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The re-introduction of captive bred cheetah into a wild environment, Makulu Makete Wildlife Reserve, Limpopo province, South Africa

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ABSTRACT

The conservation benefits of animals in captivity are limited to education and genetic preservation. However, where species or sub-species are critically endangered, the release of captive bred animals into the wild can be used as a strategy to supplement existing populations or to form new founder populations. Cheetahs *Acinonyx jubatus* born in captivity have no prior experience of survival in wild circumstances. Captive bred cheetahs are currently the greatest source of individuals. This project worked in conjunction with IUCN reintroduction guidelines and pre-existing recommendations in an attempt to develop an ideal methodology of reintroducing captive bred cheetah into the wild. Three captive bred cheetahs, one female and two males, were reintroduced onto Makulu Makete Wildlife Reserve, a predator proofed reserve in the Limpopo province of South Africa, as part of an experimental rehabilitation project. The cheetahs had to lose their homing instinct, be habituated to researchers, become accustomed to eating venison, chewing skin, infrequent large meals and strength development within the three months spent in the enclosures. The cheetahs

were habituated to the field researchers on foot and to research vehicles for ease of monitoring. A soft release methodology was used to ease the cheetahs into the environment. Upon release they were tracked twice daily to observe behavior and interaction with their environment. The duration of the project was 20 months which includes enclosure time.

The establishment of a home range indicated that the resource need of the cheetahs was satisfied. Eight habitat types were identified in the study area and all cheetahs encompassed part of each in their home range. Though the hunting instinct was present in all the cheetahs, the appropriate hunting techniques and prey selection had to be learned overtime. There was no difference between what was stalked and what was caught. From the observed kills, prey weight ranged from small <40 kg to medium <160 kg. This weight range is comparable to wild cheetahs that select prey within the same range. Each cheetah hunted every four to five days and consumed three to five kilograms of meat per day. Nine prey species were identified, two of which were not detected during direct observations. In the collection of scat, the trained dog found approximately a scat per hour while each direct observation by the researchers took approximately 10 hours.

These captive bred cheetahs had to learn how to hunt and how to select appropriate prey thus addressing learned behavior versus instinct. Given the frequency and intensity of injuries sustained and the extensive human influence in the form of veterinary treatment, the reintroduction was not a success. However the techniques developed and modified are relevant for future endeavors'.

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Chapter 1: The feasibility of releasing captive bred cheetah *Acinonyx jubatus* into a wild environment: taming the controversy

INTRODUCTION

The cheetah, *Acinonyx jubatus* is classified as Vulnerable both globally (IUCN 2006) and in South Africa (Friedmann and Daly 2004). Trade in cheetah is regulated under Appendix I of CITES (CITES 2000). Eastern and Southern Africa are the areas with the largest wild populations of cheetah on the continent (Santer 2001; IUCN 2006; Belbachir 2008). Smaller populations have been identified in northwestern Africa, Algeria, Niger, Benin and Burkina Faso (Belbachir 2008; Busby *et al.* 2009, IUCN 2009,). For the Red List a population is defined as "the number of individuals known or inferred to be capable of reproduction" (IUCN 2006). Therefore, the effective population is the number of individuals capable of passing on their genes through offspring being successfully raised or recruited (Jowkar *et al.* 2008). The largest populations of cheetahs occur in savanna, woodlands and mixed savanna-bushveld of sub-Saharan Africa (Durant 2000). This region of the world has a rapidly growing human population of approximately 2-3 % per annum in rural and urban areas (Struhsaker *et al.* 2005). In South Africa human populations are growing by 2.2 % per annum which is 1.6 % higher than other developing countries (Cincotta *et al.* 2000). The impacts of anthropogenic activities are evident in the deterioration of the environment because as populations increase so to do their demands on the environment. There are increases in human populations in areas surrounding current reserves and protected areas. Protected areas are often in isolated areas in ideal, fertile regions where rural people reside and land use practices result in wood harvesting and farming therefore affecting vegetative composition, structure and function (Higgins *et al.* 1999).

The different habitats and land available in South Africa, approximately 125 150 km², is suitable habitat for cheetahs (Boitani *et al.* 1999 in Marnewick *et al.* 2007). Of this 55 654 km² is under formal conservation and encompasses 44.5 % of the suitable cheetah habitat; Kruger National Park, Pilanesberg National Park, Hluhluwe-Umfolozi Park, Phinda Resource Reserve and Kgalagadi Transfrontier Park (Friedmann and Daly 2004). Sub-Saharan Africa is approximately 40 % savanna (Higgins *et al.* 1999). Distribution maps of cheetah populations the Northern Cape Province, North-West Province, northern Limpopo province, Mpumalanga and small re-introduced populations in Kwa-Zulu Natal reserves (Friedmann and Daly 2004). Recent surveys therefore confirm that cheetah occurrences in South Africa are in the north, northeast and northwest while other areas are a result of relocations (Marnewick *et al.* 2007). In habitats such as woodlands and mixed savanna-bushveld hunting techniques and range use adaptations have been observed and recorded in Namibia (Marker *et. al* 2003a), Matusadona National Park Zimbabwe (Purchase and du Toit 2000), Kruger National Park (Broomhall 2006). In Matusadona National Park Zimbabwe and Kwandwe Private Game Reserve Eastern Cape the extent of survival in thicket woodlands, which are not considered cheetah habitat, show the adaptability of cheetahs to their environment (Purchase and du Toit 2000; Bissett and Bernard 2005).

Existing threats to cheetah populations

Cheetah numbers are significantly influenced by human activities which is cause for concern (Asadi 1997; Marker *et al.* 2003a). Reintroduction of captive cheetah into controlled, monitored environments can therefore be a model method of conservation action. Cheetah in Iran, India and northwestern Africa are listed as Critically Endangered by the IUCN Red List of Threatened Species (Belbachir 2008). In northwest Africa the census was 250 individuals and 60 to 100 in Iran (Jowkar *et al.* 2008). Within these populations less than half are mature breeding individuals. Anthropogenic activities that threaten cheetah populations include the conversion of natural habitat into livestock ranches (Marker *et al.* 2003b; Marnewick 2006) and the disruption of carnivore guilds (Linnell and Strand 2000; Santer 2001; Marker *et al*. 2003b).

The main threat to cheetah survival is conflict with wildlife and livestock ranchers (Marker *et al.* 2003b; Marnewick 2006). Recently in the Limpopo province of South Africa there has been an increased conversion from livestock ranching to wildlife ranching for both economic and ecological reasons (Marnewick 2006). Change in land use means that the prey base for cheetahs has increased. Due to the commercial hunting value of wildlife, conflict arises when cheetahs prey upon antelope species that could have been hunted, for a profit, resulting in cheetah being either shot or captured and sold illegally. There have been studies in Namibia, Tanzania, Uganda and South Africa on cheetah demographics. In Namibia findings showed that conflict between landowners and cheetahs led to high frequencies of illegal removal and persecution (Marker *et al.* 2003a). In Tanzania habitat degradation outside of protected areas is the primary cause of cheetah population decline (Gros 2001). The decline of wild prey species in areas of Southern Africa is due to the grazing pressures from livestock such as goats, sheep and cattle even within protected areas (Marker *et al.* 2003a, 2003b). Cattle, sheep, goats and other species that are used for domestic agricultural purposes require food sustenance and dwelling space. Practical conservation strategies implemented on farmlands can, however, significantly contribute to the conservation of the cheetah. Poor agricultural practices are frequent and do not follow natural patterns (Marker *et al.* 2003b).

Cheetah populations show an inverse relationship to lion *Panthera leo* and spotted hyena *Crocuta crocuta* populations. Predation by these carnivores on cheetah cubs and solitary adults has been documented in the Serengeti and is the main limiting factor to cheetah cub survival (Caro 1994). This separation of less dominant and dominant carnivore species is also evident between leopards *Panthera pardus fusea* avoiding tigers *P. tigris,* genets *Genetta genetta* avoiding Iberian lynx *Lynx pardinus* and grey foxes *Dusicyon griseus* avoiding culpeo foxes *D. culpaeus* (Linnell and Strand 2000). Inter species aggression can directly influence less dominant carnivore densities. Cheetahs are more likely to avoid an area if the risk of encountering lions or spotted hyenas is great (Durant 1998; Durant 2000). By exhibiting spatial and temporal avoidance of habitat patches supporting lions and hyenas, cheetahs will inherently occur at lower densities within such areas. Lions and hyenas have been virtually extirpated outside of protected areas and occurrence of these large carnivores is greater within conservation areas, for this reason cheetahs occur in greater densities outside of protected areas (Linnell and Strand 2000; Santer 2001; Marker *et al*. 2003b). Consequently, cheetahs become highly susceptible to anthropogenic activities. In Namibia approximately 90 % of cheetahs occur on farmlands outside of protected areas (Marker *et al.* 2003b). It is, therefore, not desirable or appropriate to reintroduce captive bred cheetahs into a conservation area where there are high populations of lions and spotted hyenas. The cheetahs require the absence of these dominant carnivores to allow adaptation without pressure of predation. However, due to the anthropogenic induced ecological changes there are limited wild areas in South Africa and therefore appropriate protected areas are those with a limited population of dominant carnivores.

About cheetahs

Cheetahs are the lightest of the big cats weighing between 30 kg and 45 kg (Estes 1992; Caro 1994). Cheetahs are diurnal and hunt at dawn and dusk. The cheetahs prey base is made up of gazelle *Gazella*, impala *Aepyceros melampus* and other medium to small ungulates including calves of larger ungulates. Females are solitary unless with cubs while males can be solitary or form coalitions of two or more animals. Lone cheetahs hunt on average every two to five days while females with cubs and coalitions hunt more frequently (Estes 1992). Female cheetahs establish home ranges where resources such as food and shelter can be found. Male cheetahs establish a territory that ensure mating and resources (Estes 1992; Caro 1994). Territories are actively defended against other males and scent marked using urine (Estes 1992; Caro 1994). Litter sizes range from one to six cubs, however, cub mortality is high and few are raised to independence (Caro 1994).

Successful captive breeding of cheetahs was first recorded in 1956 at the Philadelphia Zoo. Following this birth one hundred and forty births were recorded between 1956 and 1974. Captive breeding of cheetahs is notoriously difficult, and ensuring survival of captive bred cubs has had limited success. However, with good breeding management, the De Wildt Cheetah Breeding Centre (Brits, North West province, South Africa) produced 785 cubs born between 1975 and 2005 (Bertschinger, *et al.* 2008) and it currently breeds cheetahs successfully for export. Captive cub survival from below the age of twelve months was 71.3 % while survival beyond twelve months was 66.2 % (Bertschinger *et al.* 2008). The direct conservation benefit of these cheetahs is limited as many of the facilities, such as zoos, are not actively breeding or doing any education work.

Conservation benefits for the Asiatic cheetah *Acinonyx jubatus venaticus*

The Asiatic cheetah subspecies *Acinonyx jubatus venaticus,* also referred to as the Iranian cheetah, currently occurs in few semi-arid areas of Iran and neighboring Pakistan (IUCN 2006). In 1996 the Asiatic cheetah was listed as Critically Endangered by the IUCN Red List of Threatened Animals and has not changed (IUCN 2009). The two primary cheetah prey species are listed as Vulnerable on the same IUCN list; the wild sheep *Ovis vignei* and Jebeer gazelle *Gazella bennetti* (IUCN 2006). The cheetah population has been decimated due to removal of prey species and habitat disturbance by desertification, agriculture, industry, infrastructure and general human activity. Though national parks and protected areas exist they too suffer the impacts of desertification (Asadi 1997). Species such as the Asiatic lion *Panthera leo persica* and the Caspian tiger *Panthera tigris virgata* have already become extinct in Iran due to the previously mentioned pressures. While the Asiatic lion is currently only found in India the Caspian tiger is believed extinct. In the absence of active conservation the same fate awaits the Asiatic cheetah (Asenjo 2000).

Conservation plans have been created and implemented on protected areas in Iran (Asenjo 2000). Protection of the habitat is the primary concern and laws that limit negative influence on the environment exist. The Department of the Environment, Community Green Funds and local nomadic residents are attempting to collaborate to create and implement management plans that support the conservation of cheetahs (Asenjo 2000). The Iranian Cheetah Society has been formed and is actively working to conserve the Iranian cheetah through projects involving research, education, awareness and habitat and prey conservation (www.iraniancheetah.org, 05/08/07). Informal reports of Iranian cheetahs in captivity have been received and with the correct husbandry, and co-operation these cheetahs could very possibly be bred in captivity and the offspring used to supplement the small wild population. Reintroduction of captive bred animals is an appropriate step in conservation for species that require population supplementation. However, it is critical that a study be done on how to effectively and appropriately re-introduce captive bred cheetahs into the wild whilst giving them a maximum chance of survival. The selection of the appropriate cheetah candidates should be based on proper husbandry, veterinary standards, temperament and protocol used for the Iberian lynx. By conducting this study on a less threatened subspecies of cheetah, techniques will be developed that can be used to salvage populations such as that of the Iranian cheetah.

Reintroduction regulations

The World Conservation Union, IUCN (1987), defines reintroduction as "the intentional movement of an organism into a part of its native range from which it has disappeared or become extirpated in historic times as a result of human activities or natural catastrophe." Reintroduction regulations and guidelines are prepared by the Reintroduction Specialist Group of the Species Survival Commission and approved by the IUCN Council (Jackson 1995). In 1995 the guidelines and regulations of reintroductions were revised and approved. The guidelines state that "The principle aim of any reintroduction should be to establish a viable, free-ranging population in the wild, of a species, subspecies or race." This is applicable on both local and global scales. Reintroductions are only permitted on former ranges and natural habitat and should require minimal long-term management. The participation of multidisciplinary persons from various backgrounds is recommended; such as funding bodies, non-governmental organizations, natural resource management agencies, universities, and veterinary institutes and other relevant, suitable expertise (Jackson 1995).

There are both local and international rules and regulations for reintroduction of species in general. It is clearly stated in the IUCN Position Statement (1987) that certain criteria and phases must be implemented and recorded to ensure the safety and security of the animals. The two phases include 1) the preparation and release or reintroduction of the animals and 2) the follow-up phase. The preparation and release phase requires knowledge of the area of release and the needs of the organism. The follow-up phase is long term and determines the rate of adaptation and whether the project was a success or a failure (IUCN 1987). As there have been previous studies and experimental releasing of cheetahs similar guidelines will be adapted and used as a model. The De Wildt Cheetah and Wildlife Trust's Wild Cheetah Project have developed guidelines for the reintroduction of wild caught cheetahs (Cilliers 2006). Limited information regarding purely captive bred cheetahs, their activity post-release and adaptive behavior exists and will therefore be the focus of this research. Anecdotal information exists suggesting that such releases are possible, however, the aim of this study is to determine the feasibility of a captive release using sound biological study methods while abiding by all the applicable regulations.

The success of reintroducing captive bred carnivores is lower, 13 % of 52 projects, than that of wild caught carnivores: 31 % of 45 projects (Jule *et al.* 2008). This does not differ significantly from similar research conducted by Snyder (1996) where 11 % of captive bred reintroductions were successful. Rating the success of a reintroduction is based on three commonly agreed upon criteria 1) the first wild-born population breeds successfully, 2) adult death rate must be exceeded by a three year breeding population with recruitment and 3) the establishment of a self-sustaining wild population (Snyder 1996; Ostermann *et al.* 2001; Jule *et al.* 2008). However, these criteria all focus on long term studies. Here we are developing methods to ensure that the individual captive bred animal survives. It is recommended that this study is continued to determine if criteria one can be met. All other criteria are long term and possibly not applicable to this study. This project focuses on the survival of the individual animals and their ability to adapt and be monitored continuously on a short term basis. Reintroduction of captive bred animals includes the risk based on the assumption that captive animals lack the natural behavior appropriate for wild environments (Sutherland 1998; Caro 2000; Jule *et al.* 2008). Regarding carnivores, this is predominantly evident when assessing basic survival behavior such as hunting, mating and establishing a social dominance pattern.

The failure of carnivore reintroduction projects conducted was mainly due to anthropogenic activities (poisoning, hunting, road accidents), starvation, inter species aggression and disease (Pettiffer 1979; Ferguson 1995; Nature Conservation Trust 2006). Animal related failures such as starvation are a result of inappropriate conditioning of the animal prior to release or lack of appropriate and sufficient resources within the release area (Jule *et al.* 2008). This is often a result of insufficient research of the animal and the release site. Failure is therefore a result of disregarding significant factors such as habitat suitability, food availability over the long term, the season of release, the type of release and the animal source (Griffin *et al.* 2000; Haight *et al.* 2000; Jule *et al.* 2008). There are only a few studies on the adaptability of captive bred cheetah to a wild environment. In 1979 three captive bred male cheetahs were radio collared and released in Timbavati, monitored but then removed from the reserve (Pettiffer 1979). Captive bred cheetahs from the Hoedspruit Centre for Endangered Species were introduced to the Hoedspruit Air Force Base in 1979 but had to be removed as they were chasing motorbikes (Pettiffer 1979). In 1993 two captive bred females were released into Mthethomusha Game Reserve in South Africa. One female was killed by hyenas while the other was removed due to starvation (Ferguson 1995). In 2006 a wild male, who was in captivity from the age of four years, was bonded and released with a captive bred male on Jubatus Cheetah Reserve in Limpopo Province (Nature Conservation Trust 2006). The males bonded, formed a coalition, hunted successfully and remained on the reserve. Reintroduction attempts of captive bred cheetah have taken place and with each trial new information is gained.

OBJECTIVES

The aim of this study was to determine whether captive bred cheetah can adapt to a wild environment and therefore create a model for captive release of other critically endangered subspecies in the event that an important population goes extinct due to an unforeseen catastrophe. This was determined by a) conditioning the cheetahs for wild circumstances, b) determining habitat use and the establishment of a home range, c) determining that the cheetah diet and hunting abilities mimicked wild cheetahs and d) establishing a complete understanding of diet composition through scatology.

REFERENCES

Asadi, H. 1997. The environmental limitations and future of the Asiatic cheetah in Iran. Unpublished project progress report. IUCN/SSC Cat Specialist Group.

Asenjo, R. 2000. Conservation of the Asiatic Cheetah, its Natural Habitat and Associated Biota in the I.R of Iran: Project Summary. UNDP. Global Environmental Facility.

Baskin, Y. 1993. Trumpeter swans relearn migration. *BioScience.* 43(2): 76-79

Belchabir, F. 2008. *Acinonyx jubatus ssp. Heckii.* In IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. www.iucnredlist.org. Downloaded on 30 November 2009.

Bertschinger, H.J., Meltzer, D.G.A. and van Dyk, A. 2008. Captive Breeding of Cheetahs in South Africa- 30: Years of Data from the De Wildt Cheetah and Wildlife Centre. *Reproduction Domestic Animals.* 43 (2): 66-73.

Bissett, C. and Bernard. 2006. Habitat selection and feeding ecology of the cheetah (*Acinonyx jubatus*) in the thicket vegetation: is the cheetah a savanna specialist? *Journal of Zoology.* 271: 310-317.

Broomhall, L.S. 2006. Cheetah *Acinonyx jubatus* ecology in the Kruger National Park: a comparison with other studies across the grassland-woodland gradient in African savannas*.* MSc. Thesis. University of Pretoria.

Busby, G.B.J., Gottelli, D., Wacher, T., Marker, L., Belbachir, F., De Smet, K., Belbachir-Bazir, A.F., Belghoul, M. and Durant, S. 2009. Genetic analysis of scat reveals leopard *Panthera pardus* and cheetah *Acinonyx jubatus* in Southern Algeria. *Oryx.* 43(3): 412-415.

Nature Conservation Trust. 2006. Behavioral Analysis of Cheetah Reintroductions: The Reintroduction of One Captive-born and One Wild-born Male Cheetahs (*Acinonyx jubatus)* On Jubatus Cheetah Reserve, Limpopo Province, South Africa.

Caro, T.M. 1994. *Cheetahs of the Serengeti Plains: group living in an asocial species.* The University of Chicago Press. Chicago, USA.

Caro, T.M. 2000. The behavior-conservation interface. *TREE.* 14 (9): 366-369.

Cilliers, D. 2006. Introduction of the cheetah (*Acinonyx jubatus*) to game reserves in South Africa.

Durant, S. M. 1998. Competition refuges and coexistence: an example from Serengeti carnivores. *Journal of Animal Ecology.* 67: 370-386.

Durant, S. M. 2000. Predator avoidance, breeding experience and reproductive success in endangered cheetahs, *Acinonyx jubatus. Animal Behaviour.* 60: 121-130.

Estes, R. D. 1992. *Behavior Guide to African Mammals*. The University of California Press. California, USA.

Ferguson, M. 1995. A Disastrous Cheetah Reintroduction in South Africa. *Cat News*. 23: 16-17.

Friedmann, Y. and Daly, B. 2004. Red data book of the mammals of South Africa: a conservation assessment. CBSG Southern Africa, Conservation Breeding Specialist Group (SSC/IUCN) Endangered Wildlife Trust, South Africa. 147-149.

Griffin, A. S., Blumstein, D. T. and Evans, C. S. 2000. Training Captive-Bred or Translocated Animals to Avoid Predators. *Conservation Biology.* 14(5): 1317-1326.

Gros, P.M. 2001. The status and conservation of the cheetah *Acinonyx jubatus* in Tanzania. *Biological Conservation*, 106 (2): 177-185.

Haight, R.G., Ralls, K. and Starfield, A.M. 2000. Designing Species Translocation Strategies When Population Growth and Future Funding Are Uncertain. *Conservation Biology.* 14 (5): 1298-1307.

Higgins, S.I., Shackleton, C.M. and Robinson, E.R. 1999. Changes in woody community structure and composition under contrasting land use systems in a semi-arid savanna, South Africa. *Journal of Biogeography.* 26: 619-627.

IUCN. 1987. IUCN Position Statement on the Translocation of Living Organisms: Introductions, reintroductions and re-stocking. Gland, Switzerland.

IUCN 2006. www.iucnredlist.org/. Downloaded on 30 November 2009

Jackson, P. 1995. Revised Reintroduction Guidelines. *Cat News*. 23: 27.

Jowkar, H., Hunter, L., Ziaie, H., Marker, L., Breitenmoser-Wusten, C. and Durant, S. 2008. *Acinonyx jubatus ssp. Venaticus.* In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. www.iucnredlist.org. Downloaded on 30 November 2009.

Jule, K. R., Leaver, L. A. and Lea, S. E. G. 2008. The effects of captive experience on reintroduction survival in carnivores: A review and analysis. *Biological Conservation.* 141: 355-363.

Krausman, P. R. and Morales, S. M. 2005. Acinonyx jubatus. *Mammalian species.*771: 1-6.

Linnell, J. D. C. and Strand, O. 2000. Interference, interactions, co-existence and conservation of mammalian carnivores. *Diversity and Distribution.* 6: 169-179.

Low, A. B. and Rebelo, A. G. 1998. *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environment Affaires and Tourism, Pretoria. 2nd ed.

Marker, L. L., Dickman, A. J., Mills, M. G. L. and Macdonald, D. W. 2003a. Aspects of the management of cheetahs, *Acinonyx jubatus jubatus*, trapped on Namibian farmlands. *Biological Conservation*. 11 (3): 401-412.

Marker, L. L., Dickman, A. J., Jeo R. M., Mills, M. G. L. and Macdonald, D. W. 2003b. Demography of the Namibian cheetah, *Acinonyx jubatus jubatus* . *Biological Conservation*. 114 (3): 413-425.

Marnewick, K. and Cilliers, D. 2006. Range use of two coalitions of male cheetahs, *Acinonyx jubatus* in the Thabazimbi district of the Limpopo Province, South Africa. *South African Journal of Wildlife Research*, 36 (2): 147-151.

Marnewick, K., Beckhelling, A., Cilliers, D., Mills, G., Herring, K., Caldwell, P., Hall, R. & Meintjes, S. 2007. *The status of the cheetah in South Africa*. In: Breitenmoser & Durant (Eds) The Status and Conservation Needs of the Cheetah in Southern Africa. *Cat News Special Issue 3* IUCN Cat Specialist Group. 22-31.

Nowell, K. and Jackson, P. 2001. Endangered Classification of West African Lions. *CAT News.* 41: 35-36.

Ostermann, S.D., Deforge, J.R. and Edge, W.D. 2001. Captive Breeding and Reintroduction Evaluation Criteria: A Case Study of Peninsular Bighorn Shep. *Conservation Biology.* 15(3): 749-760.

Pettifer, H.L. 1979. The experimental release of cheetah (*Acinonyx jubatus)* into the natural environment. Nature Conservation Transvaal Division. South Africa

Purchase, G.K. and du Toit, J.T. 2000. The use of space and prey by cheetahs in Matusadona National Park, Zimbabwe. *South African Journal of Wildlife Research*. 30 (4): 139

Santer, R. 2001. Letting the cat out of the bag. *Biologist*, 48 (2): 72-74.

Snyder, N.F.R., Derrickson, S.R., Beissinger, S.R., Wiley, J.W., Smith, T.B., Toone, W.D and Miller, B. 1996. Limitations of Captive Breeding in Endangered Species Recovery. *Conservation Biology.* 10 (2): 338-348.

Struhsaker, T.T., Struhsaker, P.J. and Siex, K.S. 2005. Conserving Africa's rain forests: problems in protected areas and possible solutions. *Biological Conservation.* 123: 45-54.

Van Dyk, G. and Slowtow, R. 2003. The effects of fences and lions on the ecology of African wild dogs reintroduced to Pilanesberg National Park, South Africa. *African Zoology.* 38: 79-94.

Chapter 2: Makulu Makete Wildlife Reserve, Limpopo province: release site and animal care of three captive bred cheetah *Acinonyx jubatus*

STUDY AREA

Makulu Makete Wildlife Ranch, formerly Leniesrus 204 MR and Aden 214 MR, is situated in the South African Limpopo River Valley. The reserve is entirely surrounded by predator proof electrified wildlife fencing thus minimising the risk of cheetah escape. Co-ordinates of Makulu Makete are between 28º51,78', 28º53,29' E and 22º33,52', 22º35,09' S. Approximately 25 km south-east is the town of Alldays which is in the northern most region of the Limpopo province (Fig. 2.1.). The reserve is 45 km² in size of which 2.64 km² are fairly elevated hills. The larger of the two mountains, Madiapala, is 2.08 km² in extent with an elevation of 940 meters. The smaller mountain, Kremetartkop, is 56 ha in area (De Klerk 2002). Overall altitude in Makulu Makete is approximately 670 meters. The majority of the remaining land undulates mildly. Between the Limpopo River and Soutpansberg Mountains where Makulu Makete is situated there is high elevation, high temperatures and low rainfall and is therefore defined as part of the Savanna Biome and thus semi-arid (Mucina and Rutherford 2006). Temperatures range from 4 ºC to 41 ºC with a yearly mean of 21 ºC. Summers are hot with rainfall while winters are warm with minimum frost occurrence. Rainfall data was collected from the Tuscanen weather centre 25 km west of Makulu Makete. Mean rainfall per annum recorded between 1982 and 2006 was 280 mm. Since rainfall is in the summer approximately 75 % falls between November and March. Droughts do occur and are interspersed with wet cycles (De Klerk 2002). During the dry seasons there are collected pools of water where the river flows perennially. East and south-east of the property is the Mogalakwena River which forms the border with the neighboring property on the east. Approximately 4.5 km of this river is entirely on the Makulu Makete property. Networking drainage exists throughout the property and a total of 14 waterholes are distributed on the property of which nine are functional concurrently on a rotational basis.

According to Mucina and Rutherford (2006). Makulu Makete Wildlife Reserve falls within the Savanna Biome. This biome is characterised by herbaceous layer and a distinct sparse woody upper layer. Specific to Makulu Makete where bush encroachment has occurred, the area is referred to as mixed-bushveld as a result of the dense intermediate layer. Previous land use has resulted in evident phytosociological alterations. Evidence of the savanna history can be found in historical records and maps that have remained from previous owners. Bush encroachment is due to past agricultural practices and cattle farming. Measures have been taken to reduce the extent of encroachment. However, such an endeavor requires extensive man power and time. Neighboring ranches concentrate on livestock production, irrigated agriculture or wildlife. However, given the predator proof electric fence there has been and should be no interaction between the cheetahs and the neighboring animals.

The Limpopo valley where Makulu Makete Wildlife Reserve is situated has predominantly short to medium trees and shrubs with the exception being *Adansonia digitata*, the baobab tree, *Sclerocarya birrea* subsp *caffra,* marula tree and *Lannea schweinfurthii,* false marula. Along the Mogalakwena River bank the trees are larger with a height greater than six meters. The *Adansonia digitata* are randomly distributed throughout the ranch with an exceptionally high concentration at the bases of Madiapala and Kremetartkop. Throughout the ranch there are specific frequent occurrences of *Acacia tortilis, Acacia mellifera, A. senegal* var*. leiorhachis, Kirkia acuminata, Terminelia prunioides* and other small tree and shrub species. Along the edges of the drainage course *Ziziphus mucronata* and *Lonchocarpus capassa* dominate.

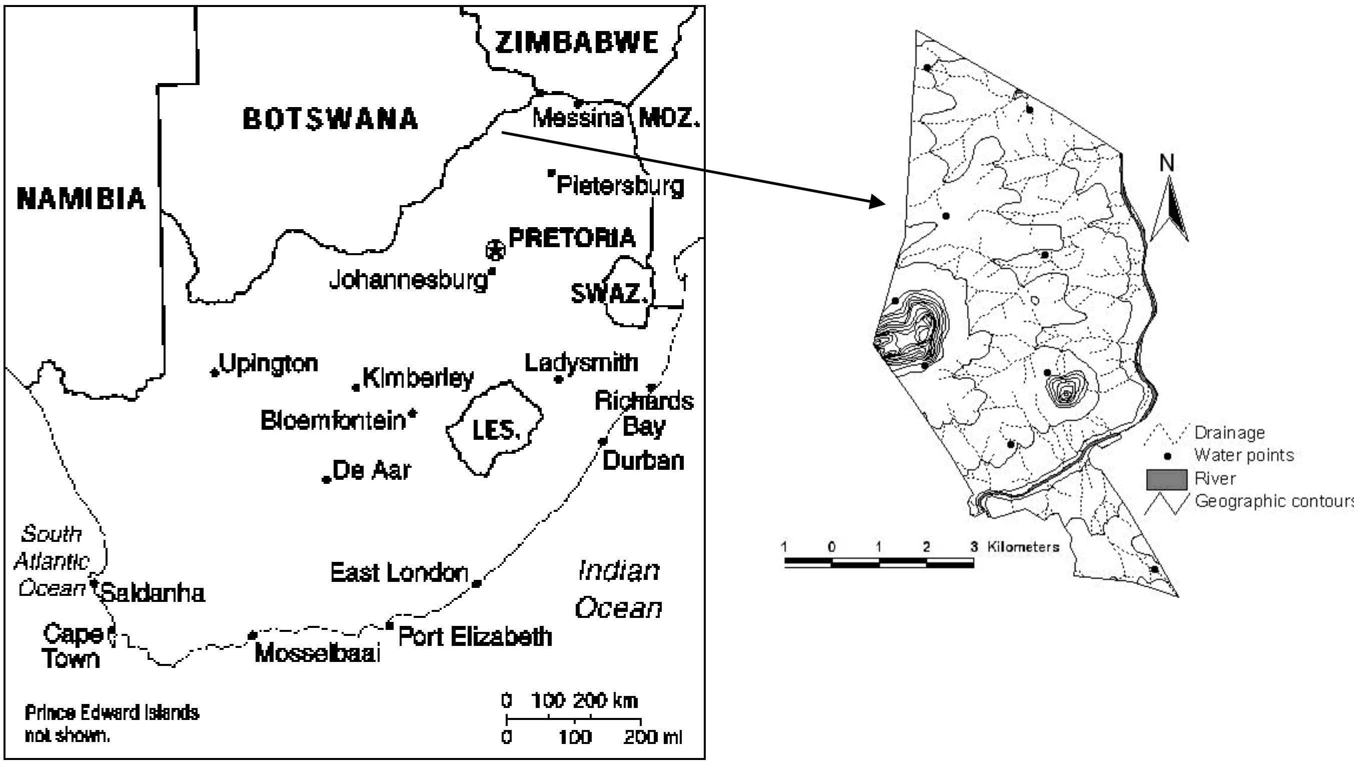

Fig. 2.1. Makulu Makete Wildlife Reserve where three captive bred cheetah were reintroduced (www.maps.google.co.za. 30/11/09).

