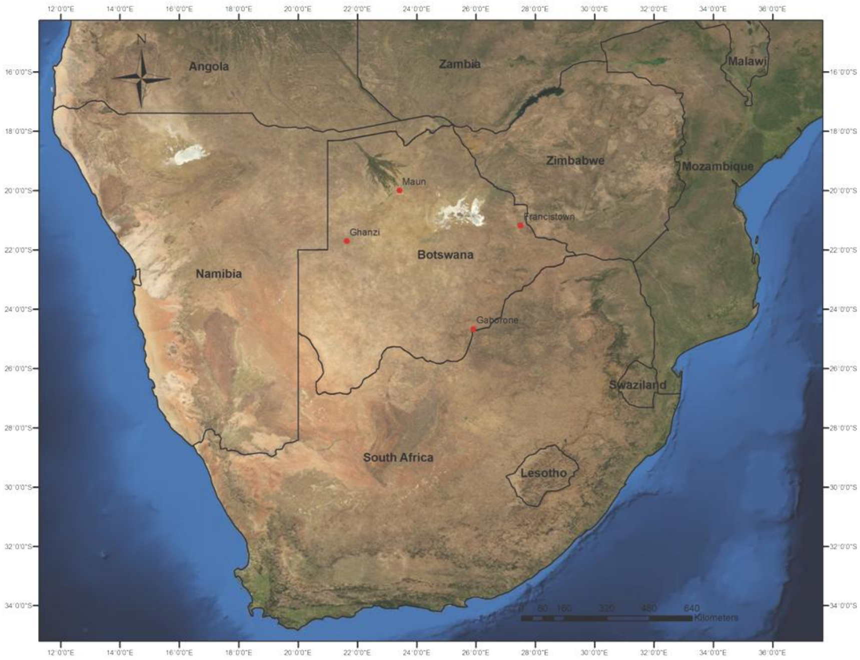

Figure 3.1 Satellite image of southern Africa showing Botswana's major towns and cities

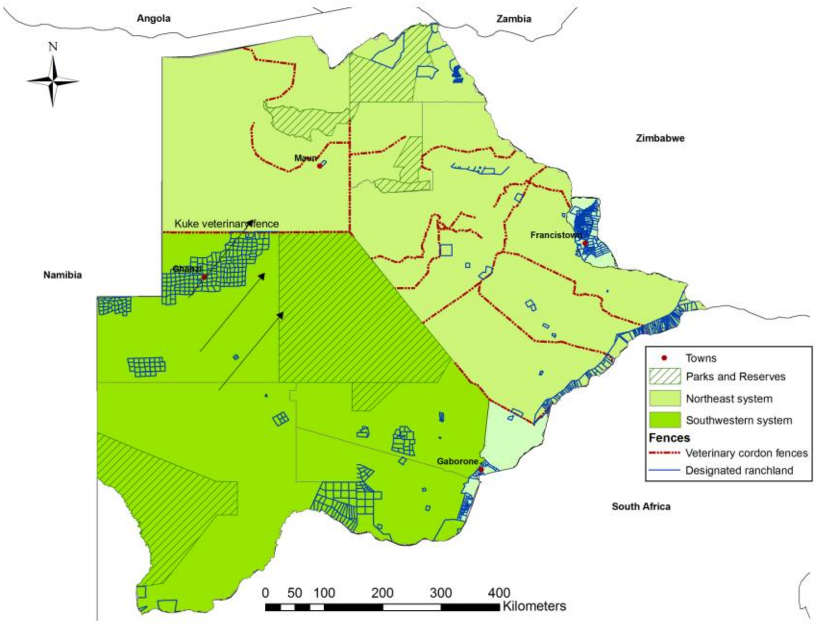

Figure 3.2 Map of Botswana showing the two distinct wildlife systems created by the veterinary cordon fences.
The arrows indicate historical wildlife migration routes

this the only park or reserve falling within Botswana territory had been the Gemsbok Game Reserve which had been created in 1932 and was managed by South Africa. In 1961, the Fauna Conservation Proclamation was enacted formalising hunting as a commercial activity by introducing controlled hunting areas and providing for the issue of hunting licenses to both residents (who were given preferential rates) and non-residents (White 1995; Mbaiwa *et al.* 2003). The term residents in this context did not include indigenous residents of the Protectorate who were allowed to continue to hunt within their tribal area (White 1995).

The Game Department became the Department of Wildlife and National Parks (DWNP) in 1967, which marks the point at which policy towards wildlife shifted. It was hoped that, by actively encouraging the wildlife industry, it would be seen as an economically viable method of land use (Child 1970, 2009b). In the same year, the 1961 Fauna Conservation Proclamation was revised to incorporate those residents previously excluded, with the proviso that if they belonged to a community that depended entirely on the hunting and gathering of veld produce for its survival they would still be allowed to do so. This served to reduce the reliance on wildlife as a means of subsistence (White 1995) but did nothing to address the overharvesting that characterised the foreign-dominated hunting market (Mbaiwa *et al.* 2003). By 1973 it was estimated that DWNP produced direct revenue from wildlife worth 430,100 South African Rand (in the early 1970s the Rand was worth approximately US$0.70 (Johnson 2011)). Nearly 75 per cent of this came from the hunting industry; the tourism industry at the time being still undeveloped due to a lack of facilities and poor infrastructure (Butynski & Von Richter 1975).

The creation of protected areas however was carried out in a somewhat haphazard manner with little reference to any ecological requirements. As the then Director of DWNP, A. C. Campbell, stated in 1973:

> *In many cases their boundaries were, and still are, arbitrary lines drawn on the map, parallels of latitude, rivers, existing tracks or roads, or administrative boundaries. Generally, their shape was calculated to interfere with the existing settlement of as few people as possible*. (Campbell 1973 p. 7)

By 1987, fifteen parks and reserves had been established (Table 3.1). While today protected areas account for approximately 17 per cent of the country and include the Central Kalahari Game Reserve (CKGR), which at 52,800 km^2 is the second largest in the world (Figure 3.3), and the Kgalagadi Transfrontier Park (KTP) (an amalgamation of the Gemsbok National Park, the Kalahari Gemsbok National Park in South Africa and the Mabuasehube Game Reserve), which in 2000 was formally launched as Africa's first Peace Park (Peace Parks Foundation 2010) (Figure 3.4).

Table 3.1 Botswana's conservation areas in 1987
(Source: IUCN/UNEP 1987; Child 2009b)

Park or Reserve	**Date established**	**Area (km²)**
Central Kalahari Game Reserve	1961	51,800
Chobe Forest Reserve	1976	2,400
Chobe National Park	1961	9,980
Gaborone Game Reserve	1980	2.39
Gemsbok National Park	1971 (Game Reserve est. 1932)	24,800
Khutse Game Reserve	1971	2,440
Mabuasehube Game Reserve	1971	1,792
Makgadikgadi Game Reserve	1970	4,140
Maun Game Reserve	1970	3
Moremi Wildlife Reserve	1962	1,800
Nxai Pan National Park	1971	2,590
Kasane Forest Reserve	-	1,200
Kazuma Forest Reserve	-	1.28
Maikelelo Forest Reserve	-	300
Sibuyu Forest Reserve	-	1,010
Total Area		**104,386**

Figure 3.3 North western area of the Central Kalahari Game Reserve

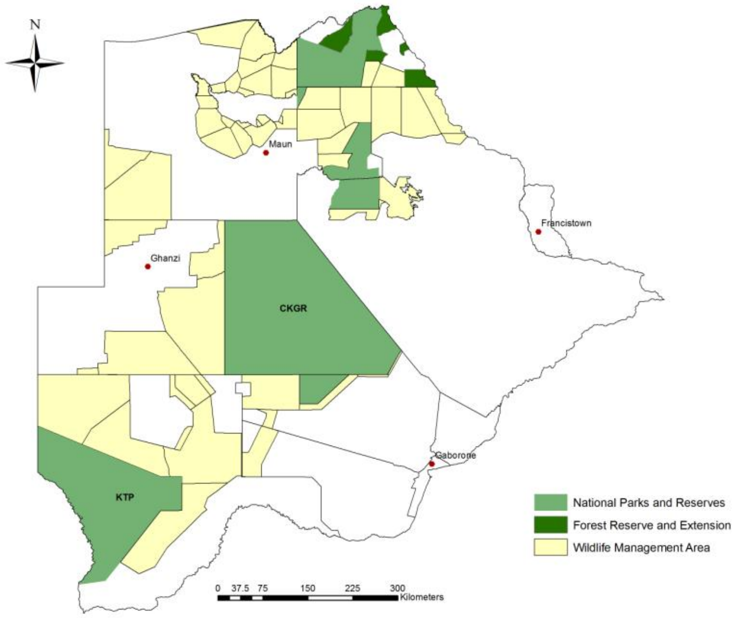

Figure 3.4 Map of Botswana showing protected areas featuring CKGR and Botswana portion of KTP

However, despite these large protected areas, the populations of many species are known to have suffered drastic declines since the mid-1970s (Crowe 1995) (Table 3.2). All wild vertebrates in Botswana are classified as game animals and officially require the possession of a licence or permit to be hunted. In addition, more than 50 species are classified as protected or partially protected game animals and it is prohibited to kill these species without a permit from DWNP unless there is a danger to human life, livestock, crops or property (Botswana Environment Statistics Unit 2005).

Table 3.2 Changes in ungulate populations in the Kalahari ecosystem between 1979 and 2003

Species	**1979***	**1994†**	**2003***
Eland (*Taurotragus oryx*)	24,767	12,784	25,966
Red hartebeest (*Alcelaphus buselaphus*)	>270,000	45,692	40,244
Blue wildebeest (*Connochaetes taurinus*)	>260,000	14,948	14,154

*1979 and 2003 figures are for Kgalagadi and Ghanzi Districts only.
† 1994 figures are for entire Southwestern System
Sources: Crowe 1995; Botswana Environment Statistics Unit 2005

3.3 The history of wildlife in Ghanzi District

The first trekkers to arrive in the Ghanzi area in the late 19th century would have seen a very different environment to that which exists today. The Kalahari here had been moulded by its wildlife and by fire, both naturally occurring and man-made. Fires caused by lightning strikes are a frequent occurrence during the summer months, particularly at the end of the dry winter, and it is thought that the Bushmen have used fire as a management tool to facilitate the hunting of game in the Kalahari for over 40,000 years (Silberbauer 1981; Perkins *et al.* 2002). This created a vast landscape of open grassland which provided ideal habitat for the enormous herds of springbok (*Antidorcas marsupialis*), blue wildebeest (*Connochaetes taurinus*), red hartebeest (*Alcelaphus buselaphus*), gemsbok (*Oryx gazella*), eland (*Taurotragus oryx*) and zebra (*Equus burchelli*) that traversed the area. The wildebeest and hartebeest particularly, being the most water dependent, migrated from their grazing grounds in the central and southern Kalahari during the summer, to the Makgadigadi Pans, to the water-filled channels created by the annual flooding of the Okavango Delta and to the swamps of the Chobe-Linyanti river system in the north in the winter (Figure 3.2). However, the migratory patterns were never as rigid as those described for populations in East Africa but rather were opportunistic and nomadic; the movement of animals between areas of water being a requirement for their survival in all semi-arid environments (Perkins *et al.* 2002). Livingstone (1912) commented that, "The quantity of grass which grows on this remarkable region is astonishing, even to those who are familiar with India" (Livingstone 1912 p.36). Even into the 1980s, Williamson *et al.* (1988) estimated the total area over which the Kalahari wildebeest population ranged at greater than 200,000 km^2 and cited a Government survey of 1979 that estimated the population to be 260,000 animals (DHV 1980; in Williamson *et al.* 1988).

Descriptions of these huge aggregations of game and the pristine landscape in which they lived can be found in the works of early explorers of the Kalahari (e.g. Bryden 1893; Passarge 1905; Livingstone 1912), and until the late 19th century the area was almost entirely the preserve of the Bushmen and the wild animals (Cooke 1985). The arrival of white settlers with their livestock marks the point at which the environment began to change, although in the early days their impact was quite small as the newcomers were poor and had relatively few cattle (Silberbauer 1981). In 1952, Debenham described Ghanzi as a group of farms with a "small local dairy-farming industry" (Debenham 1952 p. 21) and it was not until the late 1950s, with the arrival of technology that allowed for the large-scale sinking of boreholes, that the pace of change accelerated (Williamson & Williamson 1984). Some of the farmers in the Ghanzi farmlands today can trace their histories back to those first settlers, and their stories and recollections of life in this small, frontier community, and of the interactions they had with the wild animals they encountered may provide insights into the attitudes and perceptions that exist today (Campbell 2000). One farmer, whose family were one of the original group of settlers, remembers the Ghanzi of his childhood in the 1930s and '40s thus:

> *[It was] just open grasslands...like the Kalahari... [there was] anything….wildebeest, hartebeest, springbok, gemsbok - mostly it was wildebeest, eland and gemsboks. There was ... the hartebeest - it looked like you take a cup and take some water out of the sea - here to just the other side of Kang*[1] *- it wasn't millions it was more than millions…*

Silberbauer (1981) describes an encounter with "...a mixed herd of gemsbok, eland and hartebeest which covered an area five miles long by three miles wide" (Silberbauer 1981 p. 21)

Another farmer who arrived in the early 1950s remembers being able, "to look out and see a herd of springbok on the horizon" and also the vast numbers of animals that would pass through:

> *When I came in the Kalahari and even [on] the farms there was plenty of game - especially in this northern area. Actually what I do remember clearly is before the road was down, there was just a track and we went down sometimes and you'd have to stop for ten minutes - that's no exaggeration - for these herds of hartebeest and wildebeest to run across the road. And then you'd have to look for the road - it was obliterated.*

The farmer thought that the environment had started to change when the veld burning had stopped. Those changes involved the dramatic increase of woody plants and a resultant decrease in herbaceous plants, particularly grasses. This phenomenon, known as bush encroachment, has been discussed at length (e.g. Moleele *et al.* 2002; Ringrose *et al.* 2002; Ringrose *et al.* 2003) and has altered both the appearance and the productivity of the area (see Section 2.2). The cessation of burning however was not the only factor involved, over-grazing by livestock was, and is, also a major part of the problem. Counter intuitively this is not necessarily the result of over-stocking, but rather can be caused, in environments that are characterised by seasonal rainfall, by not allowing the grass sufficient recovery time between bouts of intense grazing (Savory 1991).

But the attitude of the farmers to the game was always pragmatic and highlighted the problems caused by the policies introduced with the London Convention. Cattle were what counted; they were the reason for being there and took precedence over the wild animals, which were viewed merely as competition for scarce water and food resources (Cooke 1985). This is clearly illustrated by the account given by one farmer of the prevailing attitude:

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[1] Kang is a small town/settlement 260 kilometres south east of Ghanzi

> *...we either used to shoot them or we'd push them out, because cattle were more important to us because game had no value at all ... it had no value….cattle had a value, although it wasn't very much either... but it did go up in value and it made a living.*

Hunting by Europeans in the mid-19th century in the Kalahari had impacted greatly on wildlife populations, to the extent that by the 1880s it had largely lost its appeal as a destination for large expeditions, due to the unforgiving nature of the environment and the expense involved in mounting them (Thomas & Shaw 1991). The hunting activities of the Ghanzi farmers in the early 20th century were for subsistence not sport and made little impression on game populations. There were very few people and they were dependent on horses and ox wagons to travel and transport their kills:

> *...the farmers used to go in the winter… they used to go with the ox wagon ... that's when the game wasn't so far away you see...they'd go with the ox wagon and all the women would go with... and the men would take the horses ... and then they'd ride out and they'd go and see where the game is... they'd find a place where there's a lot of game then they'd move the ox wagon closer... then they'd go and they'd bring the animal in right to the wagon and shoot him ...and then the woman would work at fat for...making soap and the skins we'd make ropes out with for catching cattle and making rims for the ox wagon you know to span the oxen in and everything like that ...and then of course the meat ...they used to cut a lot of biltong...*

As this farmer pointed out, when he started farming in the early 1950s there were only seven vehicles in the whole of the Ghanzi District. His view was that the arrival of four-wheel drive vehicles had been a major contributory factor to the depletion of game in the area. Cooke (1985) also came to this conclusion stating that "the combination of four-wheel drive vehicles and the modern rifle is lethal" (Cooke 1985 p. 82). Even so, the decline in numbers of some species is a relatively recent phenomenon. Some farmers remember large herds of springbok in the Ukwi area (about 200 kilometres south west of Ghanzi) as recently as twenty years ago; describing the number as being more than you could possibly count. But now they say they are all gone.

While mention is often made in the historical literature of the huge populations of ungulates in the Kalahari (e.g. Bryden 1893; Child 1970; Williamson *et al.* 1988), little is said of the carnivores, possibly because many are nocturnal and are therefore less visible. Interestingly, the memory of farmers whose history in the Ghanzi area goes back to the 1950s and before reveals a picture of a predator population that varies considerably both spatially and temporally. Lions today have been almost completely extirpated from all but the eastern side of the farm block, where it borders the CKGR, and even historically it seems that that is the area where they were most common, although they also occurred on the sandveld in the south. But in the west and on the hardveld they were a much rarer sight:

> *…….and they'd come in from the north from Ngamiland into the sandveld and they'd either come to E's farms... those farms over there…..in the sandveld…. or they'd come to A's and all those farms there in the south...in the sandveld. .. they wouldn't come over into the limestone…..they didn't like the limestone..but then again ...they'd...kill there and the farmers would probably blot them out before they ..had time to come here... but they …weren't on the limestone.*

Cheetahs in some parts of the farm block are remembered as being rare, while in others common. As one farmer from the north-west of Ghanzi recalled, "in the early years we seldom saw cheetah, now they're plentiful…..almost a daily basis you see them" and another also from the western side of the farm block, "Cheetahs? Never saw a cheetah! ....there wasn't a blooming cheetah in sight!" Yet in the north-east a different picture emerges, "……they were lots.... if I say that I've killed 50, 60 cheetahs here I don't think I lie ...," although later the same farmer went on to say, "the leopards give us more trouble in the olden days than cheetah."

It is hard to get a clear picture of whether leopard numbers were higher or lower in the past. They certainly seem to have been hunted in large numbers, but as one farmer explained:

> *...a leopard is the easiest….to kill of all of these lions, cheetahs, wild dogs...because if he killing anything - he's coming back and you can take meat and go and put it down for him and catch him in a trap. But a cheetah! A cheetah! …a cheetah doesn't come back or eat any meat that you put out ... no...they, they didn't come and eat ...old meat…*

But some of the most dramatic stories concern the occurrence of African wild dogs. In the present day wild dogs are seen only occasionally or rarely, usually in packs of at most 11 or 12. This appears to be a quite different picture from that of the first half of the 20th century. At this time farmers describe wild dogs as being common and plentiful and by far the most troublesome predator to their livestock. Pack sizes were apparently larger too, "…..the wild dogs took cattle because they were in big packs …thirty, forty sometimes ... yeah so they were huge packs." As a result they were killed in their hundreds. As one farmer said, "Well when we came on the farm here… wild dogs… we had tons of them……… and we used to go out on horseback and we used to hunt them…. they used to kill our cattle." Another farmer told of how a pack of 22 wild dogs that were coming back every night and taking, not just calves, but full grown cattle nearly caused him to give up farming. Wild dogs are renowned for their ability to travel long distances at considerable speed and in those early days the farmers would have to go out and hunt on horseback. This was hard enough in the summer when the wild dogs would not run as far because of the heat, but in the cooler temperatures of the winter it was a different story:

> *….and then….the winter came and during winter time it's difficult to kill a wild dog...because in the early days we were hunting...on horseback and in the winter time there is no horse that can...can run up a wild dog.*

Another farmer claimed to have killed 49 wild dogs of all ages in one night when he and some neighbours tracked a pack back to their den.

While stories of the killing of predators abound, many farmers were eager to point out that living side by side with predators was part of their everyday life and that they wouldn't kill unless they had to:

> *What I used to do if a lion came in here… I used to chase him out the first time, the second time I'd chase him out, the third time if I see him I'd probably shoot one of the pride… and they usually go if you shot one...especially if you shot the big male - but I never shot a lion unless I had to.*

These stories all illustrate the hunting and killing of predators with guns. However, from farmers' recollections the use of poison to kill predators was common in those early days and does not sit well with claims of tolerance. The indiscriminate nature of this practice (affecting as it does any animal that may be tempted to eat from a poisoned carcass) was, and to a certain extent still is, responsible for the death of many mammals and birds that are no danger to livestock but play an important role in the ecosystem. As a farmer recalled "….and predators were just poisoned - people used poison - they didn't realise it was killing the vultures and everything. Poison was a great thing at one time." Historically, poison has often been used to target black-backed jackals, which from farmers' accounts have always been numerous in the area.

As far as other mammal species are concerned, during very wet periods some farmers remember herds of buffalo (*Syncerus caffer*) passing through and even hippopotamuses (*Hippopotamus amphibius*) being occasional visitors. Primates never seem to have been a permanent feature of the Ghanzi faunal assemblage, almost certainly because of the lack of permanent surface water. But people do remember seeing chacma baboons (*Papio cynocephalus ursinus*) during the wet season in the past and vervet monkeys (*Cercopithecus aethiops*) have also been seen in the area from time to time.

The overall picture painted by these recollections suggests that wildlife in the early days of settlement was abundant but not greatly valued. This seems to apply to both predators and prey species. Both were seen as competitors for resources and in some cases commodities to be exploited. In the case of the predators it seems quite clear that the wild dog was considered the most undesirable and was persecuted accordingly. Leopard and jackal were also viewed negatively and dealt with whenever the opportunity arose, whereas cheetah seem to have had less of an impact. Lions were apparently less frequently encountered but did a lot of damage when they were.

It is therefore of great interest to determine how these species are distributed today and whether attitudes that exist now differ from those of the past.

3.4 Fences

The biggest single factor leading to the change in wildlife populations in Botswana in general, and in the Ghanzi District in particular, has been the erection of fences. When the area around Ghanzi was first settled none of the farms were fenced, with everyone's cattle mixed up together. In fact it wasn't until 1955 that the farms started to be surveyed. The survey was completed in 1960 and with the coming of Independence in 1966 it became compulsory for all farms to be fenced off. One farmer who left the area at the end of the 1950s and returned in the '70s recalled the change that was apparent:

> *…well immediately the first thing I noticed was there was hardly any game about. We were not used to sort of living here without seeing the game…It was a dramatic change I thought. And then I thought it must be the fencing. It sort of kept some of the game out. I actually felt it was...because I remember my father saying that he will never fence his farms - because the game should be free to roam….*

Fencing did not just impact on the wildlife though; it also affected the way in which people farmed. Prior to the fences going up the livestock had ranged freely and extensively throughout the area and into neighbouring WMAs such as the Grootlaagte:

> *….then they had to...change their whole concept of farming ...you know...before...I mean our cattle...we used to go and get them in the...Laagte there...they used to go out for three days and graze and come in the third day and drink water...and then go out again and we used to go and fetch them there...but when the fences came of course…we only realised then how small our farms were, because we had the whole world at our cattle...and if a fire was here we didn't use to worry about it...because the cattle used to go and graze over there then.*

At around the same time as the farms were being fenced, the Kuke veterinary fence was erected (Figure 3.2). Repeated outbreaks of Foot and Mouth Disease had frustrated efforts to secure a reliable overseas market for the country's beef. In order to qualify for a generous European Union (EU) subsidy and gain access to its market the erection of cordon fences

(Figure 3.2) to separate cattle from wildlife was necessary to conform to disease control regulations (Perkins 1996). The Kuke fence runs across the northern boundary of the Central Kalahari Game Reserve and westwards to the Namibian border. When completed in 1958, it cut off the migration route between the southern and central Kalahari areas, and the northern winter watering grounds for millions of animals. The carnage that ensued during the severe droughts of the 1960s and 80s, when hundreds of thousands of thirsty wildebeest and hartebeest reached it and found their way blocked, has been described by many authors (e.g. Silberbauer 1965; Campbell 1973; Williamson & Mbano 1988). The farmers who were there at the time also remember the scenes as animals came upon the newly fenced farms:

> *…and then they tried to make a break through and we found dead carcasses between the…four farms here - because they had tried to get through - and a few kind of - went through and probably died on the fences - but I don't know because of course you know the wires trapped them and then they lie there kicking and so we found a few like that and somehow some went back to the Kalahari and some of them tried to break through all these farms along this area - it was really - for me not a nice sight…*

Many other veterinary control fences followed, driven by the requirements of export markets, notably Europe, for stringent disease control and management strategies (Mbaiwa & Mbaiwa 2006); and with them came the death of more animals (Williamson & Williamson 1984). But the farmers came to recognise that the veterinary fences were necessary. While they disliked seeing the game dying, they understood the economic benefits they brought:

> *But then again the quarantine fences...if they hadn't put them up...then the cattle industry would have gone one way…I mean there's no doubt about it...whether you liked the fences...whether you didn't like them they served a very good purpose and we always had a stable market for our cattle which was more than what a lot of other countries actually...actually had. And if there was a foot and mouth outbreak...then they had...the area where there was a break out and a buffer zone so they could actually control the foot and mouth...which was a good thing...I mean at first I didn't like the fences but then….afterwards when you realise but...you know...the government had no option but to sort of control the foot and mouth...and it was actually a very good idea I think because sometimes...an area that did get foot and mouth...didn't affect the whole country…*

Nearly all species of medium to large free-ranging ungulates have now disappeared from the area of the farm block and are now only to be found inside the CKGR and on game-fenced farms. The one exception to this being the kudu which is able to jump the cattle fences and therefore still moves relatively freely through the area. In fact, the kudu appears to be the one ungulate that has benefited from the arrival of fences. The DWNP 2004 aerial survey, conducted during the dry season, counted most kudu outside protected areas (DWNP, 2004). Little mention is made of this species in historical accounts of the wildlife of the Kalahari, probably because it was so outnumbered by other species, but numbers have increased considerably in the past few decades, possibly through decreased competition for resources (see Chapter 4 for a discussion of prey populations).

Even before it was realised that game farming could be an economically viable proposition there were farmers who decided that something needed to be done to prevent all the game disappearing from the area. Poaching was rife and was considered by some to be a means of securing and keeping labour:

> *All my game were being poached - I looked after them - they went over to my neighbour…they shot them for their staff and people allowed their staff to go onto your farm - they closed their eye to it. Because it was to their advantage so they could get staff if the staff could get easy meat.*

This cattle farmer eventually decided to game fence his entire farm to protect the wildlife there. As the nascent safari hunting industry started to gain ground, the sons of some farmers turned to professional hunting to supplement their incomes. This seems to have been the point at which the realisation took hold that keeping game could be an economically viable proposition, and once one farmer did it then others followed:

> *…and then when the hunting started that of course gave an impetus because...other people saw that we were making something from the game - they started doing the same, even if they didn't fence they started looking after their game. They realised there was a potential for profit - they weren't just eating the cattle's fodder but they were eventually going to gain something from it.*

3.5 Conclusions

The picture painted in this section is that of an historical landscape and population (both human and wildlife) quite different from that which exists today; despite the fact that much of it is seated in the relatively recent past. It is however acknowledged that the memories and recollections of the farmers interviewed presents only one perspective on the past in the Ghanzi area. Furthermore, the possibility that the nature of the accounts given were affected by the respondents’ perception of the researcher’s interests cannot be entirely dismissed.

However, two issues stand out as being crucial to the way in which the land is managed today and to the persistence of wildlife. Fencing has undoubtedly been the major causal factor in the changes that have occurred. Although initiated by government rather than by the farmers themselves, the impact of fencing on wild ungulates in particular was enormous. Fences are now an integral part of the landscape and of the lives of both the human and wildlife populations. The other major change concerns the increase in domestic livestock and the resultant bush-encroachment (or the loss of grassland) due to over-grazing (partly caused by the fencing issue), which has altered the habitat and depleted the resource base for both livestock and wildlife.

The next chapter of this thesis is concerned with establishing the current status of ungulate and other prey populations in the Ghanzi farm block. The abundance and distribution of these species is a key factor in determining the potential for carnivores to survive alongside farmers and their livestock.

Chapter 4 - Prey populations in the Ghanzi farmlands

4.1 Introduction

The previous chapter illustrated the historical picture of wildlife in the Ghanzi farmlands, and the wider Ghanzi District area, from the perspective of those who witnessed and lived with it. The situation as it exists today will now be investigated from both biological and social perspectives. Before moving on to discuss the present-day carnivore population it is important to establish, both the reality and perception of, occurrence and abundance of naturally occurring prey species in the area. Utilising data obtained during camera trapping for carnivores and from questionnaires and informal interviews, several questions regarding naturally occurring ungulates and other prey species will be addressed:

1. What naturally occurring game species are present in the farm block and at what densities?
2. Does species richness vary across habitat and land usage types?
3. Does species abundance vary across habitat and land usage types?
4. Do perceptions of stakeholders reflect the biological picture?

Historically, as detailed in Chapter 3, large aggregations of game were present in the Ghanzi District. However, knowledge of the abundance and diversity of free-ranging game species that currently exist in the Ghanzi farmlands is patchy and based almost entirely on informal observation and perception. While some research has been undertaken to ascertain the effect on wildlife populations of livestock grazing in and around cattle posts and Wildlife Management Areas (WMA) in Botswana (e.g. Verlinden 1997; Verlinden *et al.* 1998; Wallgren *et al.* 2008), very little has occurred in the commercial, fenced farmland areas. Factors which may affect the occurrence of game species on farmland, either positively or negatively include the availability of water points and grazing/browsing, the level of bush cover, land management practices and human interference in terms of hunting/poaching and general disturbance (Bergström & Skarpe 1999; Wallgren *et al.* 2009).

The availability of a healthy and robust prey base is of critical importance when considering the sustainability and conservation potential of any population of carnivores (Fuller & Sievert 2001; Karanth *et al.* 2004b) and applies equally to populations outside as well as inside protected areas. In farming areas, the absence of such a prey resource has been linked to a greater prevalence of livestock depredation (Rasmussen 1999; Hoogesteijn 2002; Hemson 2003; Kolowski & Holekamp 2006) and, in extreme cases, may have implications for human safety (Sillero-Zubiri & Laurenson 2001; Packer *et al.* 2005). Furthermore, the importance of taking a multi-species approach to studies of wildlife communities and the impacts they face from human activities, in order to maximise the effectiveness of land management policies, has been emphasised by Wallgren *et al.* (2009) who point out that what may be applicable for one species may not be so for another.

Carnivore density can vary considerably within species, but has been shown to be positively correlated to prey biomass for a range of species e.g. cheetah (Laurenson 1995), leopard (Stander *et al.* 1997b) and tigers (Karanth *et al.* 2004b). In African savannas this, by extension, has been linked to mean annual rainfall and primary productivity (Coe *et al.* 1976). Presence-absence surveys of prey have been used to predict leopard density in Armenia (Khorozyan *et al.* 2008) and Carbone and Gittleman (2002) estimated that 10,000 kg of prey biomass would support around 90 kg of a given carnivore species. There are of course confounding factors that must be taken into account when attempting to predict carnivore density from that of prey. These include the possible shortcomings of methodology that may over- or underestimate prey density, interspecific competition and the fact that the mere existence of a wide variety of potential prey does not mean that a particular species will utilise the full spectrum available (Fuller & Sievert 2001).

A comprehensive meta-analysis of predator-prey densities in South African reserves, undertaken by Hayward *et al.* (2007), formulated equations to predict carrying capacity of African wild dog, cheetah, leopard, lion and spotted hyaena in relation to prey biomass. Two of these species, cheetah and leopard, are known to be present in the Ghanzi farmlands today, while two more, wild dog and lion, were relatively common in the recent past (see Chapter 3). Hayward *et al.* (2007) found that for wild dog, leopard and lion the biomass of significantly preferred prey was the best predictor of density, while for cheetah it was the biomass of prey in the preferred weight range (23-56 kg). However, biomass of significantly preferred prey species and biomass of prey in the preferred weight ranges provided very similar predictions in all cases (Hayward *et al.* 2007).

One of the most commonly used methodologies for estimating abundance of prey populations is that of distance sampling (Conroy & Carroll 2009). Distance sampling involves the repeated driving of set transects along which visual encounters with prey species are recorded, along with the distance and bearing from the track of the sighted animal. This allows calculations to be made that can estimate for missed sightings at greater distances. The minimum recommended sample size for estimating density using this method is 60-80 sightings (Buckland *et al.* 2001). Unfortunately, the severe bush encroachment apparent on many of the farms in the Ghanzi area (see Chapters 2 and 3) has reduced visibility into the bush from the road to practically zero in some instances. This lack of visibility, combined with the fact that all animals occur at relatively low densities in the area due to the nature of the environment and that they are extremely shy of humans due to hunting pressure, made standard distance sampling impossible due to small sample sizes. Problems of this nature were also highlighted in a study of ungulate species in a forest environment in Tanzania where low visibility, density and shyness were also major factors (Rovero & Marshall 2004). Alternative strategies had to be considered therefore in order to answer the biological research questions.

4.2 Methods

The increase in camera trapping studies over the past decade has resulted in data on prey species being obtained opportunistically while camera trapping for carnivores. These data provide valuable information on those prey species that may not otherwise have been obtained (e.g. O'Brien *et al.* 2003; Khorozyan *et al.* 2008; Stein *et al.* 2008). This can be particularly useful for rare and secretive animals that may otherwise be difficult to observe (Datta *et al.* 2008; Rovero & Marshall 2009; Tobler *et al.* 2009).

The use of a relative abundance index (RAI) based on raw count data obtained from camera trapping capture rate (number of camera days/independent photograph) and/or the inverse of that (number of independent photographs/100 trap days) is one option and has been discussed by several authors in recent years (Carbone *et al.* 2001; Carbone *et al.* 2002; Jennelle *et al.* 2002; Williams *et al.* 2002). The method has been found to provide a reliable index of true density for tigers and prey (O'Brien *et al.* 2003) and for Harvey's duiker (*Cephalophus harveyi*) (Rovero & Marshall 2009). It has also been used as a straightforward index of relative abundance (Treves *et al.* 2010). Relative abundance indices were calculated for eight free-ranging game species and, as an additional food source for predators in the area exists in the form of wildlife stock on game farms, data on these species obtained during CS2, undertaken primarily on two game farms, are also presented. Data and analysis on captures of carnivore species are detailed in Chapter 5 and data and analysis of activity patterns for both carnivore and prey species are presented in Chapter 7.

Another alternative for estimating the availability of prey is that of using estimates of occupancy as a surrogate for abundance (Conroy & Carroll 2009). Occupancy in this context is used, in broad terms, to mean that a species is present (Conroy & Carroll 2009) and more specifically, can be defined as the proportion of a sampled area that is occupied by that species (MacKenzie *et al.* 2006). There has been considerable activity around this subject in the literature of late and models have been developed to make such occupancy estimations (e.g. MacKenzie *et al.* 2002; MacKenzie & Nichols 2004; MacKenzie *et al.* 2006). The strategy can be particularly useful where the effort and/or expense required to make direct estimations of abundance are not possible and has been used to provide occupancy estimates in a number of studies across a range of taxa including tigers (Linkie *et al.* 2006), brown hyaena (Thorn *et al.* 2009), sun bears (*Helarctos malayanus*) (Linkie *et al.* 2007), five species of ungulate in the Amazonian basin (Tobler *et al.* 2009) and golden eagles (*Aquila chrysaetos*)(Martin *et al.* 2009).

The models used for this type of analysis are based on a detection history for the species concerned, such that if a site were surveyed six times it would give a matrix of the kind 001010 indicating that the species had been detected on the third and fifth sampling occasions. However, detection of any individual of a species is unlikely to be perfect for any number of reasons and that heterogeneity of detection is a key factor here. Detection histories compiled for sites comprising 1's and 0's do not provide information on individuals that may occur at a site but are not detected, in other words giving a 'false negative' (MacKenzie *et al.* 2002). Occupancy itself should be positively correlated with abundance as with increasing abundance occupancy may also increase (MacKenzie & Nichols 2004). Of course, as MacKenzie *et al.* (2006) point out, while occupancy and abundance are clearly related they are not the same thing. But Royle & Nichols (2003) take this further and make the case that probably the most important source of heterogeneity in detection probability is variation in abundance. To elaborate, where abundance varies between sites, probability of detection depends not only on the probability of detection for that species, but on the abundance of that species at any given site. In theory this linkage allows for estimations of the distribution of site-specific abundance where adequate provision has been made to characterise the distribution of detection probability (Royle & Nichols 2003). A model based on this assumption (the Royle-Nichols (RN) model) is available in the program PRESENCE 3.0 (MacKenzie 2010). In contrast to the other models available in the program, which suppose that probability of detection varies by individual and that that probability is a random value in a mixture distribution, the RN model places the mixture distribution on abundance (with site detection being a binomial and abundance a Poisson distribution) (MacKenzie *et al.* 2006). Population closure is a requirement of the model and in PRESENCE it is also assumed that individuals are distributed spatially according to a Poisson distribution which has a single parameter, λ ('lambda'), the mean. MacKenzie *et al.* (2006) elucidate that the appeal of the model is that given the assumptions that abundance follows a Poisson process and individual detectability is independent, it could be reasonable to view λ as density, from which the abundance of animals at a site can be derived (MacKenzie *et al.* 2006 p. 140). However, they continue to caution that as such assumptions are unlikely to hold in most situations, abundance estimates could therefore be viewed purely as a random effect leading to variation in detection probability. In such instances the model can be made to resemble others in the program where the mixture is placed on probability of detection.

To examine the perceptions of stakeholders, farmers who participated in the questionnaire survey were asked to estimate the abundance on their farms of several naturally occurring prey species. The species, which included some not previously mentioned, were kudu, springbok, duiker, steenbok, warthog, hares (scrub (*Lepus saxatilis*) and spring (*Pedetes capensis*)) and guineafowl (*Numida meleagris*). Livestock (n = 15) and game farmers (n = 5) were asked to say whether they thought these species were absent, rare, common or very common (Figure 4.3). As kudu and springbok cannot traverse game fences these two species were omitted from the questionnaire survey for game farmers. Information gained during informal interviews was also utilised. Further details on the methodologies used are presented in section 2.2.

4.3 Data Analysis

As detailed in Section 2.2ii, three 62-day camera trap surveys were undertaken in different parts of the farm block (see Figure 2.10) which generated 22,675 photographs in total. All pictures of domestic livestock (cattle, donkeys, horses and goats), people, vehicles and camera misfires were discarded so that only images of wildlife remained. This amounted to a total of 8,789 photographs. All images were entered into Camera Base v. 1.3 (Tobler 2007) and the date, time, camera station and species pertaining to each picture recorded. For analysis of prey species abundance and occupancy the data were filtered to exclude carnivores and small mammals (weight < 5kg) such as hares and small rodents. This left five naturally occurring ungulate species – greater kudu; common duiker; steenbok; warthog and one large rodent – the porcupine (*Hystrix africaeaustralis*). The data were further filtered to exclude photographs of the same species at the same station within a period of 60 minutes (following Bowkett *et al.* 2008; Tobler *et al.* 2009) in order to ensure that photographic events were independent. A period of one hour was selected as the criterion for independence in this instance as browsing and grazing species, such as kudu, duiker, steenbok and warthog, sometimes remained in front of the camera for long periods. The capture frequency for a species was calculated as the number of trap days/independent photograph (RAI1:Carbone *et al.* 2001), and the number of independent photos/100 trap days (RAI2: O'Brien *et al.* 2003). A camera trap day was defined as a period of 24-h when at least one camera at a station was operational. If the batteries had failed or the camera had malfunctioned then it was classed as a 'missed day'. Capture frequencies and detection histories were calculated by Camera Base. Statistical analysis was undertaken using Minitab v. 15.0 (2007) and where samples were not normally distributed nonparametric statistics were used (Siegel & Castellan Jr. 1988).

There is some concern that the abundance of group living species may be underestimated when doing line transect surveys (O'Brien *et al.* 2003), and Treves *et al.* (2010) found that there was a strong correlation between detectability and both abundance and distribution for gregarious species in their camera trap data. Following their lead therefore, photographs were studied to obtain both mean and maximum group sizes for species that had been captured in all surveys. It should be noted however that kudu, being large bodied animals, are likely to have had their group sizes underestimated by this method due to the limited number of animals that will fit into the frame of a photograph. Spearman's rank correlation coefficient was used to test for association between indices of abundance and spatial distribution and for the effect of group size on detectability.

For analysis in PRESENCE the three datasets of 62 days were each divided into 10 six-day sampling periods in order to maximise detection probability. As a result this meant that two days worth of data had to be discarded for each survey. If a camera station had malfunctioned for more than one day during any of the sampling periods, and there had been no detection of the species on other days in that sampling period, the data point for that period was entered as a missing observation. Visual analysis of the data indicated that there was heterogeneity of detection between camera stations in all surveys for all species; therefore it was deemed appropriate to employ the RN model. The primary goal of the RN model is to estimate two parameters *r*, the inherent detection probability of the species and lambda λ, the mean abundance of animals at all sites. Occupancy ψ is not estimated directly, but is derived from λ as $\psi = 1 - e^{-\lambda}$. In order to be able to use the figure given for lambda to estimate density, the size of the area surveyed in each case had to be established. The criteria used to estimate survey area can differ depending on the analysis being carried out. In this instance it was calculated using the mean distance between camera stations in each survey. A buffer of that distance was created around the camera station grid in ArcGIS v. 9.3 (ESRI Inc. 2008) and the size of the whole area within the buffer then calculated.

Differences in λ were tested for using three covariates: camera trap survey, vegetation type (hardveld or sandveld) and land use (cattle or game farms). Covariates used to test for differences in *r* were those of season (wet or dry) and of site-specific (camera station) habitat. These were classed as: thick bush, medium bush, mixed woodland, water point and pan. Kudu were modelled twice, first using all three surveys and second using only data from the cattle farms in which they are free-ranging. Models were ranked in PRESENCE using Akaike Information Criteria (AIC) (Burnham & Anderson 2002), which measures the weight of evidence for model choice amongst a set of models, the lowest value of AIC indicating the most parsimonious model.

Ungulates vary in size across their ranges and field guides are equally variable in their weight estimations. For example Kingdon (1997) gives a weight range for a female kudu of 120-215 kg while Mills & Hes (1997) merely give a weight of up to 210 kg. Hayward *et al.* (2007) used weights from Stuart and Stuart (2000) and followed George Schaller's (1972) method of using ¾ of mean female weight to calculate biomass in order to allow for predation on juveniles and sub-adults. In order to facilitate the use of their equations the same protocols were followed here except that weights were taken from the third edition of Stuart and Stuart (2006) (Table 4.1).

Table 4.1 Mass of prey species used to calculate prey abundance	
Species	**¾ mean mass of adult female (kg)**
Kudu (*Tragelaphus strepsiceros*)	135
Duiker (*Sylvicapra grimmia*)	16
Steenbok (*Raphicerus campestris*)	8
Warthog (*Phacochoerus africanus*)	45
Porcupine (*Hystrix africaeaustralis*)*	13
* Porcupines are not sexually dimorphic so ¾ mean weight of the species as described by Stuart and Stuart (2006) was used.	

4.4 Results

4.4i Camera trapping

Camera trapping sampling effort totalled 3,201 camera trap days from 56 camera stations on three sites. The number of usable photographs as a percentage of those taken ranged from 67% in CS2 to 28% in CS1. Across all camera surveys a total of 24 free-ranging mammal species, of which 15 were carnivores, one reptile species and 30 bird species were identified (a list of all species photographed can be found in Appendix I). This was broken down between surveys as follows: CS1: 18 species of mammal, one reptile species and 20 bird species captured. CS2: was conducted mainly on two game farms and accumulated 22 free-ranging mammal species and 14 bird species. CS3: 21 species of mammal and 13 bird species were captured (Table 4.2).

Table 4.2 Camera trapping effort and mammal species richness in three areas of the Ghanzi farmlands, Botswana 2009

	Camera trapping effort					**Species richness**	
Survey	**No. of camera stations**	**Camera trapping days**	**Mean trapping days/station**	**Total no. of photos**	**No. of usable photos**	**Observed mammal species**	**As % of total**
CS1	18	1023	56.83	9253	2561	18	75
CS2	20	1144	57.20	5692	3813	22	92
CS3	18	1034	57.44	7730	2415	21	88
Total	**56**	**3201**	**57.16**	**22675**	**8789**	**24**	**100**

Capture data of non-carnivore mammal species are laid out in Table 4.3 with group sizes in Table 4.4. Pooling all surveys, species were photographed between 6 and 800 times ($\bar{x}$ = 271.63 ± SE 92.32). It should be noted here that a photographic event may include more than one individual of that species. The most frequently photographed was the kudu (800 photographs) followed by warthog (493), porcupine (259), duiker (239), steenbok (185), scrub hare (158), aardvark (*Orycteropus afer*) (33) and springhare (6). Spatial distribution varied amongst species with the kudu being captured at the most stations (53) followed by duiker (44), steenbok and warthog (43) and porcupine (42). Aardvark were photographed at 18 stations. RAI_2 values ranged from 0.52 – 30.09 across all surveys ($\bar{x}$ = 9.34 ± SE 1.94) and there was no significant difference in RAI_2 values for non-carnivore species (n = 8) between surveys (Friedman test, S = 0.45, df = 2, p = 0.798), between the two surveys on cattle farms (one on sandveld and one on hardveld) (Wilcoxon signed-rank test, W = 13.0, n = 8, p = 0.933) or between the two surveys conducted on farms with hardveld type vegetation (one game and one cattle) (Wilcoxon signed-rank test, W = 15.0, n = 8, p = 0.726). Indeed, when examining the data visually (Figure 4.1) it was apparent that while the RAI_2s of warthog and kudu showed considerable variation between surveys there was no overall pattern of difference across species.

Total number of photographs obtained for a species was highly correlated to RAI_2 (r_s = 1 p = <0.01) and to spatial distribution (number of sites at which a species was detected) (r_s = 0.85 p = <0.01). There was a strong association between mean group size and RAI_2 (r_s = 0.919, p = <0.01) but not with number of sites (r_s = -0.618, p = 0.14). Maximum group size was highly correlated to both RAI_2 (r_s = 0.954, p = <0.01) and number of stations (r_s = 0.850, p = 0.015).

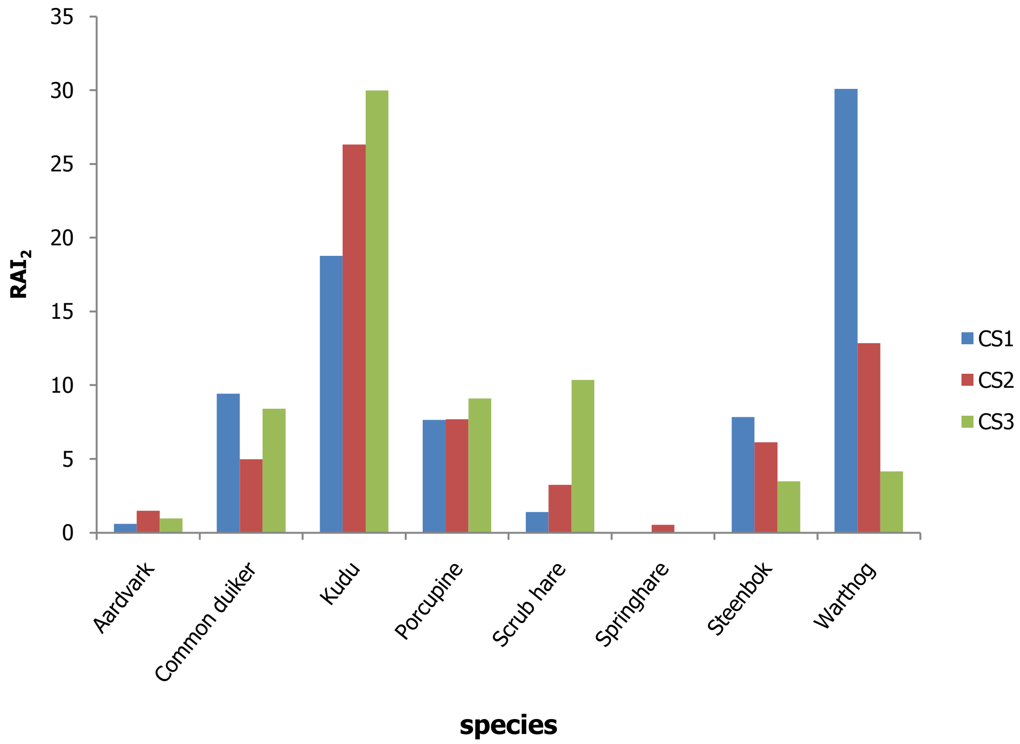


Figure 4.1 RAI_2s of eight game species in three camera trap surveys in Ghanzi farmlands in 2009.

Table 4.3 Number of stations, independent captures, capture frequencies for all non-carnivore mammal species observed during three camera trap surveys in the Ghanzi farmlands in 2009
(days/photo (RAI_1) and photos/100 trap days (RAI_2))

		CS1 (180.51 km^2)				CS2 (162.14 km^2)				CS3 (160.24 km^2)*			
Species	**Scientific name**	**Stations**	**Captures**	**RAI_1**	**RAI_2**	**Stations**	**Captures**	**RAI_1**	**RAI_2**	**Stations**	**Captures**	**RAI_1**	**RAI_2**
Aardvark	*Orycteropus afer*	6	6	167.83	0.6	7	17	67.29	1.49	5	10	103.4	0.97
Common duiker	*Sylvicapra grimmia*	17	95	10.6	9.43	13	57	20.07	4.98	14	87	11.89	8.41
Kudu	*Tragelaphus strepsiceros*	18	189	5.33	18.77	19	301†	3.8	26.31	16	310	3.34	29.98
Porcupine	*Hystrix africaeaustralis*	15	77	13.08	7.65	13	88	13.0	7.69	14	94	11.0	9.1
Scrub hare	*Lepus saxatilis*	3	14	71.93	1.39	8	37	30.92	3.23	9	107	9.66	10.35
Springhare	*Pedetes capensis*	-	-	-	-	3	6	190.67	0.52	-	-	-	-
Steenbok	*Raphicerus campestris*	15	79	12.75	7.85	16	70	16.34	6.12	12	36	28.72	3.48
Warthog	*Phacochoerus africanus*	16	303	3.32	30.09	17	147	7.78	12.85	10	43	24.05	4.16

*The ground squirrel (Xerus inauris) was also photographed during the pilot period of CS3 and an unidentified species of rodent was seen during the survey proper.
†The majority of cameras in this survey were located on two game farms bordered by game fences that kudu were not able to traverse. As a result they cannot be classed as free-ranging.

Table 4.4 Group sizes of species captured at all sites

Species	**Scientific name**	**Mean group size ± SE (range)**
Aardvark	*Orycteropus afer*	1 (1)
Common duiker	*Sylvicapra grimmia*	1.01 ± 0.01 (1-2)
Kudu	*Tragelaphus strepsiceros*	1.23 ± 0.02 (1-7)
Porcupine	*Hystrix africaeaustralis*	1.10 ± 0.02 (1-2)
Scrub hare	*Lepus saxatilis*	1 (1)
Steenbok	*Raphicerus campestris*	1.03 ± 0.01 (1-2)
Warthog	*Phacochoerus africanus*	1.78 ± 0.06 (1-6)

Table 4.5 Number of stations, independent captures, capture frequencies for all game farm species observed during a camera trap survey undertaken on two game farms in the Ghanzi farmlands in 2009
(days/photo (RAI_1) and photos/100 trap days (RAI_2))

Species	Scientific name	Stations	Captures	RAI_1	RAI_2
Blue wildebeest	*Connochaetes taurinus*	17	134	8.54	11.71
Burchell's zebra	*Equus burchelli*	13	80	14.30	6.99
Eland	*Taurotragus oryx*	12	105	10.90	9.18
Gemsbok	*Oryx gazella*	15	138	8.29	12.06
Giraffe	*Giraffa camelopardalis*	7	10	114.40	0.87
Impala	*Aepyceros melampus*	1	2	572.00	0.18
Ostrich	*Struthio camelus*	6	13	88.00	1.14
Red hartebeest	*Alcelaphus buselaphus*	13	63	18.16	5.51
Waterbuck	*Kobus ellipsiprymnus*	2	2	572.00	0.18

4.4ii Occupancy analysis

Results from the occupancy analysis are presented in Table 4.6. Estimates for total abundance *N*, as calculated by the RN model in PRESENCE, are given below but have large standard errors and confidence intervals and so should be treated with caution. Three of the four top models for duiker featured vegetation as a covariate where λ = 3.49 ± SE 1.68 for sandveld was higher than that for hardveld λ = 2.83 ± SE 0.94. There was also some evidence that habitat may influence detectability. Occupancy for sandveld (ψ = 0.995 ± SE 0.03) was also higher than that for hardveld (ψ =0.941 ± SE 0.06). The RN model estimate of abundance for duiker across all sites = 110.3. The top model for steenbok featured no covariates, suggesting equal distribution across all sites and surveys (ψ = 0.814 ± SE 0.07), abundance estimate = 94.39. Both the top two models for kudu across all surveys indicated an effect on λ of land use, where untransformed estimates were λ = 0.98 ± SE 0.25 for cattle farms, against game farms λ = 0.65 ± SE 0.2. When kudu were modelled using only data from the free-ranging population on cattle farms the top model featured no covariates, again indicating equal distribution across all sites (ψ = 0.94 ± SE 0.04) with an abundance estimate of 106.03 for the free-ranging population. For warthog, the top model showed considerable weight for an effect on λ of survey, with untransformed estimates for CS1 of λ = 1.066 ± SE 0.27 against CS2 λ = -0.15 ± SE 0.27 and CS3 λ = -0.90 ± SE 0.35 and an effect on *r* of habitat, where water points (*r* = 0.73 ± SE 0.16) were strongly favoured over medium bush (*r* = -1.33 ± SE 0.27), thick bush (*r* = -0.42 ± SE 0.17), mixed woodland (*r* = 0.34 ± SE 0.296) and pans (*r* = 0.16 ± SE 0.31). Occupancy across all sites was ψ = 0.998 ± SE 0.004 and the total abundance estimate = 137.4. The top model for porcupine featured no covariates (ψ = 0.77 ± SE 0.06), indicating no habitat effect on detectability and equal distribution over sites and surveys. Abundance estimate = 82.82.

