POPULATION AND HABITAT VIABILITY ASSESSMENT FOR THE NAMIBIAN CHEETAH (*Acinonyx jubatus*) AND LION (*Panthera leo*)

11-16 February 1996
Otjiwarongo, Namibia

Workshop Report
February 1997

SECTION 2

WORKING GROUP REPORTS - CHEETAH

Wild Management Goals and Strategies Working Group Report - Cheetah

Kallie Venkze, Daniel Kraus (facilitators), Trygve Cooper, Marshall Howe, Luke Hunter, Sandy Hurlbut, Peter Jackson, Jim Teer, Heiko Theis, Bernard Ziess

Problem 1: Although Namibia has the most endangered cheetahs of any country in the world, the population is believed to have declined to only 2,000 to 3,000 animals from an estimated 6,000 in the early 1980s, as over a 10-year period nearly 7,000 cheetah were removed from the population. Estimates of population size are not statistically reliable because effective surveys have not been conducted. Ninety percent of the national cheetah population exists on private lands, where many animals are killed as livestock and game predators.

Goal: Maintain current cheetah population numbers in Namibia.

Strategy 1. Improve/develop accurate censusing and monitoring.
Action Step: Workshop--CCF will coordinate a meeting of MET, NGO's, statisticians, field biologists and population biologists during the next 12 months to investigate the practical methods of surveying the cheetah population nationally, with consideration of funding and personnel needed.

Strategy 2. Monitor population trends.
Action Step: Implementation--Implement the censusing and monitoring program on a regional and national level.
Demography--Record critical demographic parameters of cheetah (live and dead) removed from the farmlands. The above workshop will coordinate data collection.

Strategy 3. Conduct public education and outreach.
Action Step: Education--NGOs will continue to expand existing educational outreach programs nationally, and involve environmental education centers in outreach efforts.

Problem 2: Private land owners farming livestock and game suffer depredation by cheetah and complain of lack of assistance from MET. Significant numbers of cheetah ($>$6,000 in the past 20 years) have been killed on private lands since the 1980s.

Goal: Minimize conflicts on communal lands and commercial farmlands.

Strategy 1. Develop long-term economic incentive to tolerate cheetah by:

Action Step: Continue the encouragement of conservancies through meeting of conservancy representative with farmers associations.

Action Step: Discussions among MET, NGOs and farmers should take place on the sustainable utilization of cheetah,

Action Step: Tourism should be encouraged.

Strategy 2. Promote land use methods that stimulate greater wildlife numbers.

Action Step: Land use methods will be promoted through newsletters, the media, articles in agricultural journals, and through the Conservancy Association.

Strategy 3. Increase public awareness of the value of cheetah in natural ecosystems as a national treasure.

Action Step: Awareness will be promoted through education programs by NGOs, environmental education Centers and the media.

Problem 3: Although farmers trap many 'problem' cheetah, there is no coordinated national strategy for the disposition of these animals.

Goal: Develop a management program for problem cheetah trapped on private farms and in communal areas.

Strategy 1. Identify specific sites for temporarily holding captured cheetah.

Action Step: Various sites will be researched and designated as holding areas.

Strategy 2. Identify other cheetah populations nationally and internationally in need of supplementation.

Action Step: NGOs will be responsible for identification of areas in need of supplementation.

Strategy 3. Expand the existing communication network, so that availability of captured cheetah is quickly communicated to others, both nationally and internationally.

Action Step: Communication will be increased between NGOs, MET and veterinarians.

Strategy 4. Establish funds for cheetah translocation projects.
Action Step: NGOs will seek specific funding for cheetah translocation.