STUDY ANIMALS

All cheetahs in this project were sourced from the De Wildt Cheetah Breeding Centre (Brits, North West Province, South Africa) and were born of captive bred parents. All the cheetahs were in enclosures with other cheetahs while at De Wildt, both related and unrelated. While at De Wildt each cheetah was identified by their house number and transponder number. Once brought to Makulu Makete Wildlife Reserve the cheetahs were identified by their unique spot pattern, tail bands, transponder number and collar frequency.

The cheetahs spent three months in the enclosures on Makulu Makete Wildlife Reserve and were familiarized to the habitat, environment, diet, other cheetahs and researchers. The first female brought to Makulu Makete Wildlife Reserve contracted Cryptococcus and was removed prior to release due to long term treatment. Another female was brought to the reserve and the same enclosure conditioning was implemented, diet adjustment and habituation to researchers and vehicles (discussed further in Chapter 3). A soft release was implemented for all the cheetahs where by depending on their fullness a food lure was tied to a tree outside their enclosure and the gate opened for them to walk out without being chased. A week prior to release the female was fed a top half of an impala ram *Aepyceros melampus*. On the ninth day an impala leg was tied to a tree outside her enclosure as a lure and to ensure that she was in fair condition upon release. The gate was opened on the ninth day and the female was left to walk out of the enclosure at her own pace. She was released first to familiarize herself with the area and settle into a home range. This was a preventative measure as there was the potential for male aggression towards the female despite the holding time spent in the adjacent enclosures which should have reduced the potential levels of aggression. A few weeks after release, due to a fractured toe, the female was removed from the reserve for surgery. The fractured toe from back foot was amputated. After two weeks of recovery she was re-released (chronology of the study period is depicted and explained in chapter 3).

The males were due to be released a month after the females second release; however one male died prior to release therefore only one male from the coalition was released. Cause of death was suspected to be from a snake bite however the post mortem was inconclusive. Four days prior to release the single male was fed a warthog *Phacochoerus africanus* leg. Similarly to the female, an impala leg was tied to a tree outside the enclosure to lure him out at his own pace without being chased. The male was removed from the reserve two months later as he chased motorbikes, quad bikes and was a threat to people on foot. Another male coalition was brought to the reserve and the same enclosure practices were implemented. One of the males was injured twice and died after the second injury due to a ruptured gastric ulcer. The first injury was a gemsbok *Oryx gazelle* hair that penetrated the eye. The second injury was from a failed hunt and fight with a bushbuck ram *Tragelaphus scriptus* which resulted in multiple puncture wounds. The previous removed male was then bonded with the remaining single male and released as a coalition. They separated on the first day of release possibly as a result of incomplete bonding. Once released the female cheetah established a home range while the males had both home ranges and scent marked territories.

METHODS

Vegetation structure

Vegetation structure encompasses floristic identification and vegetative classification (Werger 1979; Edwards 1983). Braun-Blanquet is primarily a technique that is used for floristic analysis and vegetation classification. When conducting a Braun-Blanquet survey plot size and plot form are variable not fixed. Size is adaptable to allow representation of one vegetation type only and to provide a uniform, typical description of the phytoceonosis represented by the vegetation in each plot. As a result different vegetative community structures, or associations, have different plot sizes (Werger 1979; Edwards 1983). The community unit theory states that smaller plots would not be representative because the community type could not be extracted from the data while a large plot would be time consuming and redundant. The statistical approach determines if a community exists or not depending on patterns.

When sampling the vegetation, several characteristics are necessary to establish what constitutes a plot (Floyd and Anderson 1987). These factors include structure, floristic list, cover abundance, sociability and habitat characteristics. The structure of a plot is determined by its homogeneity and stratification (Walker *et al.* 1988). Structural homogeneity occurs when a plot adequately represents the structure of the surrounding vegetation (Werger 1979). Factors such as height class, species and density determine structure as these indicate specific characteristics of a community. Stratification, also known as stratum, refers to the natural height layering of vegetation of similar or varying growth forms (Edwards 1983). A floristic list is a species composition list where all vegetation is recorded. Within a plot all species of a taxonomic group are recorded upon the correct identification of each individual plant. To determine cover abundance Braun-Blanquet uses a subjective scaling method.

The data collected is then entered into a computer program, TURBOVEG, which classifies plant communities into homogeneous groups. The data is then analysed for homogeneity using a multivariate analysis, the Two-way Indicator Species Analysis Program, TWINSPAN. This program organizes the floristic data into a two-way table and approximates the plant communities. The homogeneity of the vegetation units is classified according to a characteristic species and a dominant species. The characteristic species is unique to that community thus defining that community. By this means TWINSPAN identifies agro-ecological management units. These units are interpreted from a dendogram that is produced from a dichotomous key after the TWINSPAN analysis. From the dendogram management units can be subjectively interpreted. This process of division into sequential groups continues until homogenous vegetation units are grouped together and named using the binomial naming method. The binomial naming methods uses the characteristic species as the first species name, followed by the dominant species as the second species name. Following the binomial name a relevant physiognomic term which is a broad scale structural classification is inserted in accordance with Edwards (1983).

Vegetation density

The Biomass Estimates from Canopy Volume, commonly referred to as the BECVOL-model, is a quantitative descriptive model for woody plants that was introduced by Smit (1989a). This model estimates the leaf volume and mass of individual trees which in turn provides information of browsing capacity. These estimates are then given descriptive units that describe the woody plant status in a community regarding the value of the tree to browsers, fire resilience, sub-habitat for grasses and other animals and soil moisture use (Smit 1989b). The BECVOL-model allows for simultaneous measurements of complete woody plants and portions of the plant. Data was collected by walking line transects 100m in length and a width of 2m thus an area of 200m².

Bush encroachment and clearing

In the northern and central sections of the reserve there are high densities of *Colophospermum mopane*. Active control in these two areas has been implemented since 2002. Though *Grewia* species, *Colophospermum mopane* and *Terminalia prunioides* are palatable browse for wildlife, they have a great potential and evident ability to encroach thus increasing vegetation density. Excessive bush density can prevent animals from moving within the thickets to utilize the resources within them. The species removed included *Terminalia prunioides, Colophospermum mopane, Grewia* species*, Dichrostachys cinera* (Sickle bush) and *Acacia tortilis.* Clearing efforts were implemented in 2002 and 2003 but have currently been reduced because extensive man power is required and the cleared areas require maintenance to prevent re-growth. Seed sowing of palatable grasses such as Guinea grass *Panicum maximum,* Rhodes grass *Chloris gayana,* Blue buffalo grass *Cenchrus cilliaris* and Finger grass *Digitaria eriantha* complemented some areas of bush clearing. The bush removed was stacked and used to protect sown seeds from birds and to allow the young shoots time to grow before being grazed. At the end of 2003 a total of 241ha had been cleared along the roads and a total of 265 000 trees and shrubs removed.

Veterinary care

Three captive bred cheetahs, from captive origin, were brought to Makulu Makete Wildlife Reserve from De Wildt Cheetah Breeding Centre. The three cheetahs, a female and two males were fitted with standard mammalian VHF radio collars weighing 180 g (African Wildlife Tracking, Pretoria, South Africa) and the female fitted with a contraceptive implant effective for two year Suprelorin®[1] (Bertschinger *et al*. 2008). Placement of collars and contraceptive implant were fitted while cheetahs were under anesthesia using 2 mg Dormitor®[2] Medetomidine, 100 mg Ketamine®[3] and 1.5 ml Antisedon®[4] (Caldwell pers comm.1[5]). These drugs were administered by wildlife veterinarian Dr. Peter Caldwell. Each cheetah was vaccinated with Felocell®[6] and against Rabies in 2007 and 2008.

Monitoring

After release, all cheetahs were tracked using telemetry both from a vehicle and on foot. A vehicle, quad bike or Toyota single cab 4 x 4, was driven to the point on the road where the strongest signal from the collar was detected. The researchers would then walk the remainder of the distance to the cheetahs. Tracking and visual observations were conducted to assess the condition, behavior and habitat use of the cheetahs. The cheetahs were tracked twice daily during the early morning and afternoon when they were visibly active. These times ranged between 06h00 to 10h00 and 14h00 to 18h00 and varied with the seasons, weather conditions and time taken to locate the

[1] Peptech Animal Health, Sydney, Australia
[2] Pfizer Animal Health, New York, USA
[3] Pfizer Animal Health, New York, USA
[4] Pfizer Animal Health, New York, USA
[5] Dr Peter Caldwell, Old Chapel Veterinary Clinic, 222 Hertzo Ave, Villeria, Pretoria, e-mail: peter@olchapelvet.co.za
[6] Pfizer Animal Health, New York, USA

cheetahs. Duration of observations and distance to cheetahs were dependent on cheetah activity and vegetation density. Due to circumstances discussed later (Chapter 3); the cheetahs were monitored for four months following release to determine that survival was ensured. A data sheet was completed at each sighting (Appendix I). The date, time start and end, duration and a GPS (Global Positioning System) fix were recorded at the commencement of the observation. The cheetah data recorded included the sex, body condition and activity. The body condition was scored according to stomach fullness and hip protrusion (Hunter 1998) and was necessary to determine the health of animal. The activity of the cheetahs was recorded as walking, stalking, resting, eating, hunting, grooming, sitting and standing. These activities were then classified as either active or passive. Activity levels were record while the cheetahs were in the enclosure and following release.

Proximity to the cheetah at the closest and average distance was recorded to determine extent of habituation. This is discussed further in Chapter 3. The climatic conditions recorded were cloud cover, wind strength and temperature which are factors relevant to activity levels. This is discussed further in Chapter 5. Vegetation was recorded as woody vegetation density, grass height and density and the vegetation community in which the observation was taking place. This is discussed further in Chapter 4 and is relevant when determining home range and habitat usage. The presence of other animals was recorded as this was an indication to a potential hunt. Attempted hunts and successful hunts were recorded to determine prey species and hunting ability. When a kill was made the time was recorded where possible or estimated as was the prey species, sex and weight. Other details recorded included percent of carcass consumed, which portion of the carcass was consumed first and the cheetahs return to the carcass. Prey selection and hunting is discussed further in Chapter 5. When found, cheetah scat samples were collected to supplement diet data. The use and search effort of the scat collected by the researchers and domestic trained dog is discussed further in Chapter 6.

MATERIALS

Cheetah holding facilities

On the reserve there are two adjacent enclosures of which each is approximately half a ha in size and enclosed by predator proof electric fencing. Prior to release the cheetahs spent three months in holding enclosures to acclimatize to environmental conditions and adjust their diet (discussed in Chapter 3). Time spent in the enclosure by the cheetahs instilled caution towards electrical fencing, removed the homing instinct, allowed for familiarity between the cheetahs, and enabled appropriate habituation to humans and vehicles. While in the enclosure the cheetahs were weaned off their previous diet and were introduced to venison. During the habituation phase in the enclosure, the cheetahs became habituated to the researchers thus allowing close proximity during observations.

Plant Community 1 *Terminalia prunioides* Veld

This community encompasses all of Leniesrus and is subdivided into four distinct variations. The dominant characteristic tree in this community is *Grewia flava.* The dominant characteristic grass is *Aristida transvaalensis* which is a perennial grass that grows well between rocks. Herbaceous cover is generally low because of the encroachment of *Grewia flava. Terminalia prunioides* grows well on clay soils. The soil potential underlying this community is of poor suitability for arable agriculture and cannot sustain extensive vegetation production. Community 1 *Terminalia prunioides* Veld was divided into seven vegetation communities based on the varying dominant woody species, grass species and vegetation density.

Plant Community 2 *Acacia tortilis* Veld

This community occurs on old cultivated lands. There is minimal woody cover because the trees are evenly distributed. The remainder of the area is predominantly open grass lands. The dominant woody species is *Acacia tortilis* which provides nutritious browse for game. *Eragrostis rigidior* is the dominant grass of this community. It grows on land that has been disturbed by cultivation or overgrazing. *Eragrostis rigidior* grows on sand and loam soils. *Urochloa panicoides,* which is the characteristic grass in this community, grows well in clay soils, hard ground and cultivated lands. It is palatable though not preferred by animals and it possesses weed–like characteristics. There is a high density of *Lonchocarpus capassa* of which the majority is still young. *Acacia tortilis* provides nutritional browse for wildlife thus the high density of this tree has resulted in trampling and erosion in this area. Community 2 *Acacia tortilis* Veld was renamed as the eighth vegetation community; Old and Cultivated Land.

Vegetation communities

The sweetveld of northern Limpopo has a high clay content which supports invasive species such as *Terminalia prunioides*, *Colophospermum mopane*, various *Grewia* and *Acacia* species. Makulu Makete WR is no exception and suffers from intense bush encroachment which is made evident in the excessive presence of these species throughout the reserve. For this reason the plant communities were further broken down into vegetation types for management purposes (Table 2.1.). Each vegetation type was classified according vegetation structure and the occurrence of diagnostic vegetation (Fig. 2.2.).

Table 2.1. Makulu Makete Wildlife Reserve vegetation community, size, description and habitat unit equivalent.

Vegetation type	Description	~ Size	PI_/ha
Mountains and Hilly Terrain	Large rocks and used by wildlife.	368 ha	1600
Colophospermum Mopane Veld	Good browsing but low grazing potential. High tree density.	425 ha	1913
Dense *Commiphora* Woodlands	Low graze, good browse. Resembles woodland.	677 ha	2283
Northern dry *Terminalia Prunioides* Veld	Low graze, good browse. Low tree density.	312 ha	1700
Southern Sand Veld	High wildlife habitation. Few tall trees, mostly shrub.	1370 ha	2214
River and Flood Plains	Low graze. Shrubs and sparse large trees.	213 ha	1350
Drainage Course	High small tree density. High game capacity.	107 ha	1500
Old and cultivated land	High game capacity.	764 ha	800

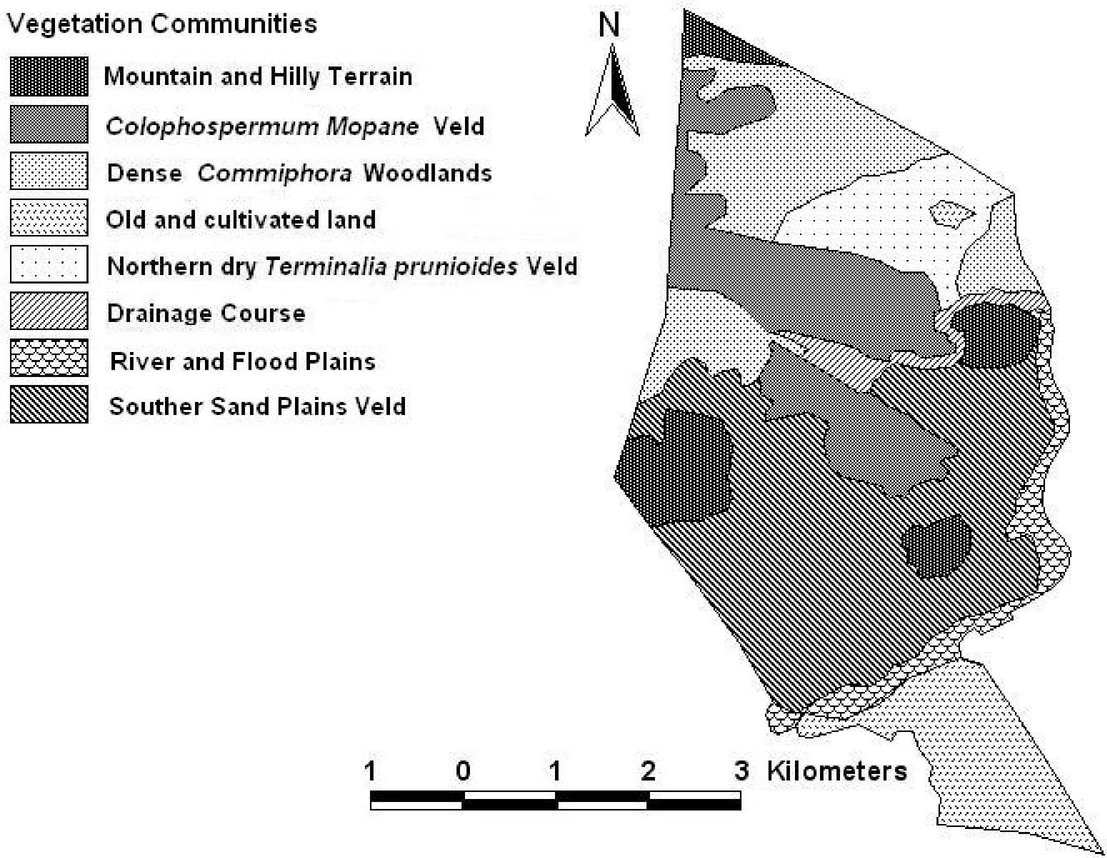

Fig. 2.2. Vegetation communities of Makulu Makete Wildlife Reserve.

Northern Dry *Terminalia prunioides* Veld

This vegetation community is 312 ha. The veld condition score is 418 thus according to the Ecological Index Method it is in moderate condition. There is evidence of bush encroachment on this vegetation community by *Grewia bicolor* and *Terminalia prunioides* which are the dominant woody species. Efforts have been made to clear this unit and, as a result, the density of *Grewia bicolor* has reduced. *Colophospermum mopane* occurs in high densities and is sub-dominant but there remains the potential for encroachment. Other sub-dominant species include *Boscia foetida rehemmanniana* and *Commiphora tenuipetiolata.* The woody species density of this vegetation community is 1700 plants per ha. The dry leaf mass $^{-1}$ ha is below the browsing height of 2 m is 498.

Colophospermum Mopane Veld

This vegetation community is 425 ha. The veld condition score is 352 and according to the Ecological Index Method the veld condition score places it in the category of poor condition but bordering fair. The dominant woody species in this unit are *Colophospermum mopane* and *Combretum apiculatum*. There is evidence of encroachment by *Grewia bicolor* and *Terminalia prunioides*. Despite this encroachment *Colophospermum mopane* dominates*.* In total the woody species density is 1913 plants^{-1} ha. The dry leaf mass $^{-1}$ ha is below the browsing height of 2 m is 805.

Dense *Commiphora* Woodlands

This vegetation community is 677 ha. The veld condition score is 385 thus according to the Ecological Index Method it is in poor condition. Though the dominant encroaching woody species are *Grewia flava*, *Grewia bicolor* and *Terminalia prunioides* it is the presence of *Commiphora africana* and *Commiphora pyracanthoides* which characterize this vegetation community. The occurrence of *Colophospermum mopane* in this area differs from other areas on the reserve because they grow as shrubs and not trees. The density of woody species is 2283 plants $^{-1}$ ha and is an indication of encroachment. The dry leaf mass $^{-1}$ ha is below the browsing height of 2 m is 855.

Mountain and Hilly Terrain Veld

This vegetation community is 368 ha and consists predominantly of rocky, elevated terrain and encompasses the two large kopjes. The veld condition score is 312 which according to the Ecological Index Method, means it is in poor condition. This unit has not suffered severely from bush encroachment but densities of *Grewia flava* and *Acacia tortilis* are relatively high, making them the dominant woody species. Clearing has also been implemented here and the density of *Grewia bicolor* and *Terminalia prunioides* has decreased. Despite the clearing efforts *Grewia flava* and *Acacia tortilis* have increased. *Terminalia prunioides, Grewia bicolor* and *Boscia foetida rehmanniana* are the sub-dominant species and occur in densities that are not considered encroaching. There are seven *Acacia* species occurring in this vegetation community, *Acacia erioloba, A. erubescens, A. karroo, A. mellifera, A. nigrescens, A. Senegal and A. tortilis.* The density of woody species is 1600 plants $^{-1}$ ha with a dry leaf mass $^{-1}$ ha of 653 below the 2 m browsing height.

Southern Sand Plains Veld

This vegetation community is 1370 ha. The veld condition score is 372 which, according to the Ecological Index Method, means it is in poor condition. This is the largest vegetation community and it spreads from the east to the west of the reserve. Most of the clearing efforts were implemented in this area, thus reducing the high density of encroaching species. This vegetation community is highly variable in structure and composition. This is the only vegetation community with a high concentration of *Adonsonia digitata*. *Grewia bicolor*, *G. flava* and *Terminalia prunioides* are encroaching heavily and have, therefore, become the dominant tree species. *Colophospermum mopane, Grewia flavescens* and *Acacia mellifera* are the sub-dominant species. The density of woody species is 2214 plants $^{-1}$ ha with a dry leaf mass $^{-1}$ ha of 917 below the 2 m browsing height.

River and Flood Plains

This vegetation community is 213 ha. According to the Ecological Index Method, a veld condition scores of 362 places it in the category of poor condition. This vegetation community encompasses the flood plains and the river. Scattered along the river edge are towering *Lonchocarpus capassa.* In areas where pools of water collect are dense reed stands. The dominant woody species are *Grewia flava* and *Terminalia prunioides*. Although these species are encroaching their numbers are not excessively high. Sub-dominant species include *Grewia bicolor, Acacia nigrescens* and *Acacia mellifera*. This unit has been cleared in some areas, thus decreasing the density of *Grewia bicolor* and *Terminalia prunioides*. The vegetation density is moderate with woody species at 1350 plants $^{-1}$ ha with a dry leaf mass $^{-1}$ ha of 546 below the 2 m browsing height.

Drainage Course Veld

This vegetation community is 107 ha. According to the Ecological Index Method, the veld condition score of 412 means the veld is in moderate condition. This vegetation community is the transition between the Southern Sand Plains Veld and the River and Flood Plains. The composition and structure of woody species is not highly variable and consists mainly of medium sized trees and shrubs. The density of woody species is 1500 plants $^{-1}$ ha with a dry leaf mass $^{-1}$ ha of 846 below the 2 m browsing height. This unit, however, suffers from encroachment by *Grewia bicolor* and *Terminalia prunioides* which are the dominant species. Sub-dominant species which occur in similar densities include *Commiphora gladulosa*, *Ziziphus mucronata* and *Acacia* species.

Old and Cultivated Land

This vegetation community is 764 ha. According to the Ecological Index Method, the veld condition score of 320 means this community is in poor condition. This unit has undergone the most recent agricultural reform which is evident in the sparse vegetation density. Approximately half of this unit consists of an impenetrable *Terminalia prunioides* stands. The dominant species is *Acacia tortilis* which occurs in pure stands. *Lonchocarpus capassa* are sparsely scattered, with saplings surrounding the parent trees. The density of woody species is 800 plants $^{-1}$ ha with a dry leaf mass $^{-1}$ ha of 234 below the 2 m browsing height.

REFERENCES

De Klerk, G.J. 2002. Resource Inventory and Management Guidelines for Makulu Makete Game Ranch. *Ecological and Wildlife Management Services*. 3-20.

Edwards, D. 1983. A broad-scale structural classification of vegetation for practical purposes. *Bothalia*. (14): 705-712.

Floyd, D. and Anderson, J.E. 1987. A comparison of the three methods for estimating plant cover. *Journal of Ecology*. 75: 221-228.

Low, A. B. and Rebelo, A. G. 1998. *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environment Affaires and Tourism, Pretoria. 2nd ed.

Mucina, L. and Rutherford, M.C. 2006. *The Vegetation of South Africa, Lesotho and Swaziland*. Strelitzia 19. South Africa National Biodiversity Institute, Pretoria.

Smit, G.N. 1989a. Quantitative description of woody plant communities: Part I. An approach. *Journal of Grasslands Science South Africa*, 6(4)

Smit, G.N. 1989b. Quantitative description of woody plant communities: Part II. Computerized calculation procedure. *Journal of Grasslands Science South Africa,* 6(4)

Walker, J., Crapper, F. and Pendridge, L.K. 1988. The crown-gap ratio *(C)* and crown cover: The field study. *Australian Journal of Ecology*. 13: 101-108.

Werger, M. J. A. 1974. On concepts and techniques applied in the Zürich-Montpellier method of vegetation survey. *Bothalia.* 11: 309 323.

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Chapter 3: The conditioning of captive bred cheetah *Acinonyx jubatus* to survive in a wild environment: feeding, habituation, behavior and pre and post release training

INTRODUCTION

Captive breeding of cheetahs is notoriously difficult, and ensuring survival of captive bred cubs has had limited success. With good breeding management, the De Wildt Cheetah Breeding Centre (Brits, North West Province, South Africa) produced 785 cubs born between 1975 and 2005 (Bertschinger *et al.* 2008) and it currently breeds cheetahs successfully for export. Captive cub survival below the age of twelve months was 71.3 % while survival beyond twelve months was 66.2 % (Bertschinger *et al.* 2008). The direct conservation benefit of these cheetahs is limited to genetic preservation and education.

Once reared into adulthood captive animals then face health issues that accompany captivity. Upon numerous occasions the susceptibility of captive carnivores to parasitism, viral disease and other ailments from chronic stress has been reported (Terio *et al.* 2004). This has been made evident by studies conducted on captive cheetahs residing in Namibia (Munson *et al.* 2004; Munson *et al.* 2005), on captive bred wolves *Canis rufus* in the USA (Phillips and Scheck 1991) and brown bears *Ursus arctos* in Sweden (Mörner *et al.* 2005). For this reason all cheetahs, included in this project, underwent thorough annual health checks conducted by a veterinarian at the De Wildt Cheetah Centre. Health checks included a gastro biopsy, dental care, blood sampling and general veterinarian check-ups. This then allows the animals to live longer than in the wild. As a result of the low risk life style and the prevention and treatment of diseases the life expectancy of the captive cheetahs averages twelve years as oppose to eight years for wild cheetahs. While the cheetahs' were in the enclosure, diet, feeding regime, interaction with humans and reaction to vehicles had to be changed.

The purpose of this phase of the study was to a) disassociate research vehicles with feeding, b) adjust diet to venison, c) mimic wild feeding circumstances and d) habituate the cheetahs to researchers and vehicles in order to increase survival potential when released into a wild environment. For ease of observation it was necessary that the cheetahs were comfortable with the observer's proximity while they were feeding.

STUDY ANIMALS

All cheetahs involved in this project were sourced from the De Wildt Cheetah Centre. Each cheetah was identified by their unique spot pattern, tail bands, transponder number and collar frequency. When brought to Makulu Makete Wildlife Reserve all cheetahs had their collars already fitted by wildlife veterinarian Dr. Peter Caldwell (Old Chapel Veterinary Clinic, Pretoria, South Africa). While at De Wildt each cheetah was identified by a unique house number, however, when brought to Makulu Makete Wildlife Reserve each was given a name. Each cheetah was weighed while receiving medical checkups to determine initial weight upon arrival (Table 3.1). The cheetahs were weighed again at varying times after release during routine checkups to measure the change in muscle mass. The cheetahs were transported fully conscious in box crates in the early hours of the morning. Upon arrival at Makulu Makete Wildlife Reserve the cheetahs were taken in to the enclosure while in the crate. The crate was then opened in the enclosure. The project duration was from October 2007 until May 2009 (Table 3.2).

Table 3.1. Identification name, age and weight of captive cheetahs when taken to Makulu Makete Wildlife Reserve for reintroduction. F for female and M for male.

De Wildt ID No.	Name	Date of Birth	Arrival weight (kg)
F515	Motsomi	08/05/04	38 kg
F536	Phoenix	16/06/04	30 kg
M465	Scruff	06/04/03	41 kg
M490	Bones	23/04/03	35 kg
M579	May-Day	01/05/07	33 kg
M580	Chaos	01/05/07	37 kg

Female Cheetahs

A female cheetah F515 was brought to Makulu Makete Wildlife Reserve in October 2007. She was bred from captive bred parents at the De Wildt Cheetah Breeding Centre. However, she contracted a cryptococcal infection and in January 2008, she was removed for treatment. She was replaced on January 23rd 2008 by female F536 who was born on the 16th of June 2004. The female was born with three siblings. While in captivity all four cheetah cubs were kept in the same camp thus allowing for cub interaction and play.

Male Cheetahs

Two males, M490 and M465 were brought to Makulu Makete Wildlife Reserve on November 23rd 2007. They were not littermates but were bonded from being raised together as cubs in captivity. On June 12th 2008 M465 was found dead in the enclosure. The post mortem was inconclusive but a snake bite is suspected. Male M490 was released the 24th of June 2008 but removed from the reserve in early August. On the 20th of August 2008 two new male cheetahs were brought to Makulu Makete Wildlife Reserve. These males were littermates; M580 and M579 were released on November 3rd. On November 10th 2008 both males sustained hunting injuries from a gemsbok *Oryx gazelle*. Cheetah male M580 had to undergo laser surgery follow the penetration of a gemsbok hair into his eyeball. On the 8th of December 2008 cheetah M580 was injured whilst hunting either a bushbuck *Tragelaphus scriptus* or a warthog *Phacochoerus africanus*, he was taken to a wildlife veterinary to be treated for multiple lacerations but died following the rupture of a stomach ulcer on 12th December. M490 and M579 were then bonded in January 2009 at De Wildt Cheetah Breeding Centre, returned to Makulu Makete Wildlife Reserve and released on March 5th 2009.

Table 3.2. Timeline of captive bred cheetah reintroduction project, Makulu Makete Wildlife Reserve. En= Enclosure, Re= Release, In= Injury, Rm= Removal and D= Death.

	Motsomi (F515)	**Phoenix (F536)**	**Bones (M490)**	**Scruff (M465)**	**May-Day (M579)**	**Chaos (M580)**
Oct 07	En					
Nov 07	En		En	En		
Dec 07	En		En	En		
Jan 08	Rm	En	En	En		
Feb 08		En	En	En		
Mar 08		En	En	En		
Apr 08		Re	En	En		
May 08		Re	En	D		
Jun 08		Re	Re			
Jul 08		Re	Re			
Aug 08		In	Re		En	En
Sept 08		Rm	Rm		En	En
Oct 08		Re	Rm		En	En
Nov 08		In	Rm		Re	In
Dec08		Rm	Rm		En	D
Jan 09		En	Rm		Rm	
Feb 09		Re	En		En	
Mar 09		Re	Re		Re	
Apr 09		Re	Re		Re	
May 09		Re	Re		Re	

CAPTIVITY

Feeding in captivity

The cheetahs for this study originated from captivity and had been fed on a diet of horse meat, chicken or IAMS® cat pellets. Female cheetah F515 was fed a diet of IAMS® cat pellets and whole chickens in a bowl while at De Wildt Cheetah Breeding Centre. All cheetah males; M490, M465, M579, M580 were fed on a diet of horse meat while at De Wildt. This diet had implications for the animals because horse meat has relatively low fat content for a domestic animal but comparatively higher levels than venison. The IAMS® cat pellets provided the essential minerals and vitamins' however a natural diet was ideal.

Cheetahs in captivity are fed twice daily with one starvation day a week. Feeding takes place every morning between 07h30 and 09h00 and again in the afternoon at 15h00. Each individual cheetah receives its own meal therefore there is no sharing. Annual health checks on each cheetah are conducted by a wildlife veterinarian to monitor animal condition and health. Tissue samples extracted from the stomachs of the animals during examinations are sent to a pathologist for precise diagnosis of renal amylodosis and gastritis. Blood samples are also taken for testing. Individuals with kidney problems, gastritis or other health ailments are fed pellets with supplements and medication while the healthy cheetahs are fed horse meat.

Habituation in captivity

Wild cheetahs are fearful of humans and will avoid interaction. Captive cheetahs in this study were not tame but they are habituated to the presence of humans. This habituation is a result of months or years of interaction with humans who feed them and manage their husbandry. Cheetahs are also viewed by tourists. However, the extent of habituation and how the cheetahs cope with situations depends on the individual animal. While in the enclosure at Makulu Makete Wildlife Reserve the cheetahs had to dissociate feeding with vehicles used on a daily basis. The risk was that the cheetahs would associate frequently used vehicles with food and this behaviour was considered undesirable for cheetahs that were to be released into a wild environment as this would delay the acquisition of hunting skills, affect daily activity on the reserve and pose a danger to the cheetahs. The reaction of the cheetahs to motorcycles and quad bikes, on the other hand, would be dependent on the individual animal and could not be predicted. Motorcycles and quad bikes are small and fast moving, thus attracting cheetah attention. While in captivity the majority of the cheetahs chased these smaller vehicles. To eliminate such undesirable behaviour towards observers and vehicles on the reserve, various techniques were devised, adapted then tested and modified through trial and error (see page 65). Captive cheetahs are accustomed to humans as a result of the conditions while in captivity, so it was necessary to reduce their familiarity on humans while in the enclosure. At the same time it would be necessary for the cheetahs to undergo behavioural conditioning to accustom them to being observed in the wild without threat to the observer. Ultimately the cheetahs should not form associations to human presence while in the wild. This methodology was adapted from Atkinson and Wood (1995) and supported by extensive field experience with rehabilitating young wild caught cheetahs (Pretorius, Unpublished data). Methodology for habituation to vehicles was recommended by Animal Behaviouralist and Wrangler, Sled Reynolds[7] (Gentle Jungle, California, USA).

[7] E-mail: gentlejungle@aol.com

Behavior in captivity

Captive cheetahs are limited in their activities. Depending on the proximity of the cheetah enclosure to the main centre, food is brought either on foot or by vehicle. The De Wildt Cheetah Breeding Centre conducts regular tours where a combination of adults and children view the animals from a vehicle or on foot as they can walk around outside the enclosures. Although there is little stimulation and enrichment for the captive animals, certain activities around the cheetahs stimulate alert responses.

After release it was necessary for the males to become accustomed to the scent of the female and her presence. It was anticipated that encounters would occur in the wild; therefore preliminary social interaction was necessary and the male and female cheetahs were kept in adjacent camps. When males M580 and M579 arrived female F536 was returned to the enclosure for a month to allow familiarization. This was repeated for a week when M490 and M579 were returned. It was also important for the males to bond to form a coalition. If no bonding occurred then the two cheetahs would separate and there would be three individual groups.

METHODS

Enclosure design

The enclosures were half a hectare each (5000 m^2). Each enclosure contained a water point, a triangular corner camp where the food would be placed and a cheetah specific crush cage (Fig. 3.1.). The crush was used when the cheetahs needed to be immobilized or treated. The two enclosures were made from and divided by diamond chicken wire which allowed visual interaction between the cheetahs. The water was replenished from fitted taps when necessary. Each enclosure had a pedestrian access gate from outside the enclosure and between the enclosures. One of the enclosures had a gate for vehicles to enter through.

Feeding regimes

During the cheetahs time in the Makulu Makete Wildlife Reserve enclosure venison quantities were supplied from Makulu Makete Wildlife Reserve. Game animals were shot to provide venison which included impala *Aepyceros melampus*, kudu *Tragelaphus strepsiceros* and warthog *Phacochoerus africanus*. Venison was supplied to the cheetahs between October 2007 and March 2009. Prior to feeding the cheetahs a whole carcass the stomach and intestines were removed because the carcasses had been in cooling storage for a period of time and would rot if the intestines remained. Prior to release each cheetah group received an unopened carcass as a means of practice. To remove the association between passenger vehicles and feeding, vehicles not frequently used in the reserve were used to deliver food. The meat was brought by a white single cab Toyota truck. Upon release the cheetahs followed this vehicle in anticipation of food. Due to the injuries sustained following release we were able to modify and condition the cheetahs. We decided to use a vehicle that was not used daily on the reserve to feed the cheetahs. In so doing the association would only be on a vehicle that was not used except for feeding while in the enclosure and consequently when supplementary feeding was necessary.

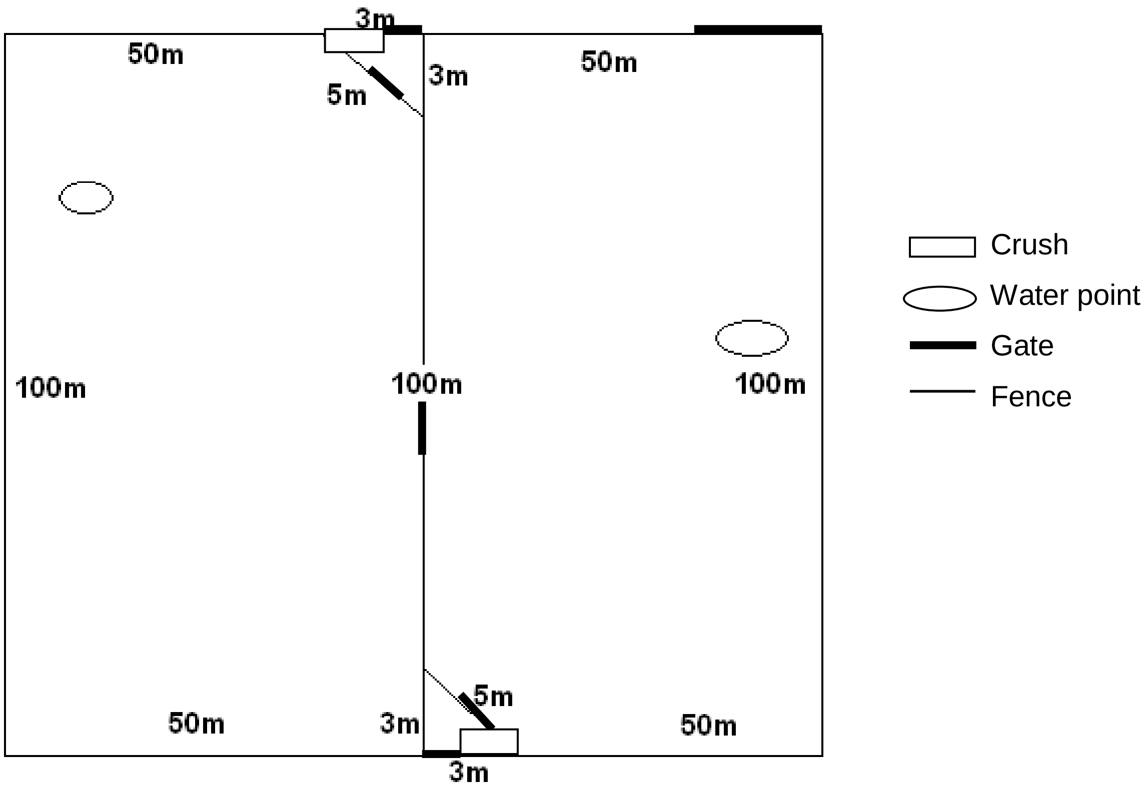

Fig. 3.1. Dimensions and specifications of cheetah enclosures on Makulu Makete Wildlife Reserve.

The cheetahs' conditions were scaled from one to five which is the same scale used while at De Wildt Cheetah Centre. Condition took into account hip protrusion and stomach size with one being emaciated and five being full with distended stomachs. Female cheetah F515 is not included in the methods and results due to her early departure from the project. While at De Wildt Cheetah Centre female F536 was fed chickens. After arrival at Makulu Makete Wildlife Reserve, F536 was fed venison that had been cut into small chunks so that she could become accustomed to the new type of food (refer to APPENDIX II for detailed feeding calendar of all cheetahs). The venison meat chunks, without bone or fur, weighed approximately 0.60 kg. This feeding regime continued daily for four days. On the fifth day she was fed larger whole but boneless meat chunks weighing approximately 2.0 kg. When she adjusted to this she was then introduced to meat on bones. To keep the meat portions small she was fed the fore limb or hind limb without skin. After she became able to consume meat around the bones, the skin was then left on the limb. This process of adjusting to venison with both skin and bones took 18 days with three to two day intervals between feeds depending on the cheetah's condition. The meat sizes increased to between 19 kg and 45 kg depending on what was available and length of the starvation days. As the pieces of meat were increased in size, the starvation days were lengthened ranging from three to six days. All food portions were weighed before the cheetahs were fed. The quantity consumed was scaled according to how much meat, skin and bones remained after feeding. Eating slowly is not advantageous in wild circumstances as the cheetahs could lose their prey it was therefore in the best interest of the cheetahs to eat rapidly to minimize kleptoparasitism when released. Adjustment was indicated by the speed and quantity consumed by the cheetah. When the female was consuming approximately 60 % of the meat, eating rapidly and continuously, she was considered adjusted to the new diet and other aspects of feeding were developed. These included the stretching of the stomach to accommodate more food from one meal which was accomplished by gradually increasing the food quantities. Tolerance to human presence while feeding was accomplished by remaining within six meter proximity while the cheetahs ate. Strength to carry a carcass was accomplished by tying a five kilogram then 10 kg pole with rope to the food. One end of the rope was tied around a wooden pole and the other end to a piece of meat; legs, ribs or half a carcass of impala, warthog or kudu. The decided added weight from the pole was to develop strength without over exerting the cheetah. Other weights were tried but were clearly too heavy as she struggled significantly to drag the pole hence the use of poles weighing five kilogram and eventually 10 kg. The increase was an adjustment to correlate with her increase in fitness.

The feeding regime was consistent for both sets of coalitions. The males were feed individual pieces of meat to see if they could consume the venison without vomiting or diarrhea. The venison fed to them included impala, warthog and kudu. Although both pairs of males had been fed horse meat they adjusted to venison. Each was given approximately two kilograms of meat without skin or bones three times a week. They were then given four to five kilograms of meat with skin but without bones twice in one week. Eating the meat around the bones and eating the skin provided strengthening of the jaws and proved that the cheetahs were capable of opening a carcass. This continued for two weeks with three to four day intervals depending on the cheetahs' condition. Following the two week period they were given meat with skin and bones weighing 20 to 35 kg (half carcasses) every three to six days depending on condition. This regime was maintained until their release. We found that a distance of six meters was ideal for ease of observations while the cheetahs were feeding. If the animal reacted by threatening to drag the carcass away then a slower, indirect approach was made until the animal settled.

It was necessary for the males to learn to share the meat because when released they would be eating from the same carcass. When the two males displayed intimate social bonding they were then fed one carcass to share. Mutual grooming, face licking and frequent bodily contact were indications of intimate social bonding. While feeding, when the cheetahs' faces touched growling and observed head slapping would following. The aggressive behaviour would subside when each ate from a different area on the carcass. There was no aggressive behaviour between M490 and M579 when they were fed a carcass to share although M490 would occasionally attempt to drag the carcass away from M579.

Increasing the capacity of the stomach was accomplished by feeding them small chunks of meat and then gradually increasing the size while simultaneously extending days between feeding to mimic conditions in the wild when food would not be regularly available. Because the starvation days increased their appetite the cheetahs consumed more and increased the capacity of their stomachs. The cheetahs were then able to gorge when food was available which is intended to sustain them between hunts. The stomach is stretched to enable them to consume large amounts of food when it is available and not waste food. Wastage reduces the energy available to the cheetah, forcing it to hunt more frequently. However, it must be noted that solitary cheetahs will not utilize a carcass completely but only to a level that is sufficient to maintain condition (Caro 1994; Hunter 1998). This method was successful as there was an evident change in the amount of food consumed. Longer starvation days led to more food being consumed when fed.

Strength is critical as this partially determines the cheetahs hunting success. The cheetah must have sufficient strength to drag the prey to the ground, kill it and then drag the carcass into shade or shelter for consumption. Strength development could only be accomplished with the females because the males used combined effort. Strength development was accomplished by attaching, by means of rope, a 5.0 kg pole to the food. The cheetah would then drag the food and the pole to concealment before eating the carcass. Before a pole was used, it had been recommended that the observer engaged in a tug-of-war with the cheetah. The researcher would tie a rope to the food, hold one end while the cheetah picked up the other end of the rope with the meat, both would then pull. This method was discontinued early because it was deemed unsafe to the researcher and unsuitable.

Vigilance and amount consumed are critical because when other predators are present food is easily stolen, kleptoparasitism. Cheetahs in the wild are susceptible to kleptoparasitism and can be killed by other predators such as lions *Panthera leo*, spotted hyenas *Crocuta crocuta* and occasionally leopard *Panthera pardus* (Durant 1998; Hunter *et al.* 2006). The presence of these predators reduces the density of cheetahs in that area and avoidance becomes the primary tactic against kleptoparasitism and predation (Durant 1998; Durant 2000a; Durant 2000b; Treves 2000). Predators present on Makulu Makete Wildlife Reserve that do display kleptoparasitism are brown hyena *Hyena brunnea*, leopard and black backed jackal *Canis mesomelas*. The cheetah must therefore be vigilant and be aware of approaching competition and threats. Once food has been secured the cheetah must eat rapidly and consume a sufficient amount of food for sustenance. Conditioning the cheetahs to become vigilant was accomplished by tying a rope to the food and attempting to steal the food when they stopped eating. The desired outcomes were for the cheetah to actively look around while feeding to identify any threats, to drag the food away when attempted steals were made, and to hold onto the food while feeding to prevent it being stolen. The attempted steals were stopped when the cheetahs became very aggressive during feeding and charging as soon as the food was on the ground.

Habituation techniques implemented

When the cheetahs arrived at Makulu Makete Wildlife Reserve all were aggressive towards humans for several reasons: stress following relocation, the association of humans with food and the assertion of dominance. To alter the habituation the researchers spent three to five hours daily with the cheetahs. The level of aggression reduced over time with all cheetahs, although the habituation period differed for each cheetah. Proximity is essential for monitoring cheetah condition, identification of the prey species, age and sex, how much has been consumed at onset of observation and an estimation of the kill time.

Captive bred animals, particularly cats, have a tendency to chase fast moving objects. On the reserve motorcycles were used as a mode of transport and tracking was conducted using a quad bike. For these reasons the cheetahs needed to become accustomed to the sound and movement without chasing these vehicles. To determine whether the cheetahs would chase the quad bike it was driven around in the enclosure. When the cheetahs expressed interest they were squirted with a water gun and chased with a stick and yelled at. This method was successful with female F536 however it was not sufficient for cheetah male M490.

Another technique attempted was the fitting of a remote controlled water jet collar onto M490. The collar is fitted with a pressurized water jet that is aimed at the trachea. When the animal displayed an undesirable behavior, such as chasing the quad bike or motorcycle, then a jet of water would be deployed. The vehicles were driven past him and when he stood up to follow he was sprayed. The timing had to be precise to create an associate between the spray and the behavior. It was imperative that no association was made with a specific person but with the behavior. This continued for several attempts, in the morning, afternoon and the following morning. The behavior did not improve as M490 began ignoring the water spray and continued following the vehicles. The collar was removed the following day.

A third method was then adopted: chasing the cheetah with the quad bike. The vehicle was driven directly in the direction of M490 who would approach the moving vehicle. He would turn and run when the vehicle was less than a meter from him, and the rider would continue the pursuit. Because this was only feasible when M490 was in an open area, this technique could not be implemented continuously. A week following the trials M490 began following motorcycles again. The same technique was used on M580 who similarly reverted to his original chasing behavior.

The final method attempted was based on recommendation by Sled Reynolds[8] and implemented under the supervision of professional animal trainers. Four people entered the enclosure equipped with a paintball gun, a CO_2 fire extinguisher and a two pronged pitchfork. The pitchfork was used to turn the cheetah when it approached the quad bike. The fire extinguisher created a loud sound and a cloud of white to reinforce the effect. The paintball gun was used to associate the quad with pain. All these elements were combined to create a stressful association with the quad bike. The fire extinguisher and a two pronged pitchfork were first used to turn the cheetah. As the cheetah ran away from the vehicle it was shot with the paintball gun. Chasing continued for 10 minutes. The next level of training was to have two people on the quad bike, one driving the other shooting with the paintball gun. The cheetahs crouched when the quad approached so a shot was fired at the ground to make them turn. The cheetahs were then followed for 10 minutes. These sessions continued twice a day for four days. On

[8] Gentle Jungle, California, USA

the final two days the quad was driven on the outside of the enclosure along the fence. When the cheetahs expressed interest they were shot with a paintball. This continued until all interest in the quad bike and motorbike ceased.

Behavior and reaction towards other cheetah

The structure and material of the enclosures allowed the cheetahs to observe and interact with each other. Interactions were classified as vocalizing between the males and the female and displays of aggression. Coalition M490 and M465 displayed bonding interactions by grooming each other, cheek rubbing, vocalising and purring. Cheetahs M580 and M579 displayed similar behavior towards each other. Such interaction confirmed the extent of bonding and reinforced the likelihood of the coalition remaining together. When M579 and M490 were attempted to bond, for unknown reasons, there were no displays of bonding.

Activity levels were classified as passive and active. While in the enclosures the cheetahs activities were limited however these activities prepared them for wild circumstances. Walking, grooming, drinking and eating were the only active activities the cheetahs could partake in. Upon release the cheetahs included stalking and hunting as active activities.

RESULTS

Feeding

As the food quantities increased the cheetahs learned to gorge themselves and eat when food was available (Fig. 3.2 to 3.10). While in the enclosure all cheetahs were able to maintain condition despite being starved for a maximum of five days (mean = 2.9, SD ± 0.4). F536 was very active while in the enclosure, and lost condition rapidly but then sustained condition two for extended periods of time. Similarly M579 lost condition rapidly however this was attributed to his young age and growth period. Successful adjustment was defined by the cheetahs' ability to open a carcass, chew the skin, eat the rib cartilage and eat around the larger bones[9]. The female cheetah took three weeks to fulfill the criteria while both male coalitions took two weeks to fulfill the criteria (mean = 17.7, SD ± 4.7). The initial method of strength training where by the carcass was tied to a tree was not feasible with F536 because of her snatch-and-run nature which made it necessary to change the feeding method to prevent injury to the cheetah and researcher. The pole method was then adopted and the female cheetah did not exhibit any difficulty in lifting the food and dragging the pole. After a month her strength developed and a heavier 10 kg pole was tied with rope to the carcass.

While in the enclosure it took several attempts to steal F536 food before she dragged it deeper into concealment and began eating more rapidly. She maintained vigilance throughout feeding by frequently lifting her head to look around, and occasionally standing to look around while feeding. Although the male coalitions were less likely to be threatened in the wild the two males were also conditioned while in the enclosure through attempted steals. Both sets of coalitions displayed the same behaviour whereby one male would watch while the other took part in a tug-of-war.

Once released all cheetahs were able to bring down prey which was dragged into concealment. All cheetahs exhibited vigilance while feeding. When there was a potential threat (nearby hyena or leopard) F536 noticeably ate faster while none of the males exhibited any altered feeding behaviour. When attempted steals were made F536 held

[9] Refer to Appendix II for detailed feeding calenders.

onto her food continuously. As a result of the one month period of vigilance conditioning through attempted food stealing, vigilant behaviour became evident when the cheetahs would look around while eating and hold their prey down with the front paws. Female F536 frequently dragged the food to the shade and places where she could conceal herself while feeding. However, she allowed the primary researchers within three meters without dragging the food further away. When not hungry feeding would begin with the ribs or the skin however, when hungry then feeding would begin with the back legs. When the males were hungry feeding would begin with the cardiovascular region, however when not very hungry then feeding would begin with the back leg.

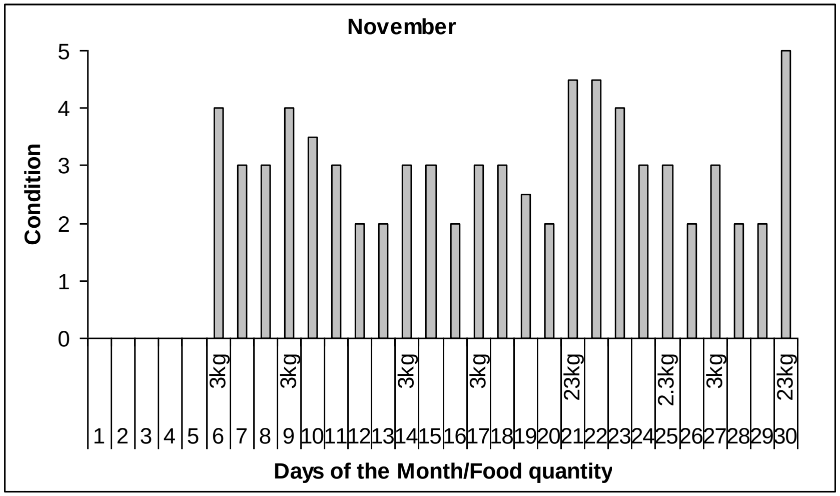

Fig. 3.2. First month feeding regime and condition of cheetah male coalition on Makulu Makete Wildlife Reserve.

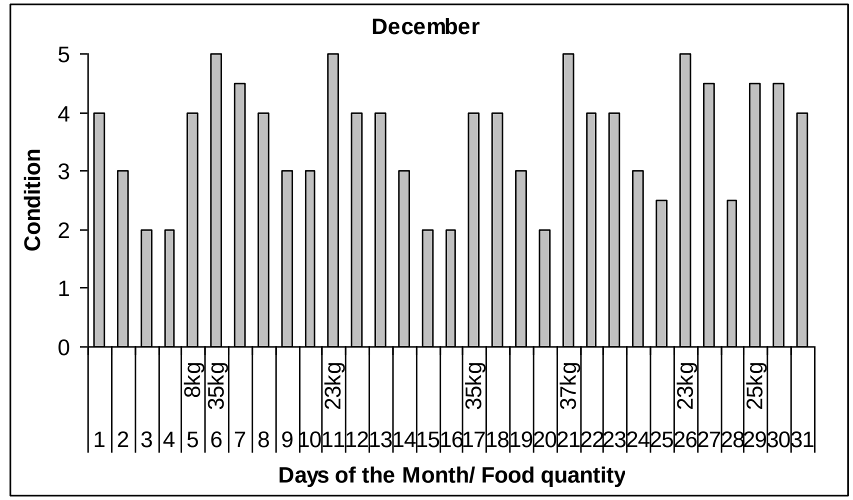

Fig. 3.3. Second month feeding regime and condition of cheetah male coalition on Makulu Makete Wildlife Reserve.

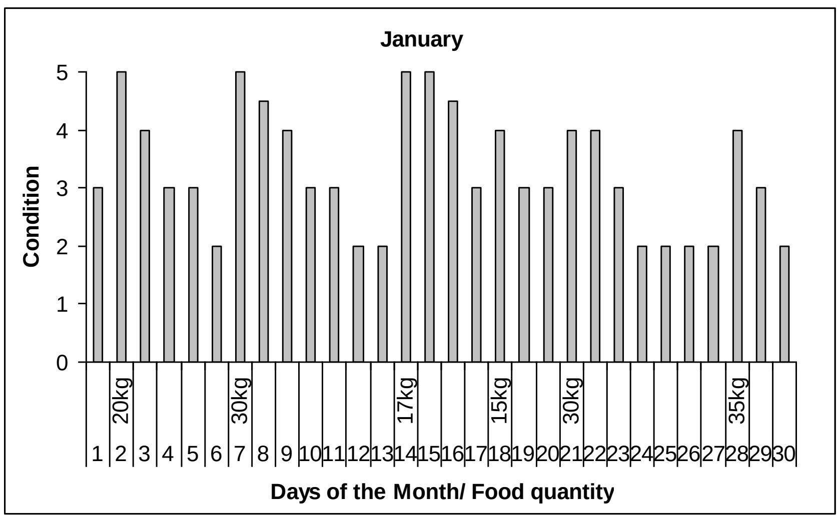

Fig. 3.4. Third month feeding regime and condition of cheetah male coalition on Makulu Makete Wildlife Reserve.

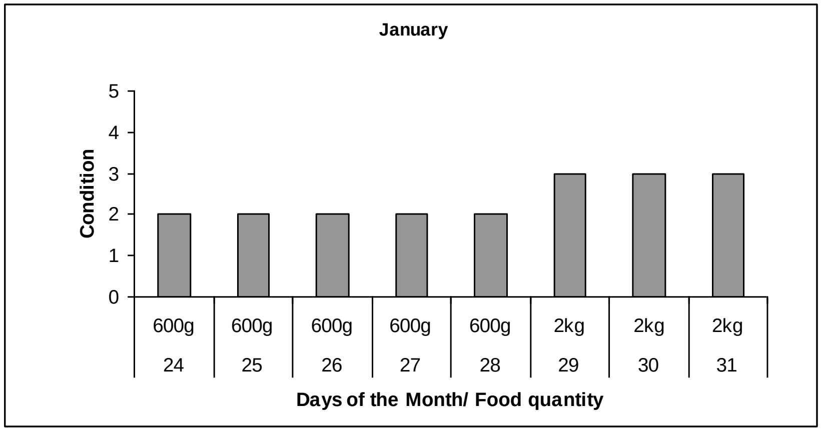

Fig. 3.5. First month feeding regime and condition of single captive female cheetah on Makulu Makete Wildlife Reserve.

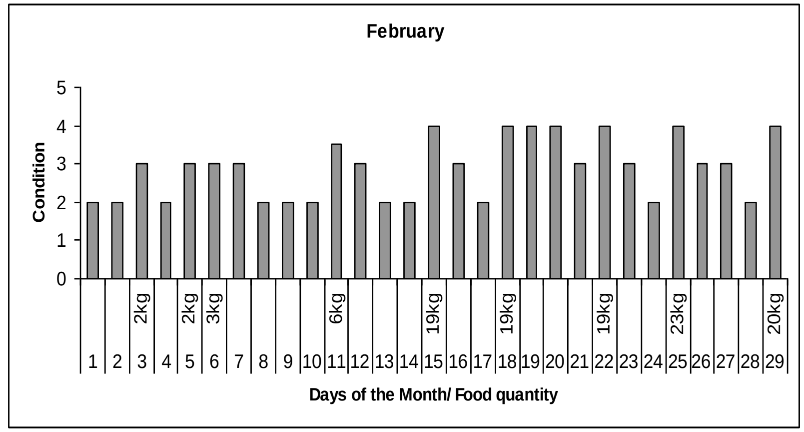

Fig. 3.6. Second month feeding regime and condition of single captive female cheetah on Makulu Makete Wildlife Reserve.

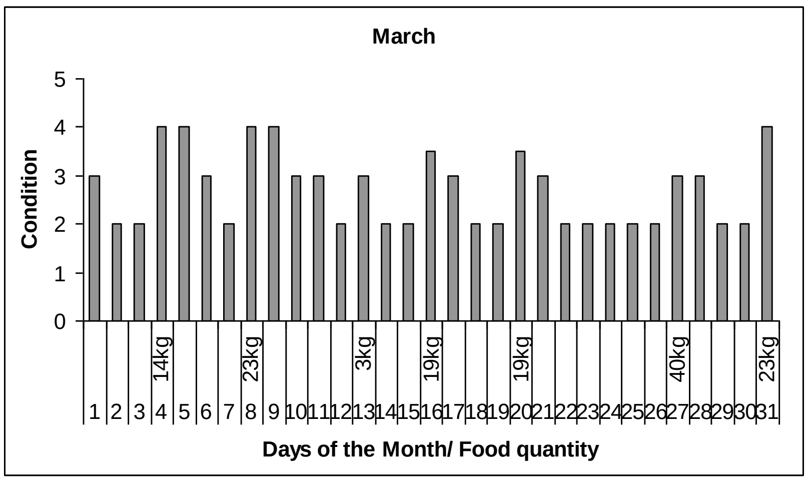

Fig. 3.7. Third month feeding regime and condition of single captive female cheetah on Makulu Makete Wildlife Reserve.

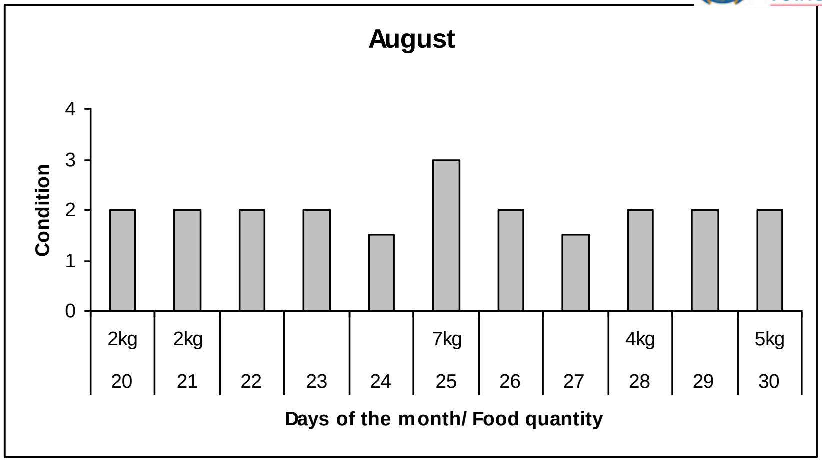

Fig. 3.8. First month feeding regime and condition of second captive cheetah male coalition on Makulu Makete Wildlife Reserve.

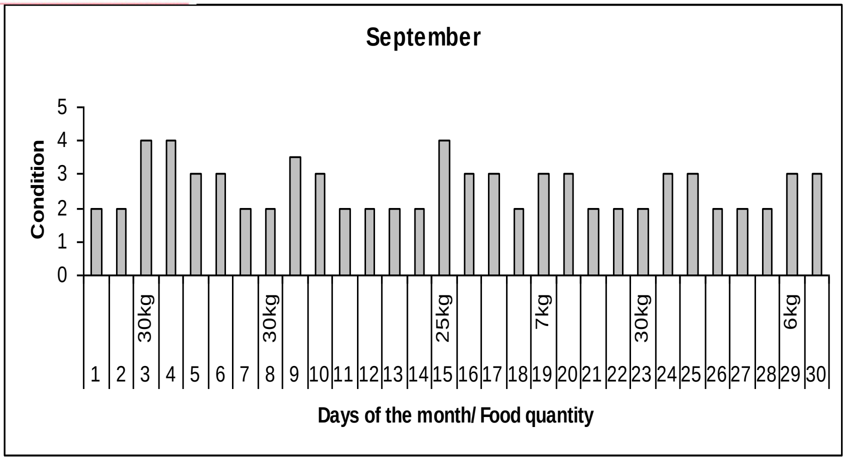

Fig. 3.9. Second month feeding regime and condition of second captive cheetah male coalition on Makulu Makete Wildlife Reserve.