Detection probabilities varied widely both within and between species across the three surveys (Table 4.7) and while occupancy levels varied considerably between species they varied less over the three surveys within species (Table 4.8) However, kudu occupancy was 16% higher in

CS1 (ψ = 0.999 ± SE 0.004) than in CS3 (ψ = 0.862 ± SE 0.096) and steenbok were more common in CS2 with an 18 % higher occupancy (ψ = 0.963 ± SE 0.083) than CS1 (ψ = 0.815 ± SE 0.094) and 14.5% higher than CS3 (ψ = 0.841 ± SE 0.166). Warthog occupancy was highest in CS1 (ψ = 0.991 ± SE 0.014) and lowest in CS2 (ψ = 0.876 ± SE 0.074). Porcupine occupancy was 18.5% higher in CS1 (ψ =0.857 ± SE 0.131) than in CS2 (ψ =0.699 ± SE 0.124). Individual lambda estimates for the three camera surveys are presented in Table 4.9. As lambda is an estimate of the mean abundance at sites (camera stations) within a survey it can be used to calculate an estimate of density for that area. Density/km^2 estimates for each species in each survey as well as for the three surveys together are presented in Table 4.10.

Table 4.6 Summary of RN occupancy models selected by PRESENCE for data on four southern African ungulate species and porcupine at 56 sites from 3 camera surveys
(Only models with an AIC weight >0.1 are shown up to a maximum of five)

Model	AIC[a]	ΔAIC[b]	AIC wt[c]	Model Like[d]	N Par[e]	-2*LogLike[f]
Common duiker (*Sylvicapra grimmia*)						
λ (veg) r (.)	546.08	0.00	0.2302	1.0000	3	540.08
λ (veg) r (habitat)	547.02	0.94	0.1438	0.6250	7	533.02
λ (survey) r (.)	547.11	1.03	0.1375	0.5975	4	539.11
λ (veg + land use) r (.)	547.11	1.03	0.1375	0.5975	4	539.11
λ (land use) r (.)	547.15	1.07	0.1348	0.5857	3	541.15
Steenbok (*Raphiceros campestris*)						
λ (.) r (.)	536.24	0.00	0.1606	1.0000	2	532.24
λ (.) r (season)	536.30	0.06	0.1558	0.9704	3	530.30
λ (survey) r (.)	537.01	0.77	0.1092	0.6805	4	529.01
λ (veg) r (.)	537.01	0.77	0.1092	0.6805	3	531.01
λ (.) r (habitat)	537.08	0.84	0.1055	0.6570	6	525.08
Greater kudu (*Tragelaphus strepsiceros*) all surveys						
λ (land use) r (habitat)	620.34	0.00	0.6526	1.0000	7	606.34
λ (land use) r (habitat + season)	621.80	1.46	0.3145	0.4819	9	603.80
Greater kudu (*Tragelaphus strepsiceros*) cattle farms only						
λ (.) r (.)	421.94	0.00	0.2736	1.0000	2	417.94
λ (.) r (habitat)	421.96	0.02	0.2709	0.9900	6	409.96
λ (.) r (season)	423.44	1.50	0.1292	0.4724	3	417.44
λ (.) r (habitat + season)	423.66	1.72	0.1158	0.4232	8	407.66
λ (veg) r (.)	423.85	1.91	0.1053	0.3848	3	417.85
Warthog (*Phacochoerus africanus*)						
λ (survey) r (habitat)	511.97	0.00	0.7388	1.0000	8	495.97
λ (.) r (habitat)	515.30	3.33	0.1398	0.1892	6	503.3
λ (survey + veg) r (habitat)	515.97	4.00	0.1000	0.1353	10	495.97
Porcupine (*Hystrix africaeaustralis*)						
λ (.) r (.)	560.99	0.00	0.3605	1.0000	2	556.99
λ (.) r (season)	562.23	1.24	0.1939	0.5379	3	556.23
λ (veg) r (.)	562.78	1.79	0.1473	0.4086	3	556.78
λ (land use) r (.)	562.88	1.89	0.1401	0.3887	3	556.88

[a] Akaike Information Criterion
[b] Relative difference in AIC values between each model and the top ranked model
[c] AIC model weight
[d] Ratio of each models AIC weight over the model weight for the top ranked model
[e] Number of parameters in the model
[f] Twice the negative log-likelihood evaluated at the maximum likelihood estimates

Table 4.7 Detection probability estimates (*r*) for four ungulate species and porcupine in three areas of the Ghanzi farmlands based on camera trap data.
Estimates were made using the Royle-Nichols model in PRESENCE 3.0

	CS1 (cattle/sandveld)		CS2 (game/hardveld)		CS3 (cattle/hardveld)		Total area	
Species	**r ± SE**	**95% CI**	**r ± SE**	**95% CI**	**r ± SE**	**95% CI**	**r ± SE**	**95% CI**
Kudu	0.124 ± 0.005	0.113 - 0.135	0.341 ± 0.095	0.155 - 0.527	0.312 ± 0.032	0.244 - 0.380	0.229 ± 0.005	0.220 - 0.238
Duiker	0.066 ± 0.004	0.058 - 0.074	0.143 ± 0.013	0.116 - 0.170	0.146 ± 0.008	0.128 - 0.164	0.166 ± 0.033	0.101 - 0.232
Steenbok	0.217 ± 0.056	0.107 - 0.327	0.092 ± 0.007	0.077 - 0.107	0.102 ± 0.056	-0.008 - 0.212	0.171 ± 0.033	0.106 - 0.237
Warthog	0.299 ± 0.021	0.254 - 0.344	0.290 ± 0.067	0.160 - 0.421	0.073 ± 0.027	0.016 - 0.130	0.213 ± 0.009	0.194 - 0.232
Porcupine	0.167 ± 0.072	0.026 - 0.308	0.161 ± 0.019	0.121 - 0.201	0.272 ± 0.060	0.154 - 0.391	0.246 ± 0.038	0.172 - 0.320

Table 4.8 Occupancy estimates (ψ) for four ungulate species and porcupine in three areas of the Ghanzi farmlands based on camera trap data.
Estimates were made using the Royle-Nichols model in PRESENCE 3.0

	CS1 (cattle/sandveld)		CS2 (game/hardveld)		CS3 (cattle/hardveld)		Total area	
Species	**ψ ± SE**	**95% CI**	**ψ ± SE**	**95% CI**	**ψ ± SE**	**95% CI**	**ψ ± SE**	**95% CI**
Kudu	0.999 ± 0.004	0.991 - 1.007	0.970 ± 0.035	0.901 - 1.039	0.862 ± 0.096	0.674 - 1.049	0.985 ± 0.016	0.954 - 1.016
Duiker	0.995 ± 0.025	0.946 - 1.044	0.883 ± 0.125	0.638 - 1.127	0.845 ± 0.133	0.584 - 1.106	0.939 ± 0.046	0.850 - 1.028
Steenbok	0.815 ± 0.094	0.630 – 1.000	0.963 ± 0.083	0.801 - 1.126	0.841 ± 0.166	0.516 - 1.166	0.814 ± 0.067	0.683 - 0.945
Warthog	0.991 ± 0.014	0.965 - 1.018	0.876 ± 0.074	0.731 - 1.020	0.922 ± 0.201	0.528 - 1.315	0.998 ± 0.004	0.990 - 1.005
Porcupine	0.857 ± 0.131	0.600 - 1.113	0.699 ± 0.124	0.457 - 0.941	0.793 ± 0.092	0.612 - 0.974	0.772 ± 0.064	0.648 - 0.897

Table 4.9 Lambda estimates (λ) for four ungulate species and porcupine in three areas of the Ghanzi farmlands. Based on camera trap data. Estimates were made using the Royle-Nichols model in PRESENCE 3.0

Species	CS1 (cattle/sandveld)		CS2 (game/hardveld)		CS3 (cattle/hardveld)		Total area	
	λ ± SE	95% CI	λ ± SE	95% CI	λ ± SE	95% CI	λ ± SE	95% CI
Kudu	5.18 ± 0.24	4.66 – 5.70	4.60 ± 0.24	4.10 - 5.09	2.28 ± 0.06	2.16 – 2.40	4.21 ± 1.06	2.13 - 6.30
Duiker	6.93 ± 0.42	6.04 – 7.81	1.45 ± 0.14	1.16 – 1.74	2.06 ± 0.16	1.72 – 2.40	2.79 ± 0.74	1.34 - 4.25
Steenbok	1.83 ± 0.10	1.61 - 2.05	3.18 ± 0.25	2.66 – 3.70	2.36 ± 0.16	2.03 – 2.69	1.68 ± 0.36	0.98 - 2.38
Warthog	2.81 ± 0.31	2.17 – 3.46	2.45 ± 0.17	2.10 – 2.80	2.40 ± 0.18	2.01 – 2.79	6.05 ± 1.57	2.97 - 9.13
Porcupine	2.13 ± 0.07	1.98 – 2.28	1.85 ± 0.23	1.38 - 2.33	1.58 ± 0.04	1.50 – 1.65	1.48 ± 0.28	0.93 - 2.03

Table 4.10 Density (km^2) estimates for four ungulate species and porcupine in three areas of the Ghanzi farmlands. Based on camera trap data and derived from lambda estimates produced by the Royle-Nichols model in PRESENCE 3.0

Species	CS1 (cattle/sandveld)		CS2 (game/hardveld)		CS3 (cattle/hardveld)		Total area	
	Density/km^2	% CV	Density/km^2	% CV	Density/km^2	% CV	Density/km^2	% CV
Kudu	0.52	4.78	0.54	5.16	0.23	2.57	0.41	5.36
Duiker	0.65	6.04	0.12	9.66	0.18	7.86	0.17	3.89
Steenbok	0.15	5.66	0.31	7.82	0.18	6.62	0.14	1.36
Warthog	0.25	10.87	0.26	6.75	0.15	7.67	0.21	8.58
Porcupine	0.18	3.32	0.15	12.17	0.14	2.28	0.12	0.85

The coefficients of variation associated with the density estimates ranged from 2% to 12% when looking at individual survey areas indicating a range of precision and accuracy. This may be as a result of a smaller than optimal number of sample sites and low levels of r for some species in some surveys. Royle & Nichols (2003) caution that values of $r \leq 0.1$ can lead to bias in estimates of λ when smaller numbers of sites are sampled. However, they continue to say that, even with small values of r, it is still possible to get reasonable estimates of λ when the number of sampling occasions ≥10 (Royle & Nichols 2003). The number of sampling occasions in this study was 10 therefore it is thought that, even though the r values are in some cases below the threshold of 0.1, the results still have validity.

The overall density estimates were more precise with coefficients of variation ranging from around <1 - 9% reflecting the larger number of sample sites and more robust levels of r.

The highest density estimate for duiker was in CS1 where the estimate of steenbok density was at its lowest. This species was at its highest density in CS2. Kudu density estimates were similar for CS1 and CS2 but lower in CS3. The four ungulate species were all at similar densities in CS3 in contrast to the other surveys where some variation was apparent. To test for a relationship between density estimates and indices of abundance for these five species, density estimates derived from occupancy analysis were used in a regression analysis of RAI_1 on density. The data were normally distributed and the linear regression indicated a strong trend between RAI_1 and density (RAI_1 = 18.25 – 26.01 x density), $F_{1,3} = 9.53$, $p = 0.054$, $r^2 = 0.68$ (Figure 4.2).

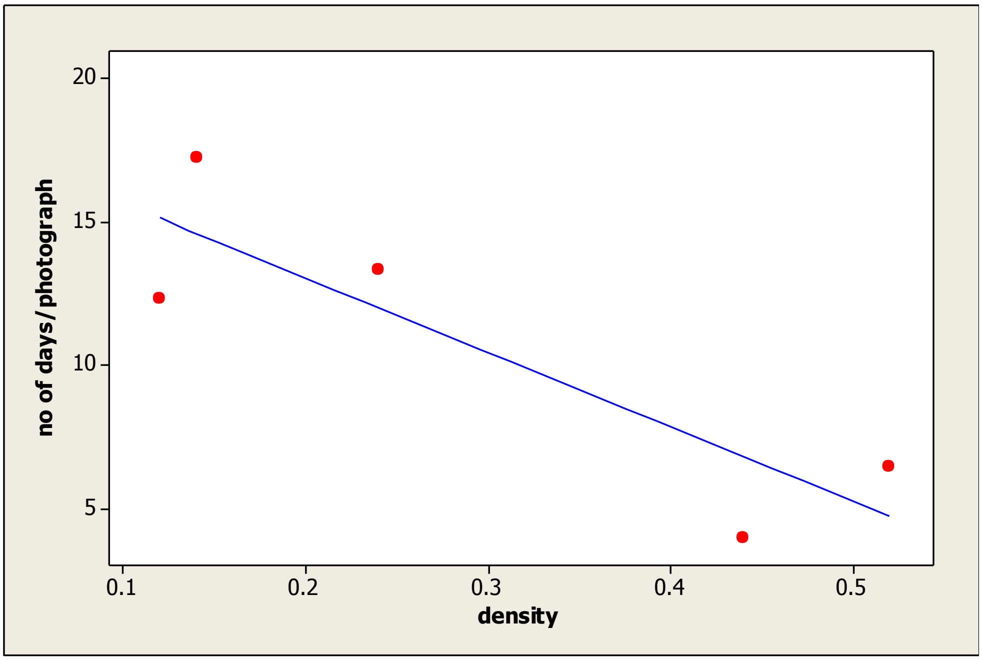


Figure 4.2 Linear regression of number of days required to acquire a photograph (RAI_1) (as a function of density derived from occupancy analysis)

4.4iii Predicting carnivore density

The equations for predicting carrying capacity of predators provided by Hayward *et al.* (2007), require the biomass of significantly preferred prey species, or of prey species within the predator's preferred weight range to be used. In the Ghanzi farmlands, only one of the four species (kudu) cited as being significantly preferred prey of African wild dog occurs naturally (Hayward *et al.* 2006c). For cheetah, none of the cited significantly preferred prey species occur naturally in the area other than springbok (Hayward *et al.* 2006b). Again, only one species cited as being significantly preferred prey (duiker) of leopard occurs naturally (Hayward *et al.* 2006a) and for lion none of the cited preferred prey species are present in the Ghanzi farmlands today (Hayward & Kerley 2005). As a result of the lack of data in the present study on preferred prey of cheetah it was therefore possible to use only the equation predicting density from prey species in the preferred weight range. There are no longer any free-ranging species in the area that fall within the cited preferred weight range for lion (Hayward & Kerley 2005) so no analysis was possible.

Prey biomass figures derived from the density estimates detailed in Table 4.10 are laid out in Table 4.11. Biomass/km^2 was higher in CS1 than in CS2 or CS3 but not significantly so (paired t-test, t = 1.54, p = 0.197; t = 1.42, p = 0.23). Using the equation (based on biomass of species in the preferred weight range) that was found by Hayward *et al.* (2007) to best predict density for cheetah (y = -2.641 + 0.411x, where the x axis = $\log_{10}$ prey biomass and the y axis = $\log_{10}$ predator density), indicates a carrying capacity of 0.58 cheetahs/100 km^2 (population estimate for total area of the three camera surveys = 3). Using this predictor did mean however that, in the study area, only the biomass of warthog could be included as they are the only species to fall within the preferred weight range. For leopard the equation for prey species within the preferred weight range of 10-40 kg (y = -2.455 + 0.456x) predicts a carrying capacity 0.69 leopards/100 km^2 (3). Again, only two species (duiker and porcupine) fall within this weight range. If the equation for preferred prey (duiker only) is used (y = -2.248 + 0.405x) a carrying capacity of 0.85 leopards/100 km^2 (4) is predicted.

Table 4.11 Available total prey biomass (kg) in three areas of the Ghanzi farmlands

Species	CS1 (180.51 km^2)	CS2 (162.14 km^2)*	CS3 (160.24 km^2)	Total area (502.89 km^2)
Kudu	12595.51	11788.79	4925.82	29310.12
Duiker	1883.68	301.78	461.95	2647.40
Steenbok	219.24	407.37	226.80	853.41
Warthog	2024.08	1874.39	1079.19	4977.65
Porcupine	415.75	313.38	287.07	1016.20

* This area consisted primarily of two game farms so the available prey biomass would be considerably higher if game farm wildlife stock was taken into account. See Table 4.5 for abundance indices of these species.

Predicted carrying capacity for African wild dog based on prey within the preferred weight range of 16-32 kg and 120-140 kg (y = -3.012 + 0.494x) is 0.72 wild dogs/100km^2 (4). Only duiker and kudu are included in these weight ranges. The equation based on preferred prey (kudu only) of y = -2.780 + 0.470x predicts 1.09 wild dogs/100 km^2 (5).

Using Carbone and Gittleman's (2002) conversion equation (y = (94.54 x ^- 1.03) x (z/ 10,000) where y = number of predators x = predator mass (kg) and z = total prey biomass (kg)), which is roughly equal to 10,000 kg of prey for 90 kg of predator, is less restrictive as it can be calculated using all prey species for which data is available. Porcupine was included in available prey biomass estimates for leopard and lion as there are recorded instances of it as a prey item for these two species (Hayward & Kerley 2005; Hayward *et al.* 2006a) but not for cheetah or wild dog (Hayward *et al.* 2006b; Hayward *et al.* 2006c). Estimates of predator body mass were taken from Carbone and Gittleman (2002) and were lion = 142 kg; leopard = 46.5 kg; cheetah = 50 kg and wild dog = 25 kg. Carrying capacities and predicted population sizes (in brackets) in the area of the three camera surveys for the four predator species using this calculation are lion = 0.40/100 km^2 (2); leopard = 1.27/100 km^2 (6); cheetah = 1.15/100 km^2 (6) and wild dog = 2.35/100 km^2 (12).

4.4iv Questionnaires and informal interviews

Of the prey species included in the questionnaire the only one that was thought to be absent by any of the participants was the springbok. This was also reflected in the camera trapping surveys where the only instance of a springbok being photographed was when a dead one was seen in the mouth of a brown hyaena. However, six farmers did say that they thought they do still occur, albeit rarely. Several farmers mentioned that they thought bush encroachment was a factor in the reduction in springbok numbers and two game farmers thought that the springbok population on their farms had been drastically reduced by cheetah. The two farmers who thought warthog were rare on their land were both located on the eastern side of the farm block, close to the border with the CKGR. Similarly, the two farmers who perceived steenbok to be rare were also both located on the eastern side, but there was no such similarity between the two farmers who thought that duiker were rare, as one was on the east while the other was on the western side. For species that are free-ranging on both livestock and game farms there was very little percentage difference in perceptions of abundance. Sixty-seven percent of livestock farmers thought that duiker were common on their

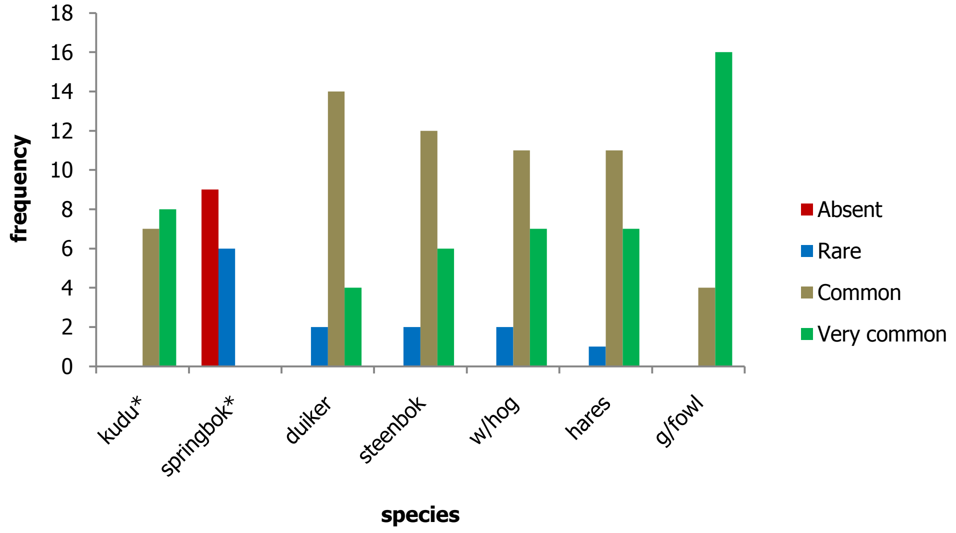


Figure 4.3 Perceptions of prey species abundance on a range of farms from questionnaires administered to livestock and game farmers (*n* = 20)
***** kudu and springbok domestic livestock farms only *n* = 15

farm compared to eighty percent of game farmers. For steenbok and warthog the percentages were also similar with sixty percent of both livestock and game farmers thinking steenbok were common, and fifty three and sixty percent respectively of the opinion that warthog were common. When a range of stakeholders were asked whether protecting natural game species was likely to reduce the risk of livestock predation 80% (*n* = 26) of respondents thought that it would.

The subject of game poaching was also raised by several farmers. A commonly cited cause for this was that of absentee farmers who do not pay their workers properly. It was thought that this left the workers with little or no alternative to poaching in order to feed themselves and their families (this issue will be discussed further in Chapter 6).

4.5 Discussion

The use of camera trapping data of prey species gathered while studying carnivores is potentially of great value in the search for detailed information on wildlife interactions and communities both inside and outside protected areas. Strategies for utilising and analysing such data are increasingly being sought, as the number of studies generating it also increases with the availability of new technology. In this study, camera trapping data on prey species were used to provide relative abundance indices, species richness and occurrence estimates, occupancy and density estimates and predictions of carrying capacity of carnivores. Questionnaires and informal interviews provided information on stakeholder attitudes and perceptions of those species.

4.5i Species occurrence and richness, RAIs and detectability

The Ghanzi area is potentially home to some 63 species of mammal of which 26 are bats and small rodents (Mills & Hes 1997). This leaves a pool of 37 species that are likely to be photographed in a camera trap survey. In this study, 24 species were recorded, nearly 65% of that number. If the large game species such as eland, gemsbok, hartebeest and wildebeest that no longer occur as free-ranging populations are excluded, as well as the two primate species (chacma baboon and vervet monkey which have only ever been recorded as transients), then more than 77% of potential mammal species were observed. Species richness was lowest in CS1 which was undertaken in the sandveld in contrast to the other two surveys. However, of the species not detected there, four were carnivores and three of those were only detected on one occasion in other surveys. It is thus likely that species richness was evenly distributed across the three areas surveyed. This underlines the power of camera trap surveys to detect species that might otherwise elude observation.

Detectability is the key issue however, especially when the aim is to establish abundance and density. Following on from work done by several researchers in the past investigating factors which may bias detectability (e.g. O'Brien *et al.* 2003; Tobler *et al.* 2008; Treves *et al.* 2010), relative abundance in this study was found to be strongly associated with both the mean and maximum group size of a species. Spatial distribution was also highly correlated with maximum group size. This confirms that, as might be expected, more widely distributed species were photographed more often and that gregariousness has an effect on measures of abundance and spatial distribution. It would appear, therefore, that indices of abundance derived from camera trap data are likely to be weighted in favour of socially gregarious species. The criterion of independence used in this survey of 1 hour between photos was more conservative than the 0.5 hours used by O'Brien *et al.* (2003), but similar to that used elsewhere (Bowkett *et al.* 2008; Tobler *et al.* 2009). Treves *et al*. (2010) were forced to be more conservative still due to their having used film cameras that provided date but not time stamps on the photographs, they therefore categorised independence by date. It is not thought likely therefore that this was a factor in estimations of detectability.

4.5ii Occupancy and density estimates

The use of occupancy analysis is becoming an increasingly popular way of analysing camera trap data (Linkie *et al.* 2007; Thorn *et al.* 2009; Tobler *et al.* 2009) and is thought to provide reasonably robust estimates where sample sizes are sufficiently large. Using the Royle-Nichols model (Royle & Nichols 2003), this study attempted to establish differences in occupancy and density between three areas of the Ghanzi farm block with differing vegetation types and land use. Additionally, the possibility that detectability of a species could be affected by the habitat in the vicinity of the camera station and the season in which the survey was undertaken was also investigated.

The only species on which there was an effect of vegetation type (hardveld or sandveld) was the duiker with occupancy higher in the survey conducted on sandveld. Kudu had lower occupancy in the survey undertaken on the game farms suggesting that they may exist at lower densities where they have competition from other large ungulates. Warthog abundance was associated with survey, with CS1 strongly favoured. It is probable this is because of the management policy on the farms where this survey was located. Additional water points are provided for wild game throughout the farm and warthog, being keen mud wallowers, especially when temperatures are high (Mills & Hes 1997), are extremely abundant. Reinforcing this conclusion, warthog had a considerably higher probability of detection at camera stations located near water points. However, a further possible confounding factor here is that, because of the aforementioned management policy, more camera stations were positioned near water points in this camera survey than in the others. The number of camera stations at which water was available could also be a reason underlying the higher recorded occupancy of kudu in this survey. A survey of prey species conducted on the same farms as CS1 in 2008 estimated kudu density at 0.78/km^2, warthog at 0.62/km^2, steenbok at 0.19/km^2 and duiker at 0.06/km^2 (Snelleman 2009). Comparing those estimates with this study's figures of kudu 0.52/km^2, warthog 0.25/km^2, steenbok 0.15/km^2 and duiker 0.65/km^2 for CS1 reveals that all Snelleman's (2009) density estimates are higher except for duiker which is considerably lower. The author acknowledged that duiker were highly likely to have been underestimated as the survey was conducted during daylight hours only and duiker avoid activity during the heat of the day. This again underlines the usefulness of camera surveys for monitoring nocturnal species. With the exception of duiker however the relative densities are in accord. The densities found here are also generally in line with those found on the Namibian farmlands which represents a similar environment and patterns of land use (Marker 2002).

The possibility that season could have an effect on detectability was not strongly conclusive. Season as a covariate did not feature in the top model for any species; however, it did feature in the top five for steenbok, kudu and porcupine and so cannot be dismissed entirely. There was however no pattern apparent, with kudu having a lower probability of detection in the wet season while steenbok and porcupine had a higher probability. Whether this was a result of reduced movement during rain or some other factor it is not possible to say.

While it is interesting to be able to model each survey separately, the standard errors and confidence intervals associated with the occupancy and lambda estimates are relatively large, and detection probability low in some cases. For this reason, estimates derived from all the surveys combined are likely to be more robust. Unfortunately, this does not provide information on population differences due to land use, vegetation or land management.

The strong trend in the relationship between density estimates derived from the occupancy analysis and the indices of abundance gives weight to the value of such indices derived from camera trap rate, especially as the use of the Royle-Nichols model places the mixture distribution on abundance. This should compensate for any effect of group size on detectability. It is however important to note that while a relationship may exist in a given area, some knowledge of actual density in that area is required in order for inferences to be drawn from such abundance indices.

The Botswana Environment Statistics Unit (2005) report on wildlife populations in Ghanzi District for 2003 listed densities of the species investigated here as: kudu 0.07/km^2; warthog 0.01/km^2; steenbok 0.06/km^2 and duiker 0.03/km^2. These figures, which were derived from aerial censuses, are significantly lower than the estimates in this study (paired t-test, $t = 3.5$, $n = 4$, $p = 0.039$), and suggest that the farmland area may have better wildlife populations than previously thought. Interestingly, the DWNP Aerial Census of Animals in Northern Botswana in the 2006 dry season (DWNP 2006) also reported considerably lower densities of these species for other areas of Botswana (including protected areas) than those estimated in this study. It is possible therefore that, for some species at least, aerial surveys do not provide robust estimates of herbivore abundance.

4.5iii Predicting carnivore density from prey biomass

Predicting carrying capacities theoretically provides a useful tool to measure the sustainability of the populations of predators with reference to the available prey base. The current abundance of these predators will be investigated in Chapter 5. Hayward's (2007) equation resulted in a predicted carrying capacity for cheetah of 0.58/100 km^2 which would be lower than the 1.5/100 km^2 reported for the Serengeti (Gros 2002), but slightly higher than the estimate for the Kgalagadi Transfrontier Park of 0.54/100 km^2 (Funston *et al.* 2001). It would also be considerably lower than the estimate of 5.23/100 km^2 derived from spoor surveys in the Jwaneng area of Botswana (Houser *et al.* 2009b). Leopard densities vary considerably across their range but in the Kalahari, Funston (2001) estimated densities ranging from 0.19 leopards/100 km^2 in dune-savanna to 0.60/100 km^2 in tree-savanna. A leopard density of 0.85/100 km^2 as predicted by Hayward's (2007) equation based on preferred prey is possible in the environment of the study area, but the lower estimate of 0.69/100 km^2 based on the equation for species within the preferred weight range is probably more feasible. For African wild dog, either of the predicted carrying capacities of 0.72 or 1.09/100 km^2, using the two different equations, seem reasonable for such a wide-ranging species.

The fact that prey species composition in the study area differed considerably from that in the areas investigated by Hayward *et al.* (2007) is problematic and reduced the number of species that could be used in calculations of biomass for significantly preferred prey species. Even doing the calculations based on prey within the preferred weight range was not ideal as this encompassed only two species for leopard and wild dog and only one species for cheetah. It was not possible to do a calculation for lion using either criterion. It is probable that Hayward's

(2007) equations are better applied to protected areas than to rangelands, where there is a reduced range of prey species and carnivores are likely to have modified their prey preferences accordingly. Carbone and Gittleman's (2002) calculation on the other hand is more generally applicable as it places no species constraints on prey biomass calculations. The predicted carrying capacities obtained using this method of 0.40/100 km^2 for lion, 1.27/100 km^2 for leopard, 1.15/100 km^2 for cheetah and 2.35/100 km^2 for wild dog do also seem to be on the high side, but wild dog in particular, as a pack-living animal subject to inverse density-dependent processes (Courchamp *et al.* 2000), may not be the best subject for such a generalised prediction method.

There is of course an important additional confounding factor regarding the prediction of carnivore density from biomass of prey in this study. The existence of game farms which stock large numbers of potential prey species means that the free-ranging prey base that exists on farmland is not the only resource available to the carnivore population. It is probable therefore that carrying capacity is higher than that estimated using biomass of free-ranging game species only. That said, getting a picture of the status of free-ranging game species in a farming area where carnivores are present provides valuable information as to the health of the ecosystem as a whole.

4.5iv Stakeholder attitudes and perceptions

There was a general consensus that a healthy natural game species population was a good thing. Most of the farmers believed that the game on their land was reasonably plentiful, although some were more active in encouraging it than others. There was a strong feeling of antipathy towards poachers and, despite the game being free-ranging, a sense of ownership among domestic livestock farmers for the game on their land.

4.5v Limitations of this study

The study design underlying this camera trapping survey was aimed at capturing medium- to large carnivores and camera layout/spacing was set accordingly. It is likely that if the main objective had been to obtain occupancy/density measures of prey species, the stringent protocols regarding camera layout and spacing could have been relaxed. Tobler *et al*. (2008) found little evidence of an effect of camera spacing or layout on their results providing all major habitat types were sampled.

4.6 Conclusions

The evidence presented here from both the biological and social data points to a relatively healthy, naturally occurring prey base in the study area which should be able to support carnivores at densities that would be expected in a semi-arid savanna environment.

Chapter 5 - Ecological aspects of carnivore populations in the Ghanzi farmlands today: species diversity, density and abundance

5.1 Introduction

In the previous chapter it was established that a reasonably healthy, if somewhat reduced in terms of diversity, naturally occurring prey base remains in the Ghanzi farmlands. It was also predicted that the biomass of this prey base could potentially support several species of large- and medium-sized predators, albeit at fairly low densities. This chapter will test this prediction by attempting to determine the diversity and abundance of carnivores in the area. This will be achieved by utilising data from spoor surveys and camera trapping. Questions that will be addressed are:

1. What species of carnivores are present in the Ghanzi farmlands?
2. At what densities do the medium to large carnivores exist in the study area and do those densities concur with carrying capacities predicted from prey biomass?
3. Does density vary with vegetation type, land use and/or management?
4. Do game farms support a higher density of carnivores than domestic livestock farms?
5. How do carnivore densities in the Ghanzi farmlands compare with those found in other areas?
6. What do the density estimates obtained in this study reveal about the current state of carnivore populations in the Ghanzi farmlands?

Historical descriptions of the study area, as seen through the eyes of those who witnessed the growth of farming in the Ghanzi farmlands, were presented in Chapter 3. The picture offered was of an open, unfenced landscape populated by large aggregations of herbivores, both migratory and sedentary, and carnivores ranging in size from lion to mongoose. Carnivore diversity was high, with all the southern African assemblage of large- and medium-sized felids and canids represented in densities that would be expected for a semi-arid savanna environment. The introduction of fences and the growth of cattle herds and human populations was shown to have had a major impact on wildlife, and the extent to which that affected present day herbivore populations was revealed in Chapter 4. These factors must also have had a considerable impact on carnivore populations. To date however, little ecological research has been conducted in the area to ascertain the current status of the carnivores, and what information does exist is largely based on problem animal control (PAC) records, held by the Department of Wildlife and National Parks (DWNP), and anecdotal evidence. Nevertheless, an evidence-based knowledge of species diversity, abundance and interaction is essential for the implementation of effective policies directed at the mitigation of human-wildlife conflict and if the conservation of carnivores outside protected areas is to be achieved (Treves & Karanth 2003).

For many of the species under investigation here, populations outside protected areas are likely to constitute a sizeable proportion of their total numbers. This is inevitable where wide-ranging large-bodied animals are concerned as the small size of many protected areas is insufficient to contain viable populations (Woodroffe & Ginsberg 1998, 2000). While Botswana is fortunate in having large areas set aside for the conservation of wildlife, the nature of its semi-arid environment means that carnivores are always likely to exist at low densities and be widely dispersed. Additionally, high levels of human activity, and in some cases persecution, in agricultural areas mean that all wildlife species are timid and hard to see making the estimation of populations difficult.

Of particular importance in this study are leopard, cheetah, brown hyaena, African wild dog, caracal and black-backed jackal as these are the species perceived as the greatest threat to livestock in the area (Selebatso 2006). Furthermore, the issue of licences for the trophy hunting of leopard on private game ranches is of considerable economic importance to the game farmers in the area. In recent years this has aroused considerable debate between DWNP and the Botswana Wildlife Producers Association (BWPA), the body that represents game farmers. With no reliable estimates of leopard populations in the country DWNP, until very recently, based their quota allocation on estimates of leopard home range and allocated a total of 22 permits countrywide which were awarded to game farms larger than 8,000 hectares, with only one licence being issued per person regardless of the number of farms owned (BWPA 2007; Johnson 2010). A major change has now taken place with a new system devised by Dr. Paul Funston, and based on a system used in Mozambique for the sustainable hunting of lions, being adopted from 2009 (Johnson 2010). This has resulted in a reduction in the number of permits and changes in the way they are allocated. The need for reliable estimates of leopard density and home range is of critical importance to the success of this initiative and to the sustainability of the leopard population and the income from trophy hunting many game farmers rely on. However, in addition to the annual quota of leopard hunting permits issued to game ranches, the hunting of 'problem' animals on adjoining farms is also licensed and current estimates suggest that in excess of 200 leopards may be killed in this way annually (BWPA 2010).

Cheetah are widely perceived in the farming community as being plentiful and, in some quarters at least, as being a major threat to livestock (Klein 2007). While Cheetah Conservation Botswana (CCB) have in the past five years started researching cheetah in the area, more information is badly needed so that an assessment of the importance of the population in the Ghanzi farmlands to the species as a whole can be made. The cheetah is listed as Vulnerable on the IUCN Red List and is on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which restricts trade to exceptional circumstances only. CITES grants Botswana only five licences for the use of cheetah as trophies a year, in comparison with 150 for Namibia and 50 for Zimbabwe, but these are not utilised as the killing of cheetah, for any reason, was outlawed in 2005 with convicted offenders facing a fine or imprisonment (Klein 2007).

Brown hyaena are endemic to southern Africa, with Botswana believed to hold approximately half of the tentatively estimated maximum total population of around 8,000 animals (Mills & Hofer 1998). While research suggests that it is primarily a scavenger of mammal remains, it has also been found to include insects, birds, eggs and fruit in its diet (Mills & Mills 1978). Evidence suggests that hunting comprises a relatively small proportion of the brown hyaena's foraging behaviour, but small mammals and birds are occasionally predated (Mills 1990). They are not thought to be a major threat to livestock but have been known to sometimes take sheep, goats, calves or poultry, although this behaviour is thought to be usually restricted to a single individual rather than widespread in a population (Skinner 1976). Nevertheless, perceptions amongst farmers often reveal a belief that brown hyaenas are a problem animal, and in Botswana they are likely to be shot, poisoned or trapped, either deliberately or incidentally, despite being listed as a protected game animal (Mills & Hofer 1998). In a comprehensive assessment of the conservation needs and priorities of the larger African carnivores carried out for the Wildlife Conservation Society (WCS), the brown hyaena scored fifth in terms of vulnerability behind the cheetah, lion, African wild dog and Ethiopian wolf (*Canis simensis*)(Ray *et al.* 2005).

The accounts in Chapter 3 suggested that African wild dog were historically perceived as one of the most plentiful carnivore species of the Ghanzi farmlands, and predicted carrying capacity, calculated from prey populations in Chapter 4, suggested the area could support anywhere between 0.7 and 2.35 wild dogs/100km^2. But recorded numbers of this species are known to have fallen drastically across their range in the past 100 years, and particularly outside protected areas (Woodroffe & Ginsberg 1999; Woodroffe *et al.* 2004). There seems little reason to suppose that the Ghanzi farmlands are an exception to this trend, although the sheer size of the area could be expected to provide sufficient habitat and resources for a reasonable population, even for a species as wide ranging as the wild dog.

Caracal are one of the most persecuted and reviled felids in certain areas of South Africa where they are perceived to be a major threat to livestock, in particular sheep and goats (shoats) (Nowell & Jackson 1996; Ray *et al.* 2005). There has been considerable debate surrounding the challenges of controlling the species and protecting livestock to the extent that a specific project, the Canis-Caracal Programme, has been initiated by the African Large Predator Unit of the University of the Free State, South Africa to address the issues surrounding livestock depredation by caracal and black-backed jackal.

The black-backed jackal itself is extremely abundant in most parts of its range reflecting its adaptability and generalist feeding behaviour (Loveridge & Nel 2004). The accounts in Chapter

3 revealed this to be true of the Ghanzi farmlands in the past and it is probable that this remains the case today. The perceptions of farmers of present day jackal abundance will be discussed in Chapter 6.

Because of the aforementioned difficulties in directly observing and recording these carnivores, which can be expensive and labour intensive to overcome, increasingly, indirect methods have been employed as time and cost effective alternatives with some measure of success. Two such methods were employed in this study - camera trap surveys and spoor, or track, surveys.

5.2 Methods

Details of the methodology used for the three camera trap and two spoor surveys carried out in different areas of the farm block are to be found in Section 2.2i. Additional details on the camera trap surveys were elucidated in Section 4.2

5.3 Data Analysis

5.3i Camera trapping

As previously described in Section 2.2i, three 62-day camera trap surveys were undertaken in different parts of the Ghanzi farm block (see Figure 5.1). For details on numbers of photographs generated and criteria used for retention or discard of photographs see Section 4.3. As for analysis of prey species, all images were entered into Camera Base v. 1.3 (Tobler 2007) and the date, time, camera station and species pertaining to each picture recorded. The criterion for determining independence of photographic events differed for carnivores from that used for prey species. In this instance, photographs of the same species at the same station within a period of 30 minutes were excluded, unless they were of identifiable individuals (following O'Brien *et al.* 2003). This is less conservative than the 60 minutes independence criterion used for prey species as carnivores did not dwell in front of cameras for long periods but rather passed by. Relative abundance indices (RAIs), capture frequencies and detection histories were calculated as described in Section 4.3. For species with unique pelage markings that enable them to be individually identified, capture-recapture sampling methods were employed (Otis *et al.* 1978) using the web-based version of the program CAPTURE (Rexstad & Burnham 1991) available at http://www.mbr-pwrc.usgs.gov/software/capture.html. These species were leopard, cheetah and brown hyaena. CAPTURE selects from eight available models according to the data. The simplest model, M_0, assumes constant capture probabilities over all sampling occasions. This is thought to be an unlikely scenario and thus the model is believed to be inappropriate (Otis *et al.* 1978). The population size estimator associated with the model is also thought to be unreliable (Karanth & Nichols 1998). Therefore, in instances where model M_0 was selected by CAPTURE as the model of choice, the second rated model was believed to provide a more appropriate population estimate. CAPTURE also computes a test statistic for population closure based on capture history. However, doubts exist as to whether this test is accurate as variability in capture probability, particularly if caused by behavioural traits, can be mistaken for a failure of the closure assumption (Otis *et al.* 1978). Additionally, the closure test is thought to have low power and to rarely be able to reject the null hypothesis of population closure (Rexstad & Burnham 1991; Lynam *et al.* 2009). Otis *et al.* (1978) suggest that closure should probably be assessed from a biological basis, but that the most robust test might lie with the M_h model (which assumes heterogeneity of detection probability for all individuals, but that heterogeneity does not vary between trapping occasions nor does it have a behavioural response). Karanth and Nichols (1998), considered the most important likely violation of the closure assumption, given the length of their sampling periods, to be that of transient individuals passing through the study area which would not have the opportunity for recapture. This kind of event would be interpreted by CAPTURE as a trap-shy behavioural response and would likely therefore lead to selection of the M_b model (Karanth & Nichols 1998). The unreliability of the closure test has led some researchers in recent studies to rely solely on biological criteria when determining the likelihood of closure (Maffei *et al.* 2005; Soisalo & Cavalcanti 2006; Kolowski & Alonso 2010). The statistic generated by CAPTURE is reported in section 5.4 but, following the lead of the aforementioned studies, the length of trapping period is believed to provide sufficient basis for confidence in a closed population.

Capture histories were compiled for leopard, cheetah and brown hyaena in each survey, where an encounter with an identified individual during a trapping period was indicated with a 1, while a 0 represented a period when that individual was not photographed (see Table 5.1 for an example of a capture history). Due to the low densities of some species, resulting in a small number of captures/recaptures, the pilot period had to be included in the capture history in some instances in order to obtain enough data points for analysis. The occasions where this was necessary are detailed in section 5.4i. It is important to emphasise that in no case did this result in a sampling period of longer than 84 days and, given the life-history features of these species, is not therefore thought to have affected assumptions of population closure. Neither did it involve using photographs taken by cameras at stations that were subsequently relocated for the survey proper. It was also necessary to divide the trapping sessions into six-day periods following the example of Silveira *et al.* (2010). This served to reduce the number of zeros in the capture history thereby facilitating analysis in CAPTURE and increasing the value of detection probability $\hat{p}$ which is required to be at least ≥ 0.1 and preferably ≥ 0.17 in order to increase the precision of abundance estimates (Otis *et al.* 1978; Harihar *et al.* 2009). Some researchers have accepted lower values for $\hat{p}$ (O'Brien *et al.* 2003; Karanth *et al.* 2004a; Maffei *et al.* 2004; Soisalo & Cavalcanti 2006), and it is possible that in areas of low density, detection probability may often fall below this level. However, Karanth *et al.* (2004a) reasoned that the jacknife population estimator associated with model M_h went some way towards redressing the problems that might accrue from such a low probability of detection.

Table 5.1 Capture history of leopards in CS3											
	Trapping occasion										
Animal ID	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Lpd_E	0	0	0	0	0	0	1	0	0	0	1
Lpd_F	0	0	0	0	0	0	1	0	0	0	1
Lpd_G	0	0	0	0	0	0	0	0	0	1	0

In some cases even these strategies were not sufficient to allow for analysis in CAPTURE as the number of captures/recaptures was just too low. Many of the problems associated with the estimation of abundance in areas of low density were highlighted by Lynam *et al.* (2009) who encountered such issues when studying tigers in Myanmar. They outlined two alternative strategies for estimating abundance when numbers are too small to allow for analysis in CAPTURE. The first alternative is to simply count the number of individual animals photographed (M_{t+1}). The second alternative, and the one that Lynam *et al.* (2009) utilised, involved 'borrowing' the daily detection probability $\hat{p}$ from an adjacent survey and using that to calculate the probability $\hat{p}_1$ of detecting an individual animal at least once during the sampling period $1 - (1- \hat{p})^i$ where i is the number of sampling occasions. This can then be used to obtain an estimate of abundance ($\hat{N}_1$) using the equation $\hat{N}_1 = M_{t+1}/ \hat{p}_1$.

Other issues in CAPTURE associated with small sample sizes surround the computation of the 95% confidence intervals (CI) in model M_h. While CAPTURE provides an approximation of the SE for its estimate of $\hat{N}$ the CI is difficult to compute (Otis *et al.* 1978). Lynam *et al.* (2009) suggest following the advice of White *et al.* (1982), whereby the CI is estimated as $\hat{N} \pm 1.96(SE)$ rounded up to the nearest integer to obtain the upper limit and rounded down to the nearest integer to get the lower limit. Should the lower limit calculated in this way be less than M_{t+1} then M_{t+1} should be used as the lower CI (White *et al.* 1982).

Calculation of density from abundance estimates was achieved by drawing a buffer area around each camera station in ArcGIS 9.3 equal to half the mean maximum distance moved (HMMDM) by animals captured more than once. The individual buffers were dissolved giving an overall buffer around the grid and the area encompassed by that buffer was assumed as the sampling area A (Karanth & Nichols 2002; Karanth *et al.* 2004a; Silver *et al.* 2004). There has been discussion in the literature over the past few years as to the appropriate measure to use for the buffer, full mean maximum distance moved (MMDM), HMMDM or a value obtained from the radius of the known home range of the species using the equation $A = \pi r^2$ where A is the estimated home range and r is the width of the buffer and all have been used in recent studies (e.g. Soisalo & Cavalcanti 2006; Dillon & Kelly 2008; Harihar *et al.* 2009; Thorn *et al.* 2009; Silveira *et al.* 2010). A comparative study undertaken in areas with a known density of leopards in South Africa found that estimates of density using HMMDM performed second best when predicting the known true density and were considerably more accurate than measures based on home range. It was outperformed only by a measure based on the mean maximum distance moved by individuals outside the area bounded by the outer camera traps, a calculation based on telemetry data (Balme *et al.* 2009). In contrast, both Dillon and Kelly (2008) and Soisalo and Cavalcanti (2006) found that HMMDM underestimated home range resulting in large overestimates of density for ocelots (*Leopardus pardalis*) and jaguars respectively. Home ranges can vary considerably across the range of any given species and there was only one species in this study (cheetah) for whom there is any knowledge of home range in the area. For this reason estimates based on MMDM or HMMDM were deemed the most appropriate measures (if sufficient data were available) and both are presented here. Following Silver (2004), MMDM was calculated cumulatively over all three surveys for each species providing the maximum data points from which to calculate buffer width. Where applicable, estimates based on home range are presented. Because each species had different movement patterns a different buffer size was applied resulting in different values for the effectively sampled area. The size of the polygon bounded by the outer camera traps however remained constant for each survey (Figure 5.1).

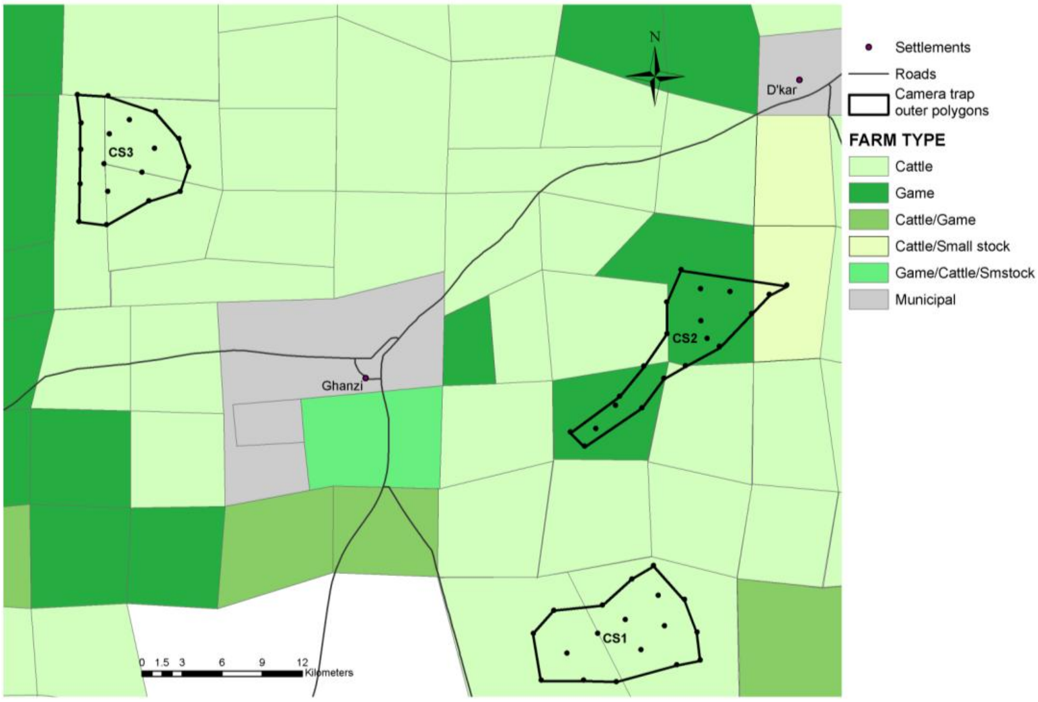


Figure 5.1 Map showing outer trap polygons of the three camera surveys and land use types on which they were conducted in the Ghanzi farmlands in 2009

There has also been debate as to whether zero distance animals (those that are captured more than once but at the same station) should be included in the calculations (Dillon & Kelly 2007).

It was decided in this instance not to include these animals as it was thought likely that such data would skew the resulting buffer widths.

Leopards are individually identifiable from their unique rosette patterns and formations (Figure 5.2), cheetahs from their unique spot pattern (Figure 5.3) and brown hyaenas from the stripes on both front and rear legs (Figure 5.4). Additional identifying information may be used from scars and ear notches although these are liable to change over time.

