Evaluating camera trapping as a method for estimating cheetah abundance in ranching areas

Kelly Marnewick[1*], Paul J. Funston[2] & K. Ullas Karanth[3]

[1]De Wildt Wild Cheetah Project, P.O. Box 16, De Wildt, 0251 South Africa

[2]Department of Nature Conservation, Tshwane University of Technology, Private Bag X680, Pretoria, 0001 South Africa

[3]Wildlife Conservation Society (International Programs), Bronx, New York, NY-10460-1099, U.S.A.

Received 21 September 2006. Accepted 15 October 2007

In order to accurately assess the status of the cheetah *Acinonyx jubatus* it is necessary to obtain data on numbers and demographic trends. However, cheetahs are notoriously difficult to survey because they occur at very low population densities and are often shy and elusive. In South Africa the problem is further complicated in areas where land is privately owned, restricting access, with dense bush and cheetahs that are frequently persecuted. Cheetahs are individually identifiable by their unique spot patterns, making them ideal candidates for capture–recapture surveys. Photographs of cheetahs were obtained using four camera traps placed successively at a total of 12 trap locations in areas of known cheetah activity within a 300 km² area in the Thabazimbi district of the Limpopo Province. During 10 trapping periods, five different cheetahs were photographed. These results were used to generate capture histories for each cheetah and the data were analysed using the capture–recapture software package CAPTURE. Closure tests indicated that the population was closed (*P* = 0.056). The M_h model was used to deal with possible heterogeneous capture probabilities among individual cheetahs. Closure tests did not reject the model assumption of population closure (*P* = 0.056). The M_h model produced a capture probability of 0.17 with an estimate of 6–14 cheetahs (*P* = 0.95) and a mean population size of seven cheetahs (S.E. = 1.93). These results are promising and will be improved with employment of more camera traps and sampling a larger area.

Key words: cheetah, camera trapping, capture–recapture, photographic identification

INTRODUCTION

In South Africa the cheetah *Acinonyx jubatus* is classified as vulnerable, with the bulk of the population occurring outside formal conservation areas on cattle and wildlife ranches (Friedmann & Daly 2004). These ranches are ideal habitat for cheetahs, due to low competition with other large carnivores (Wilson 2006) and high prey densities (Van der Waal & Dekker 2000). However, while these areas may be ecologically suitable for cheetahs, conflict with landowners occurs, often resulting in the persecution of cheetahs (Marker 2002; Wilson 2006). There is thus a need for effective population monitoring in these areas. Without baseline information it is not possible to make informed management decisions or evaluate the effectiveness of current conservation efforts. The importance of conserving cheetahs outside protected areas has also been emphasized elsewhere (McVittie 1979; Laurenson *et al.* 1995; Purchase & Du Toit 2000).

However, cheetahs are difficult to study in these areas as they use large ranges (Marnewick & Cilliers 2006), are extremely shy and elusive, and occur at low densities (McVittie 1979; Stander 1992; Gros 1998). In addition, the area is fragmented by many fences, making movement for researchers difficult. Ranch owners often do not want cheetah on their properties making it difficult to undertake activities such as collaring and releasing. Camera traps have been found to be useful tools for studying other cryptic species such as tigers (Carbone *et al.* 2001). Photographs obtained from these traps can be used to identify individuals and based on the recapture frequencies of individuals (Otis *et al.* 1978), statistical computer programs such as CAPTURE (Rextad & Burnham 1991) can be used to estimate the number of individuals in the area.

The capture–recapture method samples a proportion of the true number of animals in an area and assumes that each animal has the same probability of being captured. Because this is