Human/Livestock Interaction with Predators, Communication and Education Working Group Report - Cheetah

Kadzo Kangwana (facilitator), Helmut Ackermann, Dolly Ackermann, Piet Burger, Jochen Hein, Paul Jessen, Charles Phiri, Judy Storm

The group started by identifying problems that occur at the human/livestock interface with predators:

* Stock loss
* Poor communication skills among stakeholders
* Land carrying capacity for cheetah
* Lack of environmental education in schools
* Lack of environmental understanding by farmers/citizens
* Incompatible farming methods
* Perceived lack of support from the Ministry of Environment & Tourism
* Game-proof fencing ineffective against cheetah
* Veterinary fence impedes movement of game
* Lack of extension workers
* Extermination of predators by farmers
* All stock loss blamed on predators
* Breeding seasons are not specific so calves (prey) are present throughout the year

These problems were grouped and tackled under the following headings: Stock Loss; Land Use and Farming Practices; and Communication and Education and Changing Attitudes.

Under each of these headings, the problems were described and action steps outlined.

STOCK LOSS

Stock Loss from Cheetah

The problem: Cheetah kill small stock, especially goats, sheep and cattle calves. Farmers may tolerate a small percentage loss to cheetah, however some losses are intolerable. In 1994, 74 cheetah were reported by MET as killed by farmers, about half occurring in the

Otjiwarongo District. On game farms, cheetah also kills calves of wild species such as sable, eland, and roan. Cheetah also prey upon natural populations of small game species, including springbok *(Antidorcas marsupialis)*, impala *(Aepyceros melampus)*, and blesbok *(Damaliscus dorcas)*. Frequently, cheetah are blamed for losses caused by other predators (e.g., caracal, *Felis caracal* and jackal, *Canis mesomelas)*. Small livestock also can be lost to aardvark *(Orycteropus afer)* dens.

Action Steps:

1. Protect small stock with guard dogs, donkeys, or herdsmen.
2. Synchronize calving season as losses can be reduced by "swamping" the predators. Try to coincide calving with peaks in wild species births so that cheetah will go for the natural prey rather than the domestic animals.
3. Maintain calves less than 6 month of age in a protected camp.
4. Provide adequate prey base for cheetah to reduce their need to kill livestock.
5. Remove bottom strands of cattle fence to allow free movement of small game.
6. Control other predators more effectively.

LAND USE AND FARMING PRACTICES

Problem: 1 Many cattle farms are closely located to protected areas which are a key conservation area for cheetah.

Action Step: Change the policy and restrictions on these lands to allow these farmers to have the option to convert to game farming.

Problem 2: Under current farming breeding practices, most farmers have many breeding herds spread across the farm throughout the year, which reduces protection ability and increases the probability of losing stock.

Action Step: Breeding herds should be concentrated in one area, which is more easily protected. A large herd of animals easily flusters the cheetah. By coordinating livestock breeding with natural breeding in wild ungulate populations, predators are swamped with available prey during a narrow time window. This, in turn, reduces the likelihood that cheetah will kill livestock rather than natural prey. A safe calving area also should be established near the farmer's house, a small camp, or within a predator-proof enclosure. Breeding of more aggressive cattle breeds should be encouraged; these breeds tend to be more aggressive and will therefore better protect their calves.

Problem 3: There is bush encroachment as a result of overstocking. Once the land is bush-encroached, there is less grazing land for livestock and the wild game numbers are reduced, thus providing less prey for the cheetah. This in turn can increase cheetah predation on livestock.

Action Step: Livestock carrying capacity varies from area to area. Carrying capacities set by the Ministry of Agriculture (1962) must be revisited. A farmer needs to identify how many cattle his/her land can support. Carrying capacity also must be considered on an annual basis and according to this capacity, each farm must be stocked correctly to decrease overgrazing and the deterioration of the land.

Problem 4: Specifications laid down by the Land Bank are outdated. These specifications prevent "environmentally friendly" farming. For example, the Land Bank will not provide a soft loan to a farmer to combat bush encroachment by using manual labor. However, a loan will be provided to farmers using herbicide to remove bush. Additionally, loans cannot be obtained for game farmers, but can be secured by cattle farmers.

Action Steps: Land Bank restrictions must be changed to allow flexibility.

EDUCATION

Problem: There is a general lack of understanding about environmental issues and conservation challenges.