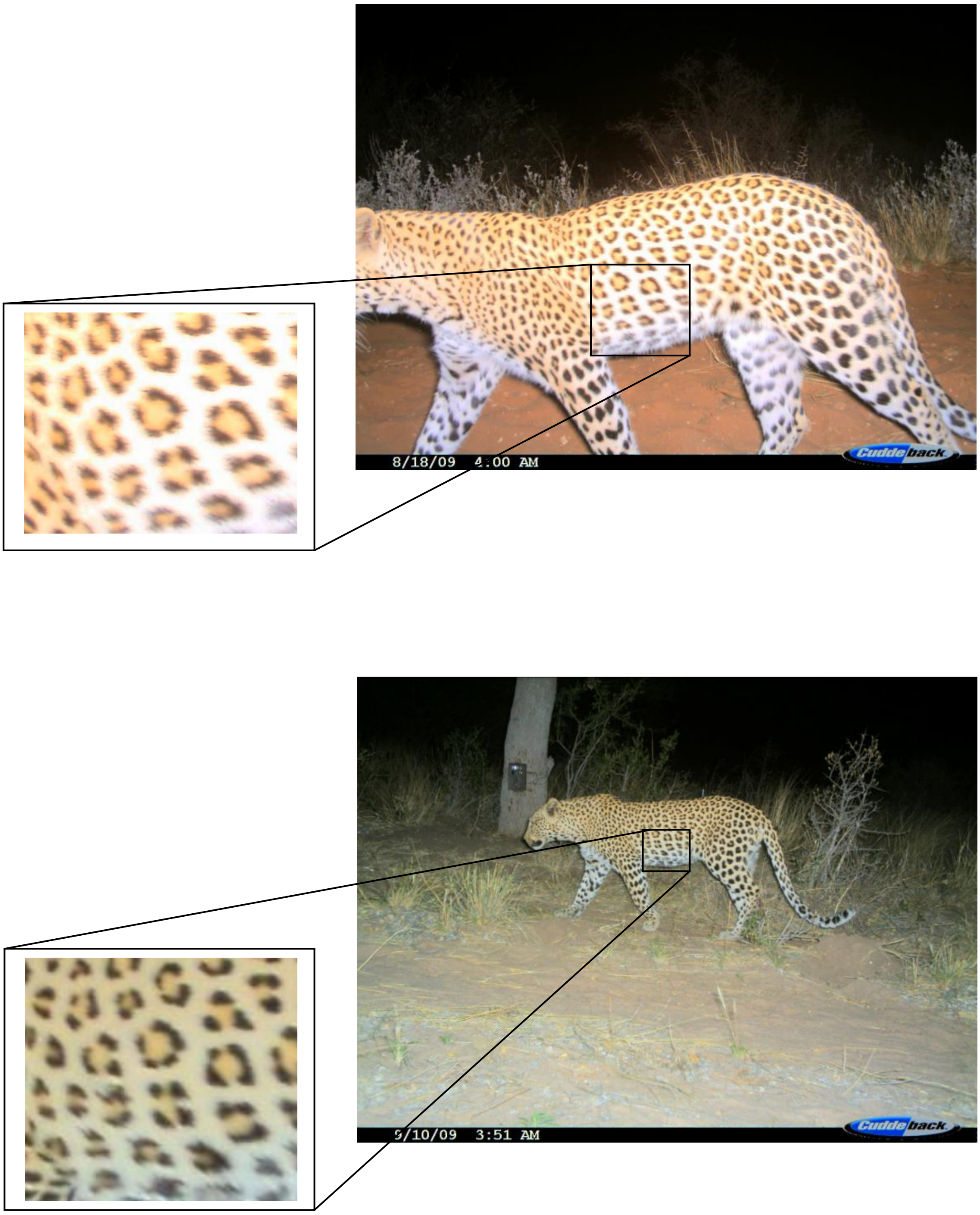


Figure 5.2 Matching rosette pattern from the flank of a leopard photographed at two different stations and on separate days during CS3

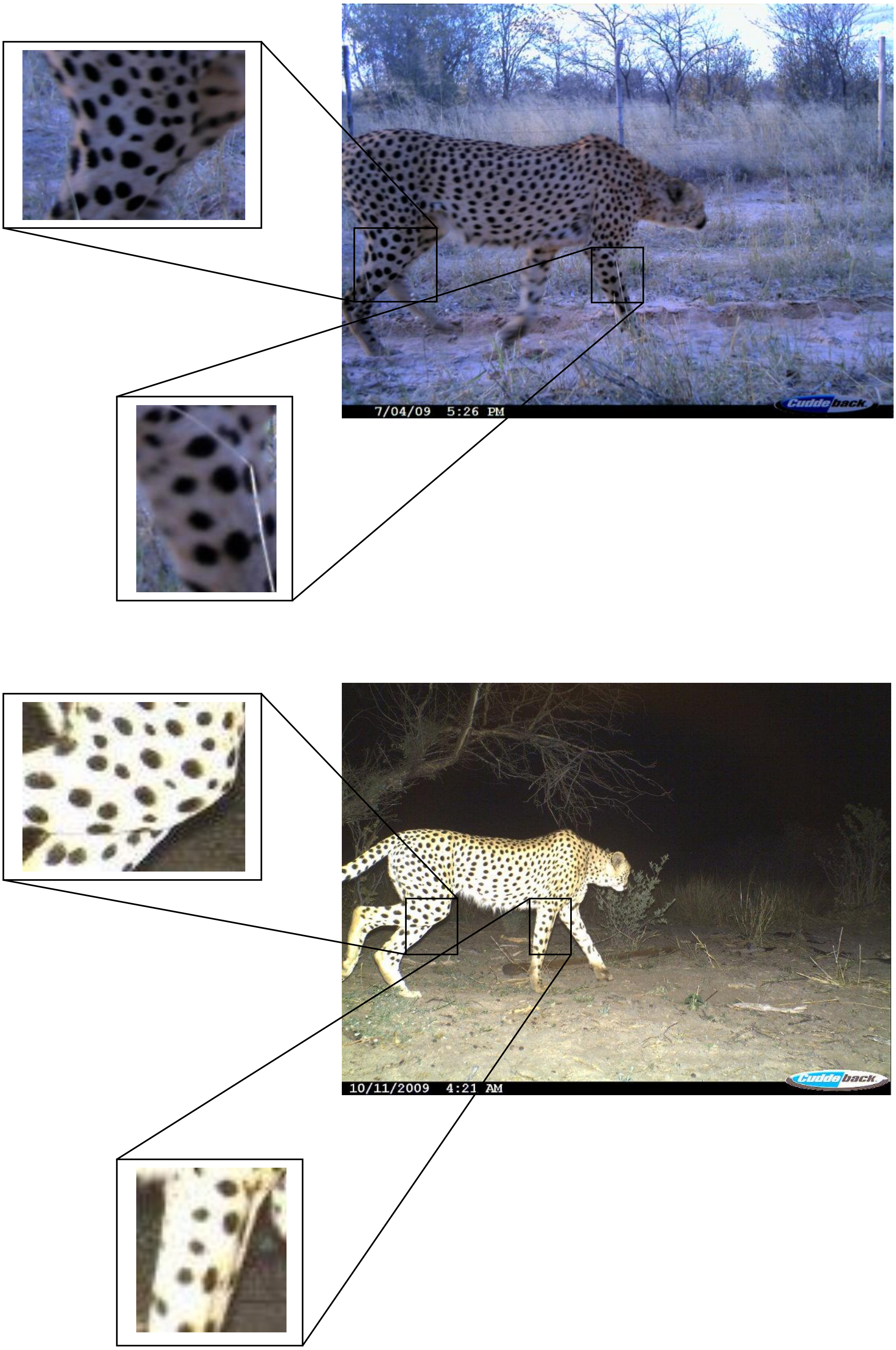


Figure 5.3 Matching spot patterns from the front and rear legs of a cheetah photographed at different camera stations on separate days
(Due to the low number of captures/recaptures for cheetah the bottom photograph in this example was not taken during this study's surveys but by CCB in a subsequent survey in the same area)

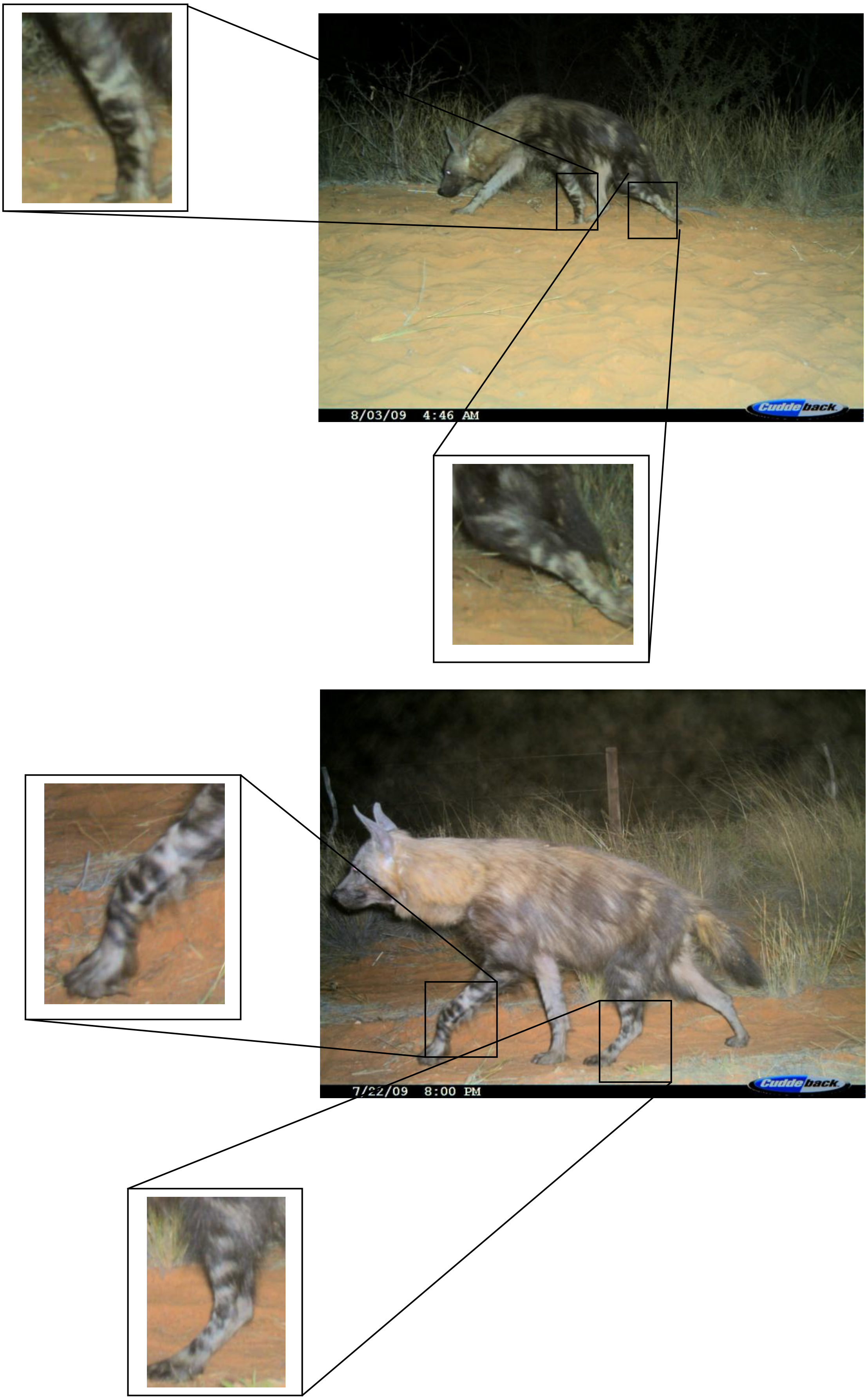


Figure 5.4 Matching leg stripe patterns of a brown hyaena photographed on separate days at different camera stations during CS3

5.3ii Spoor surveys

Following Funston *et al.* (2001, 2010), spoor frequency was defined as the number of kilometres per set of tracks and spoor density as the number of individual tracks encountered for each 100 kilometres driven. Sampling effort was determined by calculating the sum of the length of the transects expressed as a ratio to the size of the area surveyed. As the surveys were undertaken on farmland and utilised more than one farm unit, the calculation of total area surveyed was somewhat arbitrary, especially as in Spoor Survey 1 (SS1) some of the transects were tracks that ran along fence lines between farms. It was decided therefore, that as a transect that bisected a farm was approximately three kilometres on either side from that farm's boundary, this would be used as the measure from the outer transects to the area boundary. A three kilometre buffer with dissolved boundaries was created around the transects, using ArcGIS 9.3 in the same way as for the camera trap stations, and the area encompassed by that buffer assumed to be the area surveyed. The precision of spoor estimates were assessed from the spoor frequency for each species in each survey, where the distance between each set of tracks was measured and progressive means and standard errors were calculated. Bootstrap analyses (Sokal & Rohlf 1995) using R statistical software (R Development Core Team 2008), were used to determine sampling intensity, following Stander (1998), where two samples were randomly selected and then progressively increased to 4, 6, 8 $\ldots\ldots x,$ with fresh means and confidence intervals calculated each time. These were then plotted against measures of sampling effort.

Spoor density can be taken as an index of true density and surveys have been undertaken in areas of known true density of lion, leopard, cheetah, brown hyaena and African wild dog (Stander 1998; Funston *et al.* 2001; Balme *et al.* 2009; Houser *et al.* 2009b; Funston *et al.* 2010). As a result, for these species there are various calibration equations that have been determined to convert spoor density to an estimate of true density.

Means are given with standard errors as a measure of precision ($\bar{x} \pm SE$). Data were tested for normality and where not normally distributed nonparametric statistics were used. Statistical analysis was performed using Minitab 15 (Minitab Inc. 2007) unless otherwise stated.

5.4 Results

5.4i Camera trapping

Total camera trapping sampling effort during the three surveys is detailed in Table 4.3 and the capture data for non-carnivore species in Table 4.4. Data on carnivore species detected during the three camera trap surveys are presented in Table 5.2. Pooling all surveys, carnivore species were photographed between 1 and 1171 times ($\bar{x}$ = 112.2 ± SE 76.78) (Figure 5.5). As in Chapter 4, a photographic event may include more than one individual of that species. Spatial distribution varied considerably amongst species with black-backed jackal being photographed at the most stations (55), followed by brown hyaena (46), African wild cat (*Felis silvestris lybica*)(27), bat-eared fox (*Otocyon megalotis*)(25), caracal (22), Cape fox (*Vulpes chama*)(21), leopard (13), honey badger (*Mellivora capensis*) and small-spotted genet (*Genetta genetta*)(12), aardwolf (*Proteles cristata*) (11), cheetah (9), striped polecat (*Ictonyx striatus*)(8), African wild dog (2) and black-footed cat (*Felis nigripes*) and slender mongoose (*Galerella sanguinea*)(1). RAI_2 values ranged from 0.09 to 40.33 across the three surveys ($\bar{x}$ = 4.17 ± SE 1.60). Data were not normally distributed so nonparametric statistics were used. There was no significant difference in RAI_2 values for carnivore species (n = 15) between surveys (Friedman's test, s = 4.67, df = 2, p = 0.097) nor after removing species that were not photographed in all surveys (n = 11) (Friedman's test s = 2.18, df = 2, p = 0.336). Charts of

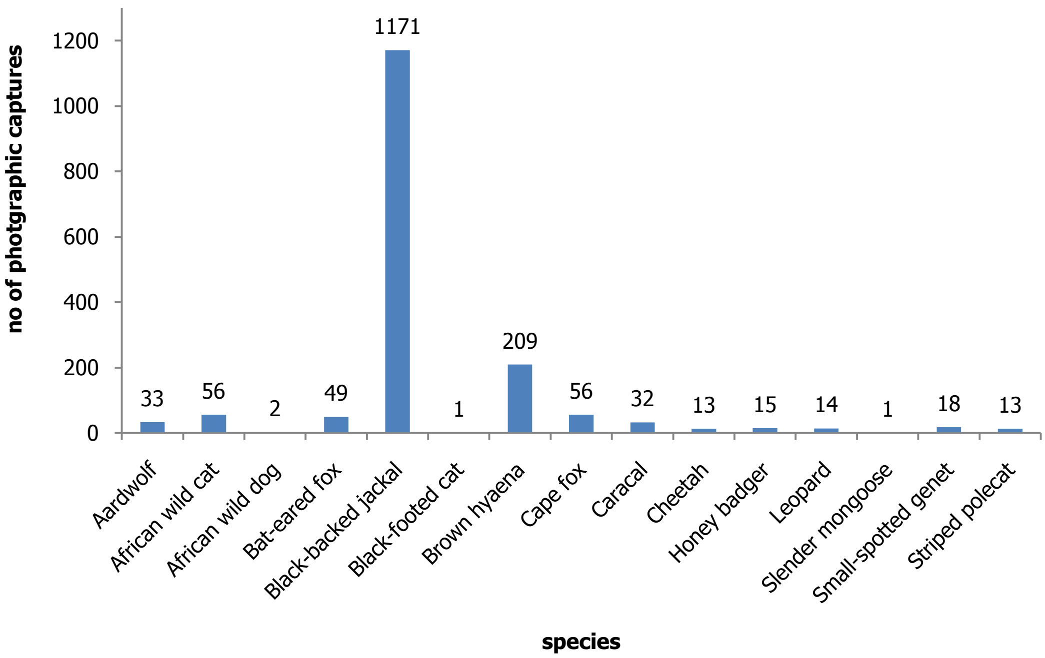


Figure 5.5 Number of photographic captures of carnivore species across three camera trap surveys in the Ghanzi farmlands in 2009

the RAI_2 values across the three surveys are presented in Figure 5.6 and Figure 5.7. Because black-backed jackals and brown hyaena were photographed so many times they have been

Table 5.2 Number of stations, independent captures and capture frequencies for all mammal carnivore species observed during three camera trap surveys in the Ghanzi farmlands in 2009
(days/photo (RAI_1) and photos/100 trap days (RAI_2))

		CS1				CS2				CS3			
Species	**Scientific name**	**Stations**	**Captures**	**RAI_1**	**RAI_2**	**Stations**	**Captures**	**RAI_1**	**RAI_2**	**Stations**	**Captures**	**RAI_1**	**RAI_2**
Aardwolf	*Proteles cristatus*	-	-	-	-	6	23	49.74	2.01	5	10	103.40	0.97
African wild cat	*Felis sylvestris lybica*	7	11	91.55	1.09	14	36	31.78	3.15	6	9	114.89	0.87
African wild dog	*Lycaon pictus*	-	-	-	-	2	2	572.00	0.18	-	-	-	-
Bat-eared fox	*Otocyon megalotis*	11	18	55.94	1.79	6	12	95.33	1.05	8	19	54.42	1.84
Black-backed jackal	*Canis mesomelas*	18	359	2.81	35.65	19	395	2.9	34.53	18	417	2.48	40.33
Black-footed cat	*Felis nigripes*	-	-	-	-	1	1	1144.00	0.09	-	-	-	-
Brown hyaena	*Parahyaena brunnea*	16	72	13.99	7.15	14	57	20.07	4.98	16	80	12.93	7.74
Cape fox	*Vulpes chama*	4	4	251.75	0.40	7	28	40.86	2.45	10	24	43.08	2.32
Caracal	*Caracal caracal*	5	7	143.86	0.70	10	17	67.29	1.49	7	8	129.25	0.77
Cheetah	*Acinonyx jubatus*	1	1	1007.00	0.10	5	9	127.11	0.79	3	3	344.67	0.29
Honey badger	*Mellivora capensis*	3	3	335.67	0.30	7	8	143.00	0.70	2	4	258.50	0.39
Leopard	*Panthera pardus*	3	3	335.67	0.30	3	4	286.00	0.35	7	7	147.71	0.68
Slender mongoose	*Galerella nigrata*	-	-	-	-	-	-	-	-	1	1	1034.00	0.10
Small-spotted genet	*Genetta genetta*	4	4	251.75	0.40	5	11	104.00	0.96	3	3	344.67	0.29
Striped polecat	*Ictonyx striatus*	4	6	167.83	0.60	1	1	1144.00	0.09	3	6	172.33	0.58

removed from the dataset in Figure 5.7 in order to increase the resolution of the other species. No overall pattern of difference in relative abundance was apparent across the three surveys, but there was a noticeable dip for brown hyaena and a peak for African wild cat in Camera Survey 2 (CS2), which was conducted primarily on two game farms, in contrast to Camera Survey 1 (CS1) and Camera Survey 3 (CS3) which took place on cattle farms. There was

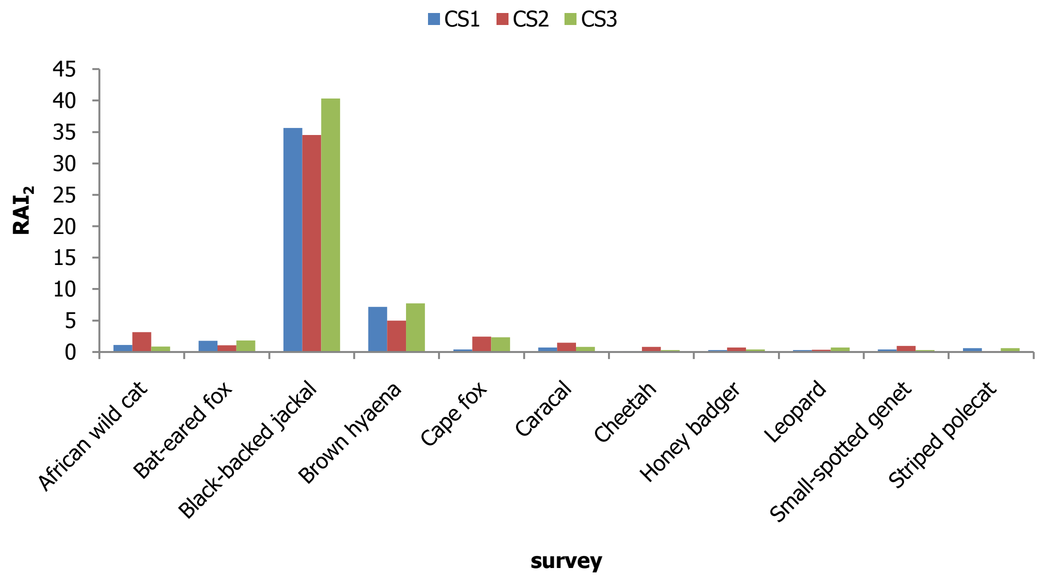


Figure 5.6 RAI_2 values for all carnivore species (n = 11) photographed in all three camera trap surveys in the Ghanzi farmlands in 2009

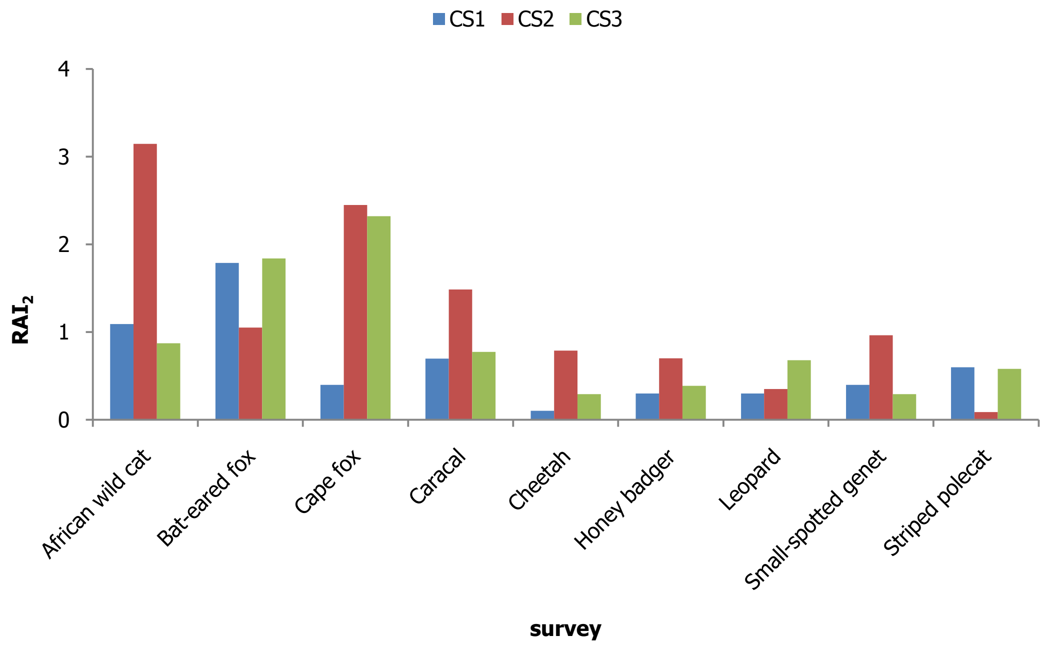


Figure 5.7 RAI_2 values for all carnivore species excluding black-backed jackal and brown hyaena (n = 9) photographed in all three camera trap surveys in the Ghanzi farmlands in 2009

however a significant difference between the two surveys carried out on cattle farms (one of which was on sandveld and the other on hardveld) when looking at all species (Wilcoxon signed-rank test, W = 15.0, n = 15, p = 0.036), but not when looking only at species common to both surveys (Wilcoxon signed-rank test, W = 13.0, n = 11, p = 0.083). There was no significant difference between the two surveys conducted on farms with hardveld type vegetation (one game and one cattle) looking at all species (Wilcoxon signed-rank test W = 65.0, n = 15, p = 0.798), nor between those two surveys looking only at species that were common to both (Wilcoxon signed-rank test, W = 30.0, n = 11, p = 0.824). Total number of photographic captures obtained for a species was highly correlated with RAI_2 (r_s = 1 p = <0.01) and with spatial distribution (number of camera stations at which a species was detected) (r_s = 0.933 p = <0.01).

Leopard

Two individual leopards were photographed in CS1, one male and one female. During the survey proper there were no recaptures, but when the pilot period was taken into account there was one recapture for the male and two recaptures for the female resulting in a total of five captures. The combined 84-day time span was divided into 6-day sampling periods resulting in a total of 14 trapping occasions and CAPTURE successfully ran the resultant capture history (Table 5.3). CAPTURE selected either M_0 or M_h as being the appropriate model and so, as discussed in Section 5.3i, it was thought appropriate to use model M_h. CAPTURE did however issue a warning that the 'data were ill conditioned' and provided a 'best guess estimate' for capture probability.

Table 5.3 Capture-recapture results, abundance and density estimates for leopard in three camera surveys undertaken in the Ghanzi farmlands in 2009

Parameter		**CS1**	**CS2**	**CS3**
Probability of capture under M_h	$\hat{p}$	0.143	[0.0727]	0.114
Closure test	z	0.671	-	0.00
	p	0.749	-	0.50
Selection criteria	M_h	0.98	-	0.99
No. occasions	T	14	11	11
No. individuals caught	M_{t+1}	2	3	3
Est. no. leopards by M_h	$\hat{N} \pm SE(\hat{N})(95\%CI)$	2 ± 1.846 (2-4)	-	4 ± 1.388 (3-7)
Est. no. leopards by borrowed $\hat{p}_1$	$\hat{N}_1 \pm SE(\hat{N}_1)(95\%CI)$		4 ± 0.475 (3-5)	
Effective sampling area using HMMDM	km^2	309.11	334.10	278.50
Est. density HMMDM	(leopards/100 km^2)	0.65	1.20	1.44
Effective sampling area using MMDM	km^2	689.13	761.75	637.95
Est. density MMDM	(leopards/100 km^2)	0.29	0.53	0.63

Three leopards were photographed in CS2 a male and a female with a sub-adult cub. The male was the same individual that had been detected in CS1. The maximum distance between camera stations at which he was recorded was 20.94 km. This male's territory therefore overlapped that of at least two females. For this capture history CAPTURE again issued a warning that the data were ill conditioned and offered a best guess value for $\hat{p}$ of 0.0727. As this was below the required value it was thought preferable therefore to employ one of the alternatives outlined in section 5.3 to obtain an estimate of abundance. These were to simply count the number of individuals captured (3) or to estimate $\hat{N}$ by borrowing daily detection probability $\hat{p}$ from the adjacent survey - CS1 (0.143), and using the minimum number of sampling occasions that could be used incorporating all captures (11). Utilising the equation specified in section 5.3 this produced an abundance estimate of 4 (± 0.475 SE) (Table 5.3).

In CS3, three leopards were again photographed, one young male, one female and one of unknown sex. One of the seven photographs was too blurred to allow for identification and so was discarded. Four days of the pilot period were added to the front of the matrix so the data could be divided into 11 x 6-day trapping occasions. No leopards were captured during the pilot period so this did not increase the number of capture-recaptures. CAPTURE executed successfully and selected either M_0 or M_h as the appropriate model and thus M_h was used. Reducing the number of trapping occasions did result in the loss of one recapture for one individual but it was necessary to do this in order to achieve a value for $\hat{p}$ >0.1 However, CAPTURE again issued a warning that the data were ill conditioned.

Calculation of the effective sampling area was achieved by following the protocol set out in section 5.3i. Data on distance moved by animals captured more than once was pooled for all three surveys. This meant that the data obtained from the male leopard captured in both CS1 and CS2 could be incorporated. The resulting buffer width was 9 km using MMDM and 4.5 km using HMMDM (Table 5.3). Density estimates ranged from 0.29 to 0.63 leopards/100 km^2 using MMDM and from 0.65 to 1.44 leopards/100 km^2 using HMMDM. Combining the three surveys, the total effective sampling area using HMMDM was 921.71 km^2 with a mean density of 1.08 leopards/100 km^2. Using MMDM the figures were 2088.83 km^2 and 0.48 leopards/100 km^2.

Cheetah

The results for cheetah in the three surveys were far more difficult to analyse and interpret. In CS1 there was only one capture of a cheetah during the survey proper and one other during the pilot period. As neither of these captures provided images of both sides and as one was of the left flank and one the right, it was not possible to determine if it was the same or different individuals. With such sparse data it was impossible to utilise CAPTURE and even estimating abundance using a borrowed $\hat{p}$ from one of the other surveys could not be justified. The third option of using M_{t+1} as the estimate of abundance was therefore utilised, resulting in an abundance estimate of one (Table 5.4).

CS2 provided a large number of cheetah captures in both the pilot and survey periods, but no recaptures in the survey proper. When combining the pilot and survey periods there was still only one recapture. Over the pilot and survey periods, two adult females and one adult male were photographed at camera stations with pairs of cameras, providing images of both sides of the animals. A further five photographs of right flanks were obtained (which included the one recapture), however one was too blurred to be able to use for identification. Four photographs of left flanks were recorded. The decision was taken to use the animals for which there were right flank pictures, along with the paired photographs, for analysis as this provided a recapture. The capture history generated consisted of six animals (four females, one male and one unsexed) with one recapture. In addition to the photographs of adult cheetah detailed above, at least three sub-adults were photographed plus two cubs approximately 8 months old. None of these juveniles were included in the analysis. The combined trapping period of 66 days was divided into 11 x 6 day trapping occasions. CAPTURE successfully executed the analysis from the resultant capture history and selected M_0 as the appropriate model with M_h as second choice. Again, model M_h was chosen as being a more likely reflection of cheetah behaviour. CAPTURE did not issue a warning about the data but the value for $\hat{p}$ was only 0.0579 and the standard error associated with $\hat{N}$ was large (Table 5.4). As a result the abundance estimate should be treated with caution.

Table 5.4 Capture-recapture results, abundance and density estimates for cheetah in three camera surveys undertaken in the Ghanzi farmlands in 2009

Parameter		**CS1**	**CS2**	**CS3**
Probability of capture under M_h	$\hat{p}$	-	0.0579	-
Closure test	z	-	1.633	-
	p	-	0.949	-
Selection criteria	M_h	-	0.95	-
No. occasions	T	-	11	-
No. individuals caught	M_{t+1}	1	6	3
Est. no. cheetahs by M_h	$\hat{N} \pm SE(\hat{N})(95\%CI)$	-	11 ± 4.525(6-20)	-
Effective sampling area using radius of mean home range	km^2	1071.82	1179.50	1005.32
Est. density	(cheetah/100 km^2)	0.09	0.93	0.30
Effective sampling area using radius of female home range	km^2	730.56	807.40	677.55
Est. density	(cheetah/100 km^2)	0.14	1.36	0.44

In CS3 one female was photographed from both sides and another from the left side only. Another photograph of a group of two animals was obtained but it was not possible to identify them. During the pilot period a photograph was also taken of a male that was known to be the territorial male in the area (L. Boast pers. comm.). There were no recaptures during the survey or the pilot period and it was not possible therefore to analyse the data using CAPTURE. As the value of $\hat{p}$ in CS2 was low, and the number of animals captured was so different from that in

CS3, it was not considered to be valid to borrow CS2's $\hat{p}$ to estimate abundance. The value for $\hat{N}$ in this instance was therefore assumed to be the same as M_{t+1} which was three – one male and two females.

The lack of recaptures created a problem for estimation of the effective sampling area using MMDM. There is however some knowledge of cheetah home range in the wider area as a result of telemetry studies carried out by CCB between 2003 and 2007. Movement data recorded for two single males and a coalition of two males in the study area, plus a lone female and a female with cubs in a reserve bordered by farmland 500 kilometres south of the study area provided a mean female home range of 273.65 km^2 and an overall mean home range figure of 471.165 km^2 (Houser *et al.* 2009a). Non-territorial male cheetahs often range nomadically over very large areas (Caro 1994) and as the home range data from the above study are quite sparse and may be biased by such behaviour, two buffer widths were calculated. One, derived from the mean female home range, of 9.3 km and the other, from the mean overall home range, of 12.25 kilometres. Both were calculated using the equation specified in section 5.3. Density estimates ranged from 0.14 cheetahs/100 km^2 in CS1 to 1.36 cheetahs/100 km^2 in CS2 using the buffer based on female home range and 0.09 cheetahs/100 km^2 in CS1 to 0.93 cheetahs/100 km^2 in CS2 using the overall mean home range. The total area surveyed totalled either 2215.51 km^2 or 3256.64 km^2 depending on the buffer width and the mean densities over this area were either 0.68 or 0.46 cheetahs/100 km^2.

Brown hyaena

Five brown hyaenas were positively identified in CS1 with photographs of both sides of the animal. A further four animals were identified from right-side only images and three for which there were only left-side images. It was decided to include the right-side individuals in the analysis as this provided more data. Four days of the pilot period were added to the front of the capture history to facilitate dividing the matrix into 11 x 6 day trapping occasions. This did not add any animals or captures to the capture history. CAPTURE selected model M_0 as the most appropriate followed by M_h and model M_h was therefore used (Table 5.5). CAPTURE produced an abundance estimate of 9 ± 1.497, but it did issue a warning that the data were ill conditioned and provided a best guess estimate of capture probability of 0.3131.

In CS2 five hyaenas were identified with right- and left-side photographs, two from right-sided photographs and one from a left-sided photograph. The left-sided animal was omitted from the analysis. Three of the animals had also been seen in CS1 with a maximum distance moved

Table 5.5 Capture-recapture results, abundance and density estimates for brown hyaena in three camera surveys undertaken in the Ghanzi farmlands in 2009

Parameter		**CS1**	**CS2**	**CS3**
Probability of capture under M_h	$\hat{p}$	0.3131	0.4432	0.3273
Closure test	z p	1.031 0.8488	1.026 0.8475	-1.802 0.03578
Selection criteria	M_h	0.83	0.82	0.83
No. occasions	T	11	11	11
No. individuals caught	M_{t+1}	9	7	9
Est. no. hyaenas by M_h	$\hat{N} \pm SE(\hat{N})(95\%CI)$	9 ± 1.497 (9-12)	8 ± 1.433 (8-11)	10 ± 1.405 (9-12)
Effective sampling area using HMMDM	km^2	241.66	255.35	216.02
Est. density HMMDM	(hyaenas/100 km^2)	3.72	3.13	4.63
Effective sampling area using MMDM	km^2	508.131	560.43	465.67
Est. density MMDM	(hyaenas/100 km^2)	1.77	1.43	2.15

between camera stations at which they were captured of 18.14 km. More details on movement and activity patterns are presented in Chapter 7. As for CS1, four days were added from the pilot period in order for an 11 x 6 day capture history matrix to be constructed. This resulted in two of the hyaenas having an additional capture in the matrix. CAPTURE again selected model M_0 as the most appropriate followed by M_h which was used with a value for $\hat{N}$ of 8 ± 1.433 being estimated (Table 5.5). Once again the data were ill conditioned and a best guess of capture probability was provided.

Eight hyaenas were identified with right- and left-sided photographs in CS3 with one more each from right-sided and left-side photographs only. The animal for which there was only a right-side image was observed to have a snare round its neck and disappeared from the survey after only three weeks. It was thought that this might contravene closure assumptions, so it was decided to omit this individual from the analysis and use the left-sided animal. As for the previous two surveys, four days of the pilot survey were added to the front of the capture history to facilitate the construction of an 11 x 6 day matrix. CAPTURE successfully ran the analysis, although again the data were ill conditioned, and the abundance estimate was 10 ± 1.405 (Table 5.5).

Calculation of the effective sampling area was achieved, as before, using data on distance moved by animals included in the analysis and were captured more than once. The data was again pooled for all three surveys, allowing the movement data for the three hyaenas captured in both CS1 and CS2 to be incorporated. The buffer width calculated from HMMDM was 3.5 kilometres and using MMDM it was 7 kilometres (Table 5.5). Density estimates ranged from 3.13 to 4.63 brown hyaenas/100 km^2 using HMMDM and from 1.43 to 2.15 brown hyaenas/100 km^2 using MMDM. Combining the three surveys, the total effective sampled area using HMMDM was 713.03 km^2 with a mean density of 3.79 hyaenas/100 km^2. Using MMDM the total effective sampled area was 1534.23 km^2 and mean density was 1.76 hyaenas/100 km^2.

Caracal

The number of captures of caracal in all three surveys was very low and as they are not individually identifiable from pelage markings the data could not be analysed in CAPTURE. Unfortunately, the low number of captures also precluded the use of PRESENCE for occupancy analysis. Estimates of abundance were therefore not possible and the measure of relative abundance obtained from photographic capture rate was the limit of analysis possible.

Black-backed jackal

Black-backed jackals are not individually identifiable so it was not possible to analyse the camera trapping data obtained for them in CAPTURE. However, the large number of captures obtained for this species meant that occupancy analysis in PRESENCE was possible following the same protocols employed for prey species outlined in section 4.3.

The data were analysed for each individual survey and also pooled over all three surveys in order to try to establish if there were differences in occupancy and/or abundance between sites. As for the prey species analysed using occupancy analysis in Chapter 4, the Royle-Nichols abundance model (Royle & Nichols 2003), both with and without covariates, was selected by PRESENCE as the model with the highest AIC weight (Table 5.6). The top two models both featured season as a covariate for *r*, while land use and vegetation type were in the second and third highest weighted models for lambda. This indicated that jackal were slightly less likely to be detected in the wet season and that abundance was marginally higher on cattle farms and in hardveld type vegetation. There was however very little difference in the AIC unit values, with just 0.94 covering the top four models.

Table 5.6 Summary of RN occupancy models selected by PRESENCE for data on black-backed jackal at 56 sites from 3 camera surveys
Models with an AIC weight >0.1 are shown

Model Black-backed jackal	**AIC[a]**	**ΔAIC[b]**	**AIC wt[c]**	**Model Like[d]**	**N Par[e]**	**-2*LogLike[f]**
λ (.) r (season)	564.37	0.00	0.2578	1.0000	3	558.37
λ (land use) r (season)	564.86	0.49	0.2018	0.7827	4	556.86
λ (veg) r (.)	565.25	0.88	0.1660	0.6440	3	559.25
λ (.) r (.)	565.31	0.94	0.1611	0.6250	2	561.31

The total abundance estimate across all sites from the top weighted model (ψ = 0.973 ± SE 0.021) was 202.28 (± SE 43.16, CI 117.69-286.88) with an average abundance per sample unit (camera station) of 3.61 (± SE 0.77) and a detection probability value of 0.36 (± SE 0.006). When analysing each survey individually the top model for both CS2 and CS3 featured no covariates indicating no effect of habitat on detectability. The top model in CS1 however did feature habitat as a covariate, where untransformed estimates indicated water points being strongly favoured (r = 0.5350 ± SE 0.19) over thick bush (r = 0.3995 ± SE 0.21) and medium bush (r = -1.5652 ± SE 0.56). Converting the overall abundance estimate to density using the same method as applied for prey species in Chapter 4 provided an estimate of 39.48 jackals/100 km^2.

Comparing the density estimates obtained using either CAPTURE or PRESENCE for the four species on which analysis was possible, with the RAI_2 value reveals a strong correlation between the two measures (Pearson correlation $r = 0.996$, $n = 4$, $p = 0.004$) (Figure 5.8).

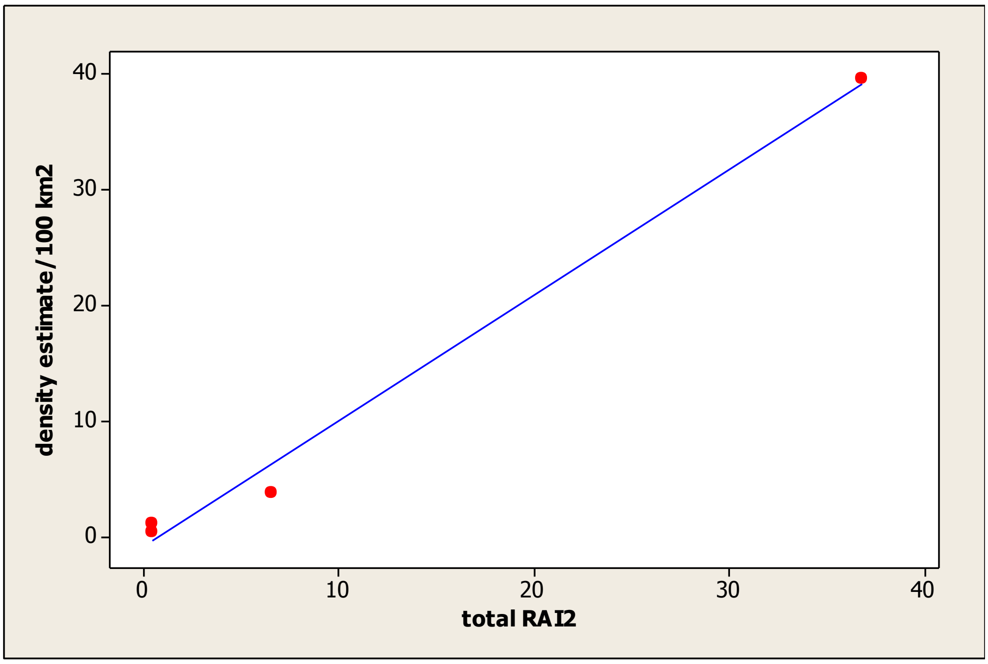


Figure 5.8 Plot of density estimates/100 km^2 and total RAI^2 values
For cheetah, leopard, brown hyaena and black-backed jackal in three camera surveys in the Ghanzi farmlands in 2009

5.4ii Spoor surveys

Details of transects and size of study areas are presented in Table 5.7 and spoor data collected on the five different species of carnivore in Table 5.8. Visual representations of the locations at which spoor was found in each survey are presented in Figure 5.9 and Figure 5.10. No leopard spoor was recorded in Spoor Survey 1 (SS1) and only five tracks were encountered in Spoor Survey 2 (SS2). Cheetah spoor were encountered on 20 occasions in SS1 in group sizes ranging from 1 to 6 ($\bar{x} = 2.3 \pm 0.34$) and 13 times in SS2 with group sizes ranging from 1 to 4 ($\bar{x} = 1.92 \pm 0.29$). As the camera trapping data indicated a higher density of cheetah on the game farms that formed part of SS1's area, the cheetah spoor from these two game farms were separated out and analysed separately. Fourteen of the 20 cheetah spoor encounters in SS1 were on these two game farms. Brown hyaena spoor was recorded on 81 occasions in SS1, of which seven were of more than one individual with a maximum group size of three. Hyaena spoor was found 99 times in SS2, of which all but one were of a single animal. Caracal spoor was found 14 times during SS1, on one occasion the spoor was of two animals. In SS2, caracal spoor was encountered 42 times with again one instance of two animals being recorded. Black-backed jackal spoor were encountered on 240 occasions in SS1 in group sizes ranging from one to five ($\bar{x} = 1.14 \pm 0.03$). There were an additional two visual sightings which were omitted from analysis as it was not known if the spoor had already been counted. During SS2 jackal spoor were recorded 283 times of which 282 were of single animals. The exception was a group of four. There were six additional visual sightings which once again were omitted from analyses for the reasons given above.

Table 5.7 Area size, number of transects and sampling effort of two spoor surveys carried out in Ghanzi farmlands in 2008/9

	SS1 (hardveld)	**SS2 (sandveld)**
Area size (km^2)	567	264
No of transects	6	5
Mean transect length (km)	10.74 ± 1.87 SE	9.9 ± 2.91 SE
Total distance of transects (km)	64.43	49.5
Total distance sampled (km)	1023	990
Sampling effort	8.08	5.33

Table 5.8 Results of two spoor surveys in the Ghanzi farmlands in 2008/9

Survey/species		**No of times spoor recorded**	**Spoor frequency (±SE)**	**No of fresh spoor**	**Spoor density/100 km**
SS1	Leopard	0	-	0	-
	Cheetah	20	51.168 ± 3.270	46	4.495
	Brown hyaena	81	12.634 ± 0.297	90	8.795
	Caracal	14	73.096 ± 4.109	15	1.466
	Black-backed jackal	240	4.264 ± 0.026	272	26.579
SS2	Leopard	5	198.0 ± 27.377	5	0.505
	Cheetah	13	76.154 ± 3.798	23	2.323
	Brown hyaena	99	9.970 ± 0.181	100	10.101
	Caracal	42	23.571 ± 4.034	42	4.242
	Black-backed jackal	283	3.498 ± 0.019	288	29.091
SS1 – game farms only	Cheetah	14	23.303 ± 1.085	32	9.809

Bootstrapping analyses (combining all transects) of SS1 and SS2 data for cheetah, brown hyaena, caracal and jackal reveal the different points at which the variance of spoor frequency stabilised for each species in each survey. Cheetah spoor stabilised at around 15 samples and 600 km in SS1, while in SS2, although less data were collected, appeared to be stable at the end of the survey at 13 samples and 1000 km (Figure 5.11). Brown hyaena spoor stabilised at around 20 samples in both surveys which was at approximately 170 and 120 km respectively (Figure 5.12). Caracal spoor had not stabilised at the end of SS1 with 14 samples and over 1000 km driven, but reached asymptote in SS2 at around 30 samples and 800 km (Figure 5.13). Black-backed jackal spoor was the most commonly encountered and reached asymptote at around 30 samples in both surveys between 90 and 100 km. Beyond these points there was no great improvement in the accuracy or precision of the estimates (Figure 5.14). Leopard spoor was not encountered frequently enough in SS2 to warrant such analysis.

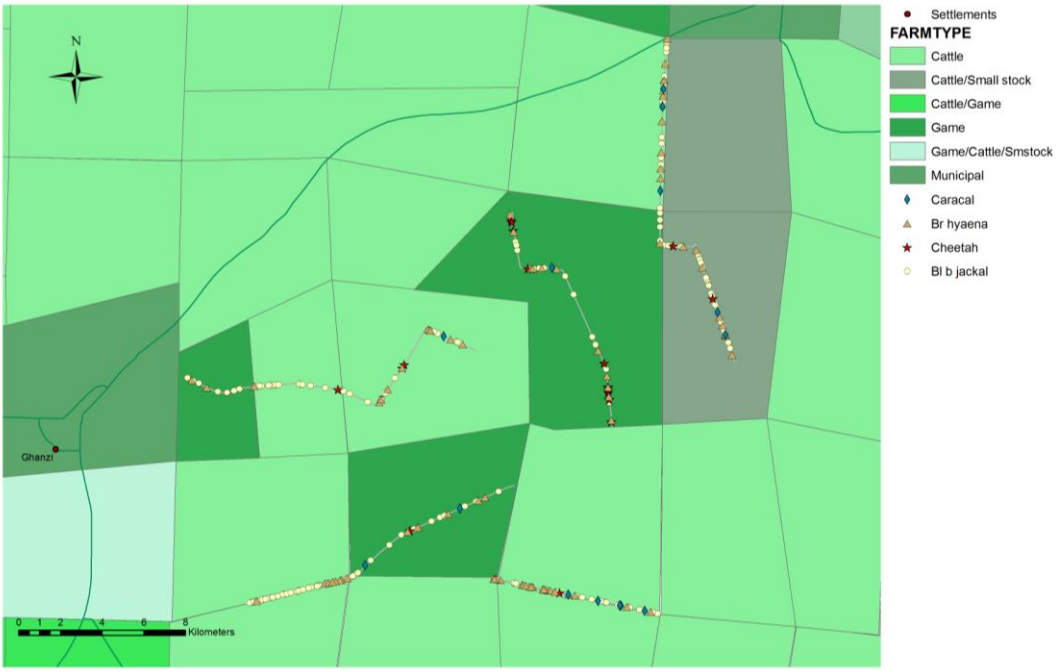


Figure 5.9 Map of SS1 showing locations of spoor of four species of carnivore

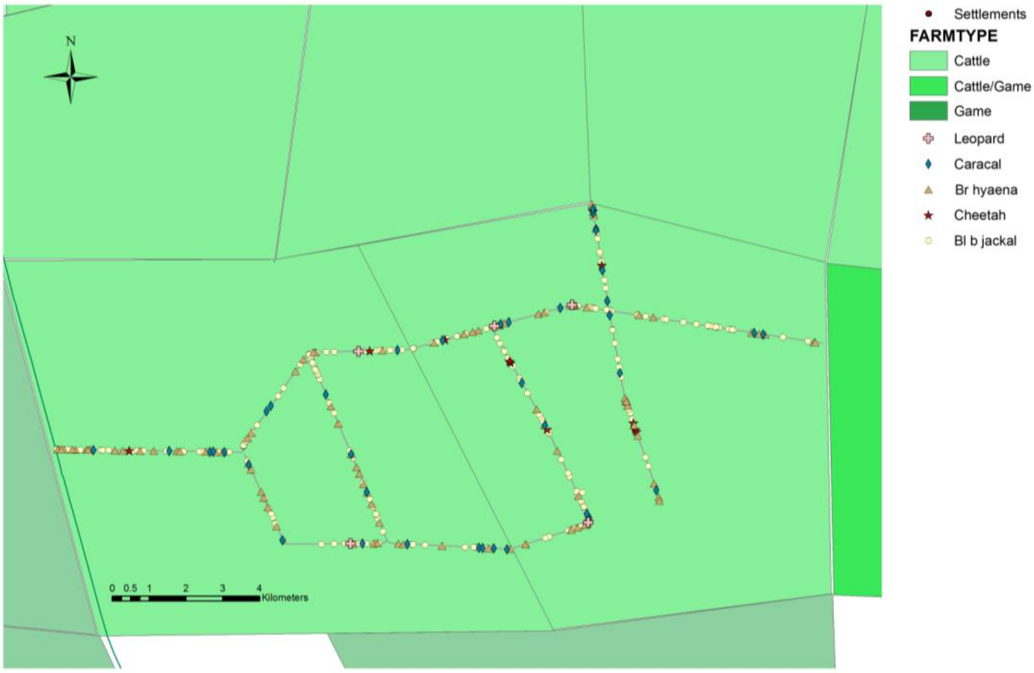


Figure 5.10 Map of SS2 showing locations of spoor of five species of carnivore

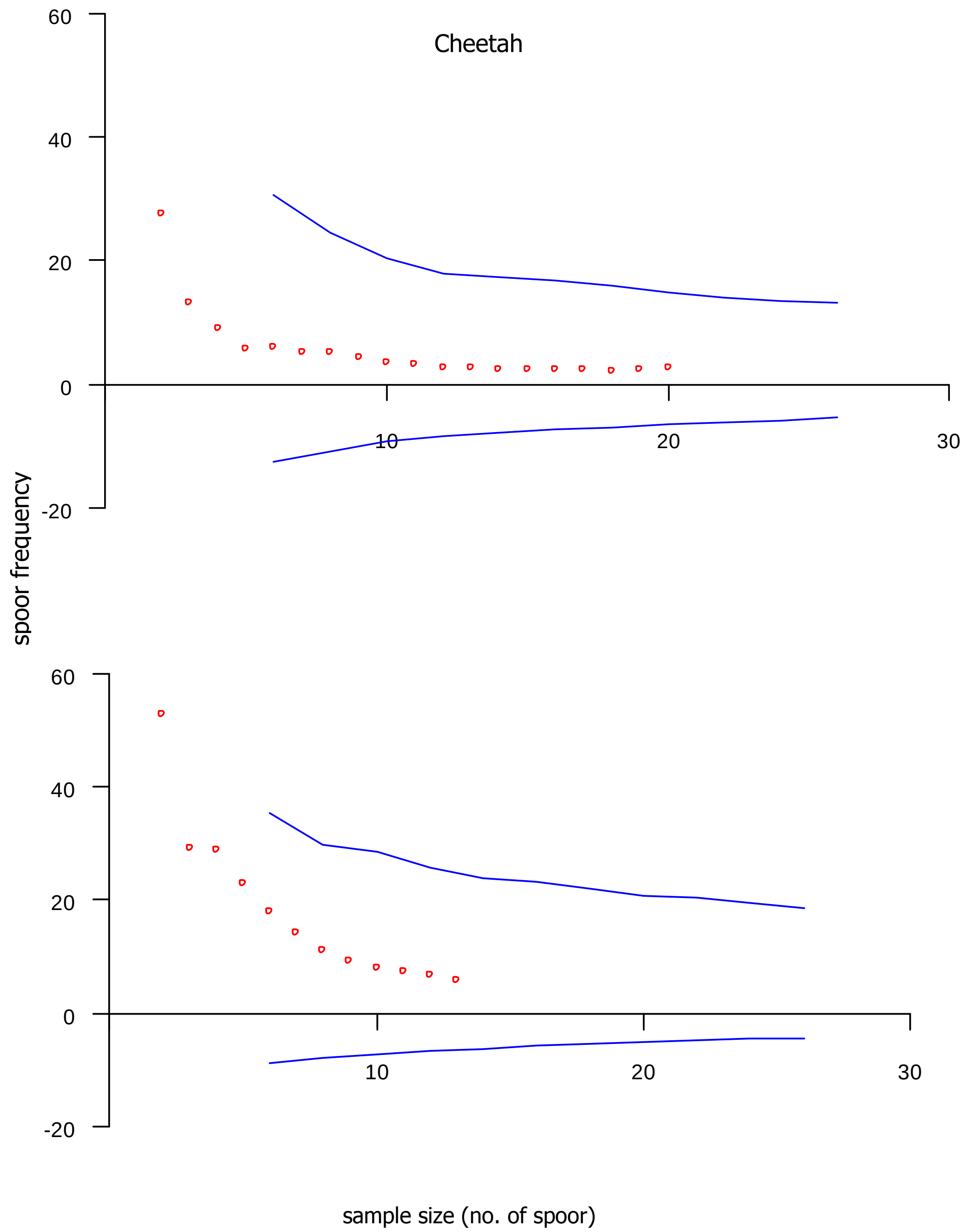


Figure 5.11 The relationship between spoor frequency and increased sampling effort
As measured by number of spoor found for cheetah SS1 (top) and SS2 (bottom) with 95% confidence intervals

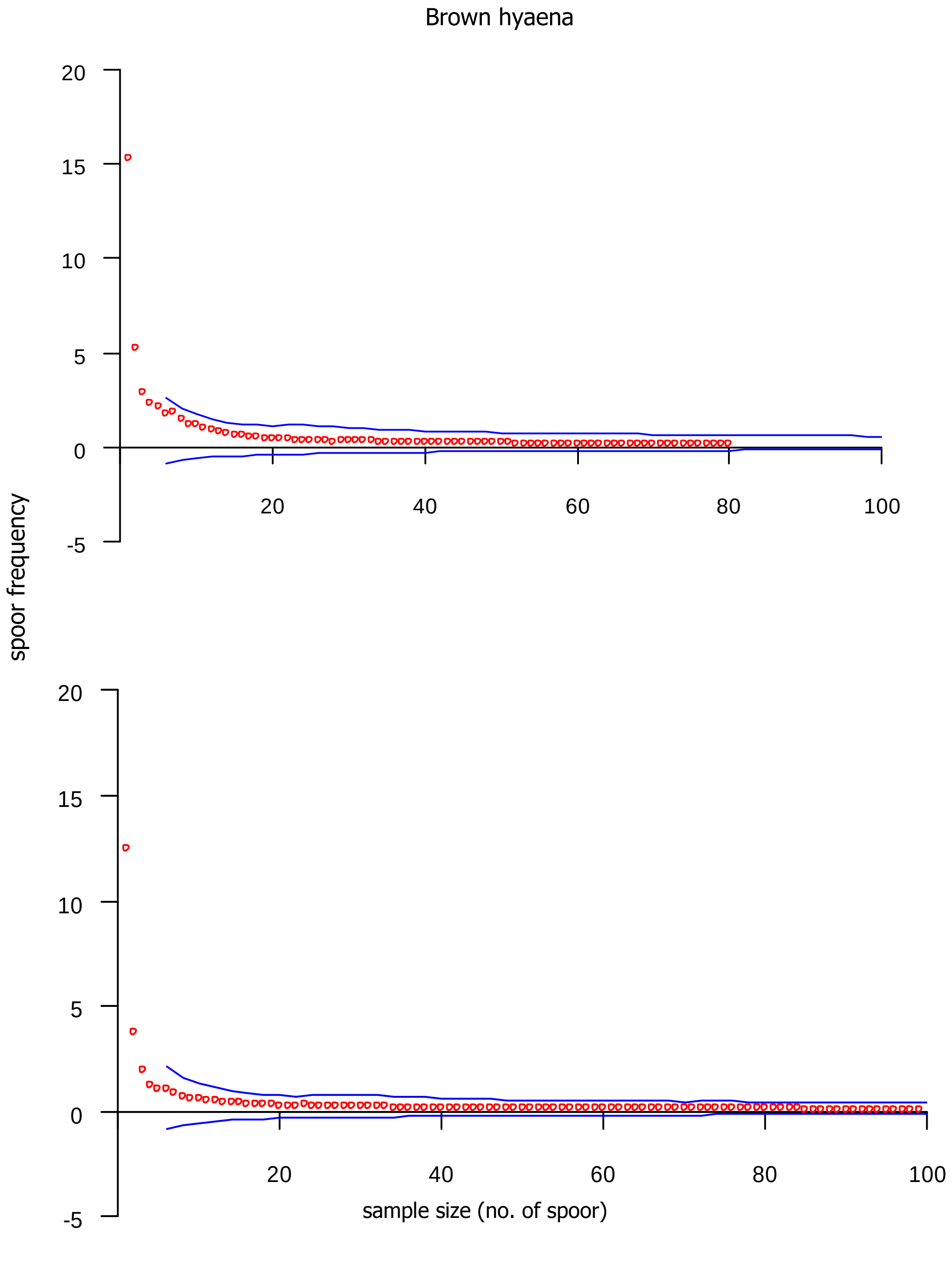


Figure 5.12 The relationship between spoor frequency and increased sampling effort
As measured by number of spoor found, for brown hyaena in SS1 (top) and SS2 (bottom) with 95% confidence intervals

