Spoor density, movement and rehabilitation of cheetahs in Botswana

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Declaration

I declare that the dissertation, which I hereby submit for the degree Magister Scientiae (Wildlife Management) at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.

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Date: 11-20-08

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Summary

The "vulnerable" listing by IUCN of cheetah *Acinonyx jubatus* in Africa has caused urgency in the protection of their habitat and development of predator management strategies. By understanding the movement and home range of cheetah in Botswana, translocation of problem cheetah or reintroduction of non-problem animals can be managed appropriately. More importantly this information will help to protect what is already there. Due to the increasing numbers of cheetahs being taken by illegal trade and poaching, there have become incidents of orphaned cubs where the only option for their survival is rehabilitation for release into the wild, or euthanasia.

The first part of the study focuses on baseline information of movement patterns of cheetah in Botswana. Eleven cheetahs were collared and monitored from 2003-2007, including males and females with and without cubs from the Ghanzi and Southern districts. The understanding of cheetah movement is critical in determining

methods of protection and survival of the species in protected areas living with competing predators such as lion *Panthera leo*, brown hyaena *Hyaena brunnea* and leopard *Panthera pardus*, as well as on farmlands where human conflict and habitat loss are the main causes of cheetah death. In the Southern district the cheetah were able to move freely in and out of the Jwana Game Reserve surrounded by communal livestock farms with low to medium conflict, utilizing various livestock protection methods, whilst Ghanzi consisted of livestock and game farms where conflict was high and protection methods were limited or nonexistent. Home ranges in males ranged from 492 km^2(in single males) to 849 km^2(in one coalition) in Ghanzi, while females ranged from 241 km^2 to 306 km^2 in Jwaneng.

In addition, in order to determine the correlation between spoor density and true density, a 15 month spoor study was conducted in Jwaneng at the Jwana Game Reserve on a population of free ranging wild cheetah. A correction factor was tested and adjusted for accuracy, resulting in two formulas to be used in the wet and dry seasons. Spoor surveys are by no means a determinant factor, as they need to be repeated over time to observe population fluctuations due to outside factors, and are time consuming and can be expensive, but they are a management tool that can be utilized for estimations of cheetah densities on private farms or protected areas.

The third part to the study was the rehabilitation of three orphaned cubs, from different families, that were put together from eight to twelve weeks old. The goal of this project was to raise and release fully functional, self sufficient, breeding animals into the wild population on a game farm. These cubs were raised in isolation until 1.5 years of age, then transferred to a 100 ha enclosure where they were given the opportunity to learn to hunt. Daily observations of their behavioural development and hunting abilities were recorded for 48 days and are presented in a descriptive way. At two years old they were released onto a 9000 ha game farm where their potential to survive on farmland was monitored. Botswana does not have the facilities or desire to keep predators captive, and if orphaned cubs could be utilized by placing them back into wild populations where they could add to the gene pool, alternatives would be available for captive bred animals or cheetahs facing life long captivity.

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Acknowledgements

This project could not have been accomplished without the formation of Cheetah Conservation Botswana (CCB), and my two partners and friends Rebecca Klein and Dr. Kyle Good. This project was set up by the three of us in 2003 with the hopes that it would add to the knowledge and protection of cheetah in Botswana and to the furtherment of education for students in the future. Without the team work and support of our board none of this work would have been possible. I would never have accomplished this work in my life time without the help of our international volunteers. I especially must thank Lorraine Boast whose continued patience and stats ability kept me going as I utilized more swear words in direct proportion to my frustration with computers. The quality of my work is at its best because of her help and friendship.

I would like to thank the Botswana Department of Wildlife and National Parks for allowing the research and handling of cheetah throughout this study, and the permits to raise and release the orphaned cheetah cubs. Thanks must go to Decu, Alice and Gracie who I watched grow up into adult cheetah, and fulfilled my life's dream of proving that rehabilitation can succeed, and orphans can learn to hunt and survive. The work I do is for their memory, and for the future cheetah that will benefit from what we learned during their lives.

Thanks to the Centre of Wildlife Management and University of Pretoria for the financial assistance in the form of bursaries, as I would not have been able to afford this degree without their help. I especially would like to thank my advisor, Dr. Michael Somers for taking on this American from Botswana after only a 15 minute introduction in his office. Thank you for your timely responses to all my questions, and there were a lot, and your comfortable demeanour and sense of humour. I must also thank Liset Swanepoel for her continued assistance in sorting out my registration problems and school fees, and the occasional funny sent by email to brighten my day.

Thank you to Dr. Laurie Marker from Cheetah Conservation Fund, Namibia for allowing me to volunteer in 2002 where my love for cheetah grew into a career, and where I was trained by my adopted south African sisters, Bonnie and Mandy Schumann. They were responsible for teaching me everything I needed to develop the research aspect of CCB. They taught me how to handle wild cheetah and take great care to keep them safe and alive at all costs. The ability to keep a sense of humour when everything seemed hopeless, and the love for the animals that keeps you going when all else fails. I watched them get their Masters and had to follow suit or suffer their wrath. Thank you for your support and comforting words during the hard times, and the laughs during the good times.

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Finally, and most importantly I would like to thank my mom who died in 2003 for her life long support and zest for life, helping to give me the courage to follow my dreams. I did it mom, I did everything I have ever wanted in Africa, because of your love and faith in me throughout my life. Thank you.

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CHAPTER 1

General Introduction

Introduction

The global status of the cheetah *Acinonyx jubatus* has declined from approximately 100,000 in 1900 to an estimated 30,000 in 1975 to less than 15,000 in the 1990s' (Myers, 1975; Marker, 1998). Free-ranging African cheetah populations are currently found in 29 countries of Southern and East Africa, North Africa and Sahel (Marker, 1998). There have been many studies on the cheetah throughout southern and eastern Africa including Namibia, South Africa, Kenya, Zimbabwe, Tanzania and Iran. However, cheetah status and movement in Botswana has been relatively unstudied.

The common factors negatively affecting cheetah populations are habitat loss and fragmentation, competition with other more aggressive predators and human conflict (Caro, 1994; Durant, 1998; Marker *et al.*, 2003). Higher densities of cheetahs and suitable habitat for cheetah populations are primarily located in the agricultural zones located outside of protected areas, and outside of fenced game reserves or on commercial farmlands (Winterbach, 2001; Marker, 2002) which increase the potential of conflict with livestock and game farmers (Marker *et al.*, 2003; Klein, 2007). In Botswana, 38% of the country is protected for wildlife in the form of National Parks and Game Reserves, which occupy 17% of the country, and Wildlife Management Areas intended for sustainable wildlife utilization occupy the remaining 21% (Herremans, 1998; Klein, 2007) (Fig. 1.1).

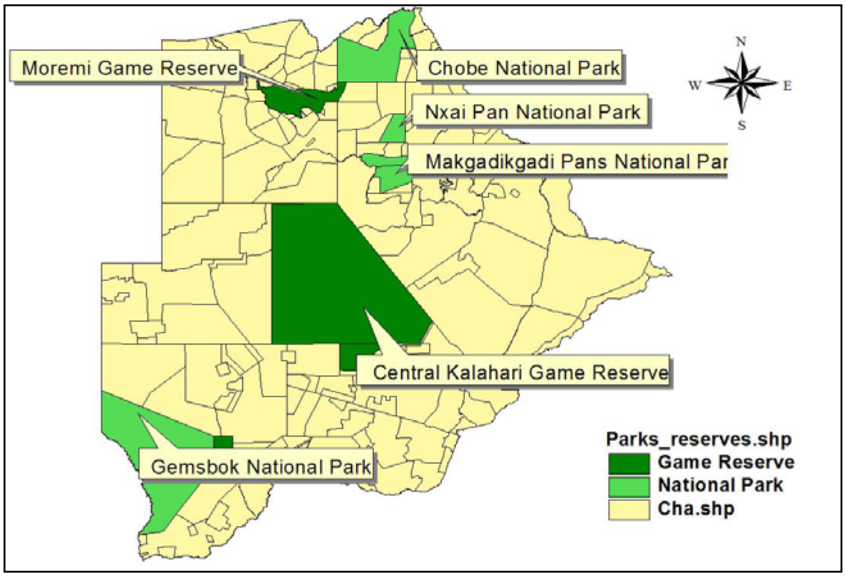

Figure 1.1 Protected Game Reserves and National Parks in Botswana.

The human population of Botswana is estimated at 1.6 million, and in a country where livestock has high economic and cultural value the numbers of livestock to people is 2: 1, with cattle numbers approximately 3 million and growing (White, 1998; Botswana Central Statistics Office CSO 2001). Due to the large numbers of livestock and increased boreholes throughout the country, the habitat is threatened with bush encroachment (Verlinden, 1997). Decreased prey densities due to human encroachment, veterinary fences blocking off migration routes, drought, poaching and over hunting also all contribute (Bonica, 1992; Verlinden, 1997; Boggs, 2000). The changes in the habitat and human influences in Botswana will negatively affect the cheetah status if the current situation does not improve.

STUDY AREA

Botswana is primarily semi-arid covered by deep Kalahari sands, with mean rainfall from 250-650 mm from the southwest to northeast. The Okavango Delta consists of an inland delta and permanent wetland located in the Northwest, with calcrete plains and salt pans in the Central Northeast, and hardveld in the East and Southeast (Fig. 1.2) (Greenway, 2001).

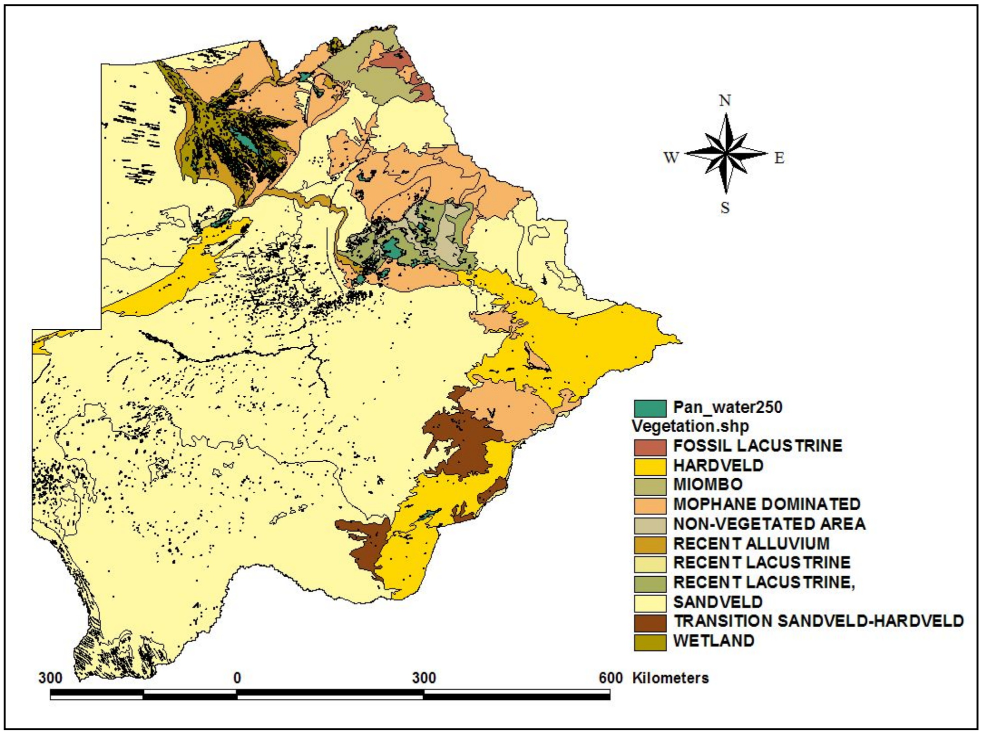

Figure 1.2 Habitat classification of Botswana

In order to decrease repetition the chapters of this dissertation will include the details of each of the study areas in Jwaneng (Chapter 2), Ghanzi (Chapter 3) and Tuli (Chapter 4).

ESTIMATED CURRENT CHEETAH NUMBERS IN BOTSWANA

The most current distribution of cheetahs in Botswana has been determined through vigorous questionnaire studies, Department of Wildlife and National Parks (DWNP) records and surveys and spoor studies conducted in Southern and Ghanzi Districts (A. Houser, *Unpublished data*) and Kgalagadi District (Funston, 1998). These results have been summarized in the cheetah status report by Klein (2007) with the current population estimates and areas of reported problem animal reports on cheetah (Figs. 1.3 & 1.4).

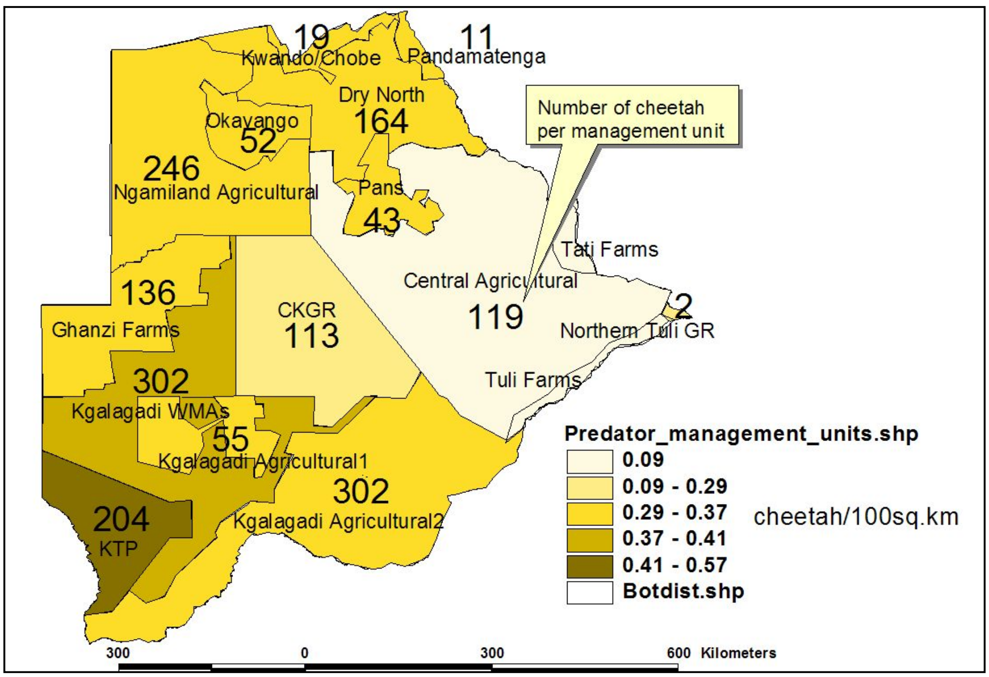

Figure 1.3 Current national cheetah estimates related to predator management zones.

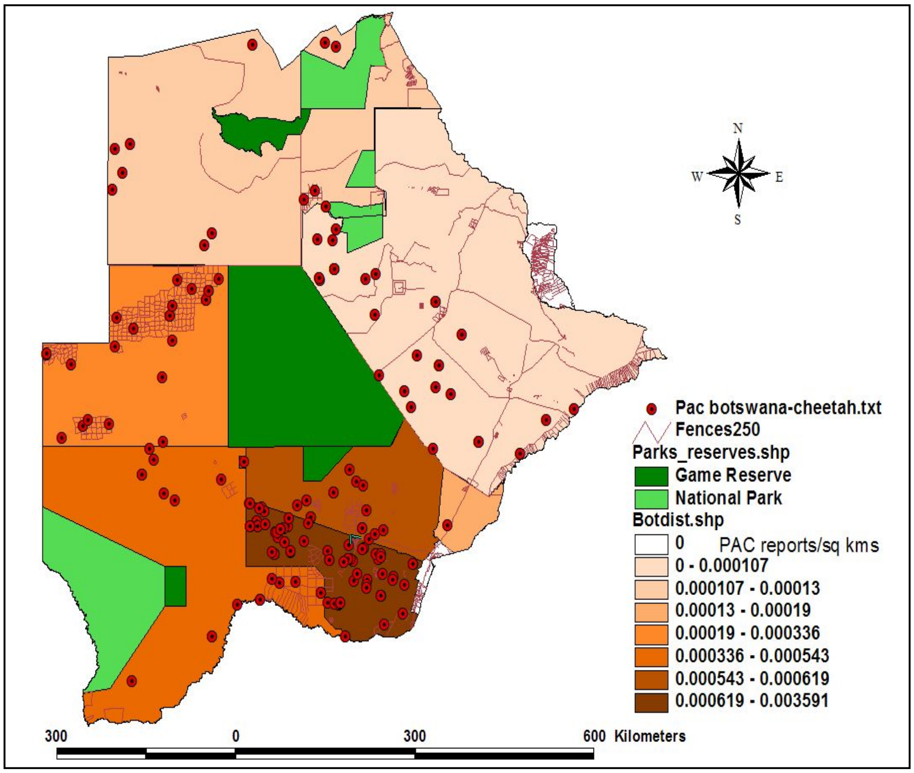

Figure 1.4 Distribution of cheetah problem animal control reports 1998-2006.

FOCUS OF THESIS

Botswana may contain the worlds second largest population of free ranging wild cheetahs (Purchase *et al*., 2007) at approximately 2500 (Klein, 2007), although very little is known about their movement and behaviour in Botswana. The loss of cheetahs due to human conflict, habitat loss and intraguild competition is only now being studied by Cheetah Conservation Botswana, Botswana Predator Conservation Program and several private projects. It is important to understand this predator's movement and behaviour in order to be able to protect the second largest wild population in Africa.

I focused my research in the primary areas of conflict located in the Southern and Ghanzi Districts. In order to conserve cheetahs it is important to find a reliable method to estimate population size to determine if there is a sustainable population in any given area of interest, and also to determine their movements within these areas. Due to high human conflict there have been increased incidents of orphaned cheetahs, and the need to develop methods of rehabilitation for release into the wild. Therefore, this Masters was divided into three projects. The first project calibrated a spoor survey method using a known population of cheetahs. The second project was a home range study to determine the movement of male and female cheetahs on farms and in protected areas. It is important to understand the movements of cheetahs in order to protect enough habitat for a population to thrive, in conjunction with identifying surrounding communities that can dramatically affect their survival (Hunter, 1998; Marker, 2002). The third project was the rehabilitation of three orphaned cubs at 2 months of age to 2.5 years, and the development of methodology to raise self sufficient, breeding animals to be released into the wild. The use of reintroduction and translocation techniques has become increasingly important when dealing with endangered or problem animals (Griffith *et al*., 1989; Stander, 1990; Magin *et al*., 1994; Wolf *et al*., 1996), with increasing interest in the areas of rehabilitation and release as a management tool (Linnell *et al*., 1997). Due to illegal trade and poaching there have been increased incidents of orphaned cheetahs, and the best result would be to develop a program that can utilize these animals by placing them back into wild populations.

CHAPTER CONTENTS

This dissertation contains three data papers, chapters 2-4, which are structured in journal format. The reference list for each project is at the end of the corresponding chapter. Chapter 4 on the rehabilitation of cheetahs is arranged similarly. However, as the results are presented in a descriptive manner, the results and discussion sections have been combined.

Chapter 2: Spoor density as a measure of true density of a known population of free ranging wild cheetah in Botswana.

Several studies have determined the true density of a population using spoor counts by developing a linear relationship between spoor count data and the true population. These results were used to obtain a correction factor that can be used to estimate population size. Stander (1998) did this for lion *Panthera leo*, leopard *Panthera pardus* and wild dog *Lycaon pictus* populations. Gusset & Burgener (2005) used Standers' regression equation (correction factor) on leopards in South Africa, whilst Funston *et al.*, (2001) found a similar regression equation in lions, and extrapolated it brown hyaena *Hyaena brunnea*, spotted hyaena *Crocuta crocuta*, cheetah and leopard.

This chapter consists of a 1.5 year study using a known population of free ranging wild cheetahs with access in and out of the Jwana Game Reserve. The aim of this work was to use Standers' methodology to calibrate the spoor survey technique to calculate a correction factor specifically for cheetahs. This equation was then tested and adjusted for accuracy in the following wet season for use in future cheetah spoor surveys. This chapter has been accepted by the *Journal of Zoology* for publication in 2009.

Chapter 3: Home range use of free ranging cheetah on farmland and in a conservation area in Botswana.

In this chapter, data on 11 cheetahs which were collared and monitored from October 2003 to April 2007, in the Southern and Ghanzi Districts of Botswana, are provided. Home range sizes in cheetahs have shown a large variation in estimates from 11 km^2 in males and 23 km^2 in females in Matusadona national park, Zimbabwe (Purchase & du Toit, 2000) to 833 km^2 in females in the Serengeti (Caro, 1994) and 320 km^2 in males in the Kgalagadi Transfrontier Park (Mills, 1998). This study investigated the home range of free ranging cheetahs in relation to gender, social grouping, age of cubs, habitat type and prey density, on Botswana farmland and an area containing a game reserve with access to surrounding communal farms. This chapter has been accepted for publication in *South African Journal of Wildlife Research* for publication in Vol. 39(1) 2009.

Chapter 4: The rehabilitation and release of three captive cheetah cubs on a game farm in Tuli, Botswana.

The rehabilitation and release of orphaned or captive raised cheetahs into the wild has been rarely documented. Three cases include; three captive bred male Cheetahs in South Africa (Pettifer, 1981) from the DeWildt Cheetah and Wildlife Trust, two females released in a game reserve in Zimbabwe (Ferguson, 1995), and in Namibia with a female and two cubs from Cheetah Conservation Fund (B. Schumann, pers. comm.). This chapter is the first to record the rehabilitation and release of three orphaned cheetah cubs, into the wild on a game farm in eastern Botswana. The development of their hunting techniques and behavioural changes were monitored intensively, and the methodology and costs of setting up a rehabilitation program were recorded. If orphaned/injured cheetahs are to be released into the wild, rehabilitation techniques must be repeatable, tested and recorded in order to provide successful methodology in conjunction with diligent post-release monitoring to determine its success. A paper from this chapter will be submitted to a journal in the future.

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CHAPTER 2

Spoor density as a measure of true density of a known population of free ranging wild cheetah in Botswana.

Abstract

Knowing abundance of animal populations is essential for their management and conservation. Determining reliable measures of abundance is however difficult, especially with wide ranging species such as cheetah *Acinonyx jubatus*. This study generated a correction factor to calculate true cheetah abundance from spoor survey data and subsequently tested its accuracy using the following season's data. Data was collected from October 2005 to December 2006 on a known population of wild, free ranging cheetahs in the Jwana Game Reserve, Botswana. The cheetahs in the area were captured, tagged and photographed. The reserve was divided into 12, 9 km transects covering all vegetation types and prey densities. Total sampling distance was 8226 km, with a spoor density of 2.32 individual cheetah spoor per 100 km. To determine a precise and accurate spoor density it was necessary to sample for a longer period during the dry season (April-September), than during the wet season (October-March). This difference may be due to cheetah behavioural changes with seasonal variations and their affects on habitat and prey. The true density was 5.23 cheetahs per 100 km^2 ranging from 3.33 to 7.78 at the low and high points of the population, respectively. A positive linear correlation between spoor and true density was observed. This relationship differed in the wet and dry season and required refinement with the following season's data. Correction factors may be viable but require further testing taking behavioural responses to seasonal, habitat and prey variations into consideration.

Introduction

An accurate estimate of population density is essential for the management and protection of endangered species, such as the cheetah *Acinonyx jubatus*, which is listed as vulnerable by IUCN (IUCN, 2007). As in most large carnivores the cheetah population is declining in Africa (Marker *et al.*, 2003) and the ability to develop an accurate, repeatable and cost effective method to assess population trends and density is required. Direct methods such as visual counts and mark and recapture are often the method of choice, however in large carnivores they rely on the visual recognition of individuals and as such are often expensive, difficult and time consuming (Stander, 1998; Gusset & Burgener, 2005). When direct methods are too expensive or impractical; as is often the case in low-density species such as the cheetah (Mills, 1997; Wilson & Delahay, 2001), the use of indirect measures that rely on the presence and detection of field signs, as an index of true density is a more favourable option. For example, it is possible to obtain relative estimates of carnivore populations by calculating the number of scat samples, den sites or spoor seen in the study area (Mills, 1997). Spoor surveys in particular have been used extensively as a monitoring tool in several species, including leopard *Panthera pardus*, lion *Panthera leo*, brown hyaena *Hyaena brunnea,* (Stander, 1998, Funston *et al.*, 1991), caracal, *Caracal caracal* (Melville & Bothma, 2006) and mountain lion *Felis concolor* (Smallwood & Fitzhugh, 1995). They are less invasive and more cost-effective than direct methods (Jewell *et al.*, 2001), whilst remaining repeatable, objective, valid and accurate (Stander *et al.*, 1997; Gusset & Burgener, 2005). However, they only provide a relative estimate of population size and a quantifying technique must be applied to calculate the population density. One technique is to use spoor measurements to identify and count individuals within a population. This has been applied to mountain lion (Smallwood & Fitzhugh 1995; Grigione *et al*., 1999; Lewinson, Fitzhugh & Galentine, 2001), tiger *Panthera tigris*

(Sharma *et al.,* 2005), and black rhino *Diceros bicornis* (Jewell *et al.,* 2001). However, it requires further study before it may be applicable for use in the field with varying substrates (Lewinson *et al.,* 2001).

Alternatively by double sampling the population by a direct technique such as capture and marking of individuals and an indirect technique such as spoor tracking, the relationship between the direct and indirect technique may be quantified and a correction factor to calibrate the indirect technique can be calculated (Eberhardt & Simmons, 1987; Wilson & Delahay, 2001). Stander (1998) showed a significant linear relationship between spoor counts and true density determined by the recognition of marked or collared lion, leopard and wild dog *Lycaon pictus*. Gusset & Burgener (2005) used Stander's regression equation to estimate the leopard population in the Waterberg region of South Africa and showed the result to be similar to that derived from the identification of individuals from spoor measurements. Funston *et al.,* (2001) also found a similar regression equation in lions and extrapolated the slope of the line to brown hyaena, spotted hyaena *Crocuta crocuta*, cheetah and leopard.

Stander (1998) found the linear relationship between spoor counts and true density to be species specific and predicted that the slope of the line would vary with habitat use and species behaviour. It therefore seems reasonable to assume that differences in, lion, leopard and wild dog home range, daily movements and road usage, compared to cheetah will cause differences in this relationship. However this correlation has not yet been quantified. The aim of this chapter is to compare cheetah spoor counts with capture and radio collaring information in an open and free ranging population of cheetahs in Southern Botswana. Thus the objectives of this study were to calibrate the spoor survey technique to calculate a correction factor for use in future cheetah spoor surveys and to subsequently test the correction factor in a spoor survey the following wet season.

Materials and Methods

STUDY AREA

The study was conducted in Jwana Game Reserve, Jwaneng, Botswana (24^{o}33'09.3 S, 24^{o}43'38.0 E). The cheetah population within the area had been monitored since November 2003 and the spoor survey was conducted from October 2005 to September 2006. The experimental zone had an area of 180.31 km^2 plus an additional 32.62 km^2 covered by the Debswana Diamond Mine. The actual mine area is fenced and although accessible to predators via warthog *Phacochoerus africanus* holes, it was assumed this area was not regularly utilized due to high human disturbance and a lack of prey. Jwaneng city centre is located 5 km south of the mine and cattle posts surround the game park. The reserve is enclosed by game fencing, allowing the free movement of predators through warthog holes and under fences. The main predators are cheetah, leopard, brown hyaena and jackal *Canis mesomelas*; lion and spotted hyaena are not present in this area, due to the numerous cattle posts and human interference.

The area is sandveld with the major tree species being *Acacia mellifera, Acacia luedritzii* and *Boscia albitrunca* (pers. obs.). Vegetation is primarily open-semi wooded savannah mixed with moderate to thick bush. The topography of the area is flat, in a sandy aerosols environment with no hills or high rises, rivers or lakes. Annual rainfall in 2006 was 581mm (Jwaneng Airport Metrology Centre, 2007). The dry season is from April to October, and the wet season from November to March. Temperatures range from below 0^{o}C to over 40 ^{o}C (Greenway, 2001). The soil type is desert sand and the roads in the reserve are primarily sandy soils with two calcrete main roads. As larger predators, including cheetah in thick bush areas, frequently, if available, use roads to travel on (Kutilek *et al.,* 1983), spoor tracking was conducted upon these sandy roads.

SPOOR SURVEY DESIGN

The spoor survey was divided into two seasons; the wet season from October 2005 to March 2006 and the dry season from April 2006 to September 2006. The spoor survey was continued for three months in the subsequent wet season from October 2006 to December 2006 in order to test the correction factor. The reserve was divided into four sections, with three transects of 9 km each driven in each section, therefore 12 transects in total (Fig. 2.1).

Transects were designed to reduce the chance of double sampling by making them as linear as possible, whilst including all habitat types. Transects were systematically ordered during each week with one transect per section was driven daily, in a set rotational order to ensure at least 48 hours had passed since the transect was last surveyed. The total distance sampled was 108 km, this equates to a ratio of 1 km of road sampled for every 1.67 km^2 study surface area. The sum of the distance surveyed expressed as a ratio of the sample area, i.e. 1 km surveyed : x km^2 survey area will be referred to as road penetration (Stander, 1998). Therefore, a high road penetration will actually be reflected by a low number.

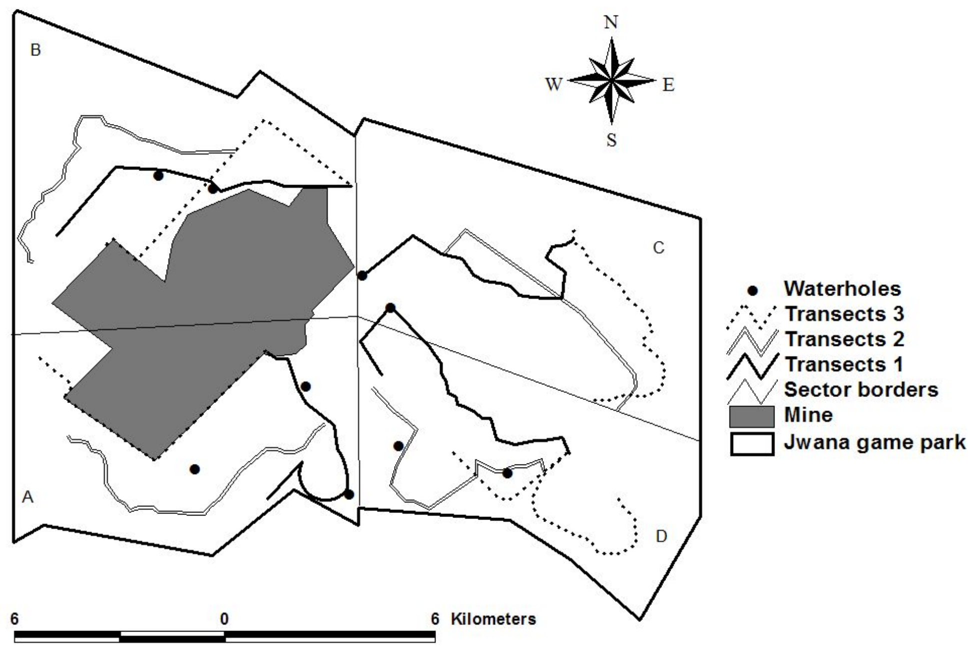

Figure 2.1 A map of Jwana game park, showing the mine area, sectors, waterholes and the transects driven during the spoor survey.

One or two 4x4 vehicle's were driven along the transects at 8-12 kph. All large predator spoor (cheetah, leopard, brown hyaena and domestic dog *Canis lupus familiaris*) were identified and recorded with the date, time, location, number of animals and individual cheetah identity if known. Due to the social grouping, cub age, known GPS locations from cell collar information, and a distinctive round hind foot in females from one specific cheetah family (F6), it was frequently possible to identify spoor to a specific individual. Each individual was only recorded once per day. Spoor identification was made by trained researchers with a minimum of two people per vehicle. The lead researcher had three years of experience spoor tracking and put additional researchers through thorough training and testing on spoor identification. Spoor were recorded as individual spoor, not as a family group, i.e. five spoor found together were counted as five individual spoor. Spoor tracking began 1 hr after sunrise and ended by 11:30am. Preparing the roads before sampling has not been found to be beneficial (Smallwood & Fitzhugh, 1995), therefore was not performed in this survey.

CHEETAH POPULATION

The number of cheetahs utilising the game park, defined as the 'true cheetah density' was calculated independently of spoor counts. The cheetah population had been monitored daily by radio telemetry, GPS cell collar data and opportunistic visuals since October 2003. Cheetahs were identified by spot patterns from tourist photographs and were individually recognisable by researchers and game park staff by the presence of ear tag/collar and spot patterns. On average 89% of cheetahs present in the reserve each month were known individuals. All spoor believed to be from new individuals was followed with the aim to obtain visuals and set traps for their capture. Cheetahs were captured using a double-ended box trap using limited access or live bait held in a separate holding cage. They were tranquilized by the project veterinarian and a medical workup was performed (Marker, 2002). Ear tags and micro-chip ID transponders were inserted for individual identification and ID photos were taken, enabling spot pattern identification. All cheetahs were released at their capture sites. A cell collar was placed on a lone female (F5, in October 2005), who gave birth to five cubs in February 2006, four of these cubs survived beyond September 2006. GPS locations were recorded 1-4 times a day for this female and visuals were obtained at least once a month after the cubs had left the den. A second female (F6) with four, 9 month old cubs was captured during October 2005. This female left her sub-adult cubs in July 2006. The mean number of days between opportunistic visuals of this family was 11.8 ± 2.2 days. F6 returned with a new litter of four cubs in November 2006. In addition to F5 and F6, visuals of unidentified cheetahs occurred almost monthly, the known locations of F5 and F6, in conjunction with the lack of ear tags and spot patterns made it possible to assign these cheetahs as 'unknown'. Attempts to capture these cheetahs were unsuccessful, however all reports from tourists and game park staff supported the population data. These reports in combination with camera trap studies have been considered reliable methods of identification of individuals (Marnewick *et al*., 2008).

To take into consideration the varying population, a mean population density for the wet and dry season was calculated, based upon the number of cheetahs known to be present each month, divided by the number of months per season. To examine the relationship between true density and spoor count data, comparisons were drawn between the true density for one specific family (F5) and the spoor density relating to that family, in the wet and dry season. This was then recalculated and graphed with two families (F5, F6) and with all cheetahs (F5, F6 & unknowns).

VALIDATION OF THE SPOOR CORRECTION FACTOR

The second wet season data between October 2006 to December 2006 were used to validate the relationship between spoor count data and true density. A new wet season correction factor was calculated by plotting the cheetah family data points (i.e. F5, F5&F6 and all cheetahs) for the first wet season and second wet season, subsequently generating a linear trend line for all the points.

STATISTICAL METHODS

Spoor frequency and spoor density were calculated in accordance to Stander (1998). Spoor frequency may be defined as the mean number of km per individual spoor (Stander, 1998), or as the mean number of km travelled to locate one spoor, i.e. if the spoor frequency equals 10 km, after 20 km of spoor tracking you would expect to see two cheetah spoor. Spoor density is defined as the number of individual cheetah spoor per 100 km (Stander, 1998) and is derived from the spoor frequency, i.e. after 100 km of spoor tracking you would expect to see 'x' number of spoor. The desired sample intensity and sample effort were also determined. Sample intensity was measured by road penetration defined as the distance that must be sampled (km) as a ratio of the study area (km^2). Two roads were randomly selected, and the predicted spoor frequencies for 1000 replicates were simulated using Monte Carlo analysis, a form of bootstrap analysis (Efron & Tibshirani, 1993). This analysis was performed using Pop Tools 2.7.5 (Hood, 2006) with the Microsoft Excel (Microsoft Corporation 1985-2003) computer programme. The road penetration, spoor frequency and confidence limits (5% and 95%) were calculated, and the process was repeated by increasing the sample progressively to 2,3,4…12 transects with replacement. New mean spoor frequencies and confidence limits were calculated after every increase. The desired sample intensity was deemed as the point where the spoor frequency had reached an asymptote and increasing the road penetration failed to considerably alter the confidence limits. The desired sample effort was determined as the point where further sampling failed to significantly alter the spoor frequency, i.e. it was accurate and precise. Precision was defined as a less than 5% change in the coefficient of variance (CV) between the full sample and this defined point, whilst accuracy was assigned as the point the spoor frequency reached an asymptote. Sample effort was examined in the wet season (October 2005 to March 2006) and the dry season (April 2006 to September 2006), separately.

All statistical tests were performed with SPSS version 11.0.1 (SPSS Inc. Chicago, USA). Data was tested for normality using Komogorov-Smornov two-sample test and the appropriate parametric or non-parametric test was chosen accordingly. Pearson's correlation coefficient was used to examine the relationship between interdependent variables. All means are quoted with standard error (X±SE) and significance was measured at $P < 0.05$; two tailed.

Results

Eight transects (transects 1 & 2) were sampled 89-93 times (mean = 91.38 ± 0.50), whilst the remaining four transects (transects 3) were sampled 44-47 times (mean = 45.75 ± 0.63) during the first wet and dry season (Fig. 2.1). There was no significant difference between the spoor frequency for transects 1, 2 and 3 therefore the differences in sampling frequency are unlikely to have influenced the final results ($f = 0.179$, $P = 0.836$). A total distance of 8226 km was sampled. The total number of spoor detected was 191, this equated to a spoor frequency of 43.07 ± 9.74 km (i.e. one individual cheetah spoor per 43.07 km sampled) and a spoor density of 2.32 cheetah spoor per 100 km.

SAMPLE INTENSITY

At low road penetration spoor frequency had large confidence limits indicating the result was unreliable (Fig. 2.2). When road penetration reached 1 km: 3.34 km^2 the spoor frequency was 51.31±0.29 km with lower and upper confidence limits of 36.94 to 67.27 km. Increases in road penetration beyond this point led to only minor decreases in the confidence interval (Fig. 2.2), therefore a road penetration of 1 km: 3.34 km^2 or above would be recommended for spoor surveying and was deemed the desired sample intensity.

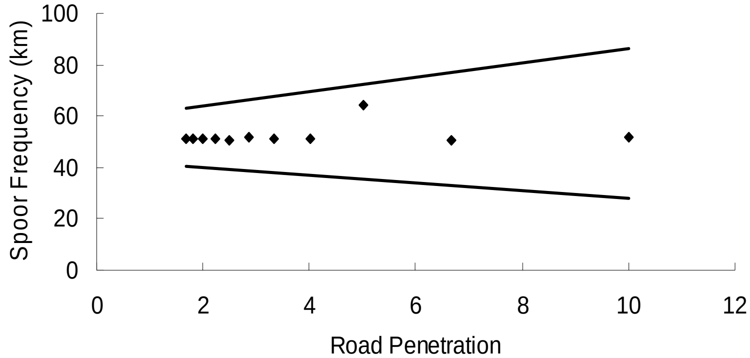

Figure 2.2 The relationship between road penetration[1] as a measure of sample intensity and cheetah spoor frequency[2]. The 5% and 95% confidence limits are shown.

[1] The total distanced sampled expressed as a ratio of 1 km surveyed : χ km^2 survey area (Stander 1998).

[2] The mean number of km's per individual spoor (Stander, 1998).

SAMPLE EFFORT

In the wet season (October 2005 to March 2006), the spoor frequency was accurate and precise when approximately 30 individual cheetah spoor were counted, this occurred after sampling 1080 km (Figs. 2.3 & 2.4). In the dry season spoor frequency was precise and accurate after approximately 90 individual cheetah spoor were counted, equivalent to sampling 3636 km (Figs. 2.4 & 2.5).

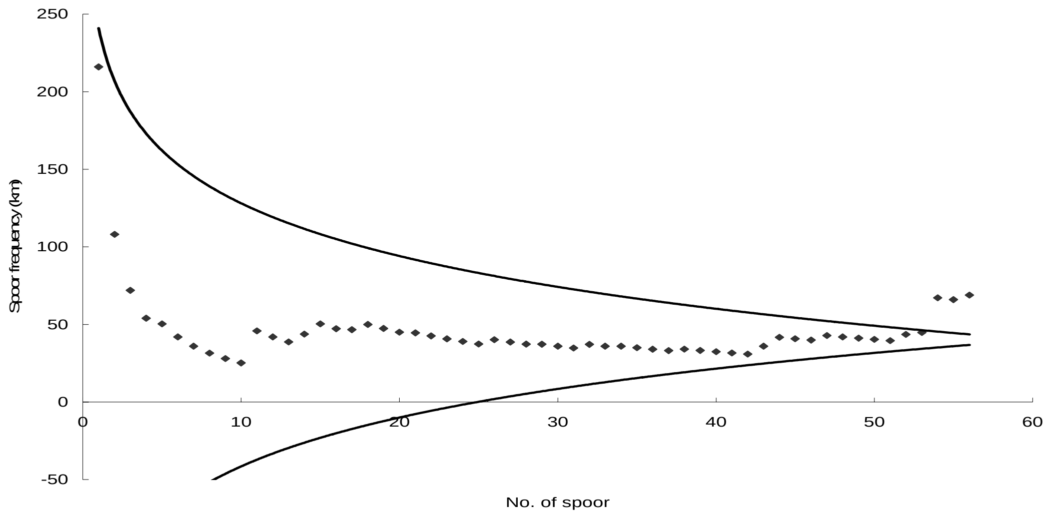

Figure 2.3 The effect of increased sample effort (measured by the number of individual cheetah spoor sampled) upon spoor frequency (mean no. of km's per cheetah spoor) during the wet season (October 2005-March 2006). The solid lines represent the 95% confidence intervals.

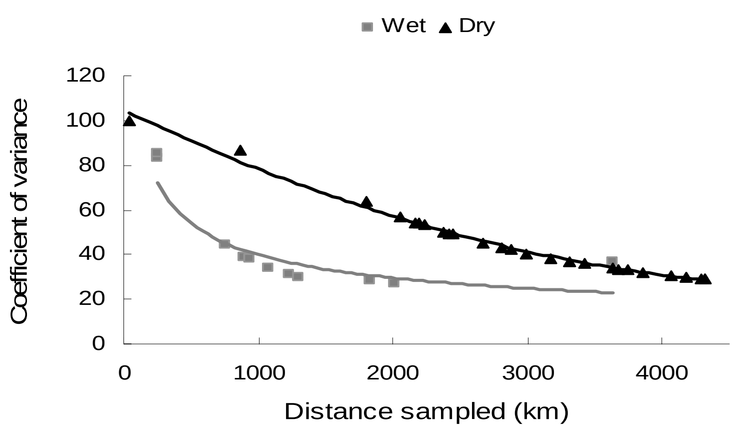

Figure 2.4 The relationship between sample effort measured by the distance sampled and the precision of spoor frequency, measured by the coefficient of variance in the wet (October 2005–March 2006) and dry season (April 2006–September 2006).