Action Step: The importance of conservation challenges, knowledge of ecology, importance of wildlife and benefits of conserving wildlife must be stressed to the public.

Within the schools (children):

1. Promote inclusion of environmental science in the syllabus throughout the school curriculum. This approach now is being promoted by some NGOs, but the Ministries must become more involved. The subject must not be considered as a soft/easy option, but rather an imperative to education.
2. Encourage school participation on world awareness days (e.g., water day).
3. Promote children's literature on the environment by NGOs and Ministries.
4. Promote use of nature trails and outdoor awareness camps during school holidays and the use of environmental education centers.
5. Increase the number of environmental education centers within the country. These centers need to be evenly distributed throughout Namibia.
6. Promote wildlife clubs and action groups within the schools.
7. Promote field trips to institutions such as the CCF, game parks, crocodile farms, or just natural areas.

8. Study specific animals under the umbrella of the school syllabus.

Amongst farmers:

1. Promote the importance of cheetah conservation and explain the problems. Also provide education on cheetah life history and behavior. This could be accomplished by NGOs and the Ministry of Environment (extension workers).
2. Create a national awareness for the importance of cheetah (e.g., Namibia is the cheetah capital of the world), use the mass media (e.g., television, radio, public displays at shows, create slogans - "welcome to cheetah world!").
3. Educate about conservation in general, emphasizing whole ecosystems and how all life forms interact.
4. Convene information days on a specific species where farmers are invited and speeches and slide shows are given.
5. Arrange for experts to attend farmers' association meetings to speak about conservation issues, new farming practices and species.

COMMUNICATION

Problem 1: There is a lack of communication between: (1) farmers and the MET, (2) farmers and farmers, (3) different departments within the same Ministry, (4) among ministries, (5) NGOs and ministries, (6) between NGOs and farmers. The response time between reporting a problem and receiving assistance is excessive.

Action Steps:

1. All concerned organizations should identify a 'point' person responsible for assisting in resolving problems. Problems should be tackled within the constraints of Ministry staff shortages by allowing NGOs or other interested parties to help. The Ministry should act in a coordinating role while being flexible as to who implements activities.
2. Encourage extension officers from the Ministry of Agriculture to visit farmers.
3. Encourage NGOs to play an intermediary role as a facilitator working directly with farmers.
4. Decentralize decision-making to minimize communication time, allowing quick response to problems. Allow 'point' Ministry people in the field to make decisions without requiring approval from headquarters in Windhoek.
5. Form special interest groups that will allow people to meet, discuss problems and share ideas.

Problem 2: Cheetah are perceived as a liability by farmers who also resent the Ministry and NGOs for their lack of response to cheetah-caused problems.

Action Steps:

1. Increase communication among all interested parties as specified above.
2. Make cheetah an asset through sustainable consumptive utilization or ecotourism.
3. Reduce response time by Ministry and NGOs to problems.
4. Centralize information on trophy hunters and game farmers/zoos/parks desiring cheetah so that farmers can contact a relevant person to eliminate his problem animal. This could be started as a private business initiative.
5. Train extension workers in effective communication and conflict resolutions.

Priority ideas/Discussion Points Made by this Working Group

1. Publicize this cheetah PHVA, including recommendations in the media and through newsletters.
2. Consider alternative farming strategies wherever possible.
   a. confine and control small calves up to 6 months of age by maintenance at the homestead or in a protected electrified camp.
   b. rely on herdsmen to maintain cattle in kraals at night when predation is severe.
   c. introduce donkeys (female with a foal) for cattle, and guard dogs for small stock.
   d. change to a more aggressive breed of cattle (i.e., introduce a Brahman bull).
   e. increase the natural prey base by putting out salt licks, constructing water points.
   f. fight bush encroachment.
   g. revise stocking rates for the carrying capacity of the land.
   h. synchronize calving period to coincide with natural prey calving.

3. Discourage farmers from shooting cheetah indiscriminately. Removing a cheetah creates a 'vacuum', which likely is to be occupied by other problem cheetah.