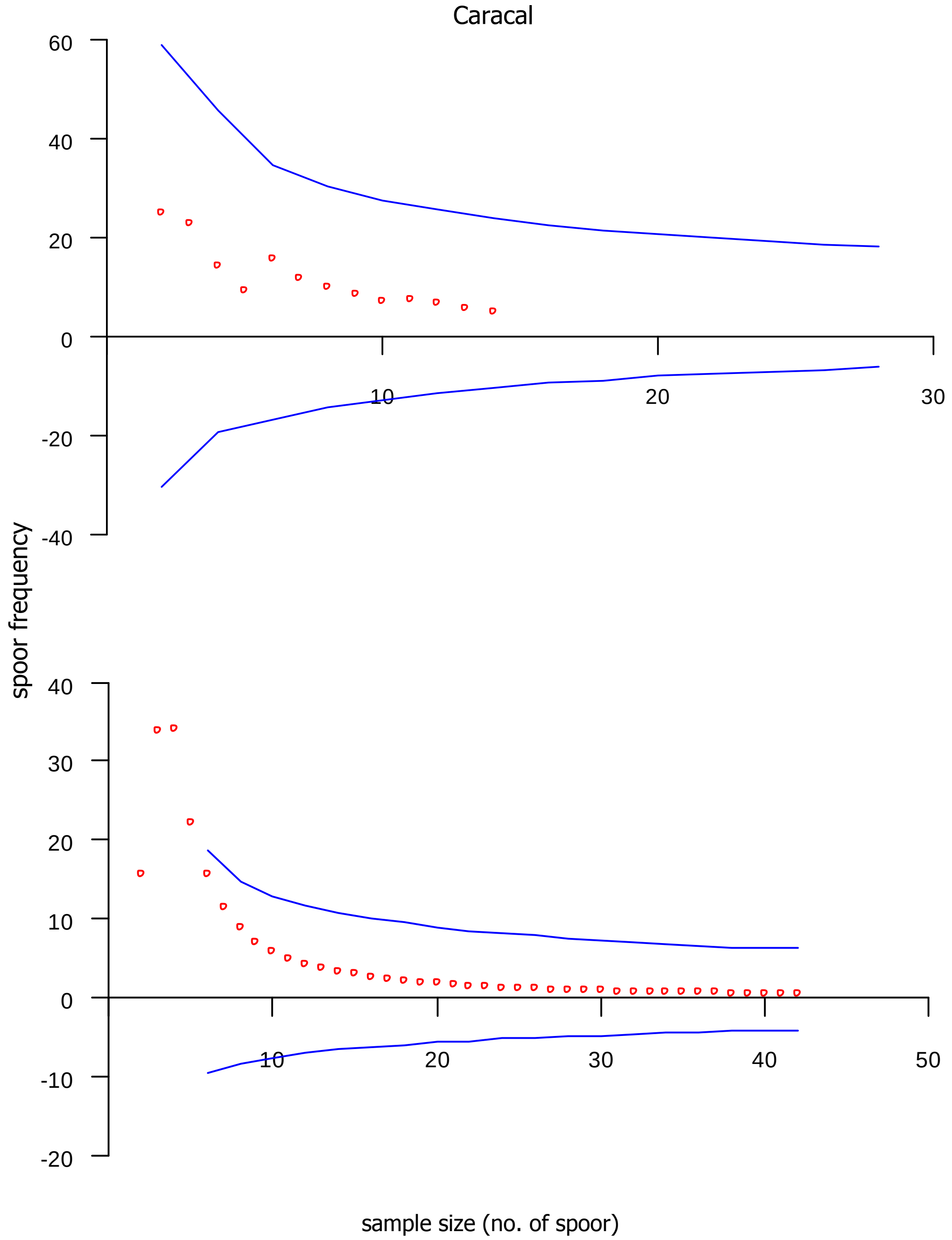


Figure 5.13 The relationship between spoor frequency and increased sampling effort
As measured by number of spoor found, for caracal in SS1 (top) and SS2 (bottom) with 95% confidence intervals

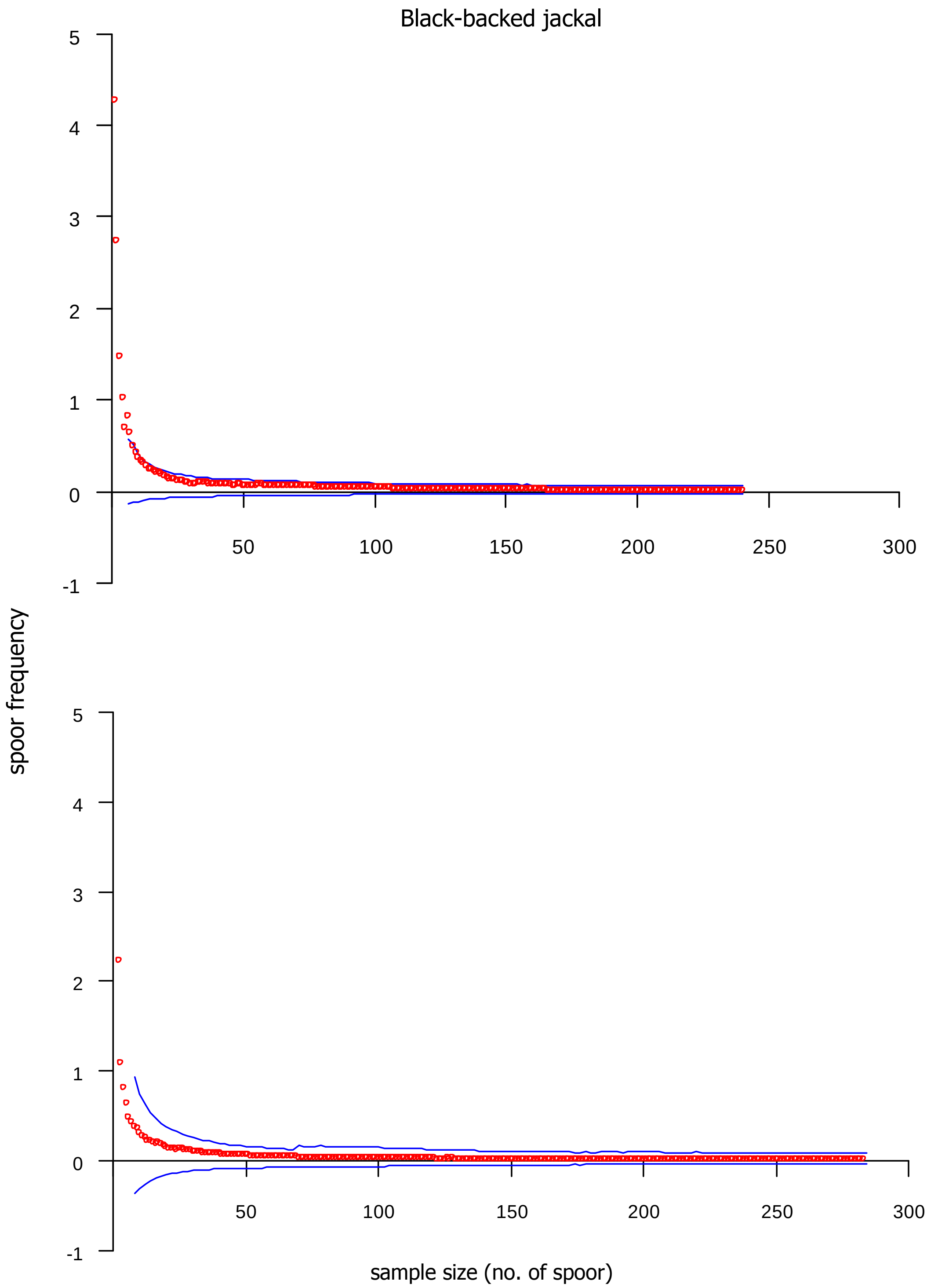


Figure 5.14 The relationship between spoor frequency and increased sampling effort
As measured by number of spoor found, for black-backed jackal in SS1 (top) and SS2 (bottom) with 95% confidence intervals

Sampling precision, as measured by the coefficient of variance (CV), increased rapidly in the first ten samples for all species (except leopard) in both surveys (Figure 5.15 and Figure 5.16). In SS1 asymptote was close to being reached at 20 samples for cheetah with CV reaching 6.39%. Asymptote was reached at around 30 samples for brown hyaena and jackal. After this point, the CV decreased by only 4.5% between 31 and 81 samples in the case of brown hyaena, and by 2.2% between 34 and 240 samples for jackal. Caracal data were sparse and while spoor frequency started to level out at around 10 samples CV was still at around 17%.

SS2 provided a similar picture for brown hyaena and jackal. Asymptote was again reached at around 30 samples for both species with a 1.5% increase in precision between 30 and 99 samples for hyaena and a 4.4% improvement in CV between 29 and 293 samples for jackal. Cheetah in SS2 were encountered less frequently and it was not possible to ascertain whether asymptote had been reached. However, CV was down to 5% at 13 samples. Caracal also reached asymptote at around 30 samples in SS2 with a 0.6% increase in precision between 32 and 42 samples, but CV was still running at over 17% at the end of the survey. Too few samples were encountered for leopard for asymptote to even be approached.

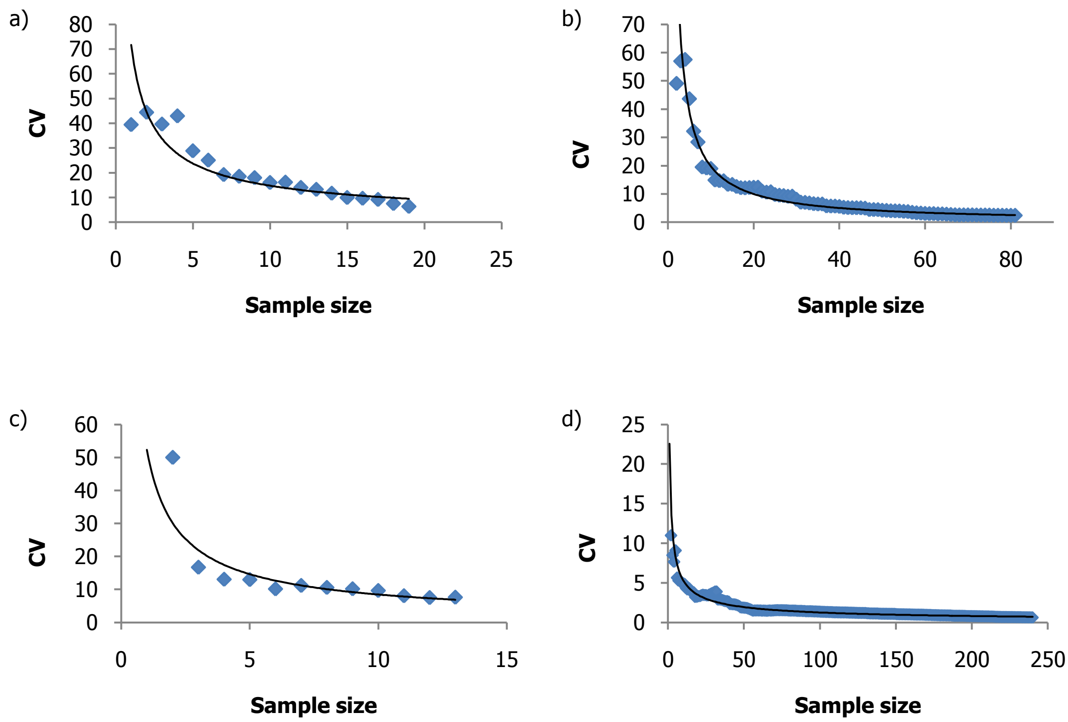


Figure 5.15. The relationship between sampling precision, as measured by the % coefficient of variance, and increased sample size in Spoor Survey 1
a) cheetah, b) brown hyaena, c) caracal and d) black-backed jackal

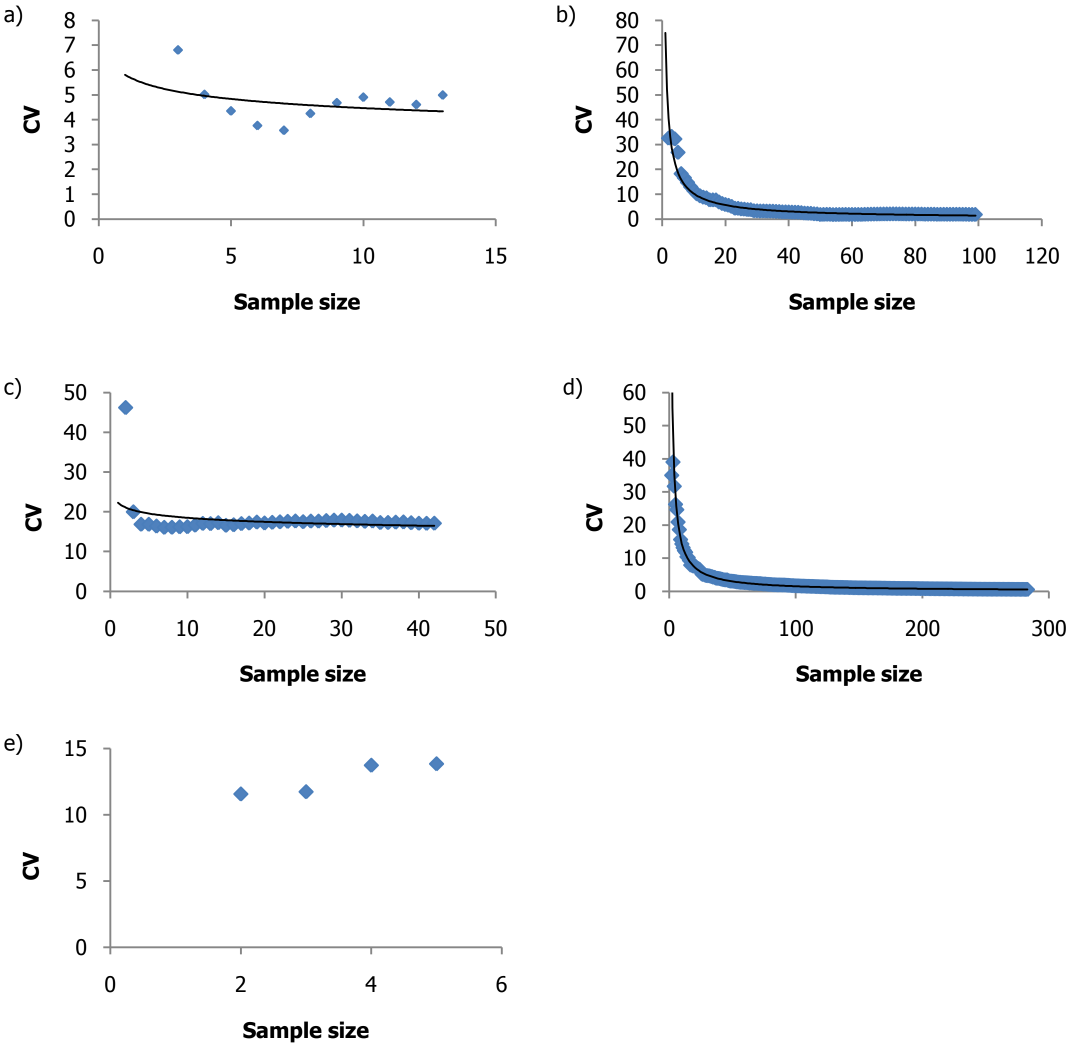


Figure 5.16 The relationship between sampling precision, as measured by the % coefficient of variance, and increased sample size in Spoor Survey 2
a) cheetah, b) brown hyaena, c) caracal, d) black-backed jackal and e) leopard

The various calibration equations formulated by researchers to convert spoor density into an estimate of true density provided very similar outcomes in both surveys (Table 5.9) for cheetah and brown hyaena. For leopard however, with so few samples, the different equations provided a wide range of values from 0.03 to 0.22 leopards/100 km^2. These calibration equations have been derived from known populations of large carnivores and are predicated on estimated home range size and kilometres moved daily. Caracal and jackal have much smaller home ranges and proportionately smaller daily travel distances than the larger carnivores. The mean adult home range of jackal in the south-west Kalahari has been estimated at 4.3 km^2 (Sillero-Zubiri *et al.* 2004) while that of adult male caracal in the KTP was 204 km^2 and adult female was 66.9 km^2 (Melville 2004). For this reason the calibration equations used to

Table 5.9 Estimates of actual density (animals/100 km^2) of predators using three different calibration equations

		Stander (1998) equation	**Funston *et al.* (2001) equation**	**Funston *et al.* (2010) equation**
SS1	Leopard	no data	no data	no data
	Cheetah	1.37	1.39	1.30
	Brown hyaena	2.68	2.65	2.67
SS2	Leopard*	0.15	0.22	0.03
	Cheetah	0.71	0.75	0.61
	Brown hyaena	3.08	3.04	3.08
SS1 – game farms only	Cheetah	2.99	2.95	2.99

* only five leopard spoor samples were encountered in SS2 and estimates of density should therefore be treated with extreme caution

convert spoor density to estimates of true density for leopard, cheetah and brown hyaena are unlikely to be appropriate. Furthermore, no spoor surveys have been undertaken for either species in areas of known density. The spoor density figures obtained in this survey for these two species therefore can only be used as an index of true density.

The density estimates obtained from the two spoor surveys and from the camera trapping surveys are presented in Figure 5.17. The camera trapping estimates for both leopard and brown hyaena are higher than those derived from spoor data, in the case of leopard considerably higher, while for cheetah they are lower. Figure 5.18 provides a comparison between density estimates for cheetah on the two game farms only. Again, the estimates from the camera trapping survey are lower.

5.4iii Abundance

In terms of abundance, extrapolating these figures to the whole 15,000 km^2 of the Ghanzi farm block would indicate a cheetah population of between 144 and 160 using the various spoor survey estimates or, from camera trapping estimates, either between 46 and 111 cheetahs using mean home range or between 68 and 162 cheetahs using mean female home range buffer widths. For leopard, population estimates can realistically only be extrapolated from camera trapping data due to the small number of spoor encounters. As a result, the population estimate for the farm block is either between 57 and 115 leopards using MMDM or from 130 to 260 leopards using the HMMDM buffer width. Calculating brown hyaena abundance from spoor survey results gives a population estimate of between 428 and 432 animals in the farm block depending on the calibration equation used and reflects the similarity of the three density estimates. The population estimate from camera trapping data ranges more widely from 547 to 736 animals using HMMDM and between 254 and 342 animals using MMDM buffer width. Extrapolating the abundance estimate from occupancy modelling of black-backed jackal provides a population estimate for the farm block of 5,922 jackals but without a calibration equation for converting spoor density into an estimate of actual density it is not possible to project the population from those data.

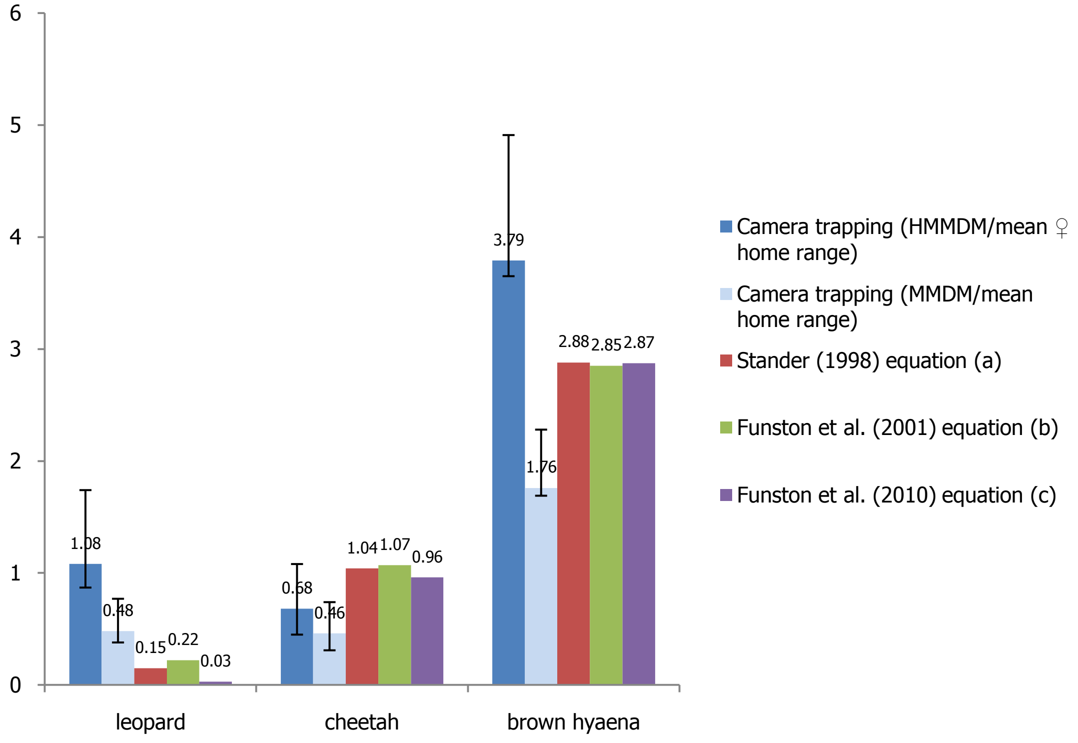


Figure 5.17 Comparison of various density estimates (animals/100km^2) for leopard, cheetah and brown hyaena in the Ghanzi farmlands
Derived from camera trapping (with lower and upper confidence limits) and spoor surveys undertaken in 2008/9 (a) $\boldsymbol{a = 0, b = 3.28}$ (b) $\boldsymbol{a = -0.23, b = 3.4}$ (c) $\boldsymbol{a = 0.4, b = 3.15}$

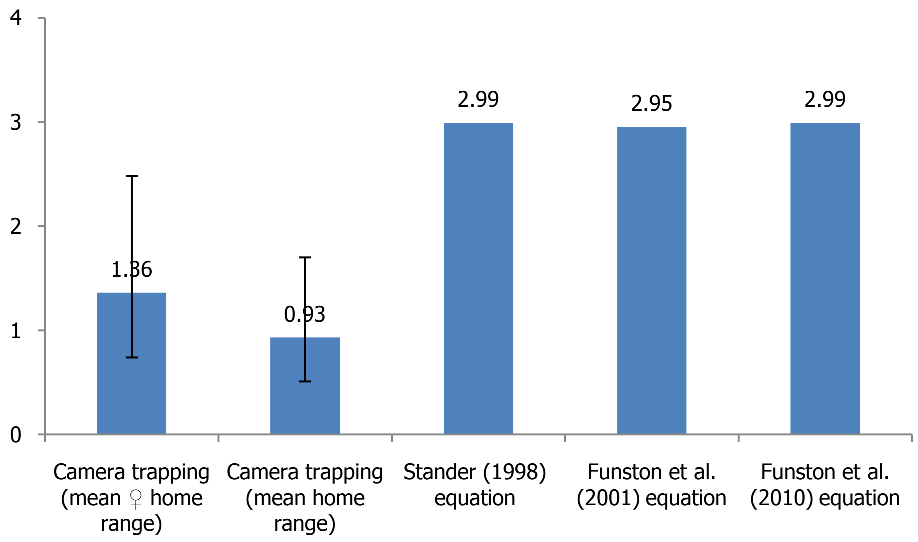


Figure 5.18 Comparison of various density estimates for cheetah on two game farms in the Ghanzi farmlands in 2009

5.5 Discussion

The aims as set out at the start of this chapter were to establish the diversity of species of carnivores present in the Ghanzi farm block today, to estimate density and abundance of the medium to large carnivores and to determine if that density varied with land use and/or management. Following on from this, it would be possible to determine whether there are differences in reported densities of the same species in other areas of southern Africa and finally, to assess the current state of carnivore populations in the Ghanzi farmlands in comparison with the historical accounts presented in Chapter 3.

Species diversity was shown to be high with 15 out of a possible 21 species (see Table 2.1) of carnivore being detected, the majority in reasonable numbers. Those not seen were lion, spotted hyaena, and four species of mongoose. The mongooses were probably not photographed due to their habits. Being small animals they generally do not use tracks except to cross them (pers. obs.) and their small size would require them to be very close to the cameras in order to trigger them. Lion and spotted hyaena are today generally restricted to northern and eastern areas of the farm block (pers. obs.) that were not sampled in this study. The predicted carrying capacity for African wild dog calculated in Chapter 4 suggested that the area could support between 0.72 and 2.35 wild dogs/100 km^2 depending on the calculation used. The fact that only two photographs were taken of a solitary animal in nearly nine months of camera trapping, and no spoor was recorded in over 2,000 kilometres of transects, suggests that the population of this species has been seriously impacted in recent times. From the oral accounts presented in Chapter 3 it was apparent that African wild dogs were common and widespread in the farmlands as recently as the 1970s, this is clearly no longer the case.

Carnivore species diversity was found to be higher in hardveld vegetation and there was a trend towards abundance also being higher on the hardveld when comparing RAI's of species found in the two surveys on cattle farms. The cattle farms sampled on the sandveld are holistically managed, a system which incorporates a sympathetic approach to wildlife with the provision of additional water points and no persecution. Furthermore, analysis of the data on prey species found no evidence of a difference between the two vegetation types in species diversity and for only one species – duiker – was there an indication of a difference in abundance, and that was in the other direction. This suggests that on farms situated on sandveld where management practices are less favourable to wildlife the differences in carnivore diversity and abundance could be even more pronounced. Certainly, evidence has been found elsewhere in the Kalahari for an effect of bush encroachment and grazing intensity on the abundance, diversity and spatial distribution of small- and medium-sized carnivores, (Blaum *et al.* 2007a; Blaum *et al.* 2007b; Blaum 2008; Blaum *et al.* 2009). There was no evidence to suggest however that species diversity or abundance was lower on cattle farms than on game farms with the exception of cheetah.

The results obtained for individual carnivore species are discussed below.

5.5i Leopard

The fact that a single male leopard was captured in two camera surveys, at camera stations more than 20 kilometres apart is of great importance as no previous data are available on leopard movement patterns or home ranges in this area. It appears from the camera trapping surveys conducted in this study that, in this part of the farm block at least, leopards occur at low density and that male home ranges overlap those of more than one female. This would agree with findings on male leopard home ranges in other areas (Stander *et al.* 1997b; Mizutani & Jewell 1998; Marker & Dickman 2005). The predicted carrying capacity for leopard of either 0.69 or 0.85 leopards/100 km^2 using Hayward *et al.*'s (2007) equations is lower than the HMMDM estimate obtained using data from the camera trapping surveys in this study of 1.08/100 km^2. The predicted 1.27 leopards/100 km^2 using Carbone and Gittleman's (2002) formula is on the other hand higher (Table 5.10). The lower estimate obtained using MMDM of 0.48 leopards/km^2 is closer to that estimated by Funston *et al.* (2001) in the KTP of 0.19 to 0.60 leopards/100 km^2 and is the preferred estimate. It is thought likely that all carnivores exist below maximum carrying capacity outside protected areas, especially in areas with relatively low prey density and high persecution such as the Ghanzi farmlands. The estimates obtained from the spoor surveys in this study are almost certainly unreliable due to the extremely low number of data points that were obtained. The estimate derived from camera trapping data is therefore considered likely to be more accurate. However the coefficients of variation (CV) for $\hat{N}$ ($cv(\hat{N}) = \frac{\widehat{SE}(\hat{N})}{\hat{N}}$) of both CS1 and CS3 were very high (92% and 35% respectively) suggesting a lack of precision caused by the small number of animals captured. The CV for $\hat{N}$ in CS2 of 12% is below the suggested limit for reliability of 20% (White *et al.* 1982). Research undertaken in 2008 on the same farms as CS1 and SS2 (Snelleman 2009) using similar methodologies revealed a somewhat contrasting picture to that described here. The spoor survey conducted in that study drove half as many kilometres (447) with a higher sampling effort ratio (8.25), but recorded 20 instances of leopard spoor resulting in a spoor frequency value of 22.35 compared to this study's 198.00 (± SE 27.38), and a spoor density of 4.47/100 km^2 compared to this study's 0.505/100 km^2. Snelleman (2009) used Funston *et al.*'s (2001) calibration equation resulting in an estimated density of 1.38 leopards/100 km^2. The camera trapping survey carried out by Snelleman (2009), which was on a smaller scale and ran for only ten days, identified five leopards, including a cub, which was not included in the analysis. This produced a population estimate for the area of 4 (± SE 2.46). However, later examination of Snelleman's raw data and comparisons with the photographs obtained in this survey revealed that there was some misidentification. There were in fact only two adult leopards, one male and one female, which were the same individuals captured in this study which commenced two months later.

Further comparisons can be made with a spoor survey carried out in 2007, over the same farms used in SS1, which found only one leopard spoor in 1026 km of transects driven (Houser *et al.* 2007). This is in accord with the level of leopard spoor found in this study on those farms. It is still relevant to question why so few leopard spoor were found and the answer may lie with species and individual specific track use. Female leopards have been found to use tracks less frequently than males (Balme *et al.* 2009) whilst there is also evidence of reduced leopard activity in areas of high human activity (Ngoprasert *et al.* 2007). Activity patterns in this study will be investigated in Chapter 7. The fact also remains that even in the camera surveys carried out in the same areas leopard numbers were extremely low. The probability of encountering spoor on a particular transect on any given day is also therefore very low. The recorded low density of leopards in the areas surveyed belies anecdotal evidence from farmers with property closer to the CKGR on the eastern side of the farm block, and also problem animal control records. This will be discussed in more detail in Chapter 6.

5.5ii Cheetah

The most striking aspect of the results for cheetah in this study is the difference in density estimates, found in both the camera trapping and spoor surveys, for the game farms compared to the livestock farms. There could be several possible reasons for this. The first possibility is that the increased availability of prey is attracting cheetah to the game farms. However with cheetah home ranges in this area so large it would be expected that cheetah present on game farms would be detected in the surrounding livestock farms in equal numbers purely on the basis of their movement patterns. The cattle farms surveyed in CS3 bordered a large (circa 35,000 hectares) game farm to the west and yet cheetah density estimates in that survey were considerably lower than those for the game farms on the eastern side of Ghanzi town which comprised CS2. Similarly, the cheetah density estimate for CS1 of 0.09 cheetahs/100 km^2 is extremely low and yet the large buffer (12.25 km) around camera positions for cheetah, based on mean home range, meant that the effectively sampled area for CS1 overlapped with that of CS2 where the estimated density was 0.93 cheetahs/100 km^2. The effectively sampled area created by this buffer is extremely large and, given the discrepancy between the density estimate it generated and that derived from spoor density, it is thought that the estimates based on female home range of between 0.14 and 1.36 cheetahs/100 km^2 are likely to more closely represent actual density.

Looking at the density estimates for spoor surveys reveals a similar pattern. The actual density estimate for cheetah on all of the farms comprising SS1 ranged from 1.30 to 1.39 cheetahs/100 km^2, depending on the calibration equation applied, while the estimate for SS2 ranged from 0.61 to 0.75 cheetahs/100 km^2. If the two game farms in SS1 are separated out the difference is even more apparent with an estimated density ranging from 2.95 to 2.99 cheetahs/100 km^2. The distance between the southernmost transect of the game farms in SS1 and the northernmost transect of the cattle farms in SS2 was 10.5 kilometres, which is less than twice the recorded mean daily distance moved (6.13 km (± 0.30 SE)) by males and less than five times that recorded for females, including those with cubs (2.16 km (± 0.07 SE)), in the Kalahari (Houser *et al.* 2009a). In Namibia, Marker *et al.* (2010) found no evidence of a concentration of cheetah movement on game farms during seven years of radio-tracking collared animals in farmland. It is possible however that female cheetahs are using game farms as the core of their home ranges, which have been found to comprise just 14% of total range size in Namibia (Marker *et al.* 2010). This could explain some of the differences found, especially as the ranges of male cheetahs in this area have been found to be much larger than those of females (Houser *et al.* 2009a). This is contrary to the findings on other populations of cheetahs in southern Africa, where female home range sizes have been found to be either equal to (Marker *et al.* 2008) or larger than those of males (Broomhall *et al.* 2003). In east Africa, a completely different pattern of ranging behaviour has been found on the Serengeti Plains, with females ranging far more widely than territorial males who defend small areas. This is thought to be as a result of the migratory nature of the prey base (Caro 1994).

Another possibility is that the comparatively large number of cheetahs recorded in SS1 represents a source population with lower numbers outside the area being indicative of perturbation and illegal killing. The number of cubs (≥2) and sub-adults (≥3) seen in CS2 suggests a relatively stable population and the lower disturbance levels on game farms may facilitate a more sedentary population.

A further option is that the differences in density estimates are merely an artefact of camera placement and transect location. As camera placement in CS2 was to a large extent driven by the location of spoor sightings in SS1, it is possible that the number of photographic captures in CS2 was skewed by cameras being preferentially placed in areas of known cheetah usage. This does not however explain the difference in spoor density between SS1 and SS2.

It is also interesting to compare the spoor survey results from this study with those of the one undertaken by CCB in 2007 (Houser *et al.* 2007). Carried out on the same farms as SS1 using almost identical transects, the same tracker and the same researcher, that survey reported a spoor density of 2.24 equating to an actual density of 0.73 cheetahs/100 km^2 using the 2001 calibration equation of Funston *et al.* (Funston *et al.* 2001). If the 2010 equation (Funston *et al.* 2010) is applied, the actual density estimate is reduced to 0.58 cheetahs/100 km^2. At face value this represents a doubling in cheetah density in two years. There was however one major difference between the two surveys, namely the season in which they were conducted. The 2007 survey was undertaken between the end of March and the end of June which straddled the end of the wet season and into the dry, while the 2008/9 survey took place between November and March entirely in the wet season. Additionally, the second half of the 2006/7 wet season was marked by very low precipitation (pers. obs.). Marker *et al.* (2008) found no evidence of significant changes in cheetah home range sizes between seasons on Namibian farmland, but intuitively, one might expect predators to have to range more widely in the dry season when prey species are more likely to aggregate around scarce water points rather than being evenly distributed throughout the environment. This could result in lower spoor frequency and density due to animals returning to the locale of any given transect less frequently. However, with the limited amount of data available, Houser *et al.* (2009a) found some evidence to suggest higher mean daily movement in the wet season. One further possibility is that there were more juveniles in the population at the time of the second survey. On seven of the 20 occasions on which spoor was encountered it was of a group of three or more animals. Based on the evidence of the camera survey in the same area, there was a female with at least three sub-adult cubs and another with at least two 6-8 month old cubs. However, it is unlikely that there were no juveniles at all in the population at the time of the first survey so it is doubtful that all of the apparent increase could be accounted for in this way. It is difficult to suggest another reason for the difference in the two surveys as there have been no changes in land use in that time period in the area surveyed and, from the evidence of the spoor surveys, no change in the relative densities of the large carnivores that would allow for competitive release.

When comparing the various density estimates obtained in this study with the carrying capacity predictions from Chapter 4 (Table 5.10), a similar picture to that for leopard outlined above is apparent. The Hayward (2007) equation predicted a carrying capacity for cheetah density of 0.58/100 km^2 which falls within the estimates from both camera and spoor surveys. The Carbone and Gittleman (2002) equation produced a carrying capacity estimate of 1.15/cheetahs 100 km^2 which is higher than the camera trapping and spoor survey estimates calculated in this study except for CS2 and SS1 which included the game farms.

Tentative estimates of cheetah density in various areas of Botswana were made in 2003 extrapolated from the results of two spoor surveys. These were the previously mentioned survey carried out in the KTP by Funston *et al.* (2001) which estimated density at 0.57 cheetahs/100 km^2, and a survey undertaken in the CKGR between 1998 and 1999 by DWNP which produced a density estimate of 0.25-0.26 cheetahs/100 km^2 (Klein 2007). A draft predator management strategy for Botswana was compiled (Winterbach 2003 cited in Klein 2007) which utilised these two figures to project likely densities in other areas of the country. The predicted density for the Ghanzi farms was 0.35 cheetahs/100 km^2 and this is lower than nearly all of the various area estimates calculated in this study.

Comparisons with estimates from studies in other semi-arid savanna areas of southern Africa suggest that the cheetah may be doing better in the Ghanzi farmlands than elsewhere. Marker (2002) estimated the minimum density in surveyed areas of the Namibian farmlands at 0.25 cheetahs/100 km^2 rising to a maximum of 0.83/100 km^2 in 2000. The estimate obtained here from camera trapping data falls within these limits but the spoor survey estimates are higher.

Prey density estimates were similar in the Namibian farmlands to those of this study, although the array of species comprised more large herbivores (Marker 2002). The notable exception to these density estimates is that for Jwana Game Park in southern Botswana of 5.23 cheetahs/100 km^2 (Houser *et al.* 2009b). However, this estimate was calculated by calibrating spoor density with a known population of cheetah in a 180.31 km^2 game reserve. It is thought that this reserve would have been too small to encompass the complete home range of many cheetahs, but could have included the edges of many as well as transient animals. Indeed, if the reserve was merely the core area of home range, making up around 14% of total range as found by Marker *et al*. (2008), then density would be considerably lower.

Overall, it is thought that the density estimate derived from the spoor surveys, and resultant population estimate is likely to be more accurate than that obtained from camera trapping data due to the low number of recaptures and value for $\hat{p}$ that was computed by CAPTURE.

Table 5.10 Comparison of predicted carrying capacities and estimated densities for four species of carnivore

Species	Predicted carrying capacity (density/100 km^2)(Carbone & Gittleman 2002)	Est. density/100 km^2 from spoor/camera trap surveys					
		SS1 (hardveld – mixed land use)	**SS1 (hardveld - game farms only)**	**SS2 (sandveld – cattle)**	**CS1 (sandveld – cattle)**	**CS2 (hardveld – game)**	**CS3 (hardveld – cattle)**
Lion	0.4	No data	No data	No data	No data	No data	No data
Leopard	1.27	No data	No data	0.03*	0.29	0.53	0.63
Cheetah	1.15	**1.30**	**2.99**	0.61	0.14†	**1.36**	0.44
Wild dog	2.35	No data	No data	No data	No data	Insufficient data	No data

Estimated densities higher than those predicted using Carbone & Gittleman's (2002) equation are highlighted in **bold**
*based on only five spoor encounters
†based on only one individual photographic capture

5.5iii Brown hyaena

In terms of the number of photographic captures and number of times spoor were recorded brown hyaena were the second most numerous species in the current study after black-backed jackal. As the brown hyaena is endemic to the southern African region and is listed as Near Threatened on the IUCN Red List this population is likely to be of great importance to the conservation of the species as a whole. Surprisingly for such an important species, relatively little research on population density or abundance has been published. It is probable that this is a result of the shy, nocturnal habits of the animal that make it difficult to study. This was certainly the case in the one major research work on the species that has been undertaken in the southern Kalahari. In that long term study Mills (1990) estimated the average density of brown hyaenas at 1.8 hyaenas/100 km^2 (CI 0.4-4.4 hyaenas/100 km^2). The recent technological developments in remote camera trapping equipment are extremely important in the study of such species, providing an effective non-invasive monitoring methodology. One such small-scale study was recently undertaken in the Pilanesberg National Park in South Africa where brown hyaena density was estimated at 2.8/100 km^2 (Thorn *et al.* 2009). However, no published data are available on brown hyaena density in commercial farmland so the findings of the current study are of particular interest. Comparing the density estimates obtained from SS1 in this study with the 2007 survey carried out by CCB (Houser *et al.* 2007) reveals very similar findings. The recorded spoor density in 2007 was 7.8 compared with 8.8 here. This translated to an actual density estimate of 2.36 hyaenas/100 km^2 using Funston *et al.*'s 2001 equation. If the 2010 equation (Funston *et al.* 2010) is applied to that 2007 spoor density it provides an actual density estimate of 2.35 hyaenas/100 km^2. These figures are ≈ 18% lower than the 2.85 and 2.87 hyaenas/100 km^2 estimated in this study using the same equations. Whether this is indicative of an upward trend in hyaena numbers it is impossible to say without further surveys, but the same factors discussed in section 5.5ii on cheetah spoor survey comparisons apply.

The CVs for the estimates of abundance produced by CAPTURE were below 20% in all three camera surveys (CS1=17%, CS2= 18% and CS3=14%), but the camera trapping estimate using HMMDM was more than 30% higher than the estimates calculated from spoor density while that using MMDM was nearly 30% lower. Determining which of these figures is more likely to be accurate is key as abundance estimates range from 254 at the lower end to 736 at the higher end of the scale. For a species with an estimated global population of less than 10,000, a population of over 700 in this area would represent more than 7% of that total, a not inconsiderable proportion. As mentioned earlier, Balme *et al.* (2009) found that, of the indirect estimation methods tested, capture-recapture provided the most accurate estimates of reference leopard density, with HMMDM outperforming all but an estimate based on data acquired through telemetry. Nevertheless, all the methodologies used were underestimates of that reference density, and it should be pointed out that MMDM was not tested (this would have produced an even lower density estimate) and only one species was sampled. It is also important to note that that study was undertaken in a quite different environment to that of the study area of this research, with variable substrates and a high density of leopards. With no calibration studies having been undertaken in areas of known density on brown hyaena, and as it is listed as Near Threatened on the IUCN Red List (IUCN 2010), it is thought to be wise in this instance to accept the lower density estimates derived using MMDM.

The latest African large carnivore spoor density calibration equation (Funston *et al.* 2010) meanwhile, has been shown to be accurate for a range of species, including brown hyaena, at varying densities on sandy substrates. As a result, it is probably prudent to estimate the population for the Ghanzi farm block at ≈ 430, especially as this figure falls in the middle of the camera trapping estimates. This still represents an important population for this species and suggests further studies on commercial farmland would be of value as, based on this evidence, brown hyaena may exist at higher densities outside protected areas, especially where larger predators have been extirpated. Indeed, it has been suggested in the past that areas of agricultural activity may be advantageous to brown hyaena (Skinner & van Aarde 1987).

Brown hyaena are characterised as solitary foragers (Mills 1982b; Skinner & Chimimba 2005) yet, some interesting behavioural observations from this study showed that, on one occasion in CS3 two adult females were photographed together while on nine occasions during the two spoor surveys tracks of more than one animal were found together.

Two animals in two different camera surveys were seen to have snares around their necks and this underlines the problems with illegal poaching that exist in the area. All available evidence suggests that brown hyaenas are not a major threat to livestock as they are generalist feeders and primarily scavengers of carrion, with less than 5% of prey items killed by hyaenas themselves (Mills & Mills 1978; Mills 1984; Maddock 1993; Maude & Mills 2005). Nevertheless, they are often targeted and killed by farmers who perceive them as livestock killers (Mills & Hofer 1998). Whether or not hyaenas were the intended target of these snares there is no doubt that they are vulnerable to them. Usually placed along fence lines, they represent a threat to any animal that moves between farms by going under fences.

5.5iv Caracal

The lack of data on caracal was disappointing, but indicates that this species exists at low densities in this area. There have been suggestions that caracal and jackal populations are linked and that interspecific competition between them serves to control their numbers (Pringle & Pringle 1979; Stuart 1984). From the evidence obtained in this study, based on photographic capture rate, the ratio of jackal to caracal is at least 24:1, while if spoor density is used as the index of abundance the ratio is lower at 7:1. In either case it is still a considerable difference.

Whether this is representative of the historical relative densities of these two species, or is indicative of an imbalance created by human activities is difficult to say. However based on the accounts of older farmers described in Chapter 3 it seems likely that, while caracal used to be more common than at present, they have always been heavily outnumbered by jackal. Furthermore, given the differences in behaviour and social structure of the two species it is thought likely that jackal are often the more numerous species (Avenant & du Plessis 2008). Farmer perceptions of the present day situation will be presented and discussed in detail in Chapter 6.

5.5v Black-backed jackal

There has been limited research into abundance and density of black-backed jackal providing little scope for comparison. However, the estimate of jackal density calculated from presence-absence data in this study of 39.48 jackals/100 km^2 (or ≈ 0.4 jackals/km^2) is in line with that found on the Namib Desert Coast of Namibia. There, linear densities were estimated to range from a minimum of 0.1-0.53/jackals km^2 in areas of low prey availability to a maximum of 16.0-32.0/km^2 at the centre of the Cape Cross seal rookery (Loveridge & Nel 2004). But, in the Drakensburg Mountains of South Africa jackal density was estimated at only one jackal /2.5 - 2.9/km^2 (Rowe-Rowe 1982). A multi-land use type study in the southern Kalahari found average densities of 1.03 jackals/km^2 on fenced ranches and 0.26 jackals/km^2 in WMAs (Wallgren *et al.* 2009). The Ghanzi farmland density is certainly higher than that, but whether it represents an unusually high density for the species in farming environments elsewhere it is not possible to say. The production of a calibration equation for jackal spoor density in an area of known density would be of great value for future studies of this species.

5.5vi Camera trapping general

The contradictory evidence in the literature regarding the application of either HMMDM or MMDM as the proxy for home range in camera trapping surveys undermines confidence in estimates obtained by this methodology. A pattern does seem to be emerging of MMDM providing more accurate estimates of home range for carnivores in South America (e.g. Soisalo & Cavalcanti 2006; Dillon & Kelly 2008; Maffei & Noss 2008), but there have not yet been sufficient trial studies in African environments to reach any conclusions. The trial conducted by Balme *et al.* (2009) did find that density determined using a buffer based on HMMDM more closely matched reference density than that calculated from measures based on HMMDM of telemetry or from the radius of mean home range. Full MMDM was not tested but, extrapolating from their results for HMMDM, would have underestimated density. Maffei and Noss (2008) suggest that the accuracy of range estimates based on mean distance moved between camera stations may be a function of the size of the camera grid in relation to home range size of the species being investigated. They suggest that, in areas where home ranges are known, the grid should cover an area at least four times mean home range. Translating these protocols to large, wide-ranging carnivores in semi-arid savanna ecosystems however would require camera grids to cover an area in excess of 1,000 km^2. In order to achieve this, cameras would either have to be spaced large distances apart, or the number of cameras would need to be extremely high. This would be prohibitively expensive for most research projects. Another possibility is that there could be an effect caused by the ranging behaviour of a species i.e. daily distance moved, in relation to grid size (Dillon & Kelly 2008). This can of course vary greatly among individuals. Mean distance moved estimates are also likely to be dependent on the number of recaptures and further investigation needs to be carried out to ascertain the minimum number of recaptures necessary to accurately estimate home range from camera data.

5.5vii Spoor surveys general

The precision of the spoor density estimates in this study vary considerably between species and survey. Funston *et al.* (2003) estimated that a minimum of 30 tracks need to be found to ensure a CV of distance between track frequencies < 20%. Only brown hyaena and black-backed jackal achieved this level of precision in both surveys while caracal exceeded the target in SS2. For only one of these species, brown hyaena, was an estimation of actual density possible due to the lack of a calibration equation for the other two. The low density of carnivores in this environment suggest that at least 1,500 kilometres of transects would need to be driven to achieve that level of precision for cheetah and more than 3,000 kilometres for leopard.

The issue of calculating the effectively surveyed area for spoor surveys is one that has not been addressed. All of the research providing calibration equations has been conducted within protected areas, or in one case an unprotected area with distinct boundaries, for which there was a known population (Stander 1998; Funston *et al.* 2001; Winterbach 2003; Houser *et al.* 2009b). The current study was undertaken on farmland across a number of farms, within a larger agricultural area, comprising a mosaic of land uses. As a result there were no defined boundaries. This is to some degree a reversal of the reasoning associated with transect selection. In a protected area roads will be selected within the boundaries of that area that provide the required coverage. On farmland transects are chosen where they exist and the area being surveyed must be calculated afterwards. In the same way that camera surveys have developed protocols for estimating buffer widths around camera stations, the issue of estimation of buffers around spoor transects needs to be investigated. Intuitively, it would be expected that this would vary depending on the ranging behaviour of a particular species in the same way that MMDM varies in camera trapping surveys. At the moment this is completely arbitrary and affects estimation of sampling penetration and population estimates at the survey level. These should be treated with caution as a result.

5.5viii Limitations of this study

This study attempted to obtain abundance and density estimates for five species of large and medium-sized carnivores in the Ghanzi farmlands. This approach has several drawbacks and limitations, in particular surrounding camera trap surveys which ideally should be designed with reference to the behavioural ecology of one species only. Regarding the spoor surveys undertaken, SS1 was implemented specifically to enable comparison with the results obtained by CCB on the same farms two years previously. However, the area covered by this survey was probably too large resulting in insufficient kilometres of transect penetration.

In general, the low density of carnivores in semi-arid savanna ecosystems requires time and labour intensive field research in order to accumulate sufficient data to provide robust density estimates. For leopard and cheetah in particular camera surveys require larger camera grids with wider camera spacing, while spoor surveys need to accumulate more kilometres and increase penetration rates. For both methodologies repeat surveys in different seasons would be beneficial.

5.6 Conclusions

The fact that no evidence was found for the presence of lions and little evidence for African wild dogs, despite available prey biomass figures suggesting they could be supported and anecdotal evidence indicating their historical presence, indicates that the carnivore population in the Ghanzi farmlands has been disrupted and altered by human activities in the recent past.

However, the ecological picture that has emerged of the current state of carnivore populations in the area appears relatively healthy. Species diversity is good with more than 71% of native carnivore species being recorded. To put this into context, a camera trapping study undertaken in a semi-arid area of north-central Namibia, across farmland and a protected area, also identified 15 species of carnivore (Stein *et al.* 2008) while Wallgren *et al.*'s (2009) study in the southern Kalahari detected 18 carnivore species in an area made up of a mix of both protected and unprotected sites. To date no comprehensive inventories of carnivore populations have been carried out in protected areas of Botswana so comparisons are not possible.

Regarding density estimates of the focal species investigated, the question remains that given the differences in density estimates obtained, which are likely to be the most accurate? For leopard the only option is the camera survey estimate, while for cheetah it is thought spoor survey estimates are likely to be more accurate due to the small number of captures/recaptures in two of the camera surveys. For brown hyaena, sufficient data were collected by both methods but very different estimates resulted. Due to the conflicting evidence over the appropriate proxy measure of home range radius that should be employed to estimate effective sampling area in camera trap surveys, it is thought prudent to accept the density estimate obtained from spoor surveys which in any case falls between the two camera trap estimates.

Jackal density could not be estimated from spoor density due to the lack of a calibration equation, so the estimate derived from occupancy modelling of presence/absence camera data is all that is available, but should probably be treated with caution.

Chapter 6 – Social and cultural attitudes towards wildlife

6.1 Introduction

The previous two chapters investigated the ecological status of both carnivores and naturally occurring prey species in the study area of the Ghanzi farmlands. In both cases, diversity and abundance was found to be reduced from the historical descriptions presented in Chapter 3 but, for species that remain, reasonably healthy populations continue to exist, at least in the areas sampled. But are these findings in accord with the perceptions and attitudes of the farmers on whose land these animals live? This chapter will address this issue by exploring the human and social side of the picture in the area and will utilise data obtained from questionnaires and interviews, both semi-structured and informal. Additionally, data taken from the Department of Wildlife and National Parks (DWNP) Problem Animal Control (PAC) records from 2000 to 2009 will be analysed for comparison with perceptions about depredation.

Questions that will be addressed are:

1. What are the prevailing attitudes among farmers to conservation, the carnivores and prey species that live on their land, problem animal control and the state-run compensation system?
2. Does livestock predation affect all forms of farming equally?
3. Do DWNP Problem Animal Control records concur with the perceptions of levels of depredation and the species that cause it?
4. Are beliefs about, and knowledge of, carnivores tied to ethnic background?
5. What solutions to human-carnivore conflict in the Ghanzi farmlands do farmers favour?

There are many different aspects to the issue of human-carnivore interactions in the Ghanzi commercial farming community. Questions surrounding socioecology, ethnicity, scale and type of farming operation, land management practices, NGO and government-led amelioration initiatives all play into the bigger picture of human/wildlife coexistence in the area. In recent years, there have been a number of studies in Botswana that have attempted to address some of these issues with regard to communal farmers at cattle posts in several areas of the country (Schiess-Meier *et al.* 2007; Gusset *et al.* 2008; Selebatso *et al.* 2008; Hemson *et al.* 2009), and they have provided valuable insights into what is undoubtedly a complex situation. This study however, is concerned with a different demographic. While it is acknowledged that communal farming areas and cattle posts constitute an important part of the picture, little attention has been paid to the large areas of commercial farmland owned and managed by the white minority. The fortunes of this group have altered considerably in the past thirty or so years and they are generally no longer scraping a living in the way described in the historical narratives of section 3.3. Many are now relatively wealthy, due in no small part to the generous subsidies on beef exports provided by the Beef Protocol Agreements of the European Union that fixed prices of Botswana beef 50 per cent higher than those of the rest of the world (Sporton & Thomas 2002), and have accumulated large landholdings. The increase in game farming for both photographic tourism and trophy hunting has also contributed to the change in economic status of the group. In the mid 1970s Russell & Russell (1979 p.7) described them as "'politically, socially and economically unimportant" a characterisation that is no longer recognisable, underlined by the appointment of a Ghanzi Afrikaner Member of Parliament as Minister for Agriculture in 2008. Russell & Russell (1979) continued to say that "… they have also been isolated from fellow Afrikaners and the events which have given Afrikanerdom much of its distinctive cast" (Russell & Russell 1979 p.7), this isolation has undoubtedly been an important factor in contributing to the unique nature of the community.