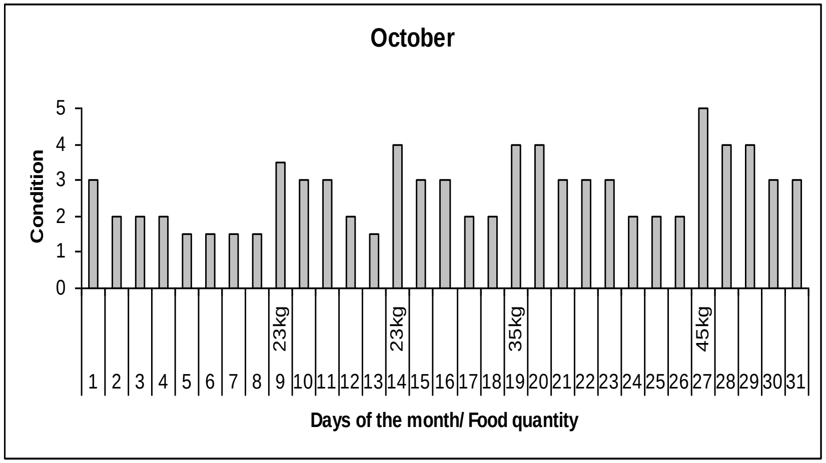

Fig. 3.10. Third month feeding regime and condition of second captive cheetah male coalition on Makulu Makete Wildlife Reserve.

Habituation

The time spent in the enclosure allowed the cheetahs to become accustomed to surveillance by the researchers without associating their presence with feeding. While in the enclosure fewer people interacted with the cheetahs. For the first month approximately three to five hours a day were spent with the cheetahs by the researchers; half the time in the morning and half in the afternoon to mimic monitoring post release. When cheetahs exhibited aggressive behavior the researcher would yell, wave sticks and behave aggressively in return. The cheetahs began to calm down and exhibited reduced aggression and by the second month the cheetahs would barely acknowledge the presence of the observers.

The most effective method of removing the instinct to chase vehicles was through the use of a paintball gun. After conditioning all cheetahs eventually ignored the quad bike and motorcycle while they were being driven within and outside the enclosure. Once released the cheetahs did attempt to chase the quad and motorbike again. However, one shot from the paintball gun ended the pursuit. The cheetahs eventually settled and ignored the quad bike and the motorbike thus proving the technique effective.

Behavior

While in the enclosure all cheetahs were seen to be pacing the fence lines either along the fence that separated the enclosures or along the front where the vehicles would pass. All cheetahs displayed high levels of activity by walking when hungry or when observing the other cheetah through the fence. Female cheetah F536 was active 26 % of the three months within the enclosure. Following release this increased to 33 % in the first three months. For the first three months in the enclosure the male activity level was lower, 12 % for the first coalition, M490 and M465 and 18 % for the second coalition M579 and M580. Following release M490 increased activity levels to 37 % in the first three months. Cheetah male M579 increased activity level to 39 % in the first three months of release. The increase in activity level is likely due to larger areas to walk, stalk and hunt in.

Female F536 was heard to make chirping sounds directed at the males. F536 would walk along the fence and, when the males approached, would begin trying to attack them through the fence. After a month this behavior was then initiated by cheetahs on both sides of the fence. After two and half months one male in particular showed less interest in the female while the other would respond vocally when chirped at. At times the males would mock pounce on F536 when she walked by the fence. A total of six attacks through the fence were observed while the female cheetah was in the enclosure adjacent to M490 and M465.

When the new males, M580 and M579, were brought to Makulu Makete Wildlife Reserve female F536 was placed back in the adjacent enclosure. This allowed for interaction through the fence. The males initiated vocalization directed at the female. After not responding for a week the female began to walk around the enclosure but did not vocalize in return. It was not until two weeks following the arrival of the males that female F536 began to interact with the males. This interaction included hissing and growling. A total of five attacks through the fence were observed while the female was adjacent to M579 and M580.

Following the death of M580 the two remaining males, M579 and M490, were bonded. Males M579 and M490 were placed in the enclosure adjacent to F536 for two weeks. M490 vocalised towards the female but did not vocalize to M579. When M579 would lose sight of M490 in the enclosure, frantic vocalizing would ensue until visual contact was re-established, M490 would not respond to the vocalising. Males M490m and M579 tolerated each other but did not bond.

DISCUSSION

Diet adjustment and habituation to researchers and vehicles were the most intensive aspects of conditioning in the enclosure. Slow progressive introduction of venison to the cheetah diet should not be rushed as this could be harmful. Improper diet adjustment could lead to the inability to digest venison resulting in diarrhea and vomiting. There are aspects of the diet adjustment that are subjective such as the defining indication of diet progression (Fig. 3.2 to 3.10). After feeding a carcass to the cheetahs, the remains would be dragged out after a 24 hour time period to condition the cheetahs to gorge when food was available. However on one occasion a carcass remained in the female cheetahs' enclosure for four days. In Fig. 3.6. the female cheetah was fed an impala head and neck. The carcass remained in the enclosure for four days until the next feeding resulting in the continued feeding of the carcass and maintained her condition. When initially introduced to venison, female cheetah F536 had to be fed small portions of venison frequently because she took longer to adjust. This was evident in her inability to consume a piece of meat that was on a bone (e.g. impala leg) or meat not in a bowl. We had to wean her slowly from stew sized chunks of meat in a bowl to full carcasses. In Fig. 3.2. the cheetah coalition was fed the lower half of an impala to share. After four days (Fig. 3.3) their condition had decreased therefore they were fed an eight kilogram piece of meat each. The following day the coalition was fed a whole young impala which was found dead on the electric fence and was given to them regardless of the previous eight kilograms. In Fig. 3.4. the male coalition was fed an impala leg each and the lower back of a kudu which is more bone than meat an approximate total of 15 kg. Three days later the coalition was fed a kudu leg weighing approximately 30 kg however, their condition did not increase significantly. This is likely due to the cheetahs not being very hungry and therefore not gorging themselves.

Habituation, however, cannot be misinterpreted. The chasing of vehicles is a threat to cheetahs and observers because the risk of injury to both is high. The halt in the cheetah chasing vehicles and humans are an indication of adjustment and effective conditioning. Immediate conditioning with a paintball gun to remove the vehicle-chase instinct is necessary. Repetition and consistency are critical while training.

The size and location of the enclosures is critical. The enclosures need to be large enough to allow the cheetahs ample space for movement while encompassing representative vegetation of the release site. The enclosures on Makulu Makete Wildlife Reserve were adequate in size. Female cheetah F536 was the most active while in the enclosure. M579 was also very active while in the enclosure and would frequently pace along the middle of the enclosures. Both continued these high levels of activity following release. The location of the enclosure affects the rate of habituation to vehicles. The enclosure on Makulu Makete Wildlife Reserve was on a main road with vehicles passing regularly. This affected the rate at which the cheetahs broke theory association with vehicles when being fed. On Monate Game Reserve where cheetah re-wilding projects are conducted, the enclosures are separated from human activity. Such a set up would be advisable for future reintroduction studies because it separates human activity from cheetah. This is ideal to reduce the amount of time and energy needed to remove the chase instinct of vehicles.

CONCLUSION

The methodology implemented in this project has been successful in the rehabilitation of young wild cheetahs. The adaptation of the methodology allowed for the three captive bred cheetahs to be successfully habituated and their diet adjusted to venison. This process cannot be rushed because the animals have to adjust and maintain the behaviors indefinitely. Methodical, reinforced training can allow for the training of captive bred cheetahs to survive in a wild environment, therefore fulfilling the conservation benefits of captive bred cheetahs.

REFERENCES

Atkinson, M.W. and Wood, P. 1995. Reintroduction of cheetah in Matusadona Zimbabwe. *Cat News*. 23: 15.

Bertschinger, H.J., Meltzer, D.G.A. and van Dyk, A. 2008. Captive Breeding of Cheetahs in South Africa- 30: Years of Data from the de Wildt Cheetah and Wildlife Centre. *Reproduction Domestic Animals.* 43 (2): 66-73.

Caro, T.M. 1993. Behavioral Solutions to Breeding Cheetahs in Captivity: Insight from the wild. *Zoo Biology*. 12(1): 19-30.

Caro, T.M. 1994. *Cheetahs of the Serengeti Plains: group living in an asocial species.* The University of Chicago Press. Chicago, USA.

Cunningham, A.A. 1996. Disease Risk of Wildlife Translocation. *Conservation Biology.* 10(2): 349-353.

Durant, S.M. 1998. Competition refuges and coexistence: an example from Serengeti carnivores. *Journal of Animal Ecology.* 67(3): 370-386.

Durant, S.M. 2000a. Living with the enemy: avoidance of hyenas and lions by cheetahs in the Serengeti. *Behavioral Ecology.* 11(6): 624-632.

Durant, S.M. 2000b. Predator avoidance, breeding experience and reproductive success in endangered cheetahs, *Acinonyx jubatus. Animal Behavior.* 60: 121-130.

Estes, R. D. 1992. *Behavior Guide to African Mammals*. The University of California Press. California, USA.

Hunter, L.T.B. 1998. The behavioral ecology of reintroduced lions and cheetahs in the Phinda Resource Reserve, Kwa-Zulu Natal, South Africa. DPhil. University of Pretoria.

Hunter, J.S., Durant, S.M. and Caro, T.M. 2006. To flee or not to flee: predator avoidance by cheetahs at kills. *Behavioral Ecology and Sociobiology.* 61(7): 1033-1042.

Mörner, T., Eriksson, H., Bröjer, C., Milsson, K., Uhlhorn, H., Agren, E., Segerstad, C.H., Jansson, D.S. and Gavier-Widen, D. 2005. Disease and mortality in free-ranging brown bear (*Ursus arctos*), gray wolf (*Canis lupus*) and wolverine (*Gulo gulo*) in Sweden. *Journal of Wildlife Disease*. 41(2): 298-303.

Munson, L., Marker, L., Dubovi, E., Spencer, J.A., Evermann, J.F. and O'Brien, S.J. 2004. Serosurvey of viral infections in free-ranging Namibian cheetahs (*Acinonyx jubatus*). *Journal of Wildlife Disease.* 40(1): 23-31.

Munson, L., Terio, K.A., Worley, M., Jago, M., Bargot-Smith, A. and Marker, L. 2005. Extrinsic factors significantly affect patterns of disease in free-ranging and captive cheetah (*Acinonyx jubatus*) populations. *Journal of Wildlife Disease.* 41(3): 542-548.

Pettifer, H.L. 1979. The experimental release of cheetah (*Acinonyx jubatus)* into the natural environment. Nature Conservation Transvaal Division. South Africa.

Phillips, M.K. and Scheck, J. 1991. Parasitism in Captive and Reintroduced Red Wolves. *Journal of Wildlife Disease.* 27(3): 498-501.

Santer, R. 2001. Letting the cat out of the bag. *Biologist*. 48 (2): 72-74.

Terio, K.A., Marker, L. and Munson, L. 2004. Evidence for chronic stress in captive but not free-ranging cheetahs (*Acinonyx jubatus*) based on adrenal morphology and function. *Journal of Wildlife Disease.* 40(2): 259-266.

Treves, A. 2000. Theory and method in studies of vigilance and aggression. *Animal Behavior.* 60: 711-722.

Chapter 4: Range use and habitat interaction by captive bred cheetah *Acinonyx jubatus* released into a wild environment: Makulu Makete Wildlife Reserve, Limpopo province

INTRODUCTION

Three captive bred cheetah *Acinonyx jubatus*, a female and two males, were brought to Makulu Makete wildlife Reserve as part of an experimental reintroduction program. All cheetahs were sourced from captivity at the De Wildt Cheetah Breeding Centre (Brits, Northwest Province, South Africa). Each cheetah under went three months of conditioning in an enclosure on the reserve to prepare for wild circumstances. Conditioning included habituation to researchers and vehicles and diet adjustment to venison. While in the enclosures the cheetahs became familiar with the environment which includes the vegetation and resident mammals. Though cheetahs are noted for their slender physical build adapted for speed, in woodland areas the cheetah often adapts their hunting technique from chase to ambush as there is more opportunity for concealment, and therefore a successful hunt (Murray *et al.* 1995, Purchase and du Toit 2000, Broomhall 2006). A study by Bissett and Bernard (2007) at Kwandwe Private Game Reserve in the Eastern Cape showed that cheetahs could adapt and hunt successfully in thicket. Cheetahs in Matusadona hunted opportunistically (Purchase and du Toit 2000). In Uganda, vegetation maps with habitat characteristics were successfully used to determine predictability of cheetah distribution (Gros and Rejmànek 1999). Purchase and du Toit (2000) found that vegetation influenced prey selection due to the feeding habits and movements of the ungulates. Browsing species such as the greater kudu *Tragelaphus strepsiceros* and bushbuck *Tragelaphus scriptus* are found in areas such as thickets (Estes 1992). Bushbuck habitat preference for dense vegetation increases their opportunity for concealment when remaining motionless. However, their solitary behavior makes them vulnerable and easy targets for cheetah. Burchell's zebra *Equus burchelli* and blue wildebeest *Connochaetes taurinus* are grazers occurring in less dense habitats (Estes 1992). Because these herbivores occur in herds vigilance when grazing is higher. Impalas *Aepyceros melampus* have the ability to adjust their diet according to which vegetation is in abundance hence they are both grazers and browsers. Impalas occur in ecotones between woodlands and open grasslands during the dry season. The cheetahs are then able to utilize the woodland vegetation, during all seasons, as concealment when hunting impala. The frequency of success in turn influences the utilization of that habitat when hunting. This adaptability to different habitats has allowed cheetahs to persist in areas influenced by anthropogenic activities.

Habitat use

Vegetation density is critical as it influences visibility, stalking approach, chase distance and general hunting strategies (Caro 1994; Muntifering *et al.* 2006; Bernard and Bissett 2007). Bernard and Bissett (2007) found that in Eastern Cape subtropical transitional thicket, stalking distance by cheetahs increased while chase distance decreased as a result an increase or decrease in visibility. A leopard study in Phinda Private Game Reserve indicated that leopards preferred to hunt in habitats where prey was easier to catch as oppose to prey abundance (Balme *et al.* 2007). Vegetation structure, which determines habitat type, is crucial because this may influence hunting attempts, techniques and success rates (Balme *et al.* 2007).

Range use

The amount of time before the establishment of a home range is a critical factor for this study because it provides insight for monitoring duration and the time period for a cheetah to determine prey availability, hunt successfully and settle. Female cheetahs have home ranges while males have both territories and home ranges; females tend to be solitary, unless with dependent cubs, while males often form coalitions of a minimum two individuals (Estes 1992; Caro 1994). A home range and territory differ in that a range is the area utilized by prey species and is not actively protected while territory is actively protected (Estes 1992; Caro 1994; Carnaby 2006). Female ranges are dependent on prey availability, density and distribution. Male territories are determined by cover and prey densities and overlap female ranges. This ensures maximum mating opportunities for the males (Gittleman and Harvey 1982; Hunter 1998). Prey density often changes with the seasons due to migratory patterns. However, given the small 4,500 ha size of Makulu Makete and the distribution and provisioning of water and supplementary feed, however, ungulate migration is negligible.

The aim of this section of the study was to determine a) the home ranges of released captive bred cheetahs b) the amount of time required by the captive bred cheetahs to investigate and settle into a preferred range area in a wild situation and c) the behavioral interaction of released captive bred cheetahs with their environment.

METHODS

Each of the three captive bred cheetah was tracked twice daily on foot. The vehicle would be driven until the telemetry signal indicated the cheetahs to be within walking distance of no more than 500m. Visual observations were feasible and made when possible. At each sighting a global positioning system (GARMIN eTrex GPS) was used to make one record of the position where the cheetah was first observed. Two points were taken per day, at the onset of the morning observation and afternoon observation. The GPS points were collected for use in home range analysis. During observations cheetah condition was recorded and scaled from one to five with one being thin and five just eaten. The scale was based on stomach fullness and protrusion of hip bones. To limit the observers' influence on the cheetah's movements, the observers used their discretion as to whether or not to observe and/ or follow the cheetahs. Factors that influenced the observers' decision included when the cheetah had last eaten, cheetahs condition and vegetation density. Additionally, these data were linked to vegetation and habitat data available for the reserve. Vegetation (trees and shrubs) density was classified as open, moderate and dense. Grass height was classified as short < 30 cm, medium 40 to 60 cm and tall >70 cm.

To determine home range and the utilization distribution (UD) Local Convex Hull (LoCoH) Home Range (Animal Movement SA v2.04 beta which is an extension in ArcView GIS 3.3) was used (www.esri.com, 05/08/09). This method accounts for hard boundaries such as fences and geological interferences such as rivers and mountains. A convex hull is constructed from a fixed number of data points and the *k*-1 nearest neighbour of each data point ($k = \sqrt{n}$ where n = # of data fixes). The union of these points creates a UD (Calenge 2006; Getz *et al*. 2007). The data was projected using Universal Transverse Mercator (UTM) which is the most commonly used (http://mathworld.wolfram.com/CylindricalProjection.html, 09/10/09).

Within the home range interaction with the environment was observed by measuring distances of the cheetahs from of the road, drainage and river taken at intervals of 20 m, 50 m and 100 m and were analysed using chi-squared. The observed data was then compared to expected data, randomly generated points in Animal Movement SA v2.04 beta extension in ArcView GIS 3.3. The activity level and distance traveled per month determined how long it was before the cheetahs settled into a home range. Daily activity is accumulated into monthly activity levels (active and passive) which were then combined with distance traveled for the first three months. Active activities were categorised as walking, stalking, eating, grooming and drinking while passive activities were sitting, standing and generally lying down resting. The Wilcoxon test was used to determine if there was a difference between amount of time being active and passive. A paired t-test (http://www.r-project.org, 20/05/09) was used to determine if there was a pair-wise difference in the activity levels per month for each cheetah. Within the eight habitats the Wilcoxon test was used to determine if there was a difference in the amount of time the cheetahs were active and passive. Interactions observed through activity levels in the eight habitat types were analysed using a paired t-test. A chi-squared test was used to determine if activity levels were more than expected in the eight habitat types.

Statistical analysis

A preference ratio was used to determine which habitats were preferred by the cheetahs (Shannon 2006).

$$\text{Preference ratio} = \frac{\text{(\# of locations in specific habitat)/ (total \# of locations)}}{\text{(area of specific habitat)/ (total area)}}$$

A Chi-square test was used to determine if the cheetahs selected for particular habitat types. Random points were generated in the Animal Movement SA v2.04 beta extension in ArcView GIS 3.3 to generate the expected values. A Spearman Rank Correlation Coefficient was used to determine the relationship between vegetation density and cheetah active activity in the eight habitat types.

RESULTS

To construct the LoCoH for female cheetah F536 and cheetah male M490, k = 14 using 95 % isopleths was used, while for cheetah male M579 k = 13 was used (Table 4.1), (Fig. 4.1.), (Fig. 4.2.) and (Fig. 4.3). Each cheetah's home range encompassed all eight habitat types. The home ranges overlapped therefore all cheetahs eventually encountered each other. Although the two males spray scented areas within the home range they did not fight when encounters occurred within these territories. The likely explanation for this phenomena being the time they spent together in the enclosure prior to release. Fighting did ensue when the female encountered M490, but there was no aggression observed when the female encountered M579.

Range use

The cheetahs remained within close proximity of the release site area for four weeks following release before exploring further. Each cheetah traveled a mean distance of 1.60 km (Range = 0.40 to 4.53 km, S.D = 1.07) from the release site in the first month of release. During the second month the average distance traveled by all cheetahs was approximately 3.80 km (Range = 1.14 to 7.43 km, S.D= 1.88) from the release site. In the third month the average distance traveled from the release site was 5.69 km (Range = 4.40 to 7.46 km, S.D = 0.82). This distance traveled encompassed the furthest point from the release site (Table 4.2). At this time all cheetahs except M579 had crossed the river and explored the entire reserve. The female explored along the river and eventually crossed the river to the Old and Cultivated Land where she eventually settled. Though the female was placed in the enclosure and re-released three times, following release she returned to the same area where the home range had been established. Key places within the territory were scent marked. Similar to the female M490 and M579 were released twice and both returned to the same home range prior to establishing a territory. Cheetah male M579 began scent marking after two and half months of release. Cheetah male M490 began scent marking after two months of release and two scent marking posts were found. Cheetah M490 was seen scent parking these posts on several occasions. LoCoH was found to provide the most accurate representation of range use for each cheetah (Table 4.3).

Although there was a distinct pattern of high activity during the first month after release the activity levels of the cheetahs fluctuated. The cheetahs were more active when hungry and begun walking when they were in condition two and continued to do so even when in condition one. When cheetahs were satiated and between condition four and five passive activities would ensue for two days. If the carcass was lost due to kleptoparasitism prior to completion then the cheetahs would resume walking.

The Wilcoxon test indicated that each cheetah showed no difference between active and passive activities during the study period, M579 (N = 4, T = 10, P > 0.05), M490 (N = 6, T = 21, P > 0.05) and F536 (N = 9, T = 45, P > 0.05). There was a difference in each cheetah's activity levels in the duration of the study period. The female cheetahs activity levels showed a pair-wise difference during the study period (t = 6.0551, df = 8, P = 0.000304) as her activities were higher at the commencement of the release period and declined after settling down into a home range. Cheetah males M579 and M490 showed a pair-wise difference in activity levels during the study period (t = 2.7221, df = 4, P = 0.05287) and (t = 3.285, df = 5, P = 0.02183) respectively as their activity increased during the study period but declined when a home range was established (Fig. 4. 4).

Table 4.1. Number of fixes, home range size and percentage of reserve used by captive bred cheetahs released on Makulu Makete Wildlife Reserve.

Cheetah	No. Fixes	LoCoH (*k*)	Home range (km^2)	Percent of reserve
F536	308	14	14	31
M490	216	14	26	60
M579	181	13	11	25

Table 4.2. Time and distance traveled before captive bred cheetahs settled into home ranges, Makulu Makete Wildlife Reserve (mn = mean).

Cheetah	Month 1		Month 2		Month 3	
	mn(km)	max(km)	mn(km)	max(km)	mn(km)	max(km)
F536	1.01	2.06	5.41	5.77	6.00	7.43
M490	2.51	4.53	3.12	6.34	6.53	7.46
M579	1.29	3.48	2.87	3.98	5.12	5.98

Table 4.3. Comparison of home ranges using different methods for analysis of three captive bred cheetahs released onto Makulu Makete Wildlife Reserve.

	LoCoH	**MCP (100%)**	**Kernel Fixed**	
Cheetah	**km²**	**km²**	**50%**	**95%**
F536	14	40	12	263
M490	26	41	21	321
M579	11	26	23	204

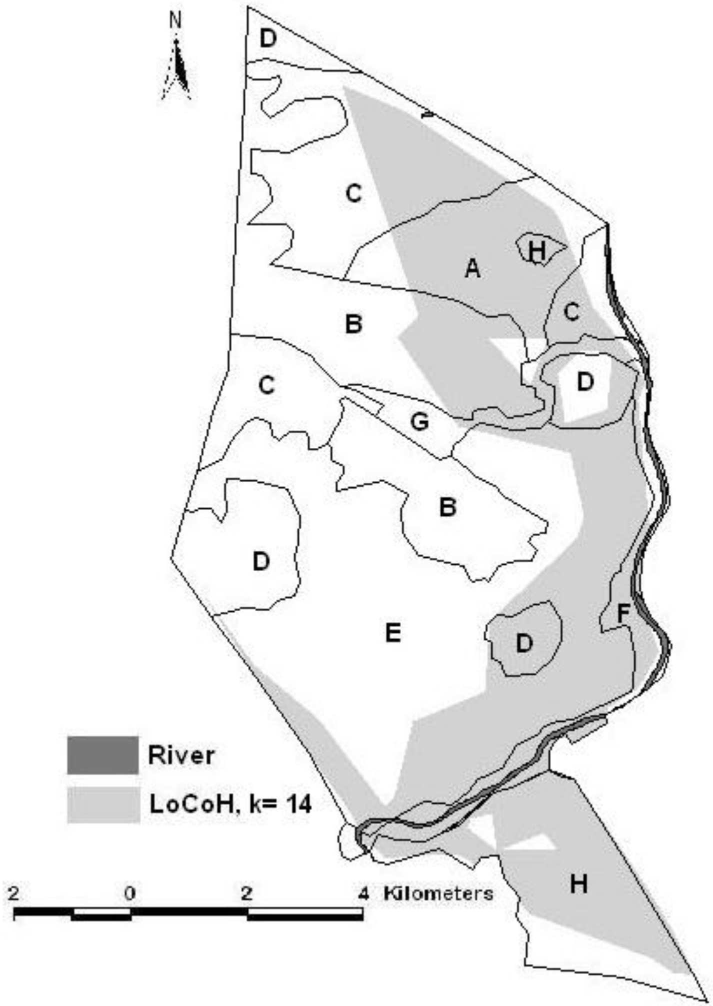

Fig. 4.1. Home Range of captive bred female cheetah F536 using Local Convex Hull at k=14, Makulu Makete Wildlife Reserve. A-Northern Dry *Terminalia pruinoides* Veld, B-*Mopane* Veld, C-Dense *Commiphora* Woodland, D-Mountain and Hilly Terrain, E-Southern Sand Veld, F-River and Flood Plain, G-Drainage Course and H-Old and Cultivated Land.

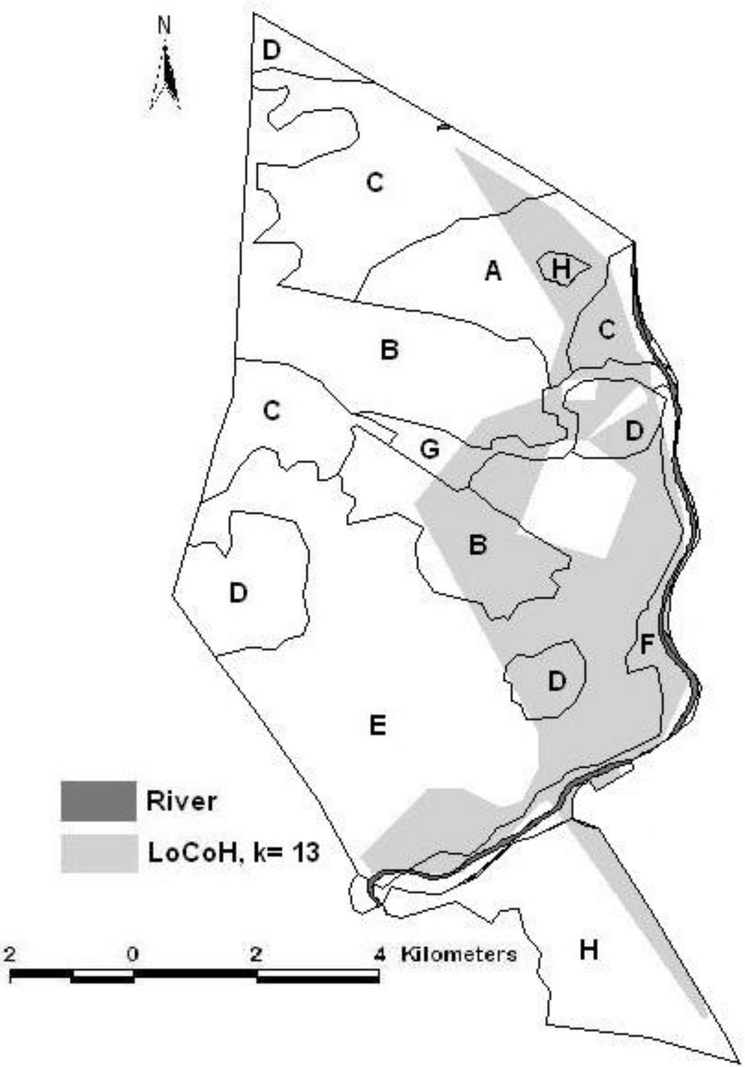

Fig. 4.2. Home Range of captive bred cheetah male M579 using Local Convex Hull at k=13. Makulu Makete Wildlife Reserve. A-Northern Dry *Terminalia pruinoides* Veld, B-*Mopane* Veld, C-Dense *Commiphora* Woodland, D-Mountain and Hilly Terrain, E-Southern Sand Veld, F-River and Flood Plain, G-Drainage Course and H-Old and Cultivated Land.

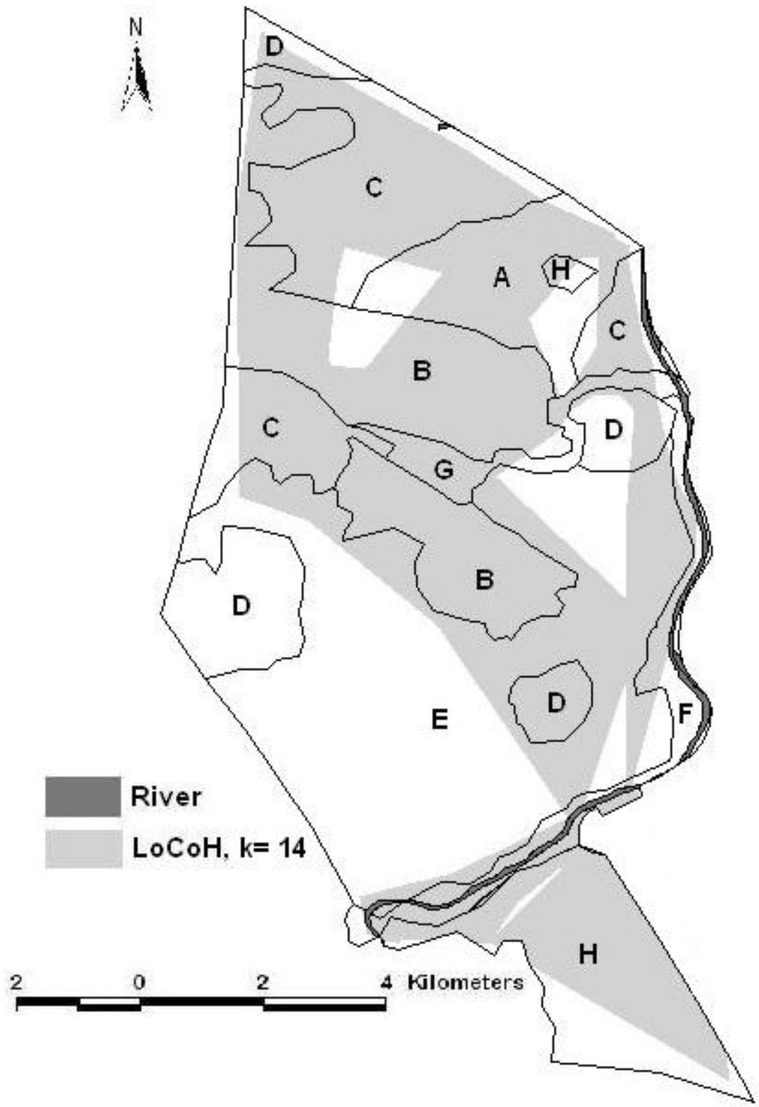

Fig. 4.3. Home Range of captive bred cheetah male M490 using Local Convex Hull at k=1. Makulu Makete Wildlife Reserve. A-Northern Dry *Terminalia pruinoides* Veld, B-*Mopane* Veld, C-Dense *Commiphora* Woodland, D-Mountain and Hilly Terrain, E-Southern Sand Veld, F-River and Flood Plain, G-Drainage Course and H-Old and Cultivated Land.

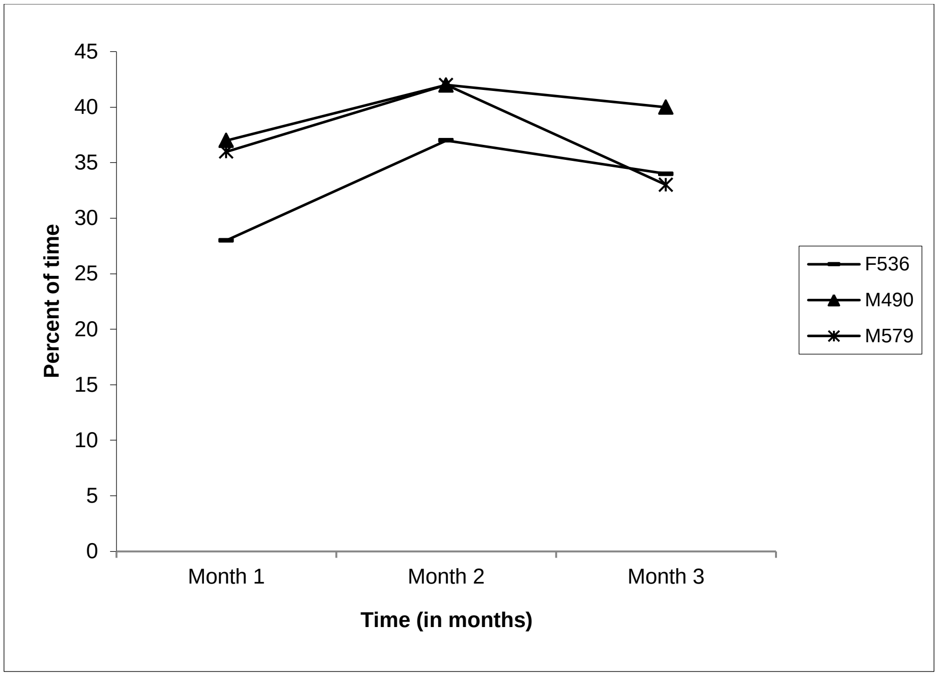

Fig. 4.4. Relative activity levels for the first three months of release of three captive bred cheetahs released onto Makulu Makete Wildlife Reserve.

Habitat use

During the study period the cheetahs roamed the entire reserve using all habitats (Fig. 4.5). There was a statistical difference in usage of the habitats by each of the cheetahs; F536 ($X^2 = 568$, $df = 7$, $P < 0.01$), M490 ($X^2 = 299$, $df = 7$, $P < 0.01$) and M579 ($X^2 = 987$, $df = 7$, $P < 0.01$). All cheetahs utilized the River and Flood Plains, Old Cultivated Lands and the Drainage Course more than expected F536 ($X^2 = 540$, $df = 2$, $P < 0.01$), M490 ($X^2 = 124$, $df = 2$, $P < 0.01$) and M579 ($X^2 = 1018$, $df = 2$, $P < 0.01$). The preference ratio (*PR*) indicated that all the cheetahs preferred the River and Flood Plains and the Drainage Course habitats (M490 $PR = 3.30$, M579 $PR = 3.83$ and F536 $PR = 5.10$) and (M490 $PR = 4.51$, M579 $PR = 6.95$ and F536 $PR = 2.90$) respectively (Table 4.4). The Dense *Commiphora* Woodland was used less than expected and was lowest in the preference ratio for all the cheetahs (M490 $PR = 0.68$, M579 $PR = 0.46$ and F536 $PR = 0.23$). The Wilcoxon test indicated that there was no difference between active and passive activities of cheetah F536 (N = 8, $T = 34$, $P > 0.05$) and M490 (N = 8, $T = 36$, $P > 0.05$). However, cheetah male M579 was more active than passive and displayed a difference in activity levels (N = 8, $T = 5$, $P = 0.10$). A paired *t*-test indicated that activity levels within each habitat had statistical pair-wise differences for the female F536 and male M490 ($t = 2.8062$, $df = 7$, $P = 0.0263$) and ($t = 4.0657$, $df = 7$, $P = 0.00478$) respectively. Cheetah male M579 activity levels per habitat type did not show statistical pair-wise differences ($t = 1.3372$, $df = 7$, $P = 0.223$). There was a weak relationship between vegetation density, both high and low and activity levels for M579 ($r_S = 0.12$, $df = 6$, $P > 0.10$) and M490 ($r_S = 0.18$, $df = 6$, $P > 0.10$). There was a weak correlation between vegetation density and activity levels for female cheetah F536 ($r_S = 0.45$, $df = 6$, $P > 0.10$). The cheetahs made 26 % of their kills in the Flood Plains, 24 % in the Old and cultivated Land and 17 % in the Southern Sand Veld (Fig. 4.6.).

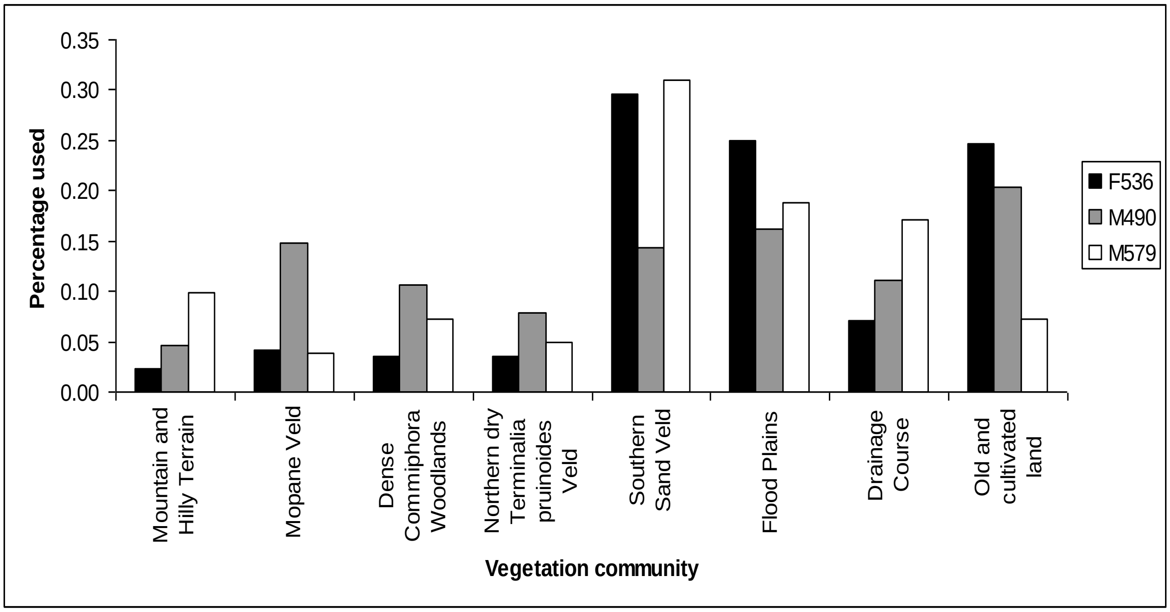

Fig. 4.5. Percentage of vegetation communities encompassed in the home range of captive bred cheetah released on Makulu Makete Wildlife Reserve.

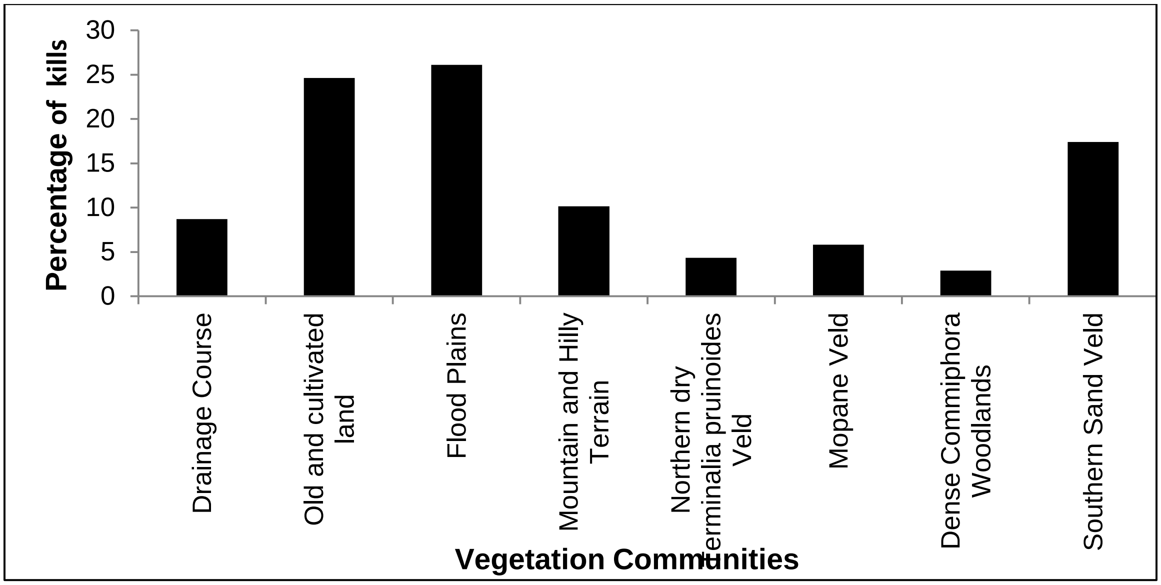

Fig. 4.6. Percentage of kills made per habitat type by released captive bred cheetah onto Makulu Makete Wildlife Reserve.

The interaction of cheetahs with roads (Fig. 4.7.), the major drainage course (Fig. 4.8.) and the river (Fig. 4.9.) were compared and only cheetah F536 used the road more than expected (df = 307, X^2 = 601, P < 0.001). Cheetah males M490 and M579 used the road less than expected (df = 215, X^2 = 141, P > 0.10) and (df =180, X^2 = 90, P > 0.10) respectively. The roads were used for walking. Each cheetah used and interacted with the drainage less than expected F536 (df = 307, X^2 = 280, P = 0.10), M490 (df = 215, X^2 = 62, P > 0.10) and M579 (df = 180, X^2 = 54, P > 0.10). The drainage area was used when the cheetahs were resting between walking bouts. Each cheetah used and interacted with the river less than expected F536 (df = 307, X^2 = 200, P > 0.10), M490 (df = 217, X^2 = 35, P < 0.10) and M579 (df = 187, X^2 = 23, P < 0.10).

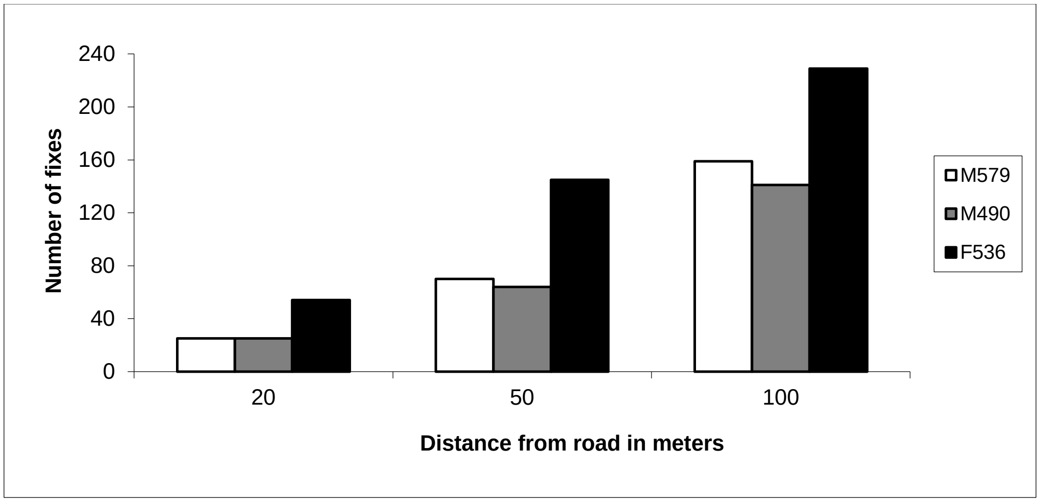

Fig. 4.7. Number of fixes at sightings of released captive bred cheetah at 20 m (S.E ± 0.63), 50 m (S.E ± 1.70) and 100 m (S.E ± 1.75) from the road on Makulu Makete Wildlife Reserve.

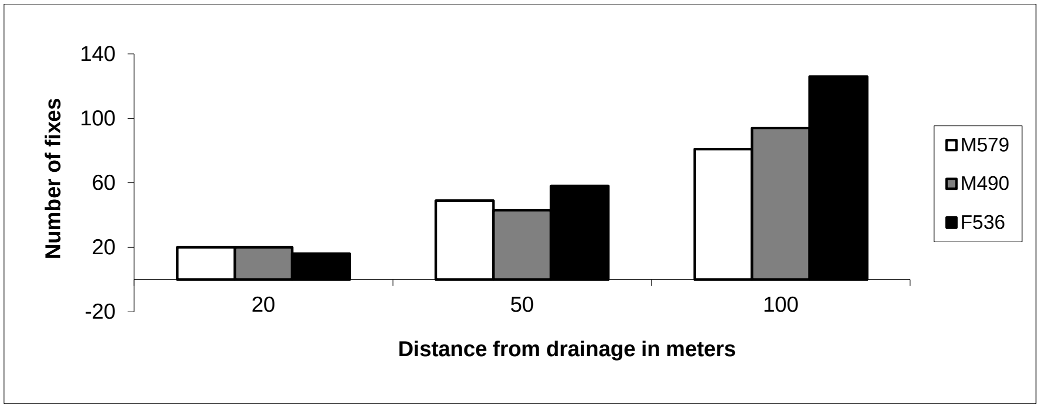

Fig. 4.8. Number of fixes at sightings of released captive bred cheetah at 20 m (S.E ± 0.09), 50 m (S.E ± 0.28) and 100 m (S.E ± 0.87) from the drainage course on Makulu Makete Wildlife Reserve.

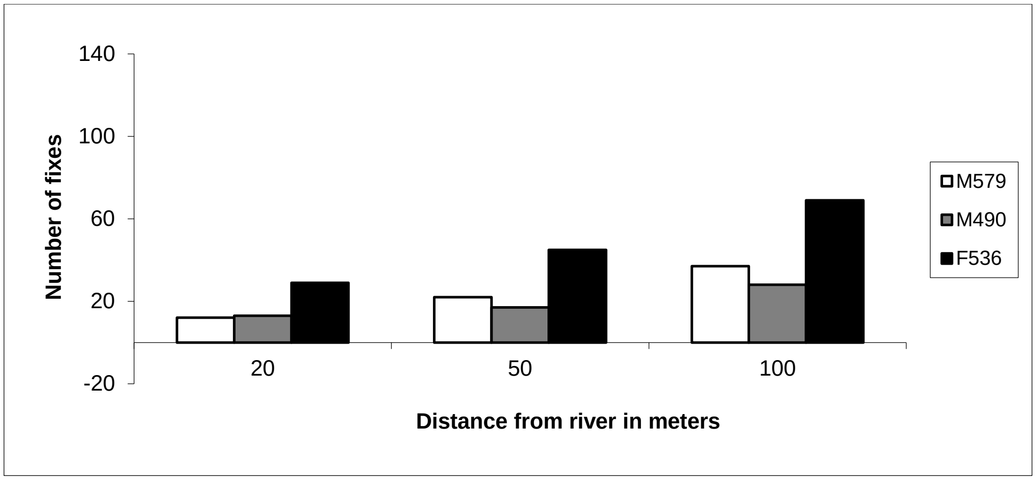

Fig. 4.9. Number of fixes at sightings of released captive bred cheetah at 20 m (SE ± 0.36), 50 m (SE ± 0.56) and 100 m (SE ± 0.81) from the Mogalakwena River on Makulu Makete Wildlife Reserve.

Table 4.4. Habitat preference (Shannon 2006) of captive cheetahs *Acinonyx jubatus* released into Makulu Makete Wildlife Reserve.

Vegetation community	**Pref. ratio (F536)**	**Pref. ratio (M490)**	**Pref. ratio (M579)**
Mountain and Hilly Terrain	0.27	0.55	1.17
Colophospermum mopane Veld	0.43	1.51	0.40
Dense *Commiphora* Woodlands	0.23	0.68	0.46
Northern dry *Terminalia prunioides* Veld	0.50	1.10	0.69
Southern Sand Veld	0.87	0.42	0.91
River and Flood Plains	5.10	3.03	3.83
Drainage Course	2.90	4.51	6.95
Old and cultivated land	1.40	1.58	0.41

DISCUSSION

The use of Minimum Convex Polygon and Kernels Fixed Home Range Analysis were not used as they over estimated the size of the home ranges, disregarded fences and other barriers (Getz *et al.* 2007, Mitchell and Powell 2008). Local Convex Hull takes hard barriers such as fences, rivers and high elevations into consideration when constructing the hulls (Table 4.3). Sufficient data was collected to determine that each cheetah established a home range. To increase the sample size a GPS point should be taken at the start and conclusion of an observation if the cheetah walks to a new location because this will increase the number of fixes which will then allow for more accurate home range analysis (Table 4.1) or the cheetahs should be released and monitored for longer.

Cheetahs and lions *Panthera leo* were reintroduced into Phinda Resource Reserve in Kwa-Zulu Natal (Hunter 1998) and all remained within the vicinity of the release site for a week. In the three months following release each cheetah explored the entire reserve. Similarly the captive bred cheetahs on Makulu Makete Wildlife Reserve remained within close proximity of the release site for a month after release. Activity levels following release were low for all cheetahs. In the second month the cheetahs began exploring more by walking greater distances and for longer time periods (Fig. 4.4.). The home range sizes of the captive cheetahs were 18 km^2 for F536, 26 km^2 for M490 and 13 km^2 for M579. On Makulu Makete Wildlife Reserve each cheetah's home range overlapped likely because of habitat and resource availability (Fig. 4.1. to Fig. 4.3.). The female cheetah did not come into estrus during the study period therefore mating opportunity was not likely to be the reason for habitat overlap. Though the males scent marked areas within the home ranges, the territories were not actively defended. Despite the overlapping home ranges, the cheetahs seemed to avoid each other and showed exclusive use of specific areas. This has been described by Caro (1994) as a social felid behavior. The female used the eastern river, Flood Plains and southern, Old and Cultivated Land boundary dominantly, cheetah male M490 used the northern, central and western Southern Sand Veld boundary and cheetah male M579 used the eastern river, Flood Plains (Fig. 4.6.).

Wild cheetahs in the Kruger National Park used the dense vegetation more than expected and used the open habitats less than expected (Broomhall, Mills and du Toit 2003). Similarly in Kwandwe Private Game Reserve in the Eastern Cape the solitary cheetahs utilized the thicket more than the largely available open vegetation (Bissett and Bernard 2007). In the Matusadona National Park the cheetahs were seen to use woodlands more than expected (Purchase and du Toit 2000). The released captive bred cheetahs on Makulu Makete Wildlife Reserve utilized the habitat in a similar manner to wild cheetahs. All home ranges encompassed the eastern region of Makulu Makete Wildlife Reserve. Though cheetahs are water independent, the eastern region is where the Mogalakwena River is situated therefore, the cheetahs were likely concentrated in this area because of their preys need for water, food and vegetation for concealment. This is supported by their distance from the river where by the cheetahs would be close to the river, approximately 100 m, but not as close as 20 m (Fig. 4.9.). There are water holes distributed throughout the reserve however this did not influence the cheetah movement, the river did. Vegetation density did not influence the cheetah movement; therefore prey presence was the likely influence where the percentage of kills directly reflects the percentage of vegetation community encompassed in the home range (Fig. 4.5.).

On Makulu Makete Wildlife Reserve the captive bred cheetahs adapted to thicket habitat in the Drainage Course, River and Flood Plain habitats and the Old Cultivated Land (Table 4.4). The movement between these preferred habitats indicates captive bred cheetahs' adaptability to different habitats therefore, behaviorally resembling wild cheetahs. The use of the road was limited and less than expected which could be supported by the use of all habitat types (Fig. 4.7.).

CONCLUSION

The three released captive bred cheetahs were able to establish home ranges and the two males, territories. The establishment of these home ranges required a three month exploration period. However, it was likely that home ranges had been established within two months following release. Each cheetah preferred the same habitat types. Interactions with these habitats were evident in the activity level within each. Activity levels and the establishment of home ranges indicated adaptation. Activities such as walking, stalking and hunting indicate activeness. An extended study period would allow for a larger sample set and the ability to analyse activity levels on a daily basis. The data of activity levels on a monthly basis are relevant for reintroduction studies as they provided insight into the length of time required to establish a home range, the activity levels and habitat interactions. Given the change in habitat in areas where cheetahs were historically distributed, this study provides encouragement and understanding that reintroduced cheetahs can adapt in varying circumstances.

REFERENCES

Balme, G., Hunter, L. and Slotow, R. 2007. Feeding habitat selection by hunting leopards *Panthera pardus* in a woodland savanna: prey catchability versus abundance. *Animal Behavior.* 74: 589-598.

Bertschinger, H.J., Meltzer, D.G.A. and van Dyk, A. 2008. Captive Breeding of Cheetahs in South Africa- 30: Years of Data from the De Wildt Cheetah and Wildlife Centre. *Reproduction Domestic Animals.* 43 (2): 66-73.

Bissett, C. and Bernard, R.T.F. 2007. Habitat selection and feeding ecology of the cheetah (*Acinonyx jubatus*) in the thicket vegetation: is the cheetah a savanna specialist? *Journal of Zoology.* 271: 310-317.

Broomhall, L.S. 2006. Cheetah *Acinonyx jubatus* ecology in the Kruger National Park: a comparison with other studies across the grassland-woodland gradient in African savannas*.* PhD. Thesis. University of Pretoria.

Broomhall, L.S., Mills, M.G.L. and du Toit, J.T. 2003. Home range and habitat use by cheetahs (*Acinonyx jubatus)* in the Kruger National Park. *Journal of Zoology.* 261: 119-128.

Calenge, C. 2006. The package “ad habitat” for the R software: A tool for the Analysis of space and habitat use by animals. *Ecological Modeling.* 197: 516-519.

Carnaby, T. 2006. *Beat About The Bush: Mammals.* Jacana Media. Johannesburg, South Africa.

Caro, T.M. 1994. *Cheetahs of the Serengeti Plains: group living in an asocial species.* The University of Chicago Press. Chicago, USA.

Estes, R. D. 1992. *Behavior Guide to African Mammals*. The University of California Press. California, USA.

Getz, W.M., Fortmann-Roe, S., Cross, P.C., Lyons, A.J., Ryan, S.J. and Wilmers, C.C. 2007. LoCoH: Nonparametric Kernel Methods for Constructing Home Ranges and Utilization Distributions. PLoS ONE 2(2): 207.

Gittleman, J.L. and Harvey, P.H. 1982**.** Carnivore Home-Range Size, Metabolic Needs and Ecology. *Behaviour Ecology Sociobiology.* 10: 57-63.

Gros, P.M. and Rejmànek, M. 1999. Status and habitat preferences of Uganda cheetahs: an attempt to predict carnivore occurrence based on vegetation structure. *Biodiversity and Conservation.* 8: 1561-1583.

Hunter, L.T.B. 1998. The behavioral ecology of reintroduced lions and cheetah in the Phinda Resource Reserve, Kwazulu-Natal, South Africa. PhD. Thesis. University of Pretoria.

Marnewick, K. and Cilliers, D. 2006. Range use of two coalitions of male cheetahs, *Acinonyx jubatus*, in the Thabazimbi district of the Limpopo Province, South Africa. *South African Journal of Wildlife Research.* 36(2): 147-151.

Mitchell, M.S and Powell, R.A. 2008. Estimated home ranges can misrepresent habitat relationships on patchy landscapes. *Ecological Modeling.* 216: 409-414.

Mucina, L. and Rutherford, M.C. 2006. *The Vegetation of South Africa, Lesotho and Swaziland.* Strelitzia 19. South Africa National Biodiversity Institute, Pretoria.

Muntifering, J.R., Dickman, A.J., Perlow, L.M., Hruskat, T., Ryan, P.G., Marker, L.L. and Jeo, R.M. 2006. Managing the matrix for large carnivores: a novel approach and perspective from cheetah (*Acinonyx jubatus*) habitat suitability modeling. *Animal Conservation.* 9: 103-112.

Murray, D.L., Boutin, S., O'Donghue, M. and Nams, V.O. 1995. Hunting Behavior of a sympatric felid and canid in relation to vegetation cover. *Animal Behavior.* 50: 1203-1210.

Shannon, G., Page, B., Slotow, R. and Duffy, K. 2006. African elephant home range and habitat selection in Pongola Game Reserve, South Africa. *African Zoology*. 41(1): 37-44.

Chapter 5: Learning versus instinct: Prey selection and hunting techniques implemented by reintroduced captive bred cheetah

INTRODUCTION

Cheetah physique is slim, slight and does not possess excessive power as they predominantly rely on speed when hunting. The cheetah head is small with short teeth and their jaws lack power. After analyzing cheetah body structure it is no surprise that out running and tripping prey is the most commonly observed method of hunting in open veld such as the Serengeti (Caro 1993). However in woodlands ambushing, opportunistic behavior and speed chasing have also been observed (Bissett and Bernard 2007). Ambushing occurs when the cheetah remains at a vantage point waiting for potential prey to pass while opportunistic behavior is when the cheetah or the prey stumbles upon the other suddenly. Five hunting techniques have been observed and outlined by Caro (1994) on the Serengeti Plains, 1) chasing alerted prey over a 600m distance in the open, 2) walking half crouched and freezing mid-stride while stalking alert prey in the open, 3) walking and using vegetation as concealment, 4) flushing small antelopes by sniffing under trees and shrubs and 5) opportunistic ambush. The most commonly observed technique in the Serengeti was the stalking of prey while walking in a half-crouched position and freezing mid-stride or dropping to the ground when prey glanced in the direction of the cheetah. This motion continues with additions and alterations of trotting or sitting immobile until at an appropriate proximity in which to attack. In full view of alert prey cheetah have been noted to run from 60 m to 600 m (Estes 1992; Caro 1994). Smaller species and young animals which are often concealed are flushed out and chased for a short distance when attempting to escape. When hunting small vertebrates cheetah bite the head and crack the skull to kill the animals (Caro 1994) however larger prey is tripped and the animal falls (Estes 1992). The animal either breaks a leg during the fall or is winded by the impact and becomes vulnerable to the cheetahs next attack to the throat.

Often prey is relatively small in comparison to the cheetah approximately < 60kg (Pettifer 1979; Phillips 1993; Bothma 1999; Broomhall 2001; Marker *et al.* 2003). It is theorized that prey larger than a cheetah, with tusks or horns, would be too heavy or dangerous to hunt as the possibility of injury increases (Estes 1992). However studies by Hunter (1998) in Phinda Resource Reserve, Kwa-Zulu Natal found that adult female and male ungulates were hunted successfully without injury to the cheetah. In the Limpopo Low veld a study by Pettifer (1979) in the Timbavati and Klaserie Private Nature Reserve regarding the release of a coalition consisting of three captive cheetahs found that the frequently observed chase, slap and trip technique was readily used when hunting. The coalition was able to successfully hunt waterbuck *Kobus ellipsiprymnus* and impala rams. In contrast, two captive bred female cheetahs sourced from the Kapama Cheetah Centre in Hoedspruit, South Africa, were released onto Mthethomusha Game Reserve in the Limpopo province adjacent to the Kruger National Park. After eight weeks in an enclosure on the reserve, both cheetahs were fed weekly due to their inability to hunt successfully (Ferguson 1995). The captive bred cheetahs on Makulu Makete Wildlife Reserve remained in an enclosure on the reserve for three months prior to release. During this time their diet was adjusted to venison and the time period between meals extended. Once released, over a period of time and with practice, the cheetahs adapted to the circumstances and improved their hunting methods. The ability to implement and improve successful hunting techniques without prior experience or teaching suggests that hunting is an instinctive behavior.

Given the distribution of cheetah in Africa their prey selection is subject to availability, abundance and size (Estes 1992; Caro 1994; Hayward *et al.* 2006b; Bissett and Bernard 2007; Purchase and du Toit 2007). When a species is killed more frequently than its relative abundance, then it is considered preferred, whereas if a species is killed less frequently than its relative abundance, it is considered avoided. Clearly, this is a simplification as this reflects not just the predator's preference but also the prey's vulnerability and the ease with which it is captured (Hayward *et al.* 2006a). Jacobs' index however, minimises the problems associated with many preference indices (Chesson 1978; Strauss 1979; Norbury and Sanson 1992; Hayward and Kerley 2005; Hayward *et al.* 2006b). In East Africa the preferred prey is Thompson gazelle *Gazella thomsonii*, the Kalahari preference is springbok *Antidorcas marsupialis* (Estes 1992), Zimbabwe impala *Aepyceros melampus* and in South Africa young kudu *Tragelaphus strepsiceros* and springbok *Antidorcas marsupialis* (Broomhall 2006, Purchase and du Toit 2007). Smaller vertebrates such as the scrub hare *Lepus saxatilis* were found in scat analysis of Namibian cheetah by Marker *et al.* (2003) and observed by Broomhall (2006) in Kruger National Park, guinea fowl *Numida meleagris* by Purchase and du Toit (2001) in Matusadona National Park Zimbabwe however similar small vertebrates such as the spring hare *Pedetes capensis* have not been recorded. Large prey consumed can be observed from carcass remains however there is the possibility that small species are included in the cheetah diet (Caro 1994) but not recorded. Typically after a kill the cheetah drags the carcass under a bush or into shade before feeding (Pettifer 1979; Estes 1992). The level of vigilance is theorized to be caused by nervousness of kleptoparasitism (Phillips 1993) therefore resulting in cheetahs being reported as rapid feeders. Typically in the absence of other predators' long periods of time ranging from four to five hours are spent at the carcass (Pettifer 1979; Nature Conservation Trust 2006).

Wild cheetahs remain with their mother until the age of 14 to 18 months during this time as the cubs develop they accompany the mother on hunts and eventually participate in hunting (Caro 1994). Participation during hunts allows the young cheetahs to learn to select and differentiate between potential and appropriate prey species. Captive cheetahs are removed from their mothers at the age of six months (Bertschinger *et al.* 2008). Young wild cheetahs interact with the mother, the environment and if present, other siblings. Cub interaction is supervised by the mother who encourages and disciplines accordingly. Such interactions develop skills such as hunting, pouncing, coordination and fitness. Captive cheetahs interact with littermates however interaction with the environment is limited. These interactions have no structure or direction.

Prior to the commencement of this project there were two wild cheetahs that were removed from the reserve, a male and a female. Data was collected by the resident ecologist for the wild cheetahs and the results were compared with the captive cheetahs where possible (Rosamund Whittle unpublished data). The comparison allowed for a preliminary indication as to the adjustment of the captive bred cheetahs to a wild environment.

A study on cheetah habitat selection in thicket vegetation provides insight into the extent of influence vegetation has on habitat use and selection (Bernard and Bissett 2007). Vegetation density is important as it influences visibility, stalking approach, chase distance and general hunting strategies (Caro 1994; Bernard and Bissett 2007). Bernard and Bissett (2007) found that in thicket stalking distance increased while chase distance decreased. Cheetahs have portrayed opportunistic hunting behavior thus depending on vegetation for concealment (Purchase and du Toit 2000). The study by Purchase and du Toit (2000) found that vegetation influenced prey selection due to habits of the ungulates. Browsing species such as greater kudu *Tragelaphus strepsiceros* and bushbuck *Tragelaphus scriptus* are found in areas with available browse such as thickets (Estes 1992). Burchell's zebra *Equus burchelli* and blue wildebeest *Connochaetes taurinus* are grazers occurring in less dense habitats (Estes 1992). Cheetahs prey on the above mentioned species thus indicating habitat utilization adaptability of cheetah in accordance to prey behavior.

The purpose of this section of the study was to determine if captive bred cheetah released into a wild environment are able to a) hunt and sustain themselves, b) determine prey selection, c) determine the time period before successful hunting established and d) determine cheetah behavior at the carcass.

METHODS

Feeding ecology can be studied in several ways namely; radio-tracking (Funston 1998; Mills and Schenk 1992; Broomhall, Mills and du Toit 2003), opportunistic observations (Creel and Creel 1996; Funston 1998; Hayward *et al.* 2006b), direct observations (Mills and Schenk 1992; Phillips 1993; Funston 1998; Krüger *et al.* 1999; Broomhall *et al.* 2003; Marker *et al.* 2003) stomach and faecal analyses (Krüger *et al*. 1999; Ray and Sunquist 2001; Marker *et al.* 2003; Breuer 2005). Mills (1992) compared the accuracy of all these methods and found that direct observations, was the least biased method for determining the feeding habits of predators. For this analysis two methods were utilised; radio tracking to establish direct observations and scat analysis.

Direct observation

The cheetahs were tracked twice daily from April 2008 until May 2009 during their peak activity time periods; 06h00 to 10h00 and 14h00 to 18h00. The data collected to determine which factors influence hunting were weather, environmental and prey characteristics. Where possible hunting techniques were observed however due to the bush density this was seldom feasible. Prey type, estimated time of kill and locality details were recorded at kill sites. The prey was then assigned to species, sex and age classes. Additionally the amount of the carcass consumed was estimated. Scat was collected to supplement kill data which is discussed in further detail in Chapter 6. Determining prey weight was scaled based on species, sex and age in accordance to previous studies (Pettifer 1979; Estes 1992; Hunter 1998; Bothma 2002; Bissett 2004). Prey weight was catagorised as small <40 kg, medium 40 kg to160 kg and large >160 kg. To determine the approximate amount consumed each edible body section was assigned a percentage of the total body mass. According to van Dyk and Slotow (2003) approximately 60 % of the carcass is edible. Each fore limb equals 5 %, each hind quarter including rump 15 % while each half (left and right rib cage including back strap) of the body will be 5 % and the pericardial cavity (heart, lungs and liver) 10 %. The head and skin make up 10 %. This was then compared to the live body mass for actual weight of food consumed. Small animals are comprised of approximately 65 % edible parts because 5 % of the bone can be consumed. As a result of the enclosure experience close proximity to the carcass was feasible without instigating a reaction from the cheetahs thus enabling the observers to locate the puncture wounds in the throat and dewclaw marks to confirm that the cheetah killed the prey and was not scavenging.

The weather data collected was temperature, wind strength and cloud cover. Environmental data collected was grass height, grass density and vegetation density. Grass data included forbs to encompass the lower vegetation level. Vegetation density encompassed trees and shrubs. Behavioral characteristics of the prey species included animal size and herd size. The presence of other animals and cheetah condition were also recorded.

Statistical analysis

Two methods were used to investigate the prey preference of the cheetahs: a preference rating and Jacobs's index (Jacobs 1974). The preference rating for the different prey sorts will be calculated as follows (Pienaar 1969; Mills and Biggs 1993):

$$\text{Preference index} = \frac{\text{kill frequency of prey}}{\text{relative abundance of prey}}$$

The Jacobs' index value will be calculated for each prey species using prey abundance and kill data (Jacob 1974):

$$D = r - p / r + p - 2rp.$$

Jacobs' index (Jacobs 1974) is used to standardise the relationship between prey relative abundance *p* (i.e. the proportion that each species makes up of the total abundance of census prey species) and the relative proportion that each species comprises as cheetah kills *r* to between +1 and -1, where +1 indicates maximum preference and -1 maximum avoidance.

The chi-squared test was used to determine if there was a difference between what was stalked and caught. A linear regression was used to determine which prey weight was preferred. The chi-squared and paired *t*-test (http://www.r-project.org, 20/05/09) was used to determine the relationship between hunting success, vegetation and climatic factors. Vegetation factors included grass height and vegetation density. Climatic factors were temperature, cloud cover and wind intensity. Grass height was classified as short < 30 cm, medium 40 - 60 cm and tall >70 cm. Vegetation data was collected by walking a line transects 100 m in length and with a width of two meters thus an area of 200 m². The Biomass Estimates from Canopy Volume commonly referred to as the BECVOL-model (Smit 1989) was then used to classify woody vegetation as open, moderate and dense. Temperature was ranked as low, medium and high. Cloud cover was classified as clear, scattered, partly and complete. Wind intensity was classified as calm, mild and strong. Though subjective these scales were consistent because data was collected by the same two observers.

Behavior at a kill site during the first four months of each cheetahs release period was calculated using linear regression to determine changes in vigilance. A chi-squared test was used to determine if there was a difference between what the wild and captive cheetahs hunted. The preference ratio and Jacob's index were used to compare prey preference of wild and captive cheetahs.

RESULTS

Hunting commenced at various times for each cheetah but was sustained by all cheetahs. Female F536 commenced hunting on the fifth day of her release, a kudu calf *Tragelaphus strepsiceros*. The male coalition, M579 and M580 commenced hunting on the first day of release, a warthog *Phacochoerus africanus*. The first single male M490 did not commence hunting for a month following release therefore a decision was made to supplement feed him until hunting independently. Data from all cheetah groups were utilized regardless of duration on the reserve though this varied from two weeks to eight months. Once hunting commenced no supplementary feeding was required. During the early months of release each cheetah was injured while hunting. The female cheetah F536 injured her toe which was then surgically amputated. Her second injury was from a shoulder laceration while hunting an impala ram. One cheetah male M580 had a gemsbok *Oryx gazella* hair penetrate his eye and the hair had to be surgically removed. The same male later had multiple puncture wounds from a either a bushbuck *Tragelaphus scriptus* or warthog *Phacochoerus africanus* encounter. Another male M579 required stitches on the fore paw due to the gemsbok hunt. Following the treatment and recovery from these injuries the eventual ability for all the cheetahs to hunt successfully indicated adjustment to the environment. Vegetation provided concealment for the cheetahs while developing their hunting skills and their fitness. For this reason ambush hunting was initially the most frequently used form of hunting.

Selected prey and the hunting techniques implemented

Data were gathered on successful and missed hunts. Animals stalked and chased but never caught were zebra, giraffe *Giraffa camelopardalis* and baboon *Papio ursinus*. All other species including bushbuck, duiker *Sylvicarpa grimmia*, impala *Aepyceros melampus*, kudu, gemsbok, steenbok *Raphicerus campestris*, waterbuck *Kobus ellipsiprymnus* and warthog were stalked and caught (Table 5.1). Kudu and waterbuck kills were juveniles within a herd or younger at a stage where the calf was concealed. Of the kills made and observed 38 % were female, 34 % were male and 28 % were unknown due to either young age or the researchers' inability to approach the carcass close enough to observe the sex. All cheetahs preferred bushbuck with a Jacobs' index of *D* = 0.81 which is significant because it is close to one which is the highest preference for Jacob's index. Though impala made up 38 % of the cheetah kills due to the relative abundance bushbuck and waterbuck had preference rating of 7.56 and 1.46 respectively and impala had a preference rating of 1.20 (Table 5.2). There was no significant difference between what was stalked and what was caught (X^2 = 13.35, *df* = 12, *P* >0.05). However, when the cheetahs were very hungry and struggling to hunt, small prey such as bat eared foxes *Otocyon megalotis* and black backed jackals *Canis mesomelas* were hunted. Medium sized prey weighing equal to or more than the cheetahs were caught most frequently (mean= 69 kg, S.E = 11.07). The proportion of kills made relative to the abundance of the species was greater for medium sized prey (Fig. 5.1.)

The hunting techniques frequently observed by the researchers were the chase-slap, flushing and the slow halted approach. While approaching both oblivious and alert prey the cheetahs would place the back paw where the fore paw had been. While hunting the cheetahs were frequently seen searching under shrubs for small prey which was then flushed. When approaching larger prey the cheetahs would walk and freeze near a shrub or when in the open lay close to the ground mid-stride when the prey looked in the cheetahs' direction.

On occasion the cheetahs would sit and observe the prey before commencing the hunt. This would continue until the cheetah reached a distance where pursuit was viable. The stalking portion of a hunt ranged from 1 to 40 minutes (*N* = 84, mean = 6.81, S.E = 0.67). Distance to prey before pursuit ranged from 10 m to 50 m. The chase was then initiated by the fleeing of the prey, the prey turning its back to the cheetah or by the cheetahs' proximity. Chase distances ranged from 10 m to 600 m. Failed hunts were due to several factors: prey awareness of the cheetah, cheetah halting a chase mid-pursuit or the preys evasive maneuvering while fleeing.

Once the cheetahs caught the prey the neck would be gripped in the jaws, the trachea blocked and the animal strangled. While gripping the neck, wild cheetahs lay behind the prey to avoid kicks and possible injuries. When first hunting the captive bred cheetahs were seen on the prey during strangulation and received kicks and superficial injuries. When the killing strangulation was observed again after several months of release, the captive bred cheetahs lay behind the prey and executed the strangulation similar to wild cheetahs. Once the cheetah has secured a grip on the quarries neck it took approximately four to six minutes for the animal to suffocate depending on the size. The first warthog killed by the coalition took 20 minutes to die. The gemsbok hunted by the coalition took 40 minutes to die while the cheetahs proceeded to consume it alive. The coalition broke the gemsbok leg during the hunt but was repelled from the neck grasp by the formidable 60 cm horns. While feeding the captive bred cheetahs were seen to hold the prey down with the front paws while wild cheetahs seldom implement such behavior (Caro 1994).

Table 5.1. Prey species, mass and kill proportions of three captive bred cheetahs released on Makulu Makete Wildlife Reserve.

		Kill proportion				
Species	**Mass (kg)** [1]	**Male**	**Female**	**Unknown**	**Total**	**S.E**
Bat eared fox	4	-	-	1	1	-
Black backed jackal	7.2	-	-	2	2	-
Vlei rat	-	-	-	2	2	-
Steenbok	10	-	2	-	2	-
Duiker	11.4	1	1	-	2	-
Bushbuck	29	5	6	2	13	2.1
Warthog	30	-	-	3	3	-
Impala	41	15	10	1	26	7.1
Kudu	136.4	-	-	3	3	-
Waterbuck	205	1	5	3	9	2
Gemsbok	225	-	-	1	1	-

[1] Average mass in kg per adult individual (Bothma 2002).

Table 5.2. Relative abundance and preference ratings of prey species caught by captive bred cheetahs, Makulu Makete Wildlife Reserve. The higher the preference rating the more the cheetahs select the prey. The closer to +1 the Jacob's index the more preferred the prey, the closer to -1 the less preferred.

	Impala	**Bushbuck**	**Waterbuck**	**Duiker**	**Steenbok**	**Kudu**
Total No.	377	30	106	30	26	190
RA	36.64	2.92	10.30	2.92	2.53	18.46
Kills	26	13	9	2	2	3
Pref. rating (PR)	1.20	7.56	1.46	1.16	1.32	0.28
Jacobs' index (D)	0.15	0.81	0.22	0.08	0.15	-0.62

RA= Relative Abundance

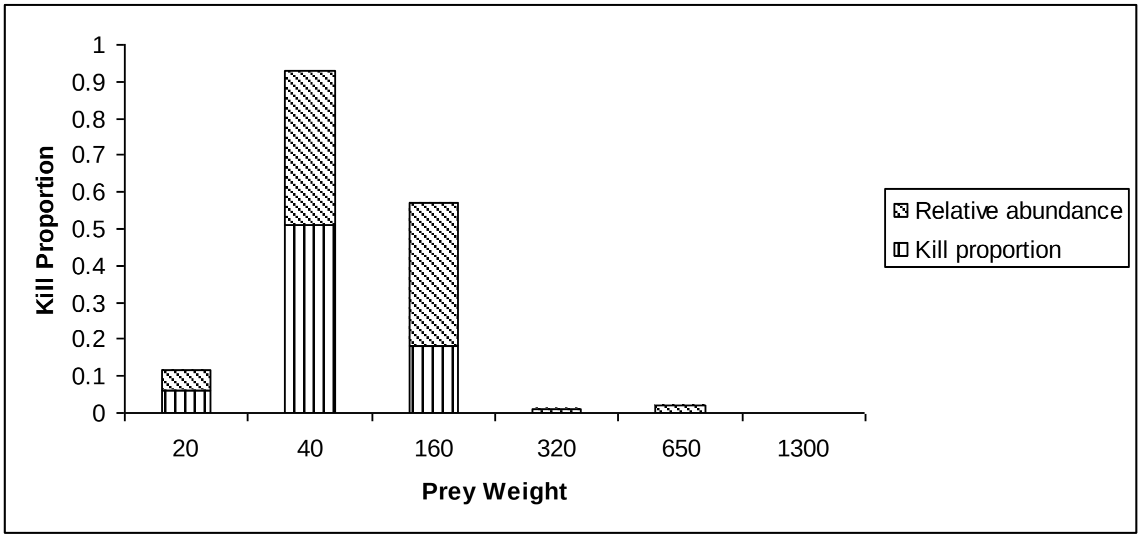

Fig. 5.1. The proportion of kills made relative to the abundance of the species caught by captive bred cheetah on Makulu Makete Wildlife Reserve.

Captive cheetah hunting success in different vegetation communities

The cheetah utilized the vegetation as concealment while stalking prey enabling the cheetahs to approach the prey, freezing mid-stride behind a shrub or crouching when in an open area. While approaching prey all cheetahs lowered their stance and placed the back paw in the same place as the fore paw to minimize noise.

The cheetahs were seen to attempt hunts and were successful in all vegetation types (Fig. 5.2.). Hunts were evenly distributed as expected throughout the vegetation communities (X^2 = 9.64, *df* =7, $P > 0.05$). Grass height was not a contributing factor to hunting success (t = 15.588, *df* = 2, P = 0.0041) (Fig. 5.3.). Of the hunts made 48 % were made in medium grass height of which 58 % were successful. Thirty seven percent of hunts were made in tall grass of which 60 % were successful. Fifteen percent of hunts were made in short grass of which 81 % were successful. Most hunting attempts were made in medium height grass however short grass had the greatest success rate. Vegetation density was a contributing factor to hunting success (t = 2.496, *df* = 2, P= 0.1299) (Fig. 5.4.). Of the climatic factors wind strength influenced hunting the most (t = 3.285, *df* = 2, P = 0.0814).

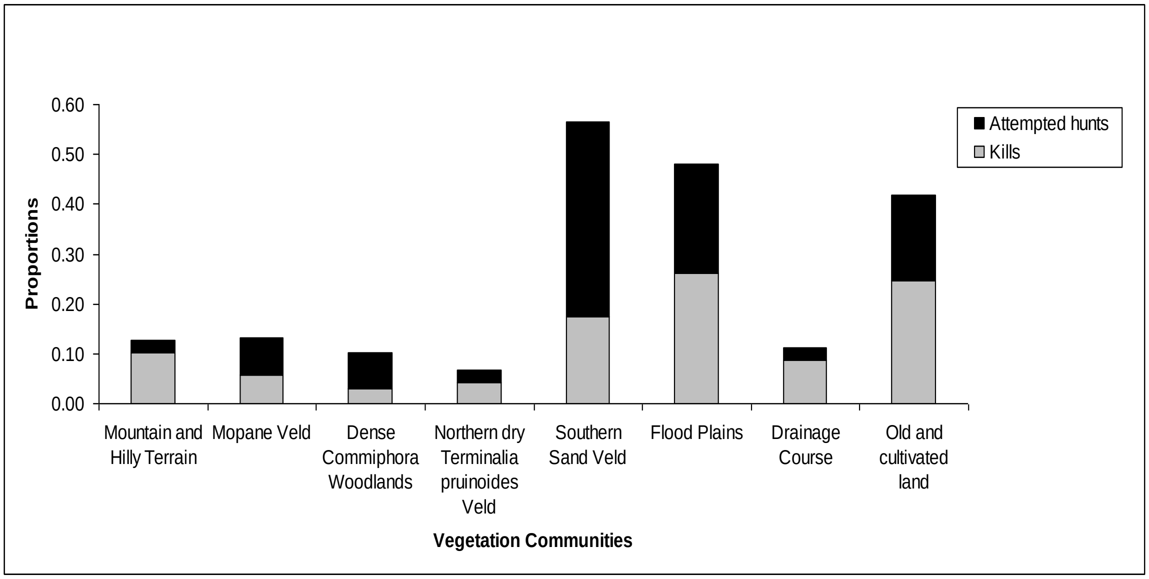

Fig. 5.2. Proportion of successful and missed hunts by captive bred cheetahs per vegetation community, Makulu Makete Wildlife Reserve.

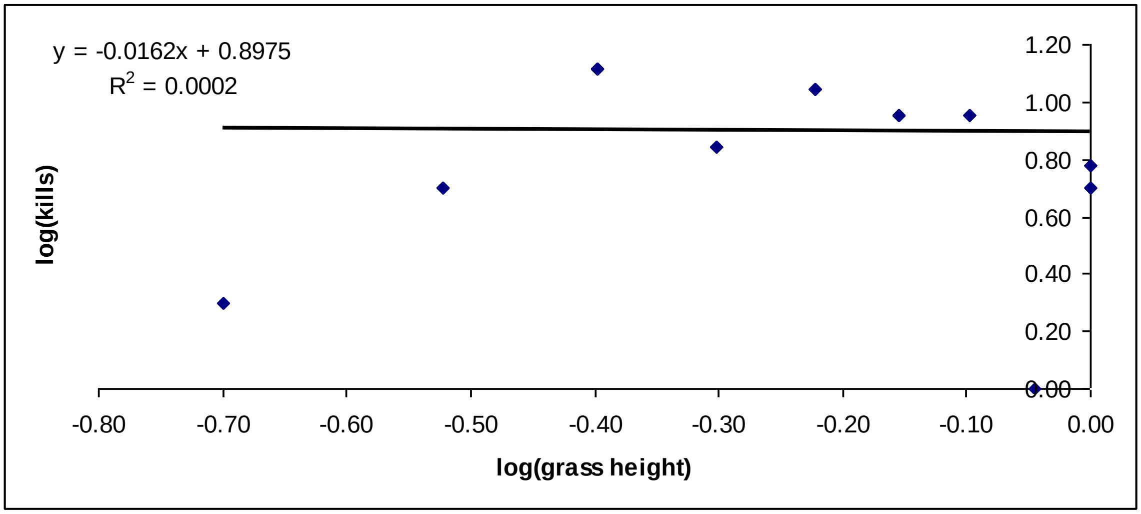

Fig. 5.3. Linear representation of relationship between grass height influence on successful hunting by reintroduced captive bred cheetah released on Makulu Makete Wildlife Reserve.

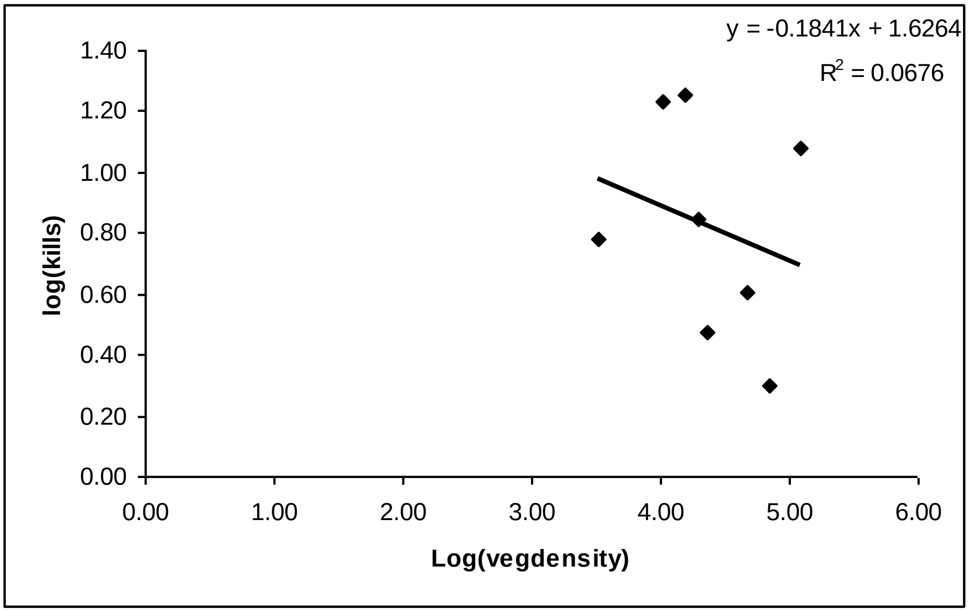

Fig. 5.4. Linear representation of relationship between vegetation density influence on successful hunting by reintroduced captive bred cheetah released on Makulu Makete Wildlife Reserve(S.E = 0.3668, P>0.05).

Cheetah behavior at kill site: Kleptoparasitism, vigilance and amount consumed

Once released the cheetahs were able to bring down their prey and open the skin to begin eating. The cheetahs consumed approximately three to five kilograms of meat per day. All cheetahs opened the carcasses back leg either at the anal opening or the inner leg where the skin is softest. Unless the carcass was stolen over night, the cheetahs would remain with their kill until all edible parts had been consumed and the cheetah was satiated. None of the cheetahs consumed the head, stomach or large bones; femurs and vertebral column. However all cheetahs consumed the ribs, parts of the intestine and approximately 20 % of the skin. Bones such as the vertebral column of small and young animals were consumed. While at a kill a cheetah displays varying degrees of vigilance; scanning the area while eating, sitting upright or walking a perimeter around the carcass. On three separate occasions the female was seen to conceal the carcass by scrapping grass and leaves over the remains. In the Serengeti following kleptoparasitism cheetahs did not return to their kills (Caro 1994). The cheetahs on Makulu Makete Wildlife Reserve were seen to return to a kill site when the carcass had been stolen overnight five times by F536, four times by M490 and M579 not at all. The cheetahs spent up to 72 hours on a kill in the absence of kleptoparasitism (*N* = 64, mean = 30, S.E = 2.77) (Table 5.3). Leopards *Panthera pardus* and brown hyenas *Hyena brunnea* occur on Makulu Makete Wildlife Reserve and were the recorded culprits of kleptoparasitism. The captive bred cheetahs were seen to chase black backed jackals away from carcass remains on several occasions.

Table 5.3. Prey weight (S.E= 2.90), retention time (S.E= 2.77) and percentage of carcass consumed (S.E= 2.46) at kill sites of three captive bred cheetahs released on Makulu Makete Wildlife Reserve.

	Cheetah weight (kg)	Prey weight mean (kg)	Prey retention mean (hrs)	Consumed (kg/day)	(% of carcass)
F536	30.00	40.79	31.47	2.56	43.97
M490	32.45	44.58	31.17	2.84	44.58
M579	41.00	42.06	31.44	2.91	48.44

When hunting commenced each of the solitary cheetahs averaged one kill a week or five kills a month (Fig. 5.5.). The cheetahs began consuming the carcass from the back leg in 49 % of the kills, from the foreleg in 15 % of kills and 37 % were unknown. The heart, lungs and liver were consumed along with edible flesh. Stomach, kidney and intestines remained however the cheetahs would consume small amounts of the intestines. Bone consumption of small animals such as bushbuck and impala lambs excluded limbs and the vertebral column. Bone consumption of larger prey was restricted to the ribs. Departure from a kill was either due to the complete consumption of edible parts or kleptoparasitism.

Vigilance, scanning rate while at a kill, increased over time for female F536 (R^2 = 0.5391) and M579 (R^2 = 0.5387) but not M490 (R^2 = 0.0560) (Fig. 5.6.). Of the 68 kills only nine were lost over night from kleptoparasitism for all cheetahs. While on a carcass each cheetah displayed varying degrees of vigilance such as looking around while crouched over the carcass, sitting upright to look around and even walking around the kill site. Frequency of these behaviors increased overtime. After securing the prey prior to feeding, the cheetahs would drag the carcass under a bush for concealment. While feeding the cheetahs were seen to hold down and secure the carcass with their front paws. When M490 and M579 were re-released both concealed their carcasses and increased their vigilance.

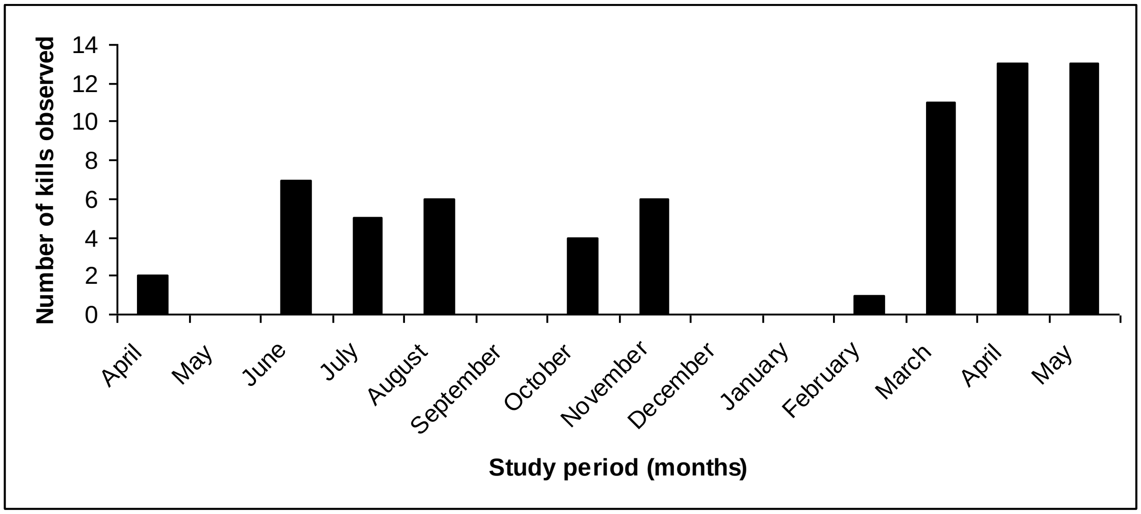

Fig. 5.5. Number of kills made per month by three captive bred cheetahs released on Makulu Makete Wildlife Reserve between April 2008 and May 2009 (There were no cheetahs present on the reserve in September and December 2008 and January 2009).

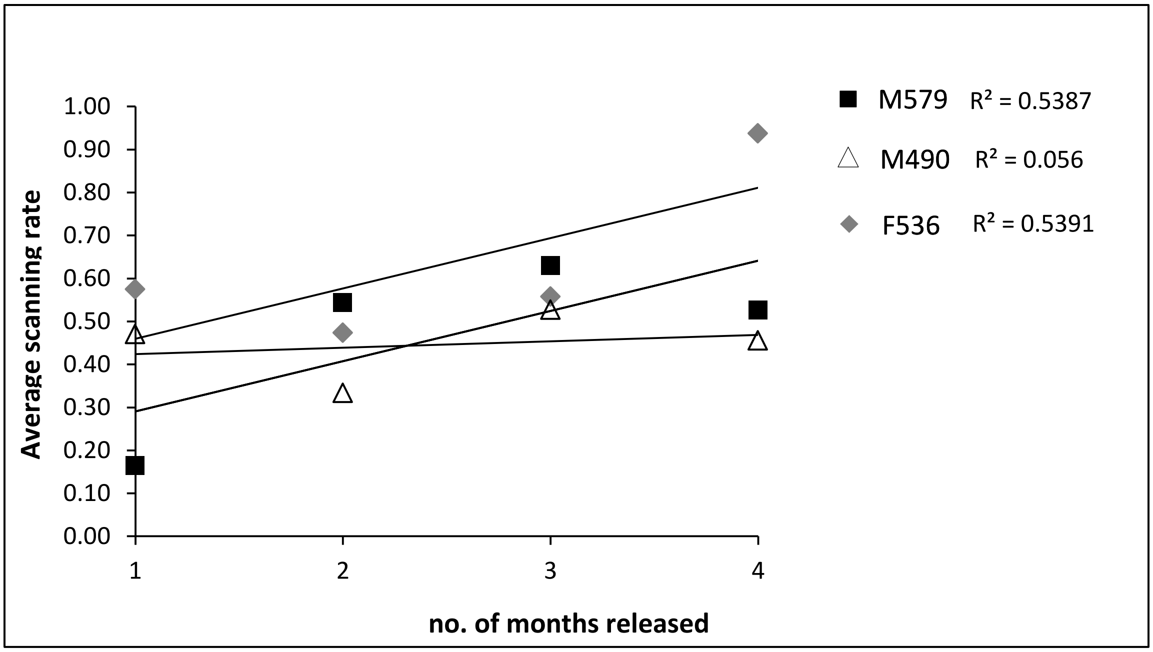

Fig. 5.6. Average scanning rate per month while at a kill site by three captive bred cheetahs released on Makulu Makete Wildlife Reserve, F536 (S.E = 0.09), M579 (S.E = 0.05) and M490 (S.E = 0.07).

Scat and spoor of brown hyena were found around cheetah kill sites were kleptoparasitism had occurred. Black-backed jackals were observed to be chased and consumed by the cheetahs on three occasions and were therefore unlikely culprits of kleptoparasitism. On other occasions the jackals would arrive while the cheetahs ate and would be ignored. Leopards were also likely culprits of kleptoparasitism.

Comparative hunting of captive versus wild cheetah

The wild and captive female cheetahs were on the reserve for approximately nine months therefore their kill data could be compared. Sufficient data was collected for the solitary wild female and was compared to the captive female (Fig. 5.7.). The data from the wild cheetah was used as the expected values and the data from the captive females was used as the observed values. There was no significant difference in hunting success between the wild female and the captive female cheetah ($X^2 = 12.277$, $df = 6$, $P < 0.05$). The preference ratio indicates that both female cheetahs preferred bushbuck and impala with the wild female preferring bushbuck the most (*PR* = 4.64) followed by impala (*PR* = 4.06). The captive female F536 preferred bushbuck the most (*PR* = 8.58) followed by impala (*PR* = 1.12). Although the captive bred and wild cheetah males spent the same amount of time on the reserve (mean = 4.6, SD ± 1.15) during this time insufficient kill data was collected for the wild male and for this reason no statistical analysis could be conducted (Fig. 5.8.). The captive male cheetahs preference ratio indicates that cheetah male M490 preferred impala (*PR* = 1.46) and cheetah M579 preferred bushbuck (*PR* = 6.86) followed by waterbuck (*PR* = 3.12). Other species could not be listed as preferred because the relative abundance was so small that even one kill would rate it as being high which would skew the results. The Jacob's index was not used because the individual sample sizes were too small for all cheetahs.

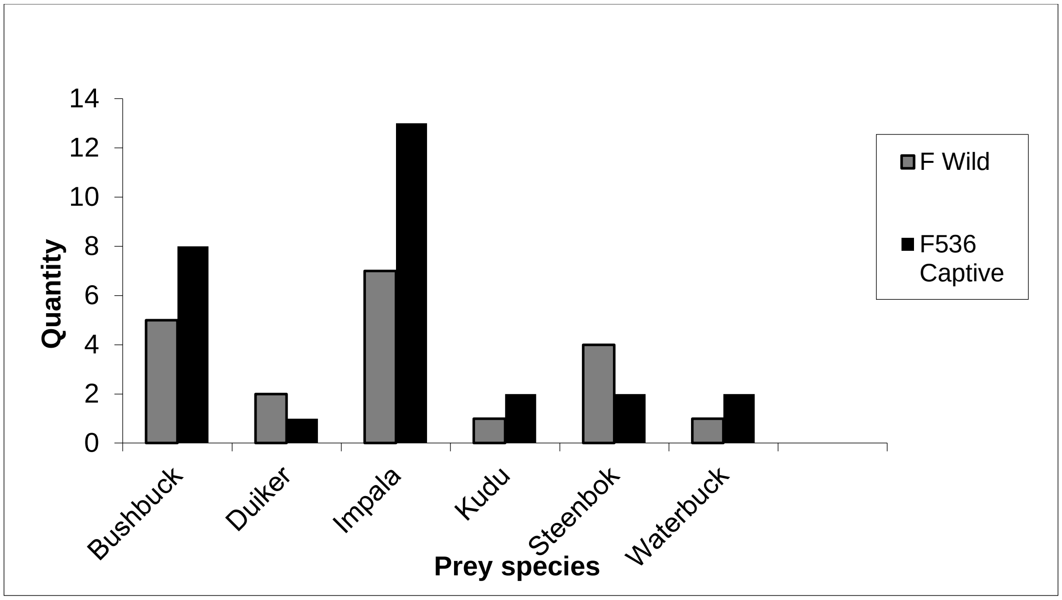

Fig. 5.7. The comparison of the prey species of a wild and captive female cheetah on Makulu Makete Wildlife Reserve.

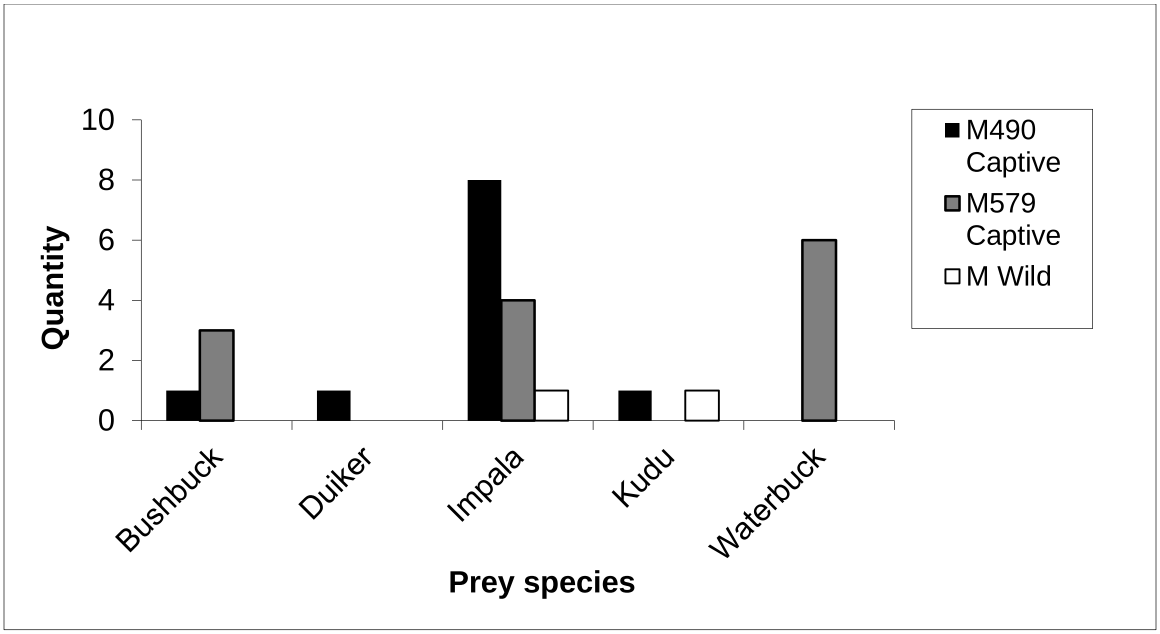

Fig. 5.8. The comparison of the prey species of a wild and two captive male cheetahs on Makulu Makete Wildlife Reserve

DISCUSSION

All three cheetahs were able to hunt successfully and sustain themselves thus indicating the success of this phase of the reintroduction (Fig. 5.5). Following release, hunting methods evolved from ambush to stalking and high speed chases and combination according to the prey. The hunting techniques used when hunting were identical to wild cheetahs though the skills had to be refined overtime. When strangulating the prey the execution was appropriate though this too had to be refined. The instinct to chase prey exists however the development of hunting techniques is a learning process (Fig. 5.2). None of these cheetahs had prior experience though instinct allowed the ability to hunt. Though this instinct is there the cheetahs had to learn which prey was appropriate in terms of risking injury. The time period while the cheetahs honed the hunting skills differed per individual and the risk of injury to the cheetah was elevated. All the cheetahs experimented with high risk prey such as zebra, gemsbok, baboons and warthog. However, over time and following experience each cheetah learned what was appropriate to hunt and ceased attempts on these animals.

The cheetahs were able to hunt both males and females of the prey species regardless of sexual dimorphism and the risk posed by the male horns. Due to the number of unknown sex kills we could not determine if there was a sex preference. Wild cheetahs do not portray a sex preference; it is the weight of the prey that is a determinant. It is likely that the captive bred cheetahs also had a weight preference rather than prey sex (Table 5.1. and Fig. 5.1.).

The individual sample size of kill data was insufficient to determine preference which is why all the cheetahs were analysed together. The relative abundance of the different species was taken into account because species with low relative abundance were ranked high even if only one kill was made which was evident for steenbok, duiker and kudu. For this reason these species were not considered as preferred prey even though they were rated (Table 5.2.).

Vegetation structure and density influences the behavior of ungulates. Solitary and paired ungulates tend to occur in dense vegetation such as bushbuck, steenbok and duiker while herd ungulates such as waterbuck, kudu and impala occur in less dense vegetation. Given these behaviors prey occurred in varying vegetation types and the cheetahs hunted in all the vegetation communities (Fig. 5.2.). The greatest hunting attempts and success were in the River and Flood Plains and the Old and Cultivated land. The Southern Sand Veld has relatively low vegetation density which likely explains the high number of missed hunts. Few hunting attempts were made in the *Mopane* Veld, Dense *Commiphora* Woodlands and least of all in the Northern dry *Terminalia prunioides* Veld. This is likely because vegetation density is high in these communities. Hunting success decreased with increasing vegetation density and in very low density hunting attempts were not made (Fig. 5.4.). The dense vegetation likely limited the visibility and maneuverability of the cheetah therefore reducing their hunting efficiency in such vegetation. Very low vegetation density likely reduced the cheetahs ability to stalk and approach the prey to a close enough proximity for optimal hunting. The grass height did not influence hunting attempts and success (Fig. 5.3.). This is likely due to the limited variation in grass height throughout the reserve.

The cheetahs all hunted prey within the same weight range. The prey weight range included medium adults and the calves and juveniles of larger ungulates. The mean retention time was the same for all cheetahs. The amount consumed was approximately the same as was the percentage of the carcass consumed. The female cheetah was at the lower end of each range but still comparable to the males (Table 5.3). All cheetahs increased their scanning rate following release (Fig. 5.6.) however female F536 increased vigilance during the first four months of the study period while both males reduced their vigilance after four months of release. The female cheetahs behaviour of raking leaves over her prey carcass and increased vigilance is likely due to greater experience with kleptoparasitism than the males.

CONCLUSION

The captive bred cheetahs have the instinct to hunt. Maximum monitoring efforts and veterinary care become necessary during early release while the cheetahs were learning due to honing hunting techniques. The three months of training received while in the enclosure were possibly beneficial in the success of this portion of the reintroduction however it is also likely that the cheetahs learned during their release time.

REFERENCES

Balme, G., Hunter, H. and Slotow, R. 2007. Feeding habitat selection by hunting leopards *Panthera pardus* in a woodland savanna: prey catchability versus abundance. *Animal Behavior.* 74: 589-598.

Bertschinger, H.J., Meltzer, D.G.A. and van Dyk, A. 2008. Captive Breeding of Cheetahs in South Africa- 30 Years of Data from the de Wildt Cheetah and Wildlife Centre. *Reproduction of Domestic Animals.* 43(2): 66-73.

Bissett, C. and Bernard, R.T.F. 2006. Habitat selection and feeding ecology of the cheetah (*Acinonyx jubatus*) in the thicket vegetation: is the cheetah a savanna specialist? *Journal of Zoology.* 271: 310-317.

Bothma, J.P. 2002. *Game Ranch Management*. (4th Ed) Van Schaik Publishers. Pretoria, South Africa

Broomhall, L.S. 2006. Cheetah *Acinonyx jubatus* ecology in the Kruger National Park: a comparison with other studies across the grassland-woodland gradient in African savannas*.* MSc. Thesis. University of Pretoria.

Caro, T.M. 1993. Behavioral Solutions to Breeding Cheetahs in Captivity: Insight from the wild. *Zoo Biology*. 12(1): 19-30.

Caro, T.M. 1994. *Cheetahs of the Serengeti Plains: group living in an asocial species.* The University of Chicago Press. Chicago, USA.

Chesson, J. 1978. Measuring preference in selective predation. *Ecology* 59: 211-215.

Creel, S.R. and Creel, N.M. 1995. Communal hunting and pack size in African wild dogs, *Lycaon pictus*. *Animal Behavior.* 50: 1325-1339.

Estes, R. D. 1992. *Behavior Guide to African Mammals*. The University of California Press. California, USA.

Ferguson, M. 1995. A Disastrous Cheetah Reintroduction in South Africa. *Cat News.* 23: 16-17.

Funston, P.J., Mills, B.G.L., Biggs, H.C. and Richardson, P.R.K.1998. Hunting by male lions: ecological influences and socioecological implications. *Animal Behavior.* 56: 1333-1345.

Hayward, M.W., Henschel, P., O'Brien, J., Hofmeyr, M., Balme, G. and Kerley, G.I.H. 2006a. Prey preference of the leopard (*Panthera pardus*). *Journal of Zoology.* 270: 298-313.

Hayward, M.W., Hofmeyr, M., O'Brien, J. and Kerley, G.I.H. 2006b. Prey preference of the cheetah (*Acinonyx jubatus)* (Felidae: Carnivora): morphology limitations or the need to capture rapidly consumable prey before kleptoparasites arrive? *Journal of Zoology.* 270: 615-627.

Hunter, L.T.B. 1998. The behavioral ecology of reintroduced lions and cheetah in the Phinda Resource Reserve, Kwazulu-Natal, South Africa. PhD. Thesis. University of Pretoria.

Jacobs, J. 1974. Quantitative Measurements of Food Selection: A Modification of the Forage Ration and Ivlev's Electivity Index. *Oecologia.* 14 (4): 413-417.

Johnson, K.G., Wei, W., Reid, D.G. and Jinch, H. 1993. Food Habits of Asiatic Leopards (*Panthera pardus fusea)* in Wolong Reserve, Sichuan, China. *Journal of Mammology.* 74 (3): 646-650.

Karanth, U. and Sunquist, M.E. 1995. Prey selection by Tiger, Leopard and Dhole in Tropical Forests. *The Journal of Animal Ecology.* 64 (4): 439-450.

Keogh, H.J. 1983. A photographical reference system of the microstructure of the hair of African Bovids. *South African Journal of Wildlife Research.* 13: 89-132.

Krüger, S.C., Lawes, M.J. and Maddock, A.H. 1999. Diet choice and capture success of wild dog *(Lycaon pictus*) in Hluhluwe-Umfolozi Park, South Africa. *Journal of Zoology, London.* 248: 543-551.

Marker, L.L., Muntifering, J.R., Dickman, A.J., Mills, M.G.L. AND Macdonald, D.W. 2003. Quantifying prey preferences of free-ranging Namibian cheetahs. *South African Journal of Wildlife Research.* 33(1): 43-53.

Mills, M.G.L. and Biggs, H.C. 1993. Prey apportionment and related ecological relationships between large carnivores in the Kruger National Park. *Symposium of the Zoological Society, London.* 65: 253-266.

Mills, M.G.L. and Schenk, T.M. 1992. Predator-prey relationships: the impact of lion predation on wildebeest and zebra populations. *Journal of Animal Ecology.* 61: 693-702.

Nature Conservation Trust. 2006. Behavioral Analysis of Cheetah Reintroductions: The Reintroduction of One Captive-born and One Wild-born Male Cheetahs (*Acinonyx jubatus)* On Jubatus Cheetah Reserve, Limpopo Province, South Africa.

Norbury, G.L. and Sanson, G.D. 1992. Problems with measuring diet selection of terrestrial, mammalian herbivores. *Australian Journal of Ecology.* 17: 1-7.

Pettifer, H.L. 1979. The experimental release of cheetah (*Acinonyx jubatus)* into the natural environment. Nature Conservation Transvaal Division. South Africa

Phillips, J.A. 1993. Bones Consumption by Cheetahs at Undisturbed Kills: Evidence for a lack of Focal-Palatine Erosion. *Journal of Mammalogy.* 74 (2): 487-492.

Piennar, U.V. 1969. Predator-prey relationships amongst the larger mammals of the Kruger National Park. *Koedoe.*12: 108-176.

Purchase, G.K. and Du Toit, J.T. 2000. The use of space and prey by cheetahs in Matusadona National Park, Zimbabwe. *South African Journal of Wildlife Research*. 30 (4): 139-144.

Straus, R.E. 1979. Reliability estimates for Ivlev's electivity index. The forage ratio and a proposed linear index of food selection. *Transactions of the American Fisheries Society*. 108: 344-352.

Van Dyk, G. and Slowtow, R. 2003. The effects of fences and lions on the ecology of African wild dogs reintroduced to Pilanesberg National Park, South Africa. *African Zoology.* 38: 79-94.

Chapter 6: The use of scatology to supplement and determine prey species of reintroduced captive bred cheetah *Acinonyx jubatus*

INTRODUCTION

The conservation benefits of animals in captivity are limited to education and genetic preservation. However, where species or sub-species are critically endangered, the release of captive bred animals into the wild can be used as a strategy to supplement existing populations or to form new founder populations. To determine the success of the reintroduction, individual survival had to be monitored. Success was therefore dependent on the cheetahs' ability to hunt and sustain themselves in a manner reflective of wild cheetahs. This was determined by the observation of hunts and the analysis of scat to determine prey species. The use of scat (faeces) analysis has been used repeatedly for the purpose of determining carnivore dietary composition. It is particularly effective when studying elusive species such as tigers *Panthera tigris* and leopards *Panthera pardus* as this method provides insight of prey selection (Johnson *et al.* 1993; Karanth and Sunquist 1995; Karanth and Nichols 2002; Mukherjee *et al.* 2004; Hayward *et al.* 2006a). Hairs consist of keratinized epidermal cells that are cemented and compacted together. Each hair follicle is divided into three sections and three keratin layers. The three sections are the base, mid shaft region and the tip. The keratin layers are the central medulla, the cortex layer surrounding the medulla and the cuticle. Hair is relatively undamaged during digestion and can be found in the fecal matter thus being appropriate for analysis. The hair of each animal is species specific, this means cuticle scale patterns on the surface of the hair and cross sections of the hair can be used to determine the origin of the hair (Keogh 1983). Hair colouration was used conservatively as this various by region. The hair found in the scat is unique to each mammalian species and can then be identified. The medulla which consists of pigmented or nonpigmented shrunken cells surrounded by air spaces is analyzed from a cross section (Douglas 1989). The cuticle is made up of overlapping scales along the length of the hair. These scales are unique in shape, size and margin type and are used for identification. This then determined what the cheetah consumed in the absence of visual observation and to confirm observations. This also allowed for comparisons and measurement of accuracy of scat analyses versus direct observations as a method of determining diet composition.

Hayward *et al.* (2006a) analysed 33 articles regarding prey selection of leopards in 41 different spatial locations which utilized scat analysis and camera trapping to gather data. Similarly Johnson *et al.* (1993) utilized scat analysis of leopard *Panthera pardus fusea* in China, Karanth and Sunquist (1995) determined the diet of leopard, tiger and dhole *Cuon alpinus* in tropical forests of India and Bagchi *et al.* (2003) analysed 109 scats of tigers in semi-arid, dry deciduous forests in the Ranthambhore National Park in India. 689 scat samples of the Ethiopian wolf *Canis simensis* were analysed by Zubiri and Gottelli (1995). Scat analysis is relevant in the event of the consumption of small prey that was not identified during a visual observation thus alleviating the bias of identifying predominantly larger prey (Hayward *et al.* 2006b). The collection of the scat for this study was accumulated using a scat detection dog *Canis familiaris* and by field researchers.

The aim of this section of the study was to a) supplement the observed diet of rehabilitated captive bred cheetah and b) determine if the use of a scat detection dog can reduce search efforts while yielding sufficient and relevant information.

METHODS

Study animals

Cheetah tracking was done twice daily between April 2008 until May 2009. Tracking was during peak activity time periods; 06h00 to 10h00 and 14h00 to 18h00 (Estes 1992) and was done on foot. A vehicle was driven until the telemetry signal indicated the cheetahs to be within what the field researchers considered to be within walking distance; normally approximately 500 m. Because the cheetahs were habituated to humans, visual observations were feasible and were made when possible. To limit the observers' influence on the cheetah's movements, the observers used their discretion as to whether or not to observe and/ or follow the cheetahs. Factors that influenced the field workers decision included when the cheetah had last eaten, cheetah condition and activity and vegetation density. A global positioning system (GARMIN eTrex GPS) was used to record a fix at each sighting. When observed, cheetah condition was recorded based on stomach fullness and protrusion of hip bones and scaled from one to five with one being emaciated and five just eaten (Hunter 1998; van Dyk and Slotow 2003).

Collection of scats occurred in two ways 1) opportunistically by the field researchers during daily tracking sessions and 2) conducting structured searches in areas of known cheetah activity using a detection dog. The risks involved in scat collection include locating the scat, the rate of decay due to environmental factors and dung beetles seasonally.

Cheetah scats are identified by the black, tar-like appearance and the sweet pungent scent and it does not calcify. To compliment the identification of cheetah scat, the surrounding tracks were identified where possible. The scat matter contains hair, teeth and bones that can be identified and linked to the prey consumed. The passage rate of bodily material is erratic and staggered as it passes through the gut. The kill frequency of a particular prey species cannot be quantified, but potentially extrapolated, from a scat analysis because one carcass can produce more than one scat therefore the number of individuals detected may exceed those actually consumed. For analysis purposes of this study one scat sample is considered a sample unit therefore an individual prey can be sampled in several scats. As a result the presence of prey consumed over an extended time period could be identified but was not quantified (Hiscocks and Bowlands 1989).

Dog Training

Pre-Training

Criteria for suitable candidate scat detection dogs include: strong motivation to play, ease of object orientation and eagerness to work towards a reward object (Wasser *et al.* 2004). Selection of potential candidate dogs for this project was based purely on availability and the pet dog of one of the project staff met the criteria as listed. This candidate was a seven month old neutered Staffordshire bull terrier male, which had undergone puppy socialising classes and basic obedience training.

Prior to the commencement of training, the two basic approaches to trauining were considered; positive reinforcement and positive punishment. With positive reinforcement training, a stimulus which the dog finds appealing (such as food, toys or play) is added when the dog performs the desired behavior thus increasing the likelihood of the dog repeating the same behavior in the future (Fjellanger 2003). With positive punishment training, a stimulus which the dog finds aversive (such as pain, fear or verbal correction) is added when the dog performs an undesired behavior thus decreasing the likelihood of the dog repeating the same behavior in the future (Fjellanger

2003). A survey conducted by Hiby *et al.* (2004) on obedience training in domestic dogs indicated that positive reinforcement training methods which utilize reward, such as food or play, yielded higher obedience results from the dog than punishment based training methods. Punishment based training has two major drawbacks; random indications made by the dog to avoid punishment or no indication for fear of punishment for incorrect indications (Fjellanger 2003). For these reasons positive reinforcement training was used in all stages of training and the reward used was the dog's toy rubber ball. In all other aspects the training procedure was conducted in accordance with the methodology as described by Wasser *et al.* (2004)

The training required several stages and three critical aspects were maintained throughout all training sessions 1) a positive reinforcement method was utilized, 2) the duration of each training session was approximately one hour with 30 minutes of preparation and 3) throughout the training period care was taken to ensure that the trainer placing the scat did not leave a track for the dog to intercept and follow.

Due to the inability to access fresh scats continuously for training purposes, scats were frozen, thawed and re-used approximately four to five times until the scent was considered degraded. Training scats were collected from wild cheetahs as anecdotal information suggests that scats from captive cheetahs may not be comparable to wild cheetah scats due to different diets and stress levels.

Stage 1

Classical conditioning

Classical conditioning involves association of a previously neutral stimulus with an unconditioned response in the animal. The aim while using this approach was to teach the dog to associate the stimulus of cheetah scat with an enjoyable response such as play. This was accomplished by placing wild cheetah scat (obtained from known marking posts in the Thabazimbi area) in a small plastic container containing a hole; the container prevented the dog from consuming the scat while the hole allowed the scent to disperse. The scent was introduced to the dog by the handler indicating the container to the dog. Positive reinforcement in the form of play with a toy rubber ball was then given to the dog. This was repeated approximately 10 times during an hour long session.

In this project the dog would be required to be restrained when detecting scat because future field excursions to wild environments could present multiple dangers to an unrestrained dog. For comfort reasons, dogs that are required to track over large areas are commonly worked in a body harness (McKay pers. comm.[10]). For these reasons the dog was worked in a body harness in all training sessions to familiarize the dog to this apparatus and to also condition the dog to the harness as a context-indicator of scat detection.

Operant conditioning

Operant conditioning involves training the dog to produce a behaviour specific to a cue or context, in this case the dog would be given a verbal cue from the handler and non-verbal signals to indicate to the dog that he was required to detect and indicate cheetah scat by sitting next to the scat. To accomplish this, the dog was exposed to the scat and requested to sit via a verbal cue from the handler prior to receiving the reward of the rubber ball. This training stage developed an indication behaviour specific to cheetah scat. In two one-hour sessions several trials were conducted in which the dog received multiple rest periods between each trial. Irrespective of whether the sit cue was given or not the dog was placed on a continuous reinforcement schedule and was

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rewarded each time he sat near the cheetah scat, thus strengthening the required response (McKinley and Young 2003). To prevent area specific behavior, the scat container was moved to various locations during this process.

Differential reinforcement schedule

The differential reinforcement schedule involved getting the dog to offer the required indication behavior of sitting close to the cheetah scat without a cue from the handler. This was only started when the dog was reliably indicating the presence of scat, by sitting on cue. The dog was led up to the scat container without the cue to sit. No reinforcement was given if the dog did not indicate by sitting (McKinley and Young 2003; Bentosela *et al.* 2008). Thirty seconds were allocated to attempt the indication behavior, during which time the handler remained silent. If the dog showed no response the handler removed and rested the dog for a brief period and approached the scat again from a different angle. This was repeated until the dog actively moved towards the scat and promptly sat at the scat, anticipating his reward. The scat was then placed on the ground not inside the container and then placed at least 20 m from the dog in veld grass shorter than 10 cm. This was repeated in different locations.

Initially a cue to search “Soek” (find) was given. This cue was repeated as required if the dog lost focus or was distracted (Fukuzawa *et al.* 2005). The reinforcer was given when the dog found the scat and indicated however if the dog found the scat and did not display the indicator behaviour the sit cue was given and the reinforcer delivered (McKinley and Young 2003). The handler was trained to interpret the dog’s behavior and make an association between the behavior and the phase of the dog’s detection activity. The handler would then provide assistance such as back tracking, pausing or encouragement, as deemed to be that required by the dog.

Stage 2

During the previous stage the dog worked on short mown grass or light veld conditions. Once the dog displayed reliable indication behavior, the terrain and amount of cover was altered. Field conditions are often challenging, therefore suitable terrain was necessary to accustom the dog to working in such conditions. The scent from the scat is also affected by vegetation cover, terrain, wind direction and topography (Wasser *et al*. 2004). For these reasons various conditions were incorporated into training to ensure that the dog and the handler had the necessary skills to work in field conditions. Scat was placed in medium cover veld grass of 10 cm to 30 cm in height. The scat placement was alternated between the ground and low tree branches to simulate cheetah scent marking habits. The dog would then search from a 50 m distant starting point. The scent would then be intercepted by walking the dog across the wind direction (Fig. 6.1).

Given the predator mosaic in the field the dog had to be taught to discriminate between cheetah scat and other predator scat. Four scats from different carnivores including brown hyena, caracal, African wild cat and cheetah were placed in a line and the dog was led down the line. If an incorrect indication was given it was ignored while correct indications were reinforced. Each trial placement varied.

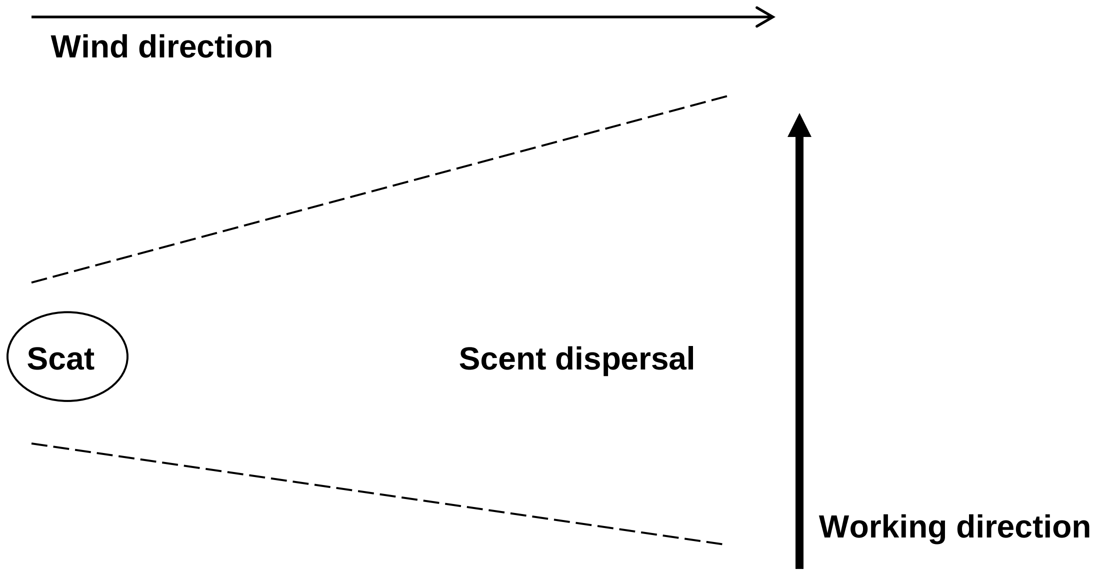

Fig. 6.1. Walking direction of the trained dog to intercept the scent of cheetah scat.

Stage 3

Until this point no field trials were conducted. However after nine training sessions the dog was indicating accurately in all training conditions. To assess the dog's performance in field conditions, known marking posts were used but scats were placed if none were at the known site. The initial field tests took place in the Thabazimbi district. The dog made supposed indication behaviours, but did not sit at the known marking post and was therefore frequently required to be re-walked in the area. It is unlikely that the dog would have found the posts without the handler's prior knowledge of the location.

Initial field tests resulted in the dog not locating the majority of the placed scats and requiring re-walking several times. In the second batch of field tests the dog found the majority of the placed scats and seldom requiring re-walking. Spray sites were assumed to have been located by the dog however this could not be confirmed due to the absence of spoor or scratch marks. No reinforcement was given when such indications were made. In the third batch of field tests the dog found all of the placed scats, unplaced scat and numerous spray sites. These sites could be confirmed by spoor and scratch marks. The successful results of the third batch of field tests illustrated the dog's competence in cheetah scat detection and indication in field conditions.

Stage 4

Collection at project site

Cheetah movement and kills were recorded during daily observations. The detection dog was then taken to known kill sites and an arbitrary 50 x 50 m block was created with either the carcass or cheetahs recorded position as the epicenter. Wind direction was detected by lightly sifting sand through the fingers. The handler would then guide the detection dog, from behind, diagonally into the wind followed by the navigator (field researchers) who helped the group stay on track. This diagonal walking continued in a zigzag motion until the dog indicated that a scent was detected. The dog was encouraged by the handler to search “Soek” (find) until the dog indicated a scat by sitting next to the scat. The scat was identified, GPS fix taken and the entire sample collected in a brown paper bag by a field researcher. Scats are best preserved by drying or freezing, given the field conditions drying was the optimal preservation method therefore the paper bags facilitated the drying process while isolating each scat sample. Each sample was labeled with collection date, GPS fix and finder (dog or field researchers). When the cheetahs were within close proximity to the search site then no search would take place for safety of the dog. In the event that the vegetation density was too great for a search then the arbitrary block would be adjusted to encompass areas that could be searched.

Scatology

Scat was collected either opportunistically by the observers or by the scat detection dog. Scats were stored in brown paper bags in a dry place until analyses were done in the laboratory. Each scat sample was place in separate plastic jars in warm water overnight. The following day each scat was deposited into a cloth (cotton) bag with an identification number. The cloth bag was then stapled shut while leaving gaps sufficient to allow particles out without losing hair. The scat was washed with detergent and water in a washing machine, filtered and rinsed with ethanol to remove sand, bones and vegetation and then oven dried at 60 °C for 24 hours. Microscope slides were then coated with a 5 % solution of gelatin. The gelatin solution was made by combining granulated gelatin with distilled water until saturated. Six drops of Eoisin methyl blue

(Merck, University of Pretoria, South Africa) were added to the solution which was then placed in a beaker and heated in a boiling water bath. The solution was then spread thinly on slides using a glass rod. Two slides each with six randomly selected hairs from the washed scat were placed on the gel coated slide using fine tipped forceps. The entire hair is placed on the slide from root to tip. After drying for 24 hours in a dust proof environment the hairs were removed, using fine tipped forceps, leaving the cuticle imprint on the slide.

Cross sections were made based on methods described by Douglas (1989). Plastic drinking straws were cut into thirds and one end was folded shut to prevent liquid escaping. Clumps of hair were laid parallel in straws. Two straws were assigned to each hair sample. In a beaker 75 % paraffin wax was heated until liquid then poured into the straw. The wax filled straws were then placed in test tubes to remain upright while cooling. Once hard and set, the outer plastic straw was removed and a longitudinal cross section of the remaining wax cylinder was cut using a sharp blade. Ten suitable cross sections were placed on two gelatin coated slides. Reference samples were made from hair samples collected from prey species in the study area to determine species of origin. The imprints and cross sections were then examined under the microscope and compared to reference samples and existing hair keys (Dreyer 1966; Perrin & Campbell 1979; Keogh 1983).

RESULTS

Prey species identified

The captive bred cheetahs caught prey species similar to those of wild cheetahs. When first released the captive bred cheetahs caught bushbuck by ambushing. As time progressed and their fitness increased, the cheetahs were able to successfully hunt waterbuck *Kobus ellipsiprymnus*, kudu *Tragelaphus strepsiceros* and impala *Aepyceros melampus* by chasing their prey down. The prey weight ranged from small to large depending on the age of the prey. The kudu and waterbuck were juveniles, medium to large prey. The impala and bushbuck were predominantly adult male and female, medium prey. Waterbuck and bushbuck calves were also caught when at the age where the mother conceals them, small prey. The female cheetah and one solitary male predominantly preyed on impala while one male preyed on waterbuck. Though released briefly the male coalition was able to successfully hunt warthog *Phacochoerus africanus* and a gemsbok *Oryx gazella*. All cheetah groups hunted bushbuck *Tragelaphus scriptus*.

Within the study time period 43 scats were collected of which 18 were identified by the detection dog, 19 collected by the researchers (Fig. 6.2). Of the scats sampled the contents of four could not be identified due to there not being any hair in the sample therefore 33 were analysed. Insufficient hair content occurs when the sample collected comprises mostly of digested flesh which is the first to pass through the digestive tract. This results in insufficient amounts of hair and can therefore not be analysed. Seven observed prey species and two smaller previously unknown prey species were identified. The seven known species previously identified during direct observations included impala, bushbuck, waterbuck, warthog, gemsbok, kudu and common duiker *Sylvicarpa grimmia* (Fig. 6.3). Though steenbok *Raphicerus campestris*, black backed jackal *Canis mesomelas* and bat eared fox *Otocyon megalotis* were observed as prey species the scatology did not reveal this. The smallest species identified was the vlei rat *Otomys irratus* using teeth collected in the scat and cleaned. The two bird feather samples found in separate scats could not be specifically identified. There was no significant difference between the kill species observed and species found in the scat analysis (X^2 = 17.175, df = 9, $P \leq 0.05$).