4. To reduce losses of game from cheetah, game farms must electrify perimeter fences. An 'information day' could be useful for demonstrating the effectiveness of electrified fences.

5. Encourage farmers to recognize the value of having cheetah on their property through farmers meetings, professional hunters, media and NGOs. Mr. J.F. Hein and NGOs will initiate this activity.
   a. increasing farmers' awareness of the importance of participating in cheetah research, including collecting samples and data. Farmers should be compensated for participating in research by the researchers provided that the cheetah is released where it was caught.
   b .promoting sustainable utilization (i.e., professional hunting of cheetah on the farmers' land). Farmers should receive almost half the trophy fee, and at least

N$1000 should be donated to the Namibia Nature Foundation to be used for further research. This approach, which will be initiated by NAPHA, will allow problem animals to be shot and eliminated.

c. promoting cheetah as a tourist attraction on conservancies.

Life History / VORTEX Modeling Working Group Report - Cheetah

Ulysses S. Seal (facilitator), Hu Berry, Olivia Forge, Laurie Marker-Kraus, Kristin Nowell

Introduction

Originally, cheetah were found from the Cape of Good Hope to the Mediterranean, throughout the Arabian Peninsula to the southern part of the former Soviet Union. Population numbers have declined from more than 100,000 in 1900 to approximately 9,000 to 12,000 today of free-ranging cheetah in Africa. Two population strongholds remain: Kenya and Tanzania in East Africa and Namibia and Botswana in southern Africa (Figure 1). The species' numbers in Namibia are estimated to have declined by approximately 50 percent in the past 10 years, leaving a population of about 2,500 animals. From 1980 to 1991 there were about 6,800 cheetah removed from the wild in Namibia according to CITES numbers (Figure 2). The number of animals removed annually declined from a peak of about 900 in 1982 and 1983 to about 200 in 1991. Of the total, 958 were live animal exports, and the remainder were shot.

Decreasing numbers are a result of a decline in the cheetah's habitat and prey base as well as conflicts with people. As humans convert more of the cheetah's habitat into farmland for livestock production, human and cheetah conflicts have emerged. Cheetah parks and reserves have led to direct competition with lions and hyenas which may take up to 50% of cheetah kills and which kill a high percentage of cheetah cubs. Rainfall also may influence cheetah cub survival through effects on prey density. Namibia is an arid to semi-arid country where rainfall is highly variable, with "droughts" being common.

As a result of predator competition in parks, most free-ranging cheetah live outside of protected areas. Surveys show that 70% of Namibian wildlife lives on farms ranging from 10,000 to 40,000 acres in size (4,050 to 16,200 hectares). Ninety-five percent of cheetah live on these private lands where prey is available, and other large predators generally are absent. Historically, the cheetah has been viewed as a pest and a threat to the livelihood of livestock farmers, and it is legal in Namibia to shoot an animal that interferes with one's property and livelihood. Human and cheetah conflicts may become even more frequent given the projected 3.3% growth rate of Namibia's human population which will result in a doubling of the current population of 1.4 million in only 20-25 years.

There was a 50-60 percent decline in wildlife numbers in the 1980's attributed to a variety of circumstances including severe drought. Partly as a result of the continued overstocking of livestock on rangelands, cheetah populations came into even greater conflict with farmers.

During this period, 80% of one of the cheetah's main prey, the kudu, died from a rabies epidemic. Combined, these events led farmers to take strong control measures against the cheetah, for either real or imagined increased predation on domestic livestock as the wild prey base declined. By the late 1980's, the cheetah population was believed to have been reduced by more than half.

Since almost all wildlife hunted as game belongs to the landowners and has an economic value through live sale, meat production, and trophy hunting, wildlife conservation strategies are developed along with livestock and pasture management practices. Alternative farm management practices also are being introduced to protect livestock from predators.

Molecular genetic studies have shown that the cheetah lacks genetic diversity rendering it less adaptable to environmental change and challenges. The cheetah's genetic uniformity may increase susceptibility to infectious diseases and pose another threat to population viability in Namibia. Disease risks include Feline Infectious Peritonitis (FIP) and anthrax. Canine Distemper Virus (CDV) is a potential catastrophic threat if the Serengeti biotype occurs in Namibia and infects cheetah. Rabies may be a periodic threat as exposure and immunity shift through time. Feline Immunodeficiency Virus (FIV) is a potential long-term disease threat to the Namibia population. The role and effects of other viral diseases and parasites in this population are unknown.

Population Simulation Modeling

The need for and effects of intensive management strategies can be modeled to suggest which practices may be the most effective in meeting management goals. In this case, the targets are the large Namibian cheetah population on private lands and the small population in Etosha Park. The Namibian population is not isolated from the population in Botswana, despite the presence of a game fence, so that movement between the countries likely occurs (although no information on rates of emigration between the populations was available) and the genetically effective population size may need to include both populations. The demographic effects of this interchange on the population dynamics in each country will depend upon rates of migration, age and sex structure of emigrants, their mortality rates, and their incorporation as breeding members into the Namibian population.

The management goals for the Namibian population include: 1) managing for a target population size, 2) determining the number, age, and sex structure of animals that might be removed annually while maintaining a demographically stable population, 3) controlling dispersing animals, and 4) undertaking translocations when necessary.

VORTEX, a simulation modeling package written by Robert Lacy and Kim Hughes, was used as a tool to study the interaction of multiple life history and population variables treated stochastically. The purpose was to explore which demographic parameters might be most sensitive to management practices and to test the effects of possible management scenarios. The VORTEX program is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wildlife populations. VORTEX models population dynamics as discrete, sequential events (e.g., births, deaths, catastrophes, etc.) that occur according to defined probabilities. The probabilities of events are modeled as constants or as random variables that follow specified distributions. VORTEX simulates a population by stepping through the series of events that describe the typical life cycle of sexually reproducing, diploid organisms.

VORTEX is not intended to give absolute answers, since it is projecting stochastically the interactions of the many parameters that enter into the model and because of the random processes involved in nature. Interpretation of the output depends upon knowledge of the biology of cheetah and of the Namibian cheetah population, the conditions affecting the population, and possible changes in natural conditions, threats, and management in the future.

Model output, as with any model, is limited by the input. The biological information for the cheetah population came from the studies of Laurenson et al. (1992), Caro (1994), Marker-Kraus et al. (1996), Nowell and Jackson (1996), and personnel working in the Ministry of Environment and Tourism (MET) who participated in this PHVA Workshop.

Input Parameters for Simulations

Age of First Reproduction and breeding system (3 years on farmlands for females and 5 years for males; polygynous).

VORTEX defines breeding as the time when young are born, not the age of sexual maturity. Cheetah breed year round in Namibia. First births in the wild occur when females are, on average, about 3 years of age in the farmland population or in Etosha. VORTEX uses the mean or median age of reproduction (with an estimate of variation, as discussed below) rather than the earliest age of cub production. Thus, although some female cheetah may first give birth at 2 years of age, the average age of first cub production (among the animals in Namibia) that produced young was estimated as 3 years. Similarly, whereas males may be physiologically capable of breeding at 2 to 3 years of age, social constraints may limit breeding to older animals. The degree of social constraint may vary with population density and age structure. For this model, we chose 5 years as the mean age of males at the birth of the first cubs sired. Since the cheetah mating system is polygynous, populations must become extremely small for male reproductive age to have a significant demographic effect in the model.