For many, the large scale of the operations involved in both the domestic livestock and game farms means that the potential for conflict is also large, and the resources available to these farmers to deal with animals they perceive as a threat are more sophisticated and have the potential to do greater damage than those that are generally employed by subsistence livestock owners. However, there remain some whose farms retain many of the characteristics of the early settlers. For these individuals, the combination of free-ranging animals and few workers to tend them makes the protection of their livestock more difficult and the impact of depredation is more pronounced.

Since 1994 Botswana has operated a state-funded compensation scheme which is administered at a local level by DWNP officers in the District concerned. When originally implemented no restrictions were placed on the species which would attract compensation payments. Within two years however it was decided that this broad scope made the scheme too difficult and expensive to administer, so a species list was introduced that limited payments to those animals listed as dangerous by the Wildlife Conservation and National Parks Act of 1992. These species are lion, leopard, hippopotamus, rhinoceros, elephant, buffalo and crocodile[2]. In 2005 it was decided to add cheetah and wild dog to the list. Claims for loss of livestock as a result of depredation by eligible species must be made at the local DWNP office within 7 days of their occurrence, and must then be verified by DWNP officers. Compensation payments currently range from P1400 for a horse to P120 for a sheep or goat (DWNP 2010) (10 Pula is roughly equivalent to £1). No extra compensation payments are available for the loss of valuable stud animals.

An important additional factor involved is the large scale of the area encompassed by the farms, which underlines their significance as habitat for wide-ranging carnivores whose populations outside protected areas may be of great consequence to species survival.

[2] Spotted hyaenas are not included in this list but the Problem Animal Control records suggest that compensation is paid for livestock depredation to this species

6.2 Methods

Twenty structured questionnaires were administered to farmers in the Ghanzi farm block comprising five game farmers, five cattle farmers and ten who farmed both cattle and small stock. Table 6.1 details the breakdown of the sample by ethnic group, farm type and age group. All were male, although in several cases the wife of the farmer was present during the interview and participated in the discussions. In most cases the interview was conducted at the house of the participant, but a few took place in public areas. Most were recorded, with the participant's permission, and were informal encounters. In all cases the questionnaire was administered in one sitting so all questions were asked during that session. While the questionnaire was structured in the same way for all participants, the conversation was allowed to follow a course directed by the farmer around each question in order to provide additional and more nuanced information than would be obtained if the questionnaire was completed in the absence of the researcher. Due to the commitment to confidentiality and anonymity given to all participants it is not possible to provide more detailed information about individual backgrounds or relationships. However, it is important to emphasise the complex nature of marital and blood relationships in the area. Many of the families are related either by marriage and/or by birth. Children of farmers often take over the management of one or two of the family's farms in their early 20's and in some cases buy other farm plots in the area. The Afrikaner community numbers around 400 people and when a marriage takes place it is common practice for everyone to be invited (pers. obs.).

Table 6.1 Breakdown of questionnaire sample by farm type, age group and ethnic group

	Age group					**Ethnic group**	
Farm type	**20s**	**30s**	**40s**	**50s**	**60s**	**Afrikaner**	**Af/Eur**
Game	0	0	3	1	1	1	4
Cattle	0	1	2	2	1	3	2
Cattle/small stock	2	3	3	1	3	9	1

In addition to the main structured questionnaire a second set of questions in the domain 'carnivores' was administered to farmers, farm workers, DWNP officials and workers in the tourist industry in an attempt to uncover any variation in knowledge and perceptions between different ethnic groups.

Additional information on the opinions, views and perceptions of various stakeholders was acquired during general conversation and social intercourse throughout the research period.

For further details of the formulation and administration of questionnaires, and of protocols employed during semi-structured interviews and participant observation see section 2.2ii.

6.3 Prevailing attitudes and perceptions of farmers to carnivores

6.3i Farming problems

The Kalahari environment presents many challenges to the livestock farmer. The Ghanzi farmland area has a mean annual rainfall of 400mm, nearly all of which falls during the wet season between October and April. This description ignores, as Thomas (2002) points out, "two of the principal characteristics of Kalahari rainfall: variability and uncertainty" (Thomas 2002 p. 21). In addition, the sandy soils have a generally low nutrient content and are relatively unfertile. This results in low quality grazing for cattle which the animals have to supplement with browse in order to maintain their condition (Skarpe & Bergstrom 1986). Farms in the area range in size from around 5,000 hectares to over 100,000 hectares and cattle herds of farmers interviewed ranged in number from 300 to more than 10,000 ($\bar{\chi}$ = 1,779 ± SE 738.16). Sheep and goat (shoat) numbers ranged from single figures to several hundred ($\bar{\chi}$ = 273 ± SE 121.59). The area is still quite isolated and there is no private veterinary provision in Ghanzi town. The Government veterinarians deal with routine vaccination, checks and inspection of livestock, but in the event of injury, sickness or accident farmers largely have to deal with the issue themselves. Additional challenges to raising domestic livestock are created by bush encroachment caused by overgrazing which has developed into a major problem in the last few decades (see section 2.2 for more details on this).

In order to assess the impact of these, and other issues, on the farmers of the Ghanzi Farm Block, and to determine whether the type of farming an individual is engaged in affects that impact and experience, domestic livestock farmers were asked to name the biggest problem they faced. The results for cattle-only farmers were evenly spread and covered theft, predation, poor grazing and infertility/poor conception rates. For farmers who also kept small stock, predation and drought were each cited as the biggest problem by two of the 10 of respondents, one farmer said disease caused him most concern, another said he had no major problems, while the remaining four said that their biggest problem was something other than the choices presented. These issues were poor land management in the past, the lack of any private veterinary support in the area, the inflexibility of the government Veterinary Department and market prices for weaners (Figure 6.1). All farmers were then asked what the greatest cause of economic loss was for them. Among game farmers two out of five cited predation while among those with small stock predation was cited by half of respondents. For cattle-only farmers predation was cited as the cause of greatest economic loss by two of the five respondents, but an equal number cited theft (Figure 6.2). One cattle farmer explained his selection of predation over disease by saying that "disease might be costly but you can do something about it ….it's not so easy to manage a predator".

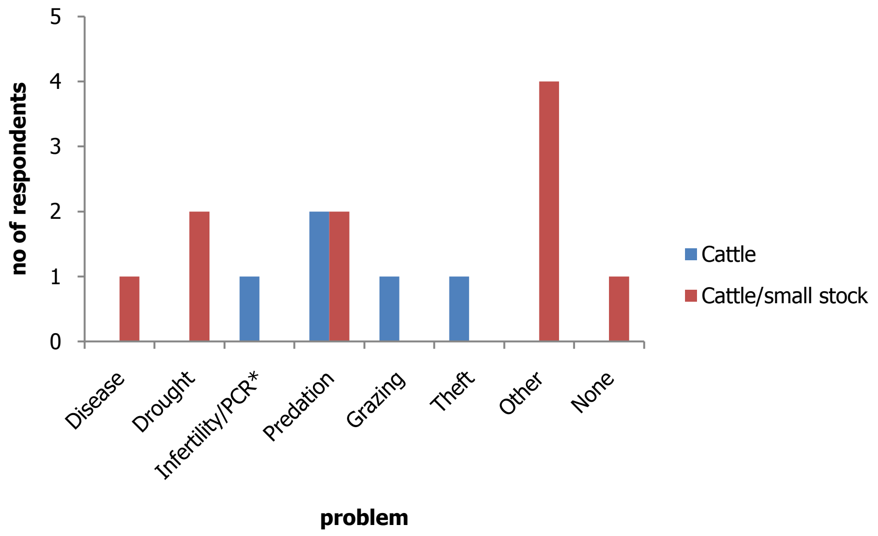


Figure 6.1 The biggest problem encountered by farmers in the Ghanzi farmlands (By farm type)
* PCR = poor conception rates

Most farmers said that the number of animals they lost to predators each year varied considerably, and some were reluctant or unable to put a figure on it for that reason, but one farmer thought he lost around 10% of his calves and 20% of his lambs and kids each year, while another said that the previous year he had lost about 30 calves and 20 small stock and another said he had lost 60 sheep. One farmer even went so far as to say that he had "stopped farming with small stock now because of predators to be quite honest". Interestingly however, he added that his problems had been exacerbated by the high level of bush encroachment on his farm which made it impossible to keep a watch on the stock or to have a dog running with the sheep.

In contrast, one cattle farmer thought he lost less than 1% of his calves to predators a year. Several others, and most of the game farmers, said that they did not know how many animals they lost to depredation. For game farmers of course it is more difficult to keep track of individual animals as they are not marked and are not subject to regular visual or physical inspections. The only way a game farmer would be likely to know if an animal was killed by a predator would be if the carcass were discovered.

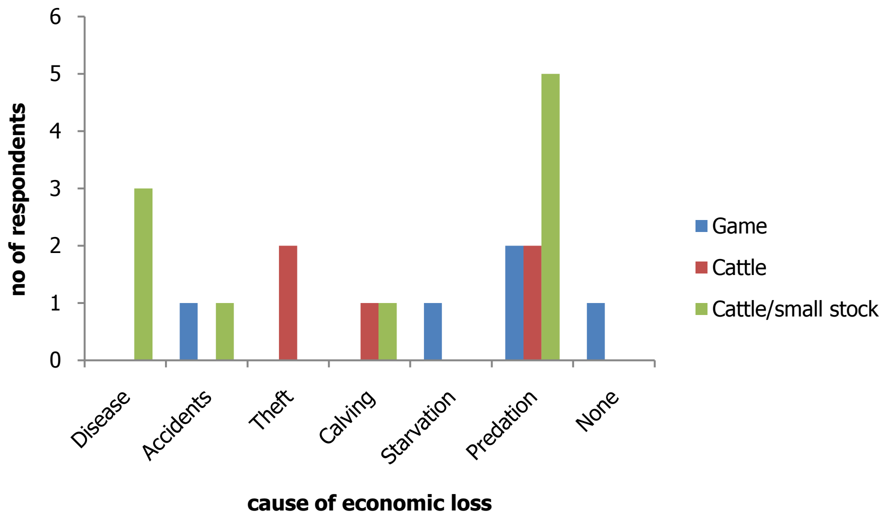


Figure 6.2 The largest cause of economic loss for farmers in the Ghanzi farmlands (By farm type)

6.3ii Livestock management and farming practices

The concerns voiced about predation raise the question of farming methods and livestock management. Several authors in the past have reported that a variety of livestock husbandry measures can be effective at reducing the levels of depredation (e.g. Smith *et al.* 2000; Ogada *et al.* 2003; Breitenmoser *et al.* 2005; Marker *et al.* 2005; Hodkinson *et al.* 2007). The nature of the environment in the Ghanzi area means that for cattle, measures such as kraaling and herding are not generally considered to be options that can be employed. This was reflected in the responses to a question which specifically asked farmers whether their cattle were kraaled, to which 100% replied that they were not, and only 33% said that their cattle were accompanied or watched by any kind of herder. The explanation for this lies with both the environment and tradition. In an echo of the situation in the Pantanal, where depredation by jaguars impacts heavily on private ranches (Zimmermann *et al.* 2005), cattle on the commercial ranches in the Ghanzi area have always been free-ranging. Farmers make the point that the way in which cattle graze makes it uneconomic to kraal them at night. As one farmer explained:

> *… they graze for eight hours, rest for four, graze another eight and then rest for four, so if you kraal it at night its losing a lot of its grazing time and its going to be losing weight then.*

This, they maintain, would have economic impacts that would at least equal those incurred by depredation. One farmer asserted that kraaling also increases the likelihood of disease in the herd. Another cattle farmer said: "I definitely would not be in favour of kraaling, because your animal production will go down" while another said: "yes it will decrease losses to predation, but it will increase losses on fertility and so on".

Restricting calving in the herd to a specific season is another practice that could allow for better monitoring and protection (Quigley & Crawshaw Jr 1992; Polisar *et al.* 2003), but there were mixed views on the benefits of this. Thirty three percent said that they did restrict calving to a specific period while the rest said that their animals calved all year round. Of those that did have a calving season the timing of it varied between first, second and fourth quarter. The lack of a calving season did not make it significantly more likely that a farmer would cite predation as either his biggest problem or the greatest cause of economic loss (G = 1.953, df = 2, p = 0.377). However, as a result of the patchiness in their employment it is difficult to assess calving seasons for effectiveness, as any farm utilising one is likely to be bordered by another with either a different calving season or none at all. Additionally, those farmers employing calving seasons who have fewer complaints about depredation also employ other farm management practices that may have an equal or greater impact. Sixty per cent of farmers did say however that they checked on their cattle more often when they were calving, and 66% said that they maintained a record-keeping system during calving.

Another livestock husbandry measure that may be effective involves leaving older animals with the herd rather than removing them. The reasoning behind this is that such animals have experience of encountering predators and are more likely to stand their ground, or even challenge a predator that either gets into a kraal or attacks a calf in the bush. Another farmer, who had fairly recently arrived in the area from South Africa, said that he used a similar strategy in that he did not dehorn his cattle so they had a means of protecting themselves. He said that Brahmans, the particular cattle breed he kept, were very protective.

For small stock however, kraaling, herding and stock-guarding animals are livestock husbandry methods than can be, and often are, utilised. Of the farmers who also kept small stock, 90% said that their shoats were tended at night, and during lambing 100% kraaled their animals. Sixty per cent utilised guard dogs to protect shoats, with all but one farmer saying that they were effective at least some of the time.

One farmer of small stock said that without guard dogs, kraaling and other measures he might as well give up farming altogether. But it was still thought to come at a cost, as another farmer made the point that kraaling is a labour intensive practice and, with the increase in education availability and levels in the country draining people from the rural areas, there was a diminishing supply of workers for the farms. An increase in such practices would also require a reversal of the trend in recent years for staffing levels to be reduced. Several farmers said that they had less people working and living at the cattle posts on their farms now than in the past. This reduction in levels of human activity was also thought, by some, to have contributed to an increase in predation levels.

Farmers were also asked during the interview whether they did anything proactive to protect their livestock, other than kraaling, herding and the use of livestock guard dogs. Fifty three per cent said they did not, and of those who did the most common response (five out of seven) was that they would shoot a predator (particularly jackal) if they started causing problems.

6.3iii Predators and livestock predation

Having established that predation is viewed as a considerable economic problem, and that livestock husbandry practices that can mitigate depredation are patchily employed, leads to the question of individual predator species and their perceived and actual impact. Farmers were asked which species of predator they thought caused them the most problems. Of the game farmers, four out of five ranked cheetah first. The one respondent who differed in his view ranked cheetah second to jackal, however his farm was located close to Ghanzi town, and he also had a small number of cattle and small stock which may have accounted for this. For the domestic livestock farmers there was greater variation. Leopard were ranked highest by three of the five cattle-only farmers, while for those who also farmed small stock jackal were ranked highest by four of ten with leopard (3) and cheetah (2) following closely behind (Figure 6.3). However, one farmer did make the point that although lions only came through his farm occasionally, and therefore could not be ranked in the top two or three, when they did they caused a great deal of damage. He said that he had lost eleven animals to lions in one incident in the previous year.

While only one farmer ranked caracal in his top two of problem predators, several incidents of caracal depredation were mentioned in interviews, questionnaires and general conversation. The common factor in all these incidents was small stock. Caracal are heavily persecuted as domestic livestock predators in South Africa, and along with the black-backed jackal, are now viewed as a major threat to the economic survival of small stock farmers (Avenant & du Plessis 2008). The spoor surveys and camera trapping undertaken in this study (see section 5.4) indicated that caracal exist at quite low density, and are probably less numerous than in the areas of South Africa where they have become such a problem. However, their impact is still felt, particularly for smaller farmers. One claimed to have lost between 70 and 100 sheep to a caracal in four months and that the attacks had been taking place during the day. The farmer

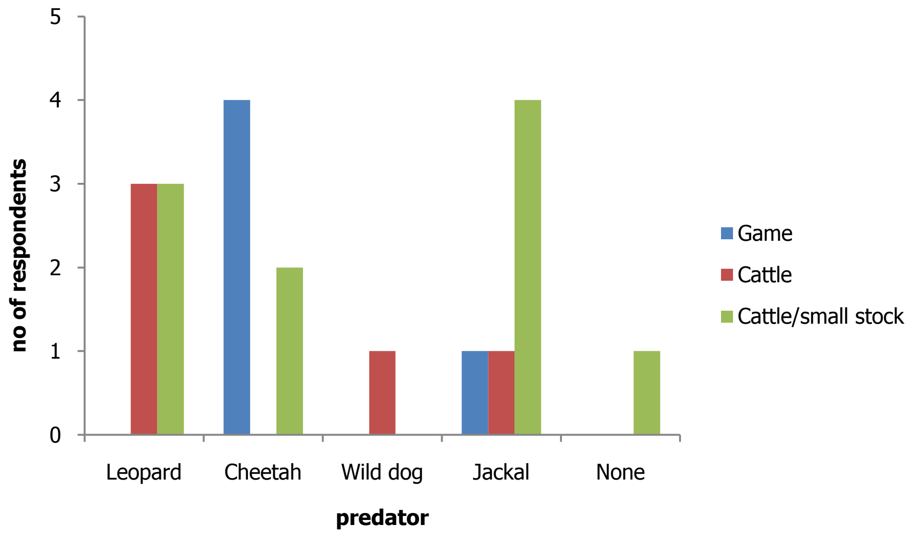


Figure 6.3 Predator species game farmers thought was their biggest problem

said that the farm workers had regularly seen spoor and had actually seen the animal on at least one occasion. Caracal are not on the list of predators that attract compensation when livestock are taken, so reporting such attacks to DWNP is not common practice (the compensation system will be discussed further later in this chapter). Farmers tend to deal with the problem themselves in these cases. This farmer's workers had put out a trap, but it was not set correctly and had been baited with an old, decomposed carcass (Figure 6.4) that would be unlikely to attract caracal which have rarely been recorded to scavenge carrion (Skinner 1979).

Figure 6.4 Trap put out to catch a caracal on a small stock farm

Another farmer said that he had shot a large male caracal that had been getting into the goat pens of his staff, killing 12 animals in one night, and had also been attacking his springbok and impala (*Aepyceros melampus*). He explained that he had no alternative but to shoot it, as if it had continued killing their stock the workers would have taken matters into their own hands and started putting down poison and snares (the issue of poisoning will be explored further later in this chapter).

There was no evidence of hostility towards brown hyaenas as killers of domestic livestock on the part of the farmers, but the above comment about workers employing poison and snares in retaliation for attacks on their goats suggests that the two hyaenas photographed with snares around their necks in this study (see section 5.5) may have been the victims of such activity. Alternatively, the snares could have been laid by poachers aiming to trap wild game for food.

It is interesting to compare the responses to this question on problem predators with the official problem animal control (PAC) records of Ghanzi District DWNP. The records for the years 2000 through 2008 were made available for this study and the total number of reported incidents of livestock loss to medium- and large-sized predators during those years is detailed in Figure 6.5. It is noticeable that reports of loss to cheetah and wild dog increased significantly after 2004 (Mann-Whitney U test: cheetah $W = 15.0$, $p = 0.02$; wild dog $W = 15.0$, $p = 0.0179$) when they were added to the list of predators that would attract compensation, from which they had previously been excluded. This was highlighted by one DWNP officer who remarked that the

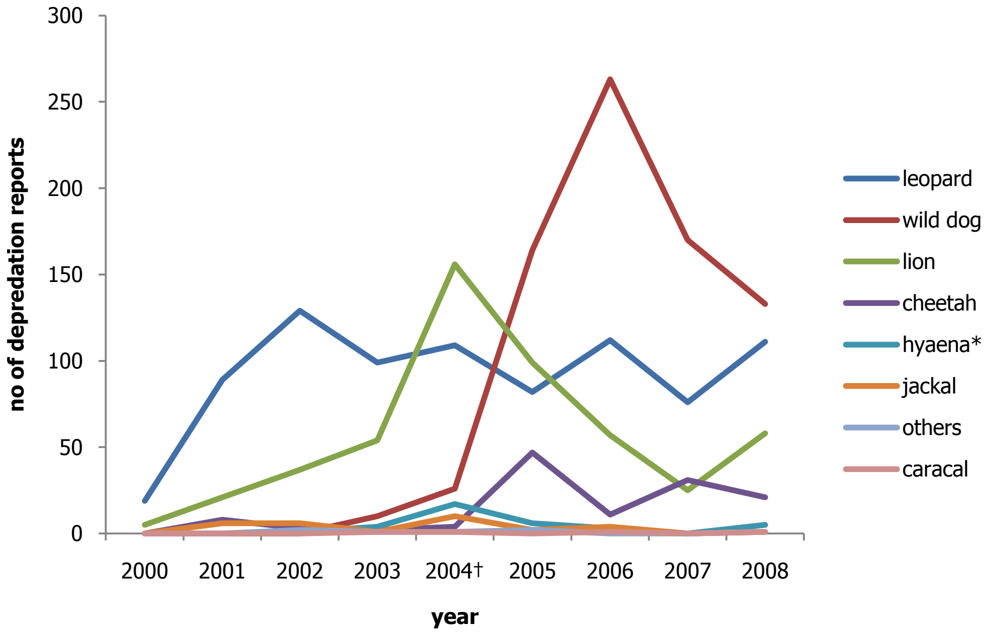


Figure 6.5 Total number of reports of livestock depredation reported to DWNP in the Ghanzi District during 2000-2008
(including those subsequently rejected)
*In some years no differentiation was made in the records between brown and spotted hyaenas so they have been pooled here
†In April 2004, cheetah and African wild dog were added to the list of animals for which compensation was awarded

official figures were unlikely to represent an accurate picture of the real situation as farmers usually only reported losses to species which attracted compensation (pers. comm.). Nevertheless, they are the only statistics available and as such are useful to a degree.

Looking across this nine-year span, livestock losses to leopard were the most frequently reported followed by wild dog and lion. However, when the figures for 2005 to 2008 (the years after the regulations changed) are plotted alone, the picture changes dramatically. Wild dog depredation reports accounted for 49% of all claims made during that period (Figure 6.6) and when the claims that were eventually rejected are removed, livestock losses to wild dogs made up 50% of the total (Figure 6.7). This strongly contradicts both the opinions of the farmers spoken to in this study and the evidence obtained from the camera trap and spoor surveys, during which only two photographs of an individual wild dog were obtained and no spoor was found (see section 5.4). However, only 16% of those wild dog depredation reports occurred in the farms within the farm block itself with the rest occurring at cattle posts, farms and settlements in the wider Ghanzi District including the Wildlife Management Areas (WMAs). It is possible therefore that the farmers within the farm block have been successful at eradicating wild dogs in their area and that the remaining populations of wild dogs are located only within WMAs, Reserves and their surrounds. However, a questionnaire survey conducted at cattle

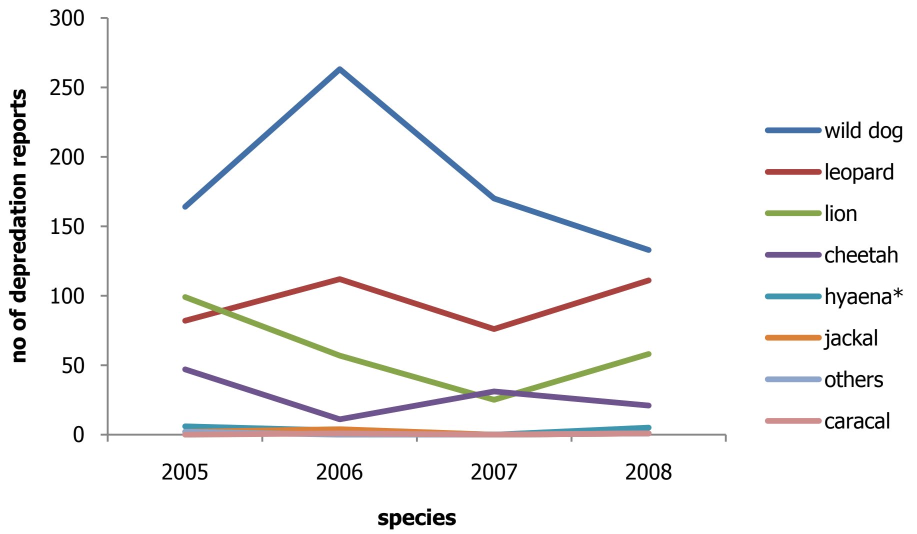


Figure 6.6 Total number of reports of livestock depredation reported to DWNP in the Ghanzi District between 2005 and 2008.
(including those subsequently rejected)
*In some years no differentiation was made in the records between brown and spotted hyaenas so they have been pooled here

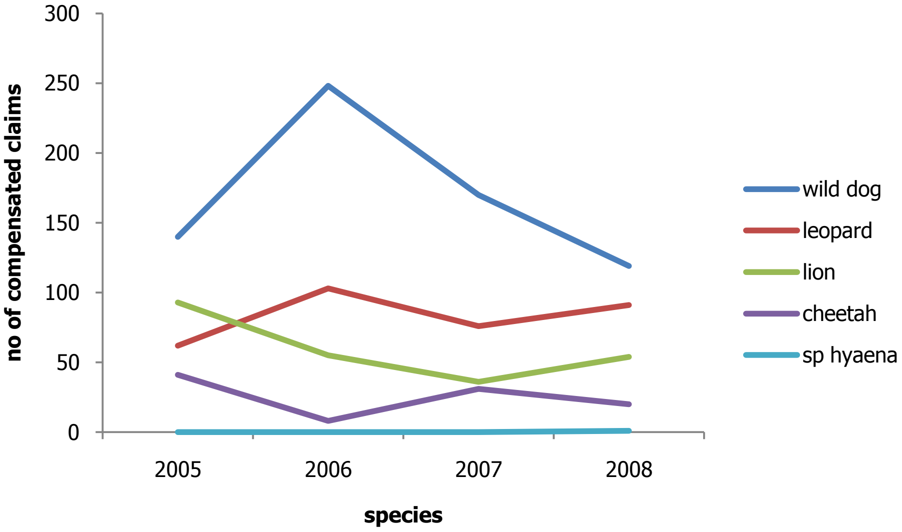


Figure 6.7 Number of compensated claims in Ghanzi District between 2005 and 2008. (By predator species)

posts and farms in the north of the country close to Moremi Game Reserve, found that perceived losses to wild dogs accounted for only 2.3% of the total with the overwhelming majority (77.2%) being attributed to jackal (Gusset *et al.* 2008). Similarly, a study in which questionnaires were administered to farmers and livestock owners within the whole of Ghanzi District, found that wild dogs were considered to be a problem predator by less than 40% of respondents, while between 50% and 60% considered leopard and jackal to be problems (Selebatso *et al.* 2008), and in the Okwa Valley area of Ghanzi District, a study into livestock depredation by wild dogs found that all predator attacks were very rare (Muir 2010).

Farmers were also asked if they thought that their livestock losses were seasonal, and if so, whether they occurred in the wet season, dry season or calving season. In Brazil, cattle predation by jaguars was found to peak during the dry season (Cavalcanti 2008), but here the variation in management practices across the farm block made this a difficult question to answer. This was reflected in the responses, with four saying wet, five dry and five calving/lambing season. Four said losses were not seasonal and two thought that livestock losses increased when the predators were breeding. When compared to the data from DWNP problem animal control records (Figure 6.8), no clear pattern of seasonality in reports was apparent, with the number of compensated livestock losses higher in the dry season than the wet between 2001 and 2005 and lower between 2006 and 2008. This may be accounted for by the extreme variability of rainfall in the area both temporally and spatially. It is not unusual for one part of the farm block to receive more than 500mm of rain in a year while another area, less than 50 kilometres away receives less than 200mm (pers. obs.). Similarly, it is also possible for all the rainfall in one wet season to fall between October and December and none to fall again until January or February of the following wet season. Without detailed precipitation records at a local level it is therefore extremely difficult to draw conclusions. The only period for which both rainfall and problem animal control records were available in this study was August 2008 to January 2009, and a comparison of those figures is presented in Figure 6.9. No pattern

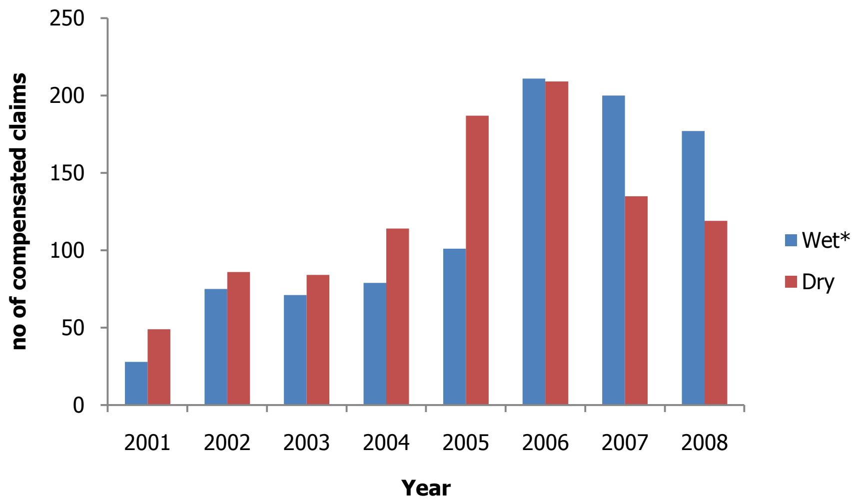


Figure 6.8 Number of compensated claims for livestock loss in wet and dry seasons from 2001 to 2008
*As the wet season starts in October a year was calculated to run from October to September, so the year 2001 runs from October 2000 to September 2001

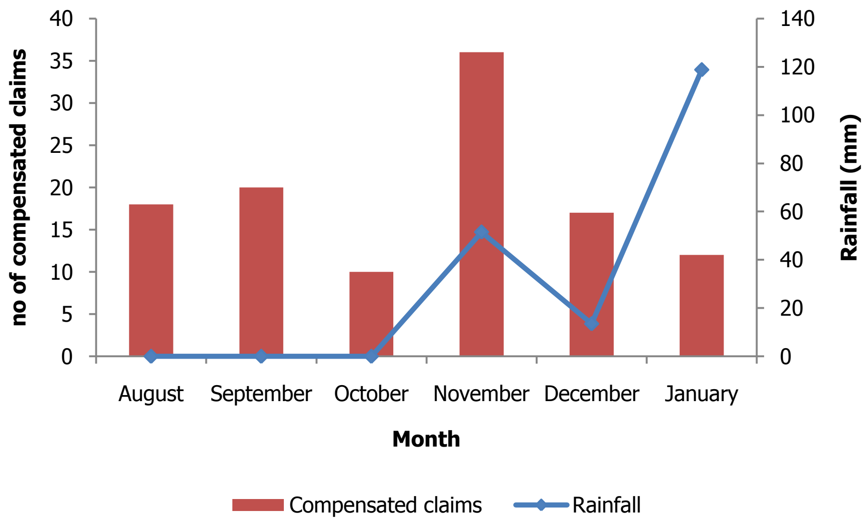


Figure 6.9 Number of compensated claims between August 2008 and January 2009. Line indicates total amount of rainfall (mm)

is apparent, but it must be emphasised that the rainfall records were for one location near Ghanzi town only, while the reported livestock losses were from the whole of Ghanzi District. An analysis of problem animal control records compared with detailed rainfall data in the farming areas around the Khutse Game Reserve also found some variability, although there did appear to be a trend for more lion depredation during dry periods (Schiess-Meier *et al.* 2007). All this does tend to concur with the varying views of the farmers as reported above. An additional confounding factor is the fact that some farmers do not actually live on their farms. This creates added problems in ascertaining patterns as it is hard for them to monitor what is going on.

In general the game farmers interviewed displayed a fairly relaxed attitude to predators on their farms. One said that he was not worried about losing animals to predators as they did not take the really valuable ones, such as rhinoceros calves, and that the antelope reproduced faster than they were depleted. Another echoed this view:

> *On the game farm we care, but we don't really bother much...if they catch a few kudus and that anyway…actually our game's getting to a stage now where the normal hunting cannot control the numbers - we're going to have make some plan - yeah because otherwise they die from hunger if you get overstocked.*

It is tempting to conclude from this that, in this instance, *more* predators would therefore be beneficial. But of course it is not as simple as that. Concern was however, expressed by some game farmers about the fate of their springbok and impala populations. There was a belief that cheetah were responsible for wiping out their entire stock of these animals. One farmer complained that in the past ten years he thought he had bought 1,000 springbok and impala to feed the cheetah. Contrasting with this was the view of what could be termed a 'recreational' game farmer who said that he "didn't care if the cheetah and leopard ate all his impala as that is what they are for". This difference in attitude emphasises the significance of economics to individual farmers.

Stories of cheetah 'decimating' the remaining free-ranging springbok herds were also mentioned by some livestock farmers. One farmer said that when he moved onto his farm ten years previously there had been a herd of around 100 springbok and the cheetah had killed and eaten them all. Another, who farmed a considerably larger area of land, said that the huge numbers of springbok that used to exist there had now all gone. He also attributed their demise to cheetah. Interestingly, a recent study in South Africa found that springbok constituted a large part of the diet of black-backed jackals on game reserves, with the evidence suggesting that this was the result of predation rather than scavenging (Klare *et al.* 2010). There is a possibility therefore, that the heavy toll on springbok numbers reported by some game and domestic livestock farmers is, at least in part, the result of jackal rather than cheetah depredation. This possibility was not mentioned by any farmers spoken to during this study.

However, given the relative densities of the two species in the area (see section 5.4), it is something that should be given serious consideration and merits further investigation. An additional factor in the failure of springbok to thrive in the area may be the bush encroachment problem. Springbok are adapted to open, short grass savanna habitats (Skinner & Chimimba 2005) of the kind that were once prevalent in the Ghanzi area, but have now all but disappeared due largely to overgrazing and changes in land management practices (see section 2.2).

Looking in more detail at the three predators that were most frequently mentioned by farmers as being the biggest problem - leopard, cheetah and jackal – 15 of the 20 farmers questioned thought that cheetah numbers had increased during their time in the area. This is considerably more than the 23% (n = 123) who were found to have a similar view by Selebatso (2006). Meanwhile, 12 thought jackal numbers had also increased, but leopard numbers were only thought to have increased by seven of the respondents, while 10 thought they had remained the same (Figure 6.10). Reasons suggested for increases in numbers, where they were thought to have occurred, tended to revolve around three main issues. Several farmers thought that the increase in cheetah numbers in particular was the result of their being protected, and there was also support for the view that the increase in game farms in the area was attracting predators. The third main reason given was that of higher levels of natural prey caused by two main factors: 1) reduced levels of hunting and 2) an increase in the number of cattle posts within farms providing more water points. This was thought to apply across the whole range of wild prey species from kudu down to guineafowl. The eradication of lions from most of the farm block was also mentioned as a contributing factor to the perceived increase in cheetah numbers, while the change in habitat from open grassland to thick bush was thought to have provided more favourable conditions for leopard. Several people were also convinced that predator numbers in the Central Kalahari Game Reserve (CKGR) had increased to the point where animals were being forced out of the reserve and into the farm block to find their own territories.

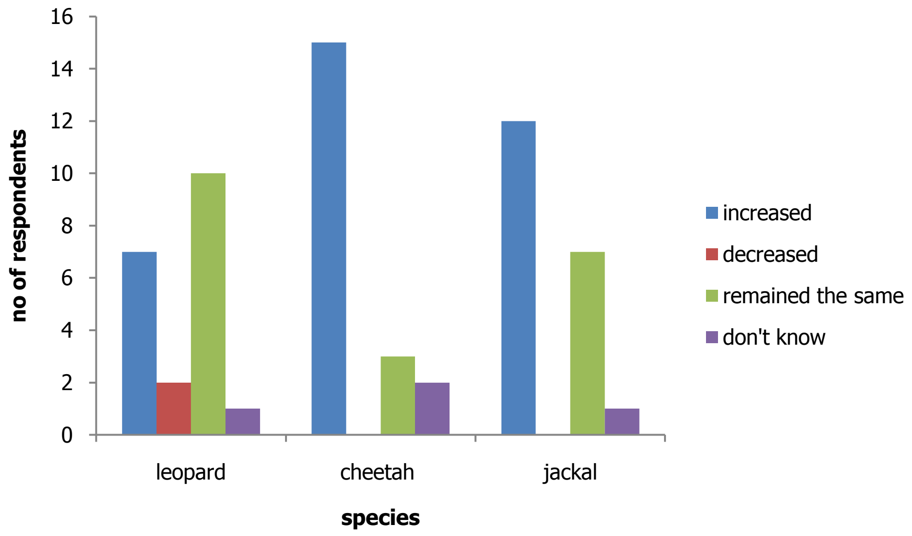


Figure 6.10 Perceptions of leopard, cheetah and jackal populations

During the study it became apparent that some parts of the farm block appeared to suffer disproportionately from cheetah livestock depredation, while other areas were apparently more prone to leopard problems. This cannot be accounted for by differences in land use as there is a mix of game, cattle and small stock throughout the area. One farm in particular, with a history of very high losses to cheetah, was one of the few in the area that still had areas of open grassland and good populations of naturally occurring game species, including springbok. The owner described his predicament:

> *Here on my farm there's just one problem and that is the cheetahs…why are they now so plenty here? I think in the Central Kalahari all round...you know there's plenty of lions, there's plenty of leopards. And these things they kill a steenbok or a duiker...there's no goats and sheeps…then some time before they have eat - here's somebody - leopard, lion or these wolfies [hyaenas]…and they chase them away from their food - that's what I think. And now with all this trouble they come here - and it is easy for them to go and kill a sheep or a goat – because I've got a lot of springboks here! Lot of springbok! And if we go now into the pan you wouldn't believe how many warthogs are here…plenty, plenty…gemsbok...eland...I've got plenty of game here…[But] it is very easy for them to go and kill a sheep.*

The level of cheetah problems experienced by this farmer raises the whole question of 'problem animals' and whether some individuals are really more likely to be livestock killers than others. When this subject came up in conversation with one of the more tolerant farmers, he asked "what is a problem animal?" Linnell *et al.* (1999) attempted to answer this question and categorised two basic types of problem individuals. The first type exists in an environment where most individuals do not have livestock within their range. When such an animal does encounter and attack livestock it can therefore be described as being in the wrong place. The second type exists in an environment in which livestock is present in the home ranges of all individuals, but kills a disproportionate amount of stock per encounter than others (Linnell *et al.* 1999). In the Ghanzi farmlands most problem animals would certainly fall into the type 2 category, except perhaps for individuals dispersing from the CKGR which could be categorised as type 1. Evidence from studies on several large predator species suggests that such problem individuals do indeed exist. Stock-raiding lions in Namibia that were habitual killers of livestock were labelled as 'problem animals', while individuals with no previous known history of livestock depredation were classified as 'occasional raiders' (Stander 1990). In Belize, individual radio-collared jaguars were also found to display widely varying levels of stock-raiding behaviour (Rabinowitz 1986).

It has also been suggested in the past that felids that attack livestock are more likely to be male (Rabinowitz 1986; Stander 1990; Linnell *et al.* 1999), although this was not found to be the case among livestock-raiding jaguars in Brazil (Cavalcanti 2008). In the Ghanzi area, at least with regard to cheetahs, the anecdotal evidence would suggest that there is no such bias. Several farmers reported females with sub-adult cubs seen attacking or feeding on livestock. Hunting and prey selection in wild felids is learned behaviour and cheetah cubs start accompanying their mothers on hunts from the age of about eight weeks (Caro 1994). Research into livestock predation by other felid species have suggested that, in some cases, this may lead to the creation of problem individuals (Rabinowitz 1986; Quigley & Crawshaw Jr 1992; Nowell & Jackson 1996), with females that have become livestock killers, for whatever reason, imprinting the behaviour on to their offspring. This would provide a reasonable explanation for the disproportionate level of cheetah problems in a particular part of the farm block, especially as dispersing female cubs are likely to subsequently utilise home ranges close to those of their mothers (Caro 1994). This could create a perpetual cycle of livestock killing animals as daughters then pass the behaviour on to their own offspring. The only way to break this cycle would be the removal of the problem individuals, a measure favoured by several farmers:

> *…I say they must put value on the heads of the problem animals so that we can sell them as a problem animal to the hunters and then you will see the numbers will increase and then you will see the problem animals they will go out…*

In general, farmers commonly spoke of cheetah with distaste and, as a species, they were not perceived to be of economic value due to their not being trophy hunted. Additionally, there was a view among many that cheetah killed in a 'wasteful' manner by not eating the entire animal and often killing more animals than they could eat:

> *…the cheetah were the most destructive...yeah in the days I kept sheep, I had a kraal of*

sheep and goats up near the house here, one night cheetah jumped in there and they killed half of them just for fun - and they eat just one.

Such 'surplus killing' is not uncommon among carnivores that attack livestock. One explanation for the behaviour is that it stems from the 'kill' instinct of the animal going into overdrive when presented with an abundance of easily caught prey, in a kraal or other enclosure, that display little or no natural anti-predator behaviour (Nowell & Jackson 1996; Linnell *et al.* 1999).

Overall, there did appear to be a disproportionately negative attitude towards cheetah that was neither in accord with the reports of depredation in the PAC records, nor with the position of cheetah in the hierarchy of predators perceived as problems by domestic livestock farmers (Figure 6.3). Furthermore, the narratives of some farmers appeared to condemn the cheetah, not only for predation on livestock, but also for hunting and killing natural prey species living in a wild state. This suggests an underlying antipathy to the species that is based on something other than economics. It could be, that as a diurnal, wide-ranging species that often lives in family groups, its visibility gives it a prominence in the minds of the farmer that other nocturnal predators do not achieve (Marker *et al.* 2003c). The activity patterns of cheetah and other carnivores in the Ghanzi farmlands will be explored in Chapter 7. It has also been suggested that the combined effects of the exclusion of cheetah from the list of species that attracted compensation prior to 2004, and the ban on killing cheetah that attack livestock exacerbated these negative perceptions in the past (Selebatso *et al.* 2008). A further possibility exists, which has been described as a 'hyper-awareness' of risk (Dickman 2010), whereby an exaggerated level of loss to a species by one person can lead to a heightened fear of that species in the wider community (Dickman 2010).

The leopard situation also presents something of a conundrum. Densities derived from spoor surveys and camera trapping in this study were low, ranging from 0.29 to 0.63 leopards/100 km^2 (section 5.4) which were well below the carrying capacity figure of 1.27 leopards/100 km^2 derived from natural prey biomass (section 4.4). Despite this, leopard were put in the top two of problem predators by 70% of the domestic livestock farmers questioned. Towards the end of 2009, Ghanzi DWNP conducted an auction to sell the skins of animals removed as problem individuals in the District in the previous year. Seventeen leopard skins were offered for sale (Figure 6.11), including five large males, but the view of several of the farmers present was that this probably represented only about one quarter of the number of leopards that had actually been killed, with the majority not being reported to DWNP. That number alone would translate to a leopard density of 0.45 leopards/100 km^2 across the farm block. This strongly suggests that some areas may have much higher densities of leopard than those in which the spoor surveys and camera trapping were carried out. The farms on the eastern side and those closest to the border with the CKGR appear to have the biggest problem and there is an urgent need for more targeted research into the leopard population in that area.

Figure 6.11 DWNP auction of skins of officially killed problem animals in Ghanzi District

The very high jackal population in the farmlands results in them being almost universally detested as a species, and many of the farmers spoken to during this study expressed the view that the killing of jackals was both routine and necessary. There is some evidence that fluctuations in jackal numbers are driven by the rabies cycle (Courtin *et al.* 2000; Bingham & Purchase 2002) and that once a peak is reached in the population an outbreak of the disease becomes more likely, resulting in a population crash. This appears to be understood by farmers in the area:

> *The jackal there were always plenty - except the jackal as you know…rabies is the thing that controls them. After rabies you get few jackal and then they build up like now - they're at a high point now…*

This view was shared by another farmer who complained that the jackals were taking his lambs and said he was sure there was going to be a rabies outbreak soon as the jackal numbers were so high. Farmers were also asked whether they had had any incidences of rabies in their cattle in the past five years. Twenty five per cent said that they had, the majority of whom (60%) said that the disease had been transmitted by jackals, while the others did not know the source. One farmer in particular said that he had lost 12 animals in the past year. A neighbouring farmer also reported recently having to shoot a rabid jackal, but had not lost any livestock. Some farmers expressed a reluctance to involve Government departments in their affairs, which is of some concern with regard to this issue, as without official involvement it would be possible for an outbreak to take hold in the area before anyone was aware of it. There is also some evidence that disturbed populations of jackal are more susceptible to rabies outbreaks due to the increase in agonistic behaviour that accompanies territorial disputes arising from the removal of individuals (M. Bing pers. comm.; McKenzie 1993; Loveridge & Macdonald 2001).

While not mentioned in anyone's top two of problem predators, the spotted hyaena was thought to have considerably increased in numbers by all the farmers interviewed in the northeast of the farm block, one of whom said, "yes, now they are giving us a problem…almost daily we hear them at night…I think the game farms have brought them back in", and another said he thought they were moving down from Ngamiland, the District to the north of Ghanzi District. There was also a view, among some, that lion numbers were on the increase again and that it was a reflection of a recovery in populations after the drought that had severely affected all wildlife populations in the 1980s. Another possibility put forward was that DWNP were now much more visible in the CKGR, which acted as a deterrent to anyone who might previously have been tempted to enter the reserve to hunt animals illegally.

When asked if they thought that overall predation levels had increased, decreased or remained stable during their time, either on the farm or in the area, 50% of the farmers thought it had remained the same. Thirty per cent however did think that predation had increased. One of the farmers who thought this was keen to point out that in his view the increase had only occurred within the previous decade. He said that prior to that, predation levels had been much lower than historically due to the eradication of lions and wild dogs. This period corresponds with the time at which the killing of cheetah, a protected species in Botswana since 1992, was made illegal for any reason, including that of predator conflict (Klein 2007). He was particularly worried about the number of cheetah he believed were on his farm and said that he thought he would soon have to start taking action to redress the balance. He also said that he knew of several other farmers in his area that felt the same way but were not speaking out about it.

One farmer who thought that predation levels had decreased attributed the fall to the increase in natural game species. He described how when he arrived on his farm in the 1970s the Bushmen had hunted out nearly all of the kudu:

> *And that's when the problem started...when the game numbers increased there was less problems with the predators...there was no warthog…steenbok and duiker very, very little. And since then the kudu have increased I mean...if I tell you it's three hundred....*

This underlines the complexity of the situation. Previously, the views of some farmers were mentioned who had attributed increased predator numbers to greater levels of natural prey abundance, and yet here was another farmer who thought that predation had decreased for the same reason. This latter view is certainly in concurrence with research into livestock predation in other species; depletion of wildlife through hunting for bushmeat in Venezuela caused jaguars to turn to cattle for survival (Hoogesteijn *et al.* 1993), while there were significantly fewer depredation events by wild dogs in Kenya in areas that retained a good natural prey base (Woodroffe *et al.* 2005a). Of course, in the presence of an adequate food supply a larger number of predators need not necessarily lead to higher levels of stock loss, but it may increase the *risk* of livestock predation if only as a result of increased encounter rate.

A further confounding factor regarding livestock predation in the area was that of feral dogs. Several farmers, especially those close to town and on the western and southern sides of the farm block, mentioned that there was a big problem with domestic dogs which were not confined at night forming packs and going hunting. But the problems were not only restricted to night time. One farmer shot five out of a pack of nine feral dogs that he found on his game farm during daylight hours. Two weeks later, three more attacked and seriously wounded a springbok ram in the middle of the afternoon on the same farm (pers. obs.), two of which the farmer subsequently managed to track down and shoot. Another farmer went so far as to say that he thought that at least some of the livestock depredations that were being attributed to cheetah and wild dogs were in actual fact caused by feral dogs, a phenomenon that has been reported elsewhere (Cozza *et al.* 1996). Importantly, feral dogs are another species that do not attract compensation for attacks on livestock in Botswana and given the disparity between reports of livestock losses to wild dogs and their apparent low abundance, as discussed earlier in this section, the question must be asked whether at least some of the livestock losses which have attracted compensation in the years since 2005, could in actual fact be the result of feral dog or jackal attacks. It has certainly been suggested in the past that the damage done by smaller carnivores, such as feral dogs and jackals, far outweighs that of the larger species which are often the focus of more concerted removal and control efforts (Sillero-Zubiri & Laurenson 2001).

All farmers were also asked whether any predator species had value for them, whether that was economic, ecological or cultural. Among the game farmers there was almost universal agreement that all the predator species had at least some economic value as tourist attractions, and for some they all also had an ecological value (Figure 6.12). The only species for which there was not unanimity were lion, spotted hyaena and jackal. The livestock farmers however were far less enthusiastic. There was a group of four farmers who believed that all the species had an ecological value. Outside of these individuals, a few thought that leopard either had, or could have, economic value as a trophy animal, and a few others expressed the view that

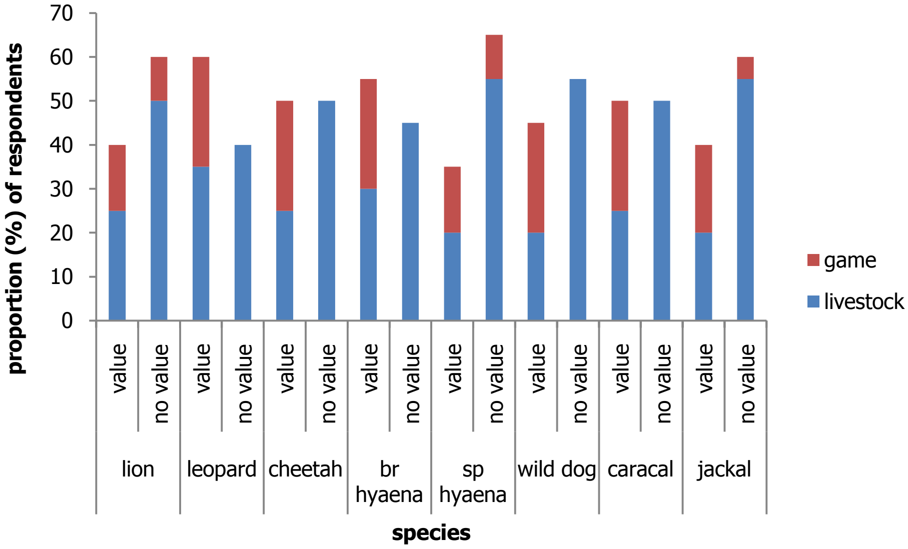


Figure 6.12 Proportion of farmers for whom predator species either had value or no value

brown hyaena had ecological value as they cleaned up carcasses. For most though, there was a strong feeling that predators had no value at all. As one farmer said:

> *….whoever sets up the laws has not set them up correctly to benefit the farmer to have them around…so those that do do some damage, there's no compensation…it's too small.*

6.3iv Compensation and problem animal control

Many of the comments and issues raised in the previous section pertained to the state-funded compensation system that operates in Botswana. It is salient therefore to explore this programme further.

Compensation schemes exist in various forms (see Nyhus *et al.* 2003 for a review) and, when supported by the community they serve, may be an effective means of persuading land owners that they can tolerate the presence of predators. However, measuring the success or failure of such schemes can be problematic and compelling evidence as to the effectiveness of existing schemes is limited (Nyhus *et al.* 2005). Their usefulness is also likely to depend on the extent to which economic issues lie at the root of the problem (Montag 2003). Additionally, a fully supported and well administered compensation scheme should provide valuable information on the real, as opposed to perceived, levels of livestock depredation in an area and the species that cause the most problems enabling more effective mitigation policies to be implemented.

All of the above makes the assessment of attitudes towards any compensation scheme of great importance when evaluating that scheme. Domestic livestock farmers in the Ghanzi farmlands were therefore asked several questions about their views on the value and effectiveness of Botswana's scheme. All respondents were first asked whether they had ever made a claim for compensation for loss of livestock due to predation. Among cattle farmers only two had made a claim, while for those with small stock an equal number (5) said they had and had not (Figure 6.13).