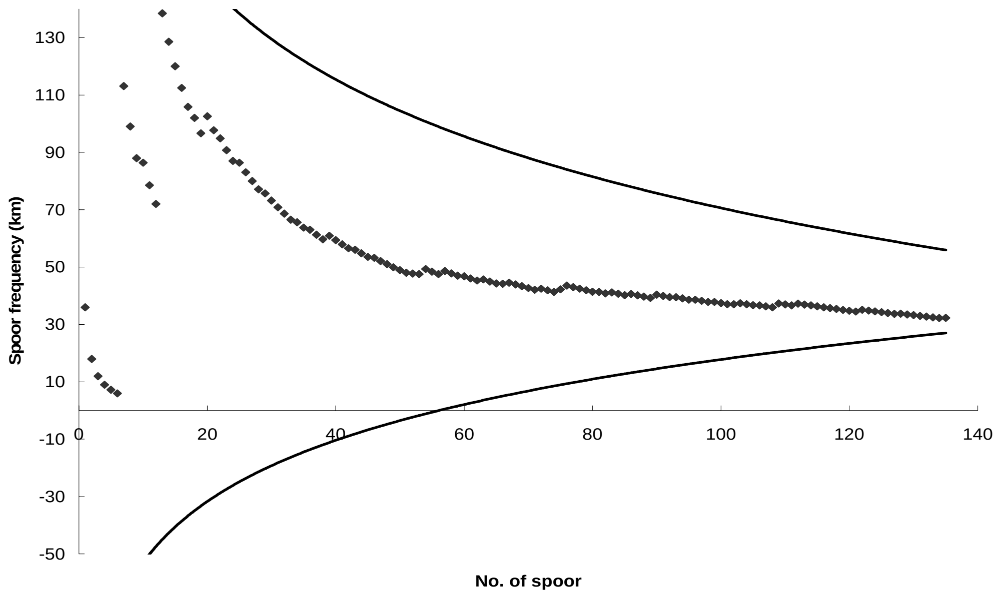

Figure 2.5 The effect of increased sample effort (measured by the number of individual cheetah spoor sampled) on spoor frequency (mean no. of km's per cheetah spoor) during the dry season (April 2006-September 2006). The solid lines represent the 95% confidence intervals.

TRUE DENSITY

A true density of 5.23 cheetahs per 100 km^2, ranging from 3.33 to 7.78 at the low and high points of the population respectively was recorded (Table 2.1). The results showed a linear relationship between spoor and true density in the wet and dry seasons, with trend line equations of $y = 0.403x – 0.071$ and $y = 0.569x – 0.406$, respectively.

Table 2.1 The true number of cheetahs in the study area per month. The wet season is in bold.

Month	F5[1]	F6[2]	Unidentified[3]	Total in study area	True Density per 100 km^2
Oct-05	**1**	**5**	**2**	**8**	**4.44**
Nov-05	**1**	**5**	**2**	**8**	**4.44**
Dec-05	**1**	**5**	**0**	**6**	**3.33**
Jan-06	**1**	**5**	**0**	**6**	**3.33**
Feb-06	**1**	**5**	**0**	**6**	**3.33**
Mar-06	**1**	**5**	**1**	**7**	**3.89**
Apr-06	6	5	1	12	6.67
May-06	6	5	1	12	6.67
Jun-06	6	5	3	14	7.78
Jul-06	6	5	1	12	6.67
Aug-06	6	4	1	11	6.11
Sep-06	6	4	1	11	6.11

[1] determined by cell collar data and monthly visuals
[2] determined by visuals every 11.8±2.2 days
[3] determined by researcher visuals, supported by game park officers and tourists photographs.

During the first wet season 1.45 cheetah spoor were detected per 100 km, this contrasts with 3.10 cheetah spoor per 100 km in the dry season. This increase in spoor density corresponded with the observed increase in cheetah population from 3.80 cheetahs per 100 km^2 in the wet season to 6.67 cheetahs per 100 km^2 in the dry season.

VALIDATION OF THE SPOOR CORRECTION FACTOR

The second wet season (October 2006 to December 2006) was sampled for 3 months, during this time the spoor frequency was deemed accurate and precise (at 864 km, 50 spoor). The spoor density in the second wet season was 4.44 cheetah spoor per 100 km, using the specified correction factor for the wet season the true density should equal 10.84

cheetahs per 100 km^2. However, by direct observation the true density was 7.22 cheetahs per 100 km^2. Therefore the correction factor overestimated true cheetah density. Modification of the spoor / true density trend line to incorporate both wet seasons data, resulted in a significant linear relationship between spoor and true density ($r = 0.968$, $P = 0.002$) and a trend line of y = 1.450x + 0.676 (Fig. 2.6).

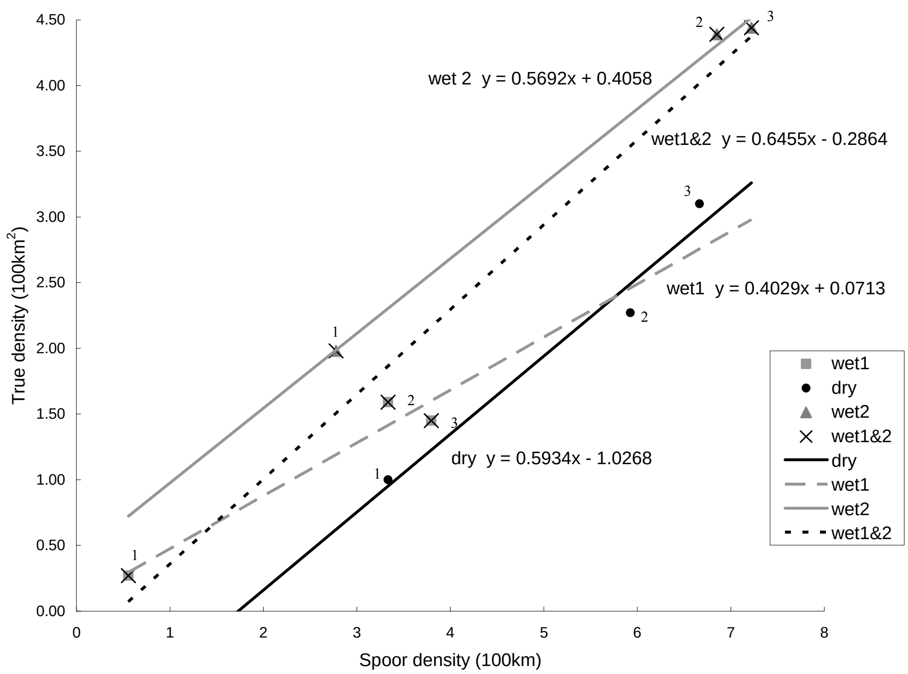

Figure 2.6 The relationship between true density and spoor density. The data points represent the true and spoor density relevant to one cheetah family[1], two cheetah families[2] and all cheetahs[3] present in the study area during the first and second wet season and the dry season.

Discussion

The use of spoor surveys as a tool to determine the true density of a species is of extreme interest in the field of conservation. However, the relationship between species density derived from a spoor survey and the true density of a species is only beginning to be understood (Stander, 1998; Funston *et al.,* 2001; Gussett & Burgener, 2005). This study intended to examine and test this relationship in a known population of free moving cheetahs in southern Botswana.

The spoor survey resulted in a spoor density of 2.32 cheetah spoor per 100 km. These results contrast with Funston *et al.,* (2001) who estimated a true cheetah density of 0.54 per 100 km^2 from photographic surveys and 0.57 per 100 km^2 from spoor studies in the dune/savannah habitat in the Kgalagadi Transfrontier Park, southern Botswana. The higher density reported within this study may be due to a combination of factors; including habitat type, prey availability, season and the absence of large carnivores such as lion and spotted hyaena. Cheetahs are known to survive better outside of protected areas, where there is reduced competition from these large predators (Winterbach, 2001; Marker *et al.,* 2003).

The sample effort required in the dry season (90 spoor, 3636 km) was higher than that required in the wet season (30 spoor, 1080 km) for spoor frequency to be deemed accurate and precise. It was observed that the spoor density increased between the wet and dry season, which corresponded to the addition of five cubs to the study area. These seasonal differences may be explained by the relationship between spoor frequency and road usage as a function of cheetah range utilization (Stander, 1998).

During the wet season, cheetahs may not have to travel as far for prey and habitat requirements, therefore they may stay in smaller areas for longer periods of time. The higher grasses will provide concealment for predators to stalk open areas for hunting while using the thicker bush areas for resting (Caro, 1994; Purchase, 1998; Broomhall *et al.,* 2003). This may concentrate the cheetahs' movements in a more confined area, which would enable a spoor study to reach the true population number in fewer kilometres in the wet season, and result in a different relationship between spoor and true density than in the dry season. This is supported by Marker (2002) who noted that cheetah annual home range size decreased with increased rainfall.

Conversely, during the dry season, increased prey movements to locate water mean cheetahs must travel further to satisfy dietary requirements. In combination with difficulties in locating thick bush for cover or to conceal cubs, cheetahs may occupy a larger area during this time. This is supported by GPS cell collar data collected during this study, which showed that F5 occupied a larger area and spent more time outside of the study area in the dry season, compared to during the wet season. Hence, it is reasonable to assume that in the wet season a spoor study can be conducted in a shorter period of time to obtain an accurate estimate of spoor density than is possible during the dry season.

Previous studies have found a sample effort of 30 spoor (1200 km) for leopards (Stander, 1998) or 50 spoor (1900 km) for lions in tree habitat, compared to 33 spoor (3480 km) in dune habitat (Funston *et al.,* 2001) to provide accurate results. This highlights the effect, variation in habitat, species, prey availability and season can have. These factors combined are known to affect cheetah behaviour and movement, not necessarily any one individually (Fitzgibbon, 1990; Caro, 1994; Broomhall *et al*., 2003).

Unlike previous studies on leopard and lion where spoor density over estimated true density (Stander, 1998; Funston *et al.,* 2001), this study showed cheetah spoor density to be an underestimate of true density in both the wet and dry seasons. This may be due to cheetah movement upon roads. The movement of cheetahs on roadways along with many other predators is partly due to its convenience and easy mode of travel (Smallwood & Fitzhugh, 1993). It was observed that in coalitions and families, cheetahs do not move in a straight line together down a road or path and they are often spread out sometimes up to 50-100 m apart. Therefore, the chances of all members being on the roadway at one time is rare, which may have resulted in the underestimation. Other factors may include misidentification and unobserved spoor that were not represented.

The quantifiable relationship between spoor and true density obtained in the first wet season could not be accurately applied to the second wet season when tested. Even with study area, survey technique, trackers and cheetah families remaining constant, the observed cheetah spoor increased by 306% in the second wet season, despite only a 190% increase in true cheetah density, therefore altering the relationship between spoor and true density. The first wet season had 364 mm more rain than the second wet season, this affected the habitat resulting in increased vegetation and watering points. These factors affected prey movements and density causing changes in cheetah behaviour and their use of roads. It was necessary to modify the wet season correction factor to incorporate the second season's data due to this variation in rainfall. By consolidating a below average wet season with a very high wet season the accuracy of the spoor and true density relationship was increased. This was tested using full and partial wet season data sets.

A limitation of this research was the small study area and the low number of study animals sampled. However, this allowed the population to be closely monitored and for individual family travel patterns to become well known. During this study we noticed a very cyclic and predictable movement pattern of the two main families. Within a month the two families would overlap in an area for up to 1 week and then move to different areas within the park for the remaining period. This pattern of movement was consistently repeated. Another limiting factor was the use of an open population containing breeding females over a long period of time. The addition of cubs and removal of sub-adults and females when they left to breed or were den bound, may have altered the spoor density and increased the required sample effort. This interruption in study animal presence should be considered in populations with breeding females, to ensure the study is carried out long enough to avoid underestimating the population. This study was unable to validate the dry season trend line with a second dry season. It may be necessary to do this in the future to refine accuracy.

In conclusion a quantifiable relationship between spoor and true density was established for the wet and dry season separately, with populations being underestimated by spoor. However this relationship required modification to incorporate the second wet season data to avoid overestimating true density. This study demonstrated the suitability of spoor surveys as a tool in long-term monitoring of populations and in the use of correction factors. However, these factors should be used with caution ensuring thorough testing of the relationship to accommodate changes in habitat and behaviour.

Future research on known cheetah populations, to repeat, test and refine this work, should be conducted. Behavioural patterns vary with season, habitat and prey and may cause an animal to react differently than what a mathematical calculation predicts. Calibration studies need to be performed numerous times in order to incorporate natural environmental fluctuations, atypical or singular events and trends over time within the correction factor. This study was unique in that it was able to not only develop a correction factor, but test and refine it in the same area, keeping most variables constant. Previous studies have been unable to test their correction factor in this manner, with a known population. This reinforces the importance of taking all variables into account when using a spoor survey to determine true density.

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CHAPTER 3

Home range use of free ranging cheetah on farm and conservation land in Botswana

Abstract

Cheetah movements should be considered when developing management strategies for long term survival and co-existence with humans. Although work has been done in Namibia, South Africa and Tanzania little data on the home range and territory size of cheetahs in Botswana has been published. This study aimed to estimate male and female home range sizes and daily movement on farmland and a game reserve in Botswana. Cheetahs were monitored from October 2003 to April 2007. The cheetahs were fitted with cell/GPS or VHF collars and released back into their home range. Single male home ranges were 494 km^2 and 663 km^2 and a coalition of two males had a home range of 849 km^2 (fixed kernel method). The females' home ranges were 241 km^2 and 306 km^2 (fixed kernel method). Females travelled a mean distance of 2.16 ± 0.07 km/day (range; 0-20 km/day) compared to 6.13 ± 0.30 km/day (range; 0-39 km/day) in males. Female maximum daily travel increased from 4.17 km/day when cubs where in the den to 8.16 km/day when cubs had left the den.

Introduction

Like many large carnivores, the worldwide cheetah population has declined dramatically over the last century, from 100,000 in 1900 to 12,000-15,000 in 1995 (Marker *et al.*, 2003a). The species is currently listed as vulnerable by IUCN (IUCN, 2007) and after Namibia, Botswana is believed to have the second largest free ranging cheetah population in the world (Purchase *et al*., 2007). However, little is known about the dynamics of Botswana's cheetah.

Recent studies have shown cheetahs to be more adaptable to vegetation and prey conditions than previously thought (Bissett & Bernard, 2007). They inhabit a wide range of habitats from open savannah to thick bush (Caro, 1994; Gros & Rejmánek, 1999; Durant, 2002; Broomhall *et al*,. 2003), and their home range sizes and movements vary greatly with vegetation, prey density, sex, social grouping, and age of cubs (Caro, 1994; Marker, 2002; Broomhall *et al.,* 2003). Home range sizes in cheetahs have shown large variation with estimates from 11 km^2 in males and 23 km^2 in females in Matusadona National Park, Zimbabwe (Purchase & du Toit, 2000) to 833 km^2 in females and 777 km^2 in non-territorial males in the Serengeti (Caro, 1994),

These studies were conducted in conservation areas, where cheetahs are protected from human persecution, but often subjected to high rates of intraguild competition and kleptoparisitism from lion *Panthera leo* and spotted hyaena *Crocuta crocuta*. Within Botswana and other southern African countries cheetahs are largely found outside of these protected areas, often at higher densities in agricultural, rather than conservation areas (Winterbach, 2001; Marker, 2002). In these areas human persecution is the main cause of death in adult cheetahs of breeding age (Marker *et al.,* 2003b) and conflict with livestock farming is believed to be a major threat to the overall cheetah population in Botswana (Klein, 2007). As such, it is important to study cheetah home range and movements within these farmlands to find insights, which may assist in reducing their conflict with humans.

A mean annual home range of 1651 km^2 was found in Namibian farmlands, significantly larger than recorded elsewhere (Marker *et al*., 2007). The reasons for this were unclear, in protected areas prey migrations, low rainfall and avoidance of predators are thought to increase home range size (Caro 1994; Stander *et al.* 1997; Durant 2000; Broomhall 2001; Marker *et al.* 2007) However, on farmland permanent water points ensure prey is sedentary and as aforementioned large predators are absent. Human disturbance and perturbation is known to effect species ecology and behaviour (Tuyttens & MacDonald 2000), Marker *et al.* (2007) believed this may be affecting cheetah home range size in Namibia. This paper intends to describe movements and home range size of free ranging cheetahs on Botswana farmland, to determine if a similar large home ranges exist.

Materials and Methods

STUDY AREA

The study was conducted in Jwaneng in the Southern district of Botswana and in the Ghanzi district of Botswana, from October 2003 to April 2007. The Jwaneng study area, (24^{o}33'09.3 S, 24^{o}43'38.0 E) primarily consisted of the Jwana Game Reserve (180.31 km^2), which surrounds the Jwaneng Diamond Mine, and the surrounding cattle posts. The cheetahs moved freely in and out of the reserve through warthog *Phacochoerus africanus* holes onto the surrounding farmland. The temperatures range from below zero to over 40^{o}C; with an annual mean rainfall of 398 mm (Greenway, 2001; Jwaneng Meteorology Department, 2007). The dry season is between April and October, and the wet season is between November and March. The area is sandveld with the major species being *Acacia mellifera, Acacia luedritzii* and *Boscia albitrunca* (pers. obs.). Vegetation is primarily open-semi wooded savannah mixed with moderate to thick bush. The topography of the area is flat, in a sandy aerosols environment with no hills or high rises, rivers or lakes.

The Ghanzi District study area (Ghanzi town: 21^{o}41'50.6 S, 21^{o}39'06.1 E) is part of the Kalahari ecosystem. Two thirds of this district is set aside for wildlife conservation or management (District Land Use Planning Unit-DLUPU 1995) with surrounding areas being cattle and game farms. The vegetation ranges from bush to open tree savannah, with dominant bush species of *Grewia* and *Acacia* spp. and dominant tree species being *Acacia erioloba* and *Boscia albitrunca* (Bekker & de Wit, 1991), this area is considered hardveld with some sandveld sections, with *Terminalia sericea* and *Lonchocarpus nelsii* dominating (pers. obs.). The wet season is between October and April, with an annual rainfall of 400 mm (Thomas, 2002). The topography is relatively flat with pans and valleys, dominated by Kalahari sandy arenosols (Thomas, 2002). There are no rivers or lakes in these areas, only manmade water points or natural pans within the farms, Central Kalahari Game Reserve (CKGR) and Wildlife Management Areas (WMAs).

CAPTURE AND TELEMETRY

Cheetahs were captured using double ended box traps (2 x 0.8 m) with a central treadle plate. The traps were set using live bait or limited access methods using acacia cuttings to block access to waterholes, marking trees or along fence lines.

On capture, cheetahs were transported in wooden squeeze boxes (1.2 x 0.8 m) to the field base where they were tranquilized by the project veterinarian using 30-40 µg/kg of medetomidine (Dormitor) and 1 mg/kg of tiletamine-zolazepam (Zoletil). A medical workup was conducted using methods adapted from Marker (2002). This included the fitting of a VHF radio or cell/GPS collar.

Six VHF radio collars and four cell/GPS collars were placed on 11 cheetahs in the Jwaneng and Ghanzi Districts of Botswana (one of the collars was refurbished and reused). In male coalitions, the collar was placed on one member of the coalition only. Telonics (Telonics, Arizona, USA) and Africa Wildlife Tracking (AWT) (Africa Wildlife Tracking cc, Pretoria, South Africa) VHF radio collars, weighing *ca* 100 g, were monitored using the Telonics H-antenna, with Telonics TR-4 receivers (148-152 MHz) from vehicles daily, or by plane weekly when possible. The AWT cell phone collars weighing 450 g, recorded GPS locations one to four times a day. Times were chosen considering likely rest and movement periods at different times of day. By choosing times of day when the cheetahs were moving, it would increase the chances of getting a satellite fix on their location. This would then increase our ability to accurately determine daily movement data. All cheetahs were released directly back into their home range, with the exception of one male who was released 30 km from his range in order to find a suitable release site. If released outside of their home range, only data recorded after they had returned was used in the analysis.

HOME RANGE ANALYSIS

Home ranges were calculated from GPS locations recorded *ca* every 24 hr. Only cheetahs with over 30 GPS locations (one per 24 hr) were included in the home range analysis. Animals were monitored for as long as possible and home ranges were tested for site fidelity using the animal movement extension program (Hooge *et al.,* 1999a) and for accuracy using incremental area analysis using the Ranges 6 V1.2214 program (Kenward *et al.,* 2003), in accordance with the recommendations by Hooge *et al.* (1999b). A home range size was deemed accurate if when calculated by the 95% peeled Minimum Convex Polygon (MCP) method, it reached an asymptote despite additional GPS locations.

The home range analyses were done using the animal movement extension program in conjunction with ArcView GIS 3.2 (Environmental Systems Research Institute Inc., 1992-2000). An individual's home range was calculated using the 95% peeled MCP (Jenrich & Turner, 1969) and the 95% fixed kernel method using the least squares cross-validation (LSCV) smoothing factor. The core home range was calculated with the 50% MCP and 50% fixed kernel method. The MCP area and shape is known to be heavily influenced by outlying fixes, and may include large unused areas causing an overestimation of home range size (Harris *et al*., 1990). Despite its limitations the MCP was the method of choice in the past and was recommended by IUCN in 1994 (Burgman & Fox, 2003), as such this method was chosen to draw comparisons with previous studies. Home ranges calculated from utilization distributions such as the fixed kernel method, are considered more accurate than MCPs (Worton, 1989; Worton, 1995; Seaman & Powell, 1996; Seaman *et al*., 1999) therefore were used in the majority of the analyses.