Cub Production (mean litter size = 3.5; percentage of all adult females annually with no cubs = 40% or 25%; sex ratio at birth = 0.500; 66% of adult males in breeding pool)

VORTEX combines number of cubs per litter, interval between litters, and the proportion of adult-age females producing cubs into a single variable called litter size. Field data on 53 cheetah litters of different ages, observed by farmers during the current dry period, yielded a mean litter size of 3.4 (162 cubs in 53 litters). The pooled records of the Cheetah Conservation Fund (CCF) on 53 litters indicate a mean litter size of 3.1, but a wide range of cub ages were included at the time of first observation. These litters would have been subject to age dependent mortality up until the time of first observation. Also, given the high rate of cub mortality 10 to 30 days postpartum, evaluation of these data for this age effect is important for estimation of actual litter size at birth. Examination of the data, with a regression upon age at time of observation, indicated a mean litter size of 3.7 for litters ranging in age from 1 week to 4 months. As noted, this still is likely to be an underestimate of the litter size at birth in the farmland population. Observed litter sizes range from 1 to 6 with a few litters of 7 to 8 cubs reported. We used a distribution of litter sizes to yield a mean of 3.5 cubs at the average age of 3 to 4 months, the time of first observation of many of the litters. Thus estimates of additional cub mortality in the first year are from ages 3 to 12 months.

The birth interval between successfully reared litters ranges from 15 months to 2 years for the females. The gestation period is about 90 days. Cheetah that lose litters usually breed again within 3 weeks (young animals may be delayed for 3 months). The calculation of demographic mean interbirth interval was made on the basis of all adult females in the population including those that failed to breed. The published field data are for breeders only so the proportion of adult females breeding each year is usually overestimated in this literature. We used estimates of 25% and 40% of the proportion of females not producing litters in a given year. The value of 25% not producing a litter appears likely to provide an upper limit for the productivity of this population under the habitat conditions and higher prey densities that occur during a wet period.

Annual variation in female reproduction is modeled in VORTEX by entering a standard deviation (SD) for the percent females producing litters of zero. Limited data are available from individual cheetah. This variation, which may be due to fluctuations in food abundance, variations in the age at which females reach sexual maturity, infertility in some animals, and random demographic variation was set at 12.5%. VORTEX determines the percent breeding each year of the simulation by sampling from a binomial distribution with the specified mean (25 or 40%) and SD (12.5%). The relative proportions of litters of 1 to 6 cubs are kept constant. The sex ratio at birth was set at 0.5 based on the assumption of equal numbers of males and females at birth and as reported for several wild cheetah populations.

Age of Senescence (12 years)

VORTEX assumes that animals can breed (at the normal rate) throughout adult life. Cheetah can live more than 15 years, but reproduction appears to cease by age 10 to 11 in the wild, and few animals live beyond this age in the Namibian population. We used 12 years as the maximum age in the model. One effect of maximum age in the deterministic model is an increase in generation time with increasing life expectancy, since the maximum possible age of reproduction will be extended.

Mortality (3 months to 1 year of age= 46% for cubs; >1 year = 5 to 30% for females and 5 to 50% for males)

Mortalities can be entered in VORTEX in four ways: 1) as the percentage of animals in each sex-age class expected to die each year, with a corresponding variance; 2) as a fixed number removed (e.g., harvested) in each sex-age class; 3) as a catastrophic event that reduces the normal survival rate by some fixed amount, and 4) when K (carrying capacity) is exceeded, all age classes are proportionally reduced to truncate the population to the value set for K.

Cub survival (0 to 1-year age class) is highly variable among wild felid populations. Additionally, the factors affecting this variability may differ in importance among populations and at different times in the same population. Factors that have been identified in cheetah include changes in prey availability, diseases (recent anthrax outbreak in the Etosha population; see veterinary section for this and other risks), predation (lions and hyenas, which are not a significant factor in the farmland population), and possibly inbreeding depression (as described in the captive population). A cub mortality estimate of 46% was used in these model scenarios on the basis of CCF data on the decline in mean litter sizes between 3 months and 10-14 month old animals. Reported first year mortalities in other populations have ranged up to 95% with heavy lion predation on cheetah cubs.

Survival of subadult (1 to 3 years for females and 1 to 5 years for males) and adult (3 years and older for females and 5 years or older for males) cheetah in Namibia is strongly related to human influences, especially hunting and killing of nuisance cheetah on private lands. Data on the number of animals reported killed and exported (Figure 2) have been collected by government agencies and tabulated in CITES reports (Marker-Kraus et al. 1996). The natural mortality rate may range from 5 to 10% but total annual mortality could range up to 30% with removals on the farmlands. There is a bias favoring removal of males (perhaps subadult animals) based upon the capture methods and the inclination of groups of males to repeatedly use favored tree sites.