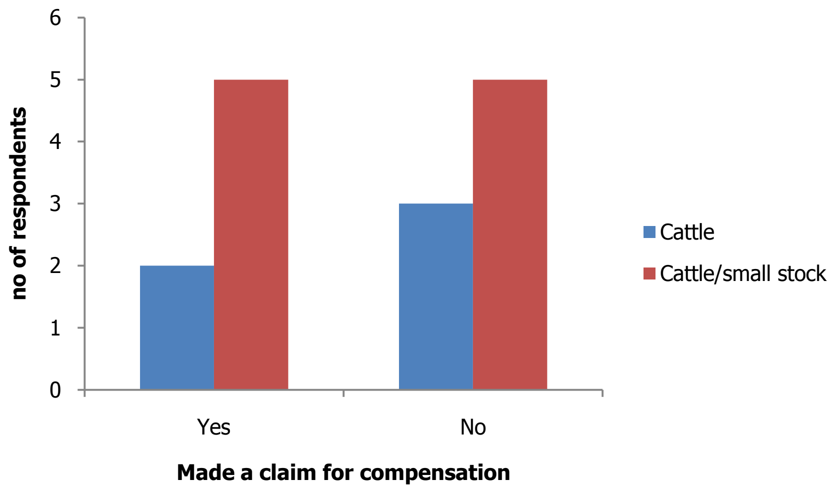


Figure 6.13 Number of livestock farmers that had ever made a claim for compensation

Those who had made claims in the past (*n* = 7) were then asked if they were happy or unhappy with the process of making their claim and with the value placed on their livestock. There was a mixed response to the first question with four saying they were unhappy, two were happy and one respondent was undecided. It was noticeable that all of those who said they were happy with the process lived within a 45 minute drive of the DWNP office in Ghanzi where they had to submit their report. The views of those who lived further out were much more negative. One farmer complained that he had had a claim rejected as he had not reported within the required seven-days after the loss. He said it would have meant making a special trip into town which would have taken up half a day and cost more in fuel than the compensation amount. The second question elicited a more polarised response with five of the seven saying that they were unhappy with the amount they had been paid. One farmer said that he only reported the loss of an animal so that DWNP would know that there was a problem, not for the compensation which did not even cover the cost of driving into town to make the claim. This attitude was not universal however. Another individual conceded that although he did not think the amount paid out for livestock loss was sufficient, he understood why it was not higher '…..if the value is too high people would let Wildlife [DWNP] do the marketing for them'. This is a valid point and should be considered alongside the statistics for the amounts that are paid out by DWNP in compensation, which are substantial. During the years for which records were available, total compensation payouts in Ghanzi District ranged from P11,600 in 2000 to nearly P238,000 in 2006. Between 2000 and 2008 a total of just under P1.1 million was awarded in compensation in the Ghanzi District alone. During the years analysed (except 2007 for which no data on the number of rejected claims were available), the mean proportion of rejected claims was 19.4% (± SE 4.03). This represents a considerable commitment for the Botswana Government. Despite this, research suggests that compensation schemes do not necessarily improve tolerance levels for predators (Naughton-Treves *et al.* 2003; Gusset *et al.* 2008) and there was little evidence here to contradict that.

Of more concern was the claim by several farmers that they did not report to DWNP as they did not want to have any government involvement in their farm. One explained:

> *We never work with Wildlife [DWNP]...the best option is - because you have to contend with bureaucracy and all that comes with it - is just to keep quiet. Which is not really.... an answer because then you don't know about the statistics.*

Similar sentiments were expressed by many other farmers who generally said that the hassle involved in making a claim was too great for the recompense that was offered. But one farmer thought that reporting was important, even if the value placed on his livestock was insufficient, and explained why he would claim again when the situation arose:

> *….I must claim…then the people know they are there and then I shoot them…otherwise if I don't claim, I shoot them, I keep quiet, nobody knows how many animals are [there]…And some farmers they are doing it!….Because they get too less so they just kill and they just keep quiet so….nobody knows how many leopards is running around in Ghanzi….but there are many!*

This view was echoed by another farmer who also said he only claimed so that DWNP knew there was a problem. He said the cost of replacing a stud goat would be in the region of 10,000 Namibian Dollars (around P9,400) and yet he thought the compensation he would receive was only P175.

There was some criticism of the attitude and competence of some DWNP officers. One cattle farmer complained that the DWNP officers who were sent out to verify a reported loss were not interested in the farmers' problems and had no incentive to help them, while another claimed that officers who had come out to his farm had mistaken domestic dog spoor for that of leopard. Other complaints from farmers surrounded the lack of resources available to DWNP. There were several stories of people making the effort to drive into town to report a loss only to be told that DWNP did not have a vehicle or enough fuel or people to go out and verify their claim.

From this it is apparent that the compensation scheme, as it currently exists, is not functioning to the satisfaction of either farmers or officials, and this may be in part because there are no incentives or requirements bound into the scheme to encourage the adoption of better livestock husbandry or other preventative measures (Madden 2004). Such measures are suggested to farmers and other livestock owners when they lose animals, but there is no penalty system for not following the advice. The Swedish system has a requirement for mitigation measures to be instigated in order for compensation to be paid, with the state covering the cost of materials for fences and providing advice on construction (Swenson & Andren 2005). However, as has been pointed out before, any changes in behaviour or practice are only likely to be effective if they are adopted because the participants themselves identify a need and choose to act upon it (Treves *et al.* 2006). In the Makgadikgadi area of Botswana, livestock owners at cattle posts were found to be reluctant to embark on such initiatives without government support (Hemson 2003). The suggestion that compensation schemes may actually perpetuate conflict situations has also been made in the past (Sillero-Zubiri & Switzer 2004) and there is evidence that this may be applicable here.

The PAC records discussed earlier almost certainly do not present a true picture of depredation levels for any given species in the area due to the reluctance of some farmers to report at all. Additionally, the omission of caracal, jackal and feral dogs from the list of species that attract compensation cannot do other than distort the picture even further. There is a strong likelihood that because of this, losses are attributed to species that attract compensation rather than to those that do not. This may also lead to persecution of some species to a level unwarranted by the reality of their impact. Similar questions were raised by Gusset *et al*. (2008) who found no evidence of the compensation system increasing tolerance levels in northern Botswana.

It is important to stress that DWNP do not employ lethal control as a first option when depredation occurs, but will try non-lethal methods such as chasing, shooting over an animal's head or, in some cases, translocation first (Figure 6.14). When opting for translocation of cheetah, DWNP rely heavily on Cheetah Conservation Botswana (CCB) for assistance in the removal, care and transport of the animals. The policy has not had a high success rate in the past with a low survival rate of the translocated animals (pers. obs.), and was not popular with the farmers, especially those whose property bordered the CKGR who have complained that the animals were being released too close to them and were concerned that the problem was being dumped in their back yard.

Figure 6.14 Cheetah caught in a live trap awaiting removal and translocation

However, the issue surrounding PAC which undoubtedly aroused the greatest disquiet and discontent among the farmers spoken to was that of the issuing of licences for the trophy hunting of problem animals. In recent years the regulations surrounding these licences have changed so that they can now only be issued to game farmers rather than to livestock farmers. In effect this means that the livestock farmers have been removed from the income stream that results from the hunting of such animals as trophies, and may also mean that 'innocent' animals are killed. One farmer explained how he thought the system should be run:

> *…I mean not giving the licence to the game farmers but giving the licence to the cattle farmer so that he can sell it to the hunter directly. Otherwise you give it to the game farmer he take the licence and he just shot a big one who are innocent. You give it to the cattle farmer himself so that he can decide, then…obviously you will take out the problem one. You must remember…the trophy hunters - the bigger the better! And for me it's not the bigger the better, I want the problem one out...that one is the one I want out.*

Regardless of the merits or demerits of the PAC trophy permit system it is really only of import with regard to leopard. The CITES quota for Botswana for annual export of cheetah (trophies or live animals) is five. This quota is not taken up however, as it is illegal to hunt or kill cheetah in Botswana for any reason (Klein 2007). In comparison to neighbouring countries Namibia, which has a CITES quota of 150, and Zimbabwe whose quota is 50, this reflects the lack of information that still exists on the cheetah population in Botswana. It has been suggested that trophy hunting could increase tolerance levels for cheetah on farmland in Namibia (Marker & Dickman 2004), and this option was suggested by several farmers in the current study. But there were also some who were not convinced that it would work:

> *…I don't think there is any value to it because it's not one of the big five…it's not a dangerous animal to go and hunt...that's what the hunter of the leopard is mainly about …these people that come in…it's the adrenalin…*

But in any event, until there is more robust information on cheetah populations there is little prospect of CITES quotas being increased sufficiently to make this a viable conservation tool in Botswana, even if the restrictions on their hunting and killing were to be relaxed.

As is apparent from the attitudes to government intervention expressed by some farmers, the issue of PAC is one that many prefer to deal with themselves. When asked, 70% of farmers questioned (n = 20) said that they had removed a predator from their farm in the past. There were three main methods employed to this end, 64% said that they had used live traps and a similar percentage had shot predators. Fifty percent said that they had used poison in the past, although several were keen to make the point that it was several years ago and that they no longer used it. Fourteen percent had used dogs to hunt a predator. Additionally, while not being targeted removal, there were several stories told of predators being deliberately hit with vehicles if encountered on the road or a farm track (Figure 6.15).

Figure 6.15 Black-backed jackal killed after being hit by a vehicle

The use of poison as a means of predator control is highly contentious in Botswana as a whole and in the Ghanzi area in particular. It has undoubtedly had an impact on vulture populations, particularly African white-backed vultures *Gyps africanus*, but also other raptors and mammal species that scavenge on carcasses (such as brown hyaena), and has been a frequent topic in the newsletters of BirdLife Botswana in recent months (BirdLife Botswana 2010). The issue has generated such concern that both BirdLife Botswana and CCB have started to lobby for a change in the law regarding its availability. The Botswana Predator Forum, a discussion list for researchers, farmers, officials and other interested stakeholders has also been extremely active on the topic over the past year. The most pernicious of the substances used is Temik®, a pesticide used on crops, that is so toxic to animals one teaspoon can kill an adult rhinoceros (Webb 2005). This substance is easily obtained in Ghanzi and, as one farmer related, while not displayed on the shelves of local stores is obtainable on request. Most of the farmers spoken to in this survey denied using poison and expressed strong feelings about those who did. But some said they had used it in the past, and a few said that they still used it selectively on small pieces of meat, mainly to deal with jackals. They were at pains to point out that these were collected at first light the following morning to prevent vultures from eating it. This measure would not of course protect nocturnal scavengers. However, stories continually circulate about farmers poisoning whole carcasses in order to deal with predator problems, and one individual freely admitted poisoning any carcasses of calves he found to deal with his cheetah problem (this is despite his having been informed that cheetahs rarely returned to a kill). He acknowledged that it was killing other species and even said that 'the vultures were dropping out of the trees', but felt that he had no choice as there were "about 30 cheetahs on his farm". There has been a backlash to this indiscriminate use of Temik® however, with one farmer in particular taking it upon himself to print and distribute leaflets to the farming community warning of the dangers of the substance.

6.3v Attitudes to conservation

The question of whether attitudes to wildlife are likely to be driven by ethnic background or identity is pertinent when considering how different groups in the area view the issue of conservation. Historically, as was mentioned in Chapter 3, Boer trekker attitudes towards wildlife and wilderness were focused on removal and taming as a means of promoting agricultural progress and sustainability (Carruthers 1995). Determining whether these views have remained intact in the Afrikaner community of the Ghanzi farmlands, and if so whether they are consistent across the generations, could have some bearing on future strategies aimed at the mitigation of human-wildlife conflict.

Questions were asked that aimed to discover how respondents felt about the conservation of predators outside protected areas in general and on their land in particular. All but one of the farmers questioned said that, in principle, they supported the conservation of predators outside protected areas. As one farmer put it "…we have to – for the future of our generation." But when asked how they felt about sharing their land with predators the responses were much more varied. The reaction of one livestock farmer to this question was quite categorical: "As a farmer I can't really do that ….for certain predators there's no way that both of us can be living on the same place".

While by no means representing the views of the whole group, there was a trend towards a diminution of tolerance. The small sample sizes involved made controlling for confounding variables difficult, but using ordinal logistic regression a significant effect of farm type was apparent with farmers who had small stock significantly less likely to be happy than cattle-only or game farmers when controlling for ethnic and age group (G = 20.337, *df* = 7, *p* = 0.005) (Figure 6.16). Afrikaners were also less happy than white non-Afrikaners but not significantly so (Figure 6.17).

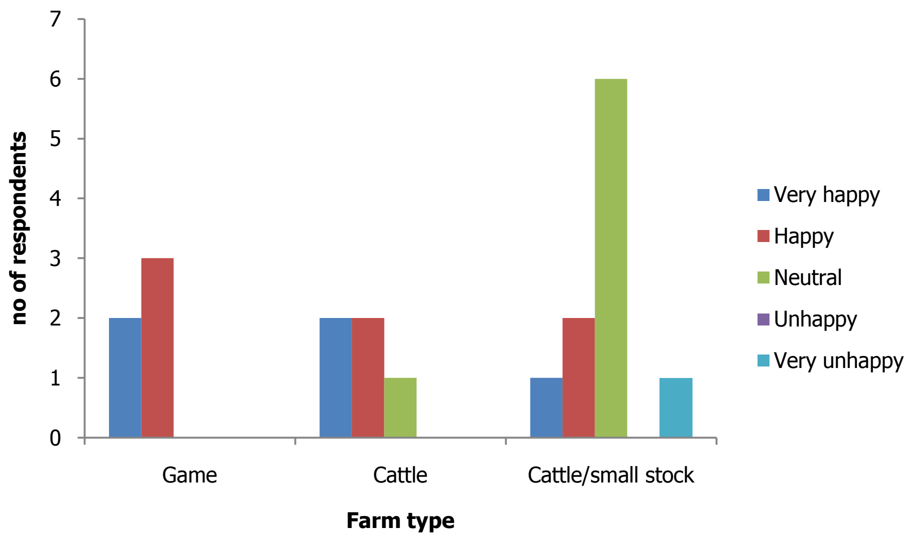


Figure 6.16 Attitude to sharing the land with predators among livestock farmers (According to farm type)

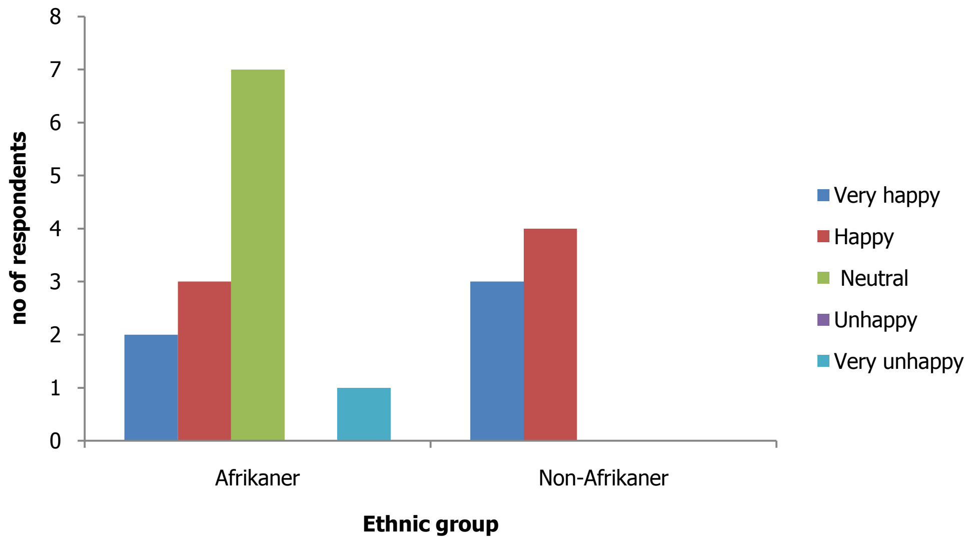


Figure 6.17 Attitude to sharing the land with predators by ethnic group (Afrikaner *n* = 13; non-Afrikaner *n* = 7)

The general feeling that emerged was that most farmers would like to be able to live with the predators but felt they were unable to because of the economic consequences they faced from loss of livestock, coupled with the low levels of compensation:

> *You know they are there - we must just control them. Its just - and I mean by control we must just sort the problem ones and leave the others because if you sort all of them - then maybe you get more problems because then the problem ones move to your place. So what I do I just sort the problem ones - the others I leave. You know it's nice if you drive there and there is a cheetah there and he eat a kudu calf or he eat a duiker or he eat a steenbok - it's nice. But if you drive there and he eat a goat you pay P15,000 for and you know you get P150 for [it] then it's not nice anymore.*

Another explained his feelings thus:

> *…because it's so nice to see this stuff...so everybody likes to protect them and I'm not there to kill everything. But for me....it's the same as people in Jo'burg they want to kill the people who break into their houses and steal their stuff every day...they must be punished and they must be in jail....but if the predators is taking my livestock it's for me the same case...but for protection they say - no there's only a few wild dogs left over there....there's only a few cheetahs you can't kill everything.*

And in a similar vein, this from another livestock farmer:

> *…you know you must also remember that not every predator is a problem animal. I mean ... I do respect that we can live them, but I also respect that thing is not going to put my child through University…*

But another took a more philosophical view, "I say the animals were there before us so we have to give them a chance as well."

The level of support for conservation outside protected areas was much higher in this study than that found by Selebatso (2008) in the wider Ghanzi District. He reported that only 47% of 123 farmers were in favour of cheetah conservation outside protected areas. That study, which also sampled smaller-scale farmers on communal lands and in WMAs, found there was a significant positive relationship between tolerance to cheetah and educational level, and also reported significantly higher levels of support for conservation outside protected areas by private and WMA farmers than by those who utilised communal land and also by Bushmen and non-indigenous groups over other ethnic or tribal groups. The trend for greater tolerance among commercial ranchers has also been reported in Kenya (Romañach *et al.* 2007). As this study focused on private farmers only, it was perhaps not surprising therefore that professed attitudes towards conservation were found to be more favourable.

6.4 Influences of ethnic background on knowledge and beliefs

The difference in feelings of Afrikaners and non-Afrikaners to sharing the land with predators, while not statistically significant, raises the question of influences of ethnic identity on attitudes, and whether the opinions and beliefs about predators expressed by farmers during questionnaires, interviews and conversations are a reflection of the ethnic background of the individual concerned. Calls for such influences to be taken into account when designing mitigation strategies are becoming increasingly common in the literature on human-wildlife conflict (e.g. Dickman 2010). But is knowledge and belief about wildlife informed by the ethnic identity of an individual? Or is it acquired through experience and personal interaction? Manfredo & Dayer (2004) use the term 'cultural character' to describe how groups may be distinguished from each other by their patterns of thought. Problems arising from such differences in knowledge and attitudes could play into the interactions between farmers and officials and, in a situation such as that in the current study, difficulties may also arise because the different groups do not share the same language as their mother tongue. The difficulties and misunderstandings that this can cause have been highlighted in the anthropological literature in the past (e.g. Strang 1997). The Batswana have a strong pastoralist tradition and cattle ownership is part of their tradition, but, when acting as law enforcers they may have different agendas and interests than those of the Afrikaner farmers. Strang (1997) encapsulates such differences thus:

> *People do not have different capacities to value: all human beings employ the same processes of defining and locating value. The difference lies in what they choose to prioritise and encourage and, perhaps most importantly, where they locate values within their environment. These cultural choices form a coherent pattern that informs every aspect of their lives, creating a particular mode of interaction with the landscape* (Strang 1997: 276).

There are also likely to be differences between traditional Batswana pastoral practices and those employed by farmers with European backgrounds (Peters 1984).

An exploration of the influence of 'cultural character' on knowledge and beliefs about carnivores could therefore provide valuable insights into prevailing attitudes and help to inform policies aimed at reducing or preventing conflict. The cultural consensus method, which has grown out of cognitive anthropology, was employed to this end when looking at differences in knowledge of fishery issues between fishery scientists and hand-line fisherman in Hawaii (Miller *et al.* 2004). In order to explore this issue in the Ghanzi farmlands a questionnaire was devised to test for cultural differences based on cultural consensus theory. The desired outcome being a better understanding of how such differences, should they exist, influence attitudes and behaviour in order to facilitate the implementation of strategies and solutions that encompass the values of all groups.

Cultural consensus theory provides analytical methods and techniques which aim to estimate the degree to which individuals conform to a set of cultural beliefs or knowledge. The cultural consensus model (CCM) exists in two forms – formal and informal. The formal version of the model scores individuals by whether they provide correct or incorrect answers to a set of questions and provides information on the proportion they know. Competence scores are estimated by performing pairwise comparisons to ascertain the similarity in response between all pairs of participants. This study utilised the informal CCM which has been described as a 'factor analysis of people' as it provides competence scores based on the level of agreement of an individual's answers to those of the group (Weller 2007). This model makes no assumptions about the inherent 'rightness' or 'wrongness' of an answer, the correct answer to a question is generated by the responses of the participants. As Romney *et al.* (1987) explain: "In this sense it is neutral about the cultural content and structure of the domain under consideration." (Romney *et al.* 1987 p. 164)

In order to utilise the cultural consensus model to analyse the questionnaire it was necessary to define the ethnic groups that participated in it. For the Afrikaner group this was relatively straightforward, but for other members of the white farming community was more complicated. It was decided to pool English-speaking, white Africans of European (usually British) descent with expatriate Europeans, also usually British, to create one group. The reasoning behind this was the clear social divide that exists between the white groups in the area. Historically, native Afrikaans speakers have preferentially socialised with each other and native English speakers likewise (although this division has broken down somewhat in the younger generation). In the past also, Afrikaners who switched to speaking English as a first language were viewed with suspicion and even contempt as it was seen as kowtowing to the English who were associated with the power base (Russell & Russell 1979). Russell and Russell (1979) summed up the importance of language in Afrikaner social divisions thus:

> *Language is the most central criterion of Afrikaner group membership, yet not all those whose mother tongue is Afrikaans are counted as Afrikaners. Afrikaans is also the home language of most Coloureds, who neither count themselves nor are counted by Afrikaners*[3] (Russell & Russell 1979 p. 67).

While the younger generation of Afrikaners in the Ghanzi farmlands are all brought up to speak both Afrikaans and English, many of the older generation still struggle with conversational English. The distinctive differences in the cultural frameworks of these two groups of European farmers in southern Africa was explored at length by Mazonde (1991) who described the Afrikaner farmers of the Tuli Block cattle ranching region of Botswana as being paternalist and seeing themselves "…to be keeping up, in their familism, an Afrikaner way of life" and to "have a familist or kinship ideology which harks back to Afrikaner peasant origins" (Mazonde 1991 p. 452). In contrast, he characterised the farmers of British descent as individualists and technocrats with a social environment dominated less by the local community than by the state (Mazonde 1991). This cultural divide is highly visible in the Ghanzi area, where marriage between and among the early Afrikaner settler families has resulted in an extremely close knit community where today, most families are related to a greater or lesser degree. The group also has a strong support network underpinned by religious allegiance to the two Christian churches, the *Gereformeerde* and the *Nederduitse Gereformeerde* which ensures that the remoteness of many of the homesteads does not result in the isolation of the inhabitants. The ties of the English speaking community are weaker and more outward looking by contrast. Because of these differences it was thought likely that the native English speakers would have a similar cultural framework, distinct from that of the Afrikaners.

The questionnaire was constructed to test knowledge and beliefs about carnivores and required participants to identify eight predator species from colour photographs and then to indicate whether they agreed or disagreed with 25 statements about predators. Participants were told that agreement or disagreement did not have to be absolute, but could fall into the 'tend to

[3] This refers to the Afrikaner group throughout southern Africa, so while Coloureds are not a constituent ethnic group in Botswana, it illustrates the complexities surrounding inclusion or exclusion of the group.

agree/disagree' area. Questions were worded in such a way that approximately the same number was thought likely to elicit agreement as disagreement.

The cultural consensus database initially consisted of the binary responses (0 or 1) of 12 Afrikaners, seven African-Europeans or Europeans, four Batswana, two Bushmen and one Shona to these 33 questions in the cultural domain 'carnivores'. The participants were farmers, DWNP officers, farm workers and field guides/tourist industry workers who were all thought to have a similar level of 'competence' in the domain.

Rows of respondents and/or columns of propositions were removed from the analysis if a) less than 90% of respondents answered any question or b) a respondent failed to answer 90% of the questions. Once this had been achieved any remaining 'don't know' responses were replaced by a 0 or a 1 by the flipping of a coin. This is considered an acceptable practice (albeit arbitrary) in such circumstances (Weller 2007). To test the sensitivity of the data to this, the values obtained by the flipping of the coin were then reversed and the data analysed again. The resulting response matrix of 26 rows (respondents) and 30 columns (propositions in the cultural domain 'carnivore') was analysed in Ucinet 6 for Windows (Borgatti *et al.* 2002) using the covariance method in the Consensus Analysis tool.

There are three criteria that need to be met in consensus analysis in order for a conclusion to be drawn that all respondents conform to a single underlying pattern of agreement. These are that 1) the ratio of the first to second eigenvalues is 3 to 1 or higher (where an eigenvalue is the column sum of squared loadings for a factor and conceptually represents the amount of variance accounted for by a factor); 2) the first factor explains a large degree of the variance and 3) there are no negative competencies on the first factor (Ross 2004).

Consensus analysis of the response matrix for the cultural domain of carnivores across all participants provided strong support for a single shared cultural knowledge base with an eigenvalue ratio of 15.769, a mean competence score of 0.813 and no negative competencies (Table 6.2). The sensitivity analysis produced very similar results with an eigenvalue ratio of 15.795, a mean competence score of 0.816 and no negative competencies, consequently only one set of results are reported.

In order to assess the difference in responses between the three main groups, individual consensus analyses were also performed. While there was consensus overall, the three groups had different patterns of response with higher competence values for Afrikaners and African-Europeans/Europeans than for Batswana. The lower competence value (0.611) coupled with the small sample size (n = 4) for the Batswana group does however mean that this is not statistically significant at the 95% confidence level, while the high competence values and larger sample sizes of both Afrikaner and African-European/European groups are significant at the same level (Romney *et al.* 1986)(Table 6.2).

Table 6.2 Consensus analysis results
Values shown are mean, standard deviation, minimum and maximum cultural competency values for each ethnic group, plus the ratio of first to second eigenvalues

	All respondents* (*n*=26)	**Afrikaner (*n*=12)**	**Af-European/European (*n*=7)**	**Batswana (*n*=4)**
Mean	0.813	0.885	0.877	0.611
SD	0.138	0.049	0.030	0.147
Minimum	0.415	0.756	0.852	0.403
Maximum	0.956	0.964	0.938	0.748
Eigenvalue ratio	15.769	18.114	20.81	5.028

* Two additional ethnic groups were represented in this category but sample sizes were insufficient for individual analysis

The agreement matrix generated from the consensus analysis was further analysed using non-metric multidimensional scaling in order to provide visual representation of the similarity between participants in their responses to the statements. The first two dimensions of this multidimensional scaling (stress = 0.113, iterations = 24) are presented in Figure 6.18.

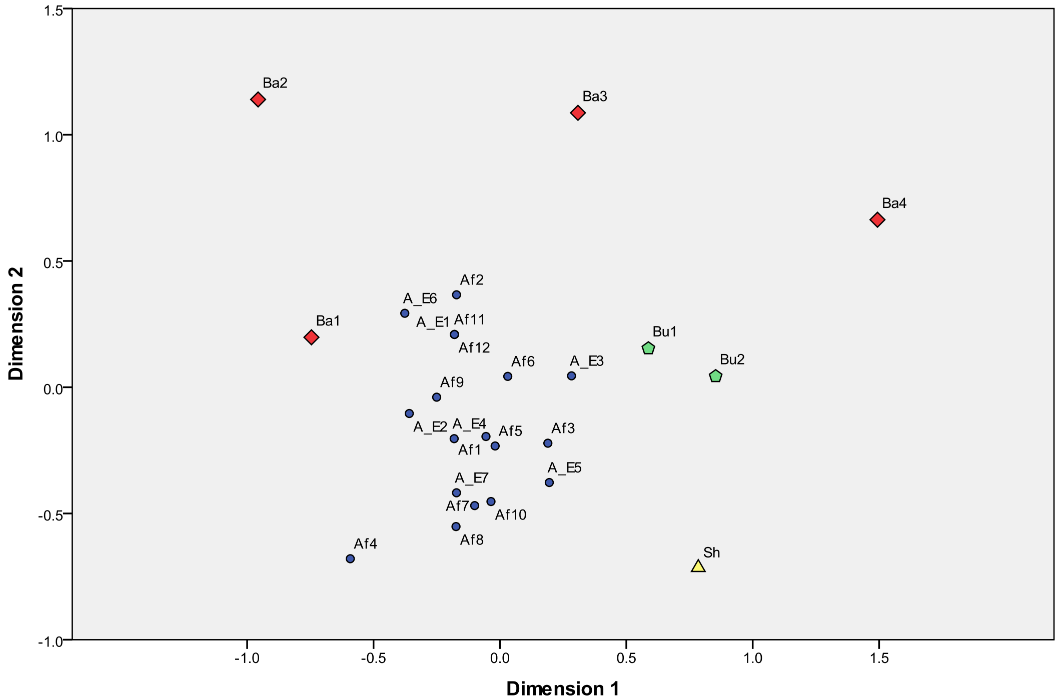


Figure 6.18 Non-metric multidimensional scaling of agreement matrix of five ethnic groups for the domain 'carnivores'.
Af=Afrikaners & A-E=African-European/European (●); Ba=Batswana (◆); Bu=Bushmen (⬟); Sh=Shona (△).

Each respondent is represented in the plot and identified by the group to which they belong. There is considerable overlap between the Afrikaner and African-European groups but the clustering of the Batswana at the top of the plot suggests that, while members of this group responded similarly to each other, their responses differed from those of the other groups for at least some questions. Similarly, the two Bushmen participants cluster on the right and the one Shona respondent also sits outside the Afrikaner/European cluster. Unfortunately, insufficient numbers of Bushmen were sampled to enable them to be analysed separately as a group and it is possible that with a larger sample, a divergence from cultural consensus would be found. This is also possibly true of the Batswana group. In Table 6.3 the consensus-derived answer key for the predator identifications and propositions is presented. The five statements that produced differing responses from Batswana respondents to those of Afrikaner/European participants all pertained to behavioural traits of three species; brown hyaena, African wild dogs and cheetah. Two of these were statements of opinion linked to livestock predation (Questions 14 & 33) and three were statements of knowledge (Questions 22, 29 and 31).

Table 6.3 Consensus findings for predator knowledge across ethnic groups in the Ghanzi farmlands in 2009

	Section 1 – animal identification	**Correct**	**Incorrect**
1	Leopard	25	1
2	Jackal	26	0
4	Cheetah	26	0
5	Spotted hyaena	26	0
6	Lion	26	0
7	African wild dog	25	1
8	Brown hyaena	25	1
	Section 2 – statement agreement	**Agree**	**Disagree**
9	Predators live on farms	**26**	0
10	Cheetahs attack people	0	**26**
11	Leopards stay on one farm all of their lives	0	**26**
12	Game farms attract predators	**19**	7
13	Cheetahs attack livestock	**25**	1
14	*Brown hyaenas attack livestock (disagree for Afrikaners and Europeans, agree for Batswana)*	11	**15**
15	Caracals attack people	0	**26**
16	The number of jackals on farms is decreasing	5	**21**
17	Predators are an important part of the ecosystem	**26**	0
18	Caracals hunt in packs	1	**25**
19	Cheetahs move around from farm to farm	**25**	1
21	Caracals attack livestock	**25**	1
22	*African wild dogs are solitary hunters (disagree for Afrikaners and Europeans, agree for Batswana)*	4	**22**
23	Jackals attack livestock	**25**	1
25	Jackals sometimes hunt in packs	**22**	4
26	Cheetahs are an endangered species	**21**	5
27	Protecting natural game species reduces the likelihood of predators taking livestock	**22**	4
28	Leopards will return to a kill over several days	**25**	1
29	*Cheetahs hide their kills in trees (disagree for Afrikaners and Europeans, agree for Batswana)*	3	**23**
30	Leopards are an endangered species	8	**18**
31	*Brown hyaenas hunt in packs (disagree for Afrikaners and Europeans, agree for Batswana)*	2	**24**
32	Eradicating one species of predator has no effect on other species	1	**25**
33	*Cheetahs follow livestock herds on farms (disagree for Afrikaners and Europeans, agree for Batswana)*	14	**12**

Notes: questions are numbered according to original implementation; the culturally correct response for all groups is highlighted in **bold.** For questions where a group differed from the consensus it is detailed in italics and highlighted in yellow.

It would appear from this that the Batswana were slightly less knowledgeable about the natural history of some species and had differing opinions as to their threat level. For the questions relating to livestock predation this could be explained by the fact that only one of the Batswana respondents was a farmer while the rest were DWNP officers. The differences in response to the knowledge questions is more difficult to explain other than by the fact that many DWNP officers come from urban or semi-urban communities and may have not had the lifelong association with wildlife that most farmers have. To conclude, the analysis revealed that while there was overall consensus amongst groups on most questions, there was also disagreement on a few. It is however acknowledged that ethnic group is only one of the differentiating factors that could have been utilised to analyse these data.

6.5 Stakeholder solutions and strategies

Taking into account the views, opinions and perceptions expressed in previous sections leads to the question of what possible solutions farmers think there may be to the conflict between farmers and predators. Responses were broken down into different categories in the same way as was done for previous questions regarding views on sharing the land. When looked at by farm type the game farmers were unanimous in their preference for trophy hunting as a solution to conflict. Domestic livestock farmers on the other hand had a more diverse set of opinions. Trophy hunting was still the most popular (6 respondents), but other options such as a change in management practices (4) and translocation (2) were also favoured, while the possibility that there might not be any solutions was also suggested two farmers (Figure 6.19). Both were Afrikaner livestock farmers one of whom kept small stock. Changes in management practices were favoured by the three oldest age groups (Figure 6.20), perhaps indicating that this view comes with experience. However, none of the options was significantly more likely to be chosen by individuals from any farm type, ethnic or age group (G = 11.502, df = 7, p = 0.118). Interestingly, the management changes advocated mostly revolved around encouraging better management of, and protection for, wild game species in order to ensure that there was a good natural prey base for the predators, rather than major shifts in livestock husbandry. As one farmer said: "…..that's what happened here with me – when the game increased the predators are almost silent." The view that there are no solutions to the problem could be viewed as pessimism or perhaps as pragmatism; as this farmer succinctly put it: "If there were a solution there wouldn't be a problem ….people would have been doing it".

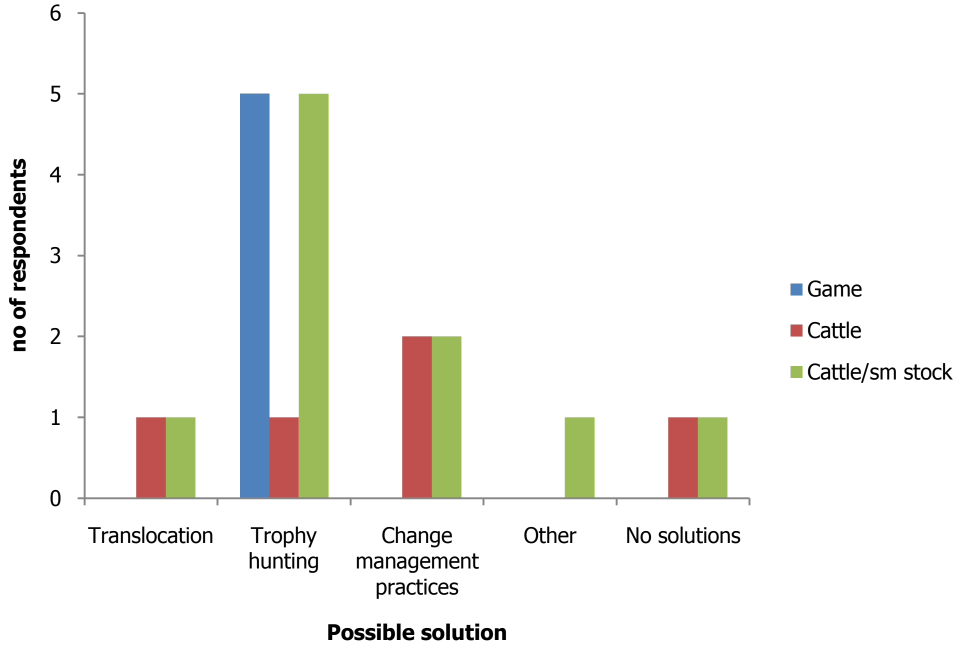


Figure 6.19 Possible solutions favoured by farmers to conflict with predators in the Ghanzi farmlands by farm type

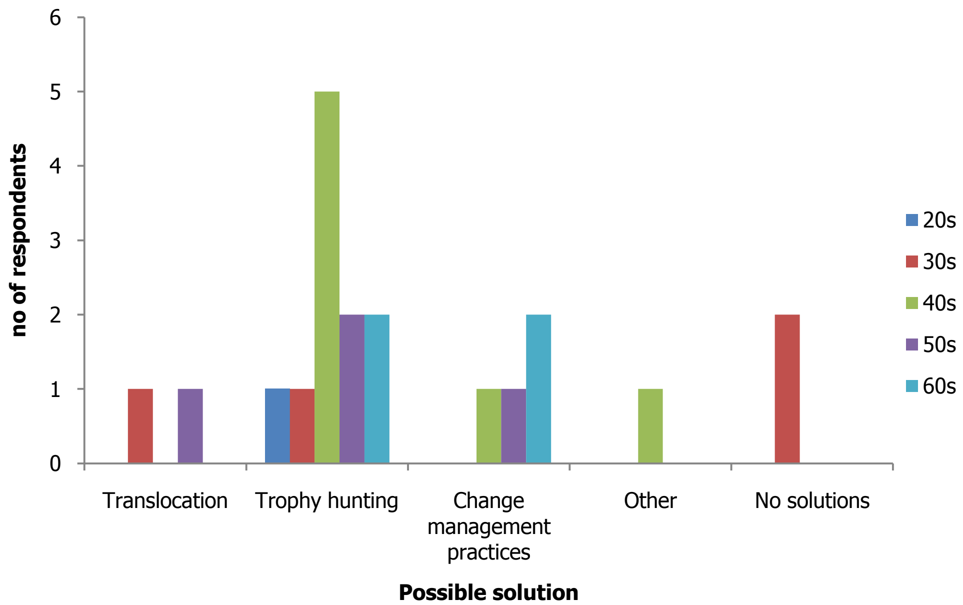


Figure 6.20 Possible solutions favoured by farmers to conflict with predators in the Ghanzi farmlands by age group

6.6 Conclusions

Livestock depredation is undoubtedly an issue in the Ghanzi farmlands, although its effects are variable in their impact and are not evenly spread. Other issues also emerged as being high on the list of concerns for some stakeholders, such as disease, drought and theft. The latter in particular appeared to be a major, although sometimes unacknowledged, factor in some parts of the farm block.

One of the strongest messages to emerge from conversations with farmers in the Ghanzi area was the view, expressed by many, that there was a lack of involvement and consultation between the government and them concerning the issue of predators on farmland. There was a feeling that their views were considered to be of no importance and were not taken into account when policy was drawn up and implemented. Such feelings have been documented in areas of human-carnivore conflict in the past (Rabinowitz 2005) and must be taken into account if resolutions are to be found (Treves *et al.* 2006).

There was also a fear amongst many that if they were honest about what was really happening they would be reported to DWNP and would end up being prosecuted and fined. While on the other side there was a sense among some DWNP officers that they did not want to upset the farmers and were walking on eggshells around them. The unwillingness of some farmers to engage with DWNP PAC initiatives makes the statistics on livestock predation in the area at best unreliable and misleading at worst. While there was also a view among some DWNP officers that the distrust with which some farmers viewed conservation NGOs and researchers was purely based on concerns that hunting quotas might be reduced if research showed that populations, of leopard in particular, were lower than thought. This failure of communication on all sides appeared to be a major factor in the problems in the area.

There was also a strong sense, among a few farmers at least, that they were working to provide food and wealth for the country but were not viewed as part of it. This may of course be an inevitable consequence of being a minority group, albeit one with some power and influence. It may also have as much to do with the Afrikaner 'closed shop mentality' as with the Batswana's ambivalence towards a group they view as being, to a certain extent, outside of their control. This leads into the issue that aroused most dissatisfaction among the livestock farmers spoken to during this study, that of the issuing of licences for the hunting and shooting of problem animals (in effect this means leopard as that is the only species for which there is an economic return.) Domestic livestock farmers were particularly concerned that they had been factored out of the equation as a result of the changes in policy surrounding the issuing of licences. The view, voiced at the skin auction, that it had resulted in domestic livestock farmers effectively opting out of the system, by deciding not to report problem animals to DWNP and then killing them themselves, could have serious consequences for the leopard population. The use of poison as a tool to deal with 'problem animals', and the collateral damage caused to other species as a result, is also of great concern. A review of the regulations regarding the sale and supply of pernicious substances such as Temik® is urgently required.

Many of the polarised views expressed likely stem from the highly segregated society that exists in the area. The history of Afrikaner settlement as described in section 2.2 led to the creation of an extremely tight knit community with a high degree of interrelatedness amongst the families. This is still largely true today and there is little interaction between the white minority and the Batswana (or any of the other ethnic groups) other than at the official interface. However, there was no strong evidence of knowledge of carnivores being governed by the ethnic identity of an individual.

A reluctance on the part of the famers to buy into government- and NGO-led initiatives to mitigate human-wildlife conflict outside protected areas, especially where the areas concerned are their farms was certainly apparent. This is not a unique phenomenon. In South America, where conflict between cattle ranchers and the jaguar has a long history, the ranchers indicated that they felt as though they were being treated as part of the problem rather than the solution (Rabinowitz 2005). In this situation however, it may also have its roots in the reluctance to engage with the state that is part of the history of the Afrikaner group. Rabinowitz (2005) also reported consistent mismatches between the beliefs of ranchers and those of conservationists as to whether a particular predator was plentiful or scarce, and such contrasting opinions *between* different stakeholders *about* predators have also been highlighted elsewhere (Knight 2000a). This theme constantly surfaced in conversations with farmers in the Ghanzi area. The feelings of disempowerment expressed by many also seem to have been exacerbated by legislation designed to protect species that are classified as endangered at a global or regional level such as the cheetah, but are perceived as common and numerous locally. This possibility has also been suggested by Selebatso (2008) and the phenomenon has been highlighted in other communities and with reference to other species (Naughton-Treves & Treves 2005; Bell *et al.* 2008). As recommended elsewhere, policies tailored towards local needs and concerns are more likely to result in the engagement of stakeholder groups with those policies (Hampshire *et al.* 2004).

There was also a feeling among some farmers that conservation NGOs were not getting a complete picture of what was happening in the area as they were either not trusted, or their roles and aims were not clearly understood. In this area, they may have fallen into the trap that always exists for outsiders, such as NGOs or researchers, of being seen as agents or allies of the authorities and their effectiveness being neutralised as a result (Treves *et al.* 2006).

While the existence of a state-funded compensation system is laudable and provides some recompense to farmers, dissatisfaction with its structure and implementation was apparent from most of the farmers spoken to. There is no doubt that the framework of the system needs to be reassessed with consideration given to incentives for better livestock husbandry, more realistic compensation levels, a less restrictive and bureaucratic reporting system and better trained PAC officers. There is also a need for the list of species for which compensation is awarded to be adjusted to include all the large- and medium-sized predators and possibly feral domestic dogs as well. Without this the PAC records will never provide an accurate reflection of the level of predation or of the species that are causing it. An alternative strategy proposed by Sillero-Zubiri & Switzer (2004), would see all farmers being paid a lump sum in return for their tolerance of predators. This would certainly remove the unwieldy bureaucracy involved in the compensation system as well as the temptation for false reporting. But it would require considerable cooperation between the various farming communities and the state to set the amount at a level that would satisfy everyone.

It is unfortunate that the potential for changes in livestock husbandry practices appear to be limited, especially with regard to cattle, due to the nature of the environment. However, that does not mean that improvements could not be achieved. In particular, more assiduous record keeping during calving would enable farmers to better keep track of their livestock and account for young animals. The holistic farming methods practised by a few cattle farmers in the area, and described in Chapter 2, are both profitable and sympathetic to wildlife. It cannot be denied however that the system is both labour and management intensive. For farmers with small stock there are undoubtedly measures that could be adopted by some, such as more consistent and widespread use of livestock guarding dogs and, as for cattle, better record keeping.

Many of the stories and experiences related in this chapter emphasise the point made by Treves *et al.* (2006) that such narratives may carry more weight than scientific data in the understanding of human-wildlife conflict situations and that, as a result, interventions that are successful in reducing economic losses at one level, may not alter general perceptions about that conflict. There is no doubt that steps need to be taken to avoid any human-wildlife conflict interventions in this area from appearing weighted in favour of the wildlife (Treves *et al.* 2006). It has been suggested that in such situations escalation can lead to an additional conflict, namely that *between* humans *about* wildlife (Madden 2004) and this certainly seems to be the case in the Ghanzi farmlands.

The all too familiar nature of the themes and concerns outlined above have been documented frequently in human-wildlife conflict research over the years. And yet overall, the majority of farmers encountered in this study were deeply engaged with their environment and its wildlife and concerned about the level of biodiversity on their land. They were also generally knowledgeable with regards to carnivore behaviour. Many actively encouraged the wild game on their farm and took active measures to deter and prevent poaching. Additionally, the relatively relaxed attitude to predators amongst game farmers was in stark contrast to the attitudes and actions reported on commercial game ranches in Namibia, where a large proportion of cheetahs trapped by owners for removal were on game farms (Marker *et al.* 2010). There were some exceptions to this rosy picture however, and there were worrying stories about the activities of some workers who had been left to manage farms for absentee owners with insufficient resources or money. These farm workers were the focus of many complaints of theft, snaring, poaching and hunting with dogs. The issue of absentee landlords is not a new one as even in the early 1970s it was estimated that one third of the farms in the area fell into this category (Russell & Russell 1979) but it is one that undoubtedly has an impact on land management and wildlife conflict.

The Ghanzi farm block is by no means unique amongst farming communities in southern Africa and while the particular mix of social groups may be peculiar to the area, the basic power structure is all too familiar. It is almost certainly the case that a complete change in land management practice and attitudes to wildlife could be effected by convincing a group of only 30 to 40 people. The barriers to that happening may be compounded by the different understanding of issues and concepts inherent when you have groups of people of different ethnic backgrounds who do not have the same language as their mother tongue.

Inherent in this description is the complexity that is to be found in the beliefs and practices of any group of people regardless of their ethnic background, and this is undoubtedly the case in the Ghanzi farming community where time, and relationships between and among people, have served to blur the dividing lines between those groups.

This chapter has demonstrated that, although the size of the farms and the nature of the environment in the Ghanzi farmlands is such that density of both human and wildlife populations is low, for the farmers there is, nevertheless, a high degree of awareness of, and contact with, the carnivores and prey species on their land. But has living in such close proximity to humans and livestock led to modifications in the behaviour and activity patterns of these animals from those recorded in protected areas where disturbance levels are low? Determining any such variations in behaviour could be of great importance in the formulation of plans for their conservation. The final data chapter of this thesis therefore will revisit the carnivores and wild prey species of the Ghanzi farmlands to determine if the attitudes and activities of the human population have affected behaviour and activity patterns of the wildlife either spatially, temporally or both. Equally, the activity of the carnivores will be examined to investigate whether the behaviour of some species may have affected the way they are perceived in the minds of the farmers.

Chapter 7 - Carnivore and prey activity patterns in the Ghanzi farmlands

7.1 Introduction

Chapters 4 and 5 established the current status of carnivore and wild prey populations in the Ghanzi farmlands and in Chapter 6 the attitudes and perceptions of farmers towards those species was investigated. In that chapter, evidence was presented that suggested that cheetah are disproportionately disliked by farmers, and it was hypothesised that this phenomenon could be driven by the more diurnal activity pattern of the species. Furthermore, more than half of respondents to the Cultural Consensus questionnaire agreed with the proposition that cheetahs follow livestock herds on farms. In this respect several issues in the previous chapter regarding farmers perceptions of wildlife are drivers of the questions that will be addressed in this chapter.

Additionally, while the information presented in Chapters 4 and 5 regarding the presence and/or density of carnivores and their prey is extremely valuable in assessing their potential for conservation, it is incomplete without knowledge of their movement and activity patterns. Data collected in spoor and camera surveys could be influenced by the level of track use by a species, and the extent to which animals range across different farm properties may influence farmers' perceptions of their abundance. From an ecological standpoint it is also of interest to know how animal activity patterns may differ from those of populations inside protected areas, as it is possible that populations that exist outside such areas may have adapted or modified their behaviour in response to the disturbance levels associated with a farming environment.

In order to investigate these issues, detail on the movements and activity patterns of the species highlighted in Chapters 4, 5 and 6 will be analysed here. Once again this will be achieved utilising the data obtained from the spoor and camera surveys. Questions to be addressed in this chapter are:

1. What are the daily activity patterns of carnivore and prey species in the Ghanzi farmlands?
2. How do these activity patterns compare with those reported for protected areas?
3. Are carnivore activity patterns influenced by external factors such as the lunar cycle?
4. Is predator movement linked to the movement of livestock as suggested in Chapter 6?
5. Do different carnivores use farm tracks to a greater or lesser extent?
6. What are the ranging patterns of carnivores in the Ghanzi farmlands?
7. Can a link be made between activity pattern and/or ranging pattern of a carnivore species and the way it is perceived by farmers?

Knowledge of the activity and movement patterns of Africa's carnivores is relatively sparse and largely confined to populations that occur in protected areas, such as for leopard in the southern Kalahari (Bothma & Bothma 2006), brown hyaena in the Central Kalahari (Owens & Owens 1978) and black-backed jackal in southern Botswana (Kaunda 2000). There are however, a few studies that have been conducted on private land (e.g. Mizutani & Jewell 1998; Marker & Dickman 2004; Marker & Dickman 2005), and several factors associated with such populations outside protected areas suggest that patterns of activity of carnivores may be modified (McVittie 1979; Kaunda 2000). These include human disturbance and persecution, competitive release caused by the extirpation of one or more species in a guild, and the activity and movement patterns of prey species. Such features may determine the level of territoriality, ranging behaviour and/or daily activity pattern of a species (Van Dyke *et al.* 1986; Tuyttens *et al.* 2000; Loveridge & Macdonald 2001; Kolowski & Holekamp 2009; Hayward & Slotow 2010). Information on the daily activity patterns of natural prey species is even rarer, despite the existence of a considerable body of research across a range of African ungulates.

In the Ghanzi farmlands, lions have been almost completely extirpated, spotted hyaena are rare (except in the north and east) and African wild dog remain at only a fraction of their historical numbers. Leopards and cheetahs however are still present, leaving them as the top predators (see Chapters 3, 4, 5 and 6). Understanding how the behaviour of these species differs from that of more protected populations could be an important management tool in the consideration of conservation options and plans. This is of particular significance in commercial farmland where carnivores and people live in close proximity and natural prey species are heavily outnumbered by domestic livestock.

The level and nature of interaction between carnivores and people in such a landscape can also affect the perceptions and attitudes of people towards those species (Knight 2000b). It has been hypothesised for instance that the social behaviour of the cheetah and its diurnal activity pattern might render it more visible than other more solitary and nocturnal predators thereby disproportionately increasing its prominence in the minds of people (Marker *et al.* 2003c). Predator species are also likely to vary in their use of human constructed tracks and trails which could affect the likelihood of their spoor being detected in spoor surveys, and may also influence the placement of cameras in camera trapping surveys. The movement behaviour of predators in this respect could also affect their visibility level and by extension the perceptions of people with regard to their abundance. In the search for solutions and measures that can mitigate conflict, an understanding of the factors that might drive those attitudes is crucial.

In an environment that is managed for livestock, knowledge about carnivore movement and activity in relation to that livestock is of some consequence, but such information is not easy to acquire. Indeed the gathering of such data is made even more difficult in areas where livestock are free-ranging as it is generally not possible to determine definitive locations for livestock herds with which to compare the location of carnivores, even if those carnivores are radio-collared. In the Ghanzi farmlands, however, there are several landowners who operate rotational grazing plans, and a few that practise holistic farming under the Holistic Resource Management plan (Savory 1988). Holistic farming requires grazing plans to be strictly controlled and monitored (see section 2.1 for more details on this) providing an opportunity for comparisons to be made between livestock and carnivore movement.

7.2 Methods

Details of the methodology used for the three camera trap and two spoor surveys carried out in different areas of the farm block are to be found in Section 2.2i. Additional information on the camera trap surveys were presented in Section 4.2.

7.3 Data analysis

In order to address Question 1, daily activity patterns were derived from camera trapping data using all photographic captures obtained during the research period both pre- and post-surveys. Activity was grouped into eight three-hour intervals to reduce the bias that may have been apparent from a low number of captures for some species.

7.3i Overlaps in activity

Percentage overlaps in activity patterns were calculated according to protocols outlined by Krebs (1989)and based on Renkonen's (1938, cited in Krebs 1989) percentage similarity measure. Proportion of activity was grouped into eight three-hour intervals as before and percentage overlap was calculated using the following equation:

$$P_{jk} = \left[\sum^{n} \left(\min P_{ij}, P_{ik} \right) \right] 100$$

where P_{jk} = percentage overlap between species j and species k

P_{ij}, P_{ik} = proportion resource *i* (activity in time period) is of the daily activity pattern of species j and species k

n = total number of time periods

7.3ii Activity relative to the lunar cycle

Addressing Question 3, movement of predators relative to the lunar cycle was analysed using camera trapping and spoor survey data by comparing encounters (photographic or spoor) on any given day with the phase of the moon on that day. Moon phase was described in terms of 'percentage full', whereby a full moon was classed as 100% and a new moon as 0%. Camera

Base version 1.3 (Tobler 2007) determines whether a photographic capture falls into day, night or crepuscular category from information on sunrise and sunset times at the geographic coordinates entered for the survey. For species with at least five night encounters in three of the four moon phases, it was therefore possible to determine from camera trapping data if activity levels at night varied according to the phase of the moon. The phase of the moon on all days on which camera traps were operational and that spoor transects were driven was determined using Quick Phase Pro version 3.3 (BlueMarmot Inc. 2010). Sampling occasions were then grouped into four categories of moon phase 0-25%, 26-50%, 51-75% and 76-100% of full. The proportion of days from each survey that fell within each phase of the lunar cycle was calculated to facilitate the calculation of a chi square statistic. For analysis of day/night activity during each lunar phase, only camera trapping data obtained during the three 62-day surveys was utilised and once again the proportion of days which fell within each phase of the moon was calculated.

7.3iii Predator movement relative to that of livestock

To address Question 4, predator movement in relation to the movement of cattle on the farm where Camera Survey 1 (CS1) and Spoor Survey 2 (SS2) were carried out was achieved by determining cattle movement in areas of individual camera stations and sections of transect was determined. The farm operates a strictly controlled rotational grazing system. The cattle were grouped into three different herds and the farm itself was divided into eight camps, each containing eight cells (Figure 7.1). For every day of the camera survey each station was scored as being either inside or outside a cattle zone and capture frequency indices, derived from the number of independent photos/trap day (RAI_2), were then calculated and compared for each station in both conditions. Spoor survey transects were divided into sections dependent on which camp they fell in. Predator spoor was then counted for days the section was driven when cattle were present in that camp and for days when they were not. In the case of transect sections that traversed the border between camps, these were deemed to have cattle present when cattle herds were in any of the surrounding cells. Spoor densities were then calculated and compared. All statistical analyses were performed using Minitab version 15 (Minitab Inc. 2007).