SAMPLE INTENSITY AND SAMPLE EFFORT

To determine how frequently data points should be recorded to obtain an accurate home range size and daily movements, sub-sampling was done. Only cell/GPS collared cheetahs with more than 1 month of study were included in the analysis, i.e. F5, M4, M5 and M6. Data were sub-sampled to simulate GPS locations being collected multiple times a day (2 or 4 times a day), once a day, twice a week, once a week, once every 2 weeks and once a month. The 95% and 50% fixed kernel methods were used to calculate new home range sizes for each data set, and daily movement was calculated as stated below.

The required sample effort, defined as the number of GPS locations required for a home range to be deemed accurate, was calculated using incremental area analysis using the Ranges 6 V1.2214 program (Kenward *et al.,* 2003). Home range size was determined using the 95% MCP method for 3, 4, 5….n GPS locations, until all the GPS locations were included. A scatter graph was plotted and the point at which an asymptote was reached was determined.

MOVEMENT

Using daily GPS readings the mean, minimum and maximum daily movement of cheetahs were calculated using the animal movement extension program (Hooge *et al.,* 1999a). If the interval between GPS locations was more than 24 hr, the distance travelled was calculated by dividing the total distance by the number of days of travel. If data were absent for more than 3 days, the distance was felt to be inaccurate and omitted. Cheetahs are known to occasionally move atypically long distances per day, to avoid biasing the mean with these journeys, outliers of two standard deviations were not included in the calculation of mean movement per day. M3, M4, M5, M6, F5 and F1 were included in the movement data, including a breakdown of F5 before the birth of her cubs, in the den and as the cubs matured.

Mean, minimum and maximum movement between 02:00-08:00, 08:00-14:00, 14:00-20:00 and 20:00-02:00 was calculated for M4 and M5. The distance travelled for F5 was calculated between 01:00 and 13:00 for 5 months then between 03:00 and 15:00 for the following 2 months.

Results

STUDY ANIMALS

Of the 11 cheetahs collared only five had more than 30 recorded GPS points and were used in the home range analysis. The remaining cheetahs were killed, or disappeared presumably due to collar failure, possible relocation out of range or death. Of all collared cheetahs 55% were known to be shot by humans (Table 3.1).

Table 3.1 Details of cheetahs collared since 2003. The cheetahs used in the home range analysis are shown in bold.

ID	Grouping at time of capture	Age (yrs)	Collar type	Botswana District	No. of days in Study	No. of GPS points	Outcome
F1	**female + cubs**	**5 (cubs 0.3)**	**radio**	**Southern**	**681**	**98**	**battery died**
F2	3 adult females	4	radio	Southern	1	1	unknown
F3	female + cubs	6-8 (cubs 1)	radio	Southern	12	4	killed
F4	female + cubs	4 (cubs 1)	radio	Southern	77	11	unknown
F5	**lone female**	**4**	**cell/GPS**	**Southern**	**553**	**480**	**collar removed**
M1	2 males	2-3	radio	Southern	1	1	unknown
M2	3 males	4	radio	Southern	34	13	killed
M3	single male	5-6	cell/GPS	Ghanzi	23	17	killed
M4	**single male**	**9**	**cell/GPS**	**Ghanzi**	**45**	**41**	**killed**
M5	**single male**	**3**	**cell/GPS**	**Ghanzi**	**141**	**137**	**killed**
M6	**2 males**	**3-4**	**cell/GPS**	**Ghanzi**	**59**	**39**	**killed**

HOME RANGE SIZES

Variation in home range size calculated by the MCP and the fixed kernel method was detected. Unless otherwise stated all results relate to the fixed kernel method. The mean female home range was 273.65 ± 32.44 km^2 (n = 2) and the mean male home range was 668.68 ± 102.31 km^2 (n = 3). This sex difference was also seen in core range size; mean female core range was 27.83 ± 17.51 km^2 and mean male core range was 70.48 ± 4.55 km^2 (Table 3.2).

Table 3.2 Cheetah home range (HR) and core range (CR) size and daily distance travelled.

	Home range size (km^2)							Distance travelled (km/day)			
ID	***n*[1]**	**95% MCP**	**50% MCP**	**CR as % of HR**	**95% kernel**	**50% kernel**	**CR as % of HR**	***n*[1]**	**Mean±SE**	**Min**	**Max**
F1	98	306.29	37.73	12.32	241.21	45.33	18.79	59	2.88±0.29	0.00	20.09
F5 all data	480	265.00	91.58	34.56	306.08	10.32	3.37	454	2.11±0.07	0.00	13.85
F5 pregnant	106	432.49	56.80	13.13	347.77	29.35	8.44	102	3.03±0.19	0.00	13.85
F5 den	58	10.51	0.97	0.09	59.37	0.49	0.01	53	1.12±0.12	0.00	4.17
F5 & cubs	316	245.23	105.35	42.96	343.45	87.57	25.50	292	1.98±0.07	0.00	8.16
Female mean±SE[a]	-	-	-	-	273.65±32.44	27.83±17.51	10.17	-	2.16±0.07	0.00	16.97
M3	-	-	-	-	-	-	-	14	6.50±1.00	1.51	18.27
M4	41	276.12	94.51	34.23	494.26	73.19	14.81	38	7.91±0.91	0.33	21.99
M5[2]	84	355.74	126.21	35.48	663.24	76.66	11.56	130	6.06±0.39	0.00	39.43
M6	39	597.90	102.43	17.13	848.55	61.60	7.25	32	5.06±0.62	0.12	18.53
Male mean±SE[b]	-	-	-	-	668.68±102.31	70.48±4.55	10.54	-	6.13±0.30	0.49	24.56

[a] home range and movement data determined from two female cheetahs, F1 and F5 (all data)
[b] home range data determined from three male cheetahs (M4, M5 & M6), movement data from four male cheetahs (M3, M4, M5, M6)
[1] *n* = number of GPS points
[2] HR is based on a 87 day period of site fidelity, the cheetah then moved north to a new area. The movement data is based on the whole study period

The mean female core range as a percentage of the home range was heavily affected by the period in the den, if this period was removed from the female data, the mean core range as a percentage of the home range was 25%; much higher than that found in males (Table 3.2). A larger home range was observed in the coalition of two males M6, than in the lone males (Table 3.2).

FEMALE WITH CUBS

During the second month of monitoring F5 travelled 12.5 km in 5 hr between 19:00 and 00:00. She remained in this area, *ca* 10-18 km outside of her normal home range, for 10 days, in the following 17 months she never returned to this area. She had five cubs *ca* 3 months later.

Whilst the cubs were in the den F5 occupied a much smaller range and travelled shorter distances per day than when the cubs had left the den. However, mean daily movements per day remained higher for the lone female, than when accompanied by cubs older than 2 months (Table 3.2).

HOME RANGE OVERLAP

F5 occupied the Jwaneng research area concurrently with an uncollared female (F6, identifiable from spoor) from October 2005 to April 2007 (Fig. 3.1).

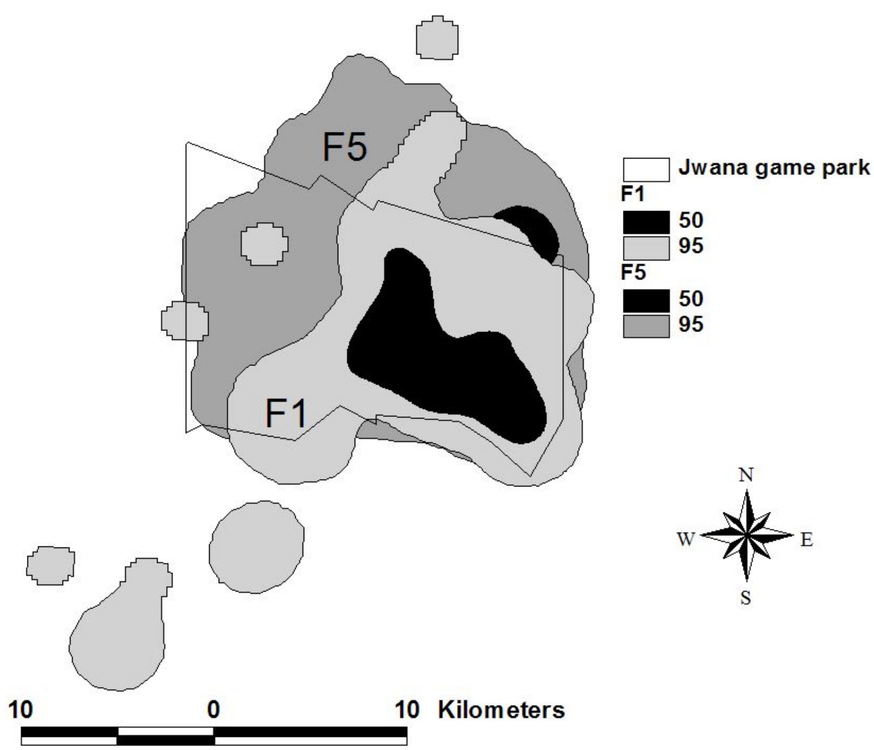

Figure 3.1 The fixed kernel home range of F1 and F5 in Jwana game reserve.

They both used the entire area of the game reserve, and neighbouring farms. F6 left her first litter in July 2006 and returned with a second litter in November 2006, where she continued to overlap home ranges with F5, and at least one of the female sub-adults from the first litter (identified from a distinctive hind foot shape).

During December 2006 M4 and M5 shared an area of *ca* 119 km^2 (based on an overlap of 100% MCP's, Fig. 3.2).

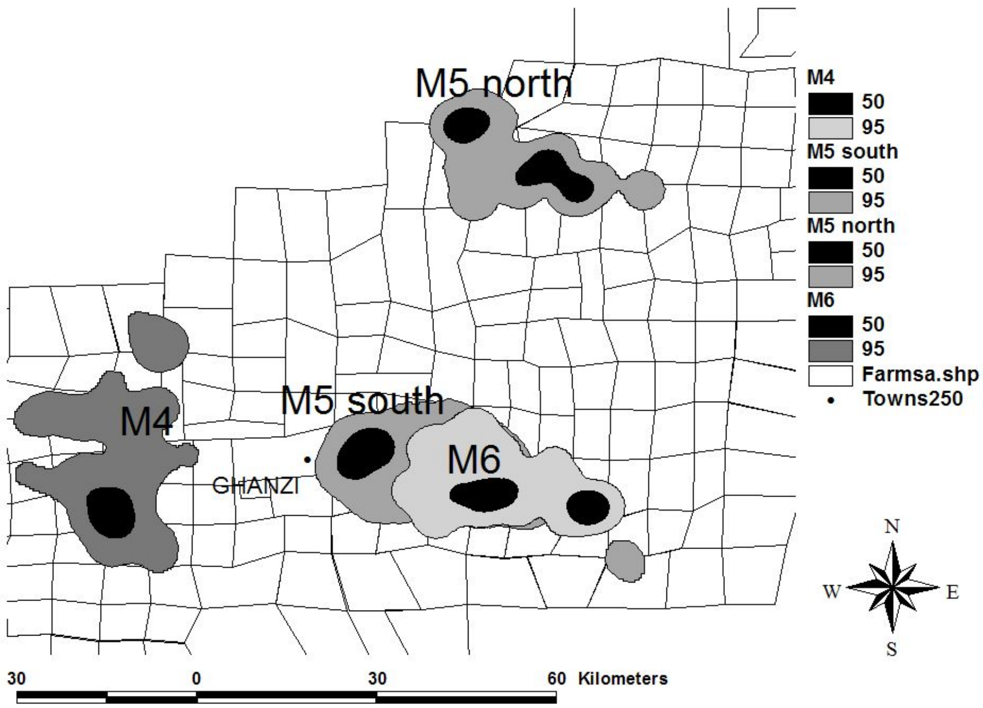

Figure 3.2 The fixed kernel home range of M4, M5 and M6, on Ghanzi farmland.

However during this time M4, the older male, moved east and his signal was eventually lost. He may have been displaced by the younger male M5. M5 only remained in this area for an additional 2 months before moving north, he too may have been displaced by two males known to be in the area.

SAMPLING INTENSITY AND EFFORT

Only minimal changes in home range size were detected when GPS locations were collected once or twice a week compared to the standardised once a day. However, when GPS locations were only recorded once every 2 weeks a large change in home range and core range size and location was observed (Table 3.3, Fig. 3.3).

Table 3.3 The effect of sample intensity on home range (HR) and core range (CR) size and distance travelled per day. Data were sub-sampled to produce data sets with different time intervals between GPS locations.

ID & GPS point interval	n^1	Home range size (km^2) 95% kernel	50% kernel	CR as % of HR	n^2	Distance travelled (km/day) Mean±SE	Min	Max
F5 (4x, 2x, 1x day)	801	309.41	9.92	3.21	452	2.30±0.07	0.00	17.23
F5 (1x day)	480	306.08	10.32	3.37	454	2.11±0.07	0.00	13.85
F5 (2x week)	157	298.55	12.31	4.12	151	1.17±0.07	0.00	7.79
F5 (1x week)	81	304.17	23.93	7.87	80	0.82±0.07	0.00	3.08
F5 (1x 2 weeks)	38	307.86	69.54	22.59	36	0.39±0.04	0.01	0.87
F5 (1x month)	19	311.81	69.45	22.27	18	0.18±0.03	0.01	0.35
M4 (4x day)	122	388.30	41.22	10.62	39	9.17±1.13	0.04	25.06
M4 (1x day)	41	494.26	73.19	14.81	38	7.91±0.91	0.33	21.99
M4 (2x week)	14	545.69	59.11	10.83	12	3.32±0.58	0.45	9.84
M4 (1x week)	7	491.64	63.03	12.82	6	1.47±0.56	0.56	2.05
M4 (1x 2 weeks)	4	723.00	189.99	26.28	3	0.92±0.30	0.48	1.50
M5 (4x day)	255	566.45	76.82	13.56	132	8.12±0.46	0.01	32.95
M5 (1x day)	84	663.24	76.66	11.56	130	6.06±0.39	0.00	39.43
M5 (2x week)	26	735.07	110.86	15.08	39	3.41±0.39	0.52	13.14
M5 (1x week)	13	742.22	97.20	13.10	18	1.84±0.29	0.43	7.39
M5 (1x 2 weeks)	6	831.71	244.36	29.38	3	1.79±0.45	0.10	3.91
M6 (2x, 4x day)	59	660.49	50.51	7.65	36	6.49±0.74	0.13	33.69
M6 (1x day)	39	848.55	61.60	7.26	32	5.06±0.62	0.00	18.53
M6 (2x week)	15	987.83	124.71	12.62	13	4.20±0.80	0.22	8.46
M6 (1x week)	8	819.85	273.32	33.34	6	1.32±0.26	0.87	3.20
M6 (1x 2 weeks)	4	443.17	108.47	24.48	3	0.93±0.26	0.51	1.41

[1] n = number of GPS points
[2] n = number of daily distances recorded

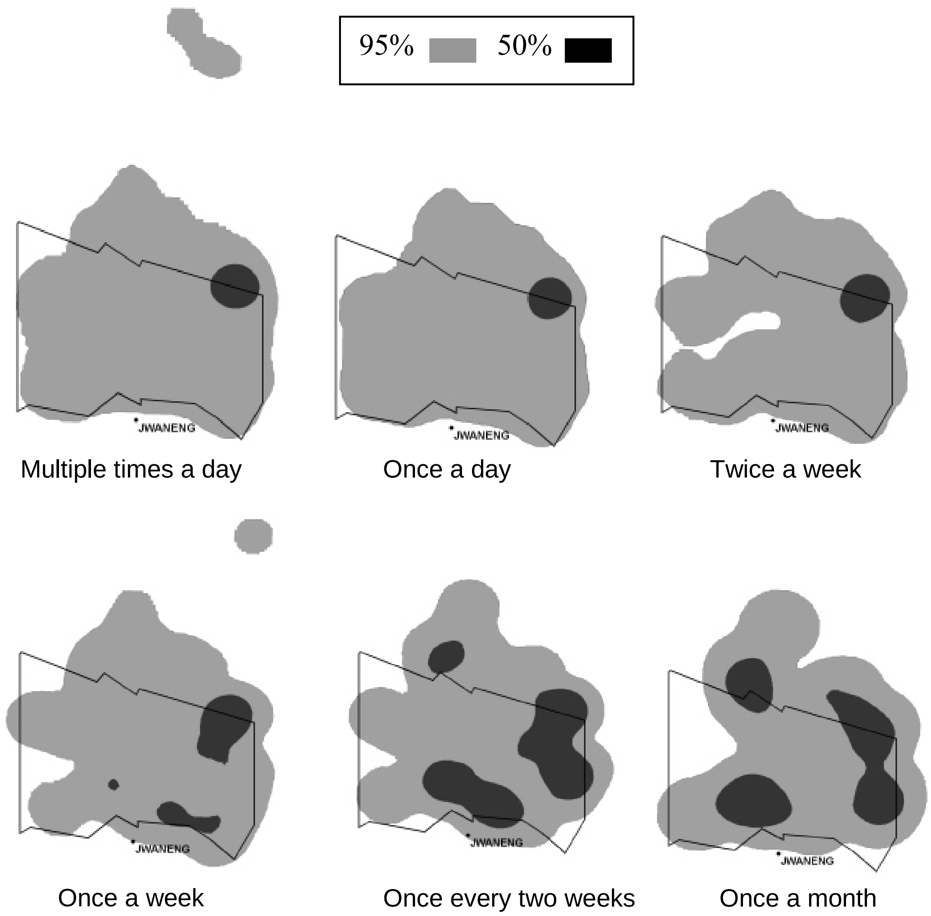

Figure 3.3 Changes in fixed kernel home range (95%) and core range (50%) size in F5 in Jwana game reserve, when the intervals between GPS locations were altered.

Sampling intensity was also shown to affect the accuracy of mean and maximum daily movements. The mean and maximum number of km travelled per day increased when GPS readings were obtained more frequently (Table 3.3).

A home range was considered accurate when the 95% MCP home range size reached an asymptote, i.e. further increases in the number of GPS locations did not alter the range size. The number of GPS locations may be considered the sample effort. Not all cheetahs reached an asymptote, in those that did this occurred between 30 to 100 GPS locations, over a time period ranging from 1 month to 3.5 months in cell/GPS collared cheetahs and 9 months in a radio collared female.

MOVEMENT

All cheetahs had minimum movements of 0.00 – 1.51 km/day, therefore it is not unusual for cheetahs to remain in the same location for over 24 hours (Table 3.2). Mean and maximum daily movement of males was larger than that of females (Table 3.2). Male cheetahs moved further during the early morning hours (02:00–08:00) and less during the hottest part of the day (08:00-14:00). They moved equal distances during the afternoon (14:00-20:00) and night hours (20:00-02:00), with the majority of long journeys taking place between 20:00 and 08:00 (Table 3.4). Females were observed to move more between the hours of 13:00 and 01:00 (15:00-03:00) than between 01:00 and 13:00 (03:00-15:00) (Table 3.4).

Table 3.4 The mean, minimum and maximum distance travelled within each time frame for males and females.

		Distance (km)		
Time	n[1]	Mean±SE	Min	Max
Males[2]				
02:00-08:00	165	3.46±0.26	0	16.18
08:00-14:00	164	1.14±0.12	0	7.84
14:00-20:00	163	2.16±0.15	0	8.46
20:00-02:00	163	2.44±0.22	0	14.47
Females[3]				
01:00-13:00 (03:00-15:00)	205	0.88±0.08	0	7.56
13:00-01:00 (15:00-03:00)	204	1.24+0.08	0	6.36

[1] n = number of daily distances recorded
[2] data from two males, M4 and M5
[3] data from one female, F5

SEASON

There were limited data to compare seasonal differences in cheetah home range size and movement. The home range and core range size of F5 was larger during the dry season, yet mean daily movement was highest during the wet season (Table 3.5).

Table 3.5 Home range size and distance traveled per day in the wet (October-March) and dry (April-September) season.

		Home range size (km^2)			Distance Travelled (km/day)			
ID and Season	n^1	95 % kernel	50% kernel	Core range as % of HR	n^2	Mean±SE	Min	Max
F5 wet	164	125.03	12.06	9.65	155	2.23±0.13	0.00	13.85
F5 dry	170	291.68	42.51	14.57	163	1.79±0.10	0.03	7.63
F5 wet 2	126	198.35	42.12	21.24	114	2.20±0.13	0.01	8.16

[1] n = number of GPS points
[2] n = number of daily distances recorded

PREVIOUS STUDIES

Home range size for both male and female cheetahs were larger than detected in previous studies, with the exception of coalition males and females in the Serengeti and all cheetahs on Namibian farmland (Table 3.6).

Table 3.6 Comparison of cheetah home range size. Sample size (number of cheetahs) is shown in brackets.