Data have been collected on individual cheetah mortality as part of a radiotelemetry and tagging study over the past 3 years (Kraus, 1996 personal communication). Twenty-six animals, 18 males and 8 females, have been monitored. The following data were useful in making preliminary estimates of crude mortality rates.

Statistic	Males	Females
Number	18	8
Total animal months	248	62
Mean (months)	13.8	7.8
Standard Deviation	9.6	5.7
Range (months)	3-32	3-19
Number dead	8	1
Mean ages (months)	64.8	56.1

Calculations of crude annual death rates were 38.6% for the males and 19.2% for the females. Four of the males were shot.

We modeled the effects of equal sex mortality and of differential greater mortality rates for males of 1.5 and 2.0 times the specified mortality rate of females. It is estimated (informed guesses) that currently about 250 animals per year are being killed or live-trapped, about 10% of the estimated population, each year. We examined the effects of mortality rates ranging from 5 to 30% for females and 5 to 50% for males. One effect of selective male mortality on the population may be to reduce the breeding pool of males and the genetically effective population size.

Catastrophes (One or two events with a 5% frequency or one event with a 10% frequency and each event with either no effect or a 20% decrease in reproduction and with either a 20%, 35%, or 50% decrease in survival).

Catastrophes are singular events outside the bounds of normal environmental variation affecting reproduction (defined in VORTEX as recruitment of individuals into the breeding population) and survival (defined in VORTEX as mortality of adults) either singly or in combination. Examples of natural catastrophes are droughts, disease, abrupt decline in prey populations, a removal or off-take event, floods, fire, or a combination of events. Catastrophes are modeled by assigning a probability of occurrence and a severity factor ranging from 0.0 (maximum or absolute effect) to 1.0 (no effect). It is also possible to model possible positive effects of an unusually good year on reproduction by setting the severity effect greater than 1.0.

Drought combined with a disease induced decline in a prey population and increased cheetah removals by farmers occurred in the early 1980's. These events can be modeled as a catastrophic event. This type of event was estimated as occurring at a 5% frequency and having several possible severity effects on survival and reproduction. There also is concern that catastrophic disease events could impact the Namibian cheetah population, with an increased frequency over the next 100 years. This is based upon recent losses to anthrax in the Etosha Park population, the cheetah's susceptibility to FIP documented in captivity, the recent CDV event in Serengeti lions, and other possibilities (see disease section in this report). Speculative estimates of the frequency and severity of epidemic disease in felid populations by the disease working group suggested a frequency of perhaps once in 10 (10%) or 20 (5%) years, with perhaps 20-35% of the population dying and with no effect on reproduction by the survivors. We included either a single or two catastrophes as possible events in the simulations. Effects were evaluated across a range of adult mortalities (5-30%) and differing ratios of male and female mortality (1:1, 1.5:1, 2:1). Average catastrophe frequencies of 0% (which provides a no catastrophe control), 5% (20 years), 10% (10 years), 14% (7 years), and 20% (5 years) were evaluated in sensitivity analyses. Survival severities of 0.50, 0.65, 0.80; (50%, 35% and 20% reduction in survival respectively), and 1.00 (no effect on survival which effectively is a no catastrophe event as a control comparison) were examined at each catastrophe frequency. Either no effect on reproduction or a 20% reduction in reproduction was included in the severity effects of the catastrophes.

Carrying Capacity 1,500, or 2,500 or 4,000 or 6,000 individuals. Environmental Variation (EV) of 600 (± 15% of 4000) animals was included in a series of simulations with K set at 4000. No trend in K and no function for a density dependent effect on reproduction were modeled.