Comparison of scatology effort

The total observation time during the study period was 633 hours during which 68 kills were recorded. Searches conducted by the trained dog and the handler were distributed through the study period. The 18 scats found by the trained dog took approximately 19 hours (x = 3 ± 0.29 S.E) to find, while the 19 scats collected by the researchers took approximately 627 hours (x = 48 ± 9.79 S.E) over a 13 month time period (Table 6.1). There was a significant difference in the search efforts between the detection dog and the scat collected by the researchers (U = 6; $P < 0.05$). Each kill observed took 9.3 hours of observation while the combined search effort to collect scat took approximately 1.2 hours per scat.

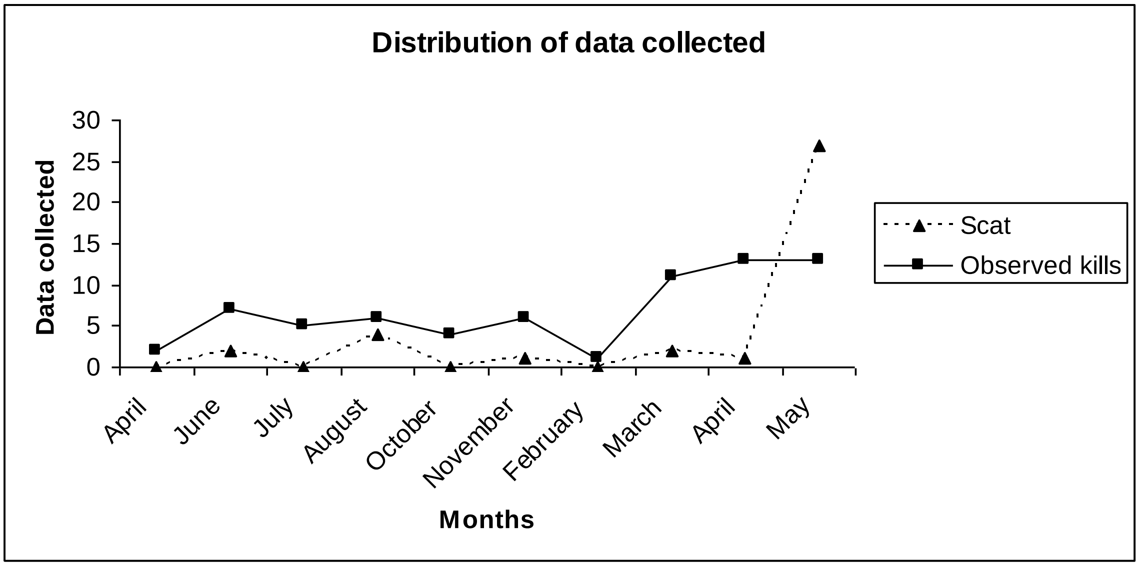

Fig. 6.2. Study time period during which scat of reintroduced captive bred cheetah was collected and kills recorded.

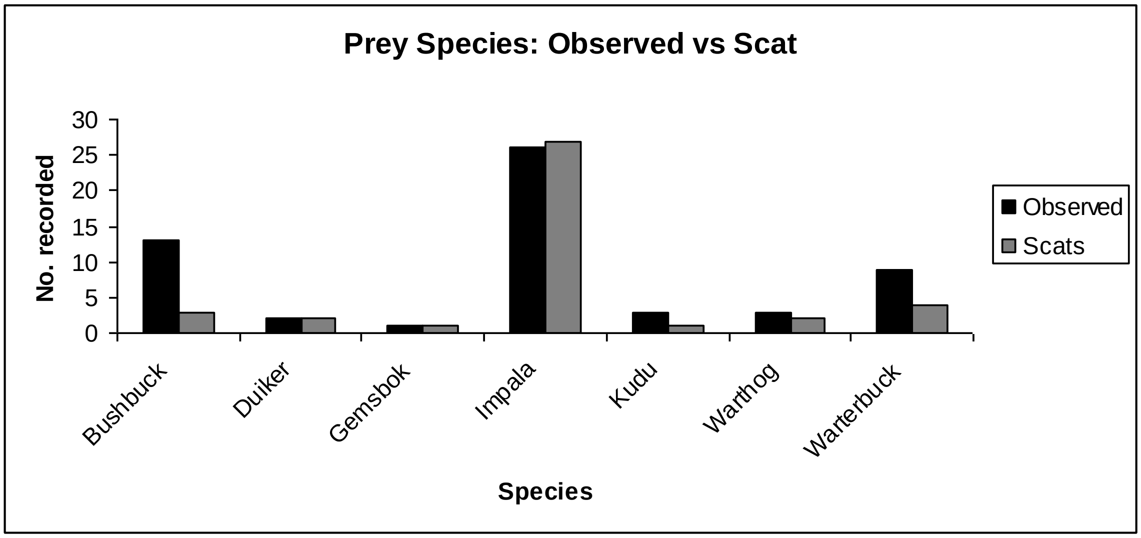

Fig. 6.3. A direct comparison of the seven main prey species observed and present in the scat of reintroduced captive bred cheetah.

Table 6.1. A comparison in the effort (hours) of scats collected, by the researchers and the scats collected by the trained detection dog, of three reintroduced captive bred cheetah onto Makulu Makete Wildlife Reserve during a 13 month study period. The total number of scats found excludes the 6 undated scats.

Date	Duration (mins)	No. of Kills observed	Duration (mins)	No. of Scats collected
Apr 08	2578	2	-	-
May 08	1226	-	231	-
Jun 08	4380	7	219	2
Jul 08	7097	5	-	-
Aug 08	1804	6	221	4
Oct 08	983	4	-	-
Nov 08	1952	6	115	1
Dec 08	411	-	-	-
Feb 09	2222	1	-	-
Mar 09	5668	11	197	2
Apr 09	4995	13	326	1
May 09	4644	13	1486	27
Total	**633hrs**	**68**	**46**	**37**

DISCUSSION

The scat analysis is 90 % comparable with direct observations regarding diet composition (Fig. 6.3.). The combination of direct observations and scat analysis revealed that captive cheetah diet included approximately twelve different prey types, two of which would not have been known without scatology and three which would not have been known without direct observations. Scatology provided qualitative information by determining diet composition but not quantitative preference. Obtaining quantitative information from scat analysis requires knowledge of passage rate, number of scats per kill and sufficient number of scats collected. The number of scats collected for the purpose of this study was sufficient.

The detection do could not be used on a monthly basis because the handler lived and worked in Johannesburg and worked on an availability basis. For this reason we could not conduct monthly searches which would have made the scat search effort more comparable to direct kills monthly (Fig. 6.2.).

Regarding the use of a dog, knowledge of the cheetahs' movement was necessary when working with the dog to identify the area and direction in which to work (Fig. 6.1.). The full potential of the detection dog would have been more evident if searches were feasible on a monthly basis and the observers did not collect the scat opportunistically (Table 6.1). If the field researchers had only recorded the location of the scat and then worked the detection dog in the area, this would have given an indication as to the capabilities of the detection dog. Walking the detection dog on a regular basis would have The use of a dog did reduce the amount of time necessary to search and collect scats and resulted in more scats being found. A limited sense of smell in comparison to a canine reduced the search capability of the field researchers. The dog must be adequately trained to avoid injury or incident when working in field conditions where there is dangerous wildlife, reduced visibility and a mosaic of scents. The detection dog was worked both on lead and off lead however on lead is better for the dogs safety and is more acceptable to reserve owners and managers. The breed of the detection dog must be suitable for endurance work in hot conditions.

CONCLUSION

The effort based on scat collection by the detection dog is efficient however, without previous knowledge of the cheetahs movements based on direct observation the success of using a dog to collect the scat would be less efficient. The opportunistic collection by field researchers is biased because the areas searched are where the cheetahs were seen on a kill and therefore can be considered as recounting what was seen. For future studies the use of telemetry, GPS collar or knowledge of marking posts to determine cheetah movements is necessary prior to using a detection dog to collect scat. This prior knowledge of the cheetahs' whereabouts reduces the search effort. Scatology itself provides a broad perspective of qualitative diet however this information does not provide quantitative information.

REFERENCES

Atkinson, M.W. and Wood,P. 1995. Reintroduction of cheetah in Matusadona Zimbabwe. *Cat News*. 23: 15.

Bagchi, S., Goyal, S.P. and Sanker, K. 2003. Prey abundance and prey selection by tigers (*Panthera tigris)* in a semi-arid, dry deciduous forest in western India. *Journal of Zoology, London.* 260: 285-290.

Bentosela, M., Barrera, G., Jakovcevic, A., Elgier, A.M. and Mustaca, A.E. 2008. Effect of reinforcement, reinforce omission and extinction on a communicative response in domestic dogs (*Canis familiaris*). *Behavioural Processes.* 78: 464-469.

Douglas, R.M. 1989. A new method of cross-sectioning hair of larger mammals. *South African Journal of Wildlife Management.* 19(2): 73-76.

Estes, R. D. 1992. *Behavior Guide to African Mammals*. The University of California Press. California, USA.

Fjellanger, R. 2003. Mine Detection Dogs: Training, Operations and Odour Detection, Report: Geneva International Centre for Humanitarian Demining. Geneva, Switzerland.

Fukuzawa, M., Mills, D.S. and Cooper, J.J. 2005. More than just words: non-semantic command variables affect obedience in the domestic dog (*Canis familiaris*). *Applied Animal Behaviour Science.* 91: 129-141

Hayward, M.W., Henschelp, P., O'Brien, J., Hofmeyr, M., Balme, G. and Kerley, G.I.H. 2006a. Prey preference of the leopard (*Panthera pardus*). *Journal of Zoology.* 270: 298-313.

Hayward, M.W., Hofmeyr, M., O'Brien, J. and Kerley, G.I.H. 2006b. Prey preference of the cheetah (*Acinonyx jubatus)* (Felidae: Carnivora): morphology limitations or the need to capture rapidly consumable prey before kleptoparasites arrive? *Journal of Zoology.* 270: 615-627.

Hiby, E.F., Rooney, N.J., and Bradshaw, J.W.S. 2004. Dog training methods: their use, effectiveness and interaction with behaviour and welfare. *Animal Welfare.* 13: 63-69.

Hiscocks, K., and Bowland, A.E. 1989. Passage rates of prey components through cheetahs. *Lammergeyer.* 40: 18-20.

Hunter, L.T.B. 1998. The behavioural ecology of reintroduced lions and cheetah in the Phinda Resource Reserve, Kwazulu-Natal, South Africa. PhD. Thesis. University of Pretoria.

Johnson, K.G., Wei, W., Reid, D.G. and Jinch, H. 1993. Food Habits of Asiatic Leopards (*Panthera pardus fusea)* in Wolong Reserve, Sichuan, China. *Journal of Mammalogy.* 74 (3): 646-650.

Karanth, U. and Sunquist, M.E. 1995. Prey selection by Tiger, Leopard and Dhole in Tropical Forests. *The Journal of Animal Ecology* 64 (4): 439-450.

Karanth, U. and Nichols, D. 2002. Monitoring Tigers and their prey: A Manual for Researchers, Managers and Conservationists in Tropical Asia. Center for Wildlife Studies. Bangalore, India. McKay

Keogh, H.J. 1983. A photographical reference system of the microstructure of the hair of African Bovids. *South African Journal of Wildlife Research.* 13: 89-132.

Mckinley, S. and Young, R.J. 2003. The efficacy of the model-rival method when compared with operant conditioning for domestic dogs to perform a retrieval-selection task. *Applied Animal Behaviour Science.* 81(4): 357– 365.

Mucina, L. and Rutherford, M.C. 2006. The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. South Africa National Biodiversity Institute, Pretoria.

Mukherjee, S., Goyal, S.P., Johnsingh, A.J.T. and Pitman, M.R.P.L. 2004. The importance of rodents in the diet of jungle cat (*Felis chaus*), caracal (*Caracal caracal*) and golden jackal (*Canis aureus*) in Sariska Tiger Reserve, Rajasthan, India. *Journal of Zoology, London.* 262: 405-411.

Van Dyk, G. and Slowtow, R. 2003. The effects of fences and lions on the ecology of African wild dogs reintroduced to Pilanesberg National Park, South Africa. *African Zoology.* 38: 79-94.

Wasser, S. K., Davenport, B., Ramage, E. R., Hunt, K. E., Parker, M., Clarke, C. and Stenhouse, G. 2004. Scat detection dogs in wildlife research and management: application to grizzly and black bears in Yellowhead Ecosystem, Alberta, Canada. *Candian Journal of Zoology.* 82: 475-492.

Zubrics, C.S. and Gottelli, D. 1995. Diet and Feeding Behavior of Ethiopian Wolves (*Canis simensis). Journal of Mammalogy.* 76(2): 531-541.

SUMMARY

The early release phase of the project supports the theory of captive bred animals' inability to adapt during reintroduction projects. Without human intervention the animals would likely not have survived the first month of release. The duration of the project was seventeen months, however, for only four of those months three cheetahs were roaming the reserve simultaneously. One cheetah or the coalition was present on the reserve for the other thirteen months. The cause of the staggered nature of the releases resulted from various reasons including injury, disease, inability to adapt or death. These are some of the same reasons why previous reintroductions of captive bred animals failed. Adaptive management was then implemented from what was learned from previous project failures and observations from this project. Habituation to project vehicles and treatment of severe injuries provided an opportunity for the cheetahs to learn. Unlike other mammals that can be taught anti-predator behaviors (Griffin *et al.* 2000) or migration routes (Baskin 1993), methodology for training carnivores to hunt appropriately has not yet been developed or refined.

The ability and the efficiency at which the cheetahs learned to hunt and adapt to the wild was dependent on the individual cheetahs. The instinct to hunt was present however, the refined skills were evidently lacking. Over time hunting commenced and signs of adaptation were portrayed. Hunting involves more than the bringing down of prey, it includes the stalking technique used depending on the habitat and the strangulation grip. Adaptation encompasses interaction with habitat such as the use of vantage points, use of vegetation for concealment when hunting and habituation to researchers and vehicles. The adaptations and hunting skills eventually portrayed by these captive bred cheetahs was reflective of wild cheetahs. The eventual adaptability of

the three cheetahs is a preliminary indication that captive bred cheetah have the potential to survive in the wild.

Captive bred cheetahs have the instincts to survive in the wild. However, there are aspects of survival that require learning. This project implemented methodology that nurtures instinct and allowed learning within the confines of existing regulations. The captive bred cheetahs displayed behaviors indicative of adaptation. Decisions that need to be made by those involved include the number of supplementary feeds and injury treatments before accepting the cheetahs' inability to hunt and adapt. The eventual fulfillments of long term criteria are still required to create a complete model. However, when necessary a preliminary model for reintroducing captive bred cheetah has been created with an allowance for adaptive management. Of the six cheetahs brought into the project only three survived as a result of human interference. With appropriate and responsible human intervention, captive bred cheetahs can be successfully reintroduced.

Controversy surrounds the applicability of reintroducing captive bred carnivores. Cumulative research has been conducted regarding the reintroduction of captive bred carnivores' versus wild carnivores (Jules *et al.* 2007). The study encompassed records of reintroductions since 1990 till the year of publication. Statistical analysis in this study showed that captive bred carnivores had a lower survival rate than wild carnivores. Common causes of failure were due to death caused by human activity, starvation, disease and inter-species competition. Lack of previous hunting experience and lack of understanding bigger carnivores can prove to be fatal. Human related deaths were often a result of habituation and lack of fear towards humans. Habituation could not and cannot be avoided as the animals are captive and in contact with humans and unless captive rearing changes over time, habituation will continue to be a factor.

The criteria frequently used to determine reintroduction success are long term and include breeding of the first wild born population, extended breeding and recruitment (Ostermann, *et al.* 2001; Jules *et al*. 2007). However, short term survival is relevant as the individuals reintroduced must survive so that population continuation is viable. Factors contributing specifically to captive bred individual's survival as illustrated by IUCN include habitat suitability, long-term food availability, release type and season. This study showed that there are several other factors to be considered that affect the survival of the released cheetahs, 1) project planning and security throughout the study period, 2) selection of appropriate release candidates given captive experience and temperaments, 3) duration and extent of conditioning and behavioral enrichment prior to release and 4) a synergy between ethologists, veterinarians, field researchers and animal handling professionals.

The feasibility of releasing captive bred cheetahs and reintroductions in general is in part dependent on human determination and funding (Webber and Rabinowitz 1996). Firstly an adequate release location is necessary and this requires predator proof fencing in South Africa, the absence of larger predators such as lions *Panthera leo* and spotted hyenas *Crocuta crocuta* and few if any wild cheetahs. The meat provided during the pre-release must be of wild origins and indicative of the cheetahs diet once released. Removal of the vehicle chase instinct and habituation to humans requires significant time and input from the monitors. Habituation is a concern once animals are released therefore it is necessary for conditioning to take place while in an enclosure prior to release. Follow up monitoring is necessary for no less than a year to determine that the individuals have settled and are surviving. Following release veterinary expenses are highly likely to occur. Once the individuals are surviving then long term population continuation can become the focus and the individuals can become part of the metapopulation by contributing offspring and genes. Before this utopia is achieved the funding for such an endeavor must be secured and allocated appropriately. Haight *et al.* (2000) created a strategy for translocated species, leading to population growth, in terms of funding availability. This strategy can be implemented on reintroduction as the premise is transferable. Haight *et al.* (2000) suggested that the survival of the released animal takes priority when release methods of low risk of failure exist, not cost depending. Soft releases are more costly as holding facilities must be erected or maintained, meat provided for the cheetahs, equipment, expertise and manpower must be budgeted for. Hard releases are less costly to the accounts but severely so to the animals involved. The number of cheetahs released into a site at a specific time should be low because the monitoring required is intensive. Over time the numbers can be increased. Monitoring, particularly of endangered or vulnerable animals, is intensive. The information gained from monitoring is highly relevant particularly for this study area with little prior information exists. Haight *et al.* (2000) suggest that if monitoring is more efficient and the benefits offset the cost of release funding then release funds should be allocated to monitoring. In regards to cheetahs, monitoring does have its benefits however so to do the pre-release activities. In this scenario high project costs must be accepted for all aspects. Uncertainty of future funding is only surpassed by uncertainty of a conservation projects outcome (Curio 1996). During the course of the project as the individual cheetahs ability to survive becomes evident then monitoring intensity can be reduced. This subjective decision is critical. As the population begins to grow through further reintroductions or cub births then monitoring intensity must increase again. Though an existing budget may exist, the likelihood of future funding sufficing to this budget may not. For this project the funds were secured throughout the study period regardless of unforeseen costs. This included tracking equipment, veterinary treatment, habituation equipment and all vehicle maintenance and running costs. The continuation of monitoring is essential however the intensity can vary over time (Kleiman 1989). The success of a reintroduction project is subject to the funds available.

Breeding of captive animals can affect genotype, phenotype and behavioral temperament resulting in what has now been termed as ‘contemporary’ evolution (Kleiman 1989; Synder 1996; Hendry and Kinnison 1999; McDougall *et al.* 2005). ‘Contemporary’ evolution occurs within a time period of less than a few hundred years or within a human lifetime (Hendry and Kinnison 1999). This can occur with both wild and captive populations. Captive populations, however, are susceptible to this evolution from natural, sexual and anthropogenic influences. These influences affect genetic variance which then affects temperament. Temperament is in turn linked to individual fitness, physiology and morphology (McDougall *et al.* 2005). In captivity where the project cheetahs were sourced, when selecting a breeding pair of cheetahs, both male and female must fulfill several criterion. Both are selected according to pedigree, area of origin and weighted equal drift similarity, WEDS (Oliehoek 2006). The major breeding lines, origin and relatedness of the cheetahs are determined through microsatellite genetic marker-based analysis thus reducing interbreeding likelihood (Bertschinger *et al.* 2008). Male cheetahs are then selected by the results of a spermiogram and the level of aggression towards females. Aggression levels are categorised and males displaying a desired level of aggression and sperm morphology are selected for breeding. Female cheetahs need only be three years of age, have no physical defects, be in good condition and have a strong constitution. This selection methodology does support gene variation however, in terms of temperament, human influences create a bias in favour of behaviors not representative of wild cheetahs (Kleiman 1989; Snyder *et al.* 1996; Hendry and Kinnison 1999; McDougall *et al.* 2005, Topàl *et al.* 2005). The cheetahs selected for this project were subject to several criterion: age, sex and general health. Over time this influence must be taken into consideration when selecting candidates for future projects.

All factors were taken into account and during the study period the behavioral enrichment and training methods became better understood. Habitat suitability and food availability are addressed prior to release. The ideal season of release would be when antelopes are lambing and calving therefore allowing for hunting familiarization. Type of reintroduction should not be questioned particularly for captive bred carnivores as soft releases increase the potential survival of the reintroduced individuals (Griffin *et al.* 2000). Prior to release preparation and conditioning has proven significant to survival potential during reintroductions (McPhee 2003, Griffin *et al.* 2000, McLean 1999, Baskin 1993). Preparing the captive bred cheetahs for circumstances in the wild provided an advantage for survival and reduced the likelihood of starvation. Training animals prior to release requires knowledge of learning methods and behavior specific to the study animal (Kleiman 1989; Sutherland 1998; Caro 2000). Domajan and Burkhard (1986 in Griffin *et al.* 2000) defined learning as “an enduring change in the mechanisms of behavior that results from experience with environmental events”. The method of learning implanted on the cheetahs in regards to vehicle chasing was instrumental conditioning. The frequency of chasing the vehicles was reduced by pairing the performance, vehicle chasing, with punishment, shooting with paintball gun. In so doing the cheetahs developed the association of chasing the vehicles with pain and ceased the activity. This chase association was only imprinted on vehicles and thus did not affect hunting. However despite the performance of the individual cheetahs involved in this study more projects utilizing this methodology need to be implemented because individual characteristics may have influenced survival potential.

Once the study animals have been identified and project planning secured the reintroduction project can commence. Reintroduction is a conservation strategy and conservation has evolved. The development of an adequate, appropriate conservation plan required the combination of interdisciplinary professions. Interdisciplinary cooperation and communication was encouraged to ensure the welfare of the cheetahs and increase the project success potential. Ethologists, veterinarians, nature conservationists and field trained personnel were all consulted and provided insightful input. Consultation with ethologists during the course of the project was critical and enabled the researchers to make appropriate and intelligent decisions. Behavioral interpretation and action recommendations could not have been appropriately explored by the researchers. Veterinary treatment was a critical factor that ensured the continuation of the project. The researchers could not administer medication or identify specifically what ailed the cheetahs. The veterinarian was therefore provided with detailed descriptions of the cheetahs' condition accompanied by photographs. When necessary the veterinarian would prompt for specific descriptions to make a diagnosis. The nature conservationist specifically trained with cheetahs, provided insight as to the handling of the animals. The researcher had experience with field work and data collection. During observations behaviors and cheetah condition were recorded and thus provided the field information and circumstances to the ethologists, veterinarians and nature conservationist. Without this synergy the reintroduction of captive bred cheetah would not have been successful in terms of individual survival. This project was the fourth of its kind and provides information for future studies but cannot be compared adequately to past events. What can be determined is the affirmation that at the conclusion of the project the captive bred cheetahs displayed wild cheetah characteristics.

REFERENCES

Bertschinger, H.J., Meltzer, D.G.A. and van Dyk, A. 2008. Captive Breeding of Cheetahs in South Africa- 30 Years of Data from the de Wildt Cheetah and Wildlife Centre. *Reproduction Domestic Animals.* 43 (2): 66-73.

Caro, T. 1999. The behavior-conservation interface. *TREE.* 14(9): 366-369.

Curio, E. 1996. Conservation needs Ethology. *TREE.* 11(6): 260-263.

Griffin, A.S., Blumstein, D.T. and Evans, C.S. 2000. Training Captive-Bred or Translocated Animals to Avoid Predators. *Conservation Biology.* 14(5): 1317-1326.

Haight, R.G., Ralls, K. and Starfield, A.M. 2000. Designing Species Translocation Strategies When Population Growth and Future Funding Are Uncertain. *Conservation Biology.* 14 (5): 1298-1307.

Hendry, A.P. and Kinnison, M.T. 1999.The Pace of Modern Life: Measuring Rates of Contemporary Microevolution. *Society for the Study of Evolution.* 53 (6): 163-1653.

IUCN. 1987. IUCN Position Statement on the Translocation of Living Organisms: Introductions, reintroductions and re-stocking. Gland, Switzerland.

Jules, K.R., Leaver, L.A. and Lea, S.E.G. 2008. The effects of captive experience on reintroduction survival in carnivores: A review and analysis. *Biological Conservation.* 141: 355-363.

Kleiman, D.G. 1989. Reintroduction of Captive Mammals for Conservation. *BioScience.* 39(3): 152-161.

Mcdougall, P.T., Réale, D., Sol, D. and Reader, S.M. 2006. Wildlife conservation and animal temperament: causes and consequences of evolutionary change for captive reintroduced, and wild populations. *Animal Conservation.* 9: 39-48.

Mclean, I.G., Hölzer, C. and Studholme, B.J.S. 1999. Teaching predator-recognition to a naïve bird: implications for management. *Biological Conservation.* 87: 123-300.

Mcphee, M.E. 2003. Generationsin captivity increases behavioral variance: considerations for captive breeding and reintroductions. *Biological Conservation.* 115: 71-77.

Oliehoek, P.A., Windig, J.J., Arendonk, J.A.M. and Bijma, P. 2006. Estimating Relatedness Between Individuals in General Populations With a Focus on Their Use in Conservation Programs. *Genetics.* 173: 483-496.

Ostermann, S.D., Deforge, J.R. and Edge, W.D. 2001. Captive Breeding and Reintroduction Evaluation Criteria: A Case Study of Peninsular Bighorn Sheep. *Conservation Biology.* 15(3): 749-760.

Sutherland, W.J. 1998. The importance of behavioral studies in conservation biology. *Animal Behavior.* 56: 801-809.

Snyder, N.F.R., Derrickson, S.R., Beissinger, S.R., Wiley, J.W., Smith, T.B., Toone, W.D. and Miller, B. 1996. Limitations of Captive Breeding in Endangered Species Recovery. *Conservation Biology.* 10(2): 338-348.

Topal, J., Gacsi, M., Miklosi, A., Viranyl, Z., Kubiny, I,E. and Csany, I. 2005. Attachment to humans: a comparative study on hand-reared wolves and differently socialized dog puppies. *Animal Behavior.* 70: 1367-1375.

Weber, W. and Rabinowitz, A. 1996. A global perspective on Large Carnivore Conservation. *Conservation Biology.* 10(4): 1046-1054.

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APPENDIX I

The De Wildt Cheetah and Wildlife Trust

Makulu Makete Wildlife Reserve
Cheetah Datasheet

Makulu Makete
spirit of the great trees

Date

Time start Time end

Duration Grid #

S E

Weather

Cheetah M ☐ F ☐

Condition 1

Activity 1 resting

Veg. area

Veg. density low

Grass density

Height of Grass

Clst dis. to cheetah

Avg dis. to cheetah

Other animals ☐

Missed hunt spp

kill ☐

Time of kill

Faeces ☐ Bone ☐

Prey spp Prey weight

% consumed

Present Carcass details Carcass return details:

Comments

APPENDIX II

Cheetah female F515 is not included in this diet calendar due to early departure from the project. This calendar depicts each cheetah groups initial three month diet adjustment feeding regime. Though all cheetah groups returned to the enclosure at varying times throughout the project their feeding regime is not depicted because their diet had already become adjusted. In this calendar F = female and M = male coalition. Release dates and deaths are indicated in the calendar. The feeding regime calendar of cheetah coalition M490 and M465 is depicted from November 2007 to April 2008. The feeding regime of female cheetah F536 is depicted from February to April 2008. The feeding regime if cheetah coalition M579 and M580 is depicted from August to October 2008.

November 2007

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				1	2	3
4	5	6 M(2 kg)	7	8	9 M(impala w/o back legs)	10
11	12	13	14 M(3 kg)	15	16	17 M(3 kg)
18	19	20	21 M(½ impala)	22	23	24
25 M(front impala leg w/skin)	26	27 M(3 kg)	28	29	30 M(Back ½ impala)	

December 2007

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2	3	4	5 M(8 kg)	6 M(young impala ram)	7	8
9	10	11 M(front ½ impala)	12	13	14	15
16	17 M(young impala)	18	19	20	21 M(impala w/o 2 legs)	22
23/30	24/31	25	26	27	28	29 M(kudu bull head)

January 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1 M(front kudu leg)	2	3	4	5
6	7 M(back kudu leg)	8	9	10	11	12
13	14 M(kudu bull ribs)	15	16	17	18 M(low kudu back w/ impala leg)	19
20	21 M(kudu leg)	22	23 F(meat w/o skin)	24 F(±600g w/o skin)	25 F(±600g w/o skin)	26 F(±600g w/o skin)
27 F(±600g w/o skin)	28 F(±2 kg w/o skin), M (impala 1 leg)	29 F(±2 kg w/o skin)	30	31		

February 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1 F(±2 kg w/o skin)	2 M(½ impala)
3 F(impala front leg w/o skin)	4	5 F(warthog front leg w/o skin)	6 F(impala front leg w/ skin)	7 M(½ impala)	8	9
10	11 F(impala back leg), M(6kg meat)	12 M(impala w/o back legs)	13	14	15 F(impala neck and head)	16
17	18 F(½ impala w/o neck), M(½impala)	19	20	21	22 F(impala head and neck), M(½ impala)	23
24	25 F(½ impala), M(½ impala)	26	27	28	29 F(½ young impala)	

March 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
						1
2 M(warthog leg)	3 M(warthog leg)	4 F(impala back leg)	5	6	7	8 F(front ½ impala)
9	10 M(warthog w/o legs)	11	12	13 F(impala front leg)	14	15 M(lower ½ impala)
16 F(back ½ warthog)	17	18	19	20 F(front ½ warthog)	21 M(back ½ impala)	22
23/ 30	24/31	25	26	27 F/M (whole impala)	28	29

April 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1	2	3 F(front ½impala)	4	5
6 M(kudu back leg)	7 F(impala front leg), M(½ impala)	8	9 M(kudu back leg)	10 F (released)	11	12
13	14	15	16 M(lower kudu back)	17	18	19
20	21 M(whole warthog)	22	23	24	25	26
27	28 M(whole warthog)	29	30			

May 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
				1	2	3
4 M(kudu ribs)	5	6	7	8	9	10 M(whole warthog)
11	12	13	14	15 M(whole warthog)	16	17
18	19	20 M(warthog w/o 2 legs)	21	22	23	24 M(warthog w/o legs)
25	26	27	28	29	30	31 M(kudu front leg + piece)

June 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1	2	3	4	5	6	7 M(whole warthog)
8	9	10	11	12 M(Dead)	13	14 M(whole warthog)
15	16	17	18	19	20	21 M(warthog leg)
22	23	24 M(Released)	25	26	27	28
29	30					

August 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21 M(±2 kg meat)	22 M(±2 kg meat)	23
24	25 M(±2 kg meat)	26	27	28 M(±4 kg meat w/skin)	29	30 M(±4 kg meat)
31						

September 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	1	2	3 M(kudu leg)	4	5	6
7	8 M(kudu back leg)	9	10	11	12	13
14	15 M(whole warthog)	16	17	18	19 M(impala back legs)	20
21	22	23 M(impala w/o legs)	24	25	26	27
28	29 M(impala back legs)	30				

October 2008

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
5	6	7	8	9 M(front ½ impala)	10	11
12	13	14	15 M(back ½ impala)	16	17	18
19 M(young impala)	20	21	22	23	24	25
26	27 M(whole impala)	28	29	30	31	Released November 1st