*To whom correspondence should be addressed.
E-mail: kelly@dewildt.org.za

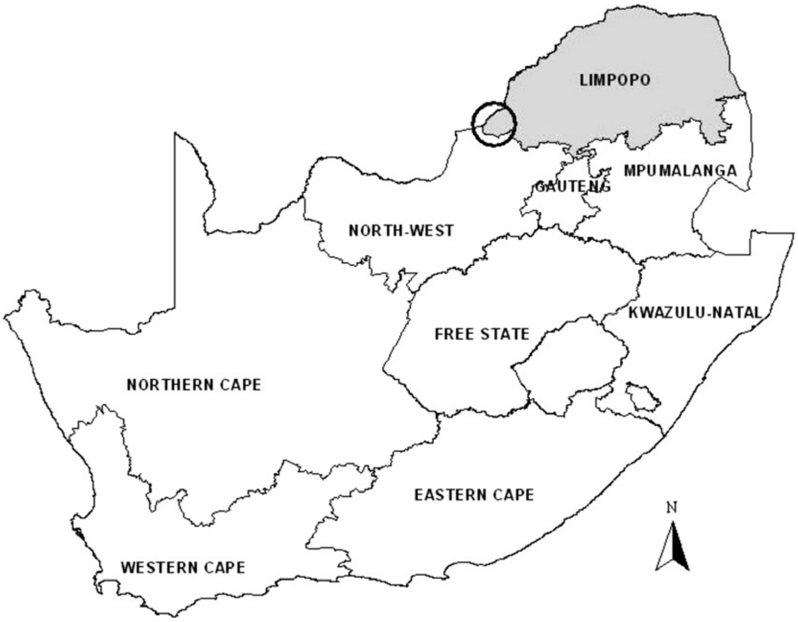

Fig. 1. Location of the Thabazimbi district in the Limpopo province of South Africa

rarely the case with large carnivores, models have been developed that adjust for biases in capture probabilities, namely heterogeneity among individuals (*h*), behavioural response (*b*), time-specific variation (*t*) and combinations of these. CAPTURE assumes that the population is demographically and geographically 'closed' during the sampling period, i.e. there are no animal deaths, emigration or immigration, and provides a statistical test of this assumption. Additionally, not all the study animals have to be captured to obtain abundance estimates as with techniques that require a 'census'. Capture–recapture modelling has recently been adapted to better suit field conditions and biological criteria, and user-friendly software has been developed that can be run on a personal computer (Karanth & Nichols 2002).

Camera trapping is useful as it is relatively non-intrusive and requires little logistical inputs from the landowner besides granting access to the ranch and results can be obtained in a relatively short period of time. Here we present results outlining the use of photographic capture–recapture sampling to survey cheetahs on South African ranch lands.

STUDY AREA

The Atherstone Collaborative Nature Reserve was used for this study, and is situated in the Thabazimbi district of the Limpopo province (Fig. 1). The reserve is 24 000 ha (240 km^2) in size. Live sale of some animals takes place and during the hunting season commercial sport hunting is offered. Artificial water holes supply the wildlife with water and during excessively dry periods, supplementary feeding takes place. The reserve is fenced but cheetahs have been found to easily move under the fences (K. Marnewick, pers. obs.).

The Thabazimbi district is situated in the Savanna Biome of South Africa and the main vegetation type in the district is Mixed Bushveld (Low & Rebelo 1996). Climatological records for Atherstone recorded a 14 year mean minimum temperature of 12.2°C and a mean maximum of 28.5°C from 1990 to 2004. The mean annual rainfall recorded on Atherstone was 482.9 mm per year for the same period.

METHODS

Photographs of cheetahs were taken using TrailMaster TM 1550 camera traps (http://www.trailmaster.com). A camera trap consists of an infrared transmitter and receiver that transmit an infrared beam. These are linked to a 35 mm camera. When the infrared beam is broken, the camera is activated and a photograph is taken. To ensure that photographs of cheetahs were obtained, camera traps were placed in areas of known cheetah activity (Karanth & Nichols 2002). Such areas were identified by exploring the study

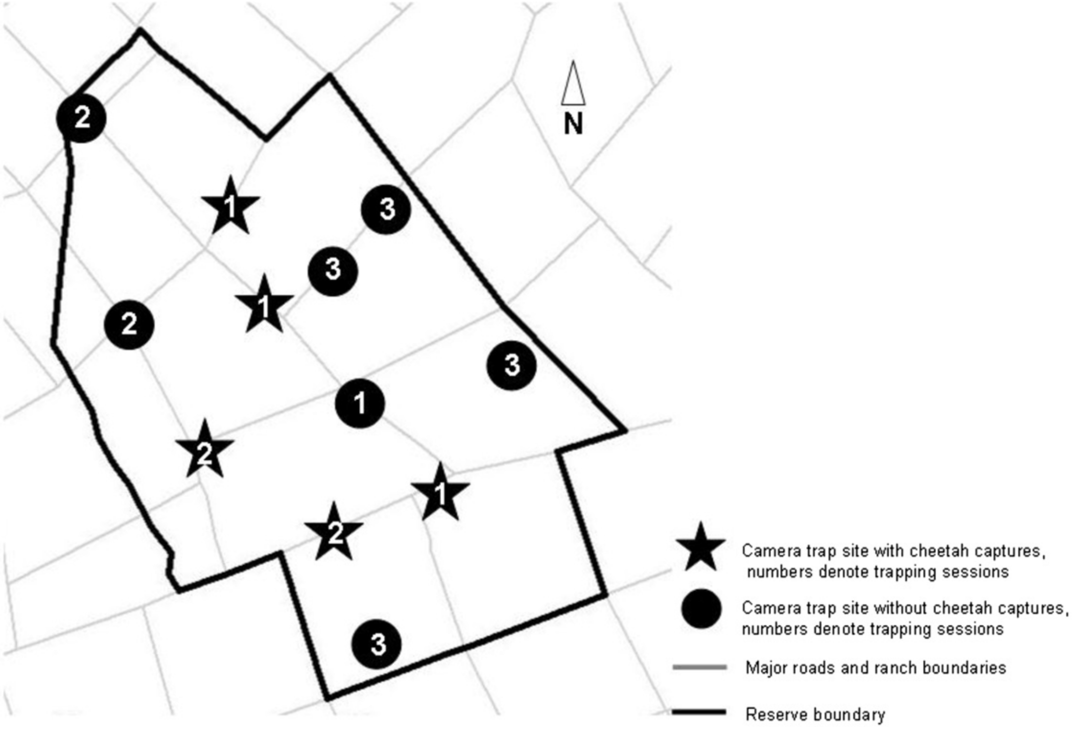

Fig. 2. Location of camera trapping sites on Atherstone Collaborative Nature Reserve showing trapping sessions, and sites where cheetahs were photographed.

area for cheetah tracks and scat. Reserve staff and hunters were also consulted to identify areas of intense cheetah activity. This took approximately two months and trapping sites identified included marking posts, roads and intersections that cheetahs regularly use.

All possible camera trap locations were mapped and evaluated, with the 12 camera trap locations being identified as being most likely to be visited by cheetahs (based on signs of previous use such as scent marking trees and tracks) and logistical feasibility of camera placement. Four traps were active for 10 days at the first locations, thereafter the traps were moved to new trapping locations for a further 10 days (Fig. 2). This was repeated a third time. This system of camera trap rotation can be used in situations where insufficient camera traps are available to cover the entire study area in a single sampling session (Karanth & Nichols 2002). The camera trap sampling duration must be short enough to ensure demographic closure during the survey (Karanth & Nichols 2002). These conditions were met by this design.

When camera traps were placed at cheetah marking posts, access to the marking post was controlled by brush packing around the post in such a way as to ensure that the cheetah could not approach the post without triggering the camera. Similarly when camera traps were placed in roads, the verge of the road was also brush packed to prevent the cheetah walking around the transmitter or receiver and avoiding being photographed. Where roads or intersections were wide, the road was narrowed by brush packing, ensuring that the cheetah moved close enough to the camera to obtain a clear photograph.

The camera delay was set on a 20 second interval with five pulses missed before a subsequent event was recorded. All other settings were kept on the default mode. The camera was also set to allow for date and time to be recorded on the photographs. The equipment was mounted on custom-made brackets, and all the wires were buried shallowly under the ground, and were fixed securely to the mounting post of the camera. The transmitter and receiver were fixed at a height of approximately 0.5 m above ground level. All tall grasses and any branches that could interrupt the infra-red beam were removed. As far as possible the camera traps were left on for 24 hours per day. In situations

Table 1. Capture matrix for capture–recapture analyses from camera trapping of cheetahs in the Thabazimbi district. L denotes picture obtained of the left hand side of the animal, R of the right hand side and F of the front.

	Trapping occasions									
Cheetah ID	1	2	3	4	5	6	7	8	9	10
G Collared	0	0	0	1 L	0	1 L & R	0	0	0	0
J Collared	0	0	0	0	0	1 L & R	0	0	0	0
N Collared	0	0	1 R & R	0	0	1 L & R	1 R	1 F, L, R	1 R	1 F, F, L
A Not collared	0	0	0	0	1 R	1 L & R	0	0	0	0
B Not collared	0	0	0	0	0	0	0	0	1 R	0

where camera traps were placed in roads that were frequently used by vehicles, the camera traps were switched off during busy periods, although this was only a last resort, with other options such as road closure being explored first. The cameras used 36 exposure 200 ASA colour film, and the flash was left on. This trap set-up has been proven to be effective for obtaining cheetah photographs at scent marking posts (Marnewick *et al.* 2006). The camera traps were checked daily for malfunctions, damage and film usage. The traps were set during the month of August, which is the end of the winter dry season.

After developing and printing the photographs, each cheetah was identified using their unique spot patterns and then allocated an identification number. Although software is available for computer aided matching (Kelly 2001), this is only necessary when large numbers of photographs need to be analysed. Once all the cheetahs in the photographs had been identified and numbered, a capture matrix was constructed following Karanth & Nichols (2002). As four camera traps were used and rotated, day one at each trapping location became day one for the entire trapping period, and day two at each trapping location became day two for the entire trapping period (Karanth & Nichols 2002). If a cheetah was photographed on a specific day it was represented by a ‘1’ next to the cheetahs number on the corresponding day of capture, and all days where cheetahs were not captured were denoted with a ‘0’. Thus the capture matrix comprised a list of 1s and 0s denoting each individual cheetahs absence or presence at a specific trapping location on a particular date.

The matrix was then imported into the program CAPTURE (http://www.mbr.pwrc.usgs.gov/software.html) (Rexstad & Burnham 1991) for analysis using capture history data from each individual animal caught to compute estimates of capture probability and population size. CAPTURE offers several models that can be selected from to accurately model the population being studied. The data set was tested for population closure during the study period as well as the appropriateness of each model selection. CAPTURE has several models giving the user the option of selecting the most appropriate model for the population being studied.

RESULTS

Five different cheetahs were photographed during 10 different trapping occasions; however, there were no captures in the first two trapping occasions (Table 1). All cheetahs photographed were mature males, three of which were singletons, with individuals G and J being members of a coalition, each of which was entered separately into the capture matrix. The matrix was then imported into CAPTURE and the various possible models were tested against the field capture data. However, limitations were placed on possible models due to the small number of captures and recaptures.

Discriminant function model selection showed that the null model (M_o) with a score of 1.00 fitted the data better than the heterogeneity model (M_h) with the next highest score of 0.88, both in the between model comparison as well as in the overall model comparison scores. Because M_h is considered to be a more robust model that is likely to best apply to cheetahs (Karanth & Nichols 2002), as opposed to the null model M_0 which assumes equal capture probability for all individual animals, we used the M_h model for all analyses. The other model comparison tests show that the time models (M_t) and behaviour models (M_b) may not be applicable because of their poor fits (scores of 0.00 and 0.30 in the discriminate function comparisons).

Closure tests revealed that the population was closed for the trapping period (P = 0.056; z = –1.601), although the evidence was marginal. The cheetah population had a capture probability of 0.17 per sampling period. The capture–recapture analyses using the Jacknife estimator produced a population size estimate of seven cheetahs (S.E. = 1.93). Estimating the total area sampled was not possible as prescribed by Karanth & Nichols (1998) and Karanth & Nichols (2002) due to absence of movement data and the small number of captures and recaptures necessary to estimate the sampled area. Therefore no density estimates were calculated.

