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Ecology and conservation of leopards, *Panthera pardus*, on selected game ranches in the Waterberg region, Limpopo, South Africa

by

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Submitted in partial fulfilment for the requirements for the degree
Magister Scientiae in Wildlife Management

in the

Centre for Wildlife Management
Faculty of Natural and Agricultural Sciences
University of Pretoria
Pretoria

Supervisor: Prof. W. van Hoven

August 2008

ECOLOGY AND CONSERVATION OF LEOPARDS, *PANTHERA PARDUS*, ON SELECTED GAME RANCHES IN THE WATERBERG REGION, SOUTH AFRICA

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ABSTRACT

Leopards (*Panthera pardus*) currently inhabit large parts outside formal conservation areas in South Africa. While leopards are not currently threatened in South Africa, regional populations are at risk. Conflict between leopards and ranchers is common in livestock and game ranching areas, often resulting in persecution. Negative attitudes towards leopards, caused by anti-predator sentiments and leopards preying on livestock and game are normally the reason for leopard persecution. The lack of data available for leopards on game ranches hampers current conservation efforts. A questionnaire survey was used to investigate the attitudes of ranchers towards leopards. Overall ranchers were positive towards leopards and negative attitudes towards leopards were attributed to their predation on livestock and game. Reported game and livestock losses were low, suggesting that local rumours play an equally important role in negative attitudes towards leopards. A Global Positioning System connected to cell phone transmitters [GPS/GMS] were fitted to leopards to determine home ranges and movement. GPS/GSM collars performed satisfactory with only 18 % of data missing. Leopards used smaller home ranges than expected. Social organisation was characterised by a mosaic of overlapping female ranges, while one male home range overlapped several female home ranges. Greater distances were travelled during the night than daytime. Home ranges of leopards covered a great number of ranches, while core areas were restricted to only a few ranches. Investigation of GPS clusters were used to determine age, sex and weight of prey killed by leopards. Data from kills were used in combination with scats to construct leopard diets. Leopards preyed on a variety of mammals, the most important being kudu (*Tragelaphus strepiceros*), bushbuck (*Tragelaphus scriptus*) and warthog (*Phacochoerus aethiopicus*). Suggestions for the management of leopards are discussed.

ACKNOWLEDGEMENTS

Studying leopard poses significant challenges to researches and significant financial resources and manpower are needed. Working in an agricultural landscape complicates the situation even further. This project not only relied on information from ranchers, but also for a considerable part of the financial commitment.

I would first like to thank Jobedi Game Lodge who funded the fuel, transport, capture of leopards, GPS/GSM collars and accommodation. In particular I would like to thank Oom Dirk and Oom Koot Coetzee for all their help and guidance in capturing leopards, Tannie Jean Coetzee for the use of the office, internet and morning coffee and Kobus Lee who helped with the monitoring of capture cages while I was in Pretoria.

Special thanks to Dr Manie Claasen and assistants who immobilised and help with collaring of the leopards.

Deon Cilliers, Kelly Marnewick and De Wildt Cheetah and Wildlife Trust who cared for and collard the first leopard caught, also for the use of two camera traps during the study.

The Centre for Wildlife Management at the University of Pretoria provided computers, telephone as well as other infrastructure needed during this study. Financial assistance was also provided by the Centre for Wildlife Management in the form of bursaries and studentships. A special thanks to the St Dierenrampen Fonds, in the Netherlands and Mr Michael Crane from the USA for donations made towards this project.

The game and livestock ranchers in the study area who participated in the questionnaire study and who provided valuable knowledge regarding leopards in the Waterberg. Special thanks to the ranchers who let me use their ranches to find kills made by leopards and to collect scats. In particular I would like to thank Oeldrich and Judy van Schalkwyk for many great conversations, dinners and scats they so eagerly collected. Quintes and Ronel for their friendliness and help with collection of scats and bait needed to put out camera traps.

To the staff and students at the Centre for Wildlife Management, especially Liset Swanepoel for all her help during the project. Ben Orban for the help with equipment and ArcView. Michael Somers for all the encouragement, coffee, tips and endless chats about the importance of publications.

Many thanks to my supervisor, Prof Wouter van Hoven, who introduced me to this project and for all his support during the project.

To my father in law, Attie van Niekerk for his comments on the questionnaire paper and who always enthusiastically commented on the results from this study. To my mother in law, Carol van Niekerk for all her support. To my mom who always supported and believed in me.

A special thanks to my wife, Corrie, for all her help with editing the manuscript, field and lab work, patience during the writing up period and for always believing in me and letting me live my dream. A special mention goes to my son, Albert and although he is still too young to know what I am doing, he still gives me a special smile when I tell him about it.

Thank you to all the numerous other people who helped me with this project who did not receive a special mention.

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CHAPTER 1:

GENERAL INTRODUCTION

1 INTRODUCTION

Leopards (*Panthera pardus*) have the widest geographic distribution of all felids and achieve this feat by their flexibility in habitat (Boitani, Corsi, De Biase, Carranza, Ravagli, Reggiani, Sinibaldi & Trapanese 1999) and having a varied diet (Hayward, Henschel, O'Brien, Hofmeyr, Balme & Kerley 2006b). Leopards are normally associated with areas of rocky hills, mountains and forests, but they also penetrate deserts where they are restricted to the moist watercourses (Skinner & Smithers 1990; Nowell & Jackson 1996). In desert-like environments leopards get moisture from the prey they consume (Bothma 2005). Consequently leopards occur over much of Africa, the Middle East and Far East, Siberia (except Artic tundra), Sri Lanka and Malaysia (Hamilton 1981; Bertram 1999) (Fig. 1) and is one of the most successful larger carnivores after the coyote (*Canis latrans*) (Eaton 1978). The only habitat in which leopards are not able to survive is unvegatated sand dunes.

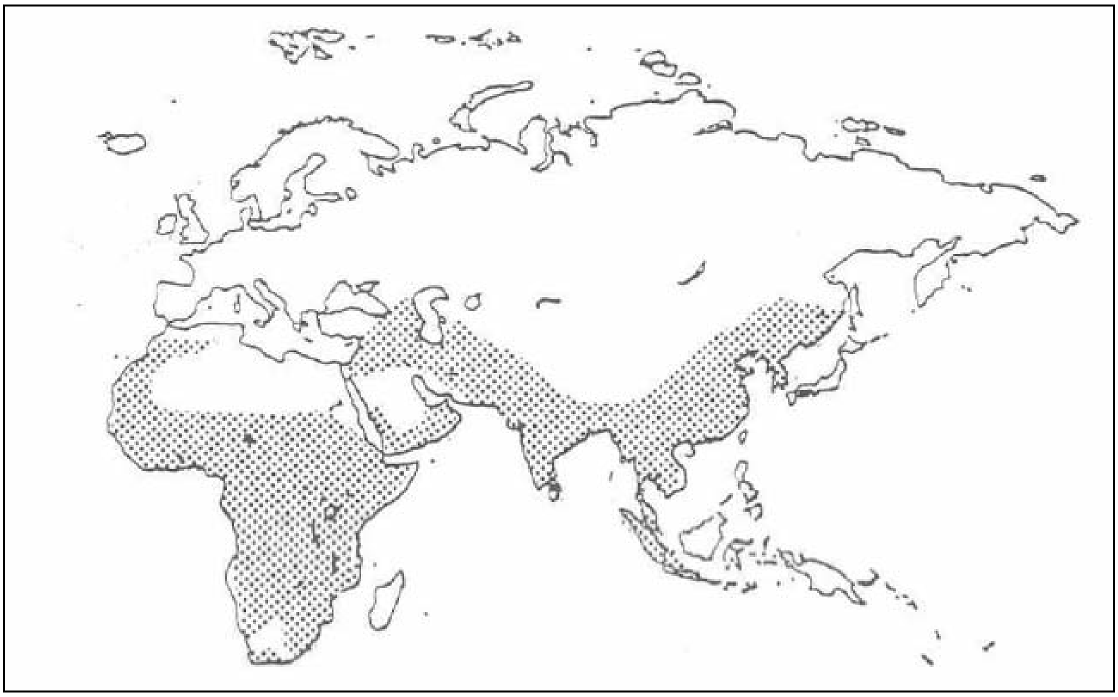
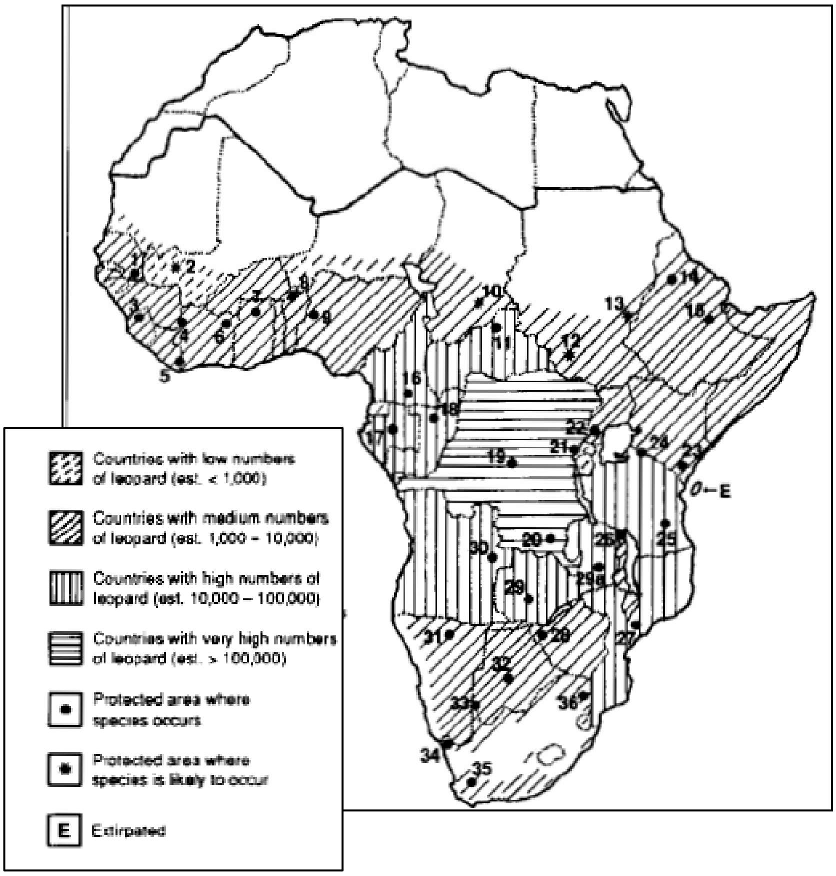


Fig. 1. A general geographic distribution of the leopard (www.CITES.org).

Leopards occur throughout sub Saharan Africa (Skinner & Smithers 1990; Boitani *et al.* 1999), and although reports indicate that leopards in west Africa are becoming rare (Martin & De Meulenaar 1988) and have disappeared from the western Sahel (Nowell & Jackson 1996), the rest of sub Saharan Africa has medium to high leopard densities (Martin & De Meulenaar 1988) (Fig. 2). In northern Africa leopards are restricted to the more remote and rugged mountainous areas (Martin & De Meulenaar 1988; Nowell & Jackson 1996) (Fig. 2) and leopards in these areas exist as threatened, isolated, small and widely separated populations (Shoemaker 1993).



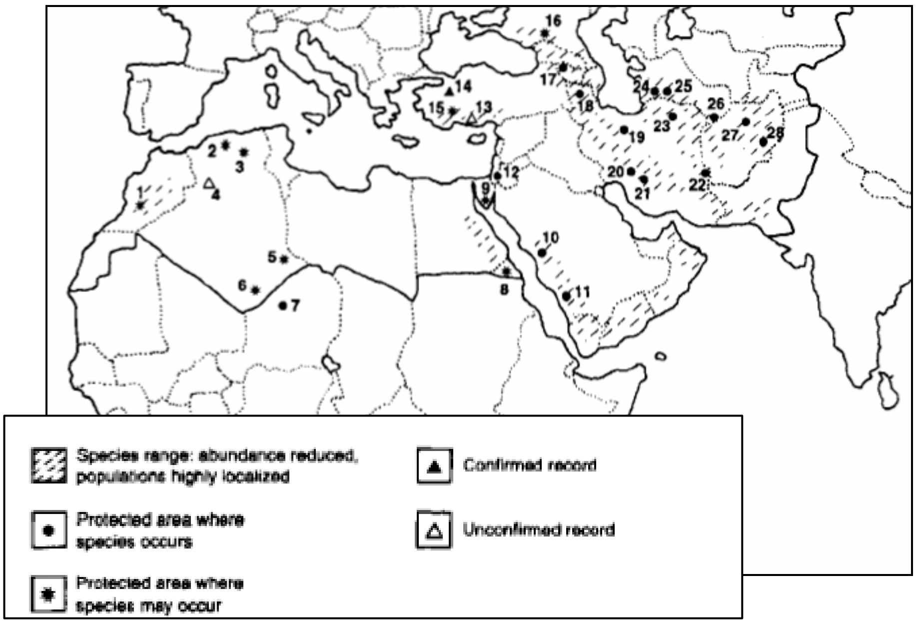


Fig. 2. Distribution and relative abundance of leopards (*Panthera pardus*) in sub Saharan and northern Africa (Martin & De Meulenaar 1988).

Leopards are widely distributed in South Africa except for the greater Karoo basin (Friedmann & Daly 2004) (Fig. 3). The Kruger National Park and surrounding private reserves seem to have the largest leopard population (>1000) (Bailey 1993), while the Kgalagadi Transfrontier Park has a estimated population of 150 (Daly, Power, Camacho, Traylor Holzer, Barber, Catterall, Flecther, Martins, Owen, Thal & Friedman 2005). Viable leopard populations in Kwazulu Natal appear to exist in Hluhluwe-Imfolozi Park, Greater St Lucia Park, Mkuzi, Phinda, Ndumu and Itala game reserves as well as other private game reserves (Daly *et al.* 2005). In the Limpopo province the species is widespread and viable populations have been reported in the Waterberg (Grimbeek 1992), Soutpansberg (Stuart & Stuart 1993), Magaliesberg (Daly *et al.* 2005) and the numerous game ranches in the province (Kharika 2005). Leopard populations have existed in the Cape Fold Mountains in the western Cape since European settlers arrived (Stuart, Macdonald & Mills 1985), while population clusters have been detected in the mountains and forested areas of the eastern Cape (Daly *et al.* 2005). The valley Bushveld of the eastern Cape also contains viable populations (Daly *et al.* 2005) and Stuart & Stuart (1989) reported that a population of leopards was living in the Orange River basin.

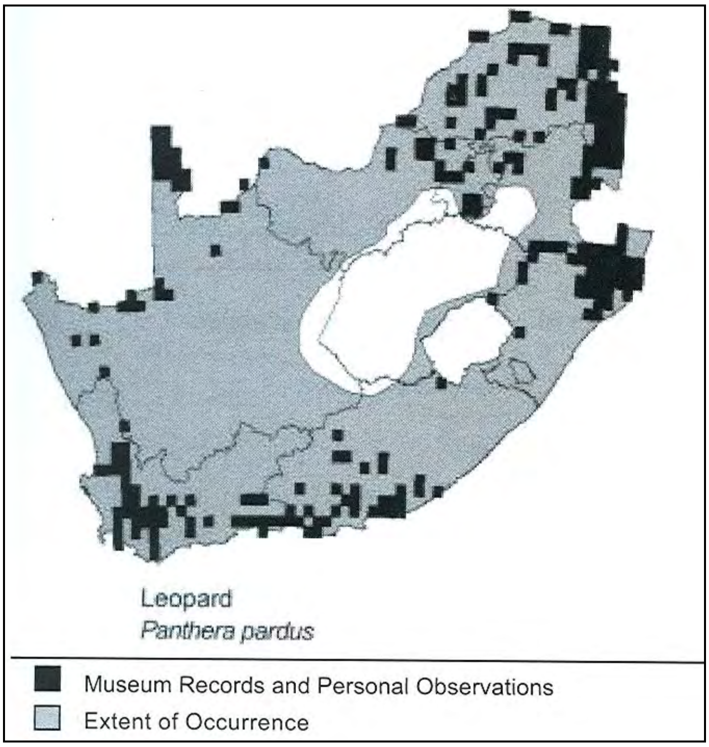


Fig. 3. Distribution of leopards in South Africa (Friedmann & Daly 2004).

The population status of leopards has been a matter of controversy ever since leopards were placed on Appendix 1 of the Convention on the International Trade of

Endangered Species (CITES) in 1973 (Nowell & Jackson 1996). Six attempts have been made to estimate the status of leopards in Africa; four of these attempts relied on questionnaires and interviews (Myers 1976; Teer & Swank 1977; Eaton 1978; Hamilton 1981). In the fifth estimate, Hamilton (1981) supplemented his estimate with results from fieldwork in Kenya. Martin & De Meulenaar (1988) expanded questionnaire data and developed a model for predicting leopard densities based on rainfall (regression analysis). Shoemaker (1993) conducted a literature review and used global correspondence to summarise the status of leopards throughout its range. All attempts to determine the status of leopards have been criticised for various reasons and the status of leopards in Africa still eludes researchers (Nowell & Jackson 1996). Martin & De Meulenaar (1988), using rainfall data, estimated the total leopard population of Africa to exceed 714 0000. This estimate has been considered an overestimate (Jackson 1989; Norton 1990), because the model fails to accurately incorporate persecution and lower prey densities as factors lowering leopard density (Nowell & Jackson 1996), while prey biomass might be in forms that leopards are unable to access or catch (Bailey 1993; Balme, Hunter & Slotow 2007).

Although the controversy around leopard population status still exists, there is general consensus that leopards are not endangered in Africa, although local populations can be at risk (Nowell & Jackson 1996; Boitani *et al.* 1999). Trade in leopard products has been regulated by CITES since 1983 and leopards are listed under Appendix 1. Countries accept annual quotas for the export of leopard trophies and skins. In 2004 South Africa requested to double its leopard quota from 75 to 150 (Doc. 19.2. www.cites.org[*]). The request was approved (Com. I. 2, www.cites.org[†]) and since 2005 South Africa has been allowed to export 150 leopard skins or trophies.

In South Africa leopards are listed by the IUCN as of least concern (Friedmann & Daly 2004). While protected areas play an important role in the conservation of leopards, only an estimated 8 % - 13 % of leopard habitat is in nationally protected areas, while the remaining 87 % - 92 % of leopard habitat is privately owned (Martin & De Meulenaar 1988; Boitani *et al.* 1999).

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[*] www.cites.org/eng/cop/13/**doc**/E13-19-2.pdf accessed on 25/04/08

[†] www.cites.org/eng/cop/13/rep/E13-ComIRep1.pdf accessed 25/04/08

The role of protected areas is also undermined by the fact that the majority of national parks in Africa (over 44 %) are not big enough to contain genetically viable leopard populations and only about 21 % of national parks in Africa (In 1975) have the ability to maintain genetic diversity in their leopard populations (Bailey 1993). In South Africa probably only the Kruger National Park and the Kgalagadi Transfrontier Park are big enough to maintain genetically viable leopard populations (Daly *et al.* 2005). The role of private land thus becomes extremely important in the conservation of leopards, not just in South Africa, but throughout their distribution range (Nowell & Jackson 1996). Unfortunately conflict between landowners and leopards hampers the conservation of leopards on private land (Daly *et al*. 2005).

In South Africa private lands containing suitable leopard habitats include game ranches, livestock ranches and private game reserves. South Africa has seen an dramatic increase in the conversion of livestock farms to game farms in last few years (Van der Waal & Dekker 2000). There is an estimated 9000 privately owned game farms and ranches in South Africa covering some 13 % of the country's total land area, compared to 5 % by national protected areas (Falkena & Van Hoven 2000). Historically conflict between leopards and livestock ranchers has limited the conservation value of ranch land for carnivore conservation, but the recent conversion of livestock ranches to game ranches is seen by some to be positive for leopard conservation (Kharika 2005). Conflict between game keepers and carnivores is a worldwide phenomenon (Graham, Beckerman & Thirgood 2005) and in southern Africa carnivores are rarely tolerated on game ranches (Hunter & Balme 2004; Lindsey, Du Toit & Mills 2005; Wilson 2006). Retaliation to livestock predation has been one of the major contributors to leopard losses in South Africa (Esterhuizen & Norton 1984), Namibia (Marker & Dickman 2005) and the rest of Africa (Nowell & Jackson 1996) and far outnumbers those shot by trophy hunters (Hunter & Balme 2004).

Understanding the conflict between game keepers and carnivores is a prerequisite to mitigate this conflict and must be based on rigorous scientific fact (Graham *et al.* 2005). Baseline information on status and distribution of the species, principle prey, range and habitat requirements are therefore important components in conservation planning and management of carnivores in conflict with humans (Weber & Rabinowitz 1996). While the ecology of leopards has been fairly well documented for protected areas in South Africa (Bothma & Le Riche 1984; Bailey 1993; Daly *et al.* 2005), research on private land in South Africa is limited (Marker & Dickman 2005).

More research on non protected areas is thus needed to help with the conservation of leopards in South Africa (Marker & Dickman 2005).

It is widely accepted that incentive-driven conservation is the way forward in the sustainable utilisation and conservation of natural resources (Hutton & Leader-Williams 2003). There is general consensus that ranchers would become more positive towards carnivores (including leopards) if they can benefit economically from the presence of these carnivores (Sillero Zubiri & Laurenson 2001; Hunter & Balme 2004; Lindsey *et al*, 2006). Some researchers reported that the attitudes of ranchers towards carnivores are difficult to change (Eaton 1978); while others (Marker, Macdonald & Mills 2003) have found that ranchers are open to change that can lead to increased tolerance towards carnivores. Various economic incentives have been put forward to increase tolerance towards southern African carnivores, e.g. hunting (Eaton 1978; Martin & De Meulenaar 1988), ecotourism (Marker *et al.* 2003; Hunter & Balme 2004) and green products (Marker *et al.* 2003). This study attempts to address some key questions regarding leopard ecology and conservation on game and livestock ranches.

The following key questions, related to leopard conservation and ecology on game ranches, were investigated:

Key questions: Rancher-leopard conflict

- What are the attitudes of ranchers towards leopards and other carnivores?
- What factors affect the attitudes of the ranchers towards leopards?
- What losses do ranchers attribute towards leopards?
- What incentives are acceptable to ranchers to increase tolerance?

Key questions: Leopard feeding ecology

- Is the investigation of GPS location clusters suitable to detect leopard kills?
- What is the prey selection of leopards on game ranches?

Key questions: Leopard spatial ecology

- What is the range size of leopard on game ranches?
- What is the size of leopard core areas?
- What is the social organisation of leopards?
- What land use properties are used by leopards?

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CHAPTER 2:

THE STUDY AREA

1 LOCATION

The study site is located in the Waterberg Mountain range in the Limpopo province, South Africa. The study area covers a surface area of 22 000 ha, while for the questionnaire survey and the home range study the surface area was 150 000 ha. The game ranch Jobedi Game Lodge (23.9791 S, 28.3058 E) formed the centre of the study area, which is about 45 km north of Vaalwater and 10 km east of Melkriver. The study site also fell inside the newly proclaimed Waterberg Biosphere Reserve (UNESCO) which covers an area of 4 000 km² (De Klerk 2003) (Fig. 1). The biosphere consists of three different zones, namely a Buffer zone, Transition zone and a Core zone. The largest part of the study area fell inside the Transition zone.

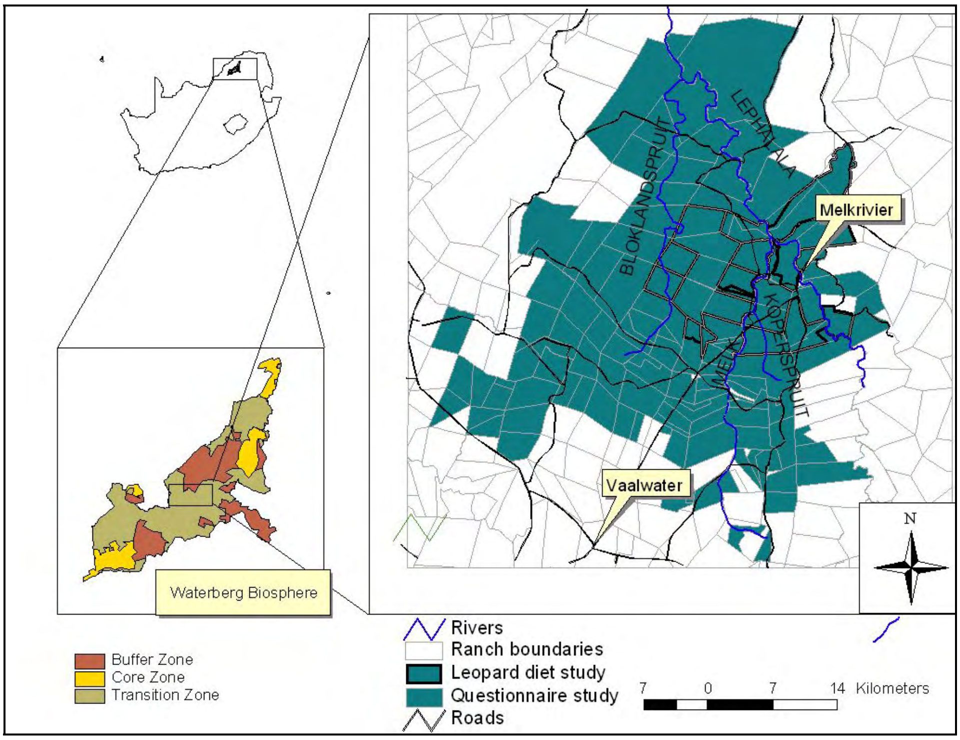

Fig. 1. Study area located in the Waterberg Biosphere Reserve.

2 LAND USE

Land use in the study area is dedicated to commercial agriculture in the form of livestock and game farming, while some crop farming occurs on the banks of the Melkriver. Recently, holiday properties have become popular in the area. A holiday game ranch is normally subdivided into 1 ha stands on which owners can build holiday houses, while the rest of the property is kept as a game ranch. Median ranch sizes for this study were 892.92 ha (Chapter 6).

3 VEGETATION

Acocks (1975) classified the vegetation in the Waterberg as Sour Bushveld, while Van Rooyen & Bredenkamp (1996) classified the vegetation in the study area as Waterberg Moist Mountain Bushveld. The newest review classifies the vegetation in the study area as Waterberg Mountain Bushveld (Mucina & Rutherford 2006).

The tree layer on the rocky slopes is characterised by white seringa *Kirkia acuminata*, stemfruit *Englerophytum magalismontanum*, common sugarbush *Protea caffra*, *Croton gratissimus*, *Combretum apiculatum, Diplorrhynchus condylocarpon, Pseudolachnostylis maprouneifolia, Albizia tanganyicensis, Combretum molle,* with common hookthorn *Acacia caffra*, red seringa *Burkea africana*, *Terminalia sericea* and *Peltophorum africanum* on deeper sandy soils (Van Rooyen & Bredenkamp 1996). On steep slopes (10 – 40°) the vegetation is characterised by *Diplorhynchus condylocarpon* savanna while on flat areas with a gradient of less than 10° vegetation is characterised by *Terminalia sericea* savanna (Tuinder 1991). Old agricultural fields are normally characterised by *Terminalia sericea* which occurs as short open woodland while grass species like *Cynodon dactylon* and *Acanthospermum glabrum* are found on the open grass veld areas (Tuinder 1991). Valley bottoms have deep soils where tall trees such as *Faurea saligna* and *Syzygium cordatum* dominate the tree layer.

The shrub layer is moderately developed and characterised by sand paper raisin *Grewia flavescens*, peeling plane *Ochna pulchra*, blue guarri *Euclea crispa*, *Rhus zeyheri*, *Vangueria infausta*, *Rhoicissus revoilii* and *Tapiphyllum parvifolium* (Van Rooyen & Bredenkamp 1996). The grass layer can be moderately to well defined and common species include wire grass *Elionurus muticus*, common russet grass *Loudetia simplex*, broadleaf bluestem *Diheteropogon amplectens*, *Trachypogon spicatus*, *Panicum maximum*, *Digitaria eriantha*, *Setaria lindenbergiana*, *Pogonarthia squarrosa*, *Urelytrum agropyroides*, *Aristida transvaalensis* and natal redtop *Melinis repens* (Van Rooyen & Bredenkamp 1996).

Vegetation structure (based on Edwards (1983)) on the mountain slopes ranges from short closed woodland to low thickets (Tuinder 1991). Slope vegetation is short (1 – 5 m) and occurs in dense stands with a mean crown to gap ratio between 0 and 2 m (Tuinder 1991). On flat areas vegetation structure ranges from short open woodland to low open woodland where vegetation is taller (2 – 10 m) and fairly open with a mean crown to gap ratio between 2 – 8.5 m (Tuinder 1991).

4 TOPOGRAPHY, GEOLOGY AND SOILS

The study area is situated on the Palala plateau which forms the centre of the Waterberg plateau, and consists of ancient sandstone of the Kransberg Subgroup of the Waterberg Group. The Waterberg plateau forms a highland area with an altitude ranging from 1100 m in the north west to 2100 m in the south west and stretches from Bela Bela to where it ends at the Sandrivierberg (Wellington 1955). The mountains have a rugged topography with steep cliffs is some areas. Slopes are rocky and rockiness ranges from 60 % to 67 % (Tuinder 1991). Rock sizes on slopes vary from rock-boulder to boulders (Tuinder 1991). Small rivers, large rivers, streams and gullies all cut into the plateau and it also contains wetlands, marshes, fountains and other wetland features.

The geology in study area consists of the Mogalakwena, Cleremont and Sandriviersberg formations. The Mogalakwena formation consists of purplish brown, coarse grained sandstone with interbedded conglomerate and boulder conglomerate, the Cleremont formation consists of coarse, white sandstone with large scale cross bedding while coarse grained yellow cross bedded sandstone rises from the Sandriviersberg formation. Sandstones and conglomerates still have shades of reddish colour which are probably due to the amount of felsitic and other ingenous debris present in the original sediments and also oxidising conditions (Du Toit 1954).

On the flat plateau areas, soils are freely drained and mostly dystrophic (leached and nutrient poor) and mesotrophic (moderately leached) with Hutton, Glenrosa and Mispah as the import soil forms. In the low lying flat areas, plinthic catenas are formed where eutrophic yellow soils are widespread, with Clovelly being the most important soil form. Exposed rocks cover most of the steep hilly areas which lead to shallow, gravely soils with Mispah and Glenrosa as import soil forms. In the valley bottoms Oakleaf and Dundee soil forms are important. Soil textures are medium to coarse sandy loam with low clay content (1.7 % to 2.9 %) which, combined with the relatively high rainfall, leads to leached nutrient poor soils (Henning 2002).

Due to the steep and rugged terrain, the Waterberg contains many drainage lines that are all water filled in the wet season. The western side of the study area is bordered by the Bloklandspruit while on the eastern side the Melkriver and Koperspruit runs through the area. The Bloklandspruit and the Melkriver both drains into the Lephalala river in the north which is one of the four larger rivers that drain from the Waterberg catchment area (Walker & Bothma 2005).

5 CLIMATE

Mean annual rainfall measured at Elandsfontein weather station (24.28 S, 28.05 E) was 612.5 mm for the period 1979 till 2000 (Institute of Soil, Climate and Water AgroMed section 2008). The rain season lasts from November to March, with a peak in January (Fig. 2). Maximum monthly rainfall measured was 302.6 mm and 50 to 80 rainy days per year can be expected. Rainfall is irregular and is mainly in the form of thunderstorms.

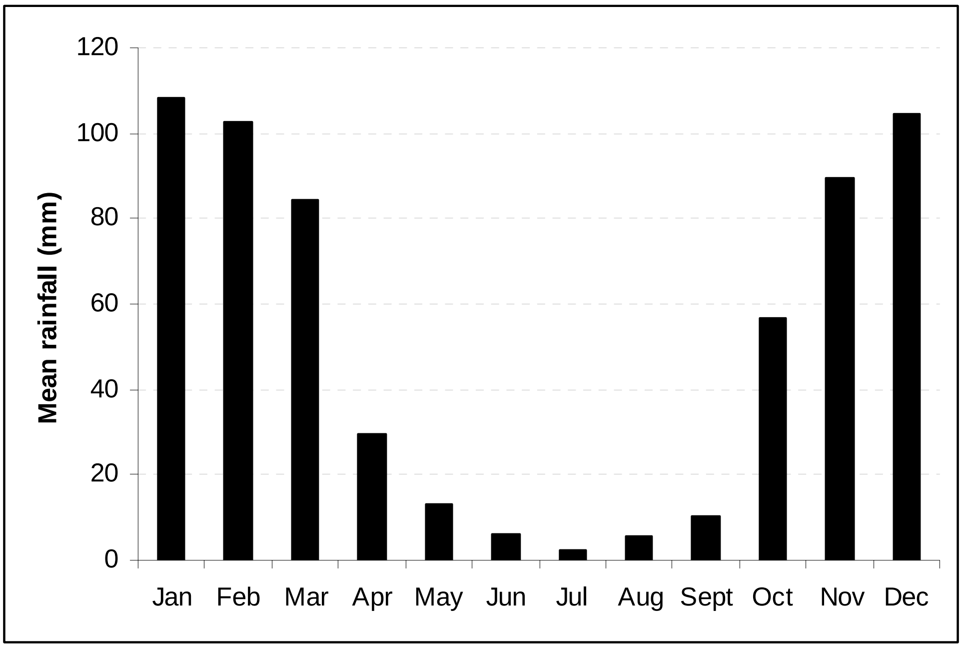

Fig. 2. Mean monthly rainfall data for Elandsfontein weather station (24.28 S, 28.05 E), the closest to the study area.

Summer can be very hot and uncomfortable whereas winters may be pleasant, but winter nights can be particularly cold. Frost can be expected during the months of June, July and August. Mean daily maximum temperature for mid summer (January) is 32 °C and for mid winter (July) 22 °C, but extremes of 42 °C and 32 °C respectively have been recorded (Institute of Soil, Climate and Water AgroMed section 2008). Mean daily minimum temperatures for mid summer (January) are 18 °C and 4 °C for mid winter (July), with extremes of 8 °C and - 7 °C respectively (Institute of Soil, Climate and Water AgroMed section 2008). Mean annual temperatures of 14.4 °C (at 08h00), 25.0 °C (at 14h00) and 16.0 °C (at 20h00) were recorded at Elandsfontein Weather station (24.28 S, 28.05 E) for the period 1979 till 2000 (Institute of Soil, Climate and Water AgroMed section 2008).

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CHAPTER 3:

GENERAL METHODS

1 INTRODUCTION

This dissertation is prepared in such a way that each data chapter is an independent separate paper. The methods and techniques are therefore described in detail in the relevant chapters (papers). This chapter thus only serves as a summary of methods used during this study. Tree nomenclature used in this dissertation follows van Wyk & Van Wyk (1997) and mammal nomenclature follows Friedmann & Daly (2004).

The following terminology was used in the study:

Wildlife ranching: Is the managed, extensive production of free ranging wildlife on large, fenced or unfenced private or communal land for recreational hunting, wildlife products, tourism, live sales of wildlife to restock other areas, and for other non consumptive uses (Bothma & Teer 1995).

Wildlife farming: Is the managed intensive production of wildlife in small, fenced enclosures on private or communal land for the production of marketable products and live animal sales (Bothma & Teer 1995).

Free – roaming: Any leopards that occur naturally in a geographic area, that can move freely in and out of fenced or unfenced properties and have a legal status of *"res nullis"*

2 CAPTURE AND CARE OF LEOPARDS

Leopards were captured using baited cage-traps with drop-door mechanisms. The traps measured 2.0 m X 0.9 m X 0.9 m and were covered with 50 mm X 25 mm three mm grid, which is a modified version of traps used by Grimbeek (1992) and recommended by De Wet (1993). A safety catch was attached to the sliding door to prevent the leopard from opening the trap door once closed (de Wet 1993). A rope fastened by a pulley system to bait activated the sliding trap door. Cages were monitored every morning and evening and the presence of all tracks was recorded. Non-target species were released on site as soon as possible, and every effort was made to catch only leopards. The capture cage was covered with a tarpaulin when a leopard was captured to reduce stress.

Leopards were immobilised by a wildlife veterinarian with a mixture of tiletamie HCL and zollazapam HCL (Zoletil; Virbac Animal Health, Halfway House, South Africa), administrated by a jab stick at a dose of 4 - 5 mg/kg of estimated live weight. Captured cats were checked for parasites, injuries and for current or previous lactation. Drugged leopards were placed back in the cage, still covered by the tarpaulin and monitored until fully recovered. Leopards were released at capture site following recovery. We conducted the research under University of Pretoria Animal Use and Care Committee ethics clearance protocol A022-06 and Limpopo leopard capture permit number CPM-004-00006.

3 COLLARS

Leopards were fitted with GPS/GSM collars from African Wildlife Tracking (http://www.awt.co.za). Collars weighed 650 g, which was between 1.5 - 2 % of the body weight of leopards. Collars were set to record a GPS location every 5 hours and send the location data via the GSM network to a server. GPS locations were stored on non volatile memory onboard the collar when no GSM network coverage was available to transmit the acquired GPS locations. Stored GPS location data was then transmitted whenever the collared animal entered an area with GSM coverage. Collar GPS units were set to search a maximum of 180 seconds to acquire a minimum of 3 satellites needed to get a GPS location. GPS location data were downloaded from the internet every morning during the study (www.yrless.co.za).

4 THE QUESTIONNAIRE SURVEY

A questionnaire survey was done in the study area to determine the attitudes of ranchers toward leopards and other carnivores, factors affecting those attitudes, livestock and game losses and what incentives can be used to benefit the conservation of leopards in the study area. Questionnaires can also prove beneficial in understanding the ranching characteristics of an area (Wilson 2006).

All ranchers in the study area were interviewed in person by Lourens Swanepoel, using a set questionnaire (Appendix). The questionnaire was based on a questionnaire used by Lindsey, Du Toit & Mills (2005). The questionnaire consisted of 5 sections: (1) Farmer section, concerning the personal information, education level and background of the farmer; (2) Ranch characteristics section, concerning the economic use and size of the property; (3) Carnivore section, concerning the presence and attitudes towards carnivores; (4) Leopard section, concerning the population status of leopards, the presence of leopards, their economic impact and value, prey base and incentives for their conservation; (5) Animal losses section, concerning livestock and game losses caused by predators and other factors.

Data were analysed statistically using *SPSS v.15* (SPSS Inc., Chicago, USA) and SAS (SAS Institute Inc., North Carolina, USA). Pearson's chi-squared test was used to test for relationships between appropriate categorical variables while independent-samples *t* tests were used for interval-scale data. Descriptive statistics were derived for all factual and attitudinal questions. The Kolmogorov-Smirnov test was used to test for normality. Appropriate nonparametric tests were used if data were not normally distributed.

5 SCAT ANALYSIS

Studying the feeding ecology of solitary nocturnal carnivore species, such as leopards, poses a significant challenge. In most cases faecal samples are the only readily available source of information that can be used to construct leopard diets. Prey hair ingested by predators normally passes undamaged through the digestive system of the predator and can then be collected in the form of scats. Prey hair in the scats can be collected and compared to known samples, because the cuticle pattern and cross sections of hair are species specific.

Scat analysis has been used successfully to determine prey selection and diets of leopards by various researchers (Grobler & Wilson 1972; Norton, Henley & Avery 1986; Le Roux & Skinner 1989; Bailey 1993; Bothma & Le Riche 1994; Ramakrishnan, Coss & Pelkey 1999; Henschel, Abernethy & White 2005). Scats are frequently found on vehicle roads (Grobler & Wilson 1972; Bailey 1993), animal paths (Bothma & Le Riche 1994) and leopard kill sites (Bailey 1993).

In this study scats were collected on vehicle roads by driving a constant speed of 30 km/h while scanning the road and sides of road for scats. Scats were also collected near kills made by leopards and on animal paths used by leopards. Liquid scats near kills were not collected as they most likely contain only protein and is thus not usable (Floyd, Mech & Jordan 1978). Only scats with a diameter of more that 20 mm were collected, as smaller scats can be confused with that of caracal (*Felis caracal*) (Norton *et al.* 1986). Scats with a diameter less that 20 mm were only collected if the scat was found with associated leopard signs (kill site and tracks). Collected scats were placed in a paper bag, each with a unique identification number and a GPS coordinate.

In the laboratory scats were washed and a minimum of 20 hairs per sample were collected (Mukherjee, Goyal & Chellam 1994). Imprints of the cuticle pattern were made in gelatine (Dreyer 1966) while cross sections were made by imbedding hair in wax and then making a cross section (Douglas 1989). Cross sections and cuticle patterns were compared to published hair keys and reference material housed at the Centre for Wildlife Management.

Results were represented in frequency of occurrence (percentage of total scats containing item) and as percent occurrence (number of times an item was found as percentage of total items found) (Ackerman, Lindzey & Hemker 1984). Diets of leopards were constructed by applying correction factors to the frequency of occurrence and the results compared to other leopard diet studies elsewhere.

6 GPS CLUSTERS

The advent of GPS telemetry has provided researchers with a powerful tool to investigate diet and prey selection of carnivores. It has been reported that leopards stay near kills made until the carcass is completely consumed (Bailey 1993). A kill will thus be represented by a cluster of GPS locations if a leopard is fitted with a GPS collar, provided that the schedule for collecting GPS locations is set at an appropriate interval (e.g. 5 hours). This method was pioneered in the USA on the cougar (*Puma concolo*r) (Anderson Jr & Lindzey 2003), but is rarely used for large predators, although it has been used successfully by Sand, Zimmerman, Wabakken, Andren & Pedersen (2005) to predict wolf kills..

Collars were scheduled to record a GPS location every 5 hours and transmit the GPS coordinate to a server using the GSM network. GPS locations were downloaded every morning from a website (http://www.yrless.co.za). Consecutive nocturnal presence at a cluster was hypothesised to represent the best predicator for a possible kill. A GPS location from the cluster was used to navigate to the cluster and the cluster was searched for possible kills. Signs of struggle, blood on ground, drag marks and leopard tracks were used to confirm a kill site if no other identifiable prey remains could be found. Jaw bones or any other biological material were colleted to assist in the estimation of age and weight of the prey animal. For each kill site a set of variables relating to kill behaviour were also recorded.

7 AGE AND WEIGHT ESTIMATION OF PREY ITEMS

Teeth replacement, wear and horn growth were used to estimate age of prey killed by leopards. For younger animals the state of molar eruption and replacement of deciduous teeth by permanent teeth were used to estimate age, while for older animals wear of permanent teeth was used (Mitchell, Shenton & Uys 1965). The size of other anatomical parts (e.g. length of spoor, femur, tibia, scapula, tail, horns) were used to estimate age if theoretical Von Bertalanffy equations were available for that particular species. Mean time of birth was recorded for group birthing animals (blue wildebeest, blesbok, impala, red hartebeest) and was used to assist in determining age of young animals of the particular group if kills of young animals were found without jaw bones.

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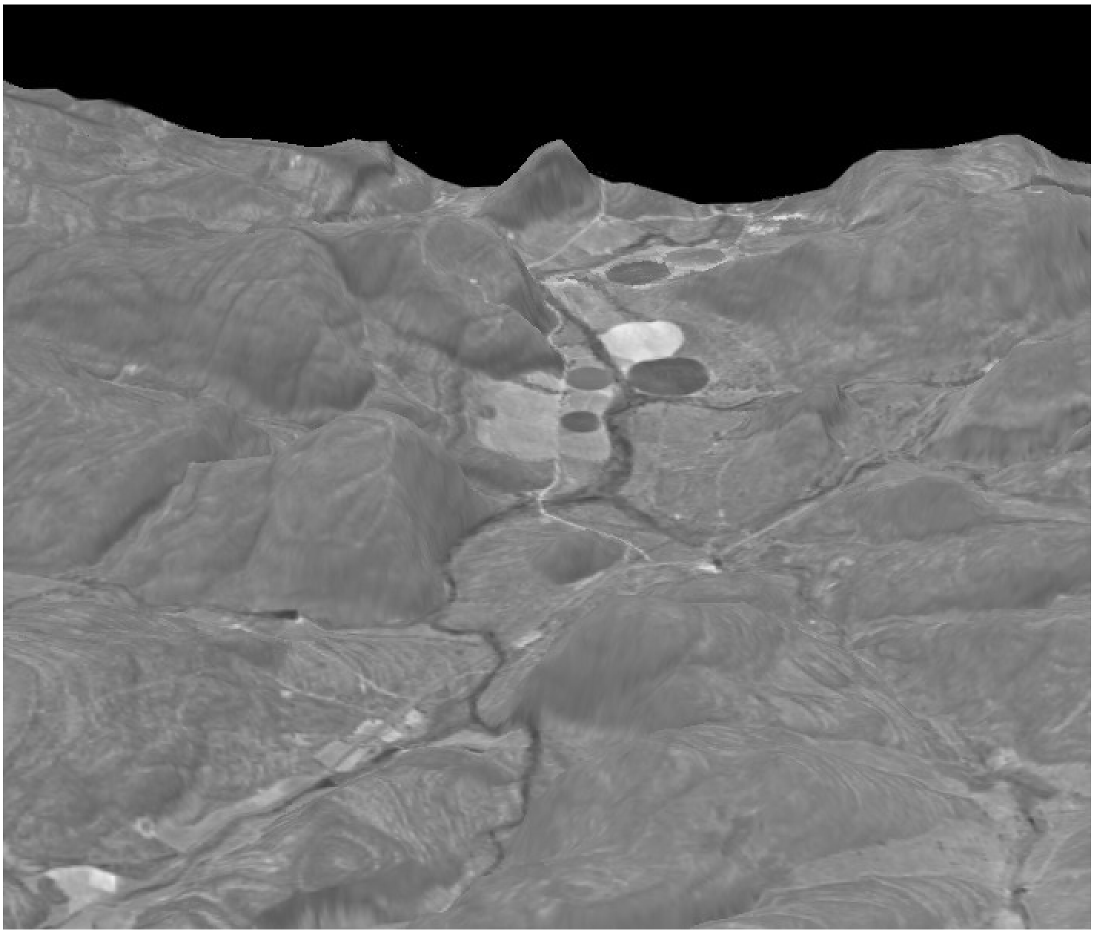
CHAPTER 4:

HOME RANGE AND MOVEMENT OF LEOPARDS (*PANTHERA PARDUS*) ON SELECTED GAME AND LIVESTOCK RANCHES IN THE WATERBERG, LIMPOPO SOUTH AFRICA



HOME RANGE AND MOVEMENT OF LEOPARDS (*PANTHERA PARDUS*) ON SELECTED GAME AND LIVESTOCK RANCHES IN THE WATERBERG, LIMPOPO SOUTH AFRICA

To be submitted to: African Journal of Zoology

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ABSTRACT

Leopards (*Panthera pardus*) are the most successful larger cat in the world. Through a combination of dietary plasticity and flexible habitat selection, leopards readily survive on altered natural habitat. In South Africa, the recent increase in game ranches is thought to benefit leopard conservation by increasing available habitat. However, leopards compete with human hunters and kill livestock, which leads to the persecution of leopards. An understanding of leopard ecology on game ranches is therefore needed for better management and conservation. In this study, we investigated the home ranges and movement of leopards on selected game ranches in the Waterberg, South Africa. One male and three females were collared, although only two leopards provided sufficient data to construct annual home ranges. Annual home range for the male was 245 km^2 and 139 km^2 for one female. Females allowed overlap at the home range level, but maintained exclusive core areas, while the male overlapped all the females. Home ranges were smaller than previously reported, albeit marginally. The male leopard moved greater distances than the females. Long male displacement distances were attributed to territorial behaviour, while females travelled the minimum distances required to capture prey. Home ranges included a large number of different ranches, although core areas were mostly restricted to consumptive wildlife utilisation ranches. We conclude that leopards still maintain a spatial organisation typical of solitary felids. However, persecution and ranch management can lead to changes in range size, overlap and movement.

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1 INTRODUCTION

The home range of an animal can be defined as the area traversed by the animal in its normal activities of gathering food, caring for young and mating (Burt 1943). The range must satisfy the energy needs of the animal (Gittleman & Harvey 1982) and uneven use of the range can provide information about the distribution, importance and accessibility of important resources such as food (Henschel 1986). The size of home ranges of carnivores appears to be influenced by food availability, body mass and population density (Gittleman & Harvey 1982; Benson, Chamberlain & Leopold 2006). As expected, larger bodied animals need larger home ranges to meet metabolic needs (McNab 1963). Herfindal, Nilsen, Andersen, Linnell & Odden (2005) reported a negative correlation between food availability and home range sizes for male and female Eurasian lynx (*Lynx lynx*), which suggests, that when food availability increases smaller home ranges are required to obtain sufficient nutrition for survival and reproduction (Benson *et al.* 2006). Leopard home ranges therefore, are much larger in the arid Kalahari than home ranges in more mesic areas (Bailey 1993; Bothma, Knight, Le Riche & Van Hensbergen 1997). Similarly, the extensive home ranges of leopards in montane areas, such as the Waterberg and Cedarberg, are thought to be as a result of lower prey density and reduced habitat diversity (Norton & Lawson 1985; Grimbeek 1992).

A positive relationship between leopard density and prey biomass has been reported by Stander, Haden, Kaqece & Ghau (1997), which suggests that if prey density increases, leopard densities should also increase. The increase in leopard density should then result in smaller home ranges (Benson *et al.* 2006). South Africa has seen a dramatic increase in the number of game ranches (over 9 000 in 2000) (Van der Waal & Dekker 2000) and in the Waterberg there are an estimated 1240 exemption ranches (De Klerk 2003). Game ranches are normally well stocked with game (Van der Waal & Dekker 2000). In theory then, an increase in game ranches should go hand in hand with an increase in prey numbers, which should ultimately lead to an increase in leopard density in the Waterberg. Indeed this reasoning is one of the main reasons why South Africa requested an increase in its leopard hunting quota in 2004 (DoP13 Doc.19.2. www.cites.org/eng/cop/13/doc/E13-19-2.pdf, site accessed on 25/04/08). In contrast, Marker & Dickman (2005) suggested that anthropogenic factors such as local tolerance towards leopards can play an equally important role in leopard density and should not be underestimated.

The fact that only an estimated 8 % of leopard range are within national protected areas (Boitani, Corsi, De Biase, Carranza, Ravagli, Reggiani, Sinibaldi & Trapanese 1999), highlights the importance of private land in the future conservation of leopards (Marker & Dickman 2005). Leopard research on private land is therefore important if informed decisions regarding leopard populations on private land are made (e.g. like increasing the leopard CITES quota). The aims of this study were to estimate the range size, movement and social organisation of leopards on private game and livestock ranches in the Waterberg. We were particularly interested to see if home range sizes have decreased since previous studies in the Waterberg and if the social organisation followed a similar pattern as reported for leopards by Bailey (1993), even if habitat is fragmented by human activities.

2 METHODS

2.1 Study area

The study was conducted within an area of 700 km² in the Palala plateau which forms the centre of the Waterberg plateau of the Waterberg, South Arica (Fig. 1).

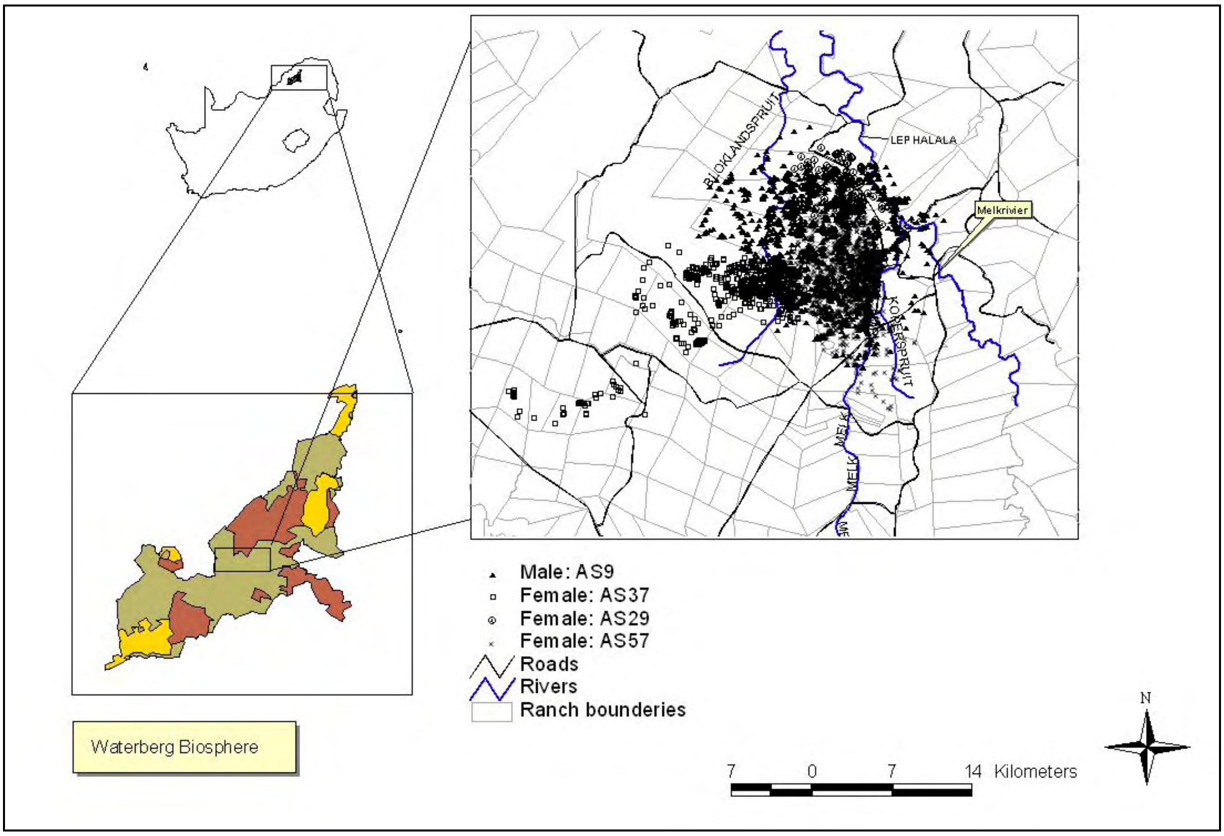

Fig. 1. Study area.

Commercial agriculture is the most important land use and livestock ranches account for 29 % of the study area, followed by ecotourism and consumptive wildlife utilisation (CWU) 21 %, CWU and livestock 19 %, ecotourism 17 % and CWU alone 15 % (Chapter 5). The area receives summer rainfall, with a definite wet season from October to March, with an annual average of 612.5 mm (Institute of Soil, Climate and Water AgroMed section 2008). The mountains have a rugged topography with steep cliffs in some areas. Small rivers, large rivers, streams and gullies all cut into the plateau and it also contains wetlands, marshes, fountains and other wetland features. Van Rooyen & Bredenkamp (1996) classified the vegetation as Waterberg Moist Mountain Bushveld while Mucina & Rutherford (2006) classified the vegetation as Waterberg Mountain Bushveld. On steep slopes (10 – 40°) the vegetation is characterised by *Diplorhynchus condylocarpon* savanna while on flat areas with a gradient of less than 10° vegetation is characterised by *Terminalia sericea* savanna (Tuinder 1991). Redundant agricultural fields are normally characterised by the tree *Terminalia sericea*, which occurs as short open woodland while grass species like *Cynodon dactylon* and *Acanthospermum glabrum* are found on the open grass veld areas (Tuinder 1991). Valley bottoms have deep soils where tall trees such as *Faurea saligna* and *Syzygium cordatum* dominate the tree layer.

2.2 Data collection and analysis

Leopards were captured using baited cage-traps with drop-door mechanisms. Trapped leopards were immobilized in the cage by a wildlife veterinarian using Zoletil (tiletamie HCL and zollazapam HCL, Virbac Animal Health, Halfway House, South Africa) at a dose of 4-5 mg/kg of estimated live weight. Drugs were administered intramuscularly in the hindquarters with a jab stick. Animals were placed back into the cage after handling and left in shade until fully recovered from where they were released at the capture site. We conducted the research under University of Pretoria Animal Use and Care Committee ethics clearance protocol A022-06 and Limpopo leopard capture permit number CPM-004-00006.

GPS/GSM (cellular network) collars (Supplier: Africa Wildlife Tracking, http://www.awt.co.za) were fitted to captured leopards. The collars weighed about 650 g equivalent to 1 % to 1.5 % of leopard body weights, which was below the recommended 3 % (Kenward 2001). GPS locations were recorded every 5 hours and location data was sent via the GSM network to a website (http://www.yrless.co.za). GPS locations were stored onboard the collar when no

GSM network coverage was available to transmit the acquired GPS locations. Stored GPS location data was transmitted whenever the collared animal entered an area with GSM coverage. Collar GPS units were set to search a maximum of 180 seconds to acquire satellites needed to get a GPS location. GPS location data were downloaded from the internet every morning during the study. Data supplied included date, time, GPS location, direction of movement, speed, GSM coverage and temperature of collar. Latitude and longitude positions were converted to UTM format compatible with ArcGIS® 9.2 (Environmental Systems Research Institute (ESRI), Redlands, CA) by using the WGS84 35S datum.

Distances moved between GPS points were estimated by using Home Range Tool for ArcGIS® 9x (Rodgers, Carr, Beyer, Smith & Kie 2007). Distances moved when 4 or more GPS points were missed, were removed from analysis, since it can alter the description of the movement pattern (Merrill & David Mech 2003). Leopards moved short distances when one to four GPS points where missed, indicating that leopards were stationary in space (Chapter 7). It was believed that including these distances in analysis would not alter the movement patterns. Missed locations ranged from 15 % to 29 % for this study (Chapter 7). Diurnal (12 h) displacement was measured between early morning (06h00) and evening locations (18h00) while nocturnal (12 h) displacement was measured between evening (18h00) and following early morning (6h00) locations to compare with results from Grimbeek (1992). Night time was divided into 3 zones: 18h00 - 23h00, 23h00 - 03h00, 03h00 - 06h00 while day time was divided into: 06h00 - 11h00, 11h00 - 15h00, 15h00 - 18h00. The year was divided into two seasons: Wet (October - March) and Dry (April - September). Daily displacement was measured as the distance travelled during 24 hours (from 06h00 day 1 to 06h00 day 2).

The home range tool (Rodgers *et al.* 2007) for ArcGIS® 9x was used to estimate minimum convex polygon (MCP) as well as a kernel based home range. The MCP enabled direct comparison with previous home range estimates for leopards. Animal movement extension (Hooge, Eichenlaub & Soloman 1999) was used to investigate if leopard MCP sizes have reached asymptotes. The adaptive kernel was constructed by increasing the proportions of the generated smoothing parameter (starting at 0.1 x h_ref and then increased at 0.1 increments) until a single polygon home range was evident (A. Rodgers, Ontario Ministry of Natural Resources, United States Forestry service, email communication, 7 February 2008). This method was used to avoid analytical problems encountered when using least square cross-validation with large

GPS location data sets (Hemson, Johnson, South, Kenward, Ripley & Macdonald 2005; Mills, Patterson & Murray 2006).

The generated MCP (95 %) home ranges of each leopard were laid over ranch boundaries to identify ranches used by individual leopards. These ranches were then clipped from the base ranch boundary layer. The proportion of different land use types that made up leopard home ranges, were calculated by adding up the land use types in the clipped layer. The time leopards spent on different land use types was calculated by counting the number of GPS points in that land use type by using the count points in polygon tool available in Hawth's tools (Beyer 2004).

Data were analysed using the *SPSS v.15* (SPSS Inc., Chicago, USA). The Kolmogorov-Smirnov test was used to investigate normality and appropriate nonparametric tests were used where data were not normally distributed.

3 RESULTS

3.1 Movements

Daily displacements were not normally distributed (Kolmogorov-Smirnov test) for the male: AS9 ($D = 0.117$, $df = 565$, $p = 0.000$), female: AS57 ($D = 0.127$, $df = 519$, $p = 0.000$), female: AS37 ($D = 0.128$, $df = 169$, $p = 0.000$) and female: AS29 ($D = 0.135$, $df = 56$, $p = 0.012$). Daily displacement distances did differ significantly among female leopards for mean distances (Kruskal-Wallace test, $D = 5.413$, $df = 2$, $p = 0.067$) or median distances (Median test, $df = 2$, $p = 0.185$). Daily displacement was longer for the male leopard (median distance = 3.4 km, mean = 4.17 km, S.E = 0.14 km) than for the female leopards (median distance = 2.18 km, mean = 2.76 km, S.E= 0.11 km). The majority of male and female daily displacements were shorter than 4 km (55 %, 74 % respectively). Long daily displacement (> 10 km) accounted for 7 % of the male's daily movement, versus 1 % of the females' daily movement. Maximum daily displacement distances were 15 km for female leopards and 16 km for the male leopard.

Movement of the male leopard was characterised by circular movement with criss-crossing through the range or rapid movement backward and forward through his range (Fig. 2). Camera traps placed at heavily scratched trees indicated that the male leopard passed the same location every 6 - 12 days (n = 20 occasions). During the latter part of the study the male leopard increased exploratory movement to the north western side of his range (Fig. 2).

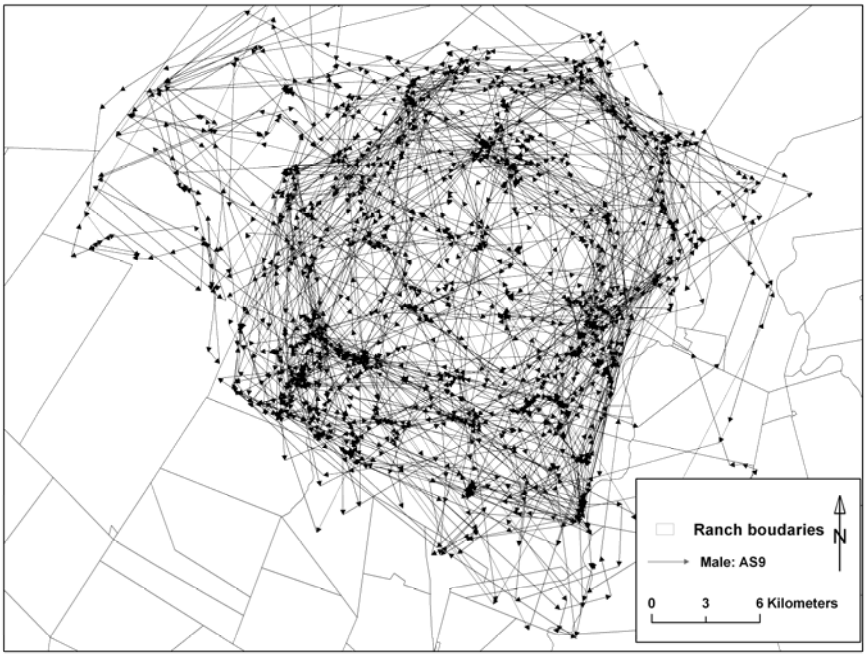

Fig. 2. Movement path of the male leopard over a period of 630 days.

3.2 Seasonal trend

The median daily displacement distances did not differ significantly between wet and dry season for the male (Wilcoxon sign rank test, Z = -0.686, p = 0.493) or female AS 57 (Z = - 1.577, p = 0.115). For the male, medial displacement for the dry season were 3.4 km (mean = 4.3 km) and 3.3 km (mean = 3.9 km) for the wet season. Medial dry season displacements for female AS57 was 2.4 km (mean = 3.20 km) and 2.30 km for wet season (mean = 2.7 km). Male medial displacements were the shortest during late wet and dry season and increased during early dry and wet season (Fig. 3). Medial displacement distances for female AS57 were the shortest throughout the wet season and early dry season and to the early wet season (Fig. 3).

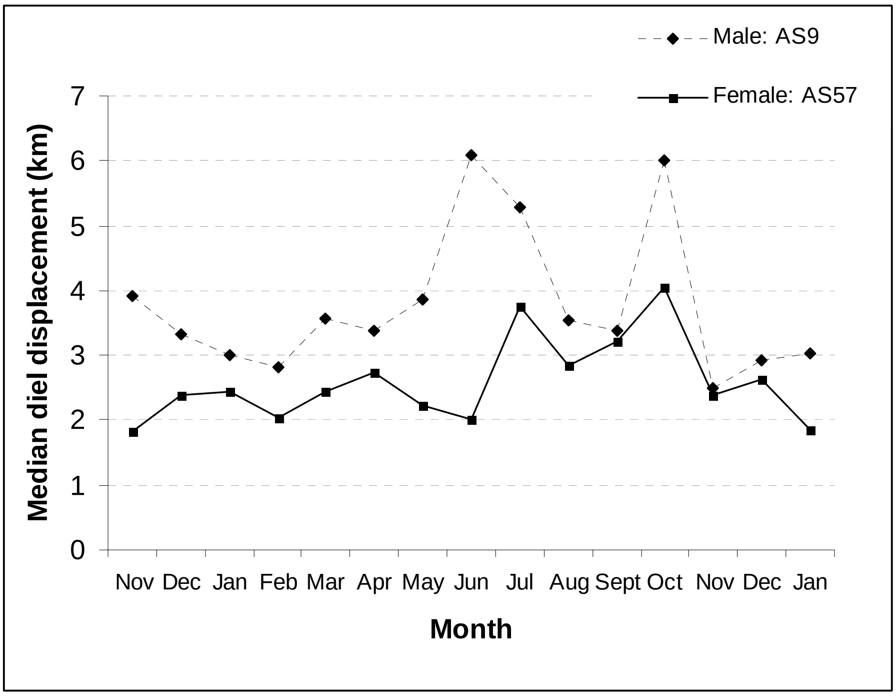

Fig. 3. Monthly changes in daily displacement for the male leopard and female AS57. Other females were omitted due to small sample sizes.

3.3 Day and night differences

The male leopard travelled significantly (Wilcoxon sign rank test, Z = -8.99, p = 0.000) longer distances during the night (median = 2.3 km, mean = 3.0 km) than during the day (median = 0.27 km, mean = 0.62 km). Female leopards followed a similar significant trend (Z = -6.549, p = 0.000) and moved a median distance of 0.30 km (mean = 0.67 km) during the day and a median distance of 0.78 km at night (mean = 1.38 km). The highest proportion (37 %) of night time displacement of the male leopard exceeded 4 km while the highest proportion of daytime displacement distances was less than 1 km (63 %) (Fig. 4). For the female leopards the highest proportions of day and night time displacements were less than 1 km (73 % and 58 % respectively), while very long displacements (> 4 km) only occurred at night (Fig. 4b).

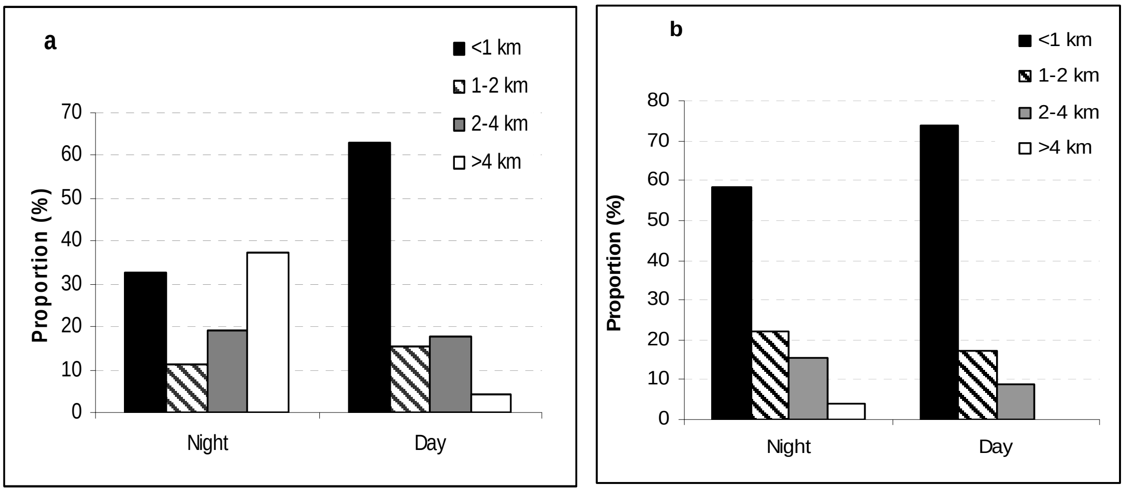

Fig. 4. (a) Proportion of short (< 1 km), medium (1 - 2 km), long (2 - 4 km) and very long (> 4 km) displacement distances during night and day for the male and (b) female leopards (n = 3).

For the male leopard, the greatest proportion of very long movement (> 4 km) occurred from 18h00 to 23h00, while early morning (03h00 - 06h00) movement were restricted to short displacements (Fig. 5). Early morning till late afternoons (06h00 - 15h00) were characterised by short displacement distances (< 1 km) while the proportion of long distances starts to increase in the late afternoon (Fig. 5). The proportion of distance categories for female leopards was fairly constant throughout day and night, although the proportion of long displacement distances (2 - 4 km) increased from 23h00 - 06h00 and very long displacements (> 4 km) were most prevalent between 18h00 - 23h00 (Fig. 5b). For both male and female leopards the greatest proportion of short displacement distances (<1 km) was found during mid day (11h00 - 15h00) (Fig. 5).

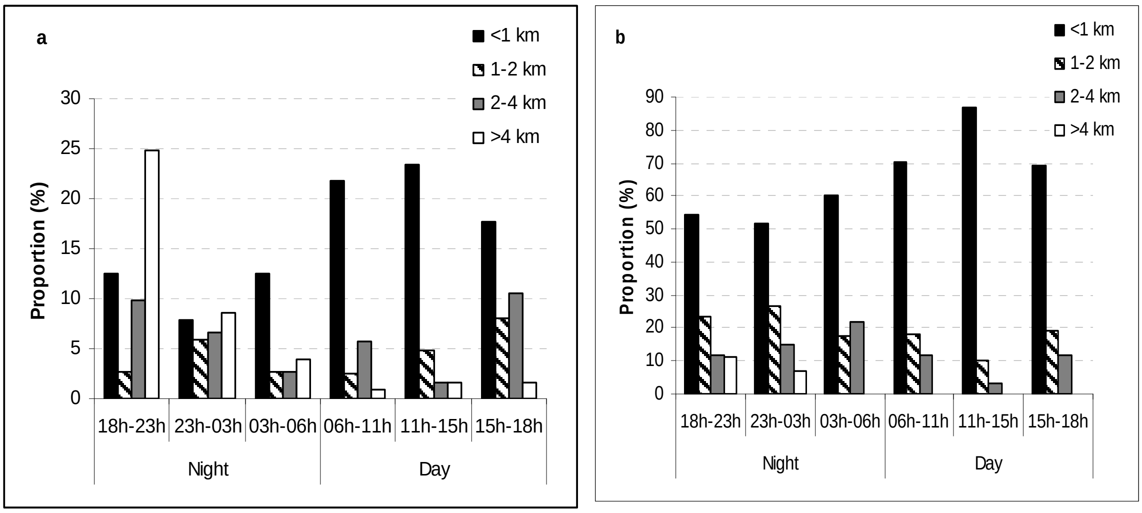

Fig. 5. Day and night changes in the proportion of short (<1 km), medium (1 - 2 km), long (2 - 4 km) and very long (> 4 km) displacement distances for (a) male, and (b) female leopards.

3.4 Home range

3.4.1 Home range size

Home range size of leopards as calculated by using the minimum convex polygon method (MCP, 95 %) ranged from 38 km² to 245 km² (Table 1), whereas 95 % kernel home ranges varied from 61 km² to 214 km² (Table 1). Observation – area curves indicated that female AS57 and male AS9 have reached MCP asymptotes while asymptotes were not reached for female AS37 and AS29 (Fig. 6). Size of the core areas ranged from 14 km² to 52 km². Wet season ranges for both male and females were larger than dry season ranges (Table 1).

Table 1. Estimated age, sex, number of days tracked and overall and seasonal home range sizes for 4 leopards tracked in the Waterberg and other areas. Home ranges size estimates based on 95 % and 100 % minimum convex polygon (MCP) and 95 % adaptive kernel method, while core areas were based on 50 % kernel isopleths

					MCP (km²)		Kernel (km²)		95 %MCP (km²)		50 %Kernel (km²)	
Collar number	**Sex**	**Age (years)**	**No of days tracked**	**Total no. fixes**	**100 %**	**95 %**	**95 %**	**50 %**	**Wet season**	**Dry season**	**Wet season**	**Dry season**
AS9	M	4	603	2212	289	245	214	52	224	153	67	37
AS57	F	4	560	2114	159	139	109	20	112	71	27	17
AS37	F	3	182	620	291[b]	221	94	23	223	217	26	4
AS29	F	7	57	228	41[b]	38	61	14				
Other studies												
Namibian ranch lands[c]	M		480[a]	47[a]		229[a]			210[a]	162[a]		
	F		630[a]	77[a]		179[a]			359[a]	117[a]		
Waterberg, South Africa[d]	M				354	303						
	F				173	157						

[a] Mean values
[b] Asymptote not reached (see fig. 5)
[c] Marker & Dickman (2005)
[d] Grimbeek (1992)

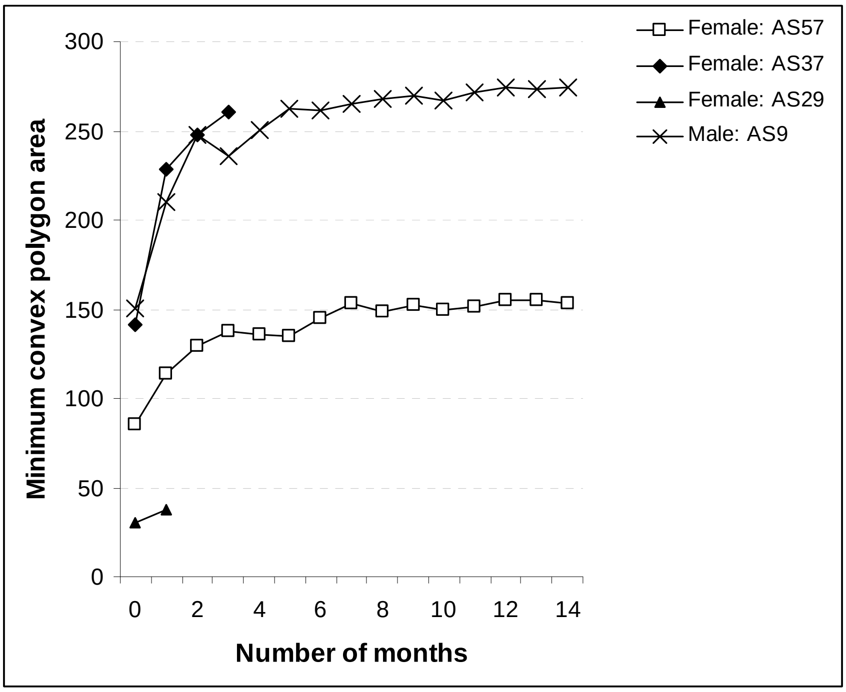

Fig. 6. Range size (100 % MCP, km²) of leopards plotted against number of months tracked. Asymptote reached only for male AS9 and female AS57.

3.4.2 Sociality

At 95 % MCP level, home range overlap between same sexes ranged from 8 % to 40 % with an average of 17 % overlap between female leopards (Fig. 6). Male MCP (95 %) overlap with females ranged from 35 % to 85 % with an average of 66 %, while female home range overlap with the male home range varied between 12 % and 48 % with an average of 31 % (Fig. 7).

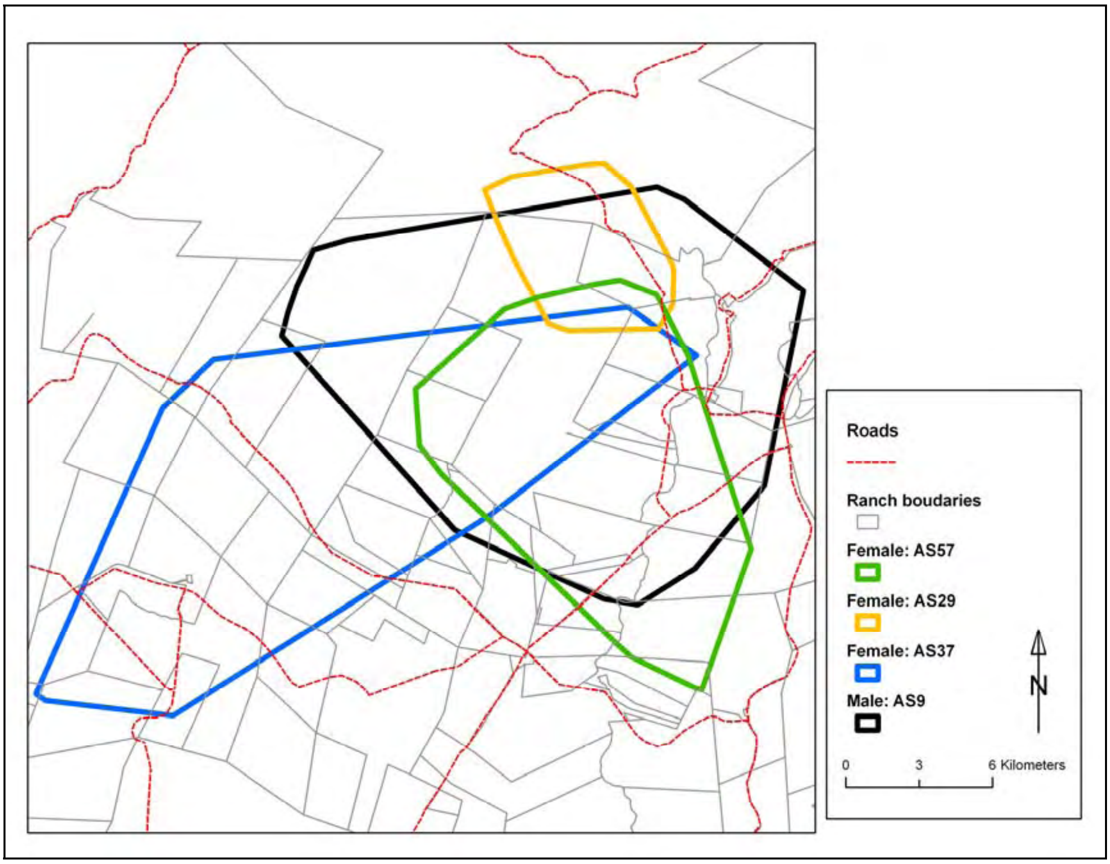

Fig. 7. Home range based on 95 % minimum convex polygon method, of one male and three female leopards on game and livestock ranches in the Waterberg, South Africa.

Core areas, based on the 50 % kernel isopleths, of female leopards did not overlap, while the core area of the male leopard overlapped with the core areas of all the females (Fig. 8). The average distance between the mid points of the female core areas was 9.3 km and ranged between 7 km to 12 km.

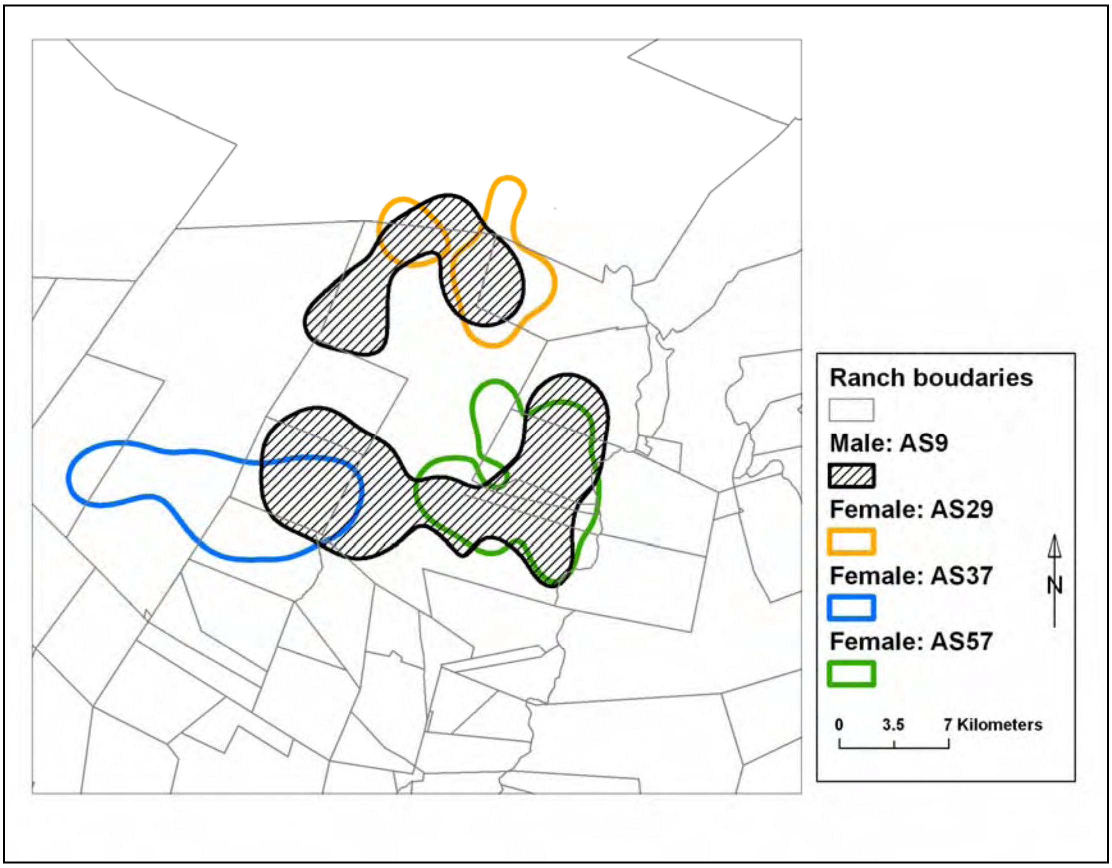

Fig. 8. Kernel (50 % isopleths) estimation of the core areas of one male and three female leopards, showing extent of overlap between male and female leopards.

3.4.3 Ranch overlap and use

For all leopards, the biggest proportion (46 %) of home ranges (95 % MCP) consisted of livestock and consumptive wildlife utilisation (CWU) properties, except for female AS37 where livestock ranches formed the largest proportion of her home range (Fig. 9a). Accordingly, most of the leopards' time is spent on livestock and CWU properties, except for female AS57, where a similar proportion of time was spent only on livestock properties (Fig. 9b). While female AS37 had spent the largest proportion of her time on livestock and CWU properties, a large proportion of her home range consisted of livestock properties (Fig. 9 a, b).

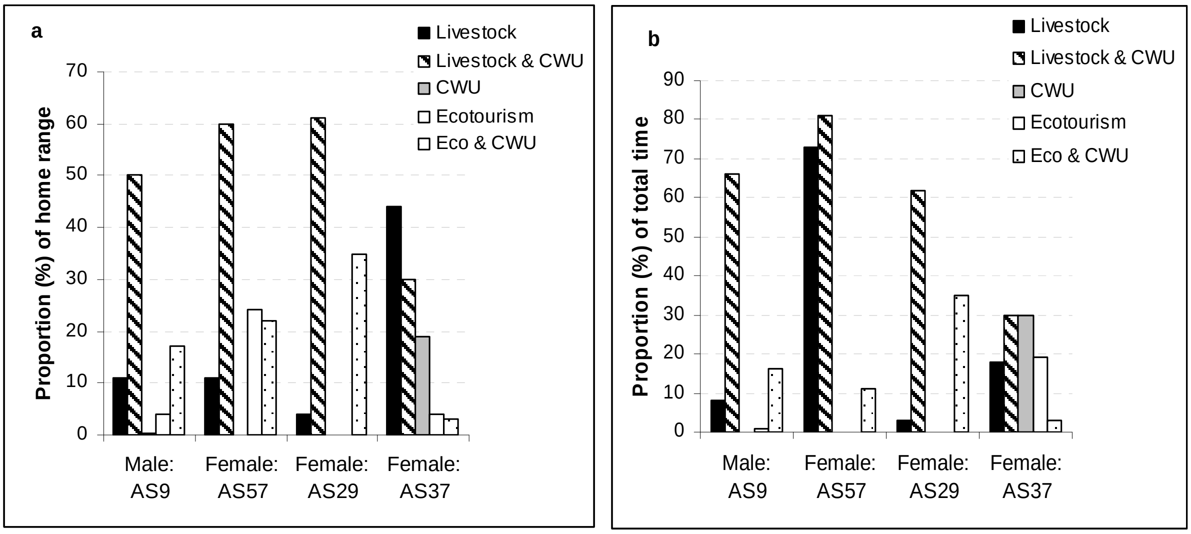

Fig. 9. (a) The proportion of different land use types that made up leopard home ranges (95 % MCP) (b) and proportion of time leopards spent on land use types.

The biggest proportion of the male leopard and female AS57's core areas consisted of livestock and CWU properties (Fig. 8a), and accordingly most of their core time was spent on these land use types (Fig. 10b). While CWU properties formed the largest proportion of female AS37's core areas, core time was spent almost equally on livestock and CWU properties and CWU properties (Fig. 10a, b). Ecotourism and CWU properties were the most important land use types for female AS29 in terms of core area and core area time.

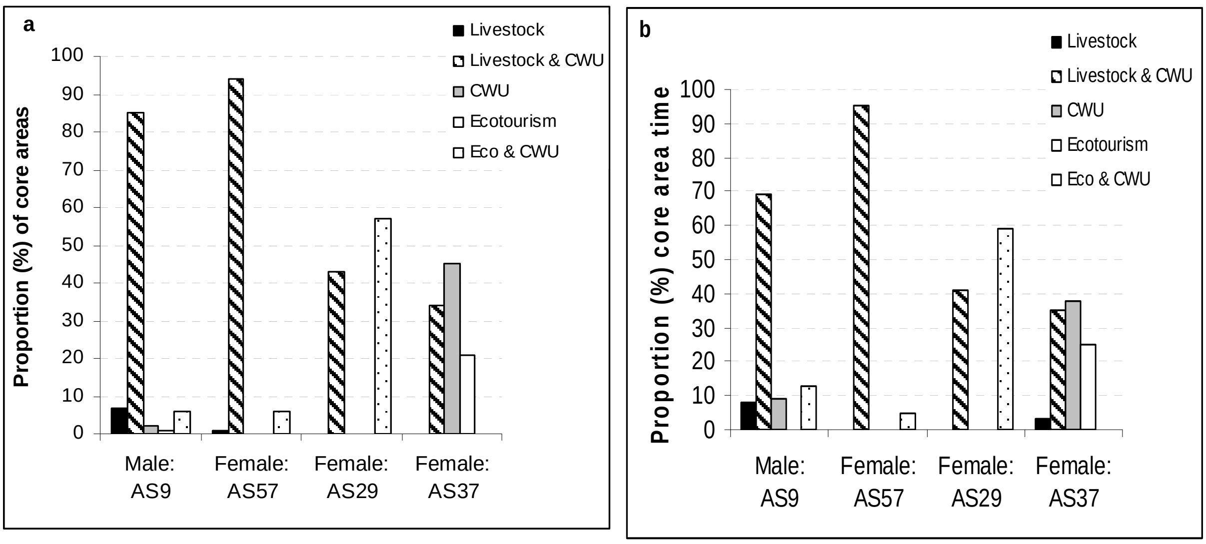

Fig. 10. (a) Proportion of land use types that made up the leopard core areas (50 % kernel isopleths), (b) and proportion of core area time spent on different land use types.

4 DISCUSSION

4.1 Collar performance

The GPS/GSM collars preformed satisfactorily and missing GPS data accounted for 18 % of data points downloaded (Chapter 7). Only two leopards reached asymptotes on the observation - area curves and thus true home ranges could only be constructed for these two leopards. The reason for the premature failures of female AS 37 and 29's collars is not known. The small sample size obtained in the study thus necessitates cautious interpretation of the data.

4.2 Movement

Mean daily distances travelled by leopards during this study were lower than previous results reported for the Waterberg. Grimbeek (1992) reported mean daily displacement of 8.6 km for a male leopard and a mean of 6.1 km for a female leopard in the Waterberg. Daily displacement distances reported here were also much lower than the 14.3 km for male leopards, and 13.4 km for female leopard with cubs, in the Kalahari (Bothma & Le Riche 1984). Results from this study were, however, similar to those found in Tsavo National Park, where daily distances travelled were 4.2 km (males) and 2.3 km (females) (Hamilton 1976). In contrast, mean daily distances travelled in Kruger National Park (2.8 km for males and 1.5 km for female) were lower than those found in this study (Bailey 1993). The difference in daily displacement distances displayed by leopards across geographic regions and habitat types can reveal how leopards are influenced by prey and other leopards (Bailey 1993). Hamilton (1976) for example, found a significant relationship between leopard home range size and daily distances moved, indicating that leopards will travel further per daily tracking period if home ranges are large. Home ranges of leopards in the Waterberg are large (Grimbeek 1992, this study), which will lead to large daily displacement distances. The lower daily displacement distances from the previous study can potentially be attributed to the increase in the number of game ranches in the Waterberg, which resulted in slightly smaller home ranges. However, another plausible explanation can be that the leopard home ranges in Grimbeek's (1992) study included large areas of crop land, where potential prey density would be at a minimum. Leopards thus had to travel quite a lot further to encounter prey and other leopards. Leopard home ranges in this study included minimal amount of crop land, which could lead to reduced daily displacement distances.

The lower daily displacement distances of female leopards compared to male leopards observed during this study were similar to results from other leopard studies (Hamilton 1981; Bothma & Le Riche 1984; Grimbeek 1992; Bailey 1993; Mizutani & Jewell 1998). The maintenance of territories and the location of females necessitates male leopards to travel further (Bailey 1993), while it appears that female leopards move the minimum distance needed to obtain prey and rear young (Mizutani & Jewell 1998).

The characteristic circular movement pattern of the male leopard observed during this study were also reported for male leopards in Kruger National Park (KNP) and leopards on livestock ranches in Kenya (Bailey 1993; Mizutani & Jewell 1998). In contrast Grimbeek (1992) did not find that leopards (male or female) moved in circular patterns, but rather cross rapidly backwards and forwards within their range. A similar observation was made by Norton & Henley (1987) for leopards in the Cederberg. While a circular movement suggests that male leopards patrol the edges of their ranges, evidence rather indicates that leopard territories are maintained by indirect means such as tree scratching and urine scraping (Bothma & Coertze 2004). Field observations of tree scratching during this study indicated that the water berry trees (*Syzygium cordatum*) were the most frequently scratched trees. Heavily scratched trees were normally found along water courses near the edge of the male's home range. Similar findings were reported by Grimbeek (1992).

Although the daily displacements for leopards during the wet and dry season were statistically similar, an increase in daily displacement in the dry season for both male and female leopards was observed. During the dry season and beginning of wet season prey will probably be more dispersed due to lower abundance of vegetation and water. Leopards will therefore have to increase their daily movement to encounter prey, which will lead to an increase in daily displacement (Grassman Jr 1999). However, it is unlikely that prey move over long distances on game ranches due to the effect of game fences (Marker & Dickman 2005). Increased daily displacement in this study could be also attributed to other non ecological factors such as human interference. For example, Bailey (1979) suggested that levels of human disturbance may influence bobcat space use. Increased daily displacements of leopards during the dry season coincided with the main sport hunting season in the Waterberg. It could be plausible that leopards disturbed by human hunters move to refuge areas, and thereby influencing movement rates. Alternatively, availability of leopard prey, hunted by sports hunters during the dry season, could be reduced or dispersed, which will lead to higher movement rates by leopards in dry season to encounter prey.

As expected both leopard sexes travelled longer distances during the night than during the day. It is known that leopards are largely nocturnal (Skinner & Smithers 1990) and Grimbeek (1992) found that leopard activity in the Waterberg peaked at around 18h00 for females and 04h00 for males. Results here indicate that a large proportion of male leopard's night distances were very long (> 4 km), which suggests that the male is travelling at high speeds during night time. Speeds of up to 2.9 km/h were reported by Bailey (1993) for male leopards in KNP during the night, which were attributed to the patrolling of home ranges. However, the greatest proportion of very long displacement distances for the male leopard occurred from 18h00 - 23h 00, which suggests that patrolling, occurs early in the night. Very long distances travelled by female leopards also peak from 18h00 - 23h00; however the highest proportion of night time movement was short distances. It therefore seems that females move the minimum distance needed to catch prey, as suggested by Bailey (1993). Day time distance categories for both sexes were dominated by short distances (< 1 km), while from mid afternoon long displacements increased. This behaviour is expected as leopards normally stay at resting sites during the day, with minimal movement needed to find shade (Bailey 1993; Bothma & Bothma 2006). Overall results here concur with Bailey (1993) which suggest that for males travelling is a nocturnal activity, while resting is the dominant daily activity. For females though, movement is restricted to the minimum needed to find food and support young (Bailey 1993). Similar results were reported for other solitary cats, such as bob cats (*Lynx rufus*) (Chamberlain, Leopold & Conner 2003).

4.3 Home ranges

Home range sizes observed here followed the expected pattern of larger home range size in males than in females. Leopards are dimorphic, with males being bigger than females, and have a polygynous breeding system (Skinner & Smithers 1990). Males therefore are expected to have larger home range sizes than females to acquire enough resources for survival and increased mating opportunities in the breeding season (Sandell 1989). Uniparental care exhibited by females though, will force females to reduce home range size and movements during the breeding season and when rearing young (Bailey 1993). Our results agree with previous studies on leopard home ranges where several female leopards have overlapping ranges which they share with one male (Muckenhirn & Eisenberg 1971; Bailey 1993; Mizutani & Jewell 1998).

Relatively high levels of overlap occurred at the home range level for female leopards, but exclusive core areas were maintained. As only one male leopard was collared, overlap between males could not be estimated. However, the male's home range overlapped with three collared females, while one more female was photographed with camera traps in his home range. The core area of the male leopard overlapped with the core areas of the three collared females. Results from leopards studied in Laikipia district in Kenya indicated that leopards maintained exclusive home ranges, suggesting territoriality among males and females (Mizutani & Jewell 1998). However, other studies have shown considerable intrasexual overlap at the home range level for both sexes (Norton & Henley 1987; Bailey 1993; Marker & Dickman 2005). Mizutani & Jewell (1998) suggested that exclusive home ranges can only be maintained when food supply is stable and evenly distributed during the most critical part of the year. Similarly, Kruuk (1972) found that territoriality of spotted hyenas can differ from one population to another, depending on the nature of food supplies. The area used by leopards in this study consisted of various different land use types, and consequently prey densities will also differ among land use types. Also, food sources can change seasonally and annually as ranches are sold; hunting takes place and land use type changes. Leopard home ranges on ranches are thus configured around unpredictable resources which will ultimately lead to a high degree of overlap (Sandell 1989), as evident in this study and on Namibian ranches (Marker & Dickman 2005).

However, research has shown that female leopards arrange their home ranges around important resources such as waterholes, denning sites and prey rich habitats which are important for cub survival and reproduction (Bailey 1993; Bothma *et al.* 1997). Samuel, Pierce & Garton (1985) identified these areas in the home range as core areas. Results from bob cats (*Lynx rufus*) have shown that females are territorial at core areas, but allow high levels of overlap at home range level (Nielsen & Woolf 2001). The core area spacing of female leopards in this study, with no overlap, is consistent with results for female bob cats (Nielsen & Woolf 2001), which suggests that female leopards are territorial at core area level.

Home range sizes reported for this study were smaller, albeit marginally, than the previous study in the Waterberg. The increase in game ranches, with a theoretical increase in prey numbers, is seen as one of the main reasons for an increase in leopard density on private land (Kharika 2005). While logic would predict that an increase in density should lead to a reduction in home range size, finding evidence for such a relationship proves challenging. Dahle & Swenson (2003) found that for brown bears (*Ursus arctos*) an inverse relationship existed between density and home range that was unrelated to food supply. Similarly, Benson *et a*l. (2006), proved that bobcat home range is more affected by bobcat density than food availability. These results suggest that while prey density may increase, it does not necessarily relate to a reduction in predator home range size. If the densities of leopard increase with an increase in prey availability, the social organisation needs to adapt, either by increasing range overlap or a reduction in range size. Bobcat females went the route of a reduction in range size and increased overlap, while bobcat males maintained the same overlap, but decreased home range and core areas (Benson *et al.* 2006). Limited data for the Waterberg does not allow for clear conclusions, but the large overlap of female home ranges (average 35 %) suggests that female leopards increased home range overlap, but maintained exclusive core areas.

Alternatively, the impact of human persecution on leopard social ecology should not be underestimated. Research has shown that badgers subjected to population control increased their home ranges and overlap (Tuyttens, Delahay, Macdonald, Cheeseman, Long & Donnelly 2000). Lynch, Kirby, Warren & Conner (2008) also found that home ranges of male bobcats increased after a 50 % population reduction. This could also be a reason for the large overlap seen in this study, although more detailed investigations are needed to quantify the effect of human removals on leopard spatial ecology.

4.4 Ranch overlap

Due to the large home ranges of leopards a substantial number of ranches were used by a single leopard. The most important land use types utilised by leopards were livestock & CWU ranches, although one female used a large proportion of livestock ranches. One of the key practices of consumptive wildlife utilisation ranches is sports hunting and/or the live sale of game, which necessitates that a high number of game are stocked. Consequently leopards spend a large proportion of their time on these properties and their core areas are almost exclusively contained on CWU ranches. The fact the female leopards configure their ranges around prey rich areas (Bailey 1993) can explain why CWU ranches are selected as core areas for females. Even female AS37's core area, whose home range consisted mostly of livestock ranches, was mostly contained on CWU ranches (Fig. 8a).

5 CONCLUSION

Movement of leopards in this study followed patterns previously documented for leopards. Male daily distances travelled were longer than females, while for both sexes, movement usually occurred at night. Long displacement distances were a characteristic of the male leopard, which was attributed to territorial behaviour. Females moved the minimum distances needed to catch prey. For both sexes dry season displacements increased, the reason for this could be attributed to a lower prey density or human hunter disturbance.

While prey density increased due to increases in game ranching, leopard home range size did not differ that much from earlier home ranges in the Waterberg. With limited data on range overlap for this and previous studies no clear conclusions could be made on how leopard spatial ecology was affected by the increase in prey density. No clear conclusion could be made that an increase in prey numbers and game ranches led to an increase in leopard numbers, and thus a decrease in home range sizes. On the contrary, it seems that leopard home ranges and density are similar to previous results reported for the Waterberg, when the number of game ranches was low. Leopard spatial organisation observed here still follows the typical spatial organisation of leopards observed elsewhere, and solitary felids world wide. Core areas of female leopards did not overlap, but were overlapped by the core area of the male leopard. Consumptive wildlife utilisation ranches were the most important land use type used by leopards; both in terms of core areas and time spent on ranches.

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CHAPTER 5:

LEOPARD (*PANTHERA PARDUS*) FOOD HABITS ON SELECTED GAME AND LIVESTOCK RANCHES IN THE WATERBERG, SOUTH AFRICA

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LEOPARD (*PANTHERA PARDUS*) FOOD HABITS ON SELECTED GAME AND LIVESTOCK RANCHES IN THE WATERBERG, SOUTH AFRICA

To be submitted to: African Journal of Ecology

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ABSTRACT

Leopards (*Panthera pardus*) still manage to persist on game and livestock ranches in South Africa. However, predation by leopards on game and livestock is a major cause of conflict between ranchers and leopards which ultimately leads to the destruction of leopards. While the feeding ecology of leopards in protected areas is well described, only limited data is available for leopard food habits on ranch land. An understanding of leopard feeding ecology on ranch land is essential in mitigation of rancher-leopard conflict. We determined leopard food habits on game and livestock ranches by analysing leopard scats collected and investigating Global Positioning System (GPS) location clusters of 2 leopards. Ninety seven GPS clusters were investigated which resulted in the detection of 77 carcasses, while 21 carcasses were found opportunistically. Thirty eight scats were analysed and composition of diet was constructed by applying correction factors. Leopards preyed on 19 prey species of which kudu (*Tragelaphus strepiceros*) were the most important and accounted for 22.99 % of biomass consumed, while bushbuck (*Tragelaphus scriptus*) accounted for 14.57 % and warthog (*Phacochoerus aethiopicus*) for 8.83 % of biomass consumed. Ungulates were the most important taxa making up 90.05 % of biomass consumed. Cattle predation was not detected even though cattle were abundant in the study area. Lagomorphs, rodents, primates and carnivores were also consumed. The mean weight of all prey killed was 37.66 kg while the mean age of prey was 16.68 months. Comparison between leopard sexes indicated that male leopards killed significantly more male prey than female leopards ($p = 0.01$). Age structure of prey killed indicated that young animals (< 2 years) were killed more than adult prey. Leopards preferred medium sized prey that selected dense vegetation and avoided plains game.

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1 INTRODUCTION

Leopards (*Panthera pardus*) are among the world's most successful larger carnivores (Eaton 1978) and are even able to persist in areas with high human densities (Nowell & Jackson 1996), something most larger carnivores are not able to do (Woodroffe 2000). Leopards achieve this feat by their remarkably diverse and adaptable diet (Mills & Harvey 2001; Hayward, Henschel, O'Brien, Hofmeyr, Balme & Kerley 2006), and their broad habitat selection (Bertram 1999). Although Hayward *et al.* (2006) showed that the leopard's most preferred prey weight is 25 kg, leopards have been recorded killing adult female eland (*Tragelaphus oryx*) (De Ruiter & Berger 2001), which can weigh between 350 - 450 kg (Skinner & Smithers 1990), giraffe calves (*Giraffa camelopardalis*) (Scheepers & Gilchrist 1991), rodents (Child 1965; Smith 1987), dung beetles (Fey 1964) and even fish (Fey 1964; Mitchell, Shenton & Uys 1965), showing their great diet flexibility. It is however thought that leopards mainly focus on prey in the 20 - 80 kg weight range (Bailey 1993; Mills & Harvey 2001) and Bailey (1993) found that 92 prey species have been documented for leopards.

The two main requirements for leopards to survive in areas seem to be sufficient cover and suitable sized prey (Bertram 1999) and it is thus no surprise that leopards are the only remaining large felid to be found frequently on agricultural land in southern Africa (Grimbeek 1992). In livestock farming areas the dietary flexibility of leopards causes them to switch to livestock when natural prey numbers are low or when hunting opportunity arises (Norton, Henley & Avery 1986; Maan & Chaudhry 2000), which leads to conflict and the subsequent killing of leopards in these areas (Esterhuizen & Norton 1984). This situation is not unique to South Africa and leopard livestock conflict has been reported for various parts of Africa (Mizutani 1999; Butler 2000; Ogada, Oguge, Woodroffe & Frank 2003), Pakistan (Maan & Chaudhry 2000) and India (Edgaonkar & Chellam 2002). Indeed it has been recognized that competition between humans and carnivores for shared resources, mainly protein, is largely responsible for the worldwide conflict between humans and carnivores (Graham, Beckerman & Thirgood 2005) and it is one of the main driving forces in the global decline of carnivore numbers (Woodroffe, Lindsey, Romanach, Stein & Ole Ranah 2005).

Although historically leopard conflict was restricted to livestock ranches, at present conflict is on the increase in the South African game farming and ranching industries.

Game ranchers especially can be quite aggressive towards carnivores, for example Marker *et al*. (2003) found that significantly more game ranchers removed cheetahs than livestock ranchers in Namibia, while Hunter and Balme (2004) reported that game farmers are even more hostile towards leopards than livestock owners. In the last decade South Africa has seen a dramatic increase in the number of game farms (Falkena & Van Hoven 2000; Van der Waal & Dekker 2000) and while this increase is seen as positive for the conservation of leopards (Kharika 2005), it can also increase conflict. An understanding of diet and prey selection of leopards on game and livestock ranches can be an important component in understanding and managing rancher-leopard conflict.

Although the feeding ecology of leopards has been well documented for protected areas in South Africa (Bothma & Le Riche 1986; Le Roux & Skinner 1989; Bailey 1993) only a few researchers have attempted to determine the diet of leopards on game and livestock farms (Norton *et al.* 1986; Grimbeek 1992; Ott, Kerley & Boshoff 2007). Sampling leopard diets is difficult (Hayward *et al.* 2006) and finding enough scats to do proper diet studies proves to be a challenge (Ott *et al.* 2007). The low density and wide ranging habits of leopards in the Waterberg makes finding scats difficult (Grimbeek 1992). However, with the advent of GPS telemetry the possibility exists to identify and investigate predator prey interactions (Anderson Jr & Lindzey 2003). Kills made by carnivores fitted with GSP collars will exhibit a cluster of GPS coordinates at potential kill sites, and by investigating these GPS clusters, prey killed can be identified to aid in feeding ecology studies (Anderson Jr & Lindzey 2003; Sand, Zimmermann, Wabakken, Andren & Pedersen 2005). This study investigated leopard food habits on game and livestock ranches with the use of scat analysis, the investigation of GPS clusters and kills found opportunistically on ranches.

2 METHODS

2.1 Collection of scats

Scats were collected on vehicle roads, animal paths and near kills made by leopards. For roads a constant speed of 30 km/h was maintained while continuously scanning the road and adjacent areas for scats. Areas frequented by leopards were identified by finding trees scratched by leopards (Grimbeek 1992; Bailey 1993) and thereafter, a suitable well-established animal path was searched for and selected. The selected animal path was walked in search of leopard scats. The survey was terminated when a maximum of 5 km was walked, or sooner if the animal path was no longer well defined. Scats were also collected near kills made by leopards. It was believed that some scats near leopard kills could be from previous kills, or small prey killed between kills. Liquid scats, which only contain protein and small amounts of hair were unusable and were not collected (Floyd, Mech & Jordan 1978).

Only scats with a diameter of more than 20 mm were collected, as smaller scats can be confused with that of caracal (*Felis caracal*) (Norton *et al.* 1986). Scats with a diameter less than 20 mm were only collected if the scat was found with associated leopard signs (kill site and tracks). Collected scats were placed in a paper bag, each with a unique identification number and a GPS coordinate.

2.2 Scat analysis

Each individually collected scat was sewn into a separate, uniquely identified, nylon sachet. Sachets were then washed until all soluble material was removed and oven dried (Bowland & Perrin 1993). Scat material was analyzed macroscopically using a reference housed at the Transvaal museum (Bothma & Le Riche 1994) and microscopically using hair cross sections and cuticle patterns. Cross sections were made according to Douglas (1989) where hair bundles were imbedded in a mixture of 25% depilatory wax and 75% paraffin wax. The method of Dreyer (1966) was adopted to make gelatine impressions of hair cuticle patterns. Cross sections and cuticle patterns were compared to published hair keys and reference collections housed at the Centre for Wildlife Management, University of Pretoria (Dreyer 1966; Keogh 1979; Perrin & Campbell 1980; Keogh 1983; Buys & Keogh 1984). A minimum of 20 hair per scat was used to make the imprints as Mukherjee *et al.* (1994) reported that prey items may be missed if less than 20 hair imprints per scat are used.

Scat contents are represented in frequency of occurrence (percentage of total scats containing item) and percent occurrence (number of times a item was found as percentage of total items found) (Ackerman, Lindzey & Hemker 1984). Percent occurrence accounts for more than one item per scat, while frequency occurrence indicates how common an item is in the diet. When prey size is highly variable, frequency of occurrence can distort the importance of different prey types in the diet while the importance of smaller prey can be overestimated (Ackerman *et al.* 1984; Karanth & Sunquist 1995). The linear regression developed by Ackerman *et al*.

(1984) was used to determine a correction factor that is needed to convert frequency of occurrence to relative biomass consumed (Henschel, Abernethy & White 2005). The correction factor was not applied to small (less than 2 kg) prey. A corrected frequency of occurrence was needed if more than one prey item was found in a scat. Thus if two items occurred in a scat, each was counted as 0.5 (Henschel *et al.* 2005).

2.3 Kills as predicted by GPS clusters

It has been reported that leopards stay near a kill until it is completely consumed, if not disturbed (Bailey 1993). Although Bothma and Le Riche (1984; 1986) reported that leopards in the Kalahari seldom stay longer than a day at a kill, various other researchers have used radio telemetry to find leopard kills (Grimbeek 1992; Bailey 1993; Balme, Hunter & Slotow 2007) . It is thus predictable that if leopards are fitted with GPS collars, and stay near a kill, a cluster of GPS points indicating the kill should be evident. This method to detect kills made by a predator has been developed for cougar (*Puma concolor*) (Anderson Jr & Lindzey 2003) in the USA and has since been successfully tested on the prediction of wolf kills (Sand *et al.* 2005). In this study four leopards were fitted with GPS/GSM collar systems (Africa Wildlife Tracking, Pretoria). Collars were scheduled to take a GPS fix every 5 hours and send the coordinates to a server using the GSM network. Although a more intensive schedule is preferable, such schedules are more taxing on battery life. A 5 hour schedule was selected as it seemed to balance battery life and the ability to predict leopard kill sites. GPS coordinates were downloaded early every morning to identify possible leopard kill sites. Consecutive nocturnal presence at a cluster was hypothesised to represent the best predictor for a possible kill (Anderson Jr & Lindzey 2003). A GPS coordinate from the cluster was then used to navigate to the potential kill site. Clusters were searched thoroughly and signs like the smell of decaying meat, insect activity, scavenger tracks and signs of struggle were used to aid in finding prey items. Selected biological samples such as jaw bones, femur, tibia and hair samples were collected at kill sites if present. Signs of struggle, blood on ground, drag marks and leopard tracks were used to confirm a kill site if no other identifiable prey remains could be found. For each kill site a set of variables relating to kill behaviour were also recorded. These included: presence of drag marks, bite wounds, area first eaten, prey leftovers, if kill was covered with vegetation, if kill was cached, tree species, tree height, tree diameter and base volume of tree.

2.4 Age and weight estimation of prey

The relative age of the prey specimens was estimated by the examination of teeth replacement, wear and horn growth. For younger animals the state of molar eruption and replacement of deciduous teeth by permanent teeth were used to estimate age, while for older animals wear of permanent teeth was used (Mitchell *et al.* 1965). The size of other anatomical parts (e.g. length of spoor, femur, tibia, scapula, tail, horns) was used to estimate age if theoretical Von Bertalanffy equations were available for that particular species. Mean time of birth was recorded for group birthing animals (blue wildebeest, blesbok, impala, red hartebeest) and was used to assist in determining age of young animals of the particular group if kills of young animals were found without jaw bones.

The following studies were used to estimate age and weight of; impala (*Aepyceros melampus*) (Roettcher & Hofmann 1970; Howells & Hanks 1975), blue wildebeest (*Connochaetes taurinus*) (Talbot & Talbot 1963; Attwell 1980), klipspringer (*Oreotragus oreotragus*) (Wilson & Child 1965), eland (*Tragelaphus oryx*) (Jeffery & Hanks 1981a;1981b), blesbok (*Damaliscus dorcas dorcas*) (Ludbrook & Ludbrook 1981; Olivier & Greyling 1991), kudu (*Tragelaphus strepsiceros*) (Simpson 1966; Wilson 1970), bushbuck (*Tragelaphus scriptus*) (Wilson & Child 1964; Simpson 1973), grey duiker (*Sylvicapra grimmia*) (Wilson, Schmidt & Hanks 1984), warthog (*Phacochoerus africanus*) (Bradley 1972; Spinage & Jolly 1974; Mason 1984), and Burchell's zebra (*Equus burchelli*) (Smuts 1972; Spinage 1972; Smuts 1974). No ageing references could be found for waterbuck (*Kobus ellipsiprymnus*) and red hartebeest (*Alcelaphus buselaphus*). Data from Defassa waterbuck (*Kobus defassa ugandae*) (Spinage 1967; 1969) were used to age waterbuck while criteria from Lichtenstein's hartebeest (*Sigmoceros lichtensteinii*) (Mitchell 1965; Wilson 1966) were used to estimate age and weight of red hartebeest. Data from Skinner & Smithers (1990) were used for age and weight estimates of aardvark (*Orycteropus afer*), porcupine (*Hystrix africaeaustralis*), lagomorphs and other rodents. Combined average weights of males and females, for a specific age, were used if the sex of the species could not be identified.

2.5 Prey abundance and prey selection

Prey numbers, for economically important species, were obtained from non-sampling methods as supplied by ranchers. Counts were based on known group counts, aerial counts and total counts. Economically important game species are species that are used for hunting and game auctions by game ranchers. Jacobs' index (Jacobs 1974; Hayward *et al.* 2006) was used to examine leopard prey preference. Index ranges from +1 to -1, where +1 indicates maximum preference and -1 maximum avoidance.

2.6 Analysis

Data were analysed using the *SPSS v.15* (SPSS Inc., Chicago, USA). The Kolmogorov-Smirnov test was used to investigate normality. Data were transformed if non normal distributions were detected and reanalyzed. Nonparametric procedures were used if normality could not be achieved with transformations. Pearson's chi-squared test was used for categorical variables and independent-samples *t* test for interval-scale data. One way ANOVA was used for multiple variable statistics. Descriptive statistics were derived for all interval scale data.

3 STUDY AREA

The study area was in the Waterberg in the Limpopo province, South Africa and fell inside the Waterberg Biosphere. The land use in the area is dedicated to commercial agriculture in the form of livestock and game ranching. Recently holiday properties have become popular in the study area where some game ranches are subdivided into smaller holiday ranches. Typically game ranches are divided into an area where up to a 100 one hectare stands are sold to buyers to build holiday houses, while the rest of the ranch is kept as a game ranch.

The landscape is rugged and irregular while the vegetation is classified as Waterberg mountain Bushveld (Mucina & Rutherford 2006) and is characterized by *Faurea saligna – Protea caffra* Bushveld on higher slopes and *Diplorhynchus condylocarpon* broad leaved deciduous Bushveld on rocky mid- and foot slopes. *Burkea africana-Terminalia sericea* savannah characterized the lower lying valleys and deeper sandy plateaus, while the grass layer is moderately to well developed. Altitude in the study area varies from 1 220 m above sea level in south to the highest point in the north at 1 402 m. Main drainage lines form temporary streams that drain into the Melkriver and Bloklandspruit, which in turn drain into the Lephalala River. The main rainfall season is summer and precipitation is in the form of thunderstorms while winters are very dry. Wet season is from October to March with a peak in January.

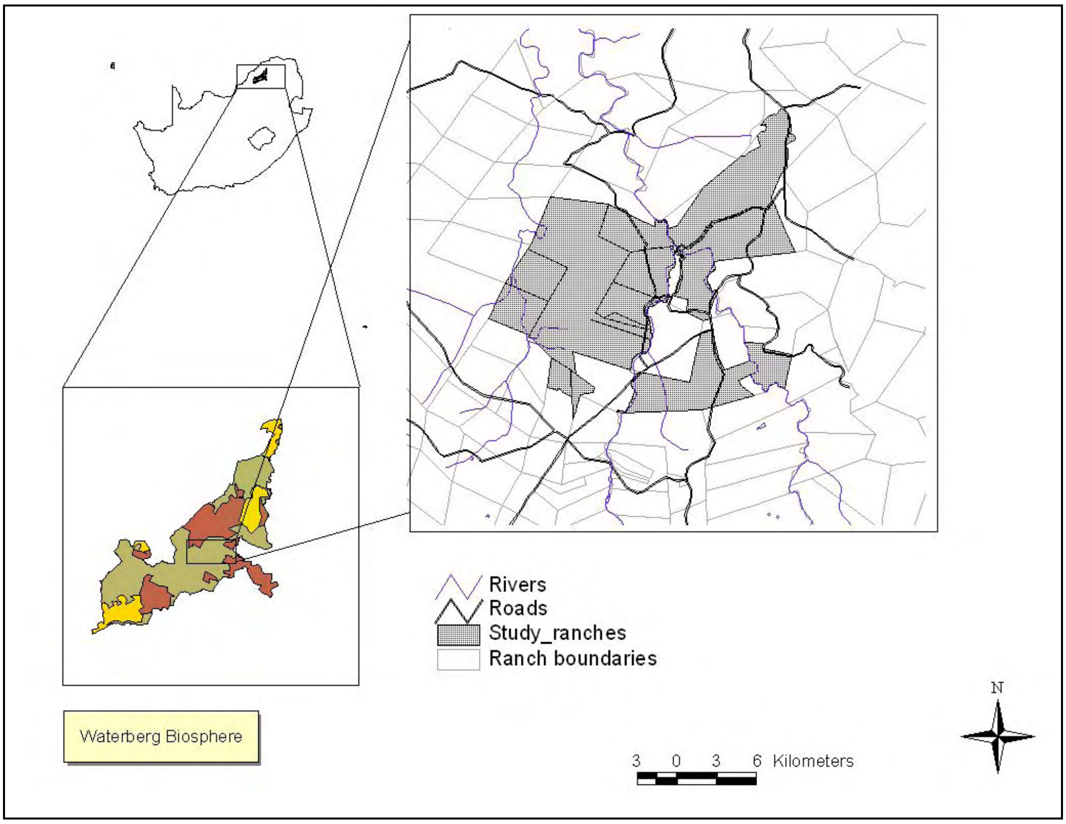

Fig. 1: Map of the study area showing the Waterberg Biosphere and the ranches where kills were investigated and scats collected.

4 RESULTS

4.1 GPS cluster investigations and opportunistic kills found

Over a 14 month period (November 2005 to February 2007) 97 potential GPS clusters from GPS collar location data were investigated. Only 2 out of the 4 collared leopards survived more than 4 months after collaring due to unknown reasons. Thus the 97 clusters investigated only represent two individual leopards (1 male and 1 female, the female gave birth 4 months into study period). Typically, a leopard will reach a cluster, stay for a period of days depending on prey size and leave the cluster after the prey was consumed (Fig 2).

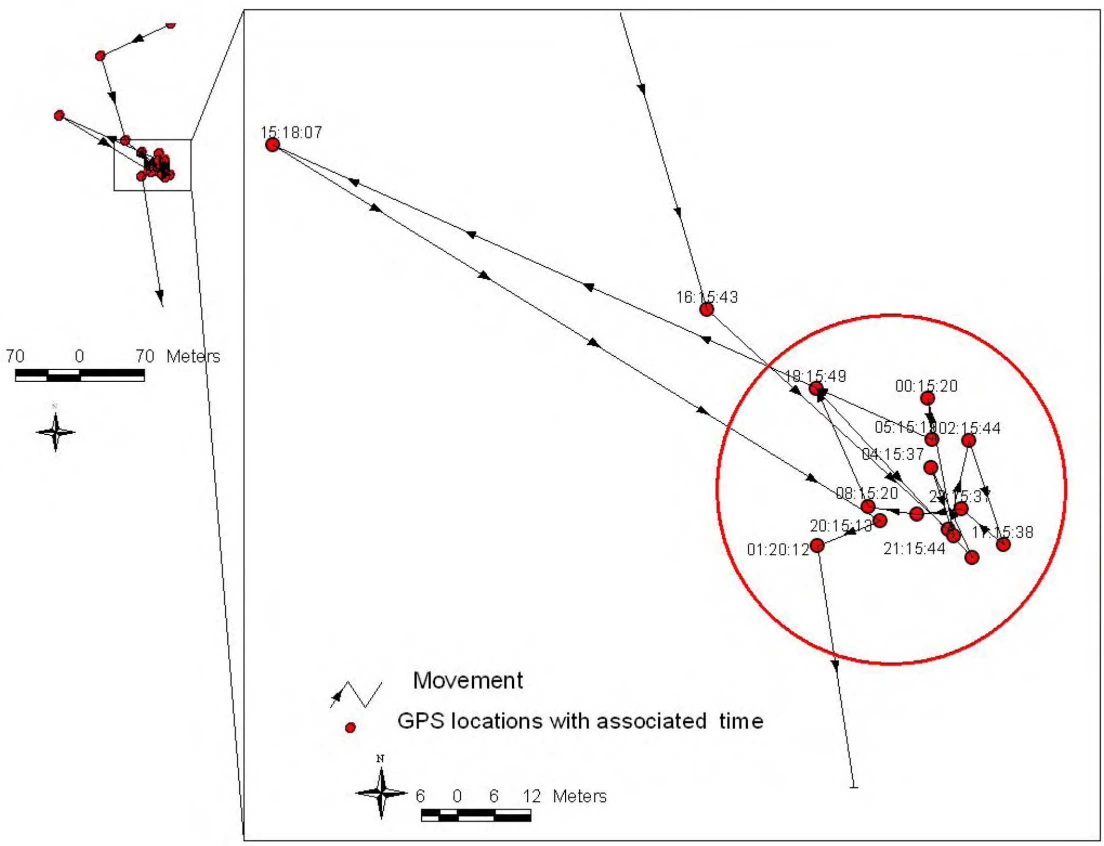

Fig. 2: Schematic presentation of GPS location data representing a kill. Red circle represents search radius, nocturnal times in cluster associates positively with a probable kill.

For the male leopard 41 GPS clusters were investigated, which resulted in finding 33 kills, while 56 GPS clusters were investigated for the female leopard, which resulted in finding 44 kills. Success in finding a kill was high, with a 79.38 % success rate, and generally the sooner clusters were investigated, the better the chances were in finding a kill, which agrees with results from Sand *et al*. (2005). Prey species could not be identified at 2 clusters investigated, although the presence of blood and drag marks indicated that leopards killed the prey. Clusters were investigated on 16 different ranches. One ranch kept only livestock, 10 were stocked with game and livestock while 5 ranches were stocked only with game.

A total of 21 kills from unknown leopards were found during the study period. On all 21 occasions, camera traps were placed at kills to possibly determine the sex of the individual leopards. The sex of the leopards could be identified on 9 occasions (a female once, female with cubs on 4 occasions, male on 4 occasions) and on 12 occasions the sex of the leopard could not be identified.

Leopards preyed on 18 prey species based on the kills found (Table 1). Kudu (*Tragelaphus strepiceros*) accounted for 24.75 % of kills found, while warthog (*Phacochoerus aethiopicus*) accounted for 21.78 % and impala (*Aepyceros melampus*) for 12.87 %. All other species accounted for less than 10 % of kills found. As expected kills found were biased towards larger bodied animals and ungulates accounted for 94.04 % of all kills found, while smaller bodied animals accounted for less than 6 % of all kills found. A large percentage of kills were found on ranches stocked with game and livestock (67.33 % of all kills found, n = 68), 31.68 % (n = 32) on ranches stocked with only game while only one kill (n = 1) was found on a livestock ranch. No livestock kills were found while investigating GPS clusters, although two incidences of leopard attacking livestock were reported by ranchers with livestock.

4.2 Scat analysis

Fifty-five scats were collected over a 12 month period. Scats were not easy to find and substantial effort was needed to find a single scat. An average of 60 km was driven to find a scat, while an average of 13 km was walked to find scats on animal paths. Most scats (52.7 %, n = 29) were found near kills made by leopards, 20 % (n = 11) on animal paths, 25.5 % (n = 14) on vehicle roads and one in woodland. The majority of the scats were found on ranches stocked with game and livestock (67 %, n = 37) while 33 % (n = 18) were found on ranches stocked only with game. Prey species could not be identified in six of the scats found. No scats were found on ranches that were only stocked with livestock. On 13 occasions prey identified in scats found at kill sites did not match the prey species found at the kill site. Thus the 16 scats that did match the prey species at the kill sites were removed from scat analysis (Table 1) to avoid bias towards big bodied prey.

Thirty nine scats were thus analysed and 48.5 prey items were detected (1.25 items per scat) (Table 1). A wider array of small mammal taxa were found in scats than in kills (Table 1). Scats also contained a total of 19 taxa compared to 18 in kills. Bushbuck (*Tragelaphus scriptus*) remains were found in 19.23 % of all scats, but composed 15.46 % of items detected. Kudu (*Tragelaphus strepsiceros*) was the second most important prey species and occurred in 14.10 % of scats analysed, while it composed 11.34 % of items detected. Small rodents composed 6.18 % of items while larger small mammals (hyrax and small carnivores) 8.25 %. No livestock remains were found in scats. Large quantities of leopard hair were found in 10 scats and were thought to be the result of grooming. One scat contained the remains of a puff adder (*Bitis arietans*), burnt plastic and unknown plant seeds.

Table 1. Composition (%) of leopard diet on game and livestock ranches, in the Waterberg, Limpopo based on kills found at GPS clusters and scat analysis

Prey	Kills (%) (N=101)	Scats		
		Corrected count of occurrence* (N = 48.5)	Items Occurrence (%) (N = 48.5)	Frequency of occurrence (%) (N = 39)
Ungulates				
Tragelaphus strepsiceros	24.75	5.50	11.34	14.10
Phacochoerus aethiopicus	21.78	4.00	8.25	10.26
Aepyceros melampus	12.87	3.00	6.19	7.69
Tragelaphus scriptus	8.91	7.50	15.46	19.23
Alcelaphus buselaphus	5.94	1.00	2.06	2.56
Connochaetes taurinus	5.94	1.50	3.09	3.85
Oreotragus oreotragus	2.97	2.00	4.12	5.13
Equus burchelli	2.97	1.00	2.06	2.56
Tragelaphus oryx	2.97	1.00	2.06	2.56
Kobus ellipsiprymnus	1.98	1.00	2.06	2.56
Damaliscus dorcas phillipsi	0.99			
Redunca fulvorufula	0.99	3.00	6.19	7.69
Sylvicapra grimmia	0.99	1.00	2.06	2.56
Raphicerus campestris		2.00	4.12	5.13
Carnivores				
Galerella sanguina		3.00	6.19	7.69
Rodents				
Hystrix africaeaustralis	0.99			
Tatera leucogaster		2.00	4.12	5.13
Unidentified rodent		1.00	2.06	2.56
Hydracoidea				
Procavia capensis		1.00	2.06	2.56
Tubulidentata				
Orycteropus afer	0.99	1.00	2.06	2.56
Primates				
Papio ursinus	0.99			
Lagomorpha				
Pronolagus radensis	0.99			
Reptiles				
Bitis arietans		1.00	2.06	2.56
Unidentified mammal	1.98	6.00	12.37	15.38
Total	**100**	**48.5**	**100**	**124.32**

*Corrected for multiple prey items in single scat (see text)

4.3 Relative biomass

The mean weights of prey killed during this study (Table 3) was used to determine the correction factor (Ackerman *et al.* 1984) needed to estimate relative biomass consumed by leopards. Kudu were the most important prey species for leopards in the study area making up 22.99 % of relative biomass consumed (Table 3). Bushbuck (14.57 %), warthog (8.83 %) and mountain reedbuck (7.31 %) were the next important prey species. Although a wide range of taxa were killed by leopards, five species (kudu, bushbuck, warthog, impala and mountain reedbuck) provided 60.54 % of all biomass consumed by leopards. Ungulates were the most important taxa for leopards making up 90.05 % of biomass consumed, while the other taxa only played a minor role in prey biomass.

If only kills are taken into account, kudu becomes even more important. In terms of biomass consumed, based on kills only, kudu accounts for 45.39 % of biomass consumed, followed by warthog (11.45 %), red hartebeest (7.79 %) and impala (7.42 %).

Table 2: Calculation of relative biomass consumed by leopards on game and livestock ranches in the Waterberg, based on the analysis of 39 scats

Prey	A: Corrected frequency of occurrence (%) [a]	B: Body weight [b]	C: Correction factor (kg/scat) [c]	D: Relative biomass (%) [d]
Ungulates				
Tragelaphus strepsiceros	14.10	110.92	5.86	22.68
Phacochoerus aethiopicus	10.26	31.83	3.09	8.70
Aepyceros melampus	7.69	34.85	3.20	6.75
Tragelaphus scriptus	19.23	21.29	2.72	14.37
Alcelaphus buselaphus	2.56	79.33	4.75	3.34
Connochaetes taurinus	3.85	54.04	3.87	4.08
Oreotragus oreotragus	5.13	11.93	2.39	3.37
Equus burchelli	2.56	121.67	6.23	4.38
Tragelaphus oryx	2.56	111.69	5.88	4.14
Kobus ellipsiprymnus	2.56	133.79	6.66	4.68
Redunca fulvorufula	7.69	41.00[e]	3.41	7.20
Sylvicapra grimmia	2.56	15.00	2.50	1.76
Raphicerus campestris	5.13	11.09[e]	2.36	3.33
Carnivores				
Galerella sanguina	7.69	0.54[e, f]	0.54	1.15
Rodents				
Tatera leucogaster	5.13	0.06[e, f]	0.06	0.09
Unidentified rodent	2.56	0.01[e, f]	0.01	0.01
Hydracoidea				
Procavia capensis	2.56	3.30[e, f]	3.30	2.32
Tubulidentata				
Orycteropus afer	2.56	51.40[e]	3.77	2.65
Reptiles				
Bitis arietans	2.56	1.00[f]	1.000	0.703
Unidentified mammal	15.38	1.00f	1.000	4.221
Total	**124.32**			

[a] From table 1
[b] From table 3
[c] Estimated weight of prey consumed per collectible scat ($C = 1.98 + 0.035 B$)
[d] $D = (A \times C)/\sum(A \times C)$
[e] Estimated mean live weight from Skinner & Smithers (1990)
[f] No correction factor

4.4 Prey age and weight based on kills found and scat analysis

Prey weight averages based on kills found at GPS clusters and opportunistically would overestimate the average weight killed by leopards since bigger kills are more easily found. However, if the information from scats is combined with kills found, a reasonable estimate of mean weight of prey killed by leopards can be obtained (Karanth & Sunquist 1995).

The mean weight of all prey killed found in this study was 37.66 kg. However if mean weight is calculated using only kill data, the mean increases to 62.55 kg (S.E = 5.42 kg, min 1 kg, max 185.4 kg) (Table 3). If only the principle prey species is considered, the mean weight is 60.30 kg. Clearly, using only the kill data will result in overestimating the mean weight of prey killed by leopards. Leopards preferred medium sized prey based on scat analysis and kills found (Fig. 3). However, the sex of the leopard influenced the prey size category selected and there was a significant difference (t = 2.362, df = 75, p = 0.021) in mean prey weight killed between male (mean prey weight = 77.46 kg, S.E. = 8.5kg, max. 184 kg) and female leopards (50.51 kg, S.E. 7.6 kg, max. 130 kg) based on kills found. One way ANOVA analysis showed that mean prey weight also differs significantly between male, female, and female leopards with cubs (F = 4.112, df = 2, p = 0.020). A subsequent *post hoc* test (Tamhane test) indicated that male prey means were significantly higher than female leopards (male prey mean = 77.46 kg, female prey mean = 38.39 kg, p = 0.003), but were not significantly different from female leopards with cubs (mean prey weight = 62.63 kg, p = 0.725). Large prey was killed by female leopards with cubs and male leopards, but not by female leopards without cubs. Small and medium prey was however killed by all leopards (Fig. 4).

Table 3. Mean weight (kg), age (months) and sex ratio of kills found. Calculations based on 89 kills found on game ranches in the Waterberg, Limpopo, South Africa, where jaw bones and other anatomical parts were available to estimate weight and age

	Prey weight in kg					Prey age in months					Sex ratio
Species	**N**	**Mean**	**S.E**	**Max**	**Min**	**N**	**Mean**	**S.E**	**Max**	**Min**	**F/M**
Kobus ellipsiprymnus	2	133.79	36.21	170.00	97.58	2	27.00	9.00	36.00	18.00	*
Equus burchelli	3	121.67	11.33	133.00	99.00	3	8.00	1.00	9.00	6.00	*
Tragelaphus oryx	3	111.69	13.30	135.88	90.00	3	7.33	2.33	12.00	5.00	1.00
Tragelaphus strepsiceros	22	110.92	11.89	184.00	30.00	22	19.09	2.24	34.00	5.00	4.67
Alcelaphus buselaphus	6	79.33	20.59	156.00	30.00	6	14.00	3.82	24.00	4.00	0.50
Connochaetes taurinus	6	54.04	8.51	80.00	33.00	6	5.17	1.38	10.00	2.00	*
Orycteropus afer	1	51.40	*	51.40	51.40	1	24.00	*	24.00	24.00	*
Damaliscus dorcas phillipsi	1	50.00	*	50.00	50.00	1	14.00	*	14.00	14.00	*
Redunca fulvorufula	1	41.00	*	41.00	41.00	1	24.00	*	24.00	24.00	*
Aepyceros melampus	11	34.85	1.52	40.70	26.00	11	18.18	2.79	36.00	8.00	0.60
Phacochoerus aethiopicus	19	31.83	4.21	75.00	1.00	19	20.63	2.34	38.00	1.00	6.00
Tragelaphus scriptus	7	21.29	1.76	28.00	15.00	7	14.57	2.75	26.00	8.00	*
Papio ursinus	1	15.00	*	15.00	15.00	1	12.00	*	12.00	12.00	*
Sylvicapra grimmia	1	15.00	*	15.00	15.00	1	10.00	*	10.00	10.00	*
Oreotragus oreotragus	3	11.93	0.03	12.00	11.90	3	18.00	0.00	18.00	18.00	*
Hystrix africaeaustralis	1	11.00	*	11.00	11.00	1	*	*	*	*	*
Pronolagus radensis	1	2.30	*	2.30	2.30	1	*	*	*	*	*
Total	**89**	**62.55**	**5.42**	**184**	**1.00**	**89**	**16.86**	**1.05**	**38**	**1.00**	**2.18**

* Reasonable numbers were not available for estimation

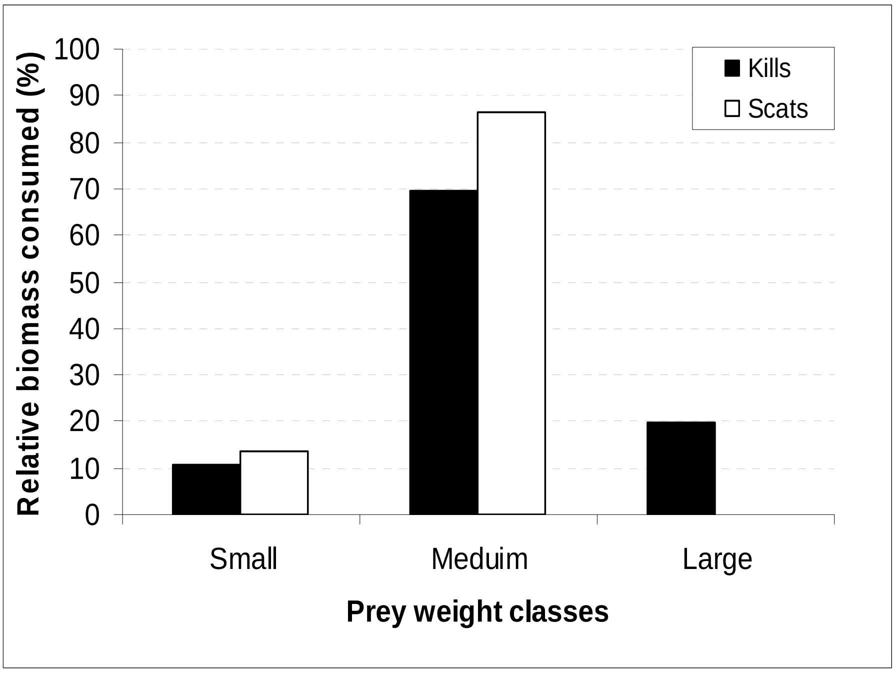

Fig. 3. Relative biomass consumed by leopards in different prey size categories based on kills found and scat analysis (Small prey 0 - 30 kg, medium prey 31 - 170 kg, large prey >171 kg). Weight classes based on Karanth & Sunquist (1995).

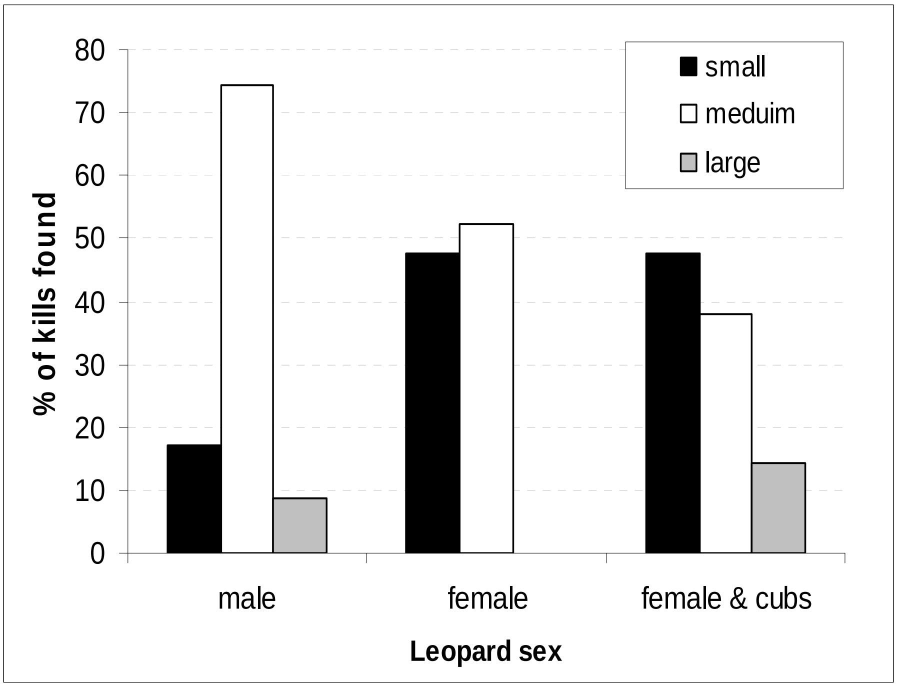

Fig. 4. Relationship between prey weight categories (Small: 0-30kg, Medium: 31-170 kg, Large: >171 kg) and leopard sexes based on kills found on game ranches in the Waterberg. Weight classes based on Karanth & Sunquist (1995).

Significantly more female prey than male prey were killed (χ^2 = 7.407, df = 1, *p* = 0.006). The overall sex ratio of 2.18 females/male indicates that twice as many female prey are killed than males. Sex ratio, however, varied across different prey species (Table 3). Warthog females were killed more frequently (ratio of 6), than female kudu (ratio of 4.67), while red hartebeest and impala had the lowest sex ratio (0.60 & 0.50). Thus, more males were killed for every female in impala and red hartebeest. Sex of leopards also significantly influenced prey sex killed (χ^2 = 6.646, df = 1, *p* = 0.01). Most of the male prey found (73.3 % of kills found that could be sexed) were killed by male leopards while female leopards were responsible for 66.7 % of female prey kills that were found. However, if female leopards are split into leopard females with and without cubs, more male prey were killed by female leopards with cubs (Fig. 5).

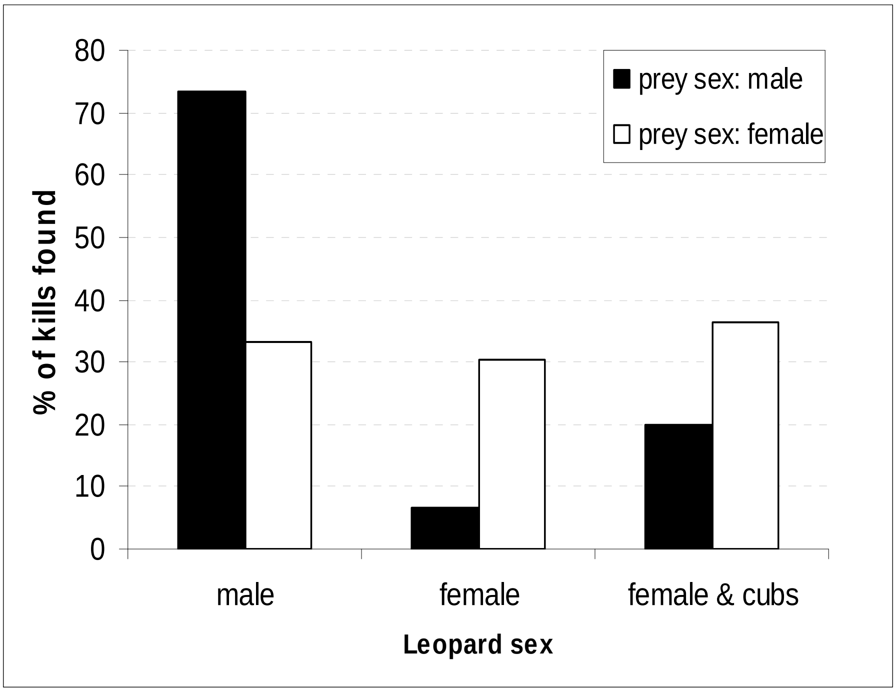

Fig. 5. Relationship between leopard sex and prey sex. Analysis based on kills found where the sex of prey could be identified (male leopard 22 kills, female 11 kills, female with cubs 15 kills).

4.5 Prey age based on kills found

The mean age for all kills found was 16.68 months (S.E 1.05 months, min = 1 month, max = 38 months, n = 87) (Table 3). However, young animals were significantly (χ^2 = 11.241, df = 2, *p* = 0.004) more preyed upon than adult prey (Figure 6), although leopard sex did not influence the age category selected (χ^2 = 1.454, df = 2, p = 0.483). On average female leopards killed older prey (mean 16.79 months, S.E. = 1.37) than male leopards (15.85 months, S.E. = 1.76), this result was however not significant (t = -0.423, df = 74, p = 0.673).

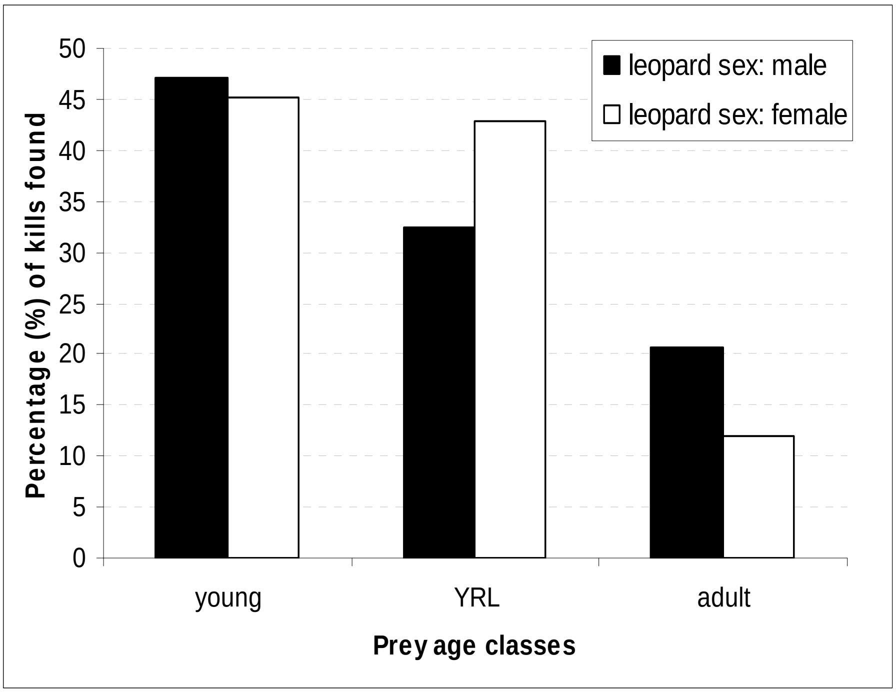

Fig. 6: Percentage of prey killed in different age classes (young = ≤12 months, yearling 12 - 24 months, adult ≥ 24) and effect of leopard sex on age classes, based on 87 kills found that could be aged on game ranches in the Waterberg.

Not enough kills could be found to classify each prey species in different age categories. Kudu, warthog and impala were classified into different age categories, although sample sizes were still too small to detect statistical differences. Adult prey were killed in low numbers, except for kudu, where female leopards killed adult kudu in greater numbers than other age categories. Earlier results indicated that female leopards with cubs were responsible for preying on large weight categories, while female leopards without cubs did not prey on large prey (see earlier, Fig. 4). Adult female kudu were therefore only killed by female leopards with cubs. No adult male kudu kills were found. No adult impala kills were found, while female leopards killed young impala and sub adults; male leopards prey on all remaining impala age categories (Table 4). Warthogs were preyed on until yearling status was achieved, where-after predation declined (Table 4)

Table 4: Proportions (%) of warthog, impala and kudu in different age categories killed by different leopard sexes

Leopard sex	Prey	N	Prey age category			
			Young	Yearling	Sub adult	Adult
Male	Warthog	5	20.00	40.00	20.00	20.00
	Impala	6	33.33	33.33	33.33	0.00
	Kudu	15	40.00	33.33	6.67	20.00
Female	Warthog	16	31.25	43.75	18.75	6.25
	Impala	9	55.56	0.00	44.44	0.00
	Kudu	7	28.57	0.00	28.57	42.86*

* Only adult female kudu were killed

4.6 Prey abundance and prey selection

Only prey numbers of the most important game for ranchers were available. Prey numbers from ranchers indicated that impala were the most abundant species (29.39 % of total animals stocked), followed by livestock 17.67 % (Table 5).

Table 5: Abundance of game and livestock as reported by ranchers; data available for 16 ranches where leopard kills were found, total area 170 km²

Species	Number	% of total
Impala	1144	29.39
Livestock	688	17.67
Kudu	551	14.15
Warthog	352	9.04
Blue wildebeest	339	8.71
Bushbuck	192	4.93
Waterbuck	187	4.80
Zebra	186	4.78
Red hartebeest	101	2.59
Blesbok	93	2.39
Eland	60	1.54

Jacobs' index values indicated that warthog and red hartebeest were the most preferred prey, while livestock and blesbok were least preferred (Fig. 7).

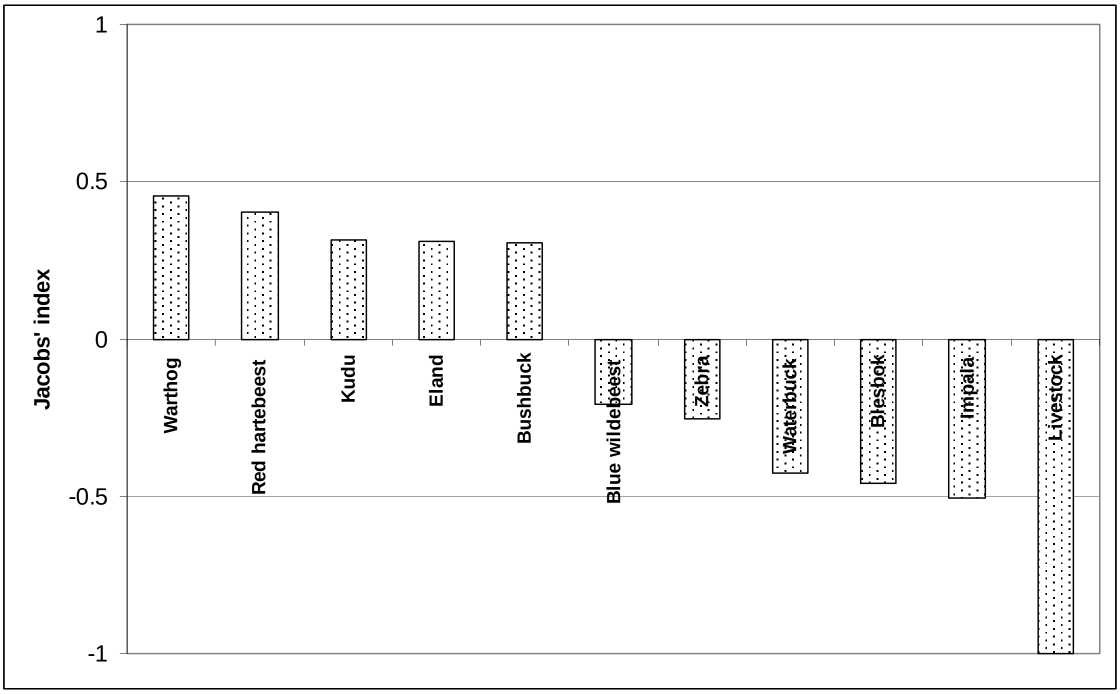

Fig. 7: Leopard prey preference on selected game ranches in the Waterberg as determined with Jacobs' index; negative values are avoided and positive values selected. Analysis is based on 101 kills found and abundance data from 16 ranches as supplied by ranchers.

4.7 Seasonality

Prey age categories differed between seasons, though results were only marginally significant (χ^2 = 5.472, df = 2, *p* = 0.065). More adult prey was killed in the dry season than in the wet season (Fig. 8). Significantly more adult kudu were killed in the dry season (χ^2 = 9.909, df = 3, *p* = 0.028), while seasonal differences for impala (χ^2 = 1.69, df = 3, *p* = 0.693) and warthog (χ^2 = 2.624, df = 3, *p* = 0.453) were not significant (Fig. 9). There was no significant interaction between leopard sex and prey age categories for the dry season (χ^2 = 1.211, df = 2, *p* = .546) and wet season (χ^2 = 1.373, df = 2, *p* = 0.503). Female leopards were responsible for 45.5 % of adult prey killed in the dry season and male leopards for 54.5 %.

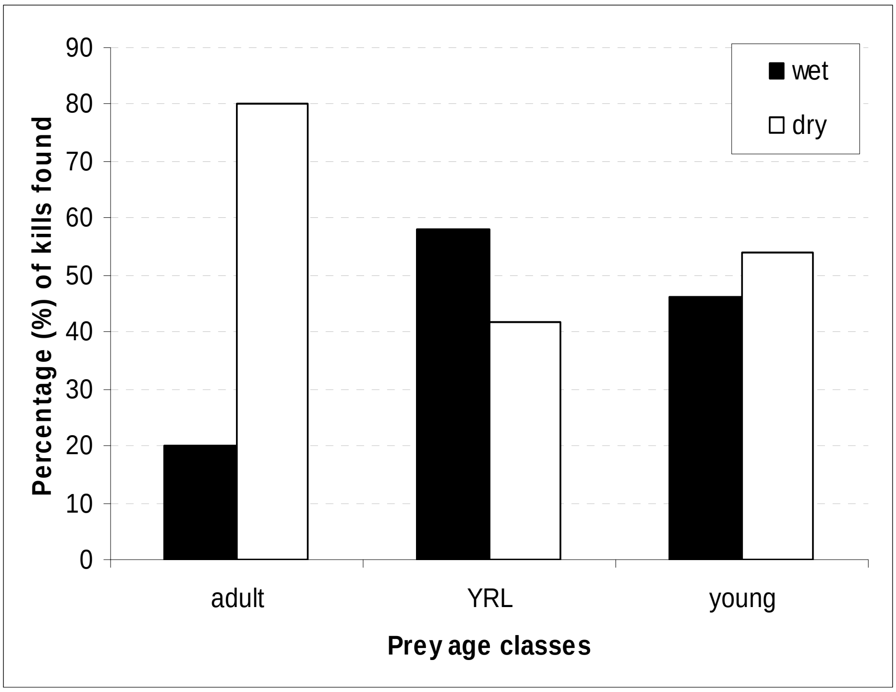

Fig. 8: Effect of season on prey age categories killed by leopards, results based on 40 kills in dry season and 47 kills in wet season

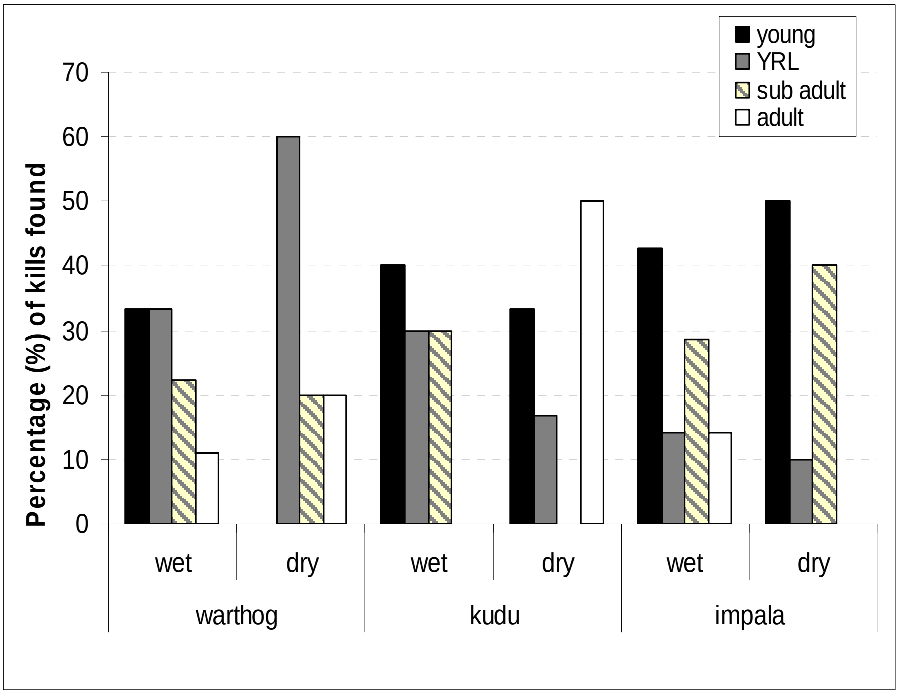

Fig. 9. Effect of season on age categories killed, for warthog, kudu and impala. Results based on 17 kills for impala, 22 kills for kudu and 23 kills for warthog (see text for explanation on age categories).

4.8 Hunting behaviour

Most prey were killed with a bite under the neck (70.37 %, n = 19), while 15.18 % (n = 5) had bite wounds to the head and the rest (14.14 %, n = 4) had wounds above the neck. Drag marks were present at 53.30 % (n = 54) of kills found. It was not possible to determine if drag marks were present at the remaining 45.5 % (n = 46) of kills found. Drag marks were absent from only one kill found. Average drag distances were 99.80 m (S.E. = 26.08 m), and differed among prey weight categories. Drag distances were not nominally distributed (Z = 2.357, p = 0.000, Kolmogorov-Smirnov test) and were log transformed. Log transformed drag distances differed significantly among prey weight categories (F = 4.223, df = 2, p = 0.020) with large prey categories dragged the shortest distance (mean 19.00 m, S.E. = 4.5 m) while small (105.56 m, 61.58 m S.E) and medium (117.30 m, S.E.= 34.82 m) were dragged further away from kill sites. Drag distance also differed between leopard sexes, where mean drag distance for females was 158.00 m (S.E. = 106. 00 m), female with cubs 107.00 m (S.E. = 55.10 m) and male leopards 61.75 m (S.E. = 14.23 m). Log transformed drag distance did not yield significant results for prey sex (F = 0.336, df = 2, p = 0.716).

Prey carcasses were normally found under trees (58.4 % of kills found, n = 59), but were also found cached in trees (24.8 %, n = 25) and under multistemmed bushes (8.9 %, n = 9) while only 2 % (n = 2) were found in open grassland. Prey caching method (in tree, under tree, under bush, in open grassland) did not differ among leopard sexes (χ^2 = 3.592, df = 4, p = 0.464). Twenty two different tree species were utilised by leopards to conceal kills made (Table 5). Different trees were used for different concealment roles, for example while most kills found near *Burkea africana* were cached in the tree, all kills found near *Englerophytum magalismontanum* were found under the tree (Table 5).

Table 5: Proportion (%) of kills found in different caching locations and tree species

	N	Under tree	Under bush [a]	In tree
Pseudolachnostylis maprouneifolia	19	73.68	5.26	21.05
Burkea africana	13	23.08		76.92
Un known	9	35.71	21.43	7.14
Englerophytum magalismontanum	8	100.00		
Diplorhynchus condylocarpon	7	71.43	14.29	14.29
Combretum molle	5	80.00	20.00	
Peltophorum africanum	5	60.00		40.00
Ficus sp	4	50.00		50.00
Combretum apiculatum	3	100.00		
Croton gratissimus	3	33.33	66.67	
Acacia caffra	2	100.00		
Combretum zeyheri	2			100.00
Dichrostachys cinerea	2	50.00	50.00	
Vitex pooara	2	50.00		50.00
Cassine transvaalensis	1			100.00
Eucaluptus sp	1	100.00		
Grewia flavescens	1	100.00		
Kirkia wilmsii	1	100.00		
Mimusops zeyheri	1			100.00
Mundulea sericea	1	100.00		
Rothmannia capensis	1	100.00		
Syzygium cordatum	1	100.00		
Ziziphus mucronata	1	100.00		

[a] Multiple stem bushes or tree

Average prey weight cached in trees was 63.89 kg (S.E. = 8.15 kg) while the maximum weight of a cached prey species was 135 kg, where an adult female cached a red hartebeest. However, estimated weight of cached animals is probably an overestimate since the carcass can be partly eaten and intestines removed before caching in trees. *Burkea africana* was the most important tree (40 % of all kills cached) used by leopards to cache kills (Table 6). It seems that heavier prey was also cached in more sturdy trees (Table 6).

Table 6. Characteristics of cache trees used by leopards

	N	%	Tree height (m)		Tree trunk circumference (mm)[a]		Tree volume (m)[b]		Carcass height in tree (m)		Prey weight (kg)[c]	
			Mean	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**	**Mean**	**S.E**
Burkea africana	10	41.67	5.30	0.56	673.00	89.17	5.21	0.49	2.25	0.23	63.47	16.30
Pseudolachnostylis maprouneifolia	4	16.67	5.00	0.91	790.00	223.08	4.88	0.52	1.88	0.31	28.27	9.97
Ficus sp	2	8.33	22.50	2.50	4000.00	0.00	7.50	2.50	2.00	0.00	34.00	4.00
Peltophorum africanum	2	8.33	8.00	0.00	1000.00	0.00	8.00	4.00	2.50	0.50	31.50	1.50
Combretum zeyheri	2	8.33	7.00	1.00	900.00	400.00	6.50	4.50	5.00	1.00	31.00	9.00
Mimusops zeyheri	1	4.17	12.00	.	2030.00	.	10.00	.	4.00	.	135.00	.
Cassine transvaalensis	1	4.17	8.00	.	1040.00	.	7.90	.	1.90	.	105.00	.
Vitex pooara	1	4.17	7.00	.	800.00	.	9.00	.	2.00	.	47.80	.
Diplorhynchus condylocarpon	1	4.17	5.00	.	800.00	.	10.00	.	2.40	.	99.00	.
Total	**24**		**8.87**	**0.99**	**1337.00**	**142.45**	**7.67**	**2.40**	**2.66**	**0.41**	**63.89**	**8.15**

[a] As measured 0.5 meters above ground level

[b] Based on diameter of canopy as projected to ground level

[c] Estimated weight based on live weight

Hair was plucked from 45.5 % of kills found. It was not possible to determine if hair was plucked from the rest of the kills found. Fifty three fresh carcasses were found and intestines were removed in 84 % of the carcasses. Intestines were normally (43.90 %) found *en route* between kill sites and cache sites, while intestines were found a similar number of times near kill sites (26.82 %) or feed sites (26.82 %). Most of the time (95 %) intestines were not covered with twigs or leaves while only female leopards were responsible for the 5 % of intestines that were covered. Leftovers nominally found at kill sites included legs, hooves, scull, hair, backbone and tail (Fig. 10). Prey leftovers were only covered (6 occasions found) by female leopards.

Fig. 10: Typical prey remains found at leopard kills (left: bushbuck remains, right: warthog remains).

5 DISCUSSION

5.1 Construction of leopard diets

Leopards in the Waterberg spend a considerable amount of their time in very rugged terrain (Grimbeek 1992), which makes finding kills difficult. Investigating clusters from GPS location data proved to be an effective method in finding kills, even in mountainous terrain. Generally the earlier a cluster can be investigated; the greater the possibility of finding a kill, although evidence of kills can be detected up to 7 to 14 days after the leopard has left. Anderson Jr & Lindzey (2003) detected kills made by cougars up to 270 days after the kill was made, however in South Africa scavengers like brown hyenas are quite common on game and livestock ranches (Mills 1991; Friedmann & Daly 2004). Brown hyenas (*Parahyaena brunnea*) will carry prey remains to their den sites (Mills & Mills 1977; Owens & Owens 1978) which will make finding prey remains at leopard kill sites very difficult if kill sites are visited long after a kill was made.

Kills found at clusters were biased towards bigger prey and our results (Table 1) agree with Karanth & Sunquist (1995) that kill data will underestimate the importance of small or young prey in the diet of carnivores if only kill data is used. However, varying the frequency of GPS location recordings could lead to the detection of smaller prey kills (Sand *et al.* 2005), but prey the size of rodents will probably never be detected using GPS collar locations. Scat analysis together with kill data from GPS location clusters therefore appears to be the best method in determining carnivore diets (Karanth & Sunquist 1995), but corrections need to be applied to frequencies of occurrences of prey items in scats to avoid biases caused by differences in prey size (Ackerman *et al.* 1984).

Leopards preyed on 17 different mammalian species and one reptile species. Scats contained a wider array of prey species compared to kills found and the importance of scat analysis combined with kills found to determine carnivore diets is clearly illustrated (Ackerman *et al.* 1984; Karanth & Sunquist 1995). The prey spectrum of this study is fairly similar to previous studies in the Waterberg where Grimbeek (1992) identified 17 different mammalian species and one avian species. Other mountainous areas in southern Africa showed similar results; Norton *et al*. (1986) reported 12 species (10 mammalian) for the Cederberg in the western Cape, Stuart & Stuart (1993) reported 14 species (12 mammalian) for western Soutpansberg. Smith (1987) found 18 species (17 mammalian) in the Rhodes Matopos National Park, Zimbabwe, although Grobler & Wilson (1972) reported 25 species (16 mammalian) for the same study site. Mammalian prey were the most important component of all these reported leopard diets and non mammalian prey accounted for less than 1 % of prey consumed (Grobler & Wilson 1972; Norton *et al.* 1986; Smith 1987; Grimbeek 1992).

Ungulates were the most important prey taxa and contributed 90 % of biomass consumed by leopards on ranches. Although Grimbeek (1992) did not calculate biomass consumed, 72.3 % of scats analysed contained remains of ungulates, compared to 79.5 % for this study. Rock hyraxes (Order Procaviidae*: Procavia capensis)* remains were found in 2.27 % of scats analysed and contributed 2.35 % of biomass consumed. Other researchers (Grobler & Wilson 1972; Norton *et al.* 1986; Smith 1987; Stuart & Stuart 1993) have reported that hyraxes are the most important prey species for leopards in mountainous areas, but these results probably overestimate the importance of small prey since uncorrected prey frequencies were used to describe those diets (Karanth & Sunquist 1995). Karanth & Sunquist (1995) suggested that the non-selective intake of small prey by leopards is the result of the elimination of large prey, rather than selection for small prey, e.g. rock hyraxes. Ranches in this study area are well stocked with game animals (Table 5) with a density of 22 animals/km², excluding small game. It is thus unlikely that large prey is limited in the study area. Grimbeek (1992) also reported a low occurrence of rock hyraxes (3.9 % of scats) in leopard diets in the Waterberg, which agrees with results for this study.

Carnivore remains were found in 7.69 % of scats and were represented by only one species (Table 1), which accounted for 1.17 % of biomass consumed. Previous studies in the Waterberg reported the predation of jackal by leopards (Grimbeek 1992), but no jackal remains were found during this study. Jackals were uncommon (*pers. ops*) in the study area and were regularly destroyed by ranchers.

Rodents, primates and other small mammals contributed little to the diet of leopards. The occurrence of these items in the leopard diet is testimony to the opportunistic feeding behaviour of leopards which is one of its key survival mechanisms. Although Pienaar (1969) reported that a high proportion of baboons kills in the Kruger National Park are attributed to leopards, various researchers have reported low incidence of baboon remains in leopard scats (Hamilton 1981; Norton *et al.* 1986).

Baboons are quite aggressive and have a well adapted defence system that could overpower most leopards (Skinner & Smithers 1990), and the belief from some ranchers that baboons are a major component of leopard diets can be discarded (Hamilton 1981). However, baboons are regularly shot in the Waterberg when they raid gardens, homes or lodges and carcasses are nominally left in the veld for scavengers. Leopards will scavenge if opportunity arises (Bailey 1993) and baboon remains found in scats could be from shot baboons. The one baboon kill found in this study was a fresh carcass and no bullet wounds could be found.

The presence of burnt plastic in one scat suggests that this leopard may have scavenged from a ranch dumpsite. It could also be that the snake remains found in the same scat was from one killed by the rancher and dumped on the same dumpsite. Scavenging is quite common in leopards (Hamilton 1981) and Turnbull-

Kemp (1967) reported that leopards will not hesitate to scavenge litter around abandoned campsites.

5.2 Prey species killed

Kudu was the most important prey species for leopards accounting for 22.99 % of the biomass consumed. The high proportion of kudu in the leopard diet was unexpected, since previous work in the Waterberg has reported that impala are the most important prey accounting for 33 % of scats analysed (14 % for this study) (Grimbeek 1992). Selection indexes (Hayward *et al.* 2006) also showed that impala are significantly preferred by leopards, and given the high density of impala in the study area (Table 4) it is surprising that impala only accounts for 6.84 % of biomass consumed. However, abundance of prey is not the only factor determining if prey will be caught by leopards, but is also influenced by the catchability of prey (Balme *et al*. 2007).

Leopards need vegetation with intermediate cover levels to be successful hunters (Balme *et al.* 2007), although Karanth & Sunquist (1995) suggested that edge habitats may also be beneficial. Leopards on game ranches in the Waterberg, as elsewhere in South Africa (Hunter & Balme 2004), are rarely tolerated by ranchers and are readily persecuted (Grimbeek 1992) (This study). This persecution has forced leopards to take refuge in mountainous areas which are inaccessible to ranchers (Grimbeek 1992; Nowell & Jackson 1996). On ranches roads are also normally constructed in non-mountainous areas which are used daily by ranch workers leading to high human activity, which could limit predation (Ogada *et al.* 2003). Impala prefer woodland with open associations, while open cover is selected at night to feed (Bailey 1993) moving away from suitable cover for leopards to hunt. The high daily human activity and lower vegetation cover severely reduce the catchability of impala. It is therefore suggested that the reduced catchability limits the predation of leopard on impala. Thus a combination of impala behaviour and human persecution have reduced the catchability of impala, although impala was the most abundant prey species, which agrees with predictions made by Balme *et al*. (2007).

The high occurrence of kudu in the leopard diet can be explained by the habitat selection of kudu and their abundance. Kudu prefer broken rocky woodland (Skinner & Smithers 1990) and avoid open woodland (Simpson 1968), habitat similar to what leopards prefer in the Waterberg (Grimbeek 1992). The Waterberg mountains have fairly dense vegetation (Mucina & Rutherford 2006) which will suit the leopards' hunting strategies, e.g. stalking and ambushing. The mountain terrain is also rocky (slopes can have up to 67 % rock cover, Chapter 2) which can assist in hunting as prey can't escape quickly. The steepness of the slope can also increase hunting success, for example lions' hunting success increases as prey escape upslope (Elliot, Cowan & Holling 1977). The density of kudu on the ranches is probably also an underestimate as the dense vegetation makes counting kudu difficult. These combined factors, i.e. dense habitat occupied by kudu, rocky terrain, density, slope angle and occupying same habitat as leopards, make kudu a prime candidate for leopard prey (Bailey 1993).

Bushbuck was also important in leopard diet, contributing 14.57 % of biomass consumed and accounted for 8.91 % of kills found. Bushbuck select closed woodland and spend a large amount of their time close to cover (Brock, Nortje & Gaigher 2003). This, combined with their size (avg. 21.29 kg in this study) and solitary nature, would explain why bushbuck are preferred by leopards (Bailey 1993; Owen-Smith & Mills 2008). Although their abundance was found to be lower than other medium sized prey, they have a higher catchability (Balme *et al.* 2007) and appear to be vulnerable to leopard predation (Bailey 1993). The abundance of bushbuck, as with kudu, is probably an underestimate due to the difficulty in counting them. The combination of bushbuck habitat selection, weight and abundance can explain their selection by leopards.

Warthog were the third most important prey species accounting for 21.48 % of kills found and contributing 8.83 % of biomass consumed. The family Suidae are not seen as preferred leopard prey because of their aggressive behaviour (Ramakrishnan, Coss & Pelkey 1999), exceeding the upper limit of leopards' preferred weight (Hayward *et al.* 2006) and their strictly diurnal behaviour (Skinner & Smithers 1990). Warthog kills are therefore limited to sub adults and juveniles, which are more susceptible to predation than adults. Warthogs have a wide habitat selection, but prefer short grassy patches in damp areas (Skinner & Smithers 1990). In areas with enough cover warthogs appear to reduce their vigilance towards predators (Scheel 1993). Damp and moist areas in the Waterberg are limited to the drainage lines, a habitat type similar to that of leopards. Warthogs usually use aardvark burrows during night to escape predation, however they are vulnerable to predation when entering or exiting burrows (Skinner & Smithers 1990). The diurnal habit of warthogs, combined with the use of burrows, probably forced leopards to hunt at dusk or dawn when warthogs enter or leave aardvark holes. Bothma & Le Riche (1984) described porcupines being abused by a particular leopard as they emerged from their burrows; Kruuk & Turner (1967) reported that leopards have the ability to develop individual tastes and killing strategies. Leopards in the Waterberg could have adapted to killing warthog entering or exiting burrows. Warthog are also abundant across all types of ranches, which will allow leopards to kill warthogs on all different land uses.

Plains and savannah species like blesbok, Burchell's zebra, blue wildebeest and red hartebeest would select open savannah habitat which will hamper the leopard's hunting strategies (Bailey 1993). However, game ranches are normally fenced and the above savannah species can be forced to sub optimal habitat (e.g. rocky mountain terrain) which will increase their vulnerability to leopard attacks. Median ranch size for the study area was 892.92 ha (mean 1200 ha) (chapter 6), and combined with the mountainous terrain limits the number of plains game that can be kept by ranchers. The young of seasonal breeders may also be abundant during certain parts of the year, and combined with the open habitat preference, will explain the limited role these species play in the leopard diet.

No livestock remains were found in scats and kills, but a questionnaire survey (Chapter 6) indicated that ranchers lose about 2 % of livestock to leopards. The low incidence of livestock predation can be attributed to husbandry practices. Livestock calves are born in open non-mountainous grass veld areas. The low predation of impala and savannah species indicate that leopards do not select prey under these habitat conditions. Human activity can also play a role as livestock calving paddocks are normally close to ranch houses. Ogada *et al*. (2003) found that high levels of human activity limit predation on livestock. Leopards normally kill livestock calves up to four months of age (Grimbeek 1992) and ranchers keep livestock in low lying areas until several months old, before moving the livestock to mountainous habitat. Similar results were reported by Ackerman *et al.* (1984) where cougar livestock predation was limited by similar husbandry practices. It appears that livestock leopard predation is attributed to poor husbandry practices and/or ranch and habitat characteristics.

5.3 Prey size

The mean prey weight of this study of 37.66 kg was high and almost double the preferred weight of 23 kg as reported by Hayward *et al*. (2006) and studies elsewhere (Karanth & Sunquist 1995; Henschel *et al.* 2005). It still fell in the preferred weight range (10 – 40 kg) of leopards (Karanth & Sunquist 1995; Hayward *et al.* 2006). These results however should be interpreted with caution even though a sample of 101 kills could be found, 77 thereof representing only one male and one female leopard. Nevertheless these results still give interesting views on leopard predatory behaviour.

Average leopard weights for the Waterberg as estimated by Grimbeek (1992) were 58.8 kg for males and 38 kg for females. Using the mean prey weights for this study the average leopard: prey body weight ratios were 1:0.64 for leopard males and 1:0.99 for leopard females. If mean principle prey weights were used the ratios for male leopards were 1:1.02 and 1:1.58 for females. Female leopards killed prey slightly heavier than their own weight and could be explained by the female leopard with cubs killing bigger prey than female without cubs (see results). Owen-Smith & Mills (2008) reported that the most common weight of prey killed by carnivores fell within one to two times the predator weight, which indicates that the principle prey species killed by leopards in this study was in their preferred weight range. Packer (1986) reported that female leopards can kill prey to a maximum of 4 times their own weight, although the mode is 1.1. The maximum prey weights killed by different leopard sexes indicated that male leopards were killing prey 3 times their own body weight, females 3.4 times their own weight and, astonishingly, females with cubs can kill prey 4.8 times their own weight. These results fell in the range as reported by Packer (1986), although female leopards with cubs were able to kill bigger prey than previously reported.

The rocky, steep and mountainous terrain occupied by the leopards probably gives them an added advantage over prey that was not adapted to the area, e. g. red hartebeest. The largest animal species killed by female leopards was red hartebeest which can explain the large leopard: prey weight ratios. However, average leopard weights (male and female combined, 48 kg) resulted in a weight ratio of 1:0.78. Female leopards without cubs did not kill large prey and preferred prey in the small and medium weight classes, while although male leopards preferred medium prey, they also kill large prey. Female leopards are small and even though they have the ability to kill large prey (see above) the risk of injury increases with prey weight. While this result proves the strength of leopards, medium sized prey were still preferred, which agrees with other studies (Bailey 1993; Karanth & Sunquist 1995; Bothma, Van Rooyen & Le Riche 1997; Henschel *et al.* 2005). Body mass ratios reported here were comparable to other leopard studies (Karanth & Sunquist 1995).

Having growing cubs puts extra pressure on female leopards to provide enough food for the survival of the female and her offspring. Female leopards with cubs achieve increased food intake by becoming more successful. In the prey-poor Kalahari Bothma & Coertze (2004) proved that female leopards with cubs kill smaller prey in a higher frequency than females without cubs, to sustain the growing cubs. The results of this study suggest that female leopards with cubs achieve increased food intake by killing larger, more catchable prey, such as female kudu. This result agrees with results from Anderson Jr & Lindzey (2003) where female cougars with cubs killed a higher number of large prey than adult female cougars. Laurenson (1995) also found that lactating cheetah killed larger prey items compared to non lactating cheetah. It therefore seems that in a prey-rich environment lactating female leopards sustain their increased energy needs by preying on larger catchable prey.

The preference for bigger prey in this study supports the theory that vertebrate predators would be energy maximisers in prey-rich environments where there are enough large prey, whereas in prey-poor environments they would be non-selective number maximisers (Griffiths 1975; Karanth & Sunquist 1995).

5.4 Age and sex classes

Significantly more female warthog and kudu prey were killed than males. Male warthog, as with all suides, are fierce fighters and can inflict serious damage to a predator (Ramakrishnan *et al.* 1999; Hayward *et al.* 2006). Leopards however have the ability to kill male warthogs when opportunity arises. Taylor (1976) reported that adult male wild pig have a tendency to be solitary, which not only deprives them of group vigilance, but also increases individual predator encountering probabilities. Karanth & Sunquist (1995) suggests that this behavioural trait can make them susceptible to leopard predation. Warthog males are also solitary during the non breeding season and normally form temporary associations with female and offspring (Cumming 1975).

Warthog females are quite a lot smaller than males (Skinner & Smithers 1990) and could be much more easily overpowered by leopards. Although female warthog are killed in greater numbers than males, most prey is yearlings and adult female warthogs only account for 28 % of warthogs killed.

The large size of male kudu, the presence of horns and a muscular neck would render them difficult to kill by leopards (Bailey 1993). Pienaar (1969) reported that 73 % (82.4 % this study) of kudu killed by leopards in Kruger National Park were females. The smaller size and behaviour of female kudus would make them more vulnerable to leopard predation, regardless of age (Bailey 1993).

The number of impala killed was equally distributed between wet and dry season, but only males were killed in the dry season. Similar results were reported for KNP (Pienaar 1969; Bailey 1993) where more male impala were killed during the dry than wet seasons. Grimbeek (1992) reported that 83 % (37 % for this study) of impala kills found in the Waterberg were female, although no seasonal data were available. Subordinate and bachelor male impalas are forced out by territorial males during the rut and are forced to use marginal habitat, e.g. denser habitat (Anderson 1972). Bachelor herds are also smaller in size than breeding herds which would also reduce vigilance (Bailey 1993). These combined factors probably explain why more sub adult or subordinate adult male impala are killed in the dry season by leopards (Bailey 1993). In the wet season more females were killed (yearling and adult) and can be explained by the fact that all the female impala killed were pregnant. Pregnant impala will move away from the herd to give birth in thick undergrowth, which will reduce vigilance and increase vulnerability to predation (Skinner & Smithers 1990). No young impala kills could be found, but it can't be concluded that leopard do not kill the young of impala as kills found are biased towards bigger animals.

The young of all prey species were preyed upon significantly more than the adults. Vitale (1989) showed that young animals are less adept to escape predation and are thus preferentially selected by predators. Even between leopard sexes young and yearlings were killed more regularly than adults, although male leopards killed more adult prey than females. Between seasons, adult prey was killed more in the dry season than wet season when young and yearling prey was abundant.

5.5 Prey density and selection

Impala was the most abundant prey species, followed by kudu, warthog and blue wildebeest, which agrees with previous reports for game ranches (Van der Waal & Dekker 2000). Game ranchers stock game according to the hunting market and in South Africa impala, kudu and wildebeest are the most hunted (Bothma 2002). Blesbok were kept in low numbers and can be explained by the fact that blesbok are highveld species not adapted to the Waterberg. Blesbok will have trouble breeding and young will be killed by predators. However, some ranchers buy stock before the hunting season and then release the stock on the ranch for the hunting season. Blesbok numbers thus represent the minimum number during the non hunting season. Jacobs' indices indicated that warthog, red hartebeest, kudu, eland and bushbuck are preferred by the Waterberg leopards. Red hartebeest, blesbok and eland were stocked in low numbers by ranchers (Table 5). Red hartebeest is an open savannah species not well adapted to mountainous terrain. Red hartebeest may also be naive about leopards which will increase their vulnerability towards predation. These factors probably explain why red hartebeest is killed so easily by leopards, which is evident in this study where even adult hartebeest were killed.

5.6 Hunting behaviour

Leopards kill prey by strangulation or a bite through the nape of the neck (Turnbull-Kemp 1967; Bothma & Le Riche 1984), while small prey could be killed with a bite to the head (Skinner & Smithers 1990). This agrees with results from this study where most prey were killed by suffocation (bite under neck), while small prey (e.g. duiker) were killed with a bite to the head. After a kill is made, leopards will normally conceal the carcass either by caching it in a tree (Turnbull-Kemp 1967), dragging it under dense cover (Smith 1987) or covering it with plant litter (Smith 1987), although Bothma & Le Riche (1984) found no evidence of leopards covering prey in the Kalahari. In this study only 6.4 % of fresh carcasses were covered with plant material, which suggests that this is not a common behaviour for leopards in the Waterberg as Grimbeek (1992) reported similar results. Prey carcasses were normally concealed under or in trees.

While tree caching is seen as a important component of leopard feeding behaviour (Turnbull-Kemp 1967) it is probably done when scavengers disturb leopards at feed sites (Bailey 1993). Results suggest that in forested areas tree caching occurs at low frequencies and most kills are concealed under dense vegetation (Karanth & Sunquist 2000), while in areas with low scavenger densities tree caching occurs in equally low frequencies (Bothma & Le Riche 1984). However, in scavenger rich environments tree caching is quite common and 87 % of kills in KNP were cached in trees (Bailey 1993). Results from this study indicate that tree caching is not as common in the Waterberg with 24.8 % of kills found in trees. This result is much higher than previously reported (2.4 %) for the Waterberg (Grimbeek 1992). Large predators and scavengers have been exterminated from the agricultural land in the Waterberg and only brown hyena (*Parahyaena brunnea*) and jackal (*Canis mesomelas*) remain as important scavengers. Leopards are thought to be dominant over brown hyenas (Mills 1981), but camera traps placed at kill sites indicate that on some occasions brown hyenas arrive at the kill before leopards. Brown hyenas will carry carrion to den sites (Skinner, Haupt, Hoffmann & Dott 1998) which will reduce contact time at the leopard feed site and possibly avoid confrontation with the leopard. It therefore appears that brown hyena has the ability to scavenge from leopards, especially when leopards are not close to their kills.

A second scenario that can explain the higher incidence of tree caching is the type of tree used. The most common tree used to cache kills was *Burkea africana. Burkea africana* trees are characteristically found on open savannah where the grass layer is moderately to well developed (Mucina & Rutherford 2006), which will reduce the low vegetation available for leopards to conceal prey on the ground. *Burkea africana* is also a tallish tree with a spreading crown (Van Wyk & Van Wyk 1997) and would not have enough low foliage to conceal prey, as evident by the low number of prey concealed under this species. *Pseudolachnostylis maprouneifolia, Diplorhynchus condylocarpon, Englerophytum magalismontanum and Croton gratissimus* are all found on rocky foot to mid slopes and all these species have characteristic low branches with dense foliage up to ground level (Van Wyk & Van Wyk 1997), which will allow for enough cover to conceal prey. Leopards will therefore rather cache kills under these trees than in them, as was found in this study. *Peltophorum africanum* are found on old agricultural fields and also have dense low branches which will allow for good prey concealment. Kills found near *Peltophorum africanum* were either cached in or under the tree. These results support the suggestions from Balme *et al*. (2007) that landscape attributes and interspecific competition determine tree caching.

Average drag distance (99 m) was lower than previously reported (650 m) for the Waterberg (Grimbeek 1992). Dry season averages (131.18 m) were similar to what

Smith (1987) found in Zimbabwe, although wet season averages (49.0 m) were much lower than those reported by Smith (1987). Our results indicated that in wet season more young and yearling prey were killed, which will be consumed more quickly by leopards, while in the dry season more adult prey were killed. While results showed that large prey were dragged the shortest distance in total, in the dry season vegetation will shed leaves which will force the leopard to drag prey until suitable cover is found. Our results show a similar trend to Bothma & le Riche (1984) where female leopards dragged prey further than male leopards.

Hair was plucked from prey carcasses, which agrees with results from Smith (1987) and Bothma & le Riche (1984). Intestines were normally found *en route* to feed site, which agrees with Smith (1987), although Bothma & Le Riche (1984) found intestines at feed sites. Intestines and other leftovers were only covered 5 % of the time and only by female leopards. Prey remains normally consisted of legs, hooves, head, skin and hair, while small prey remains were only intestines and colon as reported by (Smith 1987).

5.7 Conservation and conflict

The ranch questionnaire survey (Chapter 6) showed that ranchers reported high losses of impala and blesbok, with low losses of kudu and warthog (Fig. 11). Results from this study showed that impala accounted for 12 % of kills found compared to 25 % as reported by ranchers. This discrepancy can be explained by the fact that important sport hunting species, like impala and blesbok, will be monitored more closely by ranchers than species which are more difficult to count, e.g. kudu, bushbuck and warthog. Any losses occurring in impala and blesbok, also blue wildebeest, red hartebeest and other plains game will be noticed by ranchers. Leopards or other carnivores will normally be blamed for the losses if no other credible reasons can be found because of the long standing leopard-rancher conflict. Plains game and impala will also be killed by leopards in more open habitat and the leopards will then drag carcasses to cover (this study). Because a road network normally exists on the open plains, drag marks will be noticed quickly by ranchers and ranch workers. Kills made in the inaccessible mountainous terrain would be not be noticed by ranchers. These described scenarios result in only certain kills being detected by ranchers, which will ultimately lead to a biased prey selection of leopards as reported by ranchers.

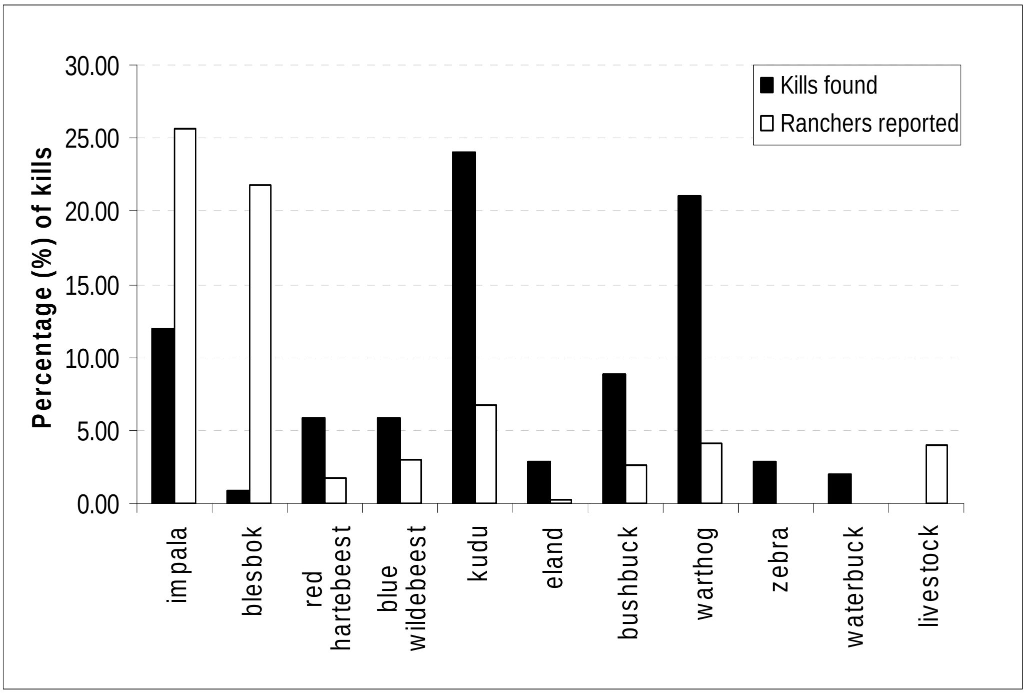

Fig. 11: Comparison between kills found during this study versus kills as reported by game and livestock ranchers in the study area. Data for kills as reported by ranchers taken from Chapter 7.

The reason leopards still survive on ranches in the Waterberg can be attributed to their prey selection. The majority of leopard prey is inconspicuous, such as kudu, bushbuck and warthog. Although ranchers have an idea of how many of these species are present on their ranch, kills made by leopards are not normally found and in that sense ranchers can never calculate the impact leopards have on their ranch.

6 CONCLUSIONS

Leopards preyed on a variety of prey, but preferred ungulates. Kudu were the most important prey in terms of biomass consumed. Impala was the most abundant prey species, but selection indexes showed that leopards did not select impala; supporting the theory that prey catchability plays an equally important role in leopard prey selection (Balme *et al.* 2007). Leopards preferred prey in the medium weight classes while average prey weight was higher than reported for other studies. The high average prey weights suggest that leopards on ranches in the Waterberg are energy maximisers and live in a prey rich environment (Karanth & Sunquist 1995). As with other studies (Bailey 1993; Karanth & Sunquist 1995) female-biased predation on ungulates was observed, albeit most prey killed were in the young and yearling age groups. Leopards followed typical feeding behaviour and prey were killed, dragged to cover, either concealed under vegetation or cached in trees. Tree caching was more common than expected and it is suggested that a combination of habitat variables and interspecific competition was responsible for this higher incidence.

Our results have some implications for leopard conservation on ranch lands in the Waterberg. The popular belief that game ranches, with their higher abundance of prey, will relate to higher leopard numbers raises some doubt. Abundance of prey alone will not lead to higher leopard densities, but factors like prey catchability (Balme *et al.* 2007), vegetation cover (Balme *et al.* 2007), human disturbance, human density and human activity levels need to be taken into account in predicting leopard abundance from prey abundance. The situation where the kills reported by ranchers differed from what we detected in this study can complicate rancher attitudes towards leopards. The biased kill data can fuel anti-predator sentiment because true impact of leopards is not known, showing the importance to communicate results from carnivore studies on ranch land to ranchers to improve rancher knowledge about carnivore ecology on ranches.

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CHAPTER 6

LIVING WITH LEOPARDS: RANCHER ATTITUDES, ANIMAL LOSSES AND CONSERVATION OF LEOPARDS IN THE WATERBERG, SOUTH AFRICA

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LIVING WITH LEOPARDS: RANCHER ATTITUDES, ANIMAL LOSSES AND CONSERVATION OF LEOPARDS IN THE WATERBERG, SOUTH AFRICA

Submitted to: South African Journal of Wildlife Research

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ABSTRACT

In South Africa leopards *Panthera pardus* are the most successful larger felids on private ranch land. The increase in game ranches in South Africa has potentially increased leopard habitat. However, the diet of leopards regularly brings them in conflict with ranchers, which in most cases leads to the destruction of the problem leopard. An understanding of the determinants of this conflict may assist in management programs and thereby reduce conflict in the future. This study investigates the attitudes of ranchers that are affected by free ranging leopards, towards leopards and their conservation. Most of the ranchers held positive views towards leopards, but English speaking ranchers were more positive than Afrikaans speaking ranchers, and young Afrikaans speaking ranchers were more positive than older ranchers. Attitudes also differed with land use, with cattle ranchers being more negative than the other land users. Ranchers ascribed their negative attitudes to the potential impact of leopards on game and livestock numbers. This finding suggested that age and culture contribute more to the attitudes towards carnivores than economic factors alone. Habituation was a popular incentive to increase the value of leopards, although other incentives were also favoured. However, the implementation of incentives is problematic due to the extensive range used by leopards and conflicting interest of different incentives (e.g. habituation versus hunting). Lastly, the establishment of conservancies seems to be the most promising

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initiative to promote leopard and other carnivore conservation on private ranch land, which will allow for easier implementation of different incentives.

1 INTRODUCTION

Large carnivores (> 5kg) face extinction worldwide under pressure from increasing human densities (Woodroffe 2000), however leopards (*Panthera pardus*) seem to be able to survive in areas with high human densities (Woodroffe 2000; Hunter, Balme, Walker, Pretorius & Rosenberg 2003). Leopards accomplish this feat by their remarkable behavioural and ecological flexibility (Woodroffe 2000; Marker & Dickman 2005) which is evident in their broad habitat selection (Nowell and Jackson 1996), and varied diet (Hayward, Henschel, O'Brien, Hofmeyr, Balme & Kerley 2006). After the coyote, the leopard is considered to be the most adaptable larger carnivore in the world (Eaton 1978). This adaptability is evident from leopard number estimates; Martin & De Meulenaar (1988) estimated 714 000 leopards are present in sub Saharan Africa. Although this is considered to be an over-estimate (Norton 1990), leopards are not considered threatened in sub Saharan Africa and are listed as being of least concern in South Africa (Friedmann & Daly 2004).

The secure conservation status of leopards does not reflect the true situation in southern Africa due to excessive persecution outside protected areas. Although protected areas play an important role in the conservation of leopards, only an estimated 8 % - 13 % of leopard range is in national protected areas, while the remaining 87 % - 92 % of leopard range is privately owned (Martin & De Meulenaar 1988; Boitani, Corsi, De Biase, Carranza, Ravagli, Reggiani, Sinibaldi & Trapanese 1999). Suitable privately owned leopard habitat in South Africa includes game ranches, livestock ranches and private game reserves. South Africa has seen a dramatic increase in the conversion of livestock farms to game farms in last few years (Van der Waal & Dekker 2000). There are an estimated 9000 privately owned game farms and ranches in South Africa covering some 13 % of the country's total land area, compared with 5 % for national protected areas (Falkena & Van Hoven 2000).

In livestock farming areas the dietary flexibility of leopards allows them to switch to livestock when natural prey numbers are low or when opportunities arise to hunt livestock (Norton, Henley & Avery 1986; Maan & Chaudhry 2000). This leads to conflict and the subsequent killing of leopards in these areas (Esterhuizen & Norton

1984). In the face of this human persecution on private stock farms, leopards only reach densities of 0.1 % of that in protected land (Nowell & Jackson 1996). Retaliation to livestock predation has been one of the major contributors to leopard losses in South Africa (Esterhuizen & Norton 1984), Namibia (Marker & Dickman 2005) and the rest of Africa (Nowell & Jackson 1996) and far outnumbers those shot by trophy hunters (Hunter & Balme 2004).

The importance of game ranches and privately-owned land in South Africa and Namibia is being recognised in the conservation of free roaming cheetahs *Acinonyx jubatus*, leopards and wild dogs *Lycaon pictus* (Grimbeek 1992; Marker, Macdonald & Mills 2003; Lindsey, Du Toit & Mills 2005; Marker & Dickman 2005; Wilson 2006). These three species need vast areas of land, and cannot be contained on small reserves or single game ranches. Game ranches and other private land can therefore potentially play an important role in the conservation of large carnivores.

Game farms are normally well stocked with game for consumptive use or ecotourism (Van der Waal & Dekker 2000). Increased game numbers would theoretically lead to an increase in suitable leopard habitat and densities (Martin & de Meulenaar 1988; Hayward, O'Brien & Kerley 2007). While a positive relationship between leopard density and prey biomass has been reported (Stander, Haden, Kaqece & Ghau 1997; Hayward *et al.* 2007), anthropogenic factors such as local tolerance towards leopards can play an equally important role in leopard density (Marker & Dickman 2005). Indeed, it has been reported that game ranchers can be quite hostile towards carnivores (Hunter & Balme 2004), and Marker *et al*. (2003) found that significantly more game ranchers removed cheetah than livestock ranchers, while most cheetahs were removed indiscriminately. This highlights the finding of Woodroffe (2000) that local attitudes as much as ecological factors determine carnivore densities.

Some researchers reported that the attitudes of ranchers towards carnivores are difficult to change (Eaton 1978), while others (Marker *et al.* 2003) found that ranchers are open to change that can lead to increased tolerance towards carnivores. There is general consensus that if impacted ranchers can benefit economically from the presence of carnivores, attitudes would change for the better (Sillero Zubiri & Laurenson 2001; Hunter & Balme 2004; Lindsey, Roulet & Romanach 2007). It is also widely accepted that incentive-driven conservation is the way forward for the sustainable utilisation and conservation of natural resources (Hutton & Leader-Williams 2003). Various economic incentives have been put forward to increase tolerance towards southern African carnivores, e.g. hunting (Eaton 1978; Martin & De Meulenaar 1988), ecotourism (Marker *et al.* 2003; Hunter & Balme 2004) and green products (Marker *et al.* 2003).

In this study, questionnaires were used to determine the attitudes of ranchers affected by free ranging leopards, towards leopard and other carnivore conservation; factors influencing those attitudes and incentives that could possibly help to increase the value of leopards to ranchers.

2 METHODS

2.1 Identification of ranchers to be interviewed

Surveys were conducted on ranches in the Waterberg Biosphere Reserve in the Limpopo Province during October 2006 to March 2007. Questionnaires need to be sampled in a random manner to be truly representative of the area surveyed (Wilson 2006). It was not possible to get all farmer data for the Waterberg Biosphere to randomly select ranchers. It was then decided to only focus on farmers on ranches where we know leopards occur. We used tracking data from four (3 female & 1 male) GPS collared leopards to identify farms (Chapter 4). Not all leopards in the study area were collard as camera trapping showed some individuals using the same range as the collared leopards. Tracking data was used to generate minimum convex polygons (MCP) with the ArcView (version 3.3, ESRI, Redlands, CA) Animal Movement Extension (Hooge, Eichenlaub & Soloman 1999). The MCP's of all five leopards were combined to generate a new total MCP. A buffer was added to the total MCP to allow for the movement of leopards beyond the total MCP. The buffer was calculated by adding the average female MCP (n = 4) to the MCP of the male leopard (n = 1) and calculating the average MCP for the male and females combined. The combined average MCP were used to estimate the boundary buffer by using the formula; $A = \pi r^2$ where A is the estimated area of a mean leopard home range (41.2 – 291 km^2) and r is the buffer width (8.1 km) (Soisalo & Cavalcanti 2006).

2.2 Questionnaire survey

All farmers were personally interviewed by LS. Respondents were informed that the Centre for Wildlife Management at the University of Pretoria was conducting the project and assured that all responses would remain anonymous. Universities are often seen as neutral, encouraging honesty and reducing compliance bias (Mitchell & Carson 1989). The researcher used an unmarked vehicle and plain clothes with no University of Pretoria branding.

A structured questionnaire, based on Lindsey *et al.* (2005) was used to interview farmers. The questionnaire consisted of 5 sections: (1) Farmer section - concerning the personal information, education level and background of the farmer; (2) Ranch characteristics section - concerning the economic use and size of the property; (3) Carnivore section - concerning the presence and attitudes towards carnivores present; (4) Leopard section - concerning the population status of leopards, the presence of leopards, their economic impact and value, prey base and incentives for their conservation; (5) Animal losses section - concerning livestock and game losses caused by predators and other factors.

2.3 Analysis

Data were analysed using the *SPSS v.15* (SPSS Inc., Chicago, USA) and SAS (SAS Institute Inc., North Carolina, USA) software packages. The attitudes towards carnivores were scored between 0 (very negative) and 5 (very positive), and scores were categorized as negative (0 - 2) and positive (3 - 5) for subsequent analysis. Rancher ages were divided into 4 categories (20 - 40, 41 - 50, 51 - 60, >61 years) and two cultural groups were used (Afrikaans speaking or English speaking). Ranches could, or could not, be part of a conservancy, while the following four land uses were used; livestock, livestock & consumptive wildlife utilization, ecotourism & consumptive wildlife utilization, ecotourism & no priority given to economics (normally the farm is kept as a holiday destination for local or foreign owners). Incentives for conservation were scored between 1 (very much disliked) to 6 (very much liked). Ranchers were asked to report game losses for 2005, per species as well as the associated financial loss per species. Average game auction prices at Vaalwater, Limpopo, (Anonymous 2006) were used to calculate financial losses if ranchers only supplied number of game lost. Pearson's chi-squared test was used for categorical variables and independent-samples *t* test for interval-scale data. Descriptive statistics were derived for all factual and attitudinal questions. The Kolmogorov-Smirnov test was used to test for normality. Appropriate non-parametric tests were used if data were not normally distributed.

3 STUDY AREA

The study area fell inside the Waterberg Biosphere (Fig. 1). The land use in the area is dedicated to commercial agriculture, in the form of livestock and game ranching, and the tourism industry, including private game reserves. The landscape is rugged while the vegetation is classified as Waterberg Mountain Bushveld (Mucina & Rutherford 2006) and is characterized by *Faurea saligna – Protea caffra* bushveld on higher slopes and *Diplorhynchus condylocarpon* broad-leaved deciduous bushveld on rocky mid- and foot slopes. *Burkea africana-Terminalia sericea* savannah characterised the lower lying valleys and deeper sandy plateaux, while the grass layer is moderately to well developed. The main rainfall season is summer with very dry winters.

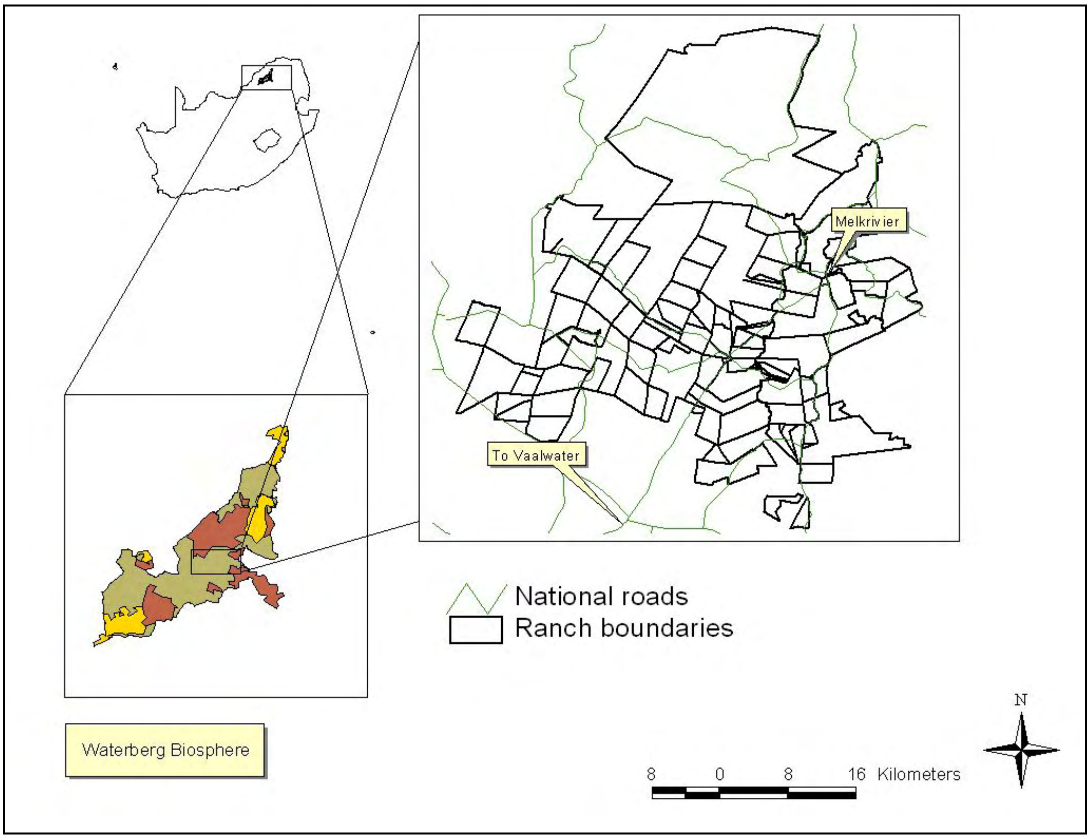

Fig. 1. Map of the study area showing the Waterberg Biosphere and the ranches from which ranchers were interviewed for this study.

4 RESULTS

4.1 Characteristics of area

The four leopards' total MCP covered an area of 579.5 km² and when the buffer was included the area increased to 1563 km². The four leopards ranged over an estimated 110 properties which belonged to 94 land owners. Only 90 land owners could be reached during the survey period of which 16 declined to be interviewed (15.5 % refusal). Most respondents who could not and would not take part in the survey were located in the buffer area (Fig. 2).

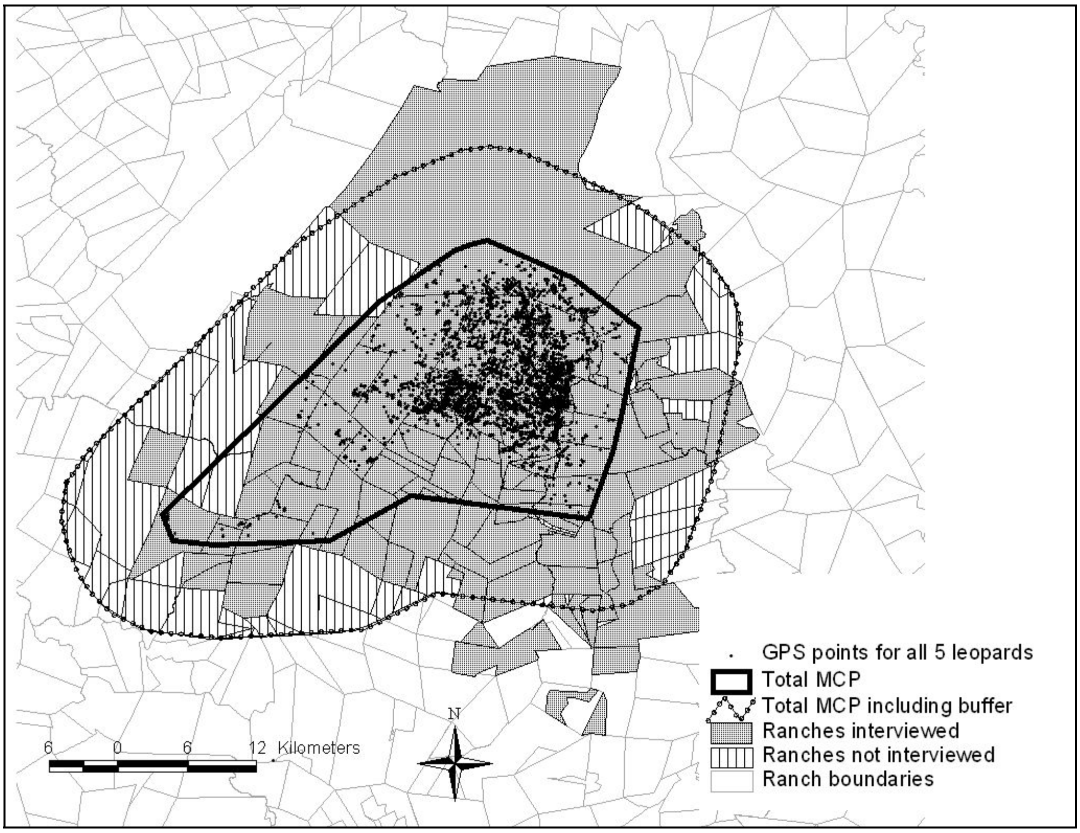

Fig. 2. GPS locations for all collared leopards, total MCP, buffer, ranchers interviewed and ranchers not interviewed during the study.

4.2 Ranch characteristics

Ranches varied in size, but the majority (59.2 %) were smaller than 1000 ha in size (Median 892.92 ha, mean = 1722.48 ± S.E. 482.96 ha). Most ranchers were involved in livestock ranching, while ranchers with no preference to economic activity and ecotourism had the smallest properties (Table 1). The bulk of the properties were fenced with standard game fences (73.97 %, n = 54), while livestock properties were typically fenced with cattle fences (26.03 %, n = 19). No properties were fenced with predator proof-fences, although 15% (n = 11) of properties had some electrical fencing.

Table 1. Mean and median ranch size (ha) in each land use category impacted on by the 4 collared leopards

	N	Mean	Median	S.E
Livestock	20	1111.75	577.83	380.57
Livestock & Consumptive wildlife utilization	15	1566.36	1051.25	416.12
Consumptive wildlife utilization	12	1849.58	1022.71	579.34
Ecotourism & no priority given to economics	13	408.81	278.42	126.87
Ecotourism & Consumptive wildlife utilization	16	3604.29	1259.62	2145.00

4.3 Rancher characteristics

Most of the respondents were Afrikaans speaking (62.2 %, n = 46) while the rest were English speaking (37.8 %, n = 28). Land use differed significantly among Afrikaans and English speaking ranchers (χ^2 = 17.544, df = 4, p = 0.002) with more Afrikaans speaking ranchers involved in livestock and CWU enterprises while English speaking ranchers were more involved in eco-tourism enterprises (Figure 3). The average age of respondents was 52.1 years (S.E. = 1.9) but the largest fraction (32.4 %) of the respondents were younger than 40 years old.

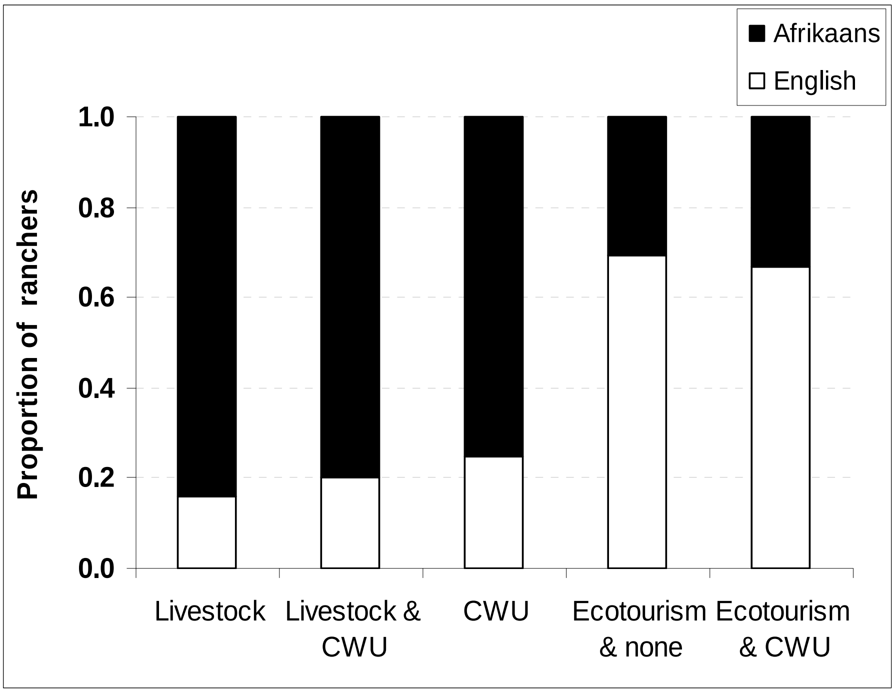

Fig. 3. Proportion of Afrikaans and English speaking ranchers involved in the different land use types.

4.4 Predators on ranches

Signs (tracks, kills, predator seen and secondary source[6]) of all four carnivores were reported by farmers, with jackals the most abundant (signs reported by 97.26 % of respondents), followed by caracal (95.89 %), brown hyena (94.52 %) and leopards (82.19 %). The presence of a predator was mostly attributed to the tracks of the predator, followed by actual sightings, while kills made by the predators were found only by a few ranchers, with the exception of leopard kills, where 37% of ranchers reported finding kills (Table 2). Ranchers identified leopard kills by looking at drag marks, tree caching and bite wounds.

Table 2. Percentage of ranchers reporting different predator signs on their ranches

Predator	Predator seen	Tracks seen	Kills found	Secondary source
Jackal	89.0	82.2	5.5	3.9
Caracal	57.3	61.6	4.1	12.3
Leopard	45.2	75.3	37.0	9.6
Brown hyena	38.4	86.3	5.5	2.7

4.5 Attitudes towards leopards and other carnivores

Attitudes towards carnivores differed and ranchers were more positive towards brown hyenas (80 % of ranchers positive) and leopards (70 %) than jackal (60 %) and caracal (60 %) (Fig. 4).

[6] When ranchers are told by workers about leopard sings

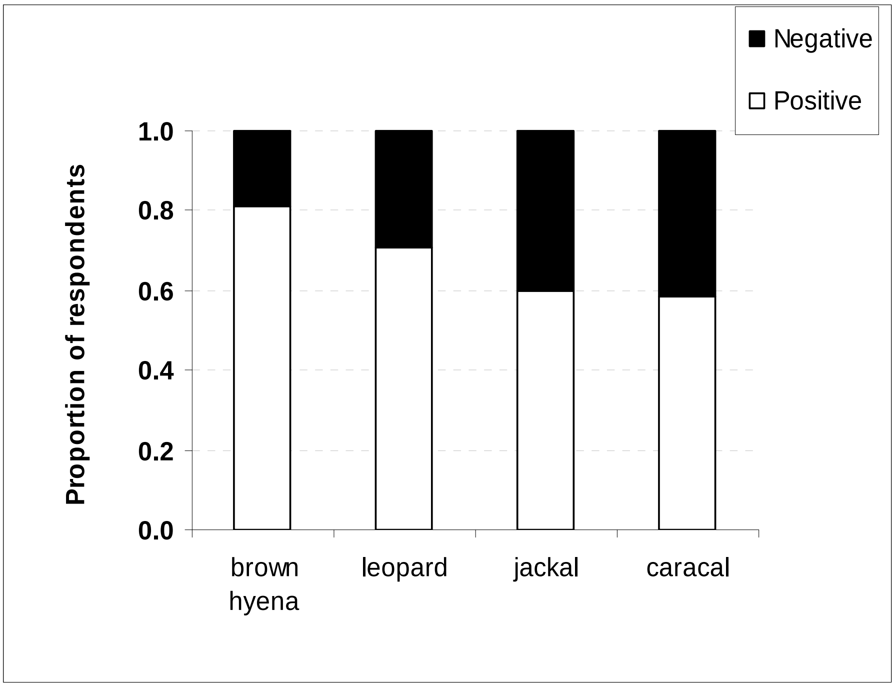

Fig. 4. Proportion of ranchers who were positive or negative towards the four predators found on ranch land (Brown hyena, n = 75; Leopard, n = 75; Jackal, n = 75; Caracal, n = 75).

Most of the ranchers attributed their negative attitude towards carnivores to the killing of livestock (Table 3). Some ranchers felt that caracals and jackals were killing too much small game, while caracals were perceived by some to be wasteful feeders. Positive remarks towards the four carnivore species were mostly attributed to their ecological function in the ecosystem, while brown hyenas and jackals were seen to play a positive role by scavenging and thereby keeping the veld clean (Table 3). Surprisingly, positive attitudes towards leopards were attributed more towards their ecological service in the ecosystem than to their financial value (ecotourism value). This was similar across all four carnivore species. The four carnivore species were not seen as important for biodiversity, which contradicts the fact that all were important for their ecological role in the ecosystem.

Table 3. The most common reasons given by ranchers for negative or positive attitudes towards the four predators present on ranches (when asked in an open ended question why they are positive or negative towards the predators)

Reasons for attitude (% of ranchers)	Leopard	Brown hyena	Jackal	Caracal
Negative reasons				
Kill livestock	27.59	23.73	24.07	26.92
Kill game & livestock	6.90	5.08	5.56	5.77
Kill game	3.45	3.39	7.41	7.69
Danger to humans	1.72	0.00	0.00	0.00
Kill too many small *	0.00	0.00	12.96	9.62
Wasteful feeders	0.00	0.00	3.70	9.62
Hunting quota too low	1.72	0.00	0.00	0.00
Positive reasons				
Ecological service supplied	31.03	33.90	25.93	25.00
Tourism value	12.07	11.86	11.11	9.62
Tourism & ecological value	10.34	3.39	3.70	3.85
Important for biodiversity	5.17	5.08	1.85	1.92
Scavenge and keep veld clean	0.00	13.56	3.70	0.00

* Small game species include antelope species with an adult weight less than 15 kg (steenbok, duiker, and klipspringer), the young of larger mammals and lagomorphs.

Although a high percentage of respondents did not experience problems with leopards (62.7 %), 37.3 % indicated that they did have a leopard problem. There was a significant relationship between land use and leopard problems, with more livestock ranchers regarding leopards as a problem compared to other land users (χ^2 = 11.406, df = 4, p = 0.022). In this respect 16 leopards have been removed from the study area since 2000 (7 males, 3 females, 6 unknown sex) and ranchers with a negative attitude towards leopards are more likely to remove leopards (χ^2 = 6.194, df =1, p = 0.013). However, the presence of livestock did not influence the removal of problem leopards (χ^2 = 0.059, df = 1, p = 0.327), but leopard removals only occurred on Afrikaans ranches (χ^2 = 6.421, df = 1, p = 0.01). The association between livestock ranchers, leopard problems and removals is expected as more Afrikaans ranchers, who as a group displayed more negative feelings towards leopards, were involved in livestock ranching than English speaking ranchers (Fig. 3).

A large percentage of the ranchers (43.1 %) had no information regarding the population trend of leopards on their properties, while 23.60 % thought the leopard population had increased, 23.60 % thought the population was stable and only 9.7 % indicated that the leopard population had declined on their ranches in the last 10 years. Many of the ranchers (86.8 %) felt that the increase in game ranches was responsible for higher leopard densities. Leopard signs were regularly encountered on properties (50.8 % of respondents found signs frequently). Land use did not affect the sightings of leopards (χ^2 = 2.310, df = 4, p = 0.679), but tracks were encountered significantly more frequently on ecotourism ranches (χ^2 =11.642, df = 4, p = 0.02) than any other ranches. Leopard kills found by ranchers were, however, found equally on all the different land uses (χ^2 = 4.814, df = 4, p = 0.307).

4.6 Animal densities and predation by leopards

Game ranches (n = 52) had an average of 406.63 (S.E. = 88.2) game animals per ranch at an average density of 0.52 (S.E. = 0.15) animals/ha. Livestock ranches (n = 36) had an average of 149.3 (S.E. = 36.40) head of livestock per ranch at an average density of 0.20 (S.E. = 0.06) animals/ha.

Most game ranchers (87.5 %) suffered game losses to leopards with an average loss of 3.74 (S.E. = 0.82, range = 11.48) animals/year which represents an average of 1.19 % (S.E. = 0.37.) of game owned. However, most game losses (62.8 %) were less than 6 animals/year, with only a small percentage of ranchers (7 %) reporting more than 28 game animals lost per year. Impala (*Aepyceros melampus*) were the most numerous game specie owned by ranchers (average = 158.52 per ranch), followed by warthog (*Phacochoerus africanus*) (67.40) and blue wildebeest (*Connochaetes taurinus*) (64.5) (Fig. 5). Ranchers reported that impala were the animals most commonly killed by leopards (25.66 % of reported kills) followed by blesbok (21.83 %), while rare game losses were very low (Fig. 5). The average financial value of game losses was R8 994.18 (S.E. = R2 763.85.) per year (range = R90 972). Ranchers with expensive, rare game (roan antelope and sable antelope) lost more money per animal, but rare game accounted for a low fraction of reported game losses (Fig. 5).

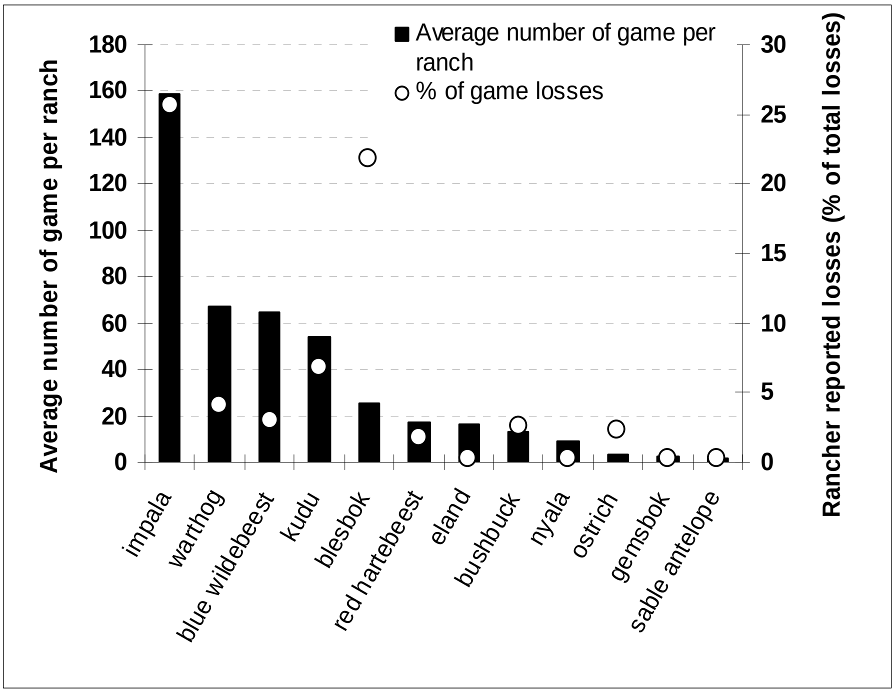

Fig. 5. The average number of game per ranch compared to the percentage of reported game losses, expressed as a percentage of total game losses as reported by ranchers (impala, n = 41 ranches; warthog, n = 17; blue wildebeest, n =31; kudu, n = 41; blesbok, n = 28, red hartebeest, n = 25; eland, n = 25; bushbuck, n = 16; nyala, n = 19; ostrich, n = 9; gemsbok, n = 7; sable antelope, n = 4).

A large number of cattle ranchers (80.5 %) suffered cattle losses to leopards with an average loss of 2.55 (S.E. = 0.55) animals per year, which represents an average 2.0 % of livestock owned. All cattle killed were younger than 3 months. An average of 5.7 (S.E. = 1.2) cattle died from disease per year, which accounted for 3.95 % of cattle owned. The average financial value of cattle lost per year was R2 464.84 (S.E. = R628.73), but varied between different livestock ranches (range = R25 800); stud ranchers especially reported high financial losses.

4.7 Factors affecting attitudes

Various factors and combinations shaped the attitudes of ranchers towards leopards and the other carnivores. Language was a significant factor in rancher attitudes towards leopards (χ^2 = 7.224, df = 1, p = 0.007), with English speaking ranchers (n = 28) more positive towards leopards. However, age also influenced the attitude towards leopards (χ^2 = 8.8167, df = 3, p = 0.031), with young Afrikaans speaking ranchers (younger than 40 years) being much more positive towards leopards than older Afrikaans speaking ranchers (> 41 years) (χ^2 = 9.665, df = 1, p = 0.001, Fig. 6).

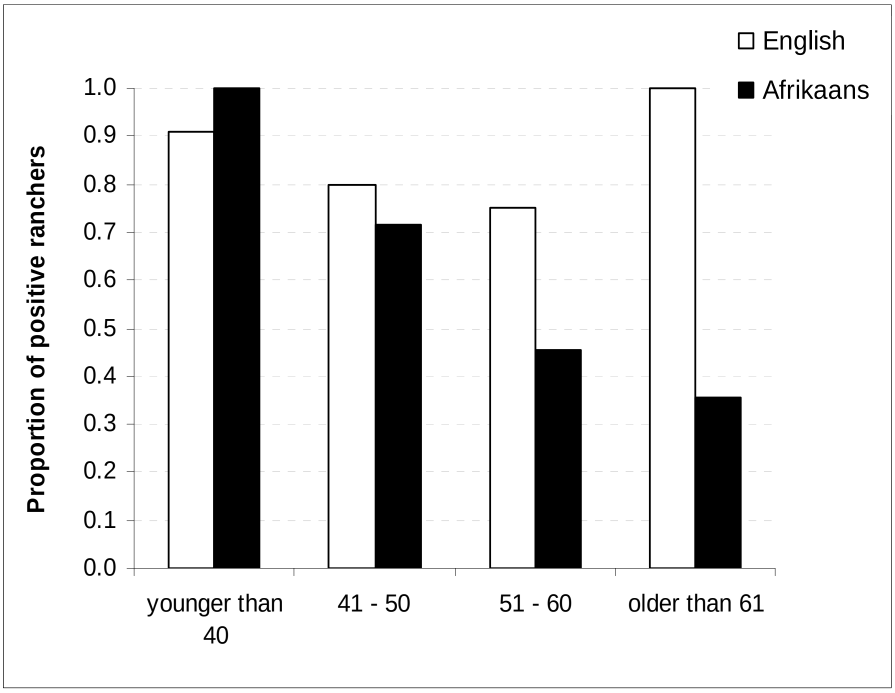

Fig. 6. The effect of rancher age and language on rancher attitude towards leopards (age data available for 70 ranchers).

Ranchers who belonged to the Waterberg Conservancy were more positive towards leopards (χ^2 = 4.804, df = 1, p = 0.0284) and other carnivores (Fig. 7). Land use also influenced attitudes (χ^2 = 12.880, df = 4, p = 0.012) (Figure 8). Ranch size, on the other hand, did not influence the attitudes of ranchers towards leopards (t = -1.00, df = 73, p = 0.318) (Kruskall Wallis test gave the same result) or the other carnivores.

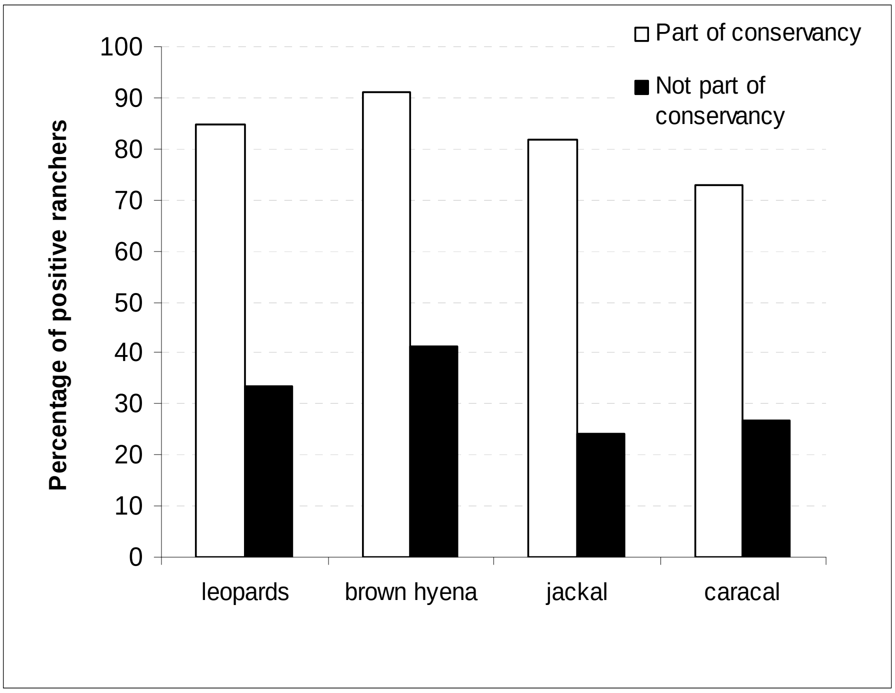

Fig. 7. The effect of belonging to the Waterberg Conservancy on the percentage of ranchers who were positive towards leopards and other carnivores (n = 75).

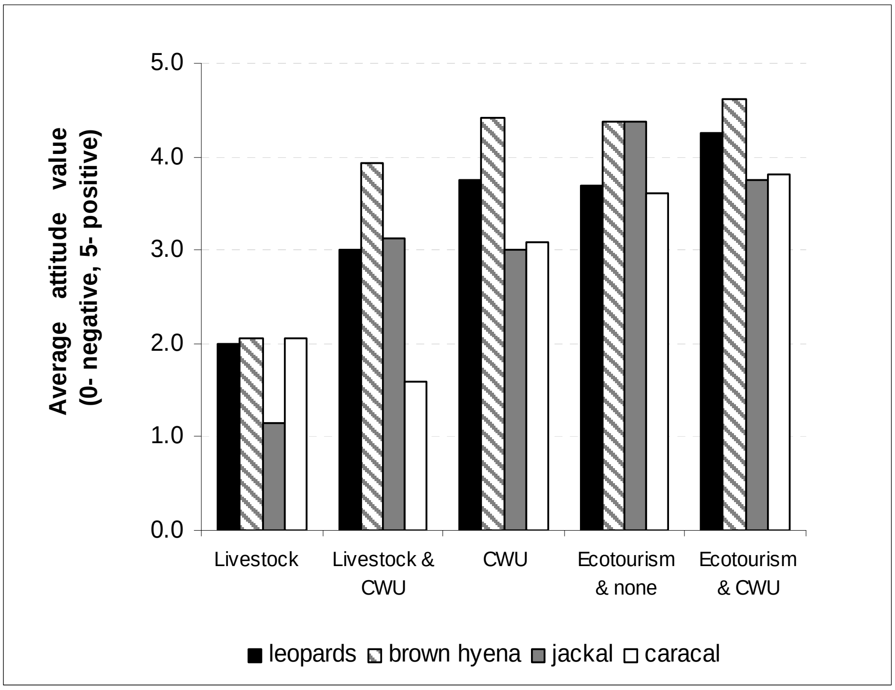

Fig. 8. The influence of different land use on the attitudes towards carnivores on ranches (data available for 19 livestock ranches, 15 livestock & CWU, 12 CWU, 13 Ecotourism & none, 16 Ecotourism & CWU).

Ranchers who frequently encountered leopard signs were also more negative towards leopards (χ^2 = 8.650, df = 3, *p* = 0.034), than ranchers who encountered leopard signs less often. Interestingly ranchers who reported a high number of leopards (actual numbers) on their ranches were more positive towards leopards (*t* =-2.876, df = 58.3, *p* = 0.006).

There was no significant relationship between rancher attitudes towards leopards and livestock/game losses, number of livestock on ranch, livestock/game density and financial losses due to leopards (Table 4). However, the number of game on a ranch had an effect on rancher attitudes towards leopards, where negative ranchers had a lower number of game on their ranches (*t* = 3.373, df = 45.307, *p* = 0.002) (Table 4).

Table 4. Analysis of the statistical relationship between livestock/game losses, livestock/game density, financial losses, livestock/game numbers and rancher attitudes towards leopards (values in bold are significant)

Ranchers with livestock	**n**	**t**	**df**	***p***	**Negative ranchers (Average)**	**Positive ranchers (Average)**
Number of livestock lost to leopards	28	0.562	26	0.579	2.79	2.14
Financial losses due to leopards (R)	31	0.978	29	0.336	5992.86	3775.00
Number of livestock per ranch	35	0.019	33	0.985	151.00	152.45
Livestock density per ranch	35	0.380	33	0.706	0.17	0.22
Livestock lost to leopards (%)	31	1.447	29	0.159	2.73	1.15
Ranchers with game						
Number of game lost to leopards	42	0.859	40	0.395	2.63	4.18
Financial losses due to leopards (R)	42	0.169	40	0.867	9699.81	8677.86
Number of game per ranch	52	3.373	45.31[a]	**0.002***	106.42	496.70
Density of game	52	1.188	50	0.240	0.19	0.62
Game lost to leopards (%)	35	0.280	33	0.781	1.03	1.26

*significant result
[a] Unequal variances assumed

Over half (50.7 %) of the ranchers indicated that leopards are presently of no value to their properties. The attitude of the ranchers towards leopards has no relationship with the fact that leopards are or are not of any value to the ranch (χ^2 = 2.476, df = 1, *p* = 0.116).

4.8 Incentives for conservation

As expected, incentives chosen by ranchers differed according to land use practices (Fig. 9). Livestock ranchers did not favour any specific incentive method, while habituation was popular with all other land use types (Fig. 9). Leopard research was also popular and ranchers felt that value would be added if leopards could be collared and tourists pay a fee to track leopards. Increased leopard hunting quotas were popular with livestock & CWU ranchers, and increased hunting quotas were more popular as an incentive to ranchers who indicated that leopards are presently of no value to their ranch.

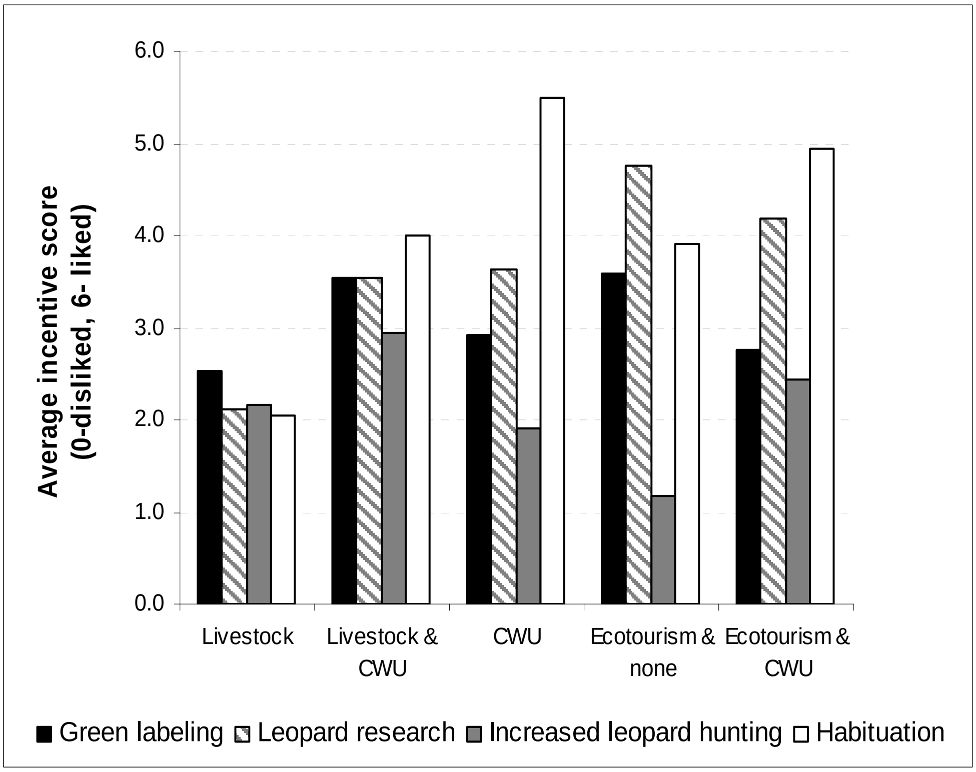

Fig. 9. The effect of ranch land use on the chosen incentive to add value to leopards on the ranch (data available for 19 livestock ranches, 15 livestock & CWU, 11 CWU, 12 Ecotourism & none, 16 Ecotourism & CWU).

Only 26.09 % of ranchers thought that game predation by leopards should be controlled, while 78.40 % of ranchers thought that livestock predation by leopards should be controlled. Improved husbandry practices were seen as one of the best methods to control problem leopards, while the hunting of problem leopards was not popular amongst ranchers. The fact that some ranchers (n = 12) indicated that the eradication of leopards is the only suitable method to control problem leopards is concerning.

Despite all the problems, 79.17% (n = 57) of ranchers still feel that leopards in the Waterberg should be conserved and would consider participating in conservation initiatives if they were asked to (61 % of ranchers) or given economic incentives (15 %), while 24 % indicated that they would never participate.

5 DISCUSSION

5.1 Attitudes and conservation

Wide ranging carnivores pose a significant challenge to conservation and management due to their large area requirements (Nowell & Jackson 1996). Our results emphasised this problem and show that a single leopard moves over a vast area and thus could impact on a large number of ranches (Figure 2). The area used by the leopards did not just consist of a matrix of different land use types, but also of a matrix of different rancher attitudes and consequent persecution probabilities. Leopards can move from an extremely positive rancher to an extreme negative rancher in a matter of minutes. Although the majority of ranchers were positive towards leopards, the actions of individual negative ranchers can have a detrimental effect on leopard numbers in the area.

Financial losses caused by wildlife are thought to contribute to the negative attitudes towards wildlife (Walpole, Goodwin & Ward 2001) and while it may be true of various wildlife species (Newmark, Manyanza, Gamassa & Sariko 1994), losses to felids are often quite low (Jackson, Wang, Lu & Chen 1994). Livestock losses reported in the questionnaires (2.0 %) were fairly similar to losses reported for leopards across Africa (Mizutani 1999; Holmern, Nyahongo & Roskaft 2007) and other big cats across the world (Oli, Taylor & Rogers 1994; Mazzolli, Graipel & Dunstone 2002; Conforti & De Azevedo 2003; Zimmermann, Walpole & Leader Williams 2005). Game losses reported by game ranchers were also low (1.19 %), and yet, despite the low livestock and game losses, negative attitudes towards leopards and other carnivores were mostly attributed to their potential impact on livestock and game (Table 3).

Statistical analysis failed to show a relationship between attitudes and economic factors (Table 4), in fact, positive game ranchers lost more game to leopards than negative ranchers. Although negative livestock ranchers lost more livestock to leopards, statistical analysis failed to show a significant relationship. Only the number of game owned by ranchers yielded a significant relationship with attitudes; where negative ranchers had a lower number of game per ranch. A small number of game is easier to monitor and losses that occur are more obvious to the rancher. In light of reasonable explanations to explain game losses, carnivores are regularly blamed for losses as a result of long standing prejudices. This scenario is exemplified by the fact that, although a low number of ranchers reported finding kills made by jackal and caracal (5.5 % & 4.1 %), these animals are still perceived as having a negative impact on game and livestock, resulting in negative rancher attitudes towards them (Table 3). This scenario can become more complex because leopards regularly scavenge (Bailey 1993). If game dies of natural causes, the associated scavenging leopard signs can be mistaken for a leopard kill.

Although game and livestock losses are low on average, individual ranchers can have substantial financial losses. In South Africa trophy animals and rare game (sable antelope, roan antelope, tssesebe, disease-free buffalo and aberrant species such as white and black springbok or red blue wildebeest) regularly fetch high prices. The record price for roan antelope in 2005 was, for example R205 000 (Anonymous 2006). If a leopard kills one of these highly priced individuals, retaliation is likely and this is one of the main reasons why carnivores are rarely tolerated on ranches (Marker *et al.* 2003). Game ranchers sometimes use predator or game proof fences to keep carnivores out (Lindsey *et al.* 2005), but only one of the ranchers in this study used predator proof fences to protect valuable game.

Impala, kudu and blue wildebeest are some of the main sport hunting species targeted by hunters in South Africa, which could explain the high abundance of these species owned by game ranchers (Bothma 2002). Impala kills accounted for the greatest number of game losses reported by ranchers, which would put leopards in direct competition with sports hunters. It is also expected that ranchers monitor savannah species (blue wildebeest, blesbok, zebra and impala) closely to set annual hunting quotas. Any change in numbers would be noticed quickly and losses could be attributed to carnivores if no other obvious reasons are apparent. Sport hunting is also becoming quite competitive in South Africa and some game ranchers have introduced exotic species (or species not native to the area) to increase the diversity of species on the ranch (Lindsey *et al.* 2005). Blesbok and red hartebeest are popular among game ranchers (Bothma 2005), and these species are more adapted to open savannah than mountainous habitat (Skinner & Smithers 1990). On fenced ranches these species can be forced to utilise sub optimal habitat, e.g. dense mountainous terrain, which would certainly favour the hunting techniques of leopards (Balme, Hunter & Slotow 2007). Under such conditions these prey species would become more vulnerable to leopard predation and ranchers could suffer high losses. In the Kruger National Park, for example, Smuts (1978) reported that a change in veld burning regime forced blue wildebeest and zebra to utilise sub optimal tall grass veld, which increased their vulnerability to lion predation and led to a subsequent decline in their numbers. Blesbok or red hartebeest living under sub optimal conditions can also suffer reproduction problems, which can lead to lower growth rates and higher mortality among young. Ranchers therefore have to buy in blesbok to supply in the hunting demand every year, which probably explains why such a high number of blesbok are killed compared with numbers owned by ranchers.

Few kudu kills were reported by ranchers; although it was found (Chapter 5) that kudu was the most important prey for leopards on ranches in the Waterberg. Kudu prefer broken, rocky terrain with enough cover (Skinner & Smithers 1990), which makes monitoring difficult. Kudu killed by leopards in the mountainous terrain would also be difficult to find and would explain the low number of kills found by ranchers. It seems that kills as reported by ranchers are biased towards game that is easily monitored, e.g. savannah species, rather than game that prefers mountainous or dense vegetation (e.g. kudu, bushbuck and klipspringer).

It seems that, although actual livestock and game losses contributed to negative attitudes towards carnivores, social factors like age and culture play an important role in shaping attitudes towards carnivores (Zimmermann *et al.* 2005). Elderly Afrikaans speaking ranchers were much more negative towards leopards and other carnivores. Bjerke, Retan & Kellert (1998) reported that attitudes towards wolves *Canis lupus* were established early in a ranchers' life and it is plausible that elderly Afrikaans speaking livestock ranchers grew up under strong anti-predator sentiments, where their negative attitudes towards leopards and other carnivores were shaped. These attitudes are almost impossible to change and a long time will lapse before they diminish. If these ranchers convert to game ranching, their negative attitudes will be transferred to the new land use. The fact that only Afrikaans speaking ranchers removed problem leopards and that the presence of cattle did not influence leopard removal, is further evidence to support this theory. On the contrarily, young Afrikaans speaking ranchers were more positive towards leopards and other carnivores indicating that new legislation and public sentiments have brought about a change in attitudes towards carnivores and management (Stadler 2005). It remains to be seen whether young Afrikaans speaking ranchers will stay positive towards carnivores in the long run.

5.2 Conservation, management and incentives

Economic benefits to ranchers living with carnivores are seen as the best method to mitigate conflict and increase tolerance towards carnivores (Lindsey *et al.* 2005). Although some ranchers indicated that leopards are of value to their ranch, only a small number attributed the value to economics. There is thus scope to increase the economic value of leopards to ranchers, and in that sense decrease negative attitudes towards leopards. Incentives that were popular among ranchers rely on leopard sightings (e.g. habituation to game drive vehicles) to increase leopard value. The feasibility to habituate free ranging leopards on game ranches to make them visible during game drive is questionable since it is a difficult task. Habituation is further complicated by the next popular incentive, namely trophy hunting. These two incentives are not compatible since the wide-ranging movement of leopards will cause a habituated leopard to move from a leopard friendly ranch to a hunting ranch where it will be an easy target to shoot (Fig. 10). The low number of permits issued reduces the effectiveness of trophy hunting as an incentive since ranchers felt that getting a hunting permit is unlikely, even with the increased CITES quotas.

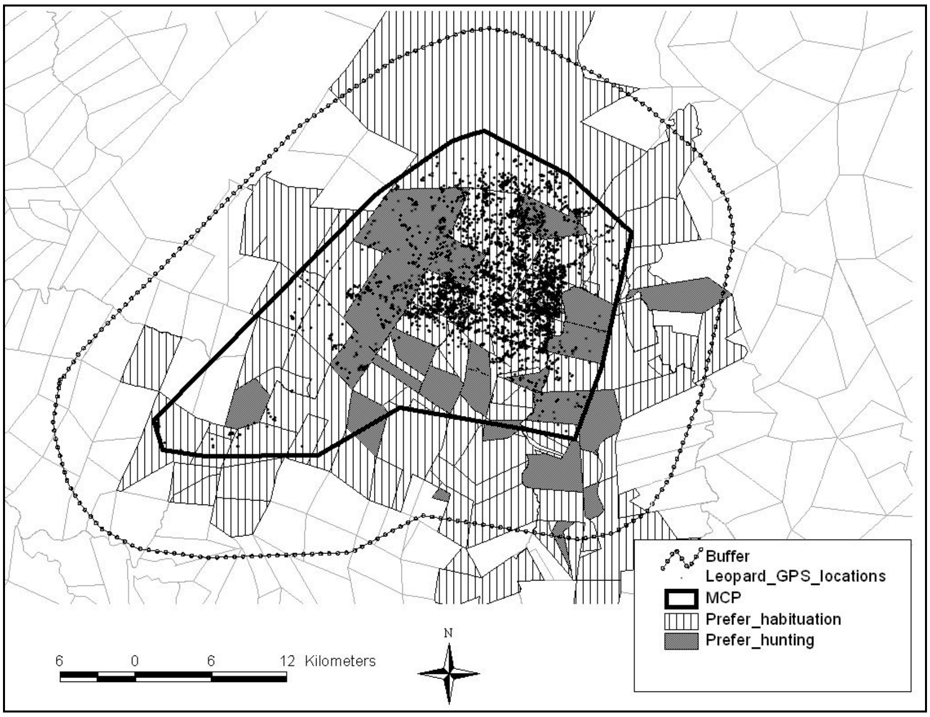

Fig. 10. Map showing ranches that would like hunting (dark grey) and habituation (vertical strips) as incentives for increasing leopard value on their properties. Black dots represent the GPS locations of 3 female and 1 male radio collared leopard, indicating that the same leopards move across both incentive methods, which would ultimately lead to conflict, showing the incompatibility of these two incentive methods on individual leopards.

The reliance on leopard sightings to increase leopard value is further demonstrated by the fact that leopard research was also a popular incentive among ranchers. Ranchers felt that if leopards could be collared, followed and then shown to tourists their financial value could be greatly increased for the ranch. The practicality of such an incentive is difficult, because radio tracking leopards in the Waterberg is extremely difficult (Grimbeek 1992), their home range encompasses a large number of ranches and the collaring of leopards for profit should not be advocated. Even though green labelling was not popular among ranchers, it is an alternative approach that would make economic benefits from carnivore conservation accessible to everyone impacted by leopards (Marker *et al.* 2003).

The formation of conservancies should be advocated (Lindsey *et al.* 2005) as conservancy members were much more positive towards leopards. It could also be easier to implement incentives such as habituation among conservancy members, while with proper research trophy hunting could also be implemented. Although a large percentage of the ranchers belonged to the Waterberg Conservancy, internal fences still remain because of conflict between landowners.

Although incentive-based conservation (Hutton & Leader-Williams 2003) is important in promoting conservation, our results indicated that financial incentives are not necessarily the most important tool for leopard conservation. Attitudes toward leopards did not differ among ranchers who felt leopards were of value or not to their ranch, which would raise doubts as to whether an increase in leopard value would increase the tolerance of all negative ranchers. Most ranchers would also consider joining conservation initiatives if they were asked to, rather than receiving an economic incentive.

The management of leopards on livestock ranches is relatively easy; various methods have been suggested to reduce livestock losses (Ogada, Oguge, Woodroffe & Frank 2003). Ranchers in this study have acknowledged the role of better husbandry practices in controlling livestock losses. Most ranchers apply some rudimentary husbandry practices but there is scope for improvement. The hunting of problem leopards is seen as an attractive method to not just control problem animals, but also to generate income to offset inflicted losses (Zimmermann *et al.* 2005). Ranchers in this study did not regard the hunting of problem leopards as an attractive method to control these leopards or generate income. The impact of a single leopard is scattered across a large number of ranches and the allocation of hunting permits to impacted ranchers is difficult.

The cost of predation on game ranches can be high (e.g. rancher with rare game) and is difficult to reduce or control. The use of predator proof fencing to keep leopards and other carnivores out of rare game breeding areas is expensive, but some ranchers have reported great success, although leopards can sometimes penetrate such fences. The erection of predator proof fences can also be detrimental to leopard ecology as it will reduce the land available for leopards, and thus increase leopard home ranges. The impact of predator proof fences on the movement of other carnivores (e.g. brown hyenas) is also not fully understood.

6 CONCLUSIONS

Although financial and animal losses attributed to leopards were low, the perceived potential threats to both game and livestock were still the primary reasons given by ranchers for negative attitudes towards leopards. The ranchers in the study area all have high living standards and it is questionable if leopards and other carnivores have a great impact on the financial sustainability of a ranch. It therefore seems that attitudes toward leopards are shaped by age, education, tradition and various other social factors, which reinforces the fact that the human dimension of wildlife conflict management must be central in carnivore conservation outside protected areas (Sillero-Zubiri & Laurenson 2001).

Although incentive-driven conservation is seen as the best method to increase tolerance among ranchers, our results indicate that no single incentive is popular, but rather that a combination of different incentives should be implemented. Alongside incentives, ranchers should be educated about mitigation methods, leopard ecology and awareness be raised about carnivore management and ecology to maintain and increase tolerance. Our results indicate that financial reasons are not the most important factor in shaping positive attitudes towards leopards, which highlights the importance of non-economic incentives in leopard conservation.

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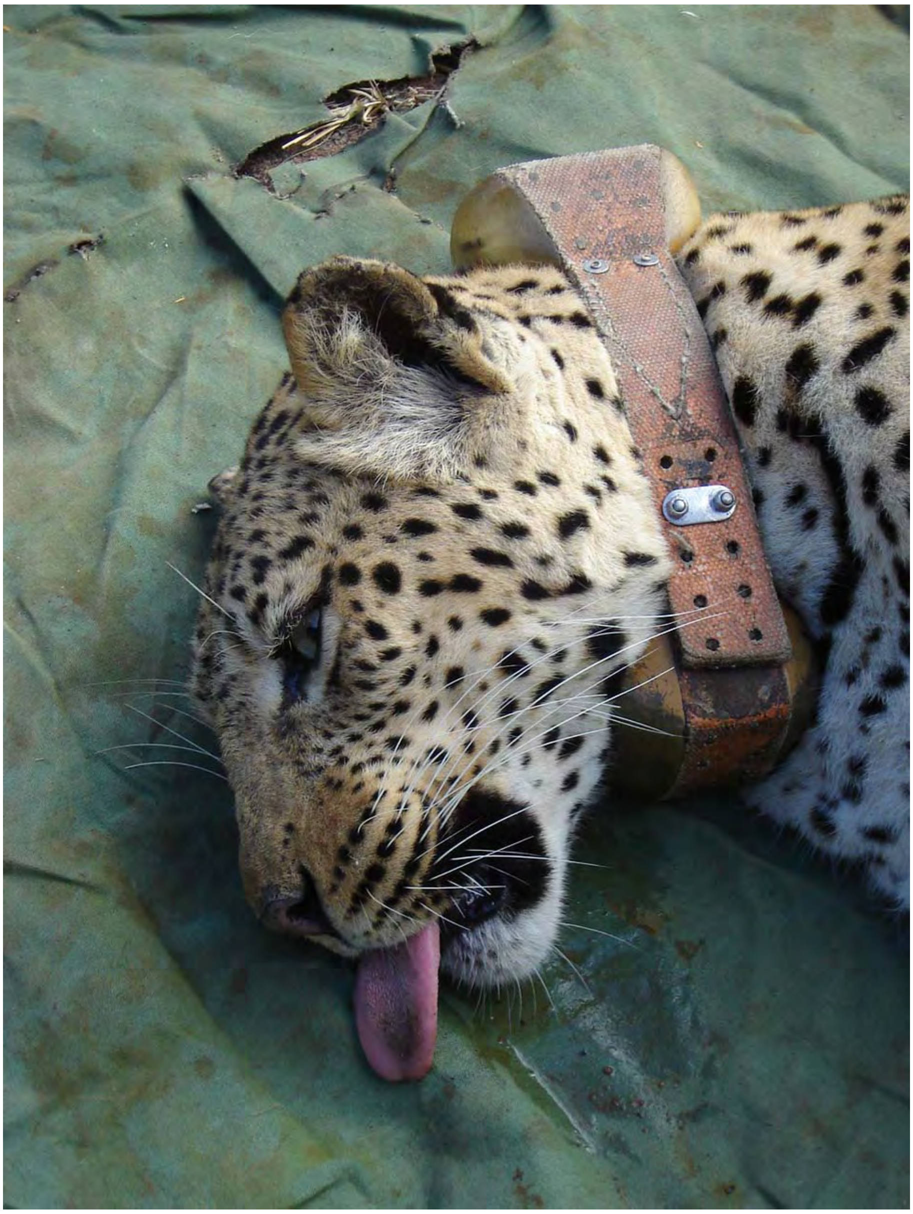
CHAPTER 7:

NOTES ON THE PERFORMANCE OF GPS/GSM COLLARS FITTED TO LEOPARDS (*PANTHERA PARDUS*) IN MOUNTAINOUS TERRAIN



NOTES ON THE PERFORMANCE OF GPS/GSM COLLARS FITTED TO LEOPARDS (*PANTHERA PARDUS*) IN MOUNTAINOUS TERRAIN

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ABSTRACT

GPS collars have the ability to gather large quantities of location data and when linked to the GSM network, data can be available quickly without tracking the animal. However due to animal behaviour, topography, vegetation and seasonality, location attempts by the GPS collar can fail or have large location errors. Fix failures do not occur at random which could lead to biased data. In this study we report on the performance of GPS/GSM collars fitted to leopards. Four leopards were collared that resulted in 6565 locations attempted. A fix failure rate of 18% was observed, and ranged from 15 % to 29 %. Single failed attempts (one fix missed) accounted for the majority of failed attempts. Fix failure rates peak during mid day and fix failure rates were higher for the wet season than the dry season. Distances moved during failed attempts were short (median 868 m) indicating that leopards did not relocate during location failures. No data was available from the collars to investigate precision of GPS locations. We were satisfied with the volume and quality of data, however significant money can be lost when collars fail and can't be retrieved.

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1 INTRODUCTION

Global positioning system (GPS) collars has the ability to store large amounts of data compared to VHF radio telemetry or satellite based systems (Gau, Mulders, Ciarniello, Heard, Chetkiewicz, Boyce, Munro, Stenhouse, Chruszcz, Gibeau, Milakovic & Parker 2004). Commercial GPS receivers are incorporated into the collars, which measure GPS ground locations by using the United States military Global Navstar constellation of satellites that orbits the earth (at about 20 000 km) (Douglas-Hamilton 1998). A minimum of 4 satellites is needed for a three dimensional (3 D) triangulation and on average location error is between 30 - 40 m (Douglas-Hamilton 1998). Two types of error are inherently associated with GPS collars, namely spatial inaccuracy and missing data from failed location attempts (Frair, Nielsen, Merrill, Lele, Boyce, Munro, Stenhouse & Beyer 2004). Location error has been drastically improved (average 15 m) since deactivation of selective availability (SA) by the US military in 2000 (Adrados, Girard, Gendner & Janeau 2002; Fielitz 2003). Researchers have used dilution of precision (DOP) and two dimensional (2D) *vs* 3D fixes as parameters to screen raw GPS location data for location error (D'eon & Delparte 2005). Although differential GPS collars still provide much higher location accuracy than non differential GPS collars, increased costs still favour the use of non differential GPS collars (Adrados *et al.* 2002).

Since GPS collars rely on satellites orbiting the earth to estimate ground locations, factors that obstruct the view of the sky in any way can potentially influence GPS performance. Factors like animal activity (Ron, Pastor, Cohen & Schwartz 1996; Moen, Pastor & Cohen 2001), sampling interval (Moen *et al.* 2001), vegetation (Rempel, Rodgers & Abraham 1995), area topography (Gau *et al.* 2004; Cain, Krausman, Jansen & Morgart 2005) and collar orientation (D'eon & Delparte 2005) can all influence location accuracy and fix rate. Most studies that report on GPS collar performance are in boreal forests (Rempel *et al.* 1995; Janeau, Adrados, Joachim, Gendner & Pépin 2004) and generally GPS performance decreases under tall trees, with increased canopy cover, tree density and basal area (Janeau *et al.* 2004). Increased fix interval (short time between locations) has a positive effect on GPS location success (Moen *et al.* 2001; Janeau *et al.* 2004). GPS collar failure to acquire location does not occur at random but systematically, which is likely to result in bias (Frair *et al.* 2004). Simulation experiments for example have shown that type II errors (failure to detect significant selection) increases with GPS location error that led to incorrect conclusions of avoidance *vs* selection in habitat selection studies

(Frair *et al.* 2004). Missing data therefore remains as one of the biggest potential sources of error and bias in GPS telemetry (D'eon & Delparte 2005). Researchers should be aware of these factors in order to account for and rectify biases it may cause (Frair *et al.* 2004; Janeau *et al.* 2004).

Three methods exist to collect data from GPS collars. The first and the simplest method are to create a store on board the GPS unit where the collar accumulates GPS locations, but has no means to download data. These collars have to be manually recovered from the animals. Recently, drop off mechanisms have been developed that allows researchers to drop collars on demand or after a specific number of days (Merrill, Adams, Nelson & David Mech 1999). Data from GPS collars can also be downloaded by using a VHF modem that communicates with the collar (Fielitz 2003). Advances in technology have allowed data from GPS collars to be downloaded via satellite (Argos system) or by using a cellular GSM (Global System for Mobile Communication) network (Fielitz 2003). The GSM network allows for the downloading of GPS location data on an almost real-time basis depending on the GSM network coverage in the area.

In this study we report on the performance of GPS/GSM collars fitted to leopards in the Waterberg, Limpopo, South Africa. We report on the number of locations attempted, fix rate, fix failure rate and time of day when location failures occurred.

2 STUDY AREA

This study was conducted on private properties (game, livestock and ecotourism) in the Waterberg Mountains, Limpopo, South Africa (Fig. 1). Topographic features include rugged mountain slopes, steep sided riverine areas, flat plateau and valley bottoms. Vegetation is classified as Waterberg mountain Bushveld (Mucina & Rutherford 2006). On steep slopes (10 – 40°) the vegetation is characterised by *Diplorhynchus condylocarpon* savanna while on flat areas with a gradient of less than 10° vegetation is characterised by *Terminalia sericea* savanna (Tuinder 1991). Old agricultural fields are normally characterised by *Terminalia sericea* which occurs as short open woodland while grass species like *Cynodon dactylon* and *Acanthospermum glabrum* are found on the open grass veld areas (Tuinder 1991). Valley bottoms have deep soils where tall trees such as *Faurea saligna* and *Syzygium cordatum* dominate the tree layer. Vegetation structure (based on Edwards (1983)) on the mountain slopes range from short closed woodland to low thickets

(Tuinder 1991). Slope vegetation is short (1 – 5 m) and occurs in dense stands with a mean crown to gap ratio between 0 and 2 m (Tuinder 1991). On flat areas vegetation structure ranges from short open woodland to low open woodland where vegetation is taller (2 – 10 m) and fairly open with a mean crown to gap ratio of 2 – 8.5 m (Tuinder 1991).

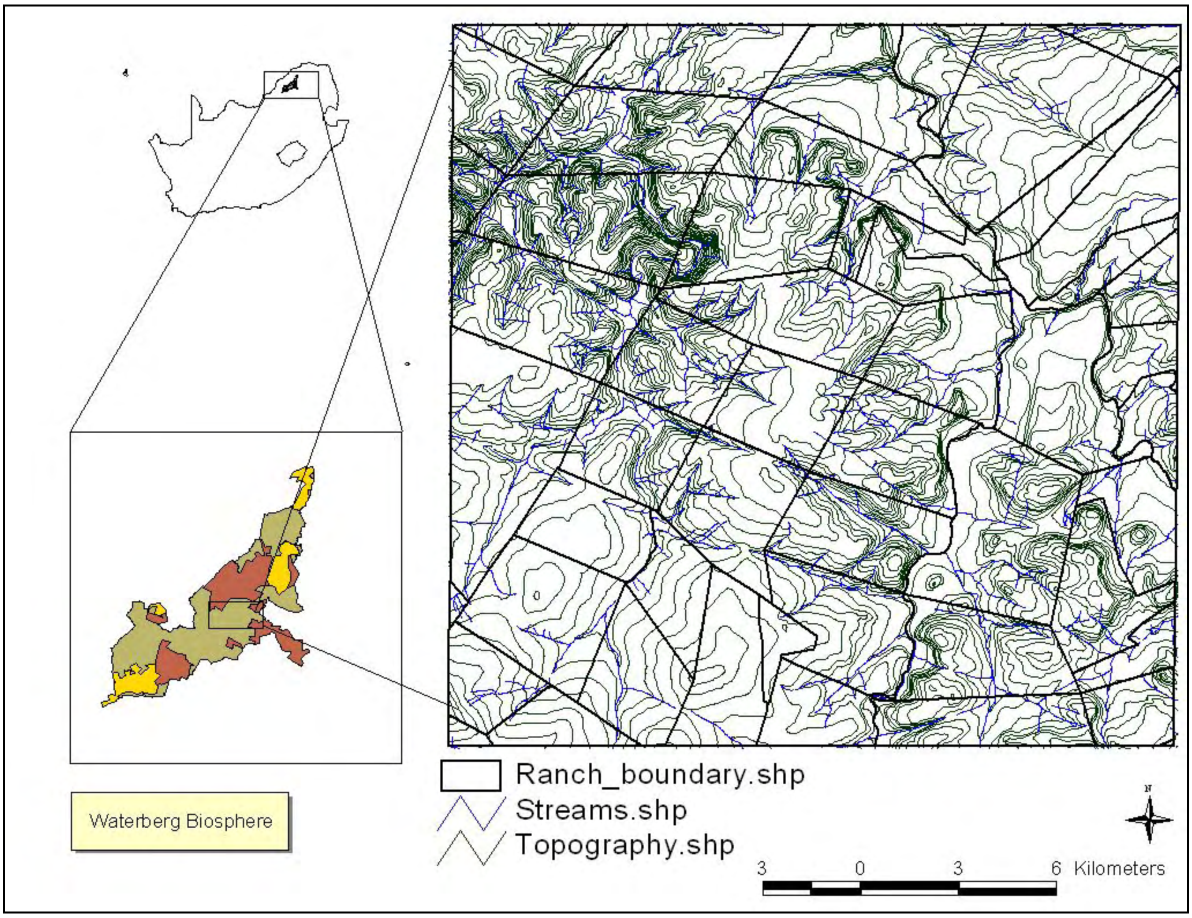

Fig. 1: Study area showing ranch boundaries and topography of the area.

3 METHODS

3.1 Capture of leopards

Leopards were captured using baited cage-traps with drop-door mechanisms fitted with safety pins to prevent leopards opening trap doors once closed (de Wet 1993). Leopards were immobilised by a wildlife veterinarian with a mixture of tiletamie HCL and zollazapam HCL (Zoletil; Virbac Animal Health, Halfway House, South Africa), administrated by a jab stick at a dose of 4 - 5 mg/kg of estimated live weight. Drugged cats were placed back into trap cages and were left in shade until leopards fully recovered and were released at the capture site. We conducted the research under University of Pretoria Animal Use and Care Committee ethics clearance protocol A022-06 and Limpopo leopard capture permit number CPM-004-00006.

3.2 Data collection

Leopards were fitted with GPS/GSM collars from African Wildlife Tracking (http://www.awt.co.za). Collars weighed 650 g which was between 1.5 – 2 % of the body weight of leopards. Collars were set to record a GPS location every 5 hours and send the location data via the GSM network to a website (http://www.yrless.co.za). GPS locations were stored on non-volatile memory onboard the collar when no GSM network coverage was available to transmit the acquired GPS locations. Stored GPS location data was transmitted whenever the collared animal entered an area with GSM coverage. Collar GPS units were set to search for a maximum of 180 seconds to acquire a minimum of 3 satellites needed to get a GPS location. GPS location data were downloaded from the internet every morning during the study. Data supplied included date, time, GPS location, direction of movement, speed, GSM coverage and temperature of collar. Latitude and longitude positions were converted to UTM format compatible with ArcMap (ESRI Redlands, CA) by using the WGS84 35S datum. Hawth's tools (Beyer 2004) were used to calculate distances travelled between GPS locations.

4 RESULTS

One male and three female leopards were fitted with GPS/GSM collars. Two collars delivered over 2000 GPS locations while the remaining two collars unexpectedly stopped functioning after 181 and 57 days respectively (Table 1). It is not known if these two leopards were destroyed by ranchers or if the collars failed. The overall (all collars) GPS location fix failure rate was 18.83 % and ranged from 15 % to 29 % (Table 1). Maximum numbers of consecutive location attempt failures were 17 for male AS29, 37 for female AS37, 29 for female AS57 and 5 for female AS29. Location data could be downloaded from the web on almost a daily basis. The longest period GPS points could not be downloaded was 7 days.

Single GPS fix failures accounted for most of the failed GPS attempts (59.24 % of all failed fixes); followed by two consecutive failed fixes (19 %), three fixes (8.05 %), and four (3.50 %) while more than 4 consecutive failed fixes accounted for 10.21 %.

Single and double failed GPS attempts were similar for all four leopards, while four consecutive failed GPS fixes and higher were more prevalent with female AS57 and AS37 (Fig.2).

Table 1: Summary of GPS collar performance and number of days leopards were tracked

Leopard collar	Nr. fixes attempted	Nr. fixes failed	Nr. locations fixed	Fix failure rate (%)*	Tracking days
Male:AS9	2793	526	2267	18.83	582
Female:AS57	2628	413	2215	15.72	548
Female:AS37	874	255	619	29.18	181
Female:AS29	270	42	228	15.56	57
Total	6565	1236	5329	18.83	

*Nr of fixes failed/Nr. of fixes attempted

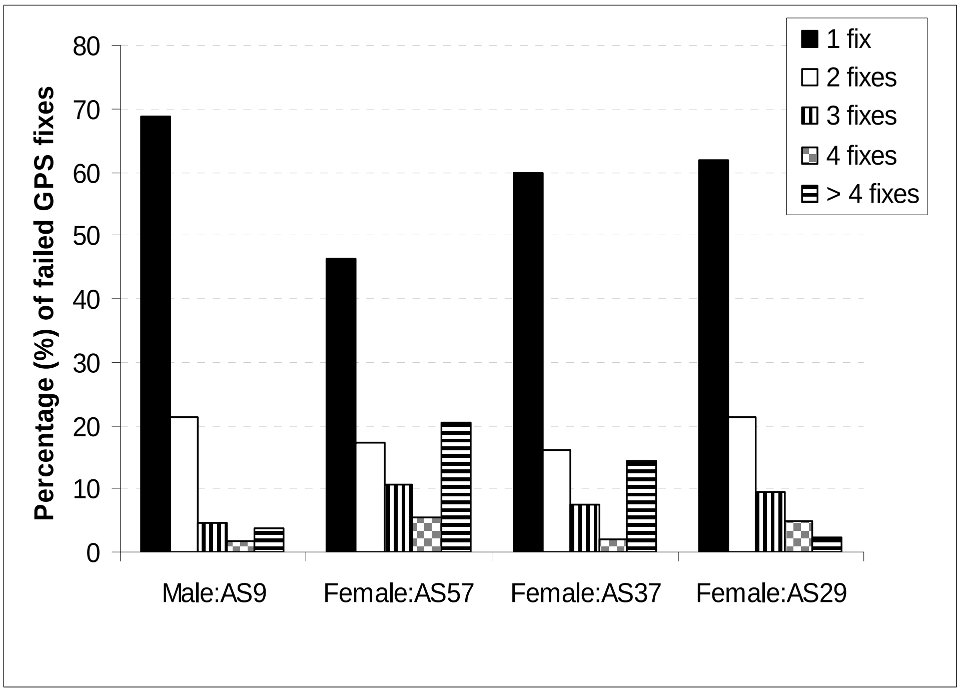

Fig. 2: A breakdown of percentage failed GPS fixes for each leopard.

GPS location attempt failures did not occur at random but there was a definite peak in GPS fix failures from mid day to late after noon for all leopards (Fig. 3). Female leopards also show a slight peak at around midnight while fix failures for the male were quite low throughout the night (Fig. 3). Time elapsed since previous successful GPS location showed a similar trend and generally in the afternoons a long time elapsed since the previous successful GPS location (Fig. 3). Female leopards also showed a slight peak in time elapsed since previous successful location at around midnight.

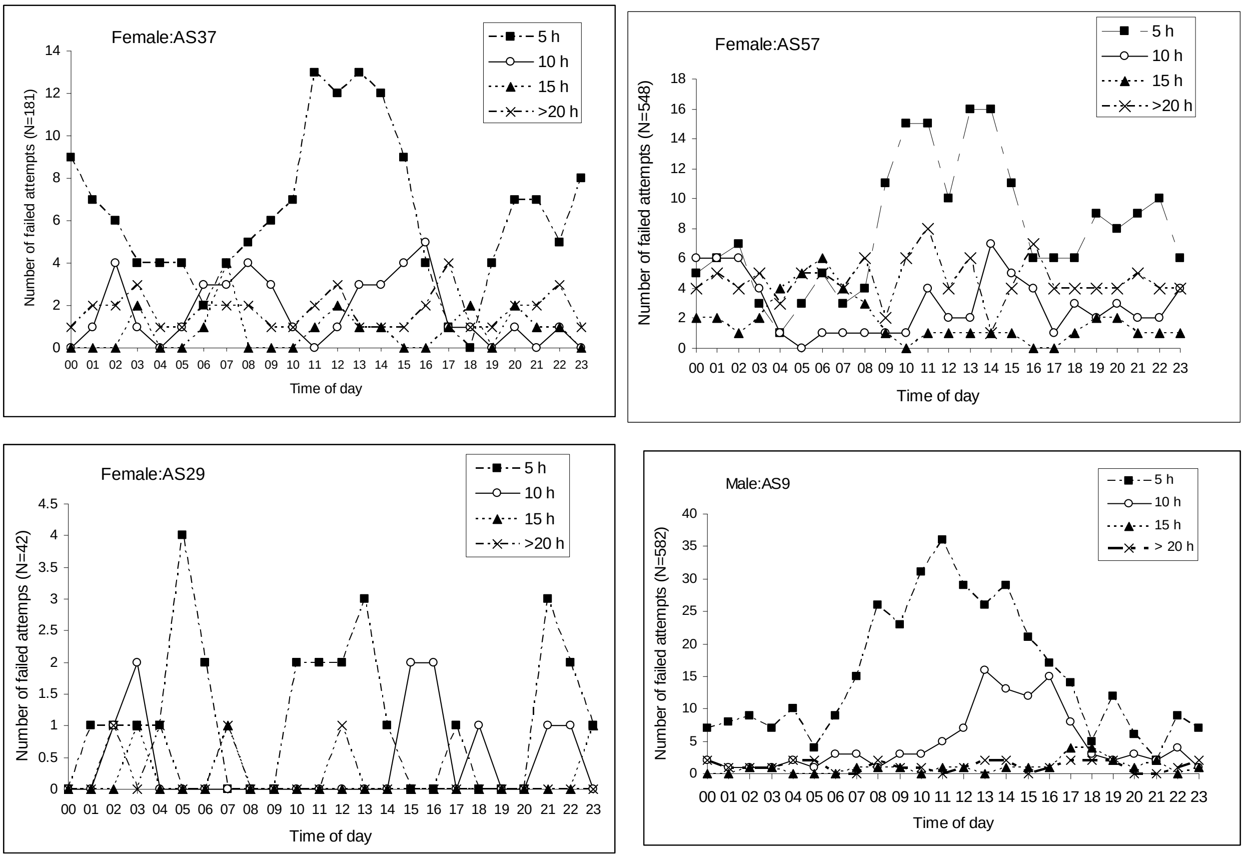

Fig. 3: Number of failed GPS fixes plotted against time of day, and time elapsed since previous successful GPS location.

Seasonality also appears to influence collar performance and higher GPS location failure rates were observed in the wet season for female leopards, although it appears that the effect is negligible for the male leopard (Fig. 4). Monthly GPS location fix failure rate were close to constant for the male leopard (Fig. 5), while rates peaked around November to January for the female leopards (Fig. 5).

Distance travelled between a previous successful GPS location and the next successful location, after failed attempts, can give valuable insight on how far the animal moved during failed attempts. Calculated displacement distances between previous successful GPS locations and the next GPS location did not show a normal distribution (P-P plots) and median values rather than means were used. Distances travelled after a 5 h delay since a previous location (1 missed fix) were short (Table 2) while distances increased with increased missed locations although the median distance of 868.62 m for all missed locations was still low. The male leopard travelled greater distances during location misses than female leopards (Table 2). Collars did not provide data on dilution of precision (DOP) of locations or if locations were 2D or 3D and therefore precision of locations could not be analysed.

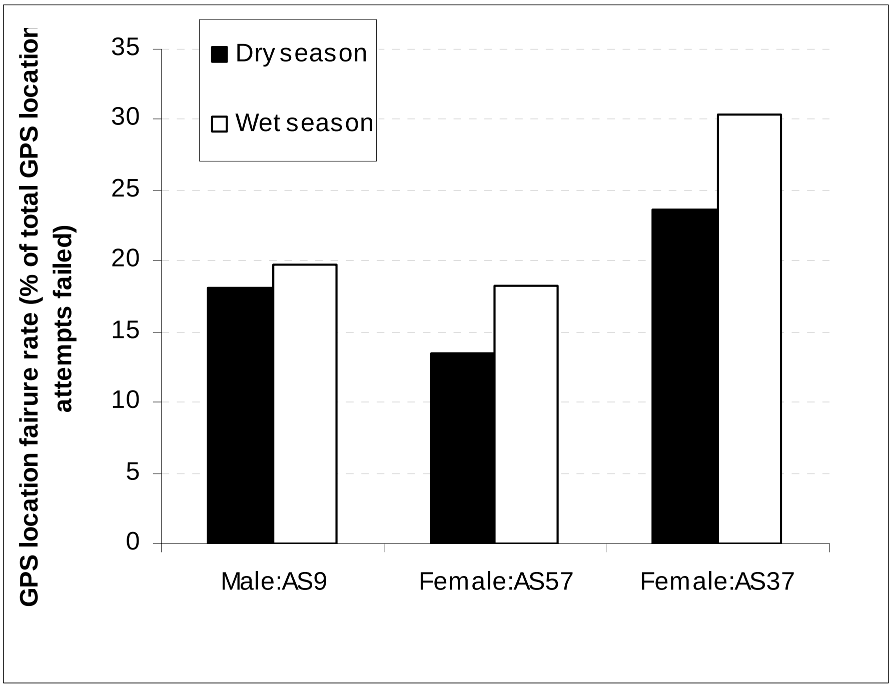

Fig. 4: The effect of season on GPS location failure rates for GPS collars fitted to female and male leopards in the Waterberg, Limpopo.

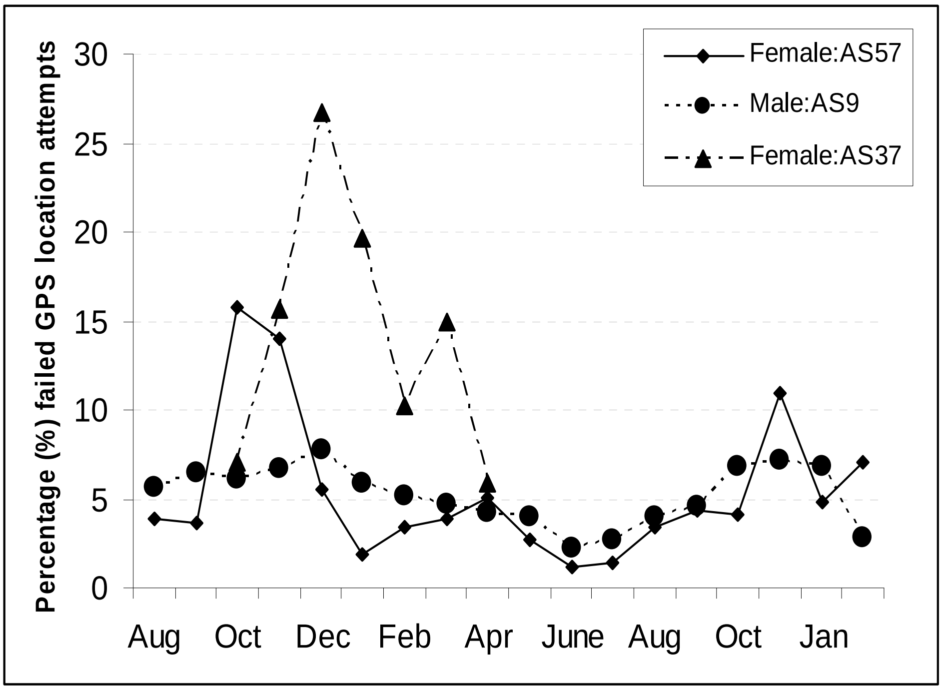

Fig. 5: Monthly GPS location attempt failure rate (%) for one male and two female leopards fitted with GPS collars (Only 7 months of data for available for AS37).

Table 2: Median (in meters) distances travelled by different leopards during failed GPS location attempts. Distance measured between previous successful GPS location and first successful GPS location after GPS failed attempts

	1 failed fix	2 failed fixes	3 failed fixes	4 failed fixes	>4 failed fixes
Male:AS9	615.88	1343.57	2109.94	3436.39	4657.07
Female:AS57	377.15	271.10	868.29	968.22	1458.70
Female:AS37	612.23	674.37	926.31	82.11	7860.17
Female:AS29	183.18	351.53	835.25	19.68	2140.73

5 DISCUSSION

GPS/GSM collars preformed well and missing GPS locations accounted for 18 % of locations attempts, however the premature failure of two collars is a reason for concern. Collar failure could not be attributed to technical problems or killing of the leopards by ranchers. GSP fix failure rates (15 % - 29 %) reported here were either lower or higher than what was reported in other studies. Gau *et al*. (2004) reported fix failure rates ranging between 22 % to 45 % for GPS collars fitted to bears in

Canada, while fix failure rates between 7.4 % and 27 % were reported by Janeau *et al*. (2004) for collars fitted to red deer in France. In Kruger National Park Rahimi & Owen-Smith (2007) reported a fix failure rate of only 3 % for sable antelope fitted with same brand of collar as in this study. Higher fix failure rates reported by this study can be explained by the topography of the study area. The rugged terrain and steep narrow valleys limited the view of the GPS collars to the GPS satellites that will result in lower GPS location acquisition. Overall fix failure rates are much lower than the first GPS collars where fix failure rates were very high (45 % to 68 %) (Obbard, Pond & Perera 1995), showing much improvement in GPS technology for wildlife telemetry.

Single GPS failed fixes accounted for the majority of missed fixes, indicating that most fix failures can be attributed to temporary interference with the GPS collar's view to GPS satellites. Animal activity plays a significant part in GPS collar fix failures (D'eon & Delparte 2005) and the view to sky can be obstructed if the animal lies down. For example bears (*Ursus* spp.) that dig while foraging will have a different fix rate than non foraging bears (Obbard *et al.* 1995). Resting leopards may cause interference with the collars' ability to take a GPS fix, resulting in single fix misses rather than multiple fix failures.

More than 4 failed fixes were more prevalent in the two females. Analysis of displacement distances between GPS locations, after failed fixes, can help to explain this phenomenon. Female leopards did not move far during the failed fix attempts, except where more than 4 failed fixes occurred. This indicates that for female leopards the majority of fix failure occurs in an area where the view to the GPS satellites is obstructed, while the female stayed relatively stationary in space. The most likely scenario that fits this description is when a female gives birth or has young that she hides. Leopards in mountainous terrain often hide their young in caves or crevasses when they are born or when she is hunting (Smith 1987). When a female returns from a hunt she will stay with her young until the next hunt. If she is in a cave all GPS fixes will probably fail resulting in a high number of consecutive failed fixes. When the female leaves the cave she will then move a great distance to hunt, resulting in a high displacement distance. Long displacement distances will thus be prevalent after a long fix failure, while fix failure will be common during the time she is with the young, e.g. during the day. Female AS57 gave birth during this study period and this scenario can be observed in her fix failures and distances moved (Fig. 2). Similar patterns were observed for female AS37 but it was uncertain if she had cubs, while the pattern for female AS29 was more erratic.

The fix failure bias for day-time locations can be explained by leopard behaviour and the terrain. During the day leopards use day-time resting sites (Skinner & Smithers 1990) and in the Waterberg these are normally on the ridges of mountains (Grimbeek 1992). Activity of male and female leopards in the Waterberg comes to a standstill from early morning to late afternoon (Grimbeek 1992), and combined with the topography of resting sites a peak in GPS fix failures will be expected during the daytime for all leopards, as was found in this study (Fig. 2). The slight peaks in fix failures around midnight for female leopards can be explained by hunting activity. Activity of female leopards peaks around midnight and is thought to be hunting related (Grimbeek 1992). During hunting leopards will use dense vegetation cover to approach potential prey (Bailey 1993). Vegetation cover can influence GPS fix negatively, where dense vegetation will result in a higher fix failure rate (Janeau *et al.* 2004). It is plausible that dense vegetation used by female leopards to hunt during the night negatively interferes with the GPS collar resulting in higher fix failures. Leopards will also drag their prey to cover where they will feed, which can also increase GPS fix failure rate that will result in a higher fix failure rate around midnight. The overall lower fix failure rate for the male leopard can be explained by the fact that male leopards cover large distances during the night (Grimbeek 1992). Male leopards also frequently travel along vehicle roads (Grimbeek 1992, Bailey 1993) where vegetation density will be lower, which will be advantageous to a higher fix rate.

The seasonal influence on GPS fix failure was more apparent for the female leopards than the male leopard. During the wet season vegetation would be denser (more leaves), which would increase GPS fix failure rates (Janeau *et al.* 2004) since denser leaf cover negatively influences GPS performance (Rempel *et al.* 1995). The fact that male leopards move greater distances than female leopards appears to counter this effect.

The deletion of 2D fixes to increase GPS location precision should de done with care or rather be avoided (D'Eon, Serrouya, Smith & Kochanny 2002; D'eon & Delparte 2005). DOP seems to be a better method to screen for data with large location errors and normally leads to expectable data loss (D'eon & Delparte 2005). GPS location error for this study could not be determined and should be addressed in future studies.

6 CONCLUSIONS

The GPS/GSM collar system proved to be reliable in delivering GPS data on almost a daily basis. GPS fix failure rates were within the expected range, while single missed fixes accounted for most failed fixes. As expected, leopard behaviour and topography of the study area influenced fix failure rates. Higher fix failure rates were observed during midday when leopards were at their day-time resting places than during night-time when leopards were active. Activity of leopards also influenced GPS fix failure rate with the more the active and wide ranging male having a lower GPS fix failure rate during the night, while female leopards' apparent denning behaviour resulted in a higher number of consecutive failed fixes. The increased leaf mass during the wet season resulted in a higher fix failure rate, although this trend was smaller for the male leopard. The non-random manner in which fix failures occurred can lead to bias when data is used for habitat or resource selection studies. Frair *et al.* (2004) suggested that sample weighing would be the best method to reduce bias in wide roaming animals or when location schedules are infrequent while iterative simulation would be more applicable for studies that temporally constrain availability. In movement studies distances between missing data should be deleted to avoid overestimating distances moved between locations (Merrill & David Mech 2003). However, when long sequences of missing data occur, no method will be able to reduce bias and simulation of data should not be attempted (Frair *et al.* 2004). Researchers using GPS collars should be aware of bias that can occur with GPS collars and what methods can be used to reduce bias.

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CHAPTER 8:

MANAGEMENT RECOMMENDATIONS

1 INTRODUCTION

Availability of space for leopards and other carnivores in South Africa has been reduced due to the expansion of agriculture and increased human density. Unfortunately, this trend is set to continue and the increase in human population is one of main threats in the survival of carnivores (Woodroffe 2001). Historically protected areas were seen as the most important areas for the conservation of animals, including carnivores. Recently however, private protected areas world wide are seen as important partners in reaching conservation targets (Mitchell 2005). In South Africa livestock ranching in marginal areas is gradually being replaced by game ranching (Jones, Stolton & Dudley 2005), which has lead to a rapid increase in the number of game ranches in the last few years (Van der Waal & Dekker 2000). In the Waterberg there are an estimated 1240 exempted game ranches (De Klerk 2003). Although, strictly speaking, game ranchers are not motivated by conservation and thus can't be labelled as private protected areas (Geist 1985; Jones *et al.* 2005), their role in the conservation of wildlife is being promoted (Marker, Macdonald & Mills 2003; Lindsey, Du Toit & Mills 2005). As an estimated 92 % of potential leopard range in Africa is found on private land (Boitani, Corsi, De Biase, Carranza, Ravagli, Reggiani, Sinibaldi & Trapanese 1999), engaging in such partnerships seems not just beneficial to leopards, but also other carnivore species.

Game ranches are normally well stocked with game (Van der Waal & Dekker 2000) which are preyed on by leopards, making them ideal leopard habitat. However, this predatory behaviour of leopards has landed them a bad name among game ranchers and leopards are rarely tolerated on these properties (Hunter & Balme 2004). While game ranching has gained popularity in the Waterberg, a large number of ranchers still keep livestock. Leopards preying on livestock is one of the most important contributors to leopard mortality in Africa (Ogada, Oguge, Woodroffe & Frank 2003) and South Africa (Esterhuizen & Norton 1984). Even though the predation of carnivores on game and livestock is a major component of anti predator sentiments (Treves & Karanth 2003), social and cultural factors also play a role (Zimmermann, Walpole & Leader Williams 2005). Finding solutions to reduce this rancher-leopard conflict should stand central in leopard conservation on private land.

Our coexistence with carnivores will depend largely on the availability of space, our tolerance of sharing this space, and our desire and inclination to extract advantage or enjoyment directly or indirectly from sharing space with these animals (Johnson, Eizirik & Lento 2001). For leopards, space seems not be a problem and game ranches cover an estimated 13.3 % of agricultural land in 2002 (Bothma 2002), while leopards can still survive on other human altered land (Nowell & Jackson 1996). Increasing tolerance among ranchers towards leopards seems to be the greatest challenge. Management of leopards on private land should therefore address tools and techniques to reduce conflict and increase tolerance among local ranchers.

2 CONFLICT BETWEEN RANCHERS AND LEOPARDS

2.1 Determinants of conflict and attitudes

Results from this study indicated that the killing of livestock and game was the most common reason given for negative attitudes towards leopards. The results found here are not unique to leopards, but consistent with results from other carnivore conflict studies across the globe (Naughton-Treves, Grossberg & Treves 2003; Kaczensky, Gossow & Blazic 2004; Zimmermann *et al.* 2005; Bagchi 2006). Unfortunately such negative attitudes, even by only a limited number of ranchers, almost always leads to the destruction of the carnivore, as found in this study and elsewhere (Marker *et al.* 2003). With the large home ranges of leopards in this study the actions of individual ranchers can have a detrimental effect on the population ecology of leopards in the area. Unless such negative attitudes are changed, conflict will always be present that can impact negatively on leopard survival on private land.

While actual numbers of game and livestock killed can be low, ranchers regularly act on perceived losses. For example, one respondent during this study reported that a leopard killed 100 blesbok in one week, this leopard was subsequently destroyed. Livestock and game losses reported by ranchers in this study were also low (1.19 % & 2.0 %, respectively). It is thus suggested that perceptions and negative attitudes towards carnivores are more influenced by social and cultural factors than financial factors (Bjerke, Retan & Kellert 1998; Naughton-Treves *et al.* 2003; Skogen & Krange 2003). Some ranchers in the Waterberg grew up under strong anti-predator sentiments, which are still evident today. Changing such negative attitudes is difficult, and if the owner changes land use, such attitudes are just transferred to the new land use (e.g. changes from livestock to game ranch).

2.2 Conflict resolution

2.2.1 Education of ranchers, managers and labourers

Education is seen as one of major components to address the negative attitudes of people towards carnivores (Morgan, Davis, Ford & Laney 2004). However, providing factual information about a specific carnivore with the hopes of fostering a positive attitude has proved unsuccessful in the past (Kellert, Black, Rush & Bath 1996). Education should therefore be site specific and directed towards the specific problems ranchers encounter in the Waterberg. Ranchers should also be provided with practical content, rather than ecological and value information (Kellert *et al.* 1996).

Attitudes of people towards carnivores are also established early in life (Bjerke *et al.* 1998) and as such education programmes should also be directed towards school children (Bailey 1993). Education programmes should emphasise the ecological indicator value of predators in ecosystems. Such programmes should also stress that people and carnivores can coexist, without decimating ungulate prey or livestock (Bailey 1993).

Education programmes should also be directed towards ranch managers, labourers, professional hunters and field guides. It is essential that managers and labourers correctly identify the tracks and killing methods of various carnivores present on ranches to correctly identify problem animals. During the questionnaire survey it also became clear that ranchers did not understand or know anything about predator control legislation in South Africa, or how trade in leopards is regulated by government and CITES. These aspects should also be addressed in education programmes.

2.2.2 Ranch management practices

a Ranches with livestock

Leopards in the Waterberg only prey on livestock less than 3 months old (Grimbeek 1992). This suggests that depredation can be limited if calves (< 3 months) are kept away from areas with a high predation risk. Indeed livestock ranchers in this study all knew that calving cows have to be removed from the mountainous areas on their ranch to limit predation. Similar results were found for bob cats preying on cattle in the USA (Ackerman, Lindzey & Hemker 1984). The problem arises when ranches are small and don't have non-mountainous areas where cows can calf. These ranchers are forced to keep cows in high predation risk areas, which ultimately leads to predation. This scenario can be overcome by using other husbandry techniques such as constructing calving kraals with electric fencing (Grimbeek 1992; Ogada *et al.* 2003). This technique is expensive and rarely used by ranchers.

Another solution could be to use indigenous cattle breeds with horns that have better maternal instincts than exotic breeds. Ranchers in the study area using indigenous breeds mention that these cows don't hide their calves during birth, which make easy prey for leopards, and will furiously protect their calves against leopards.

It is also essential that livestock ranches have adequate natural prey that can act as a buffer against livestock predation (Martins & Martins 2006). A number of studies have shown that livestock predation by carnivores are at its highest where natural prey are at low densities (Mishra 1997; Vos 2000; Woodroffe & Frank 2005). Evidence therefore suggests that carnivore predation on livestock increases as natural prey densities decreases, either seasonally (e.g. wet season *or* dry season) (Stoddart, Griffiths & Knowlton 2001) or if natural prey are decimated through intensification of livestock farming (Mishra 1997). Livestock farmers in this study indicated that the highest number of livestock losses (75 %) occurred during the wet season (when cattle calves were born), compared to the dry season when calves were already 4 months old. This agrees with other studies where livestock predation reached a peak during the wet season (Kolowski & Holekamp 2006). Efforts directed towards livestock protection should therefore be intensified during these periods.

While poaching of game was reported to be low in the study area, some farm labourers still supplement their diet with protein from game. In this respect it is important that ranchers supplement labourers' protein ration to prevent hunting pressure on game.

Stock raiding by predators can also be controlled by using livestock guarding animals such as Anatolian dogs, Alpacas, Donkeys and even herds men (Smuts 2008).

b Game ranches

The loss of game to leopards is almost impossible to control or prevent. However advances in fencing techniques have allowed for the development of predator (leopard) proof fences (Du Plessis & Smit 1999). With the cost of fencing material high, such fences are not a reality yet, but in the future they will be used more. These leopard proof fences will keep leopards out of some ranches, while it will keep leopards inside others. Effectively leopards are one of the last species roaming ''free'' and with the advent of leopard proof fences the last of the truly wild free-roaming carnivores will also be conquered. The effect of these predator proof fences is not known, but effectively it will increase home range sizes for all free roaming carnivores on ranch land, while it will reduce the size of leopards living inside predator proof ranches.

A more realistic outlook would be to limit the impact of leopards on ranches. Numerical impact of leopards on game numbers would be highest on small properties with low numbers of game. This suggests that small game ranches should be consolidated into bigger conservancies for better ecological management (Bothma 2002). Only indigenous species should be stocked on game ranches to prevent poor performance, which could lead to low reproductive rates (Bothma 2005). Exotic species may also be naïve to carnivores of the area, which can lead to higher predation rates. The habitat requirement of stocked game should also be taken into consideration. Stocking impala, for example, on a ranch with only mountains would increase its vulnerability to leopards as it is more a woodland species. Ranchers breeding with rare game should properly protect their investment against leopards. Rare game are normally kept in predator proof enclosures (Lindsey *et al.* 2005) and this should be standard procedure where leopards occur.

2.2.3 Removal of problem leopards

a Problem leopards

The description of problem carnivores is still a matter of controversy. No formal definition of problem carnivores exists, however, Stander (1990) distinguished between ‘occasional stock raiding lions’ and ‘habitual problem animals’. Occasional stock raiding lions could be translocated short (< 100 km) distances away from stock raiding areas which often resulted in them ceasing to kill livestock (Stander 1990). Habitual problem animals however, could not be translocated successfully and were best destroyed (Stander 1990). It therefore seems that the best description of a problem leopard would fit the description of a habitual problem lion. Habitual problem lions where identified by branding damage-causing individuals. When subsequent attacks of livestock reappear, individual lions causing the damage could be identified, and with long term data habitual problem animals could be distinguished from occasional raiders (Stander 1990). This method can only succeed if there is cooperation between farmers and conservation authorities (Stander 1990). Identification of problem leopards can be achieved by photographing leopards preying on livestock with camera traps placed near livestock remains. Camera traps can be loaned to livestock farmers by the conservation authorities when farmers suspect that their livestock are killed by a habitual problem leopard. After a predefined number of livestock are killed by the same leopard, efforts can be directed to capture and destroy the individual. It should be stressed that this can only succeed if preventative actions are in place to prevent livestock predation by leopards.

b *Translocations*

Studies reporting on the feasibility of using translocations to solve leopard problems in South Africa are limited. In the late 1980's Grimbeek (1992) translocated 5 'problem leopards' to various parts in the Waterberg. Only one leopard survived and was reported as a successful translocation, 3 were subsequently shot and the whereabouts of the last individual were unknown (Grimbeek 1992). Similar results were reported by Hamilton (1981) where only 2 out of 10 problem leopards translocated survived and stayed at release sites. These results seem to follow the world wide trend in the translocation of problem carnivores where failures are common and success very low. After an extensive review on carnivore translocation literature Linnell *et al*. (1997) concluded that translocations of problem carnivores seldom succeed. Results indicate that removal of problem animals is only a short-term solution if the causes of the original problem are not removed (Hamilton 1981; Stahl, Vandel, Herrenschmidt & Migot 2001). Hence, more effort needs to put into preventative methods, rather than treatment of the symptoms (Stahl *et al.* 2001). However, problem animal removal can be effective if the culprit can be identified and captured (Stander 1990). It is thus imperative that the correct 'habitual problem animal' or 'habitual stock raider' is identified (see problem leopards above). Researchers agree that habitual problem carnivores or stock raiders cannot be translocated and the best solution is to destroy such individuals (Hamilton 1981; Stander 1990; Grimbeek 1992).

The social organisation of the leopard remains the biggest reason why translocations fail (Hamilton 1981). Male home ranges form a tight mosaic with little overlap and intruders are rarely tolerated (Bailey 1993). One can thus expect that when a male leopard is released into an area already occupied by other resident males that one of four scenarios may occur. It may kill one of the resident males and claim its home range, it may be killed by one of the resident males, it may move out of the area or it may find a space to coexist with other males. The majority of results though suggest that the male moves out of the area (Hamilton 1981; Grimbeek 1992). Strange females are accepted by resident male leopards, but they are not tolerated by resident females and may undergo the same four scenarios as translocated males (Hamilton 1981). Results from mountain lion (*Puma concolor*) studies indicate that vacancies for a particular sex are only filled by the same sex, suggesting that the home range of a male is only claimed by a another male, and vice versa (Seidensticker, Hornocker, Wiles & Messick 1973). This suggests that translocation will only succeed if vacancies are available for the specific sex translocated.

Even if leopards are translocated to areas with a sparse population, success is not necessarily guaranteed. Seidensticker *et al.* (1973) found that mountain lions are only successful in colonising an area if a few resident animals are present, or if the area is adjacent to an area that provided a source of transients. It therefore seems that the absence of scarcity of resident leopards may affect the success of translocation as much as the presence of a adequate population (Hamilton 1981).

Translocated leopards will not just impact on population in the target area, but the removal of the individual will also affect the local population from where it is removed. Results for bob cats indicated that the removal of males resulted in an increase in home range size of the remaining males (Lynch, Kirby, Warren & Conner 2008). This suggests that home ranges of resident male leopards may increase as a result of the removal of a male leopard, thus the remaining males can then impact on a higher number of ranches. New males attracted to the vacant areas can engage in infanticide, which can negatively impact not just on the resident population, but also on the population that the male is translocated to (Balme & Hunter 2004). Indiscriminate removal can also lead to an increase in non-breeding sub-adults primarily by immigration from refuge areas (Knick 1990). Some evidence from studies on complete carnivore guilds suggests that the removal of one carnivore species can lead to an increase in the abundance of other carnivore species (Grimbeek 1992).

The implications of removing and translocating a leopard are thus numerous and should at best be avoided (Hamilton 1981). However, while the translocations of true habitual problem animals or stock raiders should be avoided, the majority of 'problem leopards' in South Africa are probably 'occasional stock raiders' (Grimbeek 1992). The increase in game ranches and game farmers has also led to an increase in requests to remove 'problem leopards' from these properties. The original definition of a problem leopard as a habitual problem animal or stock raider thus cannot be applied to game ranches. Thus there is scope to translocate leopards if the following scenarios exist;

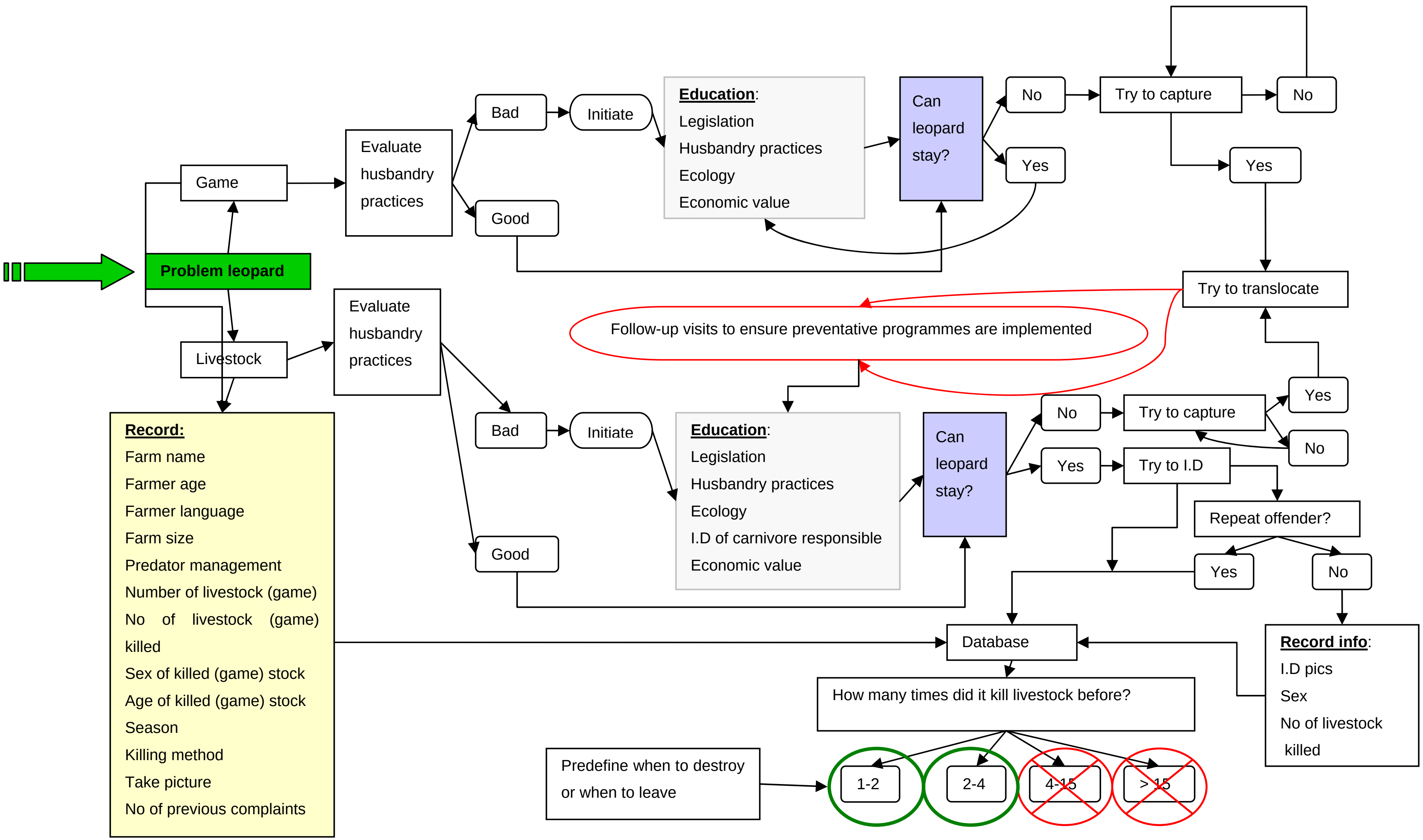
1. 'Occasional stock raider' incorrectly identified as a 'habitual problem animal' due to poor husbandry practices
2. If rancher has a problem and doesn't want the animal on his property; if such animals are not removed ranchers will take matters in their own hands and revert to more drastic tactics (e.g. poisoning, gin traps) to remove such animal, which will ultimately do more harm than good
3. 'Problem leopard' on a game ranch and the rancher wants the animal removed.

Leopards should be translocated to areas that exhibit the following characteristics, based on lion translocations (Stander 1990);

1. Large enough to contain the exploratory movement of the leopard
2. Low to no conflict between leopards and landowners
3. Far away from the source (> 100 km) to prevent the animal from returning
4. Enough prey to sustain leopards
5. Ideal leopard habitat, e.g. rocky outcrops, medium dense vegetation
6. At least a low density of leopards, or near a refuge area with some transient animals

It should be stressed that translocation is only the last resort and nature conservation officials should engage in dialogue with the rancher to prevent the removal of the leopard. The rancher should be provided with tools to manage and prevent future conflict with leopards. Translocation of 'problem animals' is just a temporary solution and every effort should be made to prevent reoccurring problems (Linnell *et al.* 1997; Stahl *et al.* 2001). A hypothetical flow diagram for different scenarios regarding the management of a 'problem leopard' is presented in Figure 1.

Fig. 1. Suggested procedure to follow when handling problem leopards



2.2.4 Trophy hunting of leopards

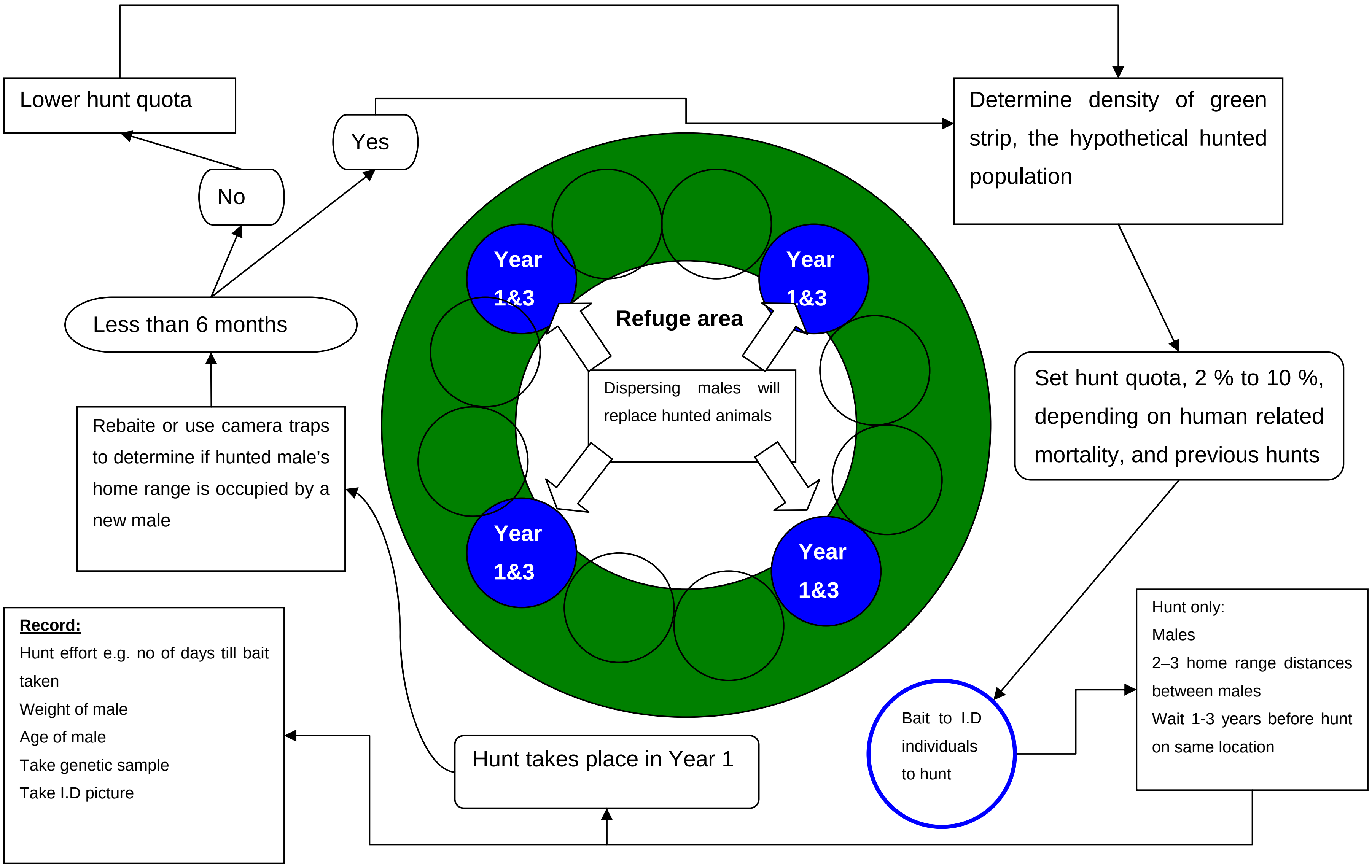
Trophy hunting of leopards is seen as an attractive method to increase the value of leopards on game ranches (Bailey 1993; Lindsey, Frank, Alexander, Mathieson & Romanach 2006). Such hunting should benefit the local ranchers impacted by the leopards. The area surrounding the proposed leopard hunting area should be evaluated to determine if leopards can immigrate to fill vacant areas (e.g. is dispersal possible?). Ideally huntable populations should be close to refuge areas (sources) in order to supply individuals to replace hunted animals (sink area). If the hunted population is isolated, but large enough to contain a viable and sustainable population, a conservative strategy is essential (Bailey 1993). It is suggested that leopards should not be hunted unless an effective population of 50 breeding adults, or 80 to 100 individuals, is present and a viable population exists in adjacent areas (Bailey 1993). Hunting rates of 5 % - 10 % have been suggested by Martin & De Meulenaar (1988), while Bailey (1993) proposed a more conservative 2 % - 3 %, assuming complete compensatory mortality. Harvest rates should take into account the level of illegal hunting and persecution in the area.

Hunting should be limited to males, as males naturally seem to be replaced more rapidly than females, they have a higher mortality rate and respond more to baits (Bailey 1993). The use of baits will allow hunters to correctly identify males and individuals that can be hunted. If a male is hunted at a specific location, the next should only be taken 2 to 3 home range distances away. This will prevent the creating of large vacancies among males, which will reduce productivity (Bailey 1993). Males should not be hunted in consecutive years on the same locality, but preferably every 2 - 3 years. This should help to maintain genetic diversity and reduce the effect of infanticide (Bailey 1993). Monitoring should be done after a male is removed to ensure that a replacement appears. Ideally a new male should appear within a period of 1 to 6 months (Bailey 1993) (Fig. 2).

By using density estimates for the Waterberg from previous studies (1/53 km^2) (Grimbeek 1992) and this study (1/47 km^2), leopard density estimates for the Waterberg Biosphere (size 4174 km^2) (De Klerk 2003) range from 78 to 88 leopards. However, this data probably underestimates the density since densities in protected areas in the Waterberg are possibly higher. Nevertheless, it seems that the population in the Waterberg Biosphere are on the limit of being a sustainable population. Therefore the hunted leopard population has to be continuously monitored and quotas adjusted accordingly to avoid overexploitation. The recent advances in camera traps provide an ideal method to estimate leopard densities.

One potential controversy with trophy hunting can be the allocation of hunting permits. Leopards have large home ranges, impacting on a large number of properties. While one rancher may carry the burden of leopard predation, another rancher a few kilometres away can have the right to hunt the leopard. Thus one rancher in an area of 245 km^2 can get all the financial reward for a leopard hunt, while the cost is divided among the remaining ranchers. While a rotation system of allocating permits has been proposed, the situation still becomes complicated if some ranchers want to habituate the leopard. The formation of conservancies seems to be the most appropriate method in resolving conflicts, where one land use dictates the area.

Fig. 2. A suggested flow chart to set annual hu



2.2.5 Ecotourism and other methods

Some ranchers do not prefer hunting and other methods should be investigated to increase tolerance and the benefit of having leopards. Habituation is a common method cited by ranchers to increase leopard value by allowing tourists to see leopards on a regular basis. However, the practicality of habituation of leopard on ranches is difficult, and habituated leopards can be killed by other ranchers. Again, by establishing conservancies, leopards can be habituated. Other methods put forward to increase tolerance include tax cuts (Rasker, Martin & Johnson 1992), the creation of conservancies (Lindsey *et al.* 2005) and green labelling of products (Marker *et al.* 2003).

2.2.6 The role of government

Free roaming leopards have no legal status and thus effectively belong to the government. The approval of South Africa's increase in CITES quota clearly states that South Africa needs to monitor its harvested leopard populations. South Africa was also urged by other countries to engage in leopard population studies to justify its quota increase (Daly, Power, Camacho, Traylor Holzer, Barber, Catterall, Flecther, Martins, Owen, Thal & Friedman 2005). While research is being conducted in the Waterberg (this study), Soutpansberg and other areas, it's mostly funded by NGO's and local residents. Governments should clearly invest in research or become involved in current studies.

Education programmes should be initiated by government at schools to educate children about the benefit of carnivores, especially in areas with carnivores. Extension work needs to be carried out to help ranchers with carnivore management and to manage problem animals. It is important that hunting quotas are given to the correct ranches and that hunts cannot happen consecutively on the same property. Records must be kept of all hunted and problem leopards removed, including information on sex, weight, age, condition, ranch name and a genetic sample taken. It is the duty of government to do follow-up and extension work on farms where problem leopards have been removed. It is important that ecologically friendly predator management practices are put in place to prevent further livestock predation.

Monitoring of translocated animals should be a requisite to monitor the effectiveness and potential use of this management technique. Unfortunately a large number of leopards have been translocated in the Waterberg without any post-release monitoring. It is also important that when leopards are monitored, information be made available to researchers, managers and other people involved. It should also be attempted to recapture translocated animals with collars to remove collars when batteries run out. Far too many translocated leopards are collared for research and monitoring, but never recaptured to remove the collars.

3 RESEARCH REQUIREMENTS

While the ecology of leopards in protected areas in South Africa is well documented, little is known about leopard ecology on private land, especially game ranches (Marker & Dickman 2005). Future research should be directed towards comparative studies of leopards on protected versus non protected areas. Specifically, research should focus on density of leopards on different land use types in order to predict the density of leopards across the Waterberg and within land use types. Private protected areas, e.g. private reserves like Welgevonden and Lapalala are seen as important core areas for leopards. It is assumed that these reserves have higher leopard densities than surrounding areas, thus acting as population sources for leopards. While this can be true, attitudes and persecution around these reserves can have a detrimental effect on the population and can even lead to declines (Balme & Hunter 2004). Research on these reserves is thus needed to estimate density, annual mortality and the impact of surrounding areas on their leopard populations.

Research should also be focused on the translocation of leopards. Data for the translocation of leopards in South Africa is severely limited and outdated. Some reports show that translocation can be successful (Hayward, Adendorff, Moolman, Hayward & Kerley 2006). Research should therefore focus on criteria needed for a successful translocation and the identification of suitable habitat where leopards could be released.

Word wide there is a general move away from lethal predator control methods (Linnell *et al.* 1997). However, in South Africa lethal control is still widely practised to control predators. It is time that studies be initiated to investigate ecologically friendly methods to control predators.

4 CONCLUSIONS

The survival of leopard on private land depends of various aspects, ranging from incentives for conservation to mitigation methods. A multifaceted approach to leopard management needs to be applied involving: education of ranchers, managers, labourers and the public; incentives to increase tolerance of leopard on ranches; research on leopard numbers and other ecological aspects; government involvement in research and management; improved management techniques. Lastly, while most ranchers in this study and elsewhere, are positive towards conservation, all suffer from the ''yes conservation is important, but not on my ranch'' mentality. The true challenge would be to change this mentality, not just for ranchers but for all people.

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APPENDIX

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Waterberg Leopard Research a

Project: Centre for Wildlife Management, UP

This questionnaire survey is being conducted as part of a wider study that aims to determine the ecology of Leopards (*Panthera pardus*) in the Waterberg. Specifically, the projects' aim is to determine the range requirements, ranging patterns, feeding ecology and population dynamics of leopards under different landuse conditions. This survey aims to determine the attitudes of South African game ranchers towards *this* species on private land. Your assistance in completing this questionnaire survey would be greatly appreciated. Your answers will be completely anonymous and entirely confidential.

Project leader: ***Prof W Van Hoven***

Researcher: ***Lourens Swanepoel***

1. RANCHER/OWNER INFORMATION

Age	
Citizenship	
Home language	
How long have you been on the property?	
What is your position on the property?	
Number of people living on property	
Educational level	

2. PROPERTY CHARACTERISTICS

Name of property	
Size of property	
Is the property part of a conservancy?	

2.1 Please provide the following details concerning the fencing of the property:

Location of fencing	
Height of fence	
Number of strands	
Electrification	
Purpose of fence	
Internal fences used	

2.2 Are artificial watering holes being used? And quantity

	Quantity	

2.3 What type of land borders your property?

State land	
Communal land	
Cattle ranch	
Mixed cattle and game ranch	
Game ranch/hunting	
Tourism property	

2.4 Please indicate the attitude of your neighbours towards predators. Please assign the appropriate number: 5=Highly favourable; 4=favourable; 3=neutral; 2=unfavourable; 1=negative

State land	
Communal land	
Cattle ranch	
Mixed cattle and game ranch	
Game ranch/hunting	
Tourism property	

2.5 What is the land use of your property?

2.6 Please indicate the relative importance of the following sources of income on your property by marking each category: 3=important; 2=marginal; 1=zero

Activity	*Score*
Trophy hunting	
Venison hunting	
Ecotourism	
Cattle	
Sheep	
Crops	
Goats	
Dairy	

Live animal sales	
Sale of rare game	

2.7 Indicate which of the following factors you think ecotourists consider as being important when selecting a destination for wildlife by giving each category a score of 0-5; 0= of no importance, 5= very important.

Activity	Importance	
	SA tourists	**Foreign tourists**
A. Spectacular scenery		
B. A high bird diversity		
C. A high mammal diversity		
D. A high floral diversity		
E. The big 5		
F. Large predators		

3. Predators

3.1 Which of the following carnivores are present on the property, and which signs indicate their presence?

	Track seen	Animals seen	Kills found	Second [8]Source
Leopards				
Brown hyena				
Jackal				
Caracal				
Cheetah				
Wild dogs				

3.2 Please rank what you consider as the most reliable source for recognizing a predator on your property, where 0=least reliable; 3=most reliable

Source	Score
Animals seen	
Tracks seen	

[8] Someone else saw the signs and told you about them.

Secondary source	

3.3 Indicate how you feel about having (or how you would feel about having) each of the following species on you property by giving each species a score of 0-5 (0=very disadvantageous, 5=very advantageous)

Species	Score	Reason
Leopards		
Brown hyenas		
Jackal		
Caracal		
Cheetahs		

3.4 Have you had problems with predators on your property in the past?

3.5 Is carnivore predation on game/livestock monitored? Please give details.

3.6 Can you estimate the amount of money loss due to predation per year?

Less than R5 000	
Between R5 000 – R25 000	
Between R25 000 – R85 000	
More than R85 000	

3.7 Are carnivore numbers currently controlled on your property? Please give details

3.8 Using the scale below, please in[...] severity of poaching on your proper[...] poaching; 5=serious

1		2		3		4		5	

4. Leopards

4.1 How would you consider your knowledge about leopards?

Above average	
Average	
Below average	
None	
Not interested	

4.2 What features/characteristics do you like/dislike about leopards?

Like	
Dislike	

4.3 Are there leopards present on the property?

Yes		No		Date
Age/Sex				

4.4 How do you know there are leopards present on the property?

Animals seen	
Tracks seen	
Kills found	
Secondary source	
No information	

4.5 How frequently is evidence of the presence of leopards seen on your property?

Seldom	
Frequently	
Rare	
Other	

4.6 Please provide information about the population trend of leopards on the property

Stable	
Declining	
Increasing	
No information	

4.7 Evidence of leopards reproducing (how do you know if cubs are born?)

Cubs seen	
Tracks seen	

4.8 Assessment of prey base: Name and rank prey species in order of importance (including livestock). 1 very important, 6 not important

1	
2	
3	
4	
5	
6	

4.9 Assessment of prey localities (where were kills found?)(1 most frequent-5 least frequent)

Location	*Score*
On mountain	
In kloof	
In woodland	
In grassveld	
Waterhole	
Other	

4.10 How many carcasses were found in the last two (2) years of different animals; also provide estimated cost of these animals

Specie	Quantity	Cost/animal

4.11 Please give a brief description of the characteristics of a problem leopard

4.12 Do you think that leopards are a problem on your property?

4.13 Do you think it is necessary to control the predation of <u>game</u> by the leopard?

4.14 Do you think it is necessary to control the predation of <u>livestock</u> by the leopard?

4.15 If yes, which of the following methods do you think are appropriate control measures, please rank from most (1) to least preferred (6).

	Score

Improving husbandry practices (e.g. closer of animals, use of guard dogs, putting anim kraals at night)	
Avoiding areas with high predation risk	
Financial compensation for predation losses	
Selectively removing problem leopards	
More hunting of leopards	
Eradication of the leopard	

4.16 Have any leopards/problem leopards been removed from the property. If yes, please provide year removed, sex and age of leopard.

Yes/No	*Age*	*Sex*	*Date*

4.17 Do you think that game reserves contribute to the influx of more leopards in your area?

4.18 Do you think it is necessary to protect (or conserve) leopards in the Waterberg?

4.19 Are the leopards of any value to the property at this moment? If yes please give details

4.20 Which of the following would increase the ''value'' of the leopard on the property? Please rank from most appropriate (1) to least (6)

	Score
Habituated leopards for easier viewing by tourists	
More hunting permits to hunt leopards	
Leopard walks on property that will illustrate leopard signs	
Indirect signs that show presence of leopards on property like camera trap pictures, GPS/GSM tracking data, or Web cam pictures	
Green labelling (leopard friendly products/beef/milk/game etc)	
Nothing	
Other	

4.21 Will you participate in a leopard conservation program?

You were asked to	
You were given an economic incentive	
Never participate in leopard conservation projects	

5. Legislation

5.1 If you had a problem leopard on your property, what would you rather do? (5=most desirable; 4=desirable; 3=probably; 2= not likely; 1 not at all)

Action	*Score*
t authority	
solve the problem	
Solve the problem personally	
Ignore it	

5.2 According to you, which would be the pertinent authority be

5.3 Can you name any official documents regarding leopards in South Africa?

5.4 Do you know what CITES stands for? Yes/No If yes, give a definition

5.5 Do you know what is the CITES leopard hunting quota for South Africa?

6. Livestock farmers

6.1 How much livestock do you have on your property?

CATTLE	**Quantity**
Bulls	
Cows	
Calves	
SHEEP	
Rams	
Ewes	
Lambs	

6.2 Do you use a defined calving/lambing season?

If yes when would that be?

Jan	Feb	Mrt	April	May	June
July	Aug	Sept	Okt	Nov	Des

6.3 What is your calving percentage

6.4 Where do your livestock calf/lamb?

Every where in veld	
In kraal near house	
In calving camps near house	
In non mountainous areas	
In mountainous areas	

6.5. Do you use a rotational grazing system?

6.6 How many camps do you use?

6.7 With which of the following carnivores do you experience problems with and why?

Predator	Y/N	Reason
Leopards		
Caracal		
Brown hyena		
Jackals		
Cheetahs		

6.8 How much livestock where killed in the last four (4) years on your property by leopards? Please provide as much information as possible

Year	Quantity	Sex	Age	Season

ivestock were lost to

Disease	
Theft	

In the last four (4) years?

6.10 How do you manage the carnivores on your property?

Ignore it	
Remove the problem individuals	
Poison	
Trap and kill problem individuals	
Carpet shooting, shoot every carnivore on site	
Trap and translocate	
Get profession help	
Other	

6.11 How frequent do you count your livestock?

6.12 How do you identify the predator involved?

6.13 What is the Breed of your cattle?

6.14 Are cattle dehorned?

6.15 What would be a good idea to increase the value of the leopard on your property?

	Sex			Method used to estimate numbers				
Species	**M**	**F**	**Tot**	**Arial count**	**Drive count**[9]	**Known groups**[10]	**Opportunistic counts**[11]	**Other**
Impala								
Blesbok								
Red hartebeest								
Blue wildebeest								
Black wildebeest								
Kudu								
Eland								
Bushbuck								
Njala								
Ostrich								
Buffalo								
Warthog								
Zebra								
Sable								
Roan								
Tsessebe								
Waterbuck								
Gemsbok								

[9] Systematic method, were the program software package DISTANCE is used

[10] Method where the owner knows specific animal groups, e.g. remember how many individuals there was in a group when released onto the farm, and monitoring thereafter.

[11] Counts made when just driving on farm or doing game drives