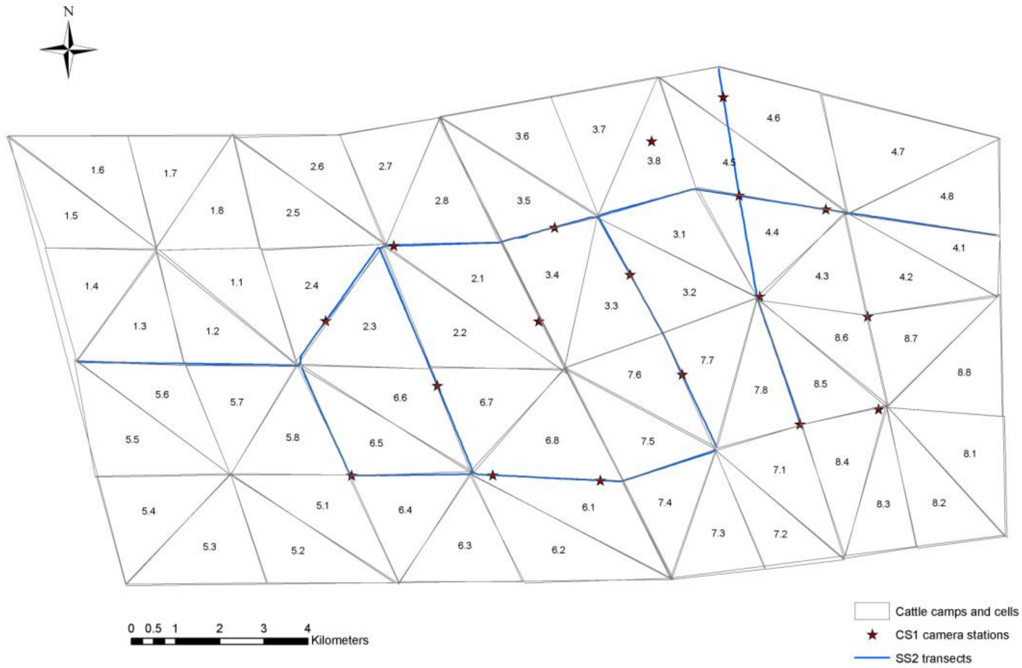


Figure 7.1 Map of farm on which CS1 and SS2 were carried out showing camps and cells, camera stations and transects

7.3iv Track use by predator species

In order to quantify any differences that may exist in track use by different predators additional data on each animal's movement was recorded during the two spoor surveys. Three variables were used: a) the animal was recorded as having crossed the track b) the animal travelled along the track for less than one kilometre c) the animal travelled along the track for more than one kilometre.

7.3v Ranging behaviour of leopard and brown hyaena

Addressing Question 6, polygons of area covered by brown hyaena and leopard were created for animals that were photographed at three or more different camera stations and the size of the area calculated using ArcGIS 9.3 (ESRI Inc. 2008).

7.4 Results

7.4i Daily activity patterns

Daily activity patterns for the five medium- to large-sized carnivores present in the study area as determined from photographic captures are illustrated in Figure 7.2. Cheetah activity was noticeably crepuscular with a peak of activity between 06:00 and 09:00 when 45% of photographic captures occurred and another smaller peak between 18:00 and 21:00 accounting for a further 25% of captures. The activity patterns of brown hyaena, leopard, caracal and jackal were all broadly nocturnal although there was more daylight activity apparent for leopard, caracal and jackal than for hyaena. Over 57% of brown hyaena captures occurred between 18:00 and 00:00, with a further 39% between 00:00 and 06:00. Similarly, 50% of leopard photos were acquired between 18:00 and 00:00 and a further 33% between 00:00 and 06:00. The peak of caracal activity was between 18:00 and 03:00, this accounted for over 66% of all captures. Jackal activity was fairly evenly spread between 18:00 and 06:00 with more than 77% of captures occurring during this time. There was no significant correlation between the percentage of daylight activity for these five species and the percentage of farmers (n = 20) who named each as their number one problem predator (p >0.05).

Activity patterns for four naturally occurring prey species are presented in Figure 7.3. Duiker exhibited crepuscular peaks but were the most noticeably nocturnal with over 72% of activity recorded between the hours of 18:00 and 05:00 and very little between 08:00 and 18:00. Steenbok showed a strong crepuscular peak in the morning but were largely diurnal with more than 80% of activity occurring between 06:00 and 18:00; warthog were similarly diurnal with 57% of captures between 09:00 and 18:00. Kudu were cathemeral with captures fairly evenly spread throughout the 24-hour period (Figure 7.3).

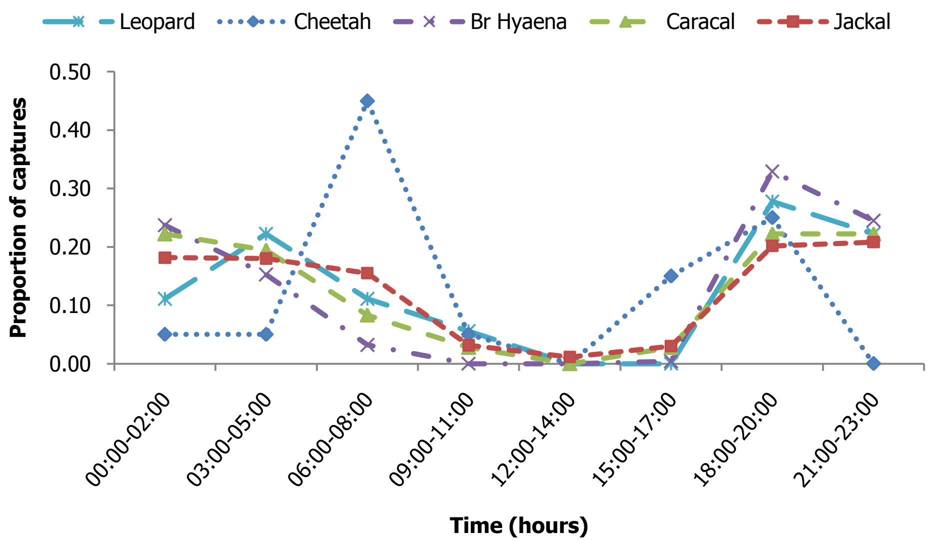


Figure 7.2 Proportion of photographic captures occurring in eight three-hourly segments for five species of carnivore during three camera surveys in the Ghanzi farmlands in 2009

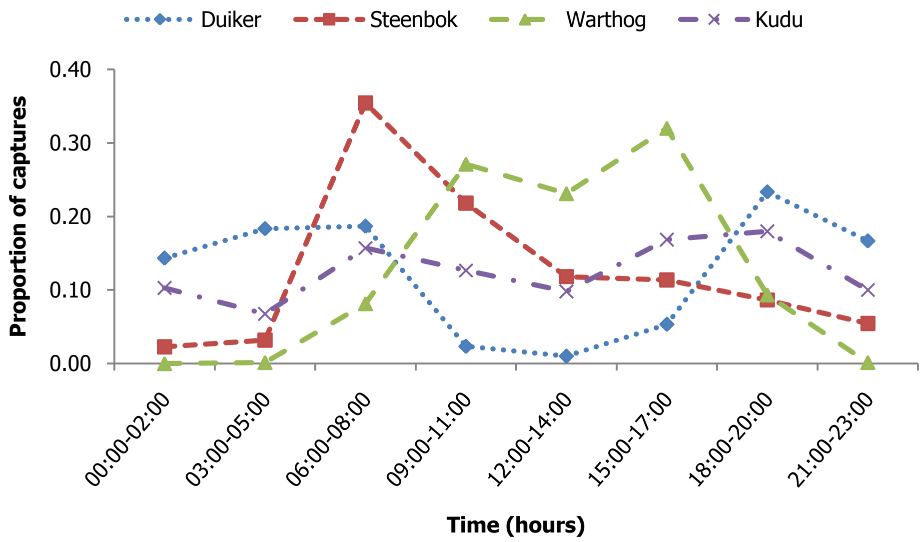


Figure 7.3 Proportion of photographic captures occurring in eight three-hourly segments for four naturally occurring prey species during three camera surveys in the Ghanzi farmlands in 2009

For the game farm species (Figure 7.4), all were active throughout the day and night with eland displaying a noticeable crepuscular peak between 18:00 and 21:00 when 29% of photographic captures occurred (see Table 4.5 for full photographic capture details). All species except gemsbok reduced their activity levels between 12:00 and 15:00, the hottest part of the day. Gemsbok activity increased during this period (Figure 7.4).

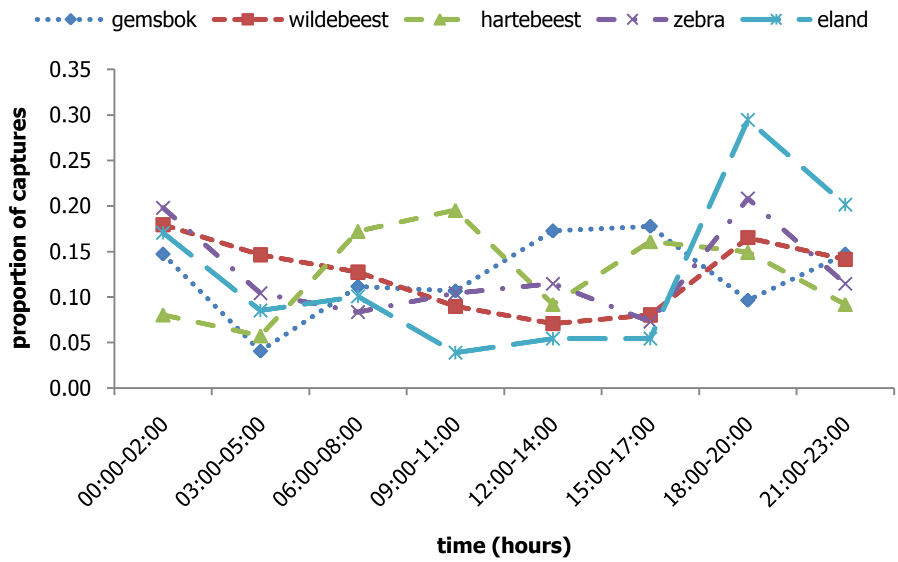


Figure 7.4 Proportion of photographic captures occurring in eight three-hourly segments for five game farm species during one camera survey in the Ghanzi farmlands in 2009.
No. of captures: gemsbok = 138; wildebeest = 134; hartebeest = 63; zebra = 80; eland = 105

For three of the carnivore species there were sufficient data (see Table 5.2 for details of captures) to enable comparisons between summer and winter activity patterns (Figure 7.5). Brown hyaena and caracal activity both displayed a strong crepuscular peak at dusk in winter which occurred earlier than in summer with the change in sunset time. The commencement and cessation of nocturnal activity for jackal did not vary between summer and winter but the peak of activity occurred earlier in winter (Figure 7.5).

Activity patterns of jackal overlapped those of duiker and kudu by >65% and of steenbok by 42%. Cheetah activity overlapped that of all prey species by at least 37%. For leopard, activity overlapped with all prey species by at least 35% with the exception of warthog. Caracal activity overlapped most with that of duiker (84%). Brown hyaena, as scavengers, are not thought likely to be affected by activity of prey species, but overlapped with duiker and kudu by more than 45% (Figure 7.6).

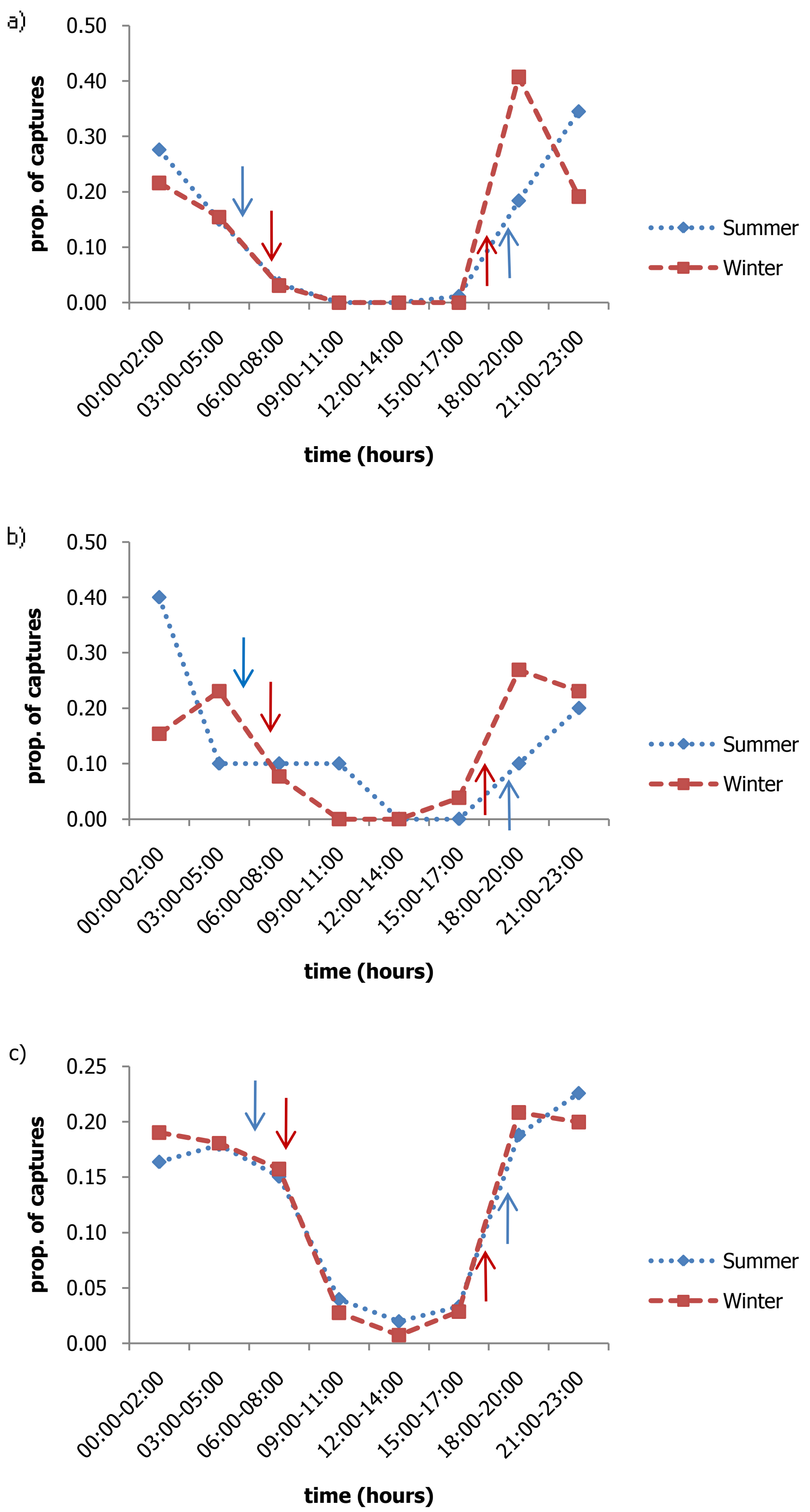


Figure 7.5 Proportion of photographic captures occurring in eight three-hourly segments in summer and winter for three species of carnivore during three camera surveys in the Ghanzi farmlands in 2009
a) brown hyaena; b) caracal; c) black-backed jackal.
Solstice sunrise and sunset times for summer are indicated by blue arrows and for winter by red arrows

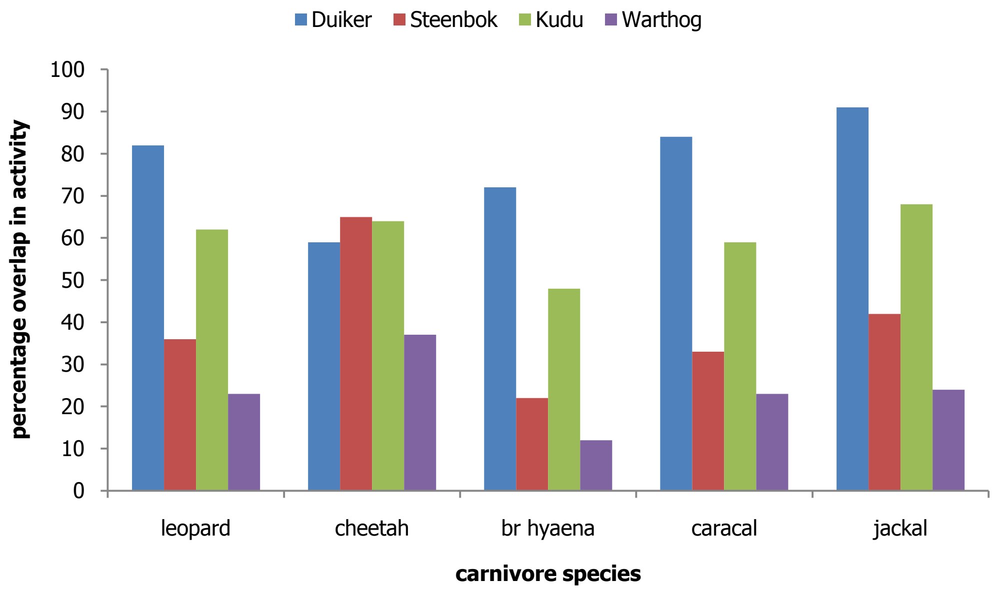


Figure 7.6 Percentage activity pattern overlap between five species of carnivore and four prey species

7.4ii Movement of predators relative to the lunar cycle

All camera trap and spoor survey data for the five medium- and large-sized predators were examined and the date of each encounter was compared with the phase of the moon at that time. As described in section 7.2, the moon phases were divided into four categories, with encounters being classed as falling into 0-25%, 26-50%, 51-75% or 76-100% of the full moon. Survey effort for each phase was not equal, so the number of camera trap days and transects driven in each phase were calculated and the mean number of encounters (photos taken or spoor encountered) per species in each phase was calculated and is presented in Figure 7.7a. Due to the large number of jackal and brown hyaena encounters the data are also presented minus these two species (Figure 7.7b). A chi-square goodness-of-fit test was used to test for differences between the numbers of observed and expected encounters in each moon phase, where the proportions were adjusted to take account of the differing survey effort. Encounters did not vary significantly between the different phases of the lunar cycle for leopard ($\chi^2 = 1.26$, $df = 3$, $p = 0.738$)(there were however, two expected values <5 for leopard so this result may not be reliable), cheetah ($\chi^2 = 2.708$, $df = 3$, $p = 0.439$) or caracal ($\chi^2 = 3.135$, $df = 3$, $p = 0.371$). Minitab (Minitab Inc. 2007) provides information on the contribution to the chi square value by category, and for brown hyaena there was a significant difference in encounter levels, with fewer in the 0-25% and 51-75% phases than expected ($\chi^2 = 17.497$, $df = 3$, $p = <0.001$), and also for jackal which were significantly less likely to be encountered in the 0-25% phase ($\chi^2 = 13.80$, $df = 3$, $p = 0.003$). There was a significant difference in night-time activity for brown hyaena with the number of photos taken at night fewer than expected during the 0-25% phase of the lunar cycle and more than expected in the 26-50% phase ($\chi^2 = 9.799$, $df = 3$, $p = 0.02$).

For caracal, there was no significant difference in night-time activity between moon phases (χ^2 = 1.601, *df* = 3, *p* = 0.659), while for jackal significantly fewer photos were taken during the 0-25% phase and more during the 76-100% phase (χ^2 = 54.611, *df* = 3, *p* = <0.001). Data for individual species are presented in Figure 7.8.

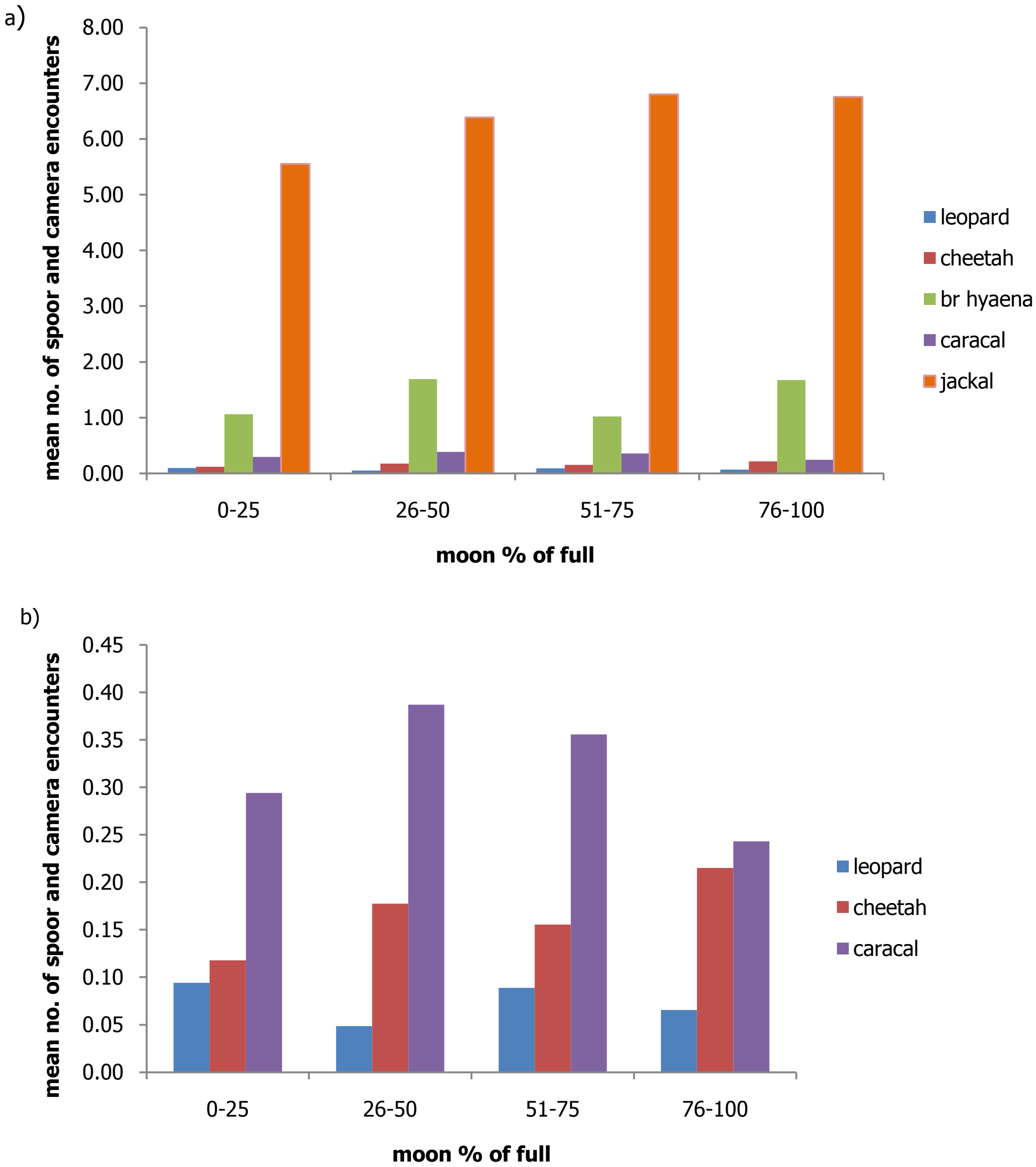


Figure 7.7 Mean number of spoor and photographic encounters across the lunar cycle in the Ghanzi farmlands in 2008/9
a) five species of carnivore; b) three species of carnivore

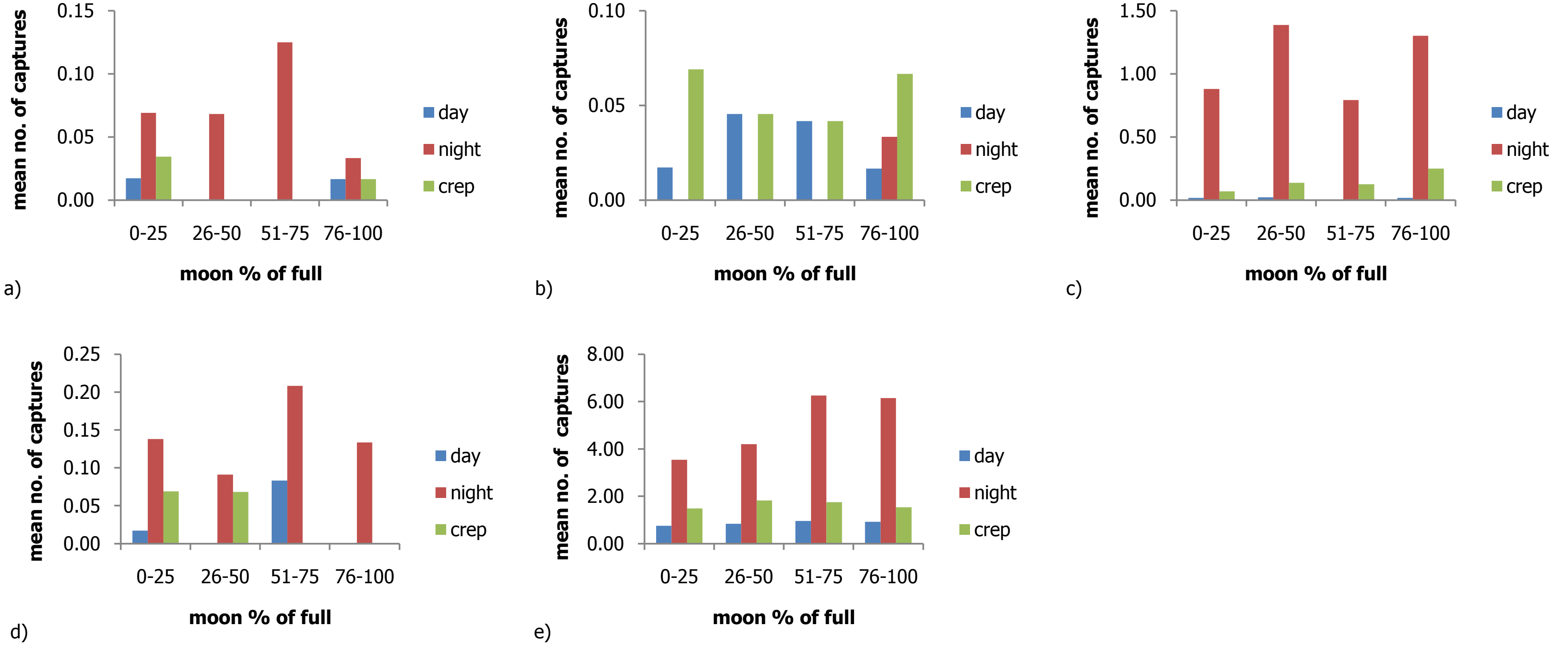


Figure 7.8 Mean number of photographic captures in day, night and crepuscular time zones during four phases of the lunar cycle for five species of predator during three camera surveys in the Ghanzi farmlands in 2009
a) leopard; b) cheetah; c) brown hyaena; d) caracal; e) black-backed jackal

7.4iii Movement of predators relative to cattle herds

Analysis of RAI_2 values obtained during the 62 days of CS1 (Figure 7.9) found no significant difference between the abundance of predators ($n = 5$) at individual camera stations when cattle were present in surrounding cells and when they were not present (Wilcoxon signed-rank test, $W = 96.0$, $n = 18$, $p = 0.663$). As jackals are known to feed on the placentas of calving cattle (pers.obs.) and therefore thought more likely to be in cattle areas for this reason, the same analysis was performed again looking at data for both jackal only and for all predators excluding jackal ($n = 4$). Again, there was no significant difference in the RAI_2 values (Wilcoxon signed-rank test, jackal only $W = 107.0$, $n = 18$, $p = 0.36$; predators minus jackal $W = 63.0$, $n = 18$, $p = 0.816$) between areas where cattle were present and those where they were not. For some stations in the above analysis there were low numbers of trap nights, for either cattle present and/or cattle not present, so the data were filtered to remove all stations that did not have a minimum of 10 trap nights for both states. There was no significant difference looking at all predators (Wilcoxon signed-rank test, $W = 44.0$, $n = 12$, $p = 0.724$), all predators minus jackal (Wilcoxon signed-rank test, $W = 24.0$, $n = 12$, $p = 0.760$), or jackal only (Wilcoxon signed-rank test, $W = 50.0$, $n = 12$, $p = 0.41$). A further analysis was performed looking only at cheetah, leopard and brown hyaena which again found no significant difference in RAI_2 values between stations in areas with cattle and those without, (Wilcoxon signed-rank test, $W = 55.0$, $n = 18$, $p = 0.518$). When the data were filtered by number of trap nights as before, there was still no significant difference in RAI_2 values (Wilcoxon signed-rank test, $W = 25.0$, $n = 12$, $p = 0.838$).

Analysis of spoor survey data found that for all predators ($n = 5$) spoor density (Figure 7.10) was significantly higher on sections of transect in camps where cattle were present than in those where cattle were not present (Wilcoxon signed-rank test, $W = 76.0$, $n = 13$, $p = 0.036$), but when jackal were removed from the dataset (Figure 7.11) there was no significant difference between predator ($n = 4$) spoor density in camps with and without cattle (Wilcoxon signed-rank test, $W = 59.0$, $n = 13$, $p = 0.126$) and when the analysis was performed with jackal only, there was a significant likelihood that they would be found in cattle areas rather than non-cattle areas (Wilcoxon signed-rank test, $W = 67.0$, $n = 13$, $p = 0.031$). However, as for the camera survey data there were some transect sections that had low values for the number of occasions they had been driven, for either cattle present or no cattle present states. The data were therefore filtered to exclude transect sections that had not been driven at least five times in each state and the analyses performed again. With this dataset, there was no significant difference in spoor density values between transect sections with or without cattle for all predators ($n = 5$) (Wilcoxon signed-rank test, $W = 24.0$, $n = 8$, $p = 0.441$), for all predators minus jackal ($n = 4$) (Wilcoxon signed-rank test, $W = 16.0$, $n = 8$, $p = 0.80$) or for jackal only (Wilcoxon signed-rank test, $W = 23.0$, $n = 8$, $p = 0.151$). It may be that the significant effect found in the unfiltered data was caused by the presence of an outlier in the jackal spoor density values on one transect section in the cattle present state. When the outlier was removed and the analysis performed again there was no significant difference in spoor density (Wilcoxon signed-rank test, $W = 55.0$, $n = 12$, $p = 0.056$), but there was a strong trend.

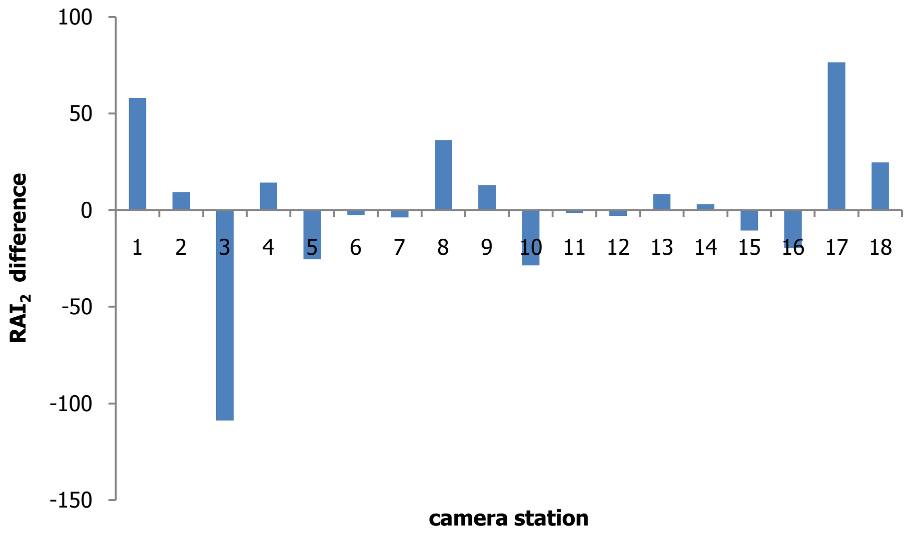


Figure 7.9 The difference between RAI_2 values of predators ($n = 5$) at all camera stations when cattle were present and not present during CS1
Positive values indicate higher levels of predator activity when cattle were present

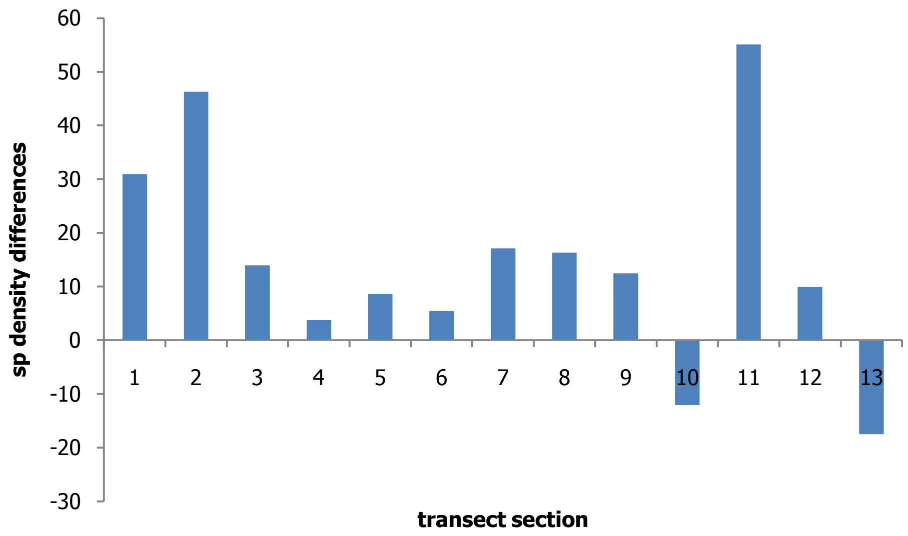


Figure 7.10 The difference between spoor densities of predators ($n = 5$) on all transect sections when cattle were present and not present during SS2
Positive values indicate higher levels of predator activity when cattle were present

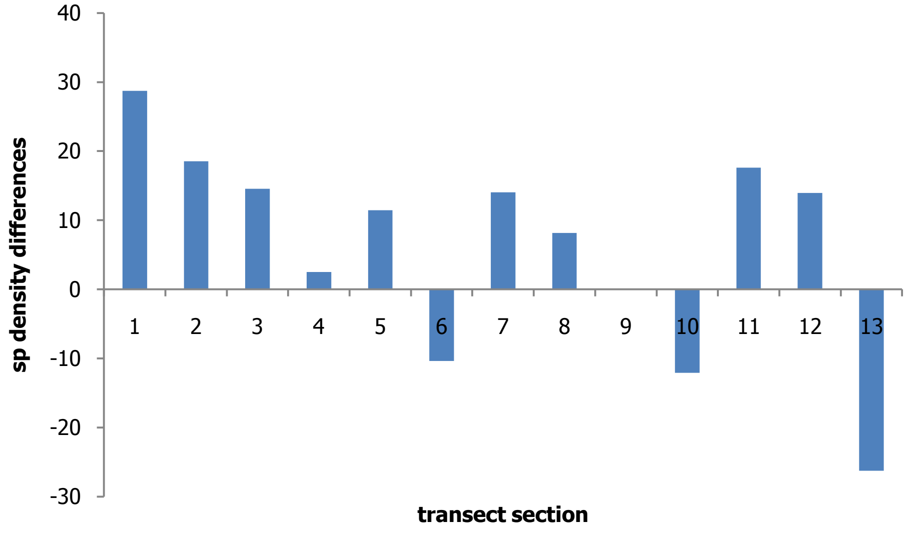


Figure 7.11 The difference between spoor densities of predators minus jackal (*n* = 4) on all transect sections when cattle were present and not present during SS2
Positive values indicate higher levels of predator activity when cattle were present

As for the camera trap data, a further analysis was performed looking only at cheetah, leopard and brown hyaena spoor densities. Again there was no significant difference between spoor density in camps with or without cattle present using all the transect sections (Wilcoxon signed-rank test, *W* = 59.0, *n* = 13, *p* = 0.126) or when filtering the sections by number of times driven as above (Wilcoxon signed-rank test, *W* = 14.0, *n* = 8, *p* = 1.0).

7.4iv Track use by predator species

The proportions of different track usages for each species over the two surveys are presented in Figure 7.12. There were also several instances of an animal using a track for four or five kilometres. The spoor of a caracal was followed along a track for over four kilometres on one occasion, brown hyaenas were also recorded using tracks for >4 kilometres once and for >5 kilometres on three separate occasions. Jackal spoor were followed along a track for >5 kilometres on seven occasions. When comparing all three classes of track use across species for which there were sufficient data points (*n* = 4) there was a significant difference in the use of tracks (χ^2 = 35.138, *df* = 6, *p* = <0.001) with brown hyaena crossing a track contributing most (χ^2 = 10.709) to the total chi square value. A comparison was also carried out using just the two track-use classes concerned with length of travel along a track once it was utilised, here there was no significant difference between the four species (χ^2 = 6.731, *df* = 3, *p* = 0.081).

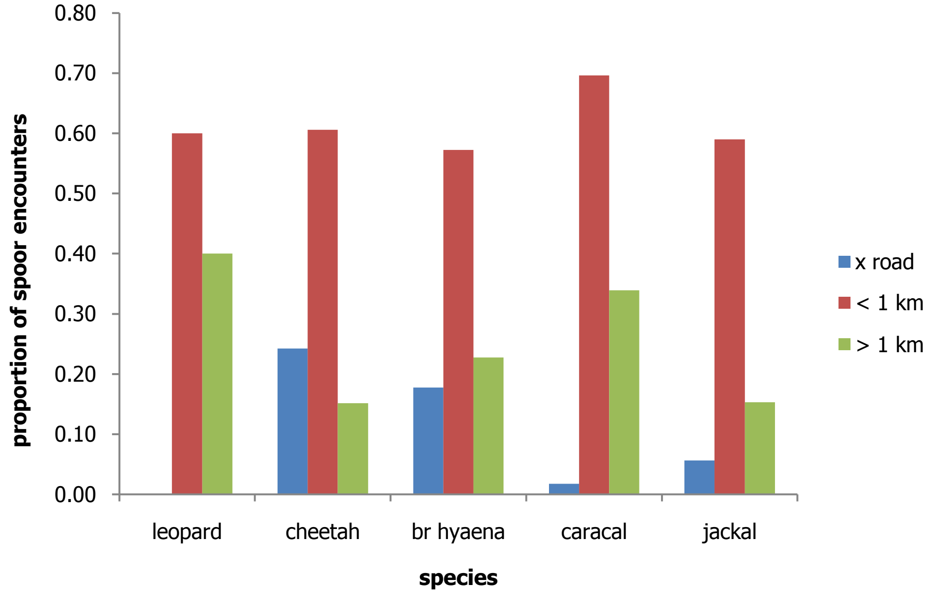


Figure 7.12 Track use by five species of carnivore in two spoor surveys in the Ghanzi farmlands in 2009

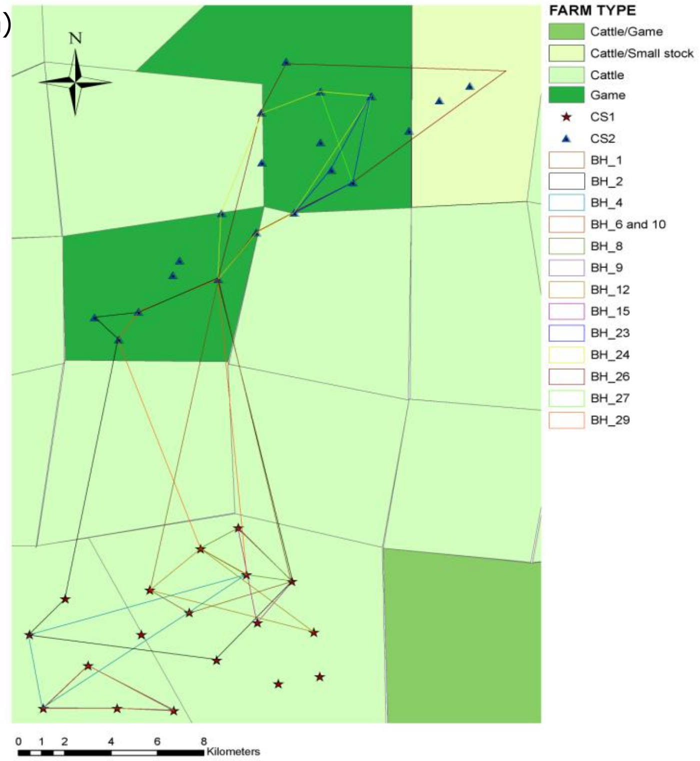
7.4v Ranging behaviour of brown hyaena and leopard

Fourteen brown hyaenas were photographed at more than three camera stations in CS1 and CS2, their 'ranges' are illustrated in Figure 7.13a. Three of these animals (BH_1, BH_2 and BH_29) were captured at cameras in both surveys. The largest 'range' recorded was that for BH_2, a male, that was photographed at ten different camera stations across the two surveys over an area of 122.48 km^2. The only other male for which there was such movement data was BH_6, the remaining twelve animals were female.

In CS3, six hyaenas were photographed at three or more camera stations with the largest 'range' being recorded for BH_33, a female, of 53.01 km^2 (Figure 7.13b). Only one male was positively identified, BH_39, four were female and one of unknown sex.

The largest area recorded for a leopard was that of LPD_A, a male, which was captured at camera stations in both CS1 and CS2 that were 20.94 kilometres apart (Figure 7.14a). In CS3, one leopard, a female, was captured at three or more camera stations over an area of 6.64 km^2 (Figure 7.14b). No cheetahs were captured at three or more stations during any of the camera surveys.

a)



b)

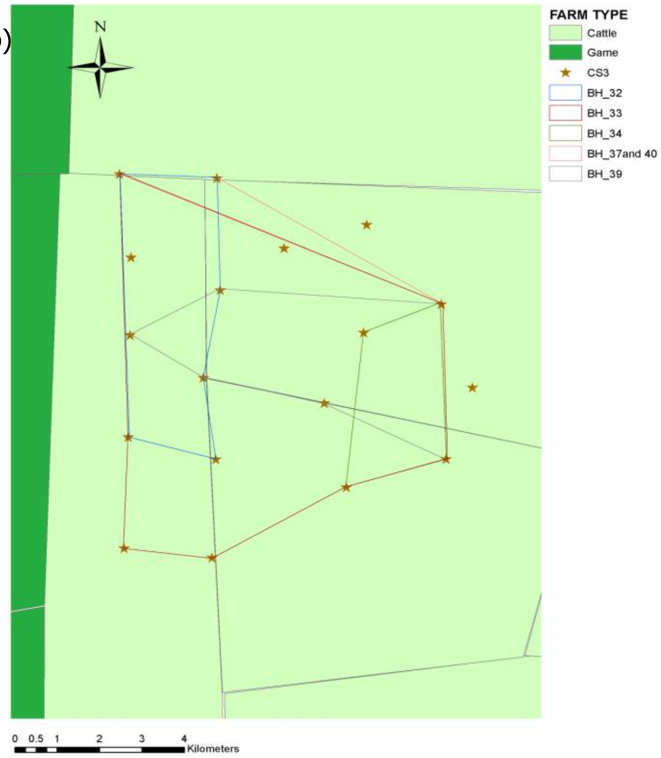
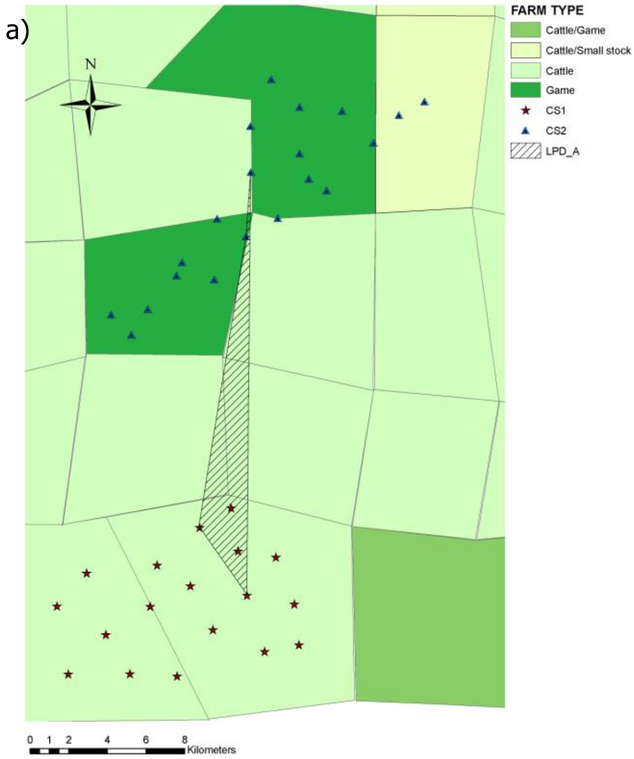


Figure 7.13 Ranges of brown hyaena captured at three or more camera stations in the Ghanzi farmlands in 2009
a) CS1 and CS2; b) CS3



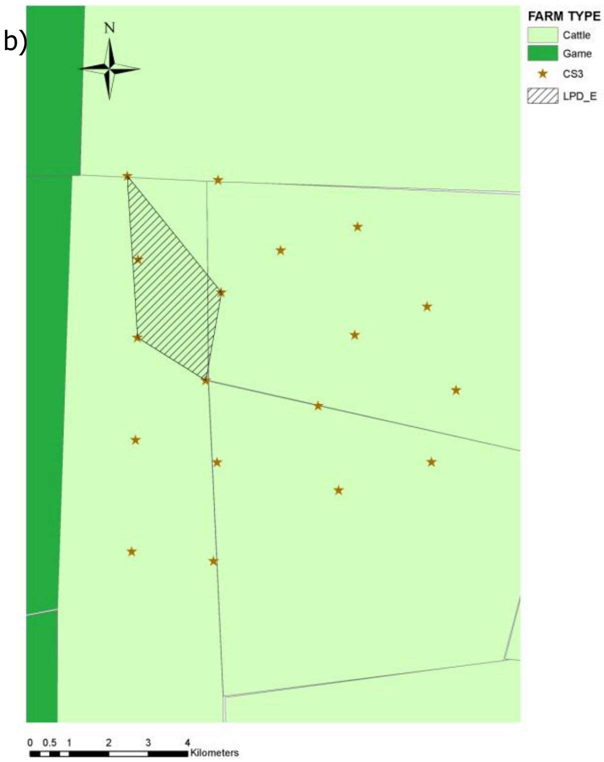


Figure 7.14 Ranges of leopards captured at three or more stations in the Ghanzi farmlands in 2009
a) CS1and CS2; b) CS3

7.5 Discussion

Knowledge of how carnivore species might adapt and modify their behaviour in areas of high human disturbance is of importance when considering their conservation outside protected areas (Nowell & Jackson 1996). The activity pattern and visibility of a species may also affect the way it is perceived by the community in which it exists. In the past, a variety of studies have attempted to provide information relating to activity patterns of carnivores based on telemetry data: leopards in Nepal and the southern Kalahari (Odden & Wegge 2005; Bothma & Bothma 2006); caracal in South Africa (Avenant & Nel 1998) and grey wolves, *Canis lupus*, in Poland (Theuerkauf *et al.* 2003), and, increasingly in recent years from data obtained from camera trapping: wild felids in Malaysia (Azlan & Mohd Sharma 2006); ocelots in Argentina and Peru (Di Bitetti *et al.* 2006; Kolowski & Alonso 2010) and small carnivores in Taiwan (Chen *et al.* 2009). However, as with most studies of carnivores, these have been heavily biased towards populations inside protected areas. This study aimed to provide much needed data on carnivore and prey species movement and activity patterns in a human- and livestock-dominated environment.

7.5i Daily activity patterns and activity relative to the lunar cycle

Leopard

For leopard, the data available were limited and for that reason probably cannot be taken as a reliable indication of leopard activity pattern. That said, the small number of photographic captures acquired are generally in agreement with Hayward & Slotow's (2010) findings of activity peaks between 19:00-20:00 and 03:00-06:00, although not with the one between 21:00-02:00. Similarly, movement patterns of leopards in the Kgalagadi Transfrontier Park (KTP) in the southern Kalahari and in north eastern Namibia have been found to be predominantly nocturnal (Stander *et al.* 1997b; Bothma & Bothma 2006), but in the KTP there was a degree of daytime activity that was postulated to be related to the lack of human persecution in the study area (Bothma & Bothma 2006). There is also some evidence to suggest that males may be more nocturnal than females (Odden & Wegge 2005) and certainly the only strictly daytime (as opposed to crepuscular) photographic captures obtained in this study were of a female. Activity of leopard overlapped with the three antelope prey species by >35% and with duiker by 82% but by much less with warthog. Previous research has indicated that leopard preferentially predate on small antelope species such as duiker and steenbok (Owen-Smith & Mills 2008) and this finding is consistent with that.

There are no published data to support a relationship between leopard activity pattern and the lunar cycle and none was found in this study but, once again, with such a small dataset this should not be taken as conclusive evidence that none exists.

Cheetah

There are few published data on cheetah daily activity patterns so while this dataset is relatively small it still provides important information regarding cheetah movement. Cheetah were noticeably crepuscular with a large peak around dawn and a smaller one at dusk. This is broadly in accord with what is known about the activity pattern of the species (Bissett & Bernard 2007). A meta-analysis of activity patterns of five species of African predator and seven prey species conducted by Hayward & Slotow (2010) also found crepuscular peaks of activity for cheetah, but with the majority occurring at dusk. They also found evidence that cheetah were significantly more active during the day at hotter sites, and the Ghanzi area would certainly qualify as such. This, allied with the findings of this study, adds further support to the suggestion put forward by Marker *et al.* (2003c) (and discussed in section 6.3iii), that the level of activity displayed by cheetah during the day is a contributory factor to the species' prominence in the minds of farmers. Seventy five per cent of farmers questioned thought that cheetah numbers had increased during their time in the area, and as most farmers are active around their farms tending to livestock in the early morning this would maximise the likelihood of encounters. A cautionary note however regarding sample sizes from camera trapping in this study which were small making conclusions difficult.

Cheetah activity overlapped the four naturally occurring prey species tested by more than 35% and the crepuscular peaks in activity for steenbok, duiker and warthog were noticeably similar. In protected areas these are not recorded as cheetah's preferred prey species (Hayward *et al.* 2006b), but steenbok and duiker in particular are frequently taken in the Ghanzi farmlands (pers.obs.). Of the prey species present as stock on game farms all were active throughout the 24-hour period and, while in protected areas they may not be considered as potential prey for cheetah, there is some evidence that in conditions of competitive release larger prey are taken more frequently (McVittie 1979).

There was no evidence that cheetah change their activity pattern according to the lunar cycle although analysis on a larger dataset would be of value.

Brown hyaena

Brown hyaena were the most nocturnal of the five carnivore species with more than 80% of photographic captures occurring at night and a further 11% classed as crepuscular. There was a strong peak in activity between 18:00-20:00 with more than 30% of all captures occurring in this three-hour window. One of the very few accounts to have looked into brown hyaena activity period also noted this peak (Owens & Owens 1978) which was even more pronounced when the data were divided into seasonal periods. Owens & Owens (1978) also remarked on the change in time of commencement of the night's activity between summer and winter. The data in this study did not confirm this as, although activity peaked one hour earlier in winter, there was no difference in the time at which it started and ended (Figure 7.5). Mills (1984) found that brown hyaenas in the southern Kalahari were active on average for 42.6% of the 24-hour period. While it is not possible from camera trap data to determine mean activity for individuals, photographic captures of hyaenas in this study were obtained over 62.5% of the 24-hour period. This finding is in accord with the limited published accounts on brown hyaena activity (Mills 1990; Mills & Hofer 1998). As noted previously, it is thought unlikely that brown hyaena activity is driven by prey movement patterns as they are predominantly scavengers. Brown hyaena were barely mentioned in any context by the respondents to the questionnaires in Chapter 6, except when specifically referred to, and their almost uniformly nocturnal activity patterns result in few encounters with humans.

The results on movement relative to the lunar cycle are somewhat confusing, as although encounters were lower than expected in the 0-25% phase, as might be expected, they were also lower than expected in the 51-75% phase. When night-time encounters during camera trapping only were taken into account there were also significantly more encounters than would be expected in the 26-50% phase. There are no published studies on brown hyaena movements in relation to the lunar cycle with which to compare these findings. It does appear that activity is reduced during the darkest period, but the other significant results may just be an artefact of the data.

Caracal

Caracal are often described as being predominantly nocturnal, especially outside protected areas (Stuart 1981; Nowell & Jackson 1996; Skinner & Chimimba 2005), but diurnal activity was apparent in this study despite the high level of human activity that accompanies livestock farming. They were active throughout the night and during the morning until 11:30. No photographic captures were recorded between 12:00-17:00. Avenant & Nel (1998) found that daytime activity was largely dependent on ambient temperature with 22^{o}C being the upper limit at which movement was detected. This appears to be contradicted here as more daytime activity was recorded in the summer months than in the winter (Figure 7.5), but data are fairly sparse. There was also a much more pronounced peak of activity between 00:00-02:00 in the summer.

Hares and rodents form a substantial part of caracal diet, and there were little or no data obtained in this study on these species, but caracal activity did overlap considerably with the four naturally occurring prey species sampled here and duiker and steenbok in particular are known caracal prey items (Avenant & Nel 2002).

No relationship between caracal activity pattern and the lunar cycle was found which concurs with the findings of Avenant & Nel (1998).