DISCUSSION

The TrailMaster™ camera trap system proved reliable and produced good-quality photographs of cheetahs which could be used for individual recognition. The system was also durable and worked efficiently even after heavy rain or after being trampled by elephants *Loxodonta africana*. Traps were checked daily in this study; however for a larger study it will not be feasible to check traps daily due to travelling time and distances between traps. Although it is difficult to determine the minimum interval we suggest once a week to be sufficient. No ideal interval for trap checking is presented as it is not possible to predict when traps will be interfered with by wildlife and how much film will be used over a specific period of time. Such factors are dependent on the trapping site with photographic capture rates of all species and animal interference with traps being important variables (e.g. an antelope resting in the trapping site over night could use an entire film in one evening). Owing to the very small size of the properties in our study area (mean = 1800 ha) (Wilson 2006) and the fact that they are game fenced, prey species are highly sedentary and thus not likely to affect cheetah movements on a seasonal basis. We therefore had no indication that season would affect the study design in our area.

We do not know why no cheetahs were photographed during the first two trapping occasions, as avoidance due to human activity is unlikely given the generally high levels of human activity in the area. Cheetah tracks have shown cheetahs investigating vehicles left on a road overnight (K. Marnewick, pers obs.), further suggesting that unusual objects should not necessarily deter them.

Owing to the small number of cameras available only one camera was used per trap, which resulted in photographs of only one side of a cheetah being taken. However, although spot patterns of cheetahs are not the same on both sides, it was nevertheless generally possible to link the left and right side of the cheetahs as more than one photograph of each cheetah was invariably taken at each visit. This was especially the case at scent marking trees where the beam was generally broken on multiple occasions. Identification was further aided by the fact that three of the cheetahs photographed had previously been fitted with radio-collars, during which time they were extensively photographed. However, for future studies photographs of both flanks should be obtained at the same time by using two cameras linked with a multi-camera trigger (Karanth & Nichols 2002).

Placing of the camera traps proved to be challenging. Although camera traps should ideally be placed randomly or in a grid format. This was not thought best for our study as cheetahs were not expected to be distributed evenly over the landscape, generally having areas of preferred use (Caro 1994). We thus followed Karanth & Nichols (1998) and placed traps where we thought we had the highest likelihood of obtaining photographs. The logistical problems in finding scent trees and road intersections regularly used by cheetahs suggested that this might not be feasible when setting up a larger sampling design. It is proposed that in a larger study, suitable camera trapping sites are investigated using available movement and habitat data in a Geographic Information System (GIS) environment.

The M_o model assumes no variation in capture probability associated with individuals or occasions, suggesting that all cheetahs would have an equal capture probability. However, the M_o model always scores highest in functional model selection ranking because it has the least parameters. Thus it makes the most restrictive assumptions of random mixings. For cheetahs this is unlikely because they have areas of preferred use and substantial range overlap (Caro 1994), increasing the probability of capture in these areas. By comparison the M_h model allows for heterogeneous capture probabilities and thus allows each animal to have a different capture probability (Karanth & Nichols 2002). Thus as it scored second highest in the functional model selection procedure it was considered to be the most appropriate model for this study.

This study was designed as a pilot programme to determine the effectiveness of capture–recapture sampling using camera traps for surveying cheetahs in ranching areas, and the importance of the results lie in a preliminary assessment of the applicability of the method. The study design needs improving before conclusive results can be made, but the results obtained thus far suggest that this is indeed achievable.

To improve the reliability of these results a larger area needs to be sampled, to expose more cheetahs to the traps, and as intensively as possible (by using more camera traps), to increase capture probabilities within logistical and financial constrains. It is important to ensure coverage of the whole study area without leaving gaps that are sufficiently large to contain a single cheetah's movements and within which a cheetah could have no probability of capture (Karanth & Nichols 1998). Thus the ideal trap placement will depend on the biology of the animals being studied. Once the methodology has been refined, long-term camera-trapping surveys could be used to obtain additional population parameters such as survival, mortality, recruitment and dispersal rates by applying open capture–recapture models (Karanth & Nichols 1998; Karanth *et al.* 2006).

ACKNOWLEDGEMENTS

The camera traps for this survey were kindly sponsored by the Miami Metro Zoo. Atherstone Collaborative Nature Reserve generously provided accommodation and access to their property for the field work. The staff of Atherstone: Conrad, Micho and their teams are thanked for all their support and enthusiasm. Advice and support given by Prof. Gus Mills is greatly appreciated. F. Zimmermann and C. Stuart gave valuable comments on earlier drafts of the manuscript.

REFERENCES

CARBONE, C., CHRISTIE, S., CONFORTI, K., COULSON, T., FRANKLIN, N., GINSBERG, J.R., GRIFFITHS, M., HOLDEN, J., KAWANISHI, K., KINNAIRD, M., LAIDLAW, R., LYNAM, A., MACDOUNALD, D.W., MARTYR, D., McDOUGAL, C., NATH, L., O'BRIAN, T., SEIDENSTICKER, J., SMITH, D.J.L., SUNQUIST, M., TILSON, R. & WAN SHAHRUDDIN, N.W. 2001. The use of photographic rates to estimate densities of tiger and other cryptic mammals. *Anim. Conserv.* 4: 75–79.

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

FRIEDMANN, Y. & DALY, B. 2004. Red data book of the mammals of South Africa: a conservation assessment. Endangered Wildlife Trust and CBSG, Johannesburg.

GROS, P.M. 1998. Status of the cheetah *Acinonyx jubatus* in Kenya: a field-interview assessment. *Biol. Conserv.* 85: 137–149.

KARANTH, K.U. & NICHOLS, J.D. 1998. Estimation of tiger densities in India using photographic captures and recaptures. *Ecology* 79(8): 2852–2861.

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

KARANTH, K.U., NICHOLS, J.D., KUMAR N.S. & HINES, J.E. 2006. Assessing tiger population dynamics form photographic capture–recapture sampling. *Ecology* 87(11): 2925–2937.

KELLY, M.J. 2001. Computer-aided photograph matching in studies using individual identification: an example from Serengeti cheetahs. *J. Mammal.* 82(2): 440–449.

LAURENSON, M.K., WIELEBNOWSKI, N. & CARO, T.M. 1995. Extrinsic factors and juvenile mortality in cheetahs. *Conserv. Biol.* 9(5): 1329–1331.

LOW, A.B. & REBELO, A.G. 1996. Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

MARNEWICK K., BOTHMA J. du P. & VERDOORN, G.H. 2006. Using camera-trapping to investigate the use of a tree as a scent-marking post by cheetahs in the Thabazimbi district. *S. Afr. J. Wildl. Res.* 36(2): 139–145.

MARNEWICK, K. & CILLIERS, D. 2006. Range use of two coalitions of male cheetahs *Acinonyx jubatus* in the Thabazimbi district of the Limpopo province, South Africa. *S. Afr. J. Wildl. Res.* 36(2): 147–151.

MARKER, L.L. 2002. Aspects of cheetah *Acinonyx jubatus* biology, ecology and conservation strategies on Namibian farmlands. Ph,D, thesis, University of Oxford, Oxford.

McVITTIE, R. 1979. Changes in the social behavior of South West African cheetah. *Madoqua* 11(3): 171–184.

OTIS, D.L., BURNHAM, K.P., WHITE, G.C. & ANDERSON, D.R. 1978. Statistical inference from capture data on closed animal populations. *Wildl. Monogr.* 62: 1–135.

PURCHASE, G.K. & DU TOIT, J.T. 2000. The use of space and prey by cheetahs in Matusadona National Park, Zimbabwe. *S. Afr. J. Wildl. Res.* 30: 139–144.

REXSTAD, E. & BURNHAM, K.P. 1991. User's Guide for Interactive Program CAPTURE. Colorado State University, Fort Collins.

STANDER, P. 1992. Conserving large African carnivores in a developing world. In: Van Hoven, W., Ebedes, H.

& Conroy, A. Wildlife ranching: a celebration of diversity. Proceedings of the 3rd International Wildlife Ranching Symposium, October 1992, Pretoria.
VAN DER WAAL, C. & DEKKER, B. 2000. Game ranching in the Northern Province of South Africa. *S. Afr. J. Wildl. Res.* 30(4): 151–156.
WILSON, K.A. 2006. Status and distribution of cheetah outside formal conservation areas in the Thabazimbi District, Limpopo province. M.Sc. (Wildlife Management) dissertation, University of Pretoria.

Corresponding Editor: M.G.L. Mills