Study	Location	Protected area	Method	Home range size (km^2) Single male	Coalition male	Female
Caro (1994)	Serengeti Plains	Y	Minimum polygon	37 (22)	777 (9)	833 (19)
Mills (1998)	Kalahari Gemsbok N.P.	Y	MCP	-	125 (3)	320 (4)
Purchase & du Toit (2000)	Matusadona, Zimbabwe	Y	95% MCP	32.1 (2)	-	23.0 (1)
Broomhall, Mills & du Toit (2003)	Kruger N.P	Y	95% MCP	126 (1)	195 (1)	161 (2)
Bissett & Bernard (2006)	Kwande S. Africa	Y	95% Kernel	-	32.7 (1)	64.0 (1)
Cristescu (2006)	Shamwari. S. Africa	Y	95% Kernel	-		61 (2)
Marnewick & Cilliers (2006)	S. African farmland	N	100% MCP	-	250 (2)	-
Marker *et al.* (2007)	Namibian farmland	N	95% Kernel	1490 (15)	1344 (11)	2161 (15)
This study	Botswana farmland	N	95% MCP	316 (2)	598 (1)	409.9 (2)
This study	Botswana farmland	N	95% Kernel	579 (2)	849 (1)	668.7 (2)

Discussion

HOME RANGE AND CORE RANGE SIZE

The home range sizes (273.65 ± 32.44 km^2 for females and 668.68 ± 102.31 km^2 for males) of Botswana cheetahs were larger than reported in protected areas in previous studies (Mills, 1998; Purchase & du Toit, 2000; Broomhall *et al.*, 2003; Cristescu, 2006; Bissett & Bernard, 2007), with the exception of the Serengeti where female cheetahs had a home range of 833 km^2 and coalition cheetahs had a range of 777km^2 (Caro, 1994). Large home ranges were also reported on Namibian farmlands, averaging 1651 km^2

(Marker *et al.* 2007). The reason for these large ranges was unclear, in the Serengeti the migratory patterns of prey is thought to affect cheetah home range.

On Namibian or Botswana farmland, the permanent water points encourage sedentary, but often patchy prey distributions, with high prey densities on game farms but lower densities on those cattle farms which experience poaching. This patchy prey distribution may be increasing cheetah home range size on Botswana farmland. Additionally, human conflict and perturbation may affect cheetah behaviour causing them to move further and occupy larger home ranges (Marker *et al.,* 2007).

The disturbance of social groupings, when a coalition member is shot, may alter the remaining cheetah's movements, whilst any encounter with humans may cause the cheetahs to move away, increasing its overall home range. This may partially account for the larger home ranges recorded in males than in females, as males were predominantly on farmland and females in protected areas.

Female home range size was consistently smaller than male home range size by 200-600 km^2, and showed less variation in size than was found between the male cheetahs. These differences may be due to sex, with males having to travel further in order to find females for breeding purposes (Caro, 1994), or alternatively, they may be due to the location and outside stressors in the different areas of Ghanzi versus Jwaneng.

In Ghanzi, farmers captured the study males at marking trees; no females were captured. In Jwaneng, male and female cheetahs were collared; however the males were killed before enough data could be collected. Ghanzi cheetahs may have suffered increased competition with leopard and occasionally lion compared to Jwaneng where lion were nonexistent and leopard numbers were very low. Farmer conflict, with primarily game farmers in Ghanzi, was more prevalent in this area than in Jwaneng, where the females primarily stayed within the game reserve (i.e. protected) and encountered less conflict with communal livestock farmers using predator avoidance techniques. Cheetahs may need to move more frequently on farmland due to these conflict issues, as they may affect the availability of prey and the location of breeding females, therefore adding considerably to the stressors affecting cheetah movement on farms (Marker, 2003b).

The single males (M4 and M5) held smaller home ranges than the coalition of two male cheetahs (M6). Previous work (Caro, 1994) has failed to find this relationship, but sample size is too low to make any conclusions.

The increase in core range size of females after the den period may be due to the increased movements of the female and cubs in order to improve their chances of survival by finding more food to feed the cubs and/or to protect them from being located by other predators (Caro, 1994; Durant, 2000). Females have been shown to hunt larger prey during cub maturation (Caro, 1994), which was noticed in this study with the regular taking of adult hartebeest.

MOVEMENT

The daily movement of the lone female (F5) decreased significantly when accompanied by cubs. Conversely, in the Serengeti, Caro (1994) observed that lone females spent less time moving than females with cubs. This observed difference may be due to F5 leaving her home range (10-18 km) to possibly find a suitable male (she gave birth to five cubs *ca* 3 months later). Caro (1994) observed that females will occasionally travel large distances from 5-12 km a day for unknown reasons, although in these cases he felt it was unlikely they were looking for a mate. This long distance travel was also noted with F1, who after leaving her first litter of cubs moved 14 km south-west of the reserve, returning 4 months later with a second litter. This repeated behaviour may indicate the lack of suitable males in the area for breeding, possibly due to human persecution. Alternatively, the females may be searching for numerous males to breed with in order to increase genetic variability, thereby possibly increasing cub survival (Gottelli *et al.,* 2007).

The maximum and mean daily movement was larger in males than females, an observation also made in Namibian cheetahs (Marker, 2002). This difference may be explained by their need to defend their territory in order to obtain females, or the males may have travelled further to occupy territory vacancies or been forced to move to avoid human conflict or competition with other cheetahs or predators. Often single males are pushed out of an area by coalitions or other territorial single males, forcing them to take on a more wandering form of life style (Durant *et al.,* 2004). This may have been the case with M5 who occupied a home range of 663 km^2 for 87 days, then travelled 40 km north to set up a 422 km^2 range. M5 only returned to his southern home range for three days before moving back to the northern area. This may have been due to the movement of a known coalition of two males into M5's southern range.

Males were shown to travel larger distances in the late evening and early morning (20:00-08:00) than during the day. All long distance (> 8.5 km) travel occurred during the study period of November – April when there was approximately 4 hr of daylight during those timeframes. Therefore it may be assumed that a large proportion of this movement was in the dark. Cheetahs are generally believed to be diurnal, however increasing evidence is showing that male cheetahs frequently move/hunt at night even in areas with a high lion presence (Bissett & Bernard, 2007). Females moved larger distances from 13:00-01:00, than from 01:00-13:00. A more detailed analysis with shorter time periods would be required to speculate about their movements, and their preference for daylight or darkness for travelling or hunting, and the affect cub presence has on that decision.

SEASON

The female home range size in the dry season was slightly larger than during the wet season. This may be due to the increased movement of prey during the dry season for food and water requirements, along with vegetation changes that may affect cheetah cover and hunting capabilities. There was not enough data to compare male seasonal movement changes.

SAMPLE INTENSITY

An accurate home range size is essential for cheetah management decisions. The selected interval in GPS readings could result in inaccurate estimates of home range size (Rooney *et al.,* 1998), which could be misleading as to the total area the cheetah population would need in order to be self sustaining. The selected interval also influences the location and size of the core range, which may place an emphasis on the wrong size of areas and location of habitat actually required for conservation. Although non-significant the biggest difference recorded was between readings obtained once a day and once every 2 weeks. Girard *et al*. (2006) also found that habitat selection could be accurately determined in Moose *Alces alces* when GPS locations were selected once every 1, 3, or 7 days, but was inaccurate when recorded once every 14 days.

Ideally, readings should be obtained daily, however, in long term studies where animals are likely to remain in the study area for a long period of time, it may be possible to obtain an accurate home range size at longer intervals between GPS locations. In this study, the F5 female had been followed eight times longer than the males. For the female it was possible to obtain an accurate home range size when readings were obtained twice a week, but in males anything less than every 24 hr became increasingly inaccurate.

Additionally, the accuracy of mean and maximum daily movement data was shown to decrease when GPS locations were recorded less than once a day. Reynolds & Laundre (1990) and de Solla *et al.* (1999) concluded that increasing the time interval between observations under-estimates the true distance travelled. If a study intends to closely examine movement data, readings of at least once per day should be recorded. The importance of time interval must be understood when designing a monitoring program, in conjunction with the financial considerations of point collection using cell/GPS collar downloads versus VHF monitoring. GPS locations are frequently accurate within 7 m for some collars; however the possibility of problems with satellite alignment frequently causes loss of data. Therefore, setting the GPS collars to download at least twice a day increases the chances of collecting enough positional data to get reliable results for interpretation. It would be less expensive and time consuming than daily VHF monitoring.

A limitation of this study was the low number of collared animals in conjunction with the length of time the collared cheetahs were studied. Collar malfunction and dispersal of cheetah out of monitoring range (Durant *et al.,* 2004) had a negligible effect, however cheetah-farmer conflict resulted in at least 55% of losses (some of the cheetahs lost to unknown factors were most likely killed). These killings were not due to actual livestock loss, but appear to be due to the perceived threat of loss and an overall intolerance to predators, this problem was also recorded in Namibian farmlands (Marker *et al*., 2003b).

This is the first study in Botswana specifically examining cheetah home range size and movements. A trend in female and male range size and distance travelled was observed, but more work needs to be done to establish the influence of sex, human persecution and intraguild competition. Studies in protected areas such as the CKGR and

WMAs of Botswana are needed to establish the differences between cheetah movements in protected areas versus unprotected areas such as farmlands.

The understanding of cheetah movement between the sexes and during cub rearing is important for the development of management strategies that will protect suitable habitats for these populations to survive. By continuing to study and understand these needs, the management of populations will be more self sustaining, through the maintenance of farmland and protected areas. The large reported home ranges of males in this study (668km^2 encompassing 11 farms (roughly 60km^2 each)) means that exposure to just one intolerant farmer in the area may be a threat to the individuals survival, and may have far reaching effects altering social patterns and ranging behaviour over a large area. Large home ranges may cause cheetah population estimates to be inflated due to repeated sightings throughout one cat's home range (Marker *et al*., 2007). This may add to the communities' intolerance of cheetahs. As highlighted in this study, the greatest difficulty was in obtaining sufficient data from the study animals before they disappeared or were killed. This signifies the plight of the cheetah farmer conflict in these areas, and the need for continued community education and research on the effectiveness of predator management strategies and their implementation.

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CHAPTER 4

The Rehabilitation and Release of Three Captive Cheetah Cubs on a Game Farm in Tuli, Botswana

Abstract

The rehabilitation and reintroduction of orphaned or captive animals, primarily endangered species is becoming an important management tool. However, methods, costs and outcomes are often poorly documented. This study took three orphaned cheetahs *Acinonyx jubatus* at 8 and 12 weeks of age, bonded them as a sibling group and rehabilitated them to become self sufficient, before eventual release onto a game farmland.

Detailed observations of their hunting and behaviour development were taken at 1.5 years of age. They were released at 2 years old onto a 9000 ha game farm where they were monitored using cell/GPS collars, and observed weekly. Home ranges were from 44- 121 km^2, the cheetahs were hunting successfully and exhibited behaviours similar to wild cheetahs. They travelled primarily between 04:00- 11:00, and 18:00- 00:00, and their mean daily travel ranged from 4.49- 9.4 km/day.

The cheetahs left the farm at 2.5 years old and were subsequently killed. Both females crossed into South Africa, where one was killed by illegal hunting, the other by a drive by shooting. The male was killed by the Botswana wildlife department, after mistaking him for a leopard. Although the rehabilitation of self sustaining animals was accomplished, they all died due to the same realities wild cheetahs encounter everyday. While rehabilitation may be achieved in a timely and cost effective manner, alone it will not secure the fate of orphaned wildlife, without the education of farmers and government

agencies to the plight of predators and other management options. This is a viable alternative for orphaned cheetahs with continued monitoring and publishing of results of future trials.

Introduction

The cheetah *Acinonyx juabtus* is present in its largest number in Namibia at close to 3000 (Marker *et al*., 2003), followed by Botswana at approximately 2500 (Klein, 2007). These countries account for almost half of the free ranging cheetahs in Africa. Yet they are threatened by human conflict and habitat loss (Marker-Kraus *et al*., 1996, Marker, 2003), illegal trade and poaching (Problem Animal Control (PAC), internal reports). In Botswana, these issues have caused incidents of orphaned or injured cheetahs that have been confiscated by the Department of Wildlife and National Parks (DWNP) and given to Cheetah Conservation Botswana (CCB) to put in a rehabilitation program for eventual release into the wild.

Wildlife rehabilitation is an essential component in the reintroduction and breeding programs of many endangered species (Holcomb, 1995). Reintroductions and translocations are becoming increasingly important tools for population and species management (Griffith *et al*., 1989; Stander, 1990; Magin *et al*., 1994; Wolf *et al*., 1996) and may be important for the survival of many endangered and threatened species worldwide.

Owing to the cheetahs' vulnerable status (IUCN, 2007) it is desirable to keep orphaned cheetahs within the wild population. The formulation of a repeatable, cost effective method of rehabilitation, to raise and release these underutilized animals, would aid in increasing, or at the very least sustaining, a viable wild population. The National Wildlife Rehabilitator's Association (NWRA, 1995) defines wildlife rehabilitation as "*the* *treatment and temporary care of injured, diseased and displaced indigenous wildlife, and the subsequent return of healthy viable animals to appropriate habitats in the wild*". In situations where cheetahs are injured or orphaned due to human related incidents, action must be taken to rectify that imbalance by giving the opportunity for those animals to be released back into the wild breeding population. The success of a reintroduced animal is recognised by the IUCN (2007) as one that produces viable offspring. Short term goals are for the released animal to support itself (i.e. through hunting) and to successfully interact within its natural environment.

Botswana does not have protected fenced reserves that allow for the relocation of rehabilitated orphaned or problem translocated cheetahs. Currently these animals may be euthanatized, kept in life long captivity, or released onto national parks (Gemsbok National Park, GNP), game reserves (Central Kalahari Game Reserve, CKGR), wildlife management areas (WMAs), or farmland. With a successful rehabilitation program these animals could be used to re-establish cheetahs into areas where the population has declined or disappeared due to human conflict, poaching, geographical isolation or intraguild competition (Caro, 1994; Laurenson, 1994; Durant, 1998; Marker *et al.*, 2003). In Botswana, where fenced reserves are not applicable, it is essential that the released cheetah does not interfere with the human population or livestock whilst adding to the current population a self sustaining, breeding animal.

The lack of fenced reserves in Botswana sets it aside from South Africa and Namibia where these reserves contain the majority of predators and game. In Botswana 17% of land is for National Parks/Reserves, with an additional 21% of land allocated for WMAs (Herrmans, 1998). The need for fenced reserves as the only place to find predators and game will hopefully remain avoidable with 38% of Botswana land protected for wildlife. It has been shown that cheetahs survive better in areas with lower densities of lions *Panthera leo* and hyaenas *Hyaena brunnea* (Kelly & Durant, 2000), and in areas with commercial farmland, where Marker *et al*. (2003) found up to 90% of Namibian cheetahs. However the removal rate from farmers due to the perceived threat of cheetahs was the greatest factor negatively affecting cheetah numbers. Increased cheetah survival is a result of working with farmers to increase livestock management protection methods, and providing a value to having cheetahs on their farms, be it through trophy hunting or ecotourism. If ecotourism continues to grow the eventual release or maintenance of current cheetah numbers on farmland may be possible. Increased interest by tourists wanting to see predators on game farms could create financial benefits for those farms that provide a safe haven for cheetahs.

There have been reintroductions and translocations of other endangered or problem species with varying degrees of success. These include wild dogs *Lycaon pictus* (Gusset *et al*., 2006), wolves *Canis lupus* (Bradley *et al*., 2005) black bear *Ursus americana* (Blanchard & Knight, 1995) and lions (Stander, 1990). These methods are becoming popular management tools for endangered wildlife populations (Linnell *et al*., 1997).

There is limited information (Pettifer, 1981; Ferguson, 1995; Schumann, 2006 pers. comm.) on the rehabilitation and release of captive-bred or orphaned cheetahs into the wild. The publishing of the results, costs and methods of rehabilitated and released animals are rare, but needed if this is to become a useful management option.

In 1979 three male captive bred DeWildt cheetahs were released on Timbavati private nature reserve (Pettifer, 1981); two survived and one was killed by a snake. In 1994 two captive bred female cheetahs were released into Mthethomusha game reserve (Ferguson, 1995); one was killed by spotted hyaena *Crocuta crocuta* within 2 weeks and the other was captured and returned to captivity due to poor condition after 1 month. In

2006, the Cheetah Conservation Fund (CCF) released a wild caught female, with two captive born cubs on property owned by CCF. (B. Schumann, pers. comm.). The mother died and the cubs survived 6 months on their own, before being recaptured as they were approaching a known cheetah killing farm.

The results of these studies show various levels of success and failure. Most of the cheetahs learned to hunt successfully, except for the two captive-bred females, while competing predators and human conflict remained the biggest threats to their survival.

This study is the first recorded rehabilitation and release of three orphaned cheetah cubs of different ages and sex, into the wild. Their management was adapted for each individual. If orphaned or injured cheetahs are to be released into the wild, rehabilitation techniques must be repeatable, tested and recorded in order to provide successful methodology in conjunction with diligent post-release monitoring to determine its success.

Rehabilitation needs to be planned and carefully organized in reference to habituation and behaviour development in captivity, as these developments can affect behavioural responses later in life (Bekoff, 1989). There must also be careful consideration of suitable release sites, prey availability and potential for human conflict (Pettifer, 1998; Bradley, 2005). Most importantly, long term monitoring and publication of results (Hunter, 1998) must occur to develop predator rehabilitation into a viable management tool (Linnell *et al.*, 1997).

Materials and Methods

STUDY ANIMALS

In December 2004, two female cheetah cubs (Alice and Gracie) of 10-12 weeks old were taken from the wild by a farmer in the Ghanzi district in western Botswana in order to use the cubs for breeding and to sell. In the wild cheetah cubs remain in the den until 8 weeks old, and do not actively accompany their mother on hunts until at least 4 months old during weaning (Caro, 1994). They, therefore, were unlikely to have participated in hunting practises in the wild by the time of capture. On January 1, 2005, the cubs became ill and were confiscated by DWNP and turned over to CCB. They were transported to Jwaneng where they were kept alive by subcutaneous fluid therapy and a slow introduction to food for 10 days. The illness was not identified, but they made a full recovery within 1 month, and were released into a 20 x 40 m boma.

In December 2004 a single male cheetah was illegally captured by another farmer in the Ghanzi district. This cheetah was approximately 3 months of age when separated from his family, and was consequently chained by the neck and tied to a wire on the farmer's veranda. The animal was chased by the dogs and continually the centre of human interactions. On February 3, 2005 the DWNP notified CCB of this incident and was given the confiscated cheetah for the rehabilitation project.

The now 6 month old cheetah was taken to a 2 ha holding boma at Mokolodi Nature Reserve in Gaborone, where it was held for 2 months before being transported to Jwaneng Game Reserve base camp and transferred into a 20 x 40 m boma. The male was introduced into the boma, separated from the females by the shade cloth covered fence of the lockdown area. They were allowed to view each other for three days through the fence before the gate was opened.

HOLDING FACILITIES IN JWANENG AND TULI

The initial holding facility was located in Jwaneng in the Southern district of Botswana, from January 2005 until May 2006. The Jwaneng base camp (24^{o}31' S, 24^{o}43' E) was located in Jwana Game Reserve (19,000 ha), which surrounds the Jwaneng Diamond

Mine. Ad lib observations were made during feeding times and throughout the day during this time period. After 1.5 years in the Jwaneng boma, the three sub-adult cheetahs were moved to a second boma within a 100 ha enclosure where they would be released in order to develop their hunting skills. The second holding enclosure was located in eastern Botswana on Kwalata, a 9000 ha game farm. This farm was located along the Limpopo River (23º03' S, 27º52' E), on the eastern side that borders South Africa. They were held in this boma for three weeks before release into the 100 ha enclosure, during this time observations were made while feeding on live kills, and randomly throughout the day.

Boma construction

The bomas contained 2-3 trees and woody vegetation and grasses, as well as a 2 x 3 m shelter with platform made of sticks and wood. The boma was divided into a lockdown area of 19 x 10 m, with a 1 x 10 m connecting alley that opened into the remaining 20 x 30 m area in back of the boma. The perimeter fence had a 1 m overhang on the inside of a 2.4 m high 5 x 5 cm bonnex fence, with the alley being completely covered at the top. The perimeter fencing was buried down into the ground 50 cm in order to prevent animals from digging into the boma area. If animals could dig into the boma, there was the possibility of the cheetahs exiting through those holes.

All outer perimeter fences (20 x 40 m) and the inner lockdown area (10 x 20 m) were covered with a double layer of 1.8 m shade cloth in order to limit visibility of human activity. In the alley 5 m down from the lockdown gate there was a second gate. Both the alley gate and lockdown gate had guillotine style sliding sections that allowed for separation of animals and food placement without visibility of humans. Both bomas were isolated from human interactions with the exception of feeding times. The boma within the 100 ha pen was of similar design, but lacked shade cloth, allowing a view of the surrounding bush.

The 100 ha enclosure

The cheetahs were released into the 100 ha enclosure at 16 (Alice, Gracie) and 19 (Decu) months of age. The area was enclosed by an eight strand 2.4 m high, electrified game fence, with four electric wires inside and one outside low to the ground. The area was stocked with 40 impala *Aepyceros melampus*, including juveniles, sub-adults and adults, five tsessebe *Damaliscus lunatus*, with free movement of steenbok *Raphicerus campestris*, common duiker *Sylvicapra grimmia*, springhare *Pedetes capensis*, scrub hare *Lepus saxatilis* and warthog *Phacochoerus africanus* via warthog holes. Due to the bottom electric line the cheetahs remained in the camp, whilst other animals moved freely in and out. The enclosure was dominated by medium to thick bush in the centre (40% of pen), with open wooded savannah areas in the northern and south eastern areas (60% of pen). There was one water point and an elevated dirt mound 3 m high located centrally in the enclosure. There was a road around the perimeter of the fence line, one road down the centre of the 100 ha area, with two 2-tracks through the thick bush areas.

Kwalata game farm

The cheetahs were released onto a 9000 ha game farm at 22 (Alice and Gracie) and 25 (Decu) months of age. The farm contained rocky outcrops in the central area and to the far west. The river bordered the eastern side of the property with river fingers entering the property providing a moderate 25 ha pond/wetland area with crocodile and waterfowl. The farm contained ostrich *Struthio camelus*, blue wildebeest *Connochaetes taurinus*, impala, red hartebeest *Alcelaphus buselaphus*, African oryx *Oryx gazella*, greater kudu

Tragelaphus strepsiceros, eland *Tragelaphus oryx,* white rhino *Ceratotherium simum* and giraffe *Giraffa camelopardalis.*

The farm managed orange *Citrus sinensis* and mango *Mangifera indica* orchards with a working staff of over 80 people who lived within the farm. The living areas and game camps were separated by game fencing along the river from the active game farm where the cheetahs and game resided. The farm was surrounded by a 2.4 m bonnex game fence that was patrolled daily, with holes being filled and repaired. Leopard *Panthera pardus*, lion and brown hyaena *Hyaena brunnea* were present during this study.

The farm allowed five game hunts per year by tourists and weekly hunts by family between March and August with a maximum of 30 impala being killed per week. There was one manager, and two gate people at the western entrances of the farm. Human contact was very low due to the separation of the inhabited areas by fencing, and the passing of vehicles down only one road through the farm.

DIET

The cheetahs were fed 1.5-3.0 kg of meat with bone per day, with a daily Calcium supplement of Calsup (5 gm/day). They were fed once per day, 6 days a week with one starvation day a week. As they grew older (12-15 months) the quantity and timing of feedings was varied (with 1-3 starvation days) to simulate hunting success in the wild (Schultheiss *et al*., 1998). Owing to an anthrax *Bacillus anthracis* outbreak in the reserve, game meat could not be fed to the cheetahs. Donkeys *Equus asinus* were therefore culled monthly from outside cattle posts, butchered and frozen. The carcass was fed to the cheetahs (Schaller, 1968, Skinner & Smithers, 1990) excluding the excess fat, intestines and rumen. The lower legs and tails were used for enrichment in the boma.

Introduction to live food

When the cheetahs were 9 (Alice and Gracie) and 12 (Decu) months old, live food (chickens *Gallus gallus)* was introduced after two starving days in order to determine their killing abilities. Live rabbits (order lagormorgha), were introduced at 12 (Alice and Gracie) and 15 (Decu) months of age. The introduction of live food only happened on those two occasions. A complete impala carcass was introduced for the first time in the Tuli boma at 15 (Alice and Gracie) and 18 (Decu) months of age, to see how the cheetahs would open and feed on large prey that they had never seen before. Four days later, the cheetahs were given an injured, live impala in order to determine their ability to kill larger game. Due to a game capture operation on the farm at the time, four injured impala were found and given within a 4 week period. This allowed each of the cheetahs' one opportunity to make a kill within the Tuli boma before being released into the 100 ha enclosure.

This one opportunity for the cheetahs to have a controlled experience on how and where to grab larger game and effect a kill, may provide an advantage for future kill attempts in an uncontrolled environment. This method provides the cheetahs with an experience they would have been given by their mothers at a younger age, when she would provide live prey for them to practice killing (Caro, 1994). The one advantage at this time is the size and strength of cheetahs at this age (15 months), their ability to kill is more efficient and does not take as much repetition as in the wild when they are smaller and weaker.

RELEASE INTO 100 HA ENCLOSURE AND OBSERVATION PROCEDURES

At 16 (Alice, Gracie) and 19 (Decu) months of age, the cheetahs were each fitted with a VHF collar (Telonics, USA) and released into the 100 ha enclosure. They were monitored daily with observation periods from 06:00-12:00 and 15:00-19:00 hr. 7 days a week for a total of 48 days. Date, time, weather, start and finish GPS locations were recorded daily and behavioural observations were recorded every 15 min, in accordance to the categories defined in Table 4.1.

Table 4.1 List and explanation of recorded behaviours and category of assignment.

Observational	Resting	Locomotive	Play
SI - sitting	PO - passed out	W - walking	CH - chasing
ST - standing	LR - lying relaxed	R - running	PL - play
LA - lying alert	GRs - groom self	PA - pacing	FI - fighting
LS - Lying sternum	RO - rolling	TR - trot	CHR- chirping
LSHU - LS head up	Str - stretching	STr T - stretch on tree	
LSHD - LS head down			
Hunting	**Exploratory**	**Contact**	**Feeding**
SB - searching behaviour	STT - standing using tree	T - touching each other	DR - drinking
STK - stalking	CL - climb	GR - grooming	E- eating
CR - crouched	SM - scent marking		
PC-pounce	SC - scenting		
ATT-attack			
	Kills	**Unknown**	

Additional information regarding hunts, kills and eating behaviour including belly size which was rated according to standards by Caro (1987) and Frame & Frame (1991) on a scale from 0-14, 8 being normal, was collected when possible. The start of a hunt was recorded when the cheetah began to chase the prey, it was then labelled as failed or success. Hunting behaviours such as stalking or searching were also recorded to determine the amount of time spent in hunting behaviours. Every behaviour change was recorded during the observation periods, if the behaviour stayed consistent it was documented only every 15 min, and if the animal was not seen or being observed during that time it was recorded as unknown. The male was more elusive and wary of humans, and to lower stress levels and avoid affecting his natural behaviour, observation time was not forced, and therefore he was observed less than the more habituated females.

RELEASE ONTO THE 9000 HA GAME FARM

On January 31, 2007 at 23-26 months of age and after 7 months in the 100 ha enclosure the three cheetahs were released into the 9000 ha game farm. A health check was performed, body measurements and blood were taken and their VHF collars were replaced by GPS/cell/VHF Tellus Basic 3H2A collars, 350 grams (Televilt, Sweden). Daily downloads of two GPS locations per day were recorded. Visuals were obtained approximately once a week to check their condition. The visits were kept short to avoid increasing their habituation to vehicles and people; their status, any kills and vigilance behaviour were recorded.

HOME RANGE AND DAILY MOVEMENT ANALYSIS

Using GPS locations recorded every 24 hr home range sizes and daily movements were calculated for each cheetah upon release onto the 9000 ha game farm. Home ranges were tested for site fidelity using the animal movement extension program (Hooge *et al.*, 1999) in conjunction with ArcView GIS 3.2 (Environmental Systems Research Institute Inc. 1992-2000). An individual's home range and core range was calculated using the 95% and 50% peeled minimum convex polygon (MCP) method, using the harmonic mean to remove 5% and 50% of outliers (Jenrich & Turner, 1969). The MCP area and shape are known to be heavily influenced by outlying fixes, and may include large unused areas causing an overestimation of home range size (Harris *et al*., 1990). Therefore, home ranges were also calculated with the 95% and 50% fixed kernel method using the least squares cross-validation smoothing factor. This method is considered more accurate than MCP (Worton, 1989; Worton, 1995; Seaman & Powell, 1996; Seaman *et al*., 1999) and the use of both methods enabled comparison with previous studies. The mean daily movement of the cheetahs was calculated using daily GPS readings and multiple GPS readings per day (4-6). Movement within the time periods of 0400-11:00, 12:00-17:00 and 18:00-00:00 hr were also calculated. Any time spent in captivity was not included in calculations of home range size or daily movement.

STATISTICAL ANALYSIS

Statistical analysis was done using SPSS version 11.0.1 (SPSS Inc. Chicago, USA) and all means were quoted with standard error (X ± SE). The Komogorov-Smornov test was used to test for normality of the data and the appropriate parametric or non-parametric test was chosen. Statistical tests included Chi-square analysis and the one way ANOVA with post hoc testing. Significance was measured at $p \leq 0.05$ and all tests were two-tailed.

Results and discussion

INTRODUCTION OF CUBS IN JWANENG BOMA

The cubs were introduced to each other in the Jwaneng boma when the females were 5 months old and the male was 8 months old. It took 24-48 hr for the three cubs to lie next to each other touching. The females were immediately very tactile with the male who initially responded with confusion and fear. Within 1 month the three cheetahs appeared to exhibit sibling type behaviour. They ate, slept and played together. The females were much more tactile with each other, often grooming, face licking and some playful swatting with each other. The male would partake in this behaviour, but he rarely initiated it. This lack of contact between related cheetahs with a non-related cheetah present within the same coalition was observed by Caro (1994). It was observed that grooming was preferred between the relatives in the coalition, however the contact increased between all members after 1 year together.

PLAY AND INTERPERSONAL RELATIONS IN JWANENG BOMA

The three cheetahs rarely showed any play activity, even with the introduction of enrichment items (balls, tails, legs, plastic bottles containing stones). On one occasion meat was thrown over the fence and Alice grabbed and ran, whilst the others chased her until they received meat. There was only limited play done when grooming, or slapping at each other as one passed by before lying down. The activity in the boma was primarily of resting and eating behaviours. They only paced before feeding time.

LEARNING TO HUNT USING LIVE PREY IN BOMAS

When the chickens were released Decu immediately grabbed the chicken by the head and crushed it. The females started chasing the chickens and picked them up and walked with them, unsure what to do. After observing Decu crushing the head the two females both grabbed the same chicken and preceded to pull in opposite directions. The females held the chicken for 10 min before it split and they ate. Two months later this was done again, and all three immediately killed their chickens.

At 12 (Alice and Gracie) and 15 (Decu) months of age, three rabbits were introduced to the boma. Decu and Alice killed immediately, however Gracie chased the rabbit as long as it moved, but would stop if the rabbit stopped. It was obvious that motion instilled the chasing behaviour as whenever the prey stopped, she lost interest and lay down. Caro (1994) also made observations of young cheetah being confused, loosing interest or giving up while hunting prey at young ages. Once there was movement, she would pursue until she had captured and killed it. This was also seen with Alice on one occasion.

Several observations were made that suggest cheetahs have a poor sense of smell in relation to locating prey. If they lost sight of a piece of meat, they were unable to relocate the meat by smell. If they watched where the meat was thrown they were able to retrieve it. This has been noted on numerous occasions with both rehabilitated and wild caught cheetahs by this researcher and others (A. Dickman, pers. comm.).

This was also observed when using live bait (goats *Capra aegagrus hircus* and sheep *Ovis aries)* in protected holding pens to trap wild cheetahs. If the prey did not move or make noise, the cheetahs would frequently pass by the trap or drink within 2 m of it and not investigate the contents. If the prey had been noticeable by smell, there should have been some investigation by the cheetahs, even if it did not enter the trap. It appears to be the motion of prey that entices the hunting behaviour and not necessarily the smell. This is an important observation when determining what predator management technique to use against cheetahs at kraals, by understanding they are attracted by movement. A visual barrier (2 m height) in addition to a physical barrier may therefore be adequate protection. This has been successfully applied in Angola (MZT, 2003). Cheetahs obviously have adequate sense of smell regarding urine, scat or rub markers when detecting oestrous or outsiders, however the behaviour observed with dead meat or prey would be of interest for further study.

At 12-13 months of age Decu was observed repeatedly taking food from the females after quickly eating his own portion. He would do this by stepping in front of the females face while they were eating, backing up with his rump in their face until they would abandon their food. The females never lashed out to protect their food, and started loosing weight. This resulted in the separation of the male from the females during feeding time using the guillotines in the alley and lockdown areas.

First impala carcass in Tuli boma

On May 17, 2006 they were given their first intact impala carcass, which they immediately attacked. Alice came first grabbing it by the rump and dragging it 3 m under a tree. Gracie followed starting at the front shoulder and dragged it 1 m with Alice still eating at the back end. Decu approached, licked the impala then laid down 3 m from the carcass as the females ate. The entire carcass was eaten, including the rumen, neck and facial meat, including the skin on the skull, with only the big bones and colon area left. They drank 4 l of water within 15 hr post feeding.

New protective behaviour from Decu

During the feed it was observed that if approached within 10 m of the carcass Decu would spring forward, head down between his shoulders, whilst stalking forward. Once a distance of 25 m was established between human and carcass Decu stopped his advance, sat down and looked at the females. This was a new behaviour, as Decu was always the first to eat; now with a fresh carcass for the first time, he had taken on a protective role. The females rarely reacted, but Decu sat vigilant between the carcass and researcher for 5 min, then turned and began eating with the females. From this point on in the study, Decu never took food from the females, but continually exhibited the protective posture until he decided it was safe to join in the feed. Decu had never stood between the researcher and his food (donkey meat or game quarters) before, this behaviour only developed once live prey was introduced in the Tuli boma and continued upon release onto the 9000 Ha farm.

First live impala kill in Tuli boma

On May 20, 2006 a 9 month old male impala, which was injured by a professional hunter, was placed into the boma. At first approach, when the impala tried to get up, all three cheetahs jumped back startled, until Alice made the first grab by the rump dragging it 10 m to under a tree. Gracie then grabbed the impala's ear, dropped the head, then went to the side of the neck dropped it again, then immediately to the choke hold area under the lower jaw of the impala.

Within 10 sec, Gracie adjusted her head grab to the area beneath the lower jaw on the neck where the trachea is most accessible, and proceeded to choke the impala using her one foot to hold down the head by the horns. This technique which Gracie used to subdue the impala by standing behind the head, and grabbing the neck under the jaw was also observed by Pettifer (1981). After 3-4 min the impala was dead and then Gracie started to feed on its neck while Alice ate on the back legs and anus area. Decu took up a protective stance by jumping over the carcass and slowly stalking forward with his head lower than his shoulders in order to stand between the feeding females and the researcher. Once he reached the fence of the boma, or the human was at least 15 m away, Decu immediately returned to the kill and began to feed.

Two days after the kill the carcass had been moved another 3 m. All was then consumed including the neck, face meat and skin, and all organ meat. Only the rumen and skeleton remained. Three days later all three cheetahs continued to eat off the skeleton, chewing on the bones, eating the intestines and rumen, but leaving the colon alone. By this time all three cheetah's belly sizes returned to normal (size 8) and their pacing of the boma increased.

On May 22, 25, 29 and June 2, the cheetahs were fed injured, live impala from game capture accidents on the farm. On May 22, Gracie made the initial kill again, with Alice dragging the impala under the tree and Decu standing aside. The kill on May 25 was made by Alice after Gracie was put in the lockdown, while Decu started to attack the posterior. On May 29, the kill was made by Decu when both females were put in the lockdown. In all three instances, the first kills were done quickly, with initial grabs at the side of the neck and head, followed by the adjustment within 5-10 sec to the area below the lower jaw where the trachea was most exposed. Once the choke hold was in place the impalas were dead within 3-4 min.

When left to their own abilities all three cheetahs made the kill; when the females were present Decu did not take the initiative, but when he was alone he killed immediately. They all took approximately 5-10 sec to sort out the normal hold as described above, and once experienced, the remaining kills were efficient and quick. When all three were together, each kept to the same duty, Alice would grab the kill and drag it under the tree, while Gracie initiated the choke hold, and Decu took the protective posture once the kill was made.

The feeding behaviour was consistent in the boma with the majority of the carcass, including internal organs being eaten the first day, followed by the neck and face meat, including skin eaten on the second day, with the rumen and intestines, except for colon eaten on the third day. By the third kill in the boma, the cheetahs started covering the carcass with grass and twigs. This same feeding pattern continued after release into the 100 ha enclosure, with the cheetahs returning to the carcass for the first 1.5 months, occasionally covering it with grass and twigs. This same consumption pattern was observed in studies by Phillips (1993) and reported by Skinner & Smithers (1990). Pettifer (1981) and Phillips (1993) also observed that rehabilitated cheetahs spent more time at the carcass and returned for multiple feeds as compared to wild cheetahs.

RELEASE INTO 100 HA ENCLOSURE

On June 6, 2006 4 days after the last kill, the boma was opened and the three cheetahs were released. The first out of the boma was Gracie followed by Alice who chased an unidentified animal into the bush. The females were followed by Decu who immediately took chase after a steenbok, capturing it 200 m from the boma near the north fence. This was the first time all three had ever run. Decu killed the steenbok within 2 min and carried it under a tree, where he was joined by the females within 15 min. He did not start feeding on the carcass until the females' arrival, as he was panting and tired from the chase. They took 1.5 hr to eat the entire carcass and remained together for the first day.

The second day after release all three went into the bush from 10:00-16:00 hr walking the enclosure briefly from 06:00-10:00, and 16:00-17:00 and then returning to the bush to lie down again. By the third and fourth days the females went off together leaving the male alone, only to join up with him in the early mornings or in late afternoons. The cheetahs had explored most of the enclosure by the third day.

Throughout the 7 months in the 100 ha enclosure, the male appeared to be independent of the females. He would hunt and walk the fence line on his own, but join the females at kills. The three cheetahs would defecate on termite mounds and along the perimeter fence on any elevated dirt pile, especially in the corners of the enclosure. The male would spray corner trees and termite mounds along the fence line.

Hunting and stalking behaviour

During the first few weeks of release the cheetahs ran after all prey, resulting in several failed chases. However, they soon started stalking animals, often progressing step by step for up to 10 min. Occasionally it would lead to a chase unless the prey startled and ran. They did not appear to initiate chases unless they were within 150 m of the prey. They were also observed crouching on their bellies with heads low, ears back and crawling when trying to stalk birds. It became possible to determine the prey being hunted by their stalking pose.

In contrast, Pettifer (1981) noted that the 2.5 year old rehabilitated cheetahs mainly chased rather than stalked their prey. It was originally believed that cheetahs cannot learn to hunt effectively if not taught by the mothers (Denis, 1964). However, cheetahs have learned to hunt without the teachings by the mother as observed by researchers in previous studies in South Africa (Pettifer, 1981; K. Marnewick & D. Cilliers, pers. comm., DeWildt unpublished data) and Namibia (B. Schumann, pers. comm., CCF unpublished data).

The development of these cheetah's natural behaviours appeared to increase when put in a natural environment. There are concerns that once in captivity animals can not be released into the wild due to the assumption that they will loose their ability to survive because of increased habituation and loss of their 'wild' instincts. Bauer (2004) observed this to be untrue in his long term studies with dolphins and manatees. After three years of captivity and sign training, these animals reverted to their natural behaviour immediately upon release into the wild, and did not approach boats or respond to signing after release. This is therefore a good example of a study where wild instincts appeared not to have been lost and reappear once the individuals are put back into the appropriate natural environment.

The relationship between road use, play activity and hunger

A relationship between hunger, road usage and play or pacing behaviour was observed during the cheetahs' time in the 100 ha enclosure. On the day of a kill the cheetahs would sleep in the same area until the following morning. On day one post kill, the cheetahs would be playing, walking, lying in the roadways, with no visible concerns or desire to look for prey. By day two, the playing had decreased, followed by more time walking the fence lines, heightened observational behaviours and less resting time. By day three, there was little to no play, less walking on the fence lines and more searching in the bush and grassy areas, resulting in the cheetahs searching for prey for longer periods during the day and less time in resting behaviours.

By day 4 and 5, they were not using the fence lines, but in the bush continually moving from bush to bush searching at the bases of trees and brush piles for prey, including attempts on birds and small mammals. They would be active up until 12:00 and start hunting by 14:00. This relationship increased day to day until a kill was made. If the kill was small the cycle of play and resting to searching behaviours would resume quicker than if it was an impala, steenbok or warthog.

It was observed during a 4-8 day period of no large kills that on days when they did not appear to have made a kill overnight, the cheetahs would be lying on the fence line seemingly satisfied. They would show no hunting behaviour or interest in stalking prey, in contrast to the day before when they were highly vigilant. The belly sizes would still remain at 3-5, appearing to need food, but their behaviour simulated that of when they had eaten and at a belly size of 8-9.

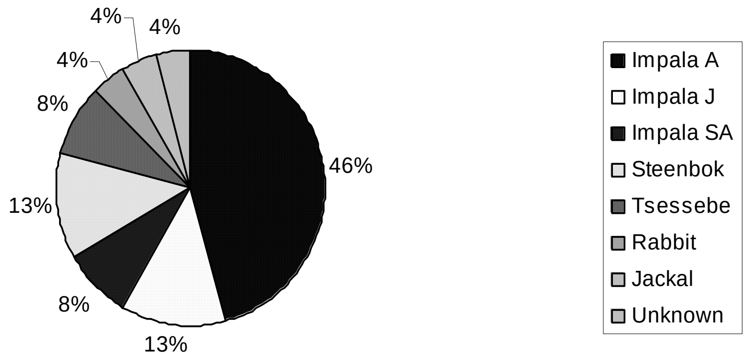
Scat samples were taken during those times in order to determine what they had eaten. It was found that scrub hare, banded mongoose *Mungos mungo*, and small rodents (order Rodentia) (A. Houser, *unpublished data*) had taken the edge off their hunger during the long bouts between larger kills, and they would respond physically with the same relaxed behaviour as seen when they made bigger kills (steenbok, impala). It was obvious that as long as they had something in their stomachs, no matter how small, they would exhibit relaxed behaviour by lying in the roads or along fence lines with decreased interest in looking for prey. It was because of this observation that it could be determined that they were eating something, and not needing to hunt big animals as frequently, even though their belly sizes at times were extremely small.

The longest interval between a large kill was 9 days, and two times during that interval, the cheetahs laid along the roadways, not even chasing impala that were within 80 m. They were satisfied with whatever small meal they had eaten. Cooper (2007) observed that hunting decisions were independent of the cheetahs hunger level, at times even with high abundance of specific prey, they chose not to hunt, possibly due to preferring smaller, less vigilant herds, or to avoid predation or kleptoparisitism that can accompany larger herds, even with no competitor present. The cheetahs hunting decisions may be affected by this genetically built in anti-predator behaviour (Hobson *et al*., 1988; McLean, 1996).

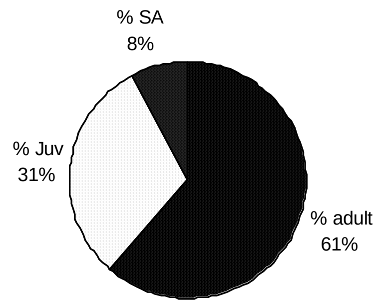
It may be possible to determine at what stage a cheetah is in with regard to their last feed by observing their movement patterns. These would range from being relaxed throughout the day, to increased exploration behaviours by actively looking under bushes and increased stalk attempts. Noting these behaviours in future studies to discover if there is a relationship would be beneficial when observing a wild cheetahs with no observation history, if wanting to establish where in the feeding cycle the animal is. Caro (1994) states that the belly size is accurate to determine level of hunger. However, in this study their hunting of smaller prey made belly size less reliable when trying to determine the time from their last hunt and possible hunger level, compared to their behavioural changes, and daily movement patterns.

Cheetah kills attempts, success and failures

The cheetahs were taking primarily impala, steenbok, tsessebe, hares and other unknown prey items, consisting primarily of adult and juveniles with some sub-adults of mixed sex (Fig. 4.1).



a)



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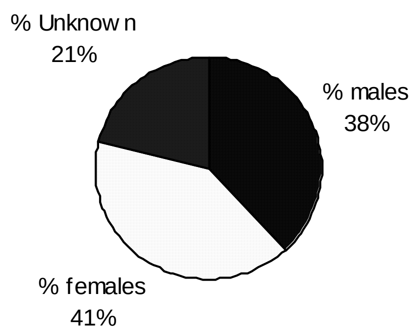

c)

Figure 4.1 The diet make up of the three cheetahs in the 100 ha pen (a), including the age (b) and sex (c) ratio of the 39 animal kills and failed chases (attempts).

The enclosure contained 40 impala with a mixed herd (Adults, SA, Juv), which was topped up every 2-3 months with 15-20 more, five tsessebe (3-adults, 2-juveniles) and a continual supply of steenbok and warthog entering and exiting daily through warthog holes. Of 24 observed chases, Decu and Alice led nine each and Gracie six. Decu was successful on 55.5% of attempts; Alice was successful on 44.4% of attempts, whilst Gracie was successful on 16.6% of attempts (Table 4.2).

Table 4.2 The total success and failed hunts of each cheetah from 24 observed chases, including the composition of hunts that were made. The success rate is determined from their individual totals and a combined success rate of the group.

	Hunts led by:	Successful	Failed	% Successful	Hunting Party		
					Alone	**A/G**	**DAG**
Decu	9	5	4	55.5	4	0	5
Alice	9	4	5	44.4	0	7	2
Gracie	6	1	5	16.6	2	4	0
Total	24	10	15				

DAG total success rate together 41.7%

The total kill success rate for the three cheetahs together was 41.7% out of 24 total chases. The success of Decu and Alice was higher than those observed in the Eaton (1995) study of four monitored groups of cheetahs ranging from 15-50%, with the overall wild groups success 30% hunt: kill ratio.

The majority of kills and feeding behaviour was observed from early morning to mid afternoon (Fig. 4.2). The totals were taken from the 24 chases and successful hunts including 15 animals found being eaten, without hunting data recorded, giving a total of

39 hunt attempts and kills. This is similar to Schaller's (1968, 1972) observations that the majority of kills were made between 07:00-10:00 and 16:00-18:00, and Pettifer (1981) observing the majority of hunting in the early morning hours.

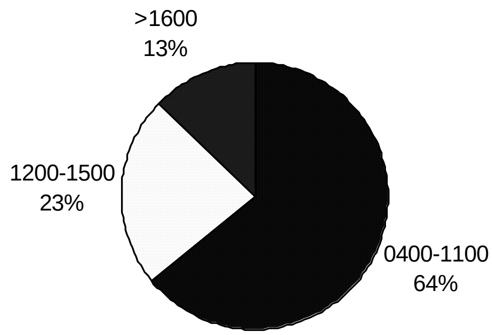

Figure 4.2 A breakdown of times during the day when the cheetahs were found hunting, or eating kills that were not observed.

Kill technique improvement

The initial kills of the cheetahs showed punctures in the neck, with tearing of the throat. However, within 4 weeks after release into the 100 ha enclosure these signs were no longer present. The technique for quick efficient kills with no visible signs of strangulation had been accomplished with time and practice. These cheetahs were never artificially fed once they were released from the boma into the 100 ha enclosure.

The only intervention required was re-supplying the 100 ha enclosure every 1-2 months with 15 impala, in order to keep the numbers between 20-40. On one occasion the impala numbers were under 13 causing the time between hunting periods to become longer as it took the cheetahs more time to locate the small herd and make kills. It was during this time that they resorted to smaller game, and appeared much thinner. This increase in difficulty in locating prey in low abundance was observed in the Pettifer (1981) study by the cheetahs' higher success rate in the smaller release area of 1100 ha as compared to their release in a 60,000 ha reserve.

On days of impala additions there were usually 3-5 kills within 24 hr due to the confusion, as the cheetahs used the fences to capture them, and would only eat one or two of the kills. This behaviour exhibits similarities to the phenomena of cheetahs going into kraals and killing multiple livestock, as their predatory response is repeatedly triggered by the confused milling livestock displaying atypical prey fleeing behaviour (CCF, 2003). The confusion shown by the cheetah by stopping the pursuit if the prey stopped, only to continue if the prey moved, may show the struggle between millions of years of intricate predator prey responses being affected by an artificial situation (kraaling). This may be due to the prey's inability to react normally by flight in a confined area, resulting in a less cost efficient response by the predator using up their energy with multiple kills, resulting in exhaustion and at times their inability to feed.

Of 14 kills, 65% of them were made within the 100 ha enclosure not along fence lines, although fences were used occasionally, the cheetahs were not dependant upon them to catch their prey.

Change in feeding behaviour

After 2 months in the 100 ha enclosure, the cheetahs started exhibiting a more natural pattern of feeding on carcasses. They started leaving the carcass with only the hindquarters, shoulder meat, chewed ribs, and organ meat eaten, and stopped returning subsequent days, which was also observed by Schaller (1972). Only during the first 4-8 weeks after release from the boma did the cheetahs stay up to 24 hr with the carcass, and return up to three days later eating it completely. The devouring of the entire carcass in the boma may have only happened due to the close proximity they resided with it, and their inability to move away, as was observed by Phillips (1993). With the ability and desire to move from the carcass inside the 100 ha enclosure, it appeared this behaviour changed resulting in the cheetahs abandoning the kill within 1.5-6 hr. There was no affect on the cheetahs feeding time due to jackal *Canis mesomelas* and vulture (family of Accipitriformes) presence whereas, brown hyaenas never entered the 100 ha enclosure and were not a threat

Time spent in behaviour categories

The time spent conducting specific behaviours was broken down into 10 categories; resting, locomotive, play, hunting, exploring, contact, and feeding. There were 3071 total observations recorded over 48 observation days (Table 4.3), with Alice observed for 186.3 hr, Gracie for 188.6 hr, and Decu for 120.5 hr.

The three cheetahs spent the majority of time in resting behaviours followed by locomotive, observation, exploring, hunting, contact, feeding and play behaviours with the least amount of time spent at kills. The females were similar in the amounts of time they spent on all activities, with the exception of feeding. Gracie was minimally higher in observation, resting, hunting and contact behaviours whilst, Decu was more active than the females in locomotive, exploring and kill behaviours. There was no significant difference in the number of observations between the cheetahs in the other behaviour categories.

Table 4.3 The observed behaviours recorded from three rehabilitated cheetahs in a 100 ha enclosure. Observations were taken every 15 min from 0600-1800 hr 7 days/week for 48 days. The hours observed were the actual hours behaviours were recorded with the unknown time removed. Unknown times were when the animal was not visible or being observed during the observation period. Differences in the number of observed behaviours between the three cheetahs was determined by Chi square analysis.

	Decu	**Alice**	**Gracie**			**DAG combined % of observations**
Behaviour category	**% of observations**	**% of observations**	**% of observations**	**X2 value**	**P value**	
Observational	16.5	17.7	18.7	1.29	0.523	17.8
Resting	41.9	43.8	45.9	1.76	0.415	44.1
Locomotive	30.3	22.4	21.6	16.7	0	24
Play	2.1	3.7	3.5	4.16	0.125	3.3
Hunting	0.4	1.9	2.1	9.43	0.009	1.6
Exploratory	2.4	1.6	1.5	2.47	0.291	1.7
Contact	0.9	1.7	1.8	2.67	0.264	1.6
Feeding	5	7.1	4.8	6.21	0.04	5.7
Kills	0.5	0.1	0.2	4.14	0.126	0.2
Total observations	759	1152	1160			3071

Play behaviour in 100 ha enclosure

The females, particularly Alice, exhibited play activity together and towards the male by hiding in the grasses or behind termite mounds pouncing out towards each other. They would display stalking techniques on each other as they would walk the fence line or pen area and on a few occasions they would hide from the approaching male and attack. Play behaviour has been associated with development of hunting skills (Schaller, 1972; Bekoff, 1981), although Caro (1995) did not see long term benefits of play for young mammals, except for the short term locomotor development and training (Martin & Caro, 1985). Caro (1995) also noted a decrease in play behaviour from average 5%/day in 4 month olds to <1%/day in 10 month old cheetahs. At 1.5-2 years of age these cheetahs showed 3% of play behaviour out of their total behaviours recorded; which was most prevalent the first and second day after a kill, less on the third day, only to be replaced by hunting behaviour by the forth and fifth day. There was more play behaviour in the 100 ha pen than was exhibited in the Jwaneng or Tuli boma.

Social behaviour

The females tended to stay together the majority of the time; occasionally they would rest up to 150 m apart during the heat of the day. The male would frequently be on the other side of the pen area between 0.5-1 km away, and would at times go up to 2 days without contact with the females.

On two occasions the females separated and were found alone with their own kills. During the early morning or late evening the females would often stop and face expectantly in a particular direction as if waiting for something. Decu would often appear from this direction within the following 15-45 min.

Chirping behaviour was seen primarily from Alice when separated from Gracie and Decu during hunt attempts. She would actively search and chirp to reunite. This behaviour was also noted in the Pettifer (1981) study animals. Decu was only observed chirping on one occasion, while Gracie was never seen emitting a chirp, but was the first to respond by arrival to Alice's vocalizations. As time went on, Alice was not observed chirping upon separation as had been observed during the first 2 months. Purring was heard frequently from all three cheetahs when together or alone when resting.

In both this study and Pettifer (1981), when the three cheetahs would meet after being separated for hours, all three would partake in facial licking and some allo-grooming, there was no indication of social dominance.

Habituation

The three cheetahs were never approached by anyone but the researcher during the three month period. Lengthy observations did not occur until the move to Tuli, and the presence of a human took time for the cheetahs to allow. Where possible a distance of at least 100 m was maintained between the researcher and the cheetahs. However, when locating the cheetahs in areas of thick bush, closer contact would be made.

On some occasions the cheetahs would walk past the vehicle or researcher, unaffected by their presence. It was noted after 1-2 weeks that the cheetahs began to accept the vehicle and researcher as was observed when they did not change their behaviour or concentration during hunts. At one point the females initiated a hunt passing the researcher on either side, and made a successful kill 300 m away. The presence of the researcher was adjusted to make sure the prey was not negatively affected by human or vehicle presence by inadvertently scaring the prey away or driving the prey toward the cheetahs.

Vehicles were seen passing the enclosure area as it was the main road through the farm. At times people would see the cheetahs and stop while they lay in the road along the fence line. This did not happen often, but the cheetahs did not run away. Decu was much more intolerant of human presence and would actively avoid people by leaving or crouching to hide from human presence. He continued this behaviour even with the researcher after 2 years, possibly due to the treatment he received upon capture at the farm when young. The females never approached people, but did not overtly avoid them. They never ran or hid, but did at times move to the bush and increase the distance between themselves and people. This behaviour was consistent with their release onto the 9000 ha farm; although they never approached humans, they were occasionally seen from a distance only 5-7 times within their 8 months roaming the farm. Only during condition checks by the researcher were they occasionally approached.

RELEASE ONTO 9000 HA FARM

It took 15 min before the three left the 100 ha enclosure area while Decu marked the gate area with urine and faeces. Upon exit from the enclosure the male saw several helmeted guineafowl *Numida meleagris* 200 m away and trotted after them to the northwest, followed by Alice who ran east 50 m from the enclosure, while Gracie trotted north. All three stayed separated from that day forward at 2-2.5 years of age. Within the 100 ha enclosure the females stayed together, with the male being alone the majority of the time. During times of captivity they seemed to stay together or visit every 1-2 days, but once released into the larger 9000 ha area, they did not seek each other out. The only subsequent time they were together was during a short time in captivity in the boma and 100 ha enclosure following a collar malfunction for Alice, and injury to Gracie.

During that time Decu stayed with Alice who was in oestrous, while Gracie would remain with them or up to 100 m away. In the wild, cheetahs would normally split off from the mother between 18 months to 2 years, with sibling groups staying together up to 6 months, followed by the brothers staying together for life in coalitions, while sisters split off from sisters and brothers at sexual maturity (Caro, 1994). Their behaviour is not abnormal in those terms, however it is interesting that they never came together on their own once released from the 100 ha enclosure onto the 9000 ha farm.

Home range and distance travelled per day within the 9000 ha farm

Alice had the largest home range on the 9000 ha farm followed by Gracie, and Decu with the smallest (Table 4.4).

Table 4.4 The home ranges on the 9000 ha game farm, excluding the dates when in captivity for collar malfunction or injury. The daily movement was determined in kilometres per day with multiple GPS locations/24hr period for the duration of study.

						Home range size (Km^2)				Daily mvmt.(km)	
ID	**Start date**	**End date**	**Exclude dates**	**No. of days**	**n (/24hr)**	**MCP 95%**	**50%**	**Kernel 95%**	**50%**	**Avg**	**Max**
Decu	31/1/07	8/1/2007	24/4/07-9/5/07	178	158	96.43	18.67	44.11	3.12	6.25 ±.04	28.1
Alice	31/1/07	6/6/2007	25/2/07-9/5/07	113	41	70.07	16.82	121.44	23.6	9.4 ±.72	25.9
Gracie	31/1/07	20/6/07	17/3/07-9/5/07	140	74	78.3	1.11	60.46	3.98	4.49 ±.60	25.4

The 100 ha enclosure was left open once the cheetahs were released and remained part of the core area within each of their individual home ranges, including the pond area on the eastern side of the farm (Fig. 4.3).

The use of the release area as part of the core home range was also noticed by Pettifer (1981). Their home range sizes were smaller as compared to wild cheetahs due to the well maintained game fence of the farm.

The daily distance per day was divided into times of day with the average distance determined using up to six GPS readings per day. The three cheetahs moved mostly between the hours of 04:00-10:00, followed by 18:00-00:00, and least during the hours 11:00-17:00 (Table 4.5, Figure 4.4).

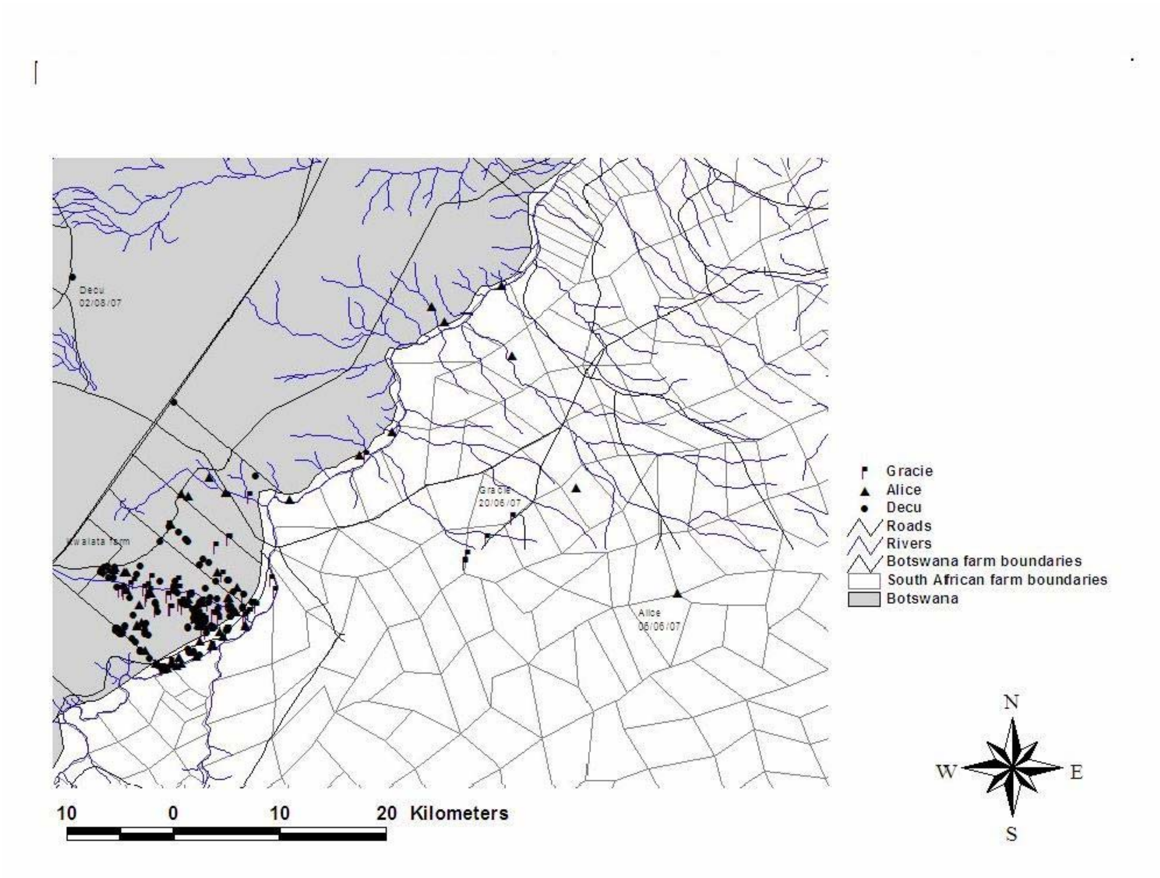

Figure 4.3 Home ranges of Decu, Alice and Gracie on 9000 ha game farm and their movement into South Africa.

Table 4.5 The average daily movement of each cheetah using multiple GPS fixes/day split into three time categories including average daily movement per time zone.

	Distance traveled per time period (km)		
	0400-1100	**1100-1700**	**1800-0000**
Decu	1.6	1.5	1.2
Alice	1.6	1.7	1.6
Gracie	1.5	1.2	1.4
Mean	1.6±km	1.5±km	1.4±km
No. of points	749	394	442

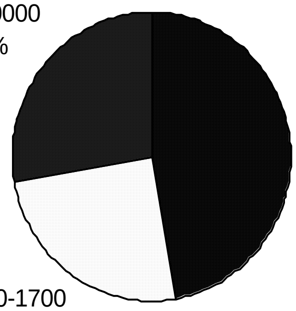

Figure 4.4 The division of a 24 hour day into three time zones of travel. Multiple GPS readings/day were used throughout the study period to determine times of travel for all three cheetahs combined.

There was a significant difference in the mean daily km's travelled between the three cheetahs (*f* = 14.463, $P < 0.001$). Alice travelled the furthest at 9.4 km/day, followed by Decu 6.25 km/day and Gracie 4.49 km/day (Table 4.4). Cheetahs are believed to primarily travel during the day (McVittie, 1979, Frame, 1984) with late evening and night travel observed by Schaller (1972) and Stander (1990). Pettifer *et al*., (1980) observed random diurnal movement with early morning travel decreasing in late afternoons. In these previous cases night travel was observed more in areas with little or no lion presence, as was also observed with these study cheetahs.

Collar malfunction/injury

Follow up visits to check the condition of the three cheetahs 5 weeks after release on March 6 found Decu in the northeast area with a full belly, and Gracie looking thin with a possible head injury. Alice had been seen in good condition along a fence line but due to a collar malfunction on February 20, she was not located for another month.

Due to Gracie's possible injury and poor condition she was darted and put into the holding boma to feed and condition up. Gracie was joined by Alice on March 22 when she was located and placed in captivity to replace her faulty collar. They were kept in captivity and fed dead game carcasses; totalling 6 weeks for Alice and 10 weeks for Gracie. It took 2 weeks after release from the 100 ha enclosure for all three to be seen with kills and in good condition.

Change in social behaviour and first oestrous cycle

Upon introduction into the boma, the females appeared less tolerant of one another, noting they had not been together since release at the end of January. At one point Gracie dominated Alice by laying her on her back, with some swatting, but only for a few sec. After 2 days the females were together, touching and allo-grooming as before their first release. During the 2 weeks Gracie was in the boma, GPS cell collar locations revealed Decu was also staying close to the boma.