Black-backed jackal

Jackal activity patterns were broadly nocturnal, with low levels of daytime captures. There were no noticeable crepuscular peaks or night-time troughs as were found by Ferguson *et al.* (1988), McKenzie (1990) and Kaunda (2000), although, when the seasons were examined separately there was a slight dip in activity between 00:00-03:00 during the summer months (Figure 7.5). While, using the common definition of crepuscular of one hour pre- and post-sunrise and sunset, nearly 22% of photographic captures of jackal were classed as such across the three camera surveys, these appeared to be the commencement and cessation of the night's movements rather than peak periods of activity (Figure 7.2). It has been suggested that black-backed jackals are likely to be more active in the day in areas with little or no human activity (Loveridge & Nel 2004), and this has been found to be the case in comparisons of coyote, *Canis latrans,* activity patterns during periods, or in areas, of high and low human disturbance (Kitchen *et al.* 2000; McClennen *et al.* 2001). Black-backed jackals are thought to have very similar activity cycles to coyotes (Ferguson *et al.* 1988), but in contrast to the coyote research, jackals on a nature reserve in the Transvaal tended to start their evening activity one hour later and to become inactive one hour earlier in the morning than a population in a stock-farming area (Ferguson *et al.* 1988). In the Mokolodi Nature Reserve, Botswana, diurnal jackal activity was found to vary between summer and winter with less activity during daylight hours in the summer months. This was attributed to higher temperatures and increased human activity in the surrounding farming areas due to the longer daylight hours (Kaunda 2000). There was no evidence of such a seasonal shift in diurnal activity in this study, there were in fact slightly more daytime photographic captures in summer, but the population studied is subject to varying, although generally high, levels of persecution and the predominantly nocturnal activity pattern is likely to be a reflection of that. Ferguson *et al.* (1988) also found that activity commenced around two hours later in the evening during the summer and ended one hour earlier in the morning. Again there was no evidence for this in the current study, but this may be because the Ghanzi farmlands lie at lower latitude than Ferguson *et al.*'s (1988) study area.

The activity of jackal overlapped with all the prey species analysed but, as for caracal, hares and rodents make up a large proportion of jackal diet and little or no data were available. Jackal however are also known to be predators of small- and medium-sized antelopes (McKenzie 1990; Klare *et al.* 2010) and so the overlap is of interest.

Jackal encounters were significantly reduced in the darkest period of the lunar cycle when both camera trapping and spoor surveys were taken into account. This was also true of jackals in the Transvaal (Ferguson *et al.* 1988). However, when camera trapping alone was investigated the number of photographic captures at night during the 76-100% of full phase was also significantly higher. This is somewhat contrary to the findings of both Ferguson *et al.* (1988) and McKenzie (1990) whose observations and telemetry data indicated peak activity occurring during the middle section of the lunar cycle. Both of those studies relied on telemetry data and the difference in results may be due to differing methodologies.

Natural prey species

Little has been published on the subject of activity patterns of African ungulates with which to compare the findings of this study, but suggestions that diurnal activity levels amongst tropical ruminants are governed by body size, with smaller species being least active during the day (du Toit & Yetman 2005) were not borne out as steenbok in this study were almost exclusively diurnal. The proportion of diurnal activity also displayed by kudu and warthog does not suggest that behaviour has been modified in any of these species to avoid contact with people. It is possible that the nature of the Kalahari environment and the limited availability of forage is such that reducing activity levels to avoid daylight hours would curtail feeding time beyond the limit that could be sustained.

7.5ii Carnivore movement relative to livestock

Analysis of the data obtained in CS1 found no evidence that the medium- to large-sized predators were more likely to be photographed in areas where cattle were present. However, analysis of data from SS2 found significantly higher predator spoor density in cattle areas than in non-cattle areas. This was entirely attributable to black-backed jackal and indicates that jackals may be maximising the feeding opportunities presented by the presence of domestic livestock. As previously noted, jackals are known to feed on the placentas of calving cattle and it is not surprising therefore that such a relationship should have been found. There was some doubt over the presence of an outlier in the dataset however, and the association was not apparent when the data were analysed after being filtered to exclude transects driven less than five times (see section 7.4iii). The possibility that reducing the sample size when filtering the data caused a real effect to be lost cannot therefore be ruled out. The fact that there was no association between either camera trapping index or spoor density for the other predators is in line with the results of a smaller analysis of spoor data undertaken on the same farm in 2008 (Snelleman 2009). This result refutes the perception, discussed in section 6.4, that cheetahs follow livestock herds. Although, the data analysed were gathered on a farm that only raised cattle. The possibility remains that a different outcome would be apparent if a similar analysis was carried out on data from farms where small stock was present. It should also be noted that sample sizes for leopard and cheetah were small and brown hyaena, as primarily a scavenger, may be considered less likely to have a relationship with livestock herds. Also, the wide-ranging habits of the species involved mean that while a photographic capture or spoor encounter might not have been recorded in a cattle zone, there is no way of determining if that animal subsequently moved into a cattle zone and was not then detected.

The findings were however consistent with those reported for leopard in Kenya (Mizutani 1999), Ethiopian wolf (Ashenafi *et al.* 2005), grey wolf (Sidorovich *et al.* 2003), African wild dog (Rasmussen 1999) and Eurasian lynx *Lynx lynx* (Odden *et al.* 2008) in areas with relatively healthy natural prey bases, and adds weight to the suggestion that, in general, most predators do preferentially predate on natural prey species.

7.5iii Track use by carnivores

Differences in trail use found between carnivores of similar size and occupying similar niches in Neotropical forests (Harmsen *et al.* 2010) raise concerns over detection probability when monitoring carnivores by means of spoor and camera surveys. Male leopards have also been found to use roads or tracks more often than females (Balme *et al.* 2009). If some species or individuals are more likely to use tracks than others and for longer distances, then relative abundance indices derived from such methods may be rendered meaningless. Investigating track use also reveals interesting data with respect to species behaviour patterns. While it was not possible to quantify how likely an animal is to preferentially use a track over walking through the bush from data in this study, it was possible to analyse the distance travelled along a track once it had been encountered by an individual to investigate whether species-specific differences existed. No such differences were apparent, with the exception of the frequency with which brown hyaena were observed to have crossed a track rather than to have travelled along it. However, it is thought unlikely that this indicates an unwillingness to use tracks by this species given the large number of spoor encounters recorded.

There was no evidence here of any species actively avoiding the use of tracks with the exception of brown hyaena which did cross the track disproportionately. But, given the frequency with which hyaena were encountered during the spoor and camera surveys (see section 5.4) it is unlikely that this had a significant effect on the results of those two methodologies. However, there were very few data for leopard from which to draw any conclusions and it remains a possibility that the secretive nature and opportunistic hunting methods (Skinner & Chimimba 2005) of this species leads it to make less of use of tracks. This could offer at least a partial explanation for the mismatch between farmers' perceptions of their abundance (see section 6.3) and estimates derived from spoor and camera surveys.

7.5iv Ranges of brown hyaena and leopard

The ranging data obtained in this study relied on photographic captures of individually identifiable animals at static camera stations. The conclusions that can be drawn from such data are therefore by their very nature limited. However, data on brown hyaena and leopard movements are sufficiently rare to make any contribution of value.

In the southern Kalahari, brown hyaena were found to live in small groups or clans, ranging in size from one to nine, and to defend territories with both group and territory size varying according to the abundance of food resources. A small proportion of the population was also found to be solitary and nomadic (Mills 1982a). In Namibia however, food dispersion was shown to have more of an effect on these two variables and territory size was smaller (Skinner *et al.* 1995), similar in size to that reported for brown hyaenas in the CKGR (Owens & Owens 1978). It is not possible to determine from the camera trapping data in this study whether all the animals photographed within any area were members of the same group or if there were two or more groups present whose ranges overlapped. Such overlapping of territories has been found to be common in both the Kalahari and Namibia (Mills 1982a; Mills & Mills 1982; Skinner *et al.* 1995). The largest 'range' found in this study for a male hyaena of 122.48 km^2 is similar to that recorded in a communal cattle area adjoining the Makgadigadi National Park in Botswana (Maude 2005). There, home ranges of individual hyaenas, calculated from telemetry data using the Minimum Convex Polygon (MCP) method, ranged from 135 km^2 to 221 km^2. In the same study, group territory size in the WMA was calculated to be 245 km^2 (Maude 2005). Given that it is highly likely that individual hyaenas in this study ranged further than could be detected with static camera traps, there seems no reason to suppose that home range and group territory sizes in the Ghanzi farmlands differ markedly from those in the Makgadikgadi area. What is apparent is that individual ranges overlapped considerably with those of other animals, whether of the same or a different clan.

The movement data obtained for leopard provide some interesting information regarding the overlap of territory of males and females and is also suggestive of large home ranges, for males at least. The area utilised by the male photographed in CS1 and CS2 overlapped that of both females captured in those surveys. Without further data it is not possible to know if other males were also present in the area, but other studies of leopards have revealed a similar picture of male territories overlapping those of several females (Mizutani & Jewell 1998; Marker & Dickman 2005). The size of leopard home ranges is however extremely variable between regions (Mizutani & Jewell 1998) and has been shown to be negatively correlated with prey abundance (Marker & Dickman 2005). The only study to have been undertaken on leopard home ranges in a similar environment (Namibian farmlands) to that of the current study, reported leopard home ranges larger than anywhere other than those found by Bothma *et al.* (1997) in the southern Kalahari (Marker & Dickman 2005). Marker & Dickman (2005) postulated that this could be the result of prolonged human persecution, as this has been demonstrated to have long term impacts on spatial ecology in other carnivores (Tuyttens *et al.* 2000). This is certainly a factor that would be applicable to the Ghanzi farmlands and, given the other similarities in environment, it is thought likely therefore that the spatial ecology of leopards in this study is most likely to resemble that found in the Namibian farmlands.

7.5v Limitations of this study

In general, the most complete and accurate data on activity patterns are obtained from satellite and GPS collared animals where the individual is monitored 24-hours a day. However, camera surveys are less expensive and non-invasive and, while providing a less complete picture, can still make a valuable contribution to an area in which information is still sparse.

7.6 Conclusions

Data on activity patterns for the species investigated in this study have broadly concurred with findings on activity for those species reported elsewhere and differ very little from those reported for protected areas. The minor differences that did emerge can probably be attributed to differences in methodology and perhaps to variations in local environmental conditions. It seems on the evidence available that anthropogenic factors have not led to behaviour modifications in the species investigated in this study. There was support however for the hypothesis that cheetah occupy a more prominent place in the minds of farmers as a result of their diurnal activity pattern. Perceptions of increasing population numbers could be driven by the higher visibility level of this species.

The lack of evidence for disproportionate carnivore activity in the vicinity of livestock, with the possible exception of jackal, contradicts some perceptions that came to light in the Cultural Consensus analysis in Chapter 6. It would however appear to support the theory that predators preferentially predate on natural prey species where sufficiently large populations remain. Data here were limited however and further research, especially on farms with small stock, is needed.

Chapter 8 - Final discussion and conclusions

8.1 Synthesis

Many carnivore species are wide-ranging and exist at low densities to the extent that even large areas of protected land may be insufficient to provide them with adequate space for survival. Furthermore, rangelands in arid and semi-arid environments may present particular challenges in this respect due to the seasonality inherent in such ecosystems. If species such as these are to be conserved then populations that exist outside those protected areas may be crucial to the survival of the species as a whole. With that in mind, this study aimed to evaluate the status and conservation potential of carnivores in the Ghanzi farm block of western Botswana. The area, which on its eastern side borders the Central Kalahari Game Reserve (CKGR), was found to support a wide range of carnivore species and a healthy, if reduced, population of ungulates and other natural prey species coexisting with large herds of cattle, goats and sheep as well as game species stocked on game farms.

The current status of carnivores in the Ghanzi region was first put into context by an exploration of the historical status of wildlife and human settlement in the area. In Chapter 3, this was achieved by an examination of the records of early explorers and the memories of some of those who have lived and farmed in the area throughout the past seventy or so years. These accounts revealed a period of settlement, livestock expansion and landscape changes caused by the introduction of fences, which transformed a once wild and open area of the Kalahari with large accumulations of game species. Farmers recalled how the cattle in the early days ranged freely across the Kalahari grasslands mingling with the herds of red hartebeest, wildebeest and eland. They also spoke of lions and leopards being killed in retaliation for attacks on livestock and retold stories of the hunting and killing of large packs of African wild dogs. By contrast, the Ghanzi farmlands today have been modified to accommodate and facilitate the large-scale production of domestic livestock, predominantly cattle, and to a smaller extent the raising of game species for the trophy hunting and photographic tourism industries. Nevertheless, wild game still occurs but little research to date has been undertaken to quantify its abundance.

In Chapter 4, data from camera trap surveys were analysed in order to determine the current status of the free-ranging natural prey base within the farm block. Species richness and diversity was found to have been drastically reduced from those historical times, but a small suite of ungulate species was found to remain. The occupancy of some of these species was shown to vary slightly with vegetation and land-use types. The density of animals derived from camera trap data was considerably higher for kudu (0.41/km^2), duiker (0.17/km^2) steenbok (0.14/km^2) and warthog (0.21/km^2) than that previously recorded by Department of Wildlife and National Parks (DWNP) for the area (Botswana Environment Statistics Unit 2005), or for other areas of northern Botswana (DWNP 2006), using aerial surveys. Farmers' perceptions of the abundance of naturally occurring game species on their land broadly concurred with the results obtained using camera trap data, and it was apparent that most had a good awareness of the health, or otherwise, of the populations of these species. In Chapter 6, it was also shown that most farmers were concerned about the wild ungulates on their land and even felt a sense of ownership towards them. Additionally, nearly 85% of the participants in the Cultural Consensus questionnaire featured in that chapter agreed with the proposition that the protection of natural game species would reduce the likelihood of predators taking livestock.

The status of the carnivore species in the area was the focus of Chapter 5. Two methods were employed to determine the density and abundance of these species, spoor surveys and camera trapping. Analysis of data obtained in the camera surveys revealed that species richness was high, with 15 species out of the 21 known to occur in the area photographed. This compared favourably with carnivore species diversity found in both Namibia (Stein *et al.* 2008) and in the southern Kalahari (Wallgren *et al.* 2009). When looking at individual species, camera trapping was more effective than spoor surveys at estimating abundance of leopard due to the very small number of spoor samples found. This may have been because leopards are less likely to use tracks preferring instead to remain concealed in the bush. The number of photographic captures was also low, but density estimates derived from the data indicated leopard density estimates broadly in line with those reported for other areas of the Kalahari (Funston *et al.* 2001). However, they were based on small datasets and should be treated with appropriate caution. A possible explanation for these small datasets can be found in the data obtained on movement patterns featured in Chapter 7. This suggested that leopards in this area, particularly males, may have very large home ranges. If that were the case, and the size of leopard home ranges reported elsewhere in the Kalahari (Bothma *et al.* 1997) would suggest that it is likely, the relatively small distance used between camera stations in this study would not be optimal for a reliable assessment of leopard density and abundance. However, data from questionnaires and DWNP compensation records reported in Chapter 6 indicate a mismatch between the density estimate calculated here and both the perceptions of farmers, and the position of leopard in the compensation claims table. It is thought likely that leopard density is unevenly spread throughout the farm block and that the areas sampled in this study did not present a completely representative picture of the leopard population in the area. Further research targeted specifically at leopards in this area is urgently needed.

The opposite situation was found for cheetah where spoor were much more abundant than photographic captures. Cheetah density estimates were higher on game farms than on domestic livestock farms in both spoor and camera surveys but, although at least six adult animals were photographed during the game farm camera survey, there was only one recapture suggesting a wide-ranging and possibly disturbed population. The lack of recaptures also resulted in problems calculating the effectively sampled area for the camera surveys, so estimates of home range size had to be used instead. This was also difficult to assess due to the variation in ranging behaviour of cheetah in different areas of sub-Saharan Africa. The estimates used were derived from the small amount of published research on cheetah home ranges in the Kalahari (Houser *et al.* 2009a) and as a result, confidence in the reliability of the figures calculated for cheetah density and abundance from camera trapping is not high. Density estimates derived from the two spoor surveys of 0.61 and 1.30 cheetahs/100km^2 are thought to be more robust and are higher than previously estimated cheetah densities for the Kalahari (Funston *et al.* 2001; Klein 2007). They are also higher than those reported for the Namibian farmlands (Marker 2002). The fact that both the camera and spoor survey on the game farms produced a higher density estimate increases confidence in the findings, but does not explain the phenomenon. It would however, support the hypothesis that game farms attract predators, a proposition put to respondents in the Cultural Consensus Questionnaire featured in Chapter 6 with which the majority concurred. Extrapolations of the density estimates to the whole farm block produced a population estimate of between 144 and 160 cheetahs across the 15,000 km^2 area, a sizeable and potentially important population.

Of the three large carnivores, brown hyaena presented the best opportunity to compare the performance of the two methodologies used as good quantities of both spoor and photographic data were obtained. Density estimates obtained were fairly consistent across the study although both methodologies revealed lower densities on game farms. This would support the findings of Skinner & van Aarde (1987) that brown hyaena are more successful on domestic livestock farms where there is a greater potential source of scavenged food, than in protected areas. This is the first evidence of the status of brown hyaena in this area, and provides an extrapolated population estimate for the farm block of approximately 430 brown hyaenas. This represents an important population for the species which is endemic to southern Africa and whose total population is believed to total only around 8,000 animals (Mills & Hofer 1998). Estimates of home range were not possible from data obtained at static camera trap stations, but Chapter 7 illustrated that several animals travelled long distances over several farms. The available evidence suggests that it is likely that home ranges in the Ghanzi farmlands do not differ greatly from those recorded for the species in the Makgadikgadi area of Botswana (Maude 2005).

The medium-sized carnivores presented a greater challenge to attempts to establish their current status. Neither caracal nor black-backed jackal are individually identifiable meaning capture-recapture analysis could not be utilised. Furthermore, no spoor surveys have been conducted on these species in areas of known populations that would facilitate the calibration of spoor density with actual density. For caracal, the relatively small datasets in both camera and spoor surveys meant that no estimate of actual density could be made and therefore photographic capture rate and spoor density had to be used as an index of abundance. For black-backed jackal, occupancy modelling was employed to obtain abundance estimates as the number of photographic captures obtained was sufficient to allow for this. The resulting density estimate for the areas covered by the three camera surveys was 39.48 jackals/100 km^2. This is a higher density than that recorded for the species in the few areas for which there are data available, with the exception of the Namib Desert Coast of Namibia (Loveridge & Nel 2004). Unfortunately, it was not possible to assess how reliable this estimate might be, although it was certainly not contradicted by the perceptions of farmers as elucidated in Chapter 6.

A dramatic mismatch between DWNP compensation records, as presented in Chapter 6, and data obtained during camera and spoor surveys concerned African wild dogs. No wild dog spoor was encountered during either spoor survey and only two photographs of one animal were obtained during the three camera surveys. Wild dogs also did not feature highly in the list of problem predators farmers named in the questionnaire survey featured in Chapter 6. The compensation records however showed that, in the years since they were added to the list of predator species which attract compensation payments, depredation to African wild dogs accounted for 50% of all compensation payments made. These records covered the whole of Ghanzi District, as opposed to just the farm block, and it was thought possible that local extirpation may account for some of this discrepancy. Nevertheless, when studies conducted in other parts of northern and western Botswana were taken into account (Gusset *et al.* 2008; Selebatso *et al.* 2008; Muir 2010), there still appeared to be some considerable divergence between opinions of farmers and the government records.

Overall, the spoor and camera surveys revealed relatively good carnivore populations with species diversity that compared favourably with that found in other areas of southern Africa (Stein *et al.* 2008; Wallgren *et al.* 2009). Estimated densities of cheetah (0.14 – 1.36/100 km^2) and leopard (0.29 – 0.63/100 km^2) were lower than predicted carrying capacity as calculated from prey biomass in Chapter 4; with the exception of cheetah in the area that included game farms. Comparing these findings with the historical recollections of farmers as revealed in Chapter 3, there is some evidence of an increase in cheetah numbers since that time, while lion and wild dog numbers have decreased. But the key factor was whether this reality was reflected in the perceptions and attitudes of the current farming community.

In Chapter 6, these perceptions and attitudes were examined to assess the potential for this area to be able to conserve the medium- and large-sized predators that have been shown to occur by the spoor and camera surveys undertaken in this study. Attitudes were found to be generally less hostile than might have been expected and there was a degree of acceptance that livestock depredation, at a certain level, was a fact of life that could be tolerated. Game farmers in particular displayed a remarkably philosophical attitude.

A range of issues were cited by domestic livestock farmers on the scale of problems faced in the area but when economic loss was considered, predation became the issue of greatest concern, and in particular for those with small stock. The predator species considered to be the cause of most problems were leopard for cattle farmers, cheetah for game farmers and leopard, cheetah and jackal for those with cattle and small stock. Famers admitted using traps, shooting, dogs and in some cases poison to control predators they believed to be taking livestock. Brown hyaena were not cited as a problem by any farmers and there was very little animosity expressed towards this species. However, as reported in Chapter 5, two individuals were photographed with snares around their necks during the camera surveys indicating that, while they may not be targeted directly, they are susceptible to injury or death as a result of snares used for the poaching of wild game or poison put down for predator control.

There was, what seemed to be, a disproportionately hostile attitude towards cheetah by many farmers. Numbers of this species were thought to have increased considerably in recent years and were certainly thought to be higher than they had been historically, as outlined in Chapter 3. Cheetah were also vilified for killing wild game, particularly springbok, for killing more animals than they could eat and for being 'wasteful eaters'. They were even disliked for being hard to catch. There have been suggestions in the past that such attitudes towards this species may, at least in part, be driven by their diurnal activity pattern (Marker *et al.* 2003c) making them more visible than other more nocturnal predators. In Chapter 7, evidence was presented that would support the latter part of this hypothesis as 45% of cheetah activity was found to occur when farmers and farm workers are most likely to be active on their farms tending to livestock. The fact that cheetah are also more social than most other large felids, with the exception of lions, means that when sighted they are more likely to be in groups of two or more. This may also create a perception of their being more numerous than they actually are.

The nature of the Kalahari environment was found to make the improvement of traditional farming practices, particularly with regard to cattle, difficult to achieve. Constraints on cattle movement through the use of kraals were thought likely to result in economic consequences, with respect to animal health and condition, greater than those incurred by depredation. There was however likely to be room for improvement in livestock husbandry for small stock in some cases, and better record keeping for both cattle and small stock (especially when calving/lambing) would allow for greater accountability and awareness of losses. Most farmers who used livestock guarding dogs thought that they were at least partially effective in protecting small stock from predators. They were not universally used however and it is thus thought that an increase in the utilisation of this measure would be likely to reduce losses, providing the dogs used are properly trained and bonded with the livestock they are protecting.

No evidence was found to indicate that restricting calving or lambing to a particular season reduced depredation levels. However, the lack of consistency in the selection of season by those who had adopted this practice made evaluation of its effectiveness as an anti-predation measure difficult. In general, it was apparent that for those farmers who had not already adopted any of the above measures there was little preventative action taking place to protect livestock. The only strategy seemed to be the killing of the predator responsible if an animal was lost.

Serious concerns were voiced about the functionality of the state run compensation system which was thought by many to be overly bureaucratic and to provide insufficient recompense for losses. Doubts were also raised as to the accuracy of the statistics generated by the Problem Animal Control (PAC) records kept as part of DWNP's administration of the scheme. Both farmers and DWNP officers thought that the omission of black-backed jackal and caracal from the list of species attracting compensation led to underreporting of depredation by these species. The likelihood that some depredation events were being attributed to cheetah and wild dog when they were actually caused by packs of feral domestic dogs was also suggested. The mismatch between the official figures and the perceptions of the farmers already mentioned, combined with the unwillingness expressed by some farmers to allow government involvement in their affairs suggests that a radical rethink of the compensation system is needed. Some possible changes that could increase its effectiveness are laid out in section 8.2.

The subject of trophy licences for the hunting of 'problem leopards' was another issue that aroused considerable concern. The revision of the regulations regarding the issuing of these licences has alienated many domestic livestock farmers who feel that they have been removed from the income stream generated by this activity. It was suggested that the number of leopards being killed illegally had increased as a direct result of this change in policy. Again, there is an urgent need for more consultation between government and farmers on this issue.

All respondents in the Cultural Consensus questionnaire agreed with the proposition that predators are an important part of the ecosystem, and nearly all of the farmers spoken to were in favour of the conservation of predators outside protected areas, at least in principle. When it came to having them on their land however, there was a more mixed reaction. Farmers who kept small stock were more likely to be unhappy about having predators on their farm than either cattle-only or game farmers. Afrikaner farmers were also less happy than non-Afrikaners, but not significantly so. However, nearly all said that they would like to be able to live with predators if they could, but that currently the economic consequences were just too great.

Despite some differences in attitude between Afrikaners and non-Afrikaners overall the different ethnic groups in the area were shown to share a cultural consensus in their knowledge of the carnivore species that exist in the Ghanzi farmlands. There were some differences apparent however between Batswana knowledge of carnivores and that of both Afrikaners and those of European origin.

In Chapter 6, the Cultural Consensus analysis revealed that more than half of respondents agreed with the proposition that cheetahs follow livestock herds on farms. However, there was no evidence found to support this for any tested predator species, with the exception of black-backed jackal, from either camera trap or spoor survey data. A relationship between the presence of jackal spoor and the location of cattle herds was found in one analysis and this was postulated to be the result of jackals associating with calving cattle in order to scavenge the placentas. This analysis was however conducted on a farm that raised only cattle and therefore cannot be extrapolated to those where small stock is also present.

In Chapter 7, attention turned again to the carnivores and naturally occurring prey species in order to investigate whether the activities of the farmers, in pursuing problem animals and managing the land for domestic livestock, might have affected activity patterns and behaviour. It could be expected that in areas of relatively high human activity, associated with livestock farming, species would reduce diurnal activity to minimize encounters with people. Intuitively, it might also be supposed that if diurnal activity were reduced, movement rate might increase in line with the lunar cycle with a larger number of photographic captures occurring when light from the moon was greater. There was scant evidence to support the first supposition and in fact, as previously mentioned, cheetah activity was found to have its largest peak at precisely the time that human activity would be expected to be greatest. Similarly caracal, a primarily nocturnal species even in protected areas, displayed a surprising level of diurnal activity, even being photographed as late as 11:30 in the morning when temperatures exceeded those that had previously been thought to constrain their movements (Avenant & Nel 1998). Brown hyaena are also a nocturnal species and evidence here confirmed that with more than 80% of photographic captures occurring at night. Data for leopard were limited, but did not generally contradict previously recorded activity patterns for the species (Hayward & Slotow 2010). There was a slight indication that black-backed jackal in the Ghanzi farmlands displayed less diurnal activity than that recorded for the species elsewhere in Botswana (Kaunda 2000), but no shift in onset or cessation of activity between seasons, such as that recorded in South Africa (Ferguson *et al.* 1988), was evident. For only two species, brown hyaena and black-backed jackal, was there any suggestion of activity pattern being linked to the lunar cycle. Recorded activity levels for both species were lower during the darkest period of the moon's phase and for jackal were also significantly higher during the brightest phase. Overall however, there was little evidence for any apparent anthropogenic effects on carnivore movement or activity patterns. The same was true for the naturally occurring prey species with no evidence of modification of behaviour in comparison with the, admittedly sparse, published research on these species. It is thought possible that this is a reflection of the patchiness of resources in the Kalahari environment and the low density at which both humans and animals live.

8.2 Management recommendations

The challenges involved in developing strategies that will allow predators to be conserved in semi-arid rangelands should not be underestimated. It is also important to stress that interventions, such as improvements in livestock husbandry, that have been suggested elsewhere in the literature (see Sillero-Zubiri & Laurenson 2001 for a review) were considered by the farmers to be either impractical or uneconomic in this environment. The distinctions between East African and southern African land use and livestock husbandry practices have been commented on in the past (Woodroffe *et al.* 2005a) and the farmers of the Ghanzi farmlands are ranchers not pastoralists. They are also well educated and knowledgeable about their environment and the wildlife that exists in it. But as has been demonstrated elsewhere, the confidence that results from these factors may also mean that, while livestock depredation is undoubtedly an issue, they are more likely to complain about its effects and demand recompense for losses than those with less resources and more to lose (Naughton-Treves *et al.* 2003). It may also be the case that even if the threat from depredation were completely removed the consequences to wildlife would remain (Dickman 2010). In this respect, the situation in the Ghanzi farmlands more closely resembles conflicts between cattle ranchers and jaguars in South America than those normally associated with subsistence livestock production in Africa.

There are however some strategies, particularly with regard to community involvement, that could ameliorate conflict sufficiently to allow for the existence of an uneasy truce (Sillero-Zubiri & Laurenson 2001). Treves *et al*. (2009) emphasise the importance of considering the implementation of several different measures to alleviate conflict rather than opting to use only the first that comes to mind. Their exposition of the use of participatory intervention planning (PIP) highlights the need for consultation and communication to occur between all parties, and for it to take place at a local level (Treves *et al.* 2009). Treves *et al*. (2009) classify the various measures that either have been or can be employed to ameliorate conflicts as either direct or indirect interventions. Direct interventions are defined as those which reduce the severity or frequency of encounters between wildlife and people and their livestock such as the use of guard animals; while indirect interventions are designed to increase levels of tolerance for such encounters and include compensation schemes and the dissemination of research and education (Treves *et al.* 2009). Some measures can encompass both such as the program developed in consultation with local stakeholders aimed at conserving snow leopards (*Panthera uncia*) in Mongolia. This scheme incentivised improvements in land management and cessation of poaching by guaranteeing the purchase of local handicrafts in return for wildlife protection (Mishra *et al.* 2003). PIP should involve all stakeholders and consider all possible options for both direct and indirect interventions taking into account cost-effectiveness, applicability and feasibility (Treves *et al.* 2009). Such an approach should ensure that any interventions proposed, whether direct or indirect, are considered as part of an overall strategy for the area, and that they are tailored to local needs and conditions rather than being designed as a 'one size fits all' model. This emphasis on process rather than content and response rather than reaction is an important component of conflict resolution wherever it occurs. In order for stakeholders to engage with conservation initiatives they must be able to understand their relevance to the situation they see on a daily basis, and in particular bridging the divide between the differing perceptions of farmers and conservationists with regard to particular species and conservation in general, as discussed in section 6.6, is of critical importance. In this respect the Ghanzi farmlands are in some ways similar to the Namibian farmlands where the Cheetah Conservation Fund has for many years, and with some success, promoted initiatives designed to reduce predation and increase tolerance of cheetahs (Marker *et al.* 2010), some of which may be transferable to Botswana.

A restructuring of the state administered compensation system is recommended in order that a true picture of levels of livestock depredation and the species that cause it can be obtained. As has been recommended elsewhere, all medium- and large-sized carnivores should be included in the list of species that attract compensation (Gusset *et al.* 2008), and consultation between farmers and government should take place to establish more efficient and reliable reporting and validation procedures. Additionally, discussions should take place aimed at setting levels of recompense that more accurately reflect market value, and the introduction of incentives for better livestock husbandry should be incorporated into the system to ensure that farmers are playing their part in protecting their livestock. However, as has been pointed out in the past, even the best run compensation schemes are open to abuse and at best merely apply a sticking plaster to the problem rather than addressing its underlying causes (Sillero-Zubiri *et al.* 2007). There is also evidence to suggest that such schemes do little to increase tolerance for predators (Naughton-Treves *et al.* 2003; Václavíková *et al.*). A more radical approach would involve the implementation of a system based on conservation performance payments such as that used in Sweden (Zabel & Holm-Müller 2008). In that case payments are made based on carnivore reproductions, which would probably not be appropriate in the Ghanzi situation, but a system whereby all farmers (including game farmers) benefit from tolerating predators on their farms is worthy of consideration. Deutsch (2010) realistically suggests that, in the end, conservationists and NGO's fighting to ensure the survival of predators in such areas may have to make financial contributions towards such tolerance inducing payments.

The newly implemented sustainable leopard licensing system is suffering from teething problems and quotas for 2011 have been reduced once again due to non-compliance with regulations regarding the selection of trophy animals (BWPA 2010), although not in the Ghanzi area. However, there is still optimism that, with time and adjustments, this system will be successful in the long term. Of greater concern is the situation regarding the issuing of licenses for the hunting of 'problem leopards'. Offtake of leopards via this route is thought to exceed the number killed through the licensing system tenfold (BWPA 2010), and on top of that there must be even greater concern over the number of leopards being killed illegally. In effect this means that there are three tiers of leopard removal occurring on farmland in Botswana. There is an urgent need for consultation between DWNP and farmers with regard to the hunting of problem animals on neighbouring farms. The current situation which excludes domestic livestock farmers from this income stream, when they are the ones bearing the brunt of the losses, is not sustainable and appears to be driving some to take matters into their own hands. Furthermore, it is more likely to result in the removal of 'innocent' animals thereby perpetuating the depredation and disrupting the leopard population. Finally, a review of the regulations surrounding the sale and supply of poisons such as Temik® is needed to prevent the collateral damage to other species that has become so widespread.

Within the wider context of the potential for conservation of carnivores outside protected areas in Botswana as a whole, this study offers important insights. Previous research has thrown light onto the difficulties faced in the search for coexistence between subsistence and small-scale livestock owners in the country (Schiess-Meier *et al.* 2007; Gusset *et al.* 2008; Selebatso *et al.* 2008; Hemson *et al.* 2009). However, areas of Botswana where large-scale ranching and livestock production is prevalent present different challenges and require an understanding of an alternative socio-cultural and political landscape. This study has provided important information on the occurrence and abundance of the wildlife of one of these areas, but of equal importance is the knowledge that has been gained into the perceptions and attitudes of stakeholders towards that wildlife and towards the officials that seek to protect it. It is to be hoped that by synthesising this information with that obtained in past and future studies a strategy for conflict amelioration, that encompasses local needs and concerns, can be formulated that will facilitate the conservation of carnivores in similar areas of Botswana and elsewhere.

8.3 Further work

Several issues emerged from this study that warrant further investigation and research:

8.3i Leopard density and abundance

There is an urgent need for targeted leopard research in the Ghanzi farmlands to establish the abundance, density and spatial ecology of the species in the area. Camera trapping and spoor surveys should be conducted in areas where perceptions and records of livestock loss to the species are highest. Additionally, it would be desirable for a small number of leopards to be fitted with satellite GPS collars so that data on ranging behaviour can be obtained. This information would give the newly implemented trophy hunting permit system a firm base on which decisions about the number and allocation of permits should be made.

8.3ii Cheetah density and abundance

The widely divergent density estimates for cheetah found in this study between cattle and game farms warrant further research. As for leopard, further spoor and camera trapping surveys should be undertaken to try to determine how game farms are affecting the density and occurrence of cheetah. The possibility that a small population of cheetah has emerged in one area of the farm block that preferentially predates on livestock should be investigated. Camera trapping in this area could provide important information to this end.

8.3iii Brown hyaena populations

Research on brown hyaena populations in other farming areas of Botswana would complement both the findings of this study and research currently being undertaken on the species in protected areas. This would help to provide a better picture of the Botswana population and its importance to the conservation of the species.

8.3iv Black-backed jackal diet

The suggestion that black-backed jackals may be at least partially responsible for the depletion in springbok numbers in the area warrants further investigation. A study of the dietary composition of jackal in farming areas in Botswana would be of value.

8.3v Cultural consensus and divergence

This study provided some evidence that further research, sampling a wider pool of participants, could inform the anthropological literature about differences in knowledge and beliefs about wildlife that may exist between the various ethnic groups in the area. Knowledge of these differences would also help to guide the planning of management strategies that take all groups into account.

Many of the above recommendations for further work involve wider use of camera trap surveys. Experience gained during this study suggested that, as well as providing valuable data, the sharing of photographs obtained in such studies with the landowners, did much to engage them with the wildlife that lived on their land. Such engagement is of enormous value in the quest for coexistence between humans and carnivores.

8.4 General conclusion

The persistence of many species of carnivore may depend on their survival outside protected areas where they come into conflict with humans and their livestock. Knowledge of these wildlife populations and of the perceptions and attitudes of the stakeholders in the areas in which they live is of critical importance in the quest for some kind of coexistence.

The Ghanzi farmlands in western Botswana were found to contain good carnivore species diversity and a reduced, but healthy, naturally occurring prey base. Densities of cheetah and leopard were found to be low, but comparable to, or better than, those reported for other similar environments. A good population of brown hyaena was found to exist in the area which could be of importance to the conservation of the species as a whole. The farming community of the area were supportive of conservation in principle, but generally intolerant of predators that killed their livestock. There was found to be a wide variety of land management and livestock husbandry practices with some farmers prepared to do more than others to actively protect their livestock. Farmers with small stock were less likely to be happy about sharing the land with predators than those who farmed only cattle or game; while some species of predator elicited more feelings of antipathy than others. Game farmers expressed less hostility towards predators than domestic livestock farmers. Many farmers professed a distrust of government interference in their affairs which served to hamper efforts to obtain reliable data on livestock depredation and monitor the lethal control of predators. The socio-political landscape of the area has resulted in an arm's length approach being adopted by all parties in relation to each other that is not conducive to engagement with the concerns and issues in question.

The information gained on both the human and wildlife populations of the Ghanzi farmlands is an important component in the overall picture of the status and conservation potential of carnivores outside protected areas in Botswana.

8.5 Reflections on the experience of conducting an interdisciplinary study

Calls for interdisciplinarity to be brought to bear on the topic of conservation in general, and human-wildlife conflict in particular, have been increasing in recent years (e.g. Sillero-Zubiri & Laurenson 2001; Mascia *et al.* 2003; Campbell 2005; Chan *et al.* 2007; Treves *et al.* 2009; Dickman 2010; White & Ward 2010; Drury *et al.* 2011) and this study attempted to address this need by combining the disciplines of conservation biology and anthropology through the conduit of one researcher.

The experience of conducting such an interdisciplinary study as a single individual was not without difficulties. The differences in thought process, terminology and methodology between the biological sciences and anthropology are not inconsiderable and presented many challenges. Embarking on any new discipline requires time and study in order for the process of familiarisation with jargon and theories to occur, and attempting to achieve this while preparing for and conducting intensive, time-consuming fieldwork was no small undertaking. Inevitably, I fell short of the depth of knowledge and understanding that would have been brought to the topic by an anthropologist, but had the study been conducted by an expert in that field they would undoubtedly have faced similar challenges in mastering the requirements of biological methodologies. This serves to highlight the difficulties that confront any proponent of conflict resolution in this field in that you are trying to serve two masters, never an easy task. However, it is one that increasingly needs to be tackled as to date traditional, one dimensional strategies have failed to address the underlying and deep-rooted concerns of those affected.

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Appendix I – List of species photographed and identified in camera trap surveys

Common name	Scientific name	IUCN Red List Status (IUCN 2010) (as at 01/01/2011)
Mammals		
Aardvark	*Orycteropus afer*	LC
Aardwolf	*Proteles cristata*	LC
African wild cat	*Felis silvestris lybica*	LC
African wild dog	*Lycaon pictus*	EN
Bat-eared fox	*Otocyon megalotis*	LC
Black-backed jackal	*Canis mesomelas*	LC
Black-footed cat	*Felis nigripes*	VU
Brown hyaena	*Parahyaena brunnea*	NT
Cape fox	*Vulpes chama*	LC
Caracal	*Caracal caracal*	LC
Cheetah	*Acinonyx jubatus*	VU
Common duiker	*Sylvicapra grimmia*	LC
Ground squirrel	*Xerus inauris*	LC
Honey badger	*Mellivora capensis*	LC
Kudu	*Tragelaphus strepsiceros*	LC
Leopard	*Panthera pardus*	NT
Porcupine	*Hystrix africaeaustralis*	LC
Scrub hare	*Lepus saxatilis*	LC
Slender mongoose	*Galerella sanguinea*	LC
Small-spotted genet	*Genetta genetta*	LC
Springhare	*Pedetes capensis*	LC
Steenbok	*Raphicerus campestris*	LC
Striped polecat	*Ictonyx striatus*	LC
Warthog	*Phacochoerus africanus*	LC
Total = 24		
Reptiles		
Kalahari tent tortoise	*Psammobates oculiferus*	Not listed
Total = 1		
Birds		
African hoopoe	*Upupa africana*	Not listed
African white-backed vulture	*Gyps africanus*	NT
Barn owl	*Tyto alba*	LC
Bateleur	*Terathopius ecaudatus*	NT
Cape crow	*Corvus capensis*	LC
Blacksmith plover	*Vanellus armatus*	LC
Burchell's sandgrouse	*Pterocles burchelli*	LC
Cape glossy starling	*Lamprotornis nitens*	LC
Cape turtle dove	*Streptopelia capicola*	LC
Coqui francolin	*Peliperdix cocqui*	Not listed
Common buzzard	*Buteo buteo vulpinus*	Not listed
Double-banded sandgrouse	*Pterocles bicinctus*	LC

Common name	**Scientific name**	
Birds contd.		
Helmeted guineafowl	*Numida meleagris*	LC
Kori bustard	*Ardeotis kori*	LC
Lappet-faced vulture	*Torgos tracheliotus*	VU
Marabou stork	*Leptoptilos crumeniferus*	LC
Namaqua dove	*Oena capensis*	LC
Northern black korhaan	*Eupodotis afraoides*	LC
Ostrich	*Struthio camelus*	LC
Pale chanting goshawk	*Melierax canorus*	LC
Pied babbler	*Turdoides bicolour*	LC
Red-billed francolin	*Pternistes adspersus*	LC
Red-crested korhaan	*Eupodotis ruficrista*	LC
Red-eyed bulbul	*Pycnonotus nigricans*	LC
Secretary bird	*Sagittarius serpentarius*	LC
Southern masked weaver	*Ploceus velatus*	LC
Spotted dikkop	*Burhinus capensis*	LC
Tawny eagle	*Aquila rapax*	LC
White-faced scops owl	*Ptilopsus granti*	Not listed
Yellow-billed hornbill	*Tockus leucomelas*	LC
Total = 30		
Red List key: LC = Least concern; NT = Near threatened; VU = vulnerable; EN = Endangered; CR = Critically endangered; EW = Extinct in the wild; EX = Extinct.		

Appendix II – Livestock farmer's questionnaire

Date:	**Interviewer:**		**Questionnaire no:**	
GPS coordinates:	**S.**	**E.**		

Section A. General Details								
A1	Name:		Anonymous	☐				
A2	Ethnic Group/Tribe:							
A3	Year of birth:							
A4	Farm name:							
A5	Farm Number(s):							
A6	Are you:	Owner ☐	Lessee	☐	Manager	☐	Tenant	☐
A7	If you are the owner do you own by		Freehold	☐	Leasehold	☐		
A8	Length of time on farm/in area							

Section B. Farm Details							
B1	How many animals do you keep?:						
		Number	**Breeds**				
	Cattle						
	Sheep						
	Goats						
	Horses						
	Donkeys						
	Others						
B2	Have you had any incidence of rabies in your livestock in the last five years?			Yes	☐	No	☐
B3	If yes - what was the source of infection? How many animals were affected?						

Section C. Farm Management									
	Are your stock tended:	**Cattle**				**Sheep/Goats**			
C1	At night?	Yes	☐	No	☐	Yes	☐	No	☐
C2	During the day?	Yes	☐	No	☐	Yes	☐	No	☐
C3	Do you have a calving/lambing season?	Yes	☐	No	☐	Yes	☐	No	☐
C4	If yes when?	All year	☐			All year	☐		
Details:		1st quarter	☐			1st quarter	☐		
		2nd quarter	☐			2nd quarter	☐		
		3rd quarter	☐			3rd quarter	☐		
		4th quarter	☐			4th quarter	☐		
	During calving / lambing, do you:	**Cattle**				**Sheep/Goats**			
C5	Bring calving animals closer to homestead?	Yes	☐	No	☐	Yes	☐	No	☐
C6	Check on livestock more often than before?	Yes	☐	No	☐	Yes	☐	No	☐
C7	Maintain a record-keeping system?	Yes	☐	No	☐	Yes	☐	No	☐
C8	Kraal livestock at night?	Yes	☐	No	☐	Yes	☐	No	☐
C9	Kraal young calves / kids?	Yes	☐	No	☐	Yes	☐	No	☐
C10	Use a maternity / calving kraal?	Yes	☐	No	☐	Yes	☐	No	☐
C11	Other? *(specify)*	Yes	☐	No	☐	Yes	☐	No	☐
		Cattle				**Sheep/Goats**			
C12	Do you have a herder with your livestock?	Yes	☐	No	☐	Yes	☐	No	☐
C13	If yes are they effective?	Yes	☐	No	☐	Yes	☐	No	☐
C14	Do you keep guard animals with your livestock?	Yes	☐	No	☐	Yes	☐	No	☐
C15	If yes are they effective?	Yes	☐	No	☐	Yes	☐	No	☐
C16	Are your boundaries patrolled?	Yes	☐	No	☐				
C17	If yes how often?	Daily	☐	Weekly	☐	Monthly	☐	Other	☐
C18	Do you use rotational grazing on your farm?	Yes	☐	No	☐				
C19	Place in order of importance to you these problems that may be encountered by farmers **Rank: 1 - biggest problem; 8 - least problem**								

Disease		Insufficient or poor quality grazing		Other	
Drought					
Infertility/conception rates		Theft			
Losses due to predators		Unreliable market			

Section D: Wildlife Details					
D1	What wild game species occur on your farm?				
		absent	**rare**	**common**	**very common**
	Kudu				
	Springbok				
	Duiker				
	Steenbok				
	Warthog				
	Hares				
	Guineafowl				

Section E: Predator Details							
E1	How often do you encounter these predators on your farm? (visual/spoor/calls)						
		Daily	Weekly	Monthly	Occasionally	Rarely	Never
	Lion						
	Cheetah						
	Leopard						
	Brown hyena						
	Spotted hyena						
	African wild dog						
	Caracal						
	Jackal						

E2	During your time here have numbers				
		Increased	Decreased	Remained stable	Don't know
	Lion				
	Cheetah				
	Leopard				
	Brown hyena				
	Spotted hyena				
	African wild dog				
	Caracal				
	Jackal				
E3	What explanation do you have for any change in numbers?				

E4	Do any of these species have any value for you? *(economic, ecological, cultural)*			
		Yes	No	Details
	Lion			
	Cheetah			
	Leopard			
	Brown hyena			
	Spotted hyena			
	African wild dog			
	Caracal			
	Jackal			

Section F: Predation and conflicts

F1	Do you lose livestock to predators?	Yes ☐	No ☐	
F2	Rank these predators according to the level of problem they cause **Rank: 1 - biggest problem to 5 - least problem**			
	Lion ___ Caracal ___ Wild dog ___ Cheetah ___ Br hyena ___ Jackal ___ Leopard ___ Sp hyena ___ Other ___			
F3	How do you protect your livestock from predators?			
F4	Are losses to predators seasonal?	Yes ☐	No ☐	
F5	If yes which season?	Wet ☐	Dry ☐	Calving ☐
F6	How many animals do you think you lose to predators on avg per year? *(number or percentage)*			
F7	Have you lost animals in the past 12 months due to causes other than predators?	Yes ☐	No ☐	Specify *(number/species)*:
F8	Rank these causes of loss in terms of economic importance: **Rank 1- most important to 5 - least important**			
	Disease ___ Accidents ___ Theft ___ Predation ___ Calving ___ Starvation ___ Other ___			
F9	Can you give an approximate financial value for these losses in the last 12 months?			
F10	During your time here have problems with predators			
	Increased ☐	Decreased ☐	No change ☐	
F11	When you have a loss to a predator who do you tell? *(tick all that apply)*			
	Family ☐ Friend ☐ Neighbour ☐	DWNP ☐	NGO ☐	
F12	Have you ever had to remove a predator?	Yes ☐	No ☐	
F13	If yes - how?			
	Live trap ☐ Shoot ☐ Poison ☐	Other *(specify)*:		
F14	Have you ever contacted DWNP PAC office for assistance?	Yes ☐	No ☐	
F15	Have you ever made a claim for compensation?	Yes ☐	No ☐	
F16	If yes were you happy with process of making a claim?	Yes ☐	No ☐	Don't know ☐
F17	Were you happy with the value placed on your livestock?	Yes ☐	No ☐	Don't know ☐
F18	Would you make a claim again if the situation arose?	Yes ☐	No ☐	Don't know ☐

Appendix III – Game farmer's questionnaire

Date:	**Interviewer:**		**Questionnaire no:**		
GPS coordinates:	**S.**	**E.**			

Section A. General Details					
A1	Name:		Anonymous ☐		
A2	Ethnic Group/Tribe:				
A3	Year of birth:				
A4	Farm name:				
A5	Farm Number(s):				
A6	Are you:	Owner ☐	Lessee ☐	Manager ☐	Tenant ☐
A7	If you are the owner do you own by		Freehold ☐	Leasehold ☐	
A8	Length of time on farm/in area				

Section B. Farm Details		
B1	How many animals do you keep?	
		Number
	Giraffe	
	Eland	
	Gemsbok	
	Kudu	
	Waterbuck	
	Blue wildebeest	
	Red hartebeest	
	Zebra	
	Impala	
	Springbok	
	Ostrich	
	Other *(specify)*	
B2	What use do you make of your game? *(Tick all that apply)*	
	Trophy hunting ☐	Photographic tourism ☐	Game meat ☐
	Private use ☐	Other (specify) ☐	

Section C: Wildlife Details						
C1	What wild game species occur on your farm?					
		absent	**rare**	**common**	**very common**	**Comments**
	Duiker					
	Steenbok					
	Warthog					
	Hares					
	Guineafowl					

Section D: Predator Details								
D1	How often do you encounter these predators on your farm? (visual/spoor/calls)							
		Daily	**Weekly**	**Monthly**	**Occasionally**	**Rarely**	**Never**	**Comments**
	Lion							
	Cheetah							
	Leopard							
	Brown hyena							
	Spotted hyena							
	African wild dog							
	Caracal							
	Jackal							

D2	During your time here have numbers				
		Increased	**Decreased**	**Remained stable**	**Don't know**
	Lion				
	Cheetah				
	Leopard				
	Brown hyena				
	Spotted hyena				
	African wild dog				
	Caracal				
	Jackal				
D3	What explanation do you have for any change in numbers?				

Section D: Predator Details contd				
D4	Do any of these species have any value for you? *(economic, ecological, cultural)*			
		Yes	**No**	**Details**
	Lion			
	Cheetah			
	Leopard			
	Brown hyena			
	Spotted hyena			
	African wild dog			
	Caracal			
	Jackal			

Section E: Predation and conflicts								
E1	Do you lose game to predators?				Yes ☐	No ☐		
E2	Rank these predators according to the level of problem they cause							
	Rank: 1 - biggest problem to 5 - least problem							
	Lion		Caracal		Wild dog			
	Cheetah		Br hyena		Jackal			
	Leopard		Sp hyena		Other			
E3	Are losses to predators seasonal?				Yes ☐	No ☐		
E4	If yes which season?				Wet ☐	Dry ☐		
E5	How many animals do you think you lose to predators on avg per year? *(number or percentage)*							
E6	Have you lost animals in the past 12 months due to causes other than predators?				Yes ☐	No ☐	Specify *(number/species)* :	
E7	Place these causes of loss in terms of economic importance to you:							
	Rank 1- most important to 5 - least important							
	Disease		Accidents		Theft		Predation	
	Calving		Starvation		Other			
E8	Can you give an approximate financial value for these losses in the last 12 months?							
E9	During your time here have problems with predators							
	Increased ☐		Decreased ☐		No change ☐			
E10	When you have a loss to a predator who do you tell? *(tick all that apply)*							
	Family ☐		Friend ☐		Neighbour ☐	DWNP ☐	NGO ☐	
E11	Have you ever had to remove a predator?				Yes ☐	No ☐		
E12	If yes - how?							
	Live trap ☐		Shoot ☐		Poison ☐	Other *(specify)*:		

Section F: Attitudes							
F1	Do you support the conservation of predators outside protected areas?			Yes ☐	No ☐	Don't know ☐	
F2	How do you feel about sharing the land with predators?						
	Very happy	Happy	Neutral	Unhappy	Very unhappy		
F3	What solutions, if any, do you think can be used for the survival of predators on farmlands? *(Tick all that apply)*						
	Tourism ☐		Translocate ☐		Decrease numbers ☐		
	Trophy hunting ☐		Change in management practices ☐				
	Other *(specify)*					No solutions ☐	
F4	Where do you get your information about predators? (behaviour, control etc) *(Tick all that apply)*			Friends/neighbours ☐	NGO's/researchers ☐		
				Farming magazines ☐	Which ones?		
				TV programmes ☐	Which ones?		

Appendix IV – CCA questionnaire

Date:	Interviewer:	Questionnaire no:

General Details			
A1	Name:	Anonymous ☐	
A2	Ethnic Group/Tribe:		
A3	Year of birth:		

Predator Identification		
H1	What animal is this? (Picture #1)	
H2	What animal is this? (Picture #2)	
H3	What animal is this? (Picture #3)	
H4	What animal is this? (Picture #4)	
H5	What animal is this? (Picture #5)	
H6	What animal is this? (Picture #6)	
H7	What animal is this? (Picture #7)	
H8	What animal is this? (Picture #8)	

Predator knowledge		Agree	Disagree	Don't know
J1	Predators live on farms			
J2	Cheetahs attack people			
J3	Leopards stay on one farm all their lives			
J4	Game farms attract predators			
J5	Cheetahs attack livestock			
J6	Brown hyaenas attack livestock			
J7	Caracals attack people			
J8	The numbers of jackals on farms is decreasing			
J9	Predators are an important part of the ecosystem			
J10	Caracals hunt in packs			
J11	Cheetahs move around from farm to farm			
J12	Brown hyaena are an endangered species			
J13	Caracals attack livestock			
J14	African wild dogs are solitary hunters			
J15	Jackals attack livestock			
J16	Cheetahs kill more often than leopards			
J17	Jackals sometimes hunt in packs			
J18	Cheetahs are an endangered species			
J19	Protecting natural game species reduces the likelihood of predators taking livestock			
J20	Leopards will return to a kill over several days			
J21	Cheetahs hide their kills in trees			
J22	Leopards are an endangered species			
J23	Brown hyaenas hunt in packs			
J24	Eradicating one species of predator has no effect on other species			
J25	Cheetahs follow livestock herds on farms			

Comments: