FINAL REVIEW DRAFT

Factors relevant to the conservation management of cheetah in the Etosha National Park

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Introduction

The cheetah, *Acinonyx jubatus*, is Africa's most threatened big cat and is among the most vulnerable of the world's felid species (Nowell and Jackson 1996, IUCN 1996). Several aspects of its behavioral ecology complicate conservation management efforts. Cheetahs avoid contact with lions and spotted hyeanas (Durant 1998), which steal their kills and kill their cubs (Laurenson *et al.* 1992, Caro 1994). In protected areas where lion populations fluorish, cheetahs tend to occur at low densities (Laurenson 1995). Although in Namibia, cheetahs have persisted and even thrived on private farmland where lions and spotted hyenas have been extirpated, they come into conflict with farmers due to predation on livestock. This situation is a major potential threat to the viability of populations on private land, increasing the value of cheetah populations in protected areas, which may in the future have to suffice as refugia. Cheetahs have also been demonstrated to have very low levels of genetic diversity, which, according to theory, enhances their susceptibility to disease (O'Brien *et al.* 1986).

Namibia has one of world's largest national population of cheetahs, estimated at approximately 2,500, mostly occurring on privately owned farmland (Morsbach 1986, 1987). Namibia is the only range state to have a national conservation plan for the species (Nowell 1996), as well as two nongovernmental organizations, the Cheetah Conservation Fund and Africat, devoted to conservation of the farmland cheetah population. Etosha National Park (22,270 km^2) is the largest and most important protected area for cheetah in Namibia. However, until our study, very little was known about the status and ecology of this population.

The first written observations of cheetahs in the Etosha area date back to 1926, when the Commissioner of Southwest Africa requested local magistrates to report on the type and number of game in their area. The warden based in Namutoni reported that the cheetah, "also known as the hunting leopard, is fairly plentiful and to be found in the lightly forested country and short scrub. [It] is very shy and is seldom met with except in the early morning and late of an evening, has been met with during the day when weather is wet and cloudy. For a short distance it is very fast and can outstrip any antelope. They have been ridden down on the Reserve, but in all cases they were gorged and unable to keep any pace" (SWAA 1926). He estimated the Etosha population at 900, but not knowing his methodoloy, this cannot be taken as a reliable indication that cheetahs were once relatively abundant.

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In recent times, park management has been concerned that the number of cheetahs has been unusually low. This concern prompted park officials to acquire and release 28 cheetahs in 1970. The cheetahs came from various farms around the country. The cheetahs were kept in captivity for approximately two months before being released in good condition at Ombika, Halali and Gemsbokvlakte. Although the animals were marked, the paucity of subsequent sighting records makes it difficult to judge how the releases affected the resident population. Several of the cats were later sighted or killed on farms south of the park boundary (du Preez 1970).

Two basic ecological studies of Etosha cheetahs were initiated in the early 1970s, but both ended inconclusively, with the researchers, who had no radiotelemetry equipment, citing their frustration at being unable to reliably locate and follow study animals (Reid 1972, Lowry 1975). Since then, reports on cheetahs in Etosha have been largely anecdotal, although interesting, such as Stander's (1990) observation of cheetahs hunting at night and scavenging from a giraffe carcass, both of these being unusual incidents not widely reported in the literature. Also, Ebedes (1976) reported two suspected cases of anthrax in wild Etosha cheetahs. Hu Berry (pers. obs., cited in Gasaway *et al.* 1991) believed that the cheetah population declined from the 1970s to the early 1980s during his tenure as chief Etosha biologist.

A meeting was held at the Etosha Ecological Institute (EEI) in July 1992 to assess research priorities for cheetahs in the park. The participants concluded that there was a need to understand cheetah ecology for park management purposes: specifically, predator-prey relationships, cheetah population size and trend, and limiting factors on the population. It was decided to incorporate the predator-prey aspect into a new major research project to determine the factors causing declining or low-density populations of the major plains ungulates of Etosha (zebra, wildebeest, springbok, gemsbok: Gasaway *et al.* 1991). Other factors to be investigated were the effects of disease (anthrax) and vegetation and water quality.

While determining cheetah predation rates in order to evaluate their impact on plains ungulates was a major focus of our study, we also collected data to inform other management goals for the park's cheetahs. We estimated the size of the cheetah population on the Etosha plains, and gathered information on the importance of anthrax as a limiting factor for cheetahs.

Methods

Capture and immobilization for radio-collaring

The safe capture and immobilization of a cheetah is a delicate procedure. It is difficult enough to locate a cheetah for immobilization in the first place. When cheetahs were seen, they often disappeared before EEI capture technicians could reach the area. Many cats would not permit an approach to the 20 meters necessary for safe use of the dart gun, although we were careful to close slowly and at an oblique angle, sometimes taking two hours to cover several hundred meters. The inevitable non-trivial handling stress associated with capture, immobilization and radio-collaring (Laurenson and Caro 1995) must be minimized if the animal is to be later effectively habituated for continuous follows. In order to avoid heat stress, immobilizations were not performed during mid-day. We never immobilized more than one cheetah at a time out of a group, and we remained by the animal until it was again mobile and its group had reformed. While the other group members sometimes left the capture vicinity, all groups (including those with young cubs) remained together following the procedure. One cheetah from a group of sub-adults was moved approximately 5 km from the capture site because night was falling and hyaenas were in the vicinity. His group had reformed by the next day.

Cheetahs were immobilized with Zoletil 100 (Reading Laboratories) at 3-4 mg/kg using (** Palmer Cap-Chur rifle - descirbe equipment**). Cheetahs were fitted with radio collars manufactured by Telonics and Advanced Telemetry Systems (* give weight of ATS collar). The animals were weighed and measured and their age and health status visually assessed. Blood samples were collected in sterile vacutainers.

Anaesthetic darts were aimed at a front shoulder in order to avoid hitting the stomach area. Unfortunately, there was one fatality out of eight immobilizations. The dart struck the cheetah in the upper spine, piercing the spinal cord, and death was instantaneous.

Predation rates

The methodology we employed was continuous follows of focal radio-collared cheetahs with the aim of obtaining reliable data on the cheetahs' predation rate on ungulates. We focused on obtaining kill interval data, measuring the time interval between ungulate kills. Continuous follows are the preferred technique for studying carnivore food habits. Mills (1992, 1994) emphasizes the importance of making lengthy, unbroken observations (at least three days). Continuous follows minimized our missing sequential kills, and had the additional benefit of helping habituate focal cheetahs to being observed off-road by a vehicle. Continuous observation was broken only for brief periods, usually after the focal cheetahs had killed and eaten and were thus not inclined to begin hunting again for several hours, to return to the EEI to process data and store samples collected from the prey carcass. Researchers stayed with their focal animals, not necessarily keeping them in sight the entire time (particularly during the night), but monitoring them via radio signal if they moved in order not to miss any kills.

During continuous follows, we attempted to minimize observer influence on the activity, behavior and hunting success of the focal cheetahs. This required our constant sensitivity to the immediate environment and consideration of how observers should behave to maintain least influence. Whereas the habituated cheetahs would tolerate researchers in their immediate presence (up to 5 meters), observations were usually made from distances in excess of 300-500 meters. Close approaches were reserved for kill sampling or occasional status checks. Cheetah behavior was recorded, and kill intervals calculated immediately, and this raw information was used to prevent undue interference with the hunting success of focal animals. For instance, several cheetahs, both young adult males, were not used for this study after collaring due to their apparent discomfort under observation (e.g., hiding from the vehicle). Differential shyness of males was also noted by the Serengeti cheetah project (Caro 1994). In addition, one recently dispersed sibling group went through two sequential long periods between ungulate kills of more than 120 hours, and afterwards special care was taken to maintain maximum observation distance for this group (often over 1,000 meters). In total, over 10,000 hours of mostly continous observation (including night times) were logged between June 1992 to August 1994.

The observations were designed to be longitudinal so that seasonal variation in predation rates and patterns could be detected. We completed over six months continous observation each on two sets of cheetah mothers and cubs; other animals were also followed for lesser periods (Table 1). For seasonal analyses, we divided the year into hot-wet (Jan-Apr), cold-dry (May-Aug) and hot-dry (Sep-Dec) (Berry 1980, Lindeque 1991). Table 2 shows the number of kill intervals collected per month for each of the focal cheetah groups.

[*Tables 1 and 2 here*]

The study area for collection of predation data was the Okaukuejo study area shown in Figure 1, an area of approximately 2,000 km2, with vegetation consisting of extensive short grass plains, but including also patchy thornbush and mopane, acacia and *Terminalia* woodlands (** see other papers in this volume for description of the Etosha environment **).

[*Figure 1 here*]

Data collection focused on variables related to predation, and included prey availability, habitat, the cheetah's activity, and presence of other carnivores. Ungulate kills were sampled after the cheetahs had finished eating and abandoned the carcass. The carcass was weighed, the femur was removed for condition analysis using bone marrow (van Adrichem 1993), the skull and lower jaw taken for aging according to criteria in Rautenbach (1971) (**Gasaway et al. in prep.), and a blood smear and swabs were collected for anthrax testing.

Estimating cheetah population size

Cheetahs are infrequently sighted; it was not uncommon for periods of up to one month to pass without any staff or tourist sightings reported. We developed our population estimate by trying to recognize and count individual cheetahs. Throughout the study regular 50 to 100 kilometer circuits of parts of the Okaukuejo study area were driven in the mornings and late afternoons to locate new animals and relocate known individuals, radio-collared or not. Local Hai//om men were employed as spotters. On several occasions they found animals that we would otherwise have missed. From

July 1993 - January 1994 two of us (Nowell, Preisser) concentrated on identifying cheetahs in the eastern portion of the park (Figure 1: Namutoni plains, approximate area 1,000 km^2). Tourist and staff sightings of cheetahs were also recorded, and we travelled out to confirm observations whenever possible. Tourist sightings were collected from the general observation books in Okaukuejo, Halali and Namutoni rest camps, and special predator report forms for tourists were distributed starting in 1994 (O. Forge unpubl. data).

Individual cheetahs and cheetah groups were identified by analyzing in combination the location, date, sex/age class, group membership and any unique characteristics (e.g.,. pale coat, spot patterns, scars) of a sighted cat. Females were relatively easy to identify according to the number and size of their cubs (that is, if all the cubs were with the female and not hidden in vegetation). But there are many uncertainties involved in a method which involves different observers and does not physically mark animals. Cheetahs are seldom seen and range widely, thus leaving open the possibility of double-counting. For example, the animals identified as the "Leeubron male" and the "Ombika male" (straight line distance approx. 35 km), seen several months apart, could have been the same cat. On the other hand, cheetahs are not very territorial compared to other felids (Morsbach 1985-86, Durant *et al.* 1988, Caro 1994), leaving upon the possibility of under-counting (several sightings of a single adult female cheetah in the Namutoni/Twee Palms area within several days could have been different animals). The Serengeti cheetah project used close-up photographs of tip of the tail band patterns in order to recognize known individuals (Caro and Durant 1991) and build up a database (Caro 1994). Kruger National Park staff collected cheetah photos from tourists over a year and identified individuals by spot pattern (Bowland 1993). We were not able to collect many suitable photographs of non-radiocollard cheetahs during this study, primarily because of the dense bush and woodland vegetation that predominates in Etosha, and the fleeting nature of most cheetah observations.

Anthrax monitoring

Confirmation of anthrax in a dead animal (a cheetah or its ungulate prey) was done by means of a blood smear. Smears were examined in the EEI laboratory for characteristic capsulated bacilli under oil immersion and blue CAM's Quick Stain (C.A. Milsch (Pty) Ltd., Krugersdorp, South Africa). When blood smears were no longer feasible because the carcass was too old, we swabbed for anthrax spores from carcass remains, a radio collar if present, or the soil directly underneath the carcass. These samples were subject to heat shock in the laboratory to induce germination of anthrax colonies, if present. Blood samples collected from cheetahs during the immobilization were also processed for a serological survey for presence of antibodies to anthrax. For more information on identification of anthrax, see Lindeque et al. (in press?) *****

Results

Cheetah predation

We collected records on 177 kills made by focal radio-collared cheetahs (Table 3). Of these, 86% (152) were ungulates, 94% (143) of which were springbok, *Antidorcas marsupialis*. Scrub hares *Lepus saxatilis* (12% of kills, n=21) were taken most frequently by sub-adult and young adult cheetahs, as also described by Caro (1994) in the Serengeti. Independent young adults killed an average of 2.2 hares per month (11 hares in 5 months of continuous observations), while cheetah mothers with cubs killed an average of 0.6 hares per month (10 hares in 18 months of observations). Longer intervals between ungulate kills were often eased by consuming a scrub hare: cheetahs killed a hare an average of 51.4 hours following their last ungulate kill (SD = 24.55; n=16).

[*Table 3 here*]

Table 4 compares the sex/age ratio of 129 springbok killed by the focal cheetahs for which sex/age is known (there were also 14 adult springbok of unknown sex - most of these were carcasses quickly lost by the hunting cheetah to other predators) to the observed sex/age ratio of the springbok population during ground counts (n=9,343) in the eastern and central portions of the park in March 1993 (B. and K. Gasaway unpubl. data). When all sex/age classes are considered, the sex/age structure of springbok killed by cheetahs differed significantly from the population (X^2 = 14.054, df = 3, $p \leq 0.01$). In pairwise comparisons to the other three sex-age classes, cheetahs took significantly fewer yearlings would be

expected given their frequency in the observed population structure (Y:M - X^2 = 10.740, df = 1, $p \leq 0.01$; Y:F - X^2 = 4.364, df = 1; $p \leq 0.05$; Y:L - X^2 = 11.281, df = 1, $p \leq 0.001$). There was no significant difference between the sex ratio of adult springbok killed by cheetahs (1 M: 1.04 F) and that of the standing adult springbok population (1 M: 1.5 F) (X^2 = 2.961; df = 1; $p \leq 0.10$).

[*Table 4 here*]

Seasonal patterns were observed in cheetah predation (Table 5). Adult male springbok were taken more frequently during the cold-dry season, the main rut, when they most frequently occur alone (Bigalke 1972), and are more vulnerable to cheetah predation than when they are in groups (FitzGibbon 1990). Lambs were not surprisingly killed most frequently during the hot-wet, the primary springbok birth season (Bigalke 1970). Adult females were taken mostly during the hot-dry and hot-wet seasons, and especially during January when most are heavily pregnant and easier for cheetahs to out-sprint (13 out of 16 [81%] of females killed during this month were pregnant). In total, almost half of the adult female springbok killed by cheetahs were pregnant (21 out of 44, or 48%).

[*Table 5 here*]

We documented 110 time intervals between ungulate kills and found that, on average, a cheetah group killed an ungulate every 58.75 hours, or roughly 2.5 days. The range varied from 12 to 140 hours (SD = 30.82). The cheetah groups and their kill intervals are shown in Table 6.

[*Table 6 here*]

Comparing the data from Tables 5 and 6, there is a correlation between season, prey sex/age, and kill rate. Average kill interval length is shortest (52 hours) in the hot-wet season, when lambs, the smallest ungulate prey, are the most frequently taken sex-age class (39%). Kill intervals are longer in the cold-dry (92 hours) and hot-dry (62 hours) seasons, when adult males (56%) and adult females (44%) are respectively most frequently taken.

To expand upon previous observations (Stander, 1990), it is worth noting that 15% of cheetah kills (n=21 of 143) were made at night. Cheetahs were only seen to scavenge once, when a coalition of three hungry young sub-adults pushed an adult caracal *Caracal caracal* off its springbok kill. (A caracal was seen once to scavenge off an adult female cheetah's gemsbok calf kill, waiting 10-15 meters away until the cheetah moved off). Adult cheetahs with cubs ignored opportunities to feed upon recently dead springbok (one adult, one lamb).

Cheetah population size on the Etosha plains

We identified 14 adult and sub-adult cheetahs, comprising 10 cheetah hunting groups, with varying degrees of reliability, living on the Okaukuejo (west) plains in late 1993 (Sep-Dec) to early 1994 (Jan-Apr). Nineteen adults and sub-adults in 12 groups were identified on the Namutoni plains during this period (Table 7). The average number of adult and sub-adult cheetahs per hunting group was 1.5 (cubs are not included in our population estimates). For the approximately 3,000 km^2 area that these east and west plains systems comprise, this works out to an average density of one adult or sub-adult cheetah per 91 km^2, or one hunting group per 136 km^2.

[*Table 7 here*]

No systematic attempts were made to census cheetah on the central Halali plains, but applying the above density estimates to its approximately 1,000 km^2 area, an estimate of 11 cheetahs or 7 hunting groups is obtained. This appears to be reasonable based on tourist and staff sightings which could not be ascribed to Okaukuejo or Namutoni area cheetahs. Our total for the entire 4,000 km^2 Etosha plains system is thus 46 adult and sub-adult cheetahs, living in 29 hunting groups.

Impact of cheetah predation on the springbok population

In 1989, W. and K. Gasaway (unpubl.) estimated the total number of springbok in the east-central portion of Etosha National Park at 20,000-30,000. Their estimates were based on previous years' wet season aerial counts (EEI unpubl. data, see Lindeque 1991) as well as their own ground counts. We use these numbers for the standing population of springbok in March 1994, during our cheetah census period, in order to estimate the impact of plains cheetah predation on the park springbok population.

A plains cheetah hunting group kills an ungulate every 2.5 days, a kill rate of 146 ungulates per group per year. Of these, 94% are springbok, or 136 springbok per cheetah hunting group per year. If there are 29 cheetah hunting groups on the plains, they can be predicted to take 3,944 springbok per year, or between 13-20% of the estimated standing population. Predicted offtakes by sex-age class are shown in Table 8 in comparison to the estimated standing population.

[*Table 8 here*]

Our data showing strong preference for springbok in cheetahs is derived only from cheetahs on the Okaukuejo plains; it is possible that cheetahs on the central and eastern plains might differ in prey selection. An indication that all plains cheetahs take mainly springbok is suggested by reviewing records of cheetahs observed on kills by park staff from October 1970 to April 1992 (EEI, unpublished data). Springbok made up the large majority of kills reported from both the Halali and Namutoni areas (Figure 2).

Cheetah susceptibility to anthrax

Six of the seven radio-collared cheetahs died of anthrax, according to laboratory analysis. We suspect the seventh, "C", also died of anthrax, although the carcass bones were several weeks old when found and no anthrax spores were isolated. C, like the others, was found unexpectedly dead at a prime time of his life, and an expert local Hai//om tracker (Jakob /Ubuib) was unable to identify any sign of struggle and suggested the possibility of disease or illness (Table 9). In other words, anthrax was probably responsible for 100% of mortality of radio-collared adult cheetahs (86% minimum).

[*Table 9 here*]

All kills observed while the cheetahs were healthy tested negative for anthrax. We suspect that the cheetahs contracted anthrax through killing and consuming a springbok or other antelope which was in the process of dying of the disease. Despite this study's emphasis on continous observation, it is unfortunate that most of the cheetahs died either after monitoring had ceased or during a brief break in observations. In only one case do we have the carcass *probably* consumed by the cheetah prior to its death. Two days before cheetah H was found dead, an adult springbok carcass was found in the same area which had all the signs of being killed by a cheetah, and a high anthrax spore count was found from swabs of the bones (Lindeque et al. in submission***). Still, other routes of infection cannot be ruled out. It is interesting that cheetah "G" was survived by two 10 month old cubs, who almost surely fed off the same hypothetical anthrax-infected carcass that she did. (These cubs starved within a period of several weeks after their mother's death).

Serological surveys for cheetahs during time of immobilization found very low or undetectable levels of antibodies to the anthrax protective anthrax toxin, indicating poor immunity. In contrast, other scavenging predators (black-backed jackals, lions, spotted hyenas) of Etosha showed high antibody levels, indicating exposure and immunity to anthrax (Lindeque et al. in submission**).

Discussion

Etosha cheetah population

Our estimate of 46 plains cheetahs living in 29 hunting groups in late 1993 to early 1994 is the most quantitative population estimate so far developed in Etosha. While the methodology has many uncertainties, some support for our count is derived from the database of park staff sightings of cheetahs from 1970-1992 (Figure 3). More sightings were made on the higher-rainfall Namutoni plains in comparison to the other plains areas, just as our total number of cheetahs identified on the east plains is higher than on the west. The plains population estimate should be improved upon and

updated by continuing to analyze staff and tourist sightings. For example, three of the cheetahs listed in Table 7 have since died of anthrax (Tables 9 and 10).

[*Figure 3 and Table 10 here*]

Data are insufficient to apply the estimated plains density (0.74 adults/100 $km^{2)}$ to the remainder of the park (an additional 13,000 km2 of mainly woodland habitat) in order to obtain a population estimate for the entire Etosha National Park. We have little information about cheetahs living in the north, west and south of the park, areas with few roads which are mostly closed to tourists and have reduced park staff traffic. Staff sightings of cheetahs have been made throughout most of this area, but the frequency of sightings is lower in comparison to the plains areas (total of 61 sightings in 20 years). Water points and ungulate abundance are lower in than on the short grass plains (* co authors add appropriate reference?****).

The Etosha plains ungulates are migratory, concentrating on the Okaukuejo plains systems during the wet season, and spreading east along the southern edge of the Etosha Pan in the dry season. We were curious as to whether Etosha cheetahs also concentrate along with the antelope herds, as they do in the Serengeti (Durant et al. 1988). We investigated this by analyzing the database of Etosha staff sightings of cheetahs between October 1970 and April 1992. While there was strong fluctuation in the total number of sightings from year to year, which in part reflects changing administrative situations, breaking the data down month by month showed only minor variation (Figures 4 and 5). We combined the months into the three seasons (Figure 3), and found no significant difference between seasonal cheetah sighting rate for the three plains areas ($X^2 = 5.162$, df = 4, $p \leq 1.0$). This suggests that Etosha cheetahs do not follow springbok herds. Indeed, none of our radio-collared cheetahs shifted their ranges to the east during the dry seasons. The data do not support the possibility of major seasonal movements onto the plains of cheetahs living in more wooded parts of the park.

[*Figures 4 and 5 here*]

There are few data available from other cheetah studies to help us evaluate our density estimate of 0.74 adult or sub-adults per 100 km^2 on the Etosha plains. Counting known, mostly radio-collared individuals, Morsbach (1986, 1987) estimated cheetah density on central Namibian farmland at 2.0 adults per 100 km^2. In Kenya, Burney (1980) similarly found higher cheetah densities on pastoral lands outside (3.45 cheetahs per 100 km^2, including cubs over 3 mos of age) than inside the Masai Mara protected area (1.49 cheetahs per 100 km^2).

Plains cheetah predation as a limiting factor on the Etosha springbok population

Our results suggest that plains cheetah predation is an important source of springbok mortality. More data is needed to evaluate how significant the cheetah factor is, including kill rates for adult male cheetahs, kill rates for cheetahs of both sexes living in the wooded habitats, and more accurate cheetah and springbok population and rate of change estimates. Managers will have to judge whether this effort warrants the investment. Additional study of cheetah predation should be longitudinal, so as to cover both periods of drought and (hopefully) future years with high rainfall. We will point out that our study, despite its time-intensive nature, was relatively inexpensive, in part due to the use of trained volunteers.

Anthrax as a limiting factor on the Etosha cheetah population

Our study found exceptionally high levels of disease mortality in a protected predator population. Anthrax is a strong candidate for the major limiting factor on the cheetah population - at least the plains population, and especially in the Okaukuejo area, where most anthrax cases have been reported (Lindeque 1991, EEI unpubl. data).

Handling stress has been suggested as a factor leading to the recent disappearance of wild dogs (*Lycaon pictus*) from the Serengeti (Burrows 1995). Handling and observation stress was unlikely to have been a factor in the radio-collared cheetahs' anthrax deaths. Several of our study animals were closely monitored for up to 15 months following immobilization and radio-collaring, during which time they raised cubs and hunted successfully. One cheetah, A, was first immobilized in October 1989, when she was captured raiding chickens in the junior staff quarters and given a brand on her hind leg. She was later immobilized again in June 1992 and radio-collared. She died of anthrax in March 1993.

Only one cheetah (H) died shortly after immobilization, during the hot-wet season when ungulate anthrax mortalities peak (Lindeque 1991). The average time of death following radio-collaring for the seven cheetahs was ***XXXXX (Table 9). [* pls. add immobilization date for cheetah I to Table 9 and calcaluate average collaring-death period*] It should be mentioned that cheetahs have been immobilized and radio-collared in South Africa's Kruger National Park, where tourists are not allowed to drive off-road so that animals had to be habituated to being followed by a vehicle, as in Etosha, and none of these animals died of anthrax, despite the presence of the disease (Bowland 1993). Finally, we have no way of knowing what the anthrax mortality rate is in uncollared cheetahs in Etosha, because of the unlikelihood of finding a carcass. There have been only 26 cheetah mortalities recorded in Etosha since 1970, and seven of them were from this study (EEI unpubl. data). Most of the rest were cubs whose mothers were killed by lions, or animals killed by vehicles. Certainly in the future we recommend that any found cheetah carcass be tested for anthrax.

The Serengeti wild dogs were immobilized not only for radio-collaring, but also for prevaccination rabies antibody titers and postexposure vaccinations, due to concerns about the catastrophic effects a rabies epidemic would have on the relatively small population. However, all wild dogs disappeared within a year of the vaccinations, and it is possible that the vaccinations compromised natural immunity, thus making the animals even more vulnerable to the disease (Burrows 1995). For these reasons, and because of the potential for injury when immobilizing a cheetah, we do not recommend anthrax vaccination trials on wild park cheetahs.

Finally, although the cheetah has been predicted to be exceptionally vulnerable to disease because of its high level of genetic homogeneity, we point out that there is no clear genetic link to their anthrax morbidity in Etosha, which is the first major reported disease mortality in a wild cheetah population. The cheetah's susceptibility to anthrax is most simply explained as due to its lack of scavenging behavior - unlike other scavenging predators, cheetah behavior does not allow the population to build up immunity to the disease. While Etosha lions are immune, lions in Kruger have begun dying of anthrax there during the first recorded outbreak (**Lindeque et al in submisstion). We also point out that in the Serengeti in the early 1990s, canine distemper virus (CDV) reduced the lion population by 1/3 (Roelke-Parker *et al.* 1996), and rabies apparently completely eliminated the wild dog (Burrows 1995), while the cheetah population has been stable since first coming under study in the 1970s (Caro 1994) and was apparently unaffected by either virus (M. Roelke, T. Caro pers. comm. 1996).

Managers may be concerned that the rate of anthrax mortality may be unsustainable in the Etosha cheetah population. At present, however, with a large population of cheetahs on farmland surrounding the park, we do not recommend active intervention to try to control anthrax in the cheetah population. Anthrax must cause high turnover in the Etosha population (none of our study animals reached old age), and vacant territories may eventually be filled by animals entering from the farmlands.

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TABLES

*** Figure 1 is map of cheetah census study area from the cheetah poster at EEI ***

Table 1. Radio-collared cheetahs monitored during this study

ID	Sex	Description	Period of observation	Area
Primary study animals, continuous observation				
A+3	F	Adult + 3 cubs	Aug 92-Jan 93	W of Okaukuejo & Leeubron plains
A	F	Above adult, cubs dispersed	Jan 93-Feb 93	Leeubron plains
A1-3	1F, 2M	Independent cubs of A	Jan 93-May 93	Leeubron plains
A1	F	Young adult, dispersed from A1-3	May 93-Aug 93	Okaukuejo-Ombika plains
G+3	F	Adult + 3 newborn cubs	Feb 93-Mar 93	Gemsbokvlakte area
G	F	Above adult, cubs lost to predators	Mar 93-June 93	Gemsbokvlakte area
G+2	F	Above adult + 2 young M cubs	Dec 93-July 94	Gemsbokvlakte area
Other radiocollared cheetahs monitored occasionally				
A2	M	Young adult, dispersed from A1-3	Oct 93-Nov 93	Dry woods E of Okaukuejo
CDE	1F, 2M	Independent sub-adult coalition	Dec 92	Salvadora plains
C,D	M	Young adults, dispersed fm CDE	Oct 93	Homob area
H	F	Young adult	Mar 94	Okaukuejo area
I	F	Adult	Aerial loc. 1994-95	Sonderkap area

Table 2. Number of ungulate kill intervals for cheetah groups by month

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Totals
A + 3 lg cubs	15								2	1	0		18
A alone	1	8											9
A's 3 sub-adults		1	8	10									19
Young ad. female A1								2					2
G + 3 sm cubs		3	5										8
G alone				4	4	5							13
G + 2 cubs	10	2	1	2	1	1				7	12	5	41
Totals	26	14	14	16	5	6	0	2	2	8	12	5	110

Table 3. Prey killed by cheetahs monitored during this study

Species	Number of kills [%]
Springbok, *Antidorcas marsupialis*	143 [81.3%]
Scrub hare, *Lepus saxitilis*	21 [11.9%]
Steenbok, *Raphicerus campestris*	6 [3.4%]
Zebra foal, *Equus burchelli*	2 [1.1%]
Gemsbok calf, *Oryx gazelli*	1 --
Ostrich, *Struthio camelus*	1 --
Kori bustard, *Ardeotis kori*	1 --
Black koorhan, *Eupodotis afra*	1 --
Helmeted guineafowl, *Numida meleagris*	1 --

Other prey reported by researchers, staff or tourists

Wildebeest, *Connochaetes trachinus*
Kudu, *Tragelaphus strepsiceros*

Table 4. Comparison of cheetah-killed springbok sex/age ratios to the standing population

	Adult male	Adult female	Yearling	Lamb
Cheetah kills	33% (42)	34% (44)	7% (11)	25% (33)
Etosha population	25% (2,336)	38% (3,550)	19% (1,775)	18% (1,682)

Table 5. Sex-age classification of cheetah-killed springbok by season

Sex-age class	Hot-wet (Jan-Apri)	Cold-dry (May-Aug)	Hot-dry (Sep-Dec)
Adult male	23% (16)	56% (14)	32% (11)
Adult female	35% (24)	24% (6)	44% (15)
Yearling	3% (2)	12% (3)	15% (5)
Lamb	39% (27)	8% (2)	9% (3)

Table 6. Mean ungulate kill intervals (in hours) by cheetah group and season

Cheetah group	Hot-wet (Jan-Apr)			Cold-dry (May-Aug)			Hot-dry (Sep-Dec)			Overall	
	Mean	N	SD	Mean	N	SD	Mean	N	SD	Mean	SD
A + 3 lg cubs	39.67	15	20.74	-----	----	-----	42.33	3	20.21	40.11	20.08
A alone	29.61	9	11.84	-----	----	-----	-----	----	-----	29.61	11.84
A's 3 sub-adults	67.00	19	38.37	-----	----	-----	-----	----	-----	67.00	38.37
Young ad. female A1	-----	----	-----	111.00	2	8.49	-----	----	-----	111.00	8.49
G + 3 sm cubs	60.38	8	15.88	-----	----	-----	-----	----	-----	60.38	15.88
G alone	78.00	5	37.85	101.94	8	21.59	-----	----	-----	92.73	29.94
G + 2 sm to lg cubs	45.27	15	19.72	34.00	2	25.45	64.31	24	20.85	55.87	22.61
Seasonal means	51.92	71	29.83	92.13	12	33.34	61.87	27	21.57	58.75	30.82

Table 7. Numbers of male (M), female (F) and unknown sex (U) adult and sub-adult cheetahs estimated on the east & west Etosha plains areas, late 1993 - early 1994

Area[1]	Ad F	Ad M	Ad U	SA F	SA M	SA U	Cubs	Tot[2]	IDR[3]
Okaukuejo plains (west plains area)									
1. Leeubron (A2)		1					1	*	
2. Gemsbokvlakte (G)	1				2			3	*
3. Okaukuejo (H)			1		1		2	*	
4. Sprouk./Sonderkap (I)	1						2	1	*
5. Okondeka/Leeubron	1						1	1	**
6. Okondeka/Leeubron		1						1	**
7. Ombika		1						1	**
8. Adamax/Leeubron	1						3	1	***
9. Grootvlakte	1							1	***
10. Natco/M'bari		2					2	***	
Totals	5	3	2	1	2	1	6	14	
Namutoni plains (east plains area)									
1. Namutoni/Twee Palms	1							1	**
2. Aroe	1					5		6	**
3. Twee Palms		1	1					2	**
4. Okerfontein	1						2	1	**
5. Chudob	1							1	**
6. Chudob		1						1	**
7. Agab	1							1	**
8. Agab		1						1	**
9. Batia/Springbokfontein		2						2	***
10. Fishers Pan/Okevi	1						3	1	***
11. Kalkheuwel	1							1	***
12. Kalkheuwel		1						1	***
Totals	7	6	1			5	5	19	
Grand total	12	9	3	1	3	7	8	35	

[1] Area = water hole nearest to where cheetah group identified
[2] Cubs not included
[3] IDR = index of ID reliability, ranked 1-3 stars with decreasing certainty of identification. * = certain ID; radio-collared cheetah. ** = less certain ID; based on at least one observation by member of cheetah research team, including several animals which we attempted to capture. *** = least certain ID; based upon at least one observation by other park staff and/or tourist sightings.

Table 8. Potential impact of predation by plains cheetahs on the Etosha springbok population

	Adult male	Adult female	Yearling	Lamb
20,000 estd. standing springbok pop	5,000	7,600	3,800	3,600
Estd. number (%) killed by cheetahs	1,262 (25.2%)	1,380 (18.2%)	355 (9.3%)	947 (26.3%)
30,000 estd. standing springbok pop.	7,500	11,400	5,700	5,400
Estd. number (%) killed by cheetahs	1,262 (16.8%)	1,380 (12.1%)	355 (6.2%)	947 (17.5%)

Figure 2.
Park staff observations of cheetah kills, 10/70-4/92

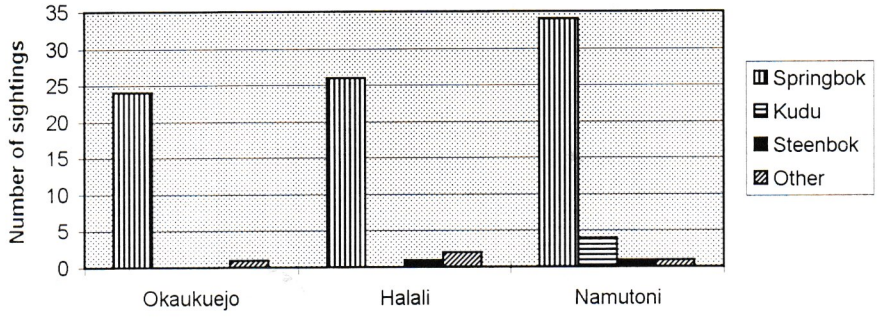

Table 9. Cheetah anthrax mortalities

Cheetah	Date found	Area found	Diagnosis method
A	Mar 93	Leeubos	Culture
*C**	*Oct 93*	*Nuamses*	*Culture*
A1	Nov 93	N of Leeubos	Blood smear
H	Mar 94	S of Okaukuejo	Blood smear
A2	Dec 94	Leeubron	Culture
G	Nov 95	Gemsbokvlakte	Culture
I	Jun 96	Duwelsvuur	Culture

** Culture was negative; anthrax suspected but not confirmed*

Figure 3. Staff sightings of cheetah by area and season

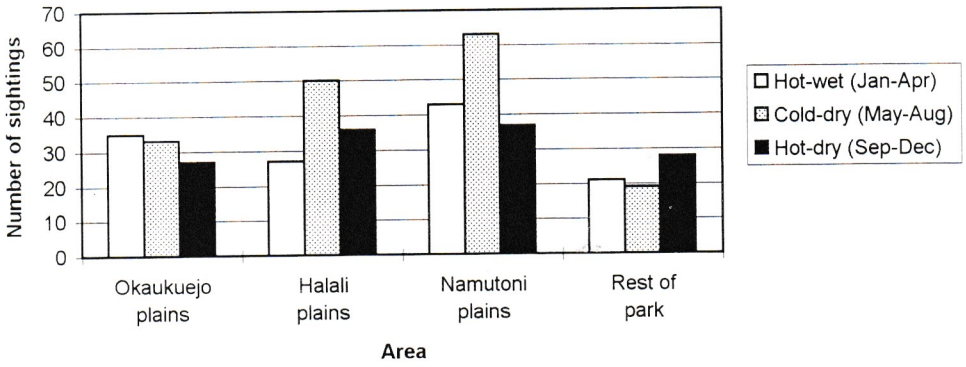

Figure 4. Staff sightings of cheetah by year

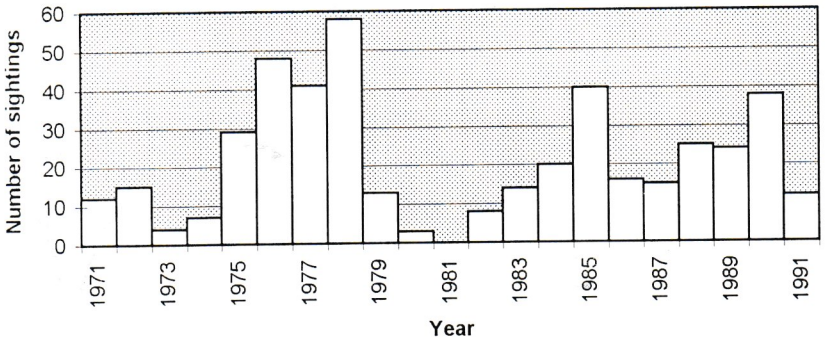

Figure 5. Staff sightings of cheetah by month (10/72-4/92)

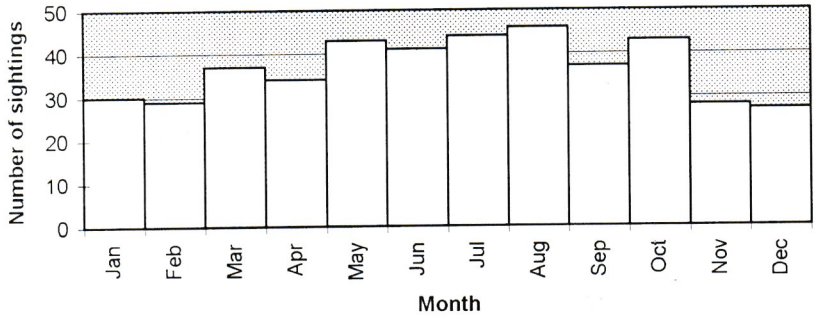

Table 10. Dates of radio-collaring and of death for focal cheetahs

Cheetah	Date radio-collared	Date died
A	Jun 92	Mar 93
A1	Jan 93	Nov 93
A2	Jun 93	Dec 94
G	Feb 93	Nov 95
C	Aug 92	Oct 93
H	Mar 94	Apr 94
I	?***	Feb 96