Upon the arrival of Alice, Decu showed increased interest in her and was let into the boma. He ignored Gracie who was aggressive towards him, and followed Alice constantly sniffing at her tail making chirring/stuttering sounds associated with mating (Eaton, 1974, Caro, 1994), mounting her within the first 5 min. The male had never shown this type of behaviour with the females, and this was the first time the male had been in physical contact with them since the end of January.

It was obvious that Alice was in oestrous with her frequent self grooming and rolling over (Caro, 1994). It is possible Gracie had been in oestrous the 2 weeks prior shown by Decu's vigilant behaviour at the boma. However, Gracie did not appear to be in oestrous at this time as she lacked the visual signs (rolling, rubbing against the fence or continuously moving in front of him lying down, and vocal cues) and did not have the attention of the male. Decu was immediately taken out of the boma, showing up for 3-4 days at a time, leaving to hunt for 1-2 days then returning to the boma. This behaviour continued for 4 weeks which was much longer than observed by Caro (1994) where males stayed to mate anywhere from 3 min to 2 days. This was possibly due to Decu's inability to make physical contact with the females in the boma. Decu was found with Alice daily during the 2.5 weeks in the 100 ha enclosure before re-release onto the game farm, with Gracie on the periphery within 50-100 m, or all three lying together.

On May 9, 2007 all three cheetahs were released back onto the 9000 ha farm after the new cell collar was put on Alice. All three were surviving on the farm with the presence of lion spoor throughout, and a coalition of two cheetahs seen on the south fence. It was observed that all three cheetahs exhibited heightened vigilance when at kills or resting when released onto the 9000 ha farm, including one incident of Alice spraying a fencepost at a kill in the same standing manner as a marking male. The cheetahs would eat the main portions (thigh, shoulder or ribs) of the kill and leave within hours, they did not return or stay in the area.

In the 100 ha enclosure the cheetahs would lie flat out around their kills, with less frequent head up observations as compared to when they resided on the 9000 ha farm. When on kills or in the bush, the cheetahs were mostly seen lying on their sternums alert or raising their heads every 5-10 sec at bush noises. It is possible they knew the threats in the 100 ha enclosure were low when compared to what they learned when released onto the farm with increased predator contact. Whenever the three would return to the 100 ha enclosure, they would return to their decreased vigilant behaviour, probably due to lack of kleptoparisitism. Hunter & Skinner (1998) observed animals adjusting their vigilance in areas with increased predator pressure, which would be the situation with these cheetahs when residing on the 9000 ha game farm, as compared to when they are in the 100 ha enclosure area.

THE SHOOTING OF ALL THREE CHEETAHS AFTER LEAVING THE 9000 HA GAME FARM

On May 25, 2007 after 4 months on the Tuli farm, Alice left through a hole in the fence line along the river when the water was low, and proceeded 21 km north through neighbouring game farms along the Limpopo river. On June 4, she crossed into South Africa travelling 6-10 km/day east until she came to a game farm in Swartwater, 55 km north east from the Tuli game farm.

On June 6, she was illegally shot by a professional hunter and his client from 30-50 m as they watched her come through a warthog hole under an electrified fence. It was explained through investigations that Alice never approached the hunter, but did not run to avoid them. Her collar was visible and cut off after the poaching incident. A neighbouring farmer found Alice's spoor 600 m from his herd of unprotected sheep (backed by GPS data). The farmer, however, did not loose any small stock to our cheetah. She did not take available small stock with game available. This case was taken to court and is being tried for illegal hunting of an endangered species in South Africa.

On June 8, after 4.5 months on the Tuli farm, Gracie left for the first time following Alice's path along the Limpopo river, crossing into South Africa and travelled into Swartwater. On June 14, CCB was contacted by farmers in the area who observed Gracie along a game farm fence beside a tarred road. Due to the newness of the fence she was pacing unable to cross the road. Gracie was headed in the direction of her sister Alice for unknown reasons, and at that time it was not known Alice had been shot.

On June 20, the project was contacted by the farmers in the area who were supportive of the cheetahs' presence, and informed that Gracie had been shot by a passer-by after having crossed the main road, heading northeast walking along a game fence. The collar was intact and left with the carcass at the side of the road. It should be noted that neither Alice nor Gracie had taken livestock or approached people during their weeks travelling through livestock and game farms.

The fact they did not run to avoid humans did hinder their survival however, wild cheetahs that have never had negative experiences with humans can behave similarly (Bauer, 2005; pers. obs., and reported by public). All farmers in the area were contacted about the two cheetahs being present and agreed to allow them to pass through their farms. The farmers contacted were supportive of the project knowing if the cheetahs became a problem they would be removed. It was due to their efforts that the one suspect was located in relation to Alice's shooting, and that Gracie was found. Hunter (1998) noted in Phinda that the humans in and around the reserve was affecting the success of relocations.

The reason Gracie left the farm within 2 days of Alice's shooting is unknown, and the fact that she followed a similar path, travelling the same distances per day to only be killed within three farms (21 km) of her sisters last known GPS location is of interest. From January 31 all three cheetahs split up, never to come together again within the next 7 months (except when in the boma). However, upon the death of her sister, Gracie proceeded to Alice's exact location, only to be killed herself. In Pettifer (1981) two male cheetahs stayed in the area for 11 days without hunting, possible to stay with an injured brother, and stayed three days in the area after another was killed.

On August 1 after 6 months on the Tuli farm, Decu left for the first time travelling 37 km north into the village of Lerala. In the early morning hours it appears he was moving through the village and was cornered in a bushy compound, unable to escape. The local people surrounded him until the Department of Wildlife and National Parks arrived.

Decu was shot by the arriving government officer who disobeyed a direct order not to shoot the collared cheetah, However, the officer stated that he thought the cheetah was a leopard. Witnesses advised that the cheetah was not aggressive or threatening, but lying down resting when he couldn't escape, until he was approached and shot. At no time were the three cheetahs reported as a threat to livestock or aggressive toward human populations. They were never reported as being seen at any time during their release, until the days of their shootings. This shows strong evidence that through this rehabilitation they did not suffer the effects of habituation to the point where they sought out human contact or became overtly visible to the surrounding communities.

These cheetahs were not supposed to be released into the farming community, but escaped from the farm when the river was low. It was decided to allow their freedom to determine if they could survive given the same opportunities of wild cheetahs on farmland, with the exception of notifying the farmers of the study to assist in their survival through education and tolerance building.

REHABILITATION METHODS, COSTS AND SUGGESTIONS

Methods

The isolation of these animals to decrease habituation is important, but not unpreventable. It has been observed that even behaviours learned in captivity will not necessarily be active when released into the wild (Bauer, 2005). As long as the context (environment) where the behaviour was learned has changed, the animals do not appear to exhibit that behaviour in the wild. Many people feel that rehabilitated animals will seek out humans for company or food (Dickinson, 1980) when released, and lack the skills to survive increasing their chances of being killed (Mathews *et al*., 2006). This has not been proven to be consistently true, as observed by Bauer (2005) with the release of captive dolphins and manatees.

If humans are not associated with food by using outside stimuli (e.g.; gate noises, whistle etc), the change of context (environment) will naturally alter the animal's behaviour, and expectations for socialization and food. Human contact does not mean the animal will seek out humans, as long as there is no reward in it. If wild animals do not relate bad stimuli to encounters with humans on a continual basis, they may also habituate over time (Lockyer, 1990). This is seen in game reserves for tourism, or on private farms where shooting of predators does not exist, and in circumstances where animals have not yet learned to fear humans due to lack of contact. Such habituation has been observed in many research projects including work in Botswana on cheetahs by CCB (pers. obs.) or any researchers that have done long term studies on wild populations and have had their presence accepted over time. This is observed in studies where the animals become used to the researchers presence and do not overtly avoid observations allowing for data collection over long periods of time.

Costs

The costs of rehabilitation for release included the initial set up of a 20 x 40 m holding boma ($3500) using wood poles and diamond mesh fence (low gauge); slaughter of a donkey ($60/month); GPS/cell collars ($3000ea); researcher ($400/month) and vehicle ($30,000) with quarterly maintenance ($1000/yr); insurance ($3000/yr); medical treatments and de-worming every 3 months, ear tags and transponders ($100). The 100 ha enclosure and game were donated by the game farm, but would cost $500/100 m to build using bonnex game fencing and 3 electric lines on the inside, and $240 per impala to stock.

Management recommendations

Future rehabilitation could be done in less time than this study. Once the cheetahs have had an opportunity to kill in the boma, and are released into a larger area where they can practice, it would not take more than 2 to 3 months for muscle development, stamina, kill technique and vigilance to solidify. During this time period the cheetahs can be monitored for any problems or injuries in their beginning attempts, they will also learn about other sources of food through successful hunts and days of no kills causing them to resort to other prey items.

The hunting enclosure does not necessarily need to be 100 ha, as it is expensive to stock with enough animals to provide hunting opportunities. The experience and conditioning can take place in an area of 20-50 ha, as long as the animal can run and chase the prey without resorting to continually using fences. The effectiveness of enclosure size for training, and the amount of time in it before successful release, is an area that would need further research, trial and error. The release of cheetahs into the wild of at least 2 years of age would be beneficial for the animal as it would be older, stronger and more experienced before encountering wild cheetahs (L. Hunter & M. Jager, pers. comm.)

Daily hand feeding of cheetahs for weeks or months following release may inadvertently cause the cheetahs to become dependant on humans for food, or at the very least associate humans with food. This may also result in the cheetahs taking much longer to wean themselves onto wild game by hunting, versus relying on their daily feed by humans. It may be necessary to provide supplemental feeding in some cases where the cheetahs are not hunting successfully, and their strength must be maintained, however, the feeding should be minimal in order to encourage hunting behaviour. It may be desirable to use this method in a release situation where habituation is desired as in some game reserves however, this method would not suffice in a wild release situation.

Giving cheetahs the opportunity and motive to hunt and provide for themselves, will result in the association of their own actions and consequences with supply of food (Dickinson, 1994), taking away the human factor. This 'opportunity teaching' is used by cheetah mothers when they take live prey to their cubs (Caro & Hauser, 1992). The instinct to hunt is there, taking the time to induce confidence will increase the cheetahs' chances for successful hunts shortly after release. By learning with just one kill, it can provide enough knowledge to build upon, producing more successful hunters resulting in lower costs and time spent on follow up visitations or substitute feeding.

When released in the wild and given more space, these cheetahs started to exhibit and develop their natural behaviours in play, which were absent when in the bomas. It is possible that captivity stifles the imagination and need for these responses as they don't need to develop predator avoidance or kill protection in captivity, because they have no threats to themselves or their food. However, when in the wild, everything changes and their innate instincts come forward through play to enhance hunting and stalking techniques rather than being necessary for their development (Schaller, 1972; Martin & Caro, 1985; Bekoff, 1989; Caro 1995), while protective or more vigilant behaviours are developed at kills through increased competition with other predators.

Nature appears to provide the appropriate behaviours and skills needed to survive relevant to the environment the cheetahs are in. There is no need for certain behaviours to develop if their response is not needed for survival; for example, in a captive boma situation and fed on dead meat, the predator does not need to learn to hunt and kill therefore will not necessarily show this activity in play as vigorously as in the wild. If there is no threat of food being taken from other predators in captivity, there is no reason to develop protective behaviours or increased vigilance as seen when they are in the wild. However, if one of these issues is introduced into a captive situation, the development of the required behaviour to adjust to the wild environment will develop, as was observed in anti-predator experiments working after only 1-2 experiences (McLean, 1996; Griffin, 2000). If these desired survival behaviours can be initiated in the captive environment months before release, it will be advantageous to the predator by giving it practical experience, building the confidence required to survive.

Further work needs to be done to develop models of live prey introduction and behaviour monitoring in order to determine the stimulus needed to bring about the desired natural response from the animal. A limiting factor may be the inability to use live prey, however the use of complete carcasses may be able to be substituted. By rigging up the carcass causing movement or by dragging it to make the predator have to struggle with it, should stimulate the hunt/kill instinct enough for the cheetah to grab at the areas of the throat or body to effect a kill. Obviously there may need to be adjustments made depending on the animal, but incentives such as these may initiate the innate wild behaviours required.

Conclusion

This research is valuable not just for cheetah rehabilitation but for any predator that may need this opportunity in order to be released back into the wild and not be limited to a life of captivity or euthanasia. Rehabilitation is not necessary for all orphaned predators if they can be used for education, or breeding in cases of endangered species programs. However, in cases when predators are bred in captivity or raised from young ages and would be of more use genetically in wild populations, this program would provide methods of rearing and captivity protocol to increase those animals chances of survival.

A case in point was a four month old leopard cub confiscated by the DWNP in Ghanzi 2006, after two months of captivity in a chicken coop surrounded by people (A. Houser, *unpublished data*). The rehabilitation methods used for the three cheetahs was adjusted and applied for this species. The female leopard was kept in a boma (only adjustment was 1.5 m overhangs, and complete coverage above the lockdown area) for 18 months, and with some adjustments to the feeding routine (enrichment) and manoeuvring, this animal was never observed visually in the 20 x 40 m boma. The only way her condition and behaviour was monitored was through motion cameras set within the boma. There were no instances of her approaching the fence or acting aggressively with human presence.

There were no opportunities to provide live food beyond chickens on two occasions, and no 100 ha release site option for her to perfect her hunting strategy. In April 2008, at 2.1 yrs of age with permission from the DWNP, it was decided to GPS collar this leopard and release her in the WMA in southern Botswana as far from cattle posts as possible west of the Gemsbok National Park, so as not to put her in direct competition with the resident lion and leopard populations. This was decided appropriate due to her ability to kill small game that entered her boma, as well as her complete lack of aggressive or habituated interest towards people.

As of January 2009, this leopard has been surviving and hunting successfully since the day of release. She has not been reported taking livestock or seen by the surrounding cattle posts of the WMA. This leopard has been staying in an area within the WMA 20 km from her release point, with the eastern side of her home range being only 8 km from a small village.

This rehabilitation methodology can be adjusted for each species according to their age, experience and habituation response during captivity. The case of this leopard and its survival learning to hunt effectively, not taking livestock or being attracted to human settlements, even though her home range is within eight km of the closest village, proves this can possibly be accomplished with other even more dangerous species. It is also evidence that the ability to hunt may be more innate than just learned behaviour. In both the leopard and cheetah scenarios they were given 2-3 opportunities to kill on their own, which was accomplished without being shown by an adult.

In this study, the cheetahs' rehabilitation was successful in that the cheetahs learned to hunt without a mother from young ages, and developed vigilant behaviour in the wild in order to keep their prey and not become victims of other predators. They also showed normal breeding behaviour after a 2 month separation, and would possibly have found mates or mated with each other if they had survived.

These cheetahs did not become livestock raiders or try to associate with humans. They adjusted to the wild quickly and did not present an inordinate amount of behaviours due to captivity that would risk their ultimate survival. Subsequently, it appeared they had the skills to survive and were given a chance for life in the wild.

By having a series of methods compiled, tested and available, the techniques can be adjusted for each animal's circumstance and instinct development. Limitations of this study include long term monitoring after release to determine breeding success, and survival due to other competitors and human conflict, as well as ineffective or nonexistent government protection laws, policies and personnel.

This is one study with promising results in the development of hunting, vigilance and survival behaviour of orphaned cheetahs, which can be built upon with further research. Release site (Hunter, 1998; Bradley, 2005), disease testing (Mathews, 2006), affects on resident populations (Molony, 2005) and human conflict issues (Marker *et al.*, 2003) must all be taken into consideration for the success of rehabilitation and release to have long term benefits.

The ability to release captive bred or wild caught cheetahs back into wild populations in the future may aid in the species survival. The cheetahs' survival upon release will only be as successful as the education and tolerance of the human population that surrounds them. The death of the three cheetahs in this study was ultimately due to the main causes of mortality in wild cheetah populations, consisting of illegal hunting, intolerance and lack of education. Consequently, rehabilitation and release programs for all predator species will be most effective with detailed monitoring after release in conjunction with continued education and tolerance of predators by farmers, and education of the children and governments who are the farmers and policy makers of the future.

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CHAPTER 5

Summary

The results of three studies consisting of spoor density, home range and rehabilitation methods of cheetahs *Acinonyx jubatus* were used to assimilate information about a vulnerable species that has not been studied exclusively in Botswana. This research assisted in quantifying a correction factor to be used in spoor studies, determining home range estimates for male and female cheetahs on farms and reserves, and in the development of rehabilitation methods to raise cheetahs that can hunt successfully. Spoor surveys can be used to gain knowledge of cheetah density in any given area in an affordable, repeatable and objective manner, and have been previously done on populations of lion *Panthera leo* and leopard *Panthera pardus* (Stander, 1998, Funston, 2001). This study was able to test this method on a known population of wild cheetahs in Jwaneng and then retest and adjust the formula using data from an additional wet season. This method produced a more accurate correction factor for the equation to determine the true cheetah density compared to spoor density. A variable to take into consideration when using this technique to determine cheetah numbers, is that there are frequently more cheetahs present than visible spoor. Cheetahs frequently travel meters apart when in a group, and the counting of spoor can underestimate the actual population present.

There was a difference in the sample effort required to get an accurate population estimate in the wet and dry seasons. More kilometres needed to be travelled in the dry season to determine population numbers compared to the wet season. The increased movement of prey in the dry season for water and suitable habitat will proportionately effect cheetah movements in order to for them to attain their food requirements and habitat. The cheetahs need habitat both for cover and concealment with prey availability to survive (Fitzgibbon, 1990; Caro, 1994; Broomhall *et al*., 2003). When setting up a

spoor survey these seasonal differences should be taken into consideration due to the variation in time and cost of the study. Spoor surveys can be used as a tool in long-term monitoring of populations; however the correction factors should be used with caution taking into account changes in habitat and behaviour. Spoor studies will be site and time specific requiring additional studies in the future to accommodate for population changes. Although this is suitable for population density in an area, it can not be used continually without adjustment and refinement over time to account for population changes.

The home ranges of cheetah were determined utilizing primarily males on farmlands, and females alone and with cubs residing in a game reserve with movement onto surrounding communal farmland. The majority of cheetah populations are known to survive better outside of protected areas with decreased competition from other predators (Winterbach, 2001; Marker *et al.*, 2003). This study found the females' home range sizes in the game reserve to be 200-600 km^2 smaller than the males' home ranges on the Ghanzi farmland. This may have been due to the difference in human conflict and competition from other predators. Ghanzi had high conflict with the farming community, which resulted in five of the eleven collared cheetahs being killed within 3-5 months after release in their current home range.

The males had larger home ranges than some observed in other studies, which may have been due to low density of game on the farmlands and increased human conflict (Marker, 2007). Single males held smaller home ranges than the coalition, which has not been observed in previous studies (Caro, 1994). The maximum daily movement was larger in males than in females, observing that females with cubs moved less km/day than lone females, but increased as the cubs aged. Males travelled farthest in late evening and early morning, as was observed in Bissett & Bernard (2007). The sample effort was most accurate for daily travel if recorded at least once per 24 hours, whilst the home ranges could be accurate if recorded at least twice per week for females, and once per day for males. The results of this study provided a baseline of home ranges for Botswana cheetah, and a tested sample effort for accuracy when designing a study to monitor home range sizes and daily movement.

The rehabilitation study showed that cheetah cubs from 2 months of age, without hunting experience could be taught to hunt by giving them opportunities to kill during maturation, similar to what the mother provides (Caro & Hauser, 1992). The isolation of the cubs decreased the habituation factor as well as putting the two families together to make one unit. It has been observed in other studies that animals in captivity will respond differently when in the wild as their natural instincts develop (Bauer, 2005). The animals will develop the instincts for survival depending on the environment they are in, and adjust accordingly. These cheetahs were observed developing more natural behaviours as time increased from the 100 ha pen where they learned to hunt to their release onto the 9000 ha farm. As their environment changed, so did their responses in prey consumption, kill efficiency, vigilance and daily travel.

It was observed that if given opportunities to hunt at a young age, their confidence and abilities developed in proportion to the stimulus encountered. Even with captivity for 1.5 years at young ages, they developed into self sufficient hunters, vigilant in the bush, and did not show an affiliation toward humans. This study was one example that can be used for methodology and time frame reference for introduction of stimuli or procedure, however the actual implementation of releasable animals could be done in a shorter time period. The costs for pens would be a one time event, with monthly feeding costs being a constant for the duration of captivity. Once the cheetahs are introduced to killing of prey, they may be able to be released and monitored within a 2 to 3 month period. Rehabilitation of orphaned cheetahs or captive bred cheetahs for release into the wild is a relatively new area of conservation management. The monitoring and publishing of studies in this area have been minimal to non-existent (Hunter, 1998), and needs to be maintained if this is to become a viable management tool for endangered or threatened species (Linnell *et al*., 1997).

The continued research and understanding of cheetah movement and populations will help in determining habitat requirements for management considerations, as well as in the reintroduction of new populations and translocation efforts of problem animals. The rehabilitation and utilization of orphaned cheetahs can then be incorporated in the results of these management concerns. The most important determinant to the success of the cheetah is the continued education of children, farmers and government agencies. Their survival will be dependant on habitat availability, decreased competition from other predators and tolerance by humans. Human conflict was found to be responsible for the majority of cheetah deaths in this study, which highlights the plight of the cheetah and the struggle ahead.

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