The carrying capacity, 'K' defines an upper limit for the population size, above which additional mortality is imposed proportionally across the age classes to return the population to the value set for K. VORTEX uses K to impose density-dependence on survival rates. Carrying capacity may increase or decline in relation to the occurrence and duration of drought cycles and wet years. Another VORTEX module has the capability of imposing density-dependent effects on reproduction that change continuously as the population approaches K. However, since data are not available to evaluate these density dependent effects in cheetah, we elected not to include these density dependent effects in these models.

We used values of K over the range of 1,500 to 6,000 to span the range of possible values for the dry and wet cycles for Namibian farmlands and to encompass the Botswana population when set at 6,000. The value of 2,500 was examined as a possible Namibian management target for population size. Also the Namibian population is thought to have been stable for several years at an estimated size of 2,500 animals. The population in Etosha National Park is estimated at about 100 animals. It is separated from the farmland population by fencing (although this may not bar exchange) and is subject to different threats. We included annual environmental variation (EV) in K in a set of simulations with K set at 4000 and SD set at 600 or 15% of K. This would provide fluctuations over the range of about 2800 to 5200 animals

(±2 SD for 95% of cases in a normal distribution). No trend of change in K was tested. Environmental variation effects were included in mortality and reproduction. This range of values for K would have virtually no effect on the rates of heterozygosity loss over the 100 year time period of these projections. Also the addition of heterozygosity to the population by new mutations will be significant with populations this large (the rate of addition will increase approximately linearly with effective population size) and counterbalance the loss of heterozygosity by random drift.

Inbreeding Depression (not included in the models)

It is recognized that the cheetah population may be subject to the effects of inbreeding depression in the population already present as a result of historical events in the species. This may impact the wild population's vulnerability to disease events. These intrinsic demographic effects on reproduction and mortality are already incorporated in the estimates of mortality and reproduction in the present population used in the models. However, we did not use the option (included within VORTEX) for additional inbreeding depression effects on juvenile mortality in the future projections for the farmland cheetah models. Their relatively large population (>1,000) size will result in a low rate of heterozygosity loss by drift or randomly over the 100 year time period of these projections. Also, the model does not include the acquisition of heterozygosity with new mutations. This source of heterozygosity increases with increasing population size and will be significant, with respect to the rate of loss of heterozygosity by random drift, with populations in the thousands. Inclusion of inbreeding depression has no detectable effects in the model on the dynamics of populations of 1000 or more animals over the 100 year (about 18 - 20 cheetah generations) time span of these projections. The loss of heterozygosity over 100 years, from the start of the simulations, in populations of this size would be less than 1% of the starting level of heterozygosity or less than 0.05% per generation. This rate and magnitude of loss has no detectable additional effect on juvenile mortality or other population parameters regardless of the level of heterozygosity in the starting population or the average number of lethal equivalents (up to 10) per individual carried in the population at the start of the simulations. The model does provide and report information on the rate of loss of heterozygosity, the rate of allelic loss, and the rate of inbreeding under each scenario. There is no known way to estimate inbreeding depression effects on fitness from measured levels of molecular heterozygosity (DNA, RNA, or protein) for which there are no control comparisons.

Starting Age Distribution (stable).

We initialized the model runs with a stable age distribution, which distributes the total population among the sex-age classes in accordance with the specified mortality and reproductive schedules in the scenario, using a deterministic Leslie Matrix algorithm. Deterministic values for population growth rate, generation time, adult sex ratio, and age structure are calculated and reported in the output.

Starting Population Size (1,500 to 6,000)

We used starting population sizes of 1,500, 2,500, 4,000 and 6,000 cheetah representing the range of possible population sizes in dry and wet years and considering the Namibian population alone or connected with that in Botswana.

Iterations and Years of Projection (100 years and 200 repetitions).

Each scenario was repeated 200 times, and projections were made for the next 100 years. Output results were summarized at 10-year intervals as used in the time series figures. Each scenario tabulated in the tables has a corresponding file number for reference and retrieval of other results, if needed. The simulations were run using VORTEX versions 7.1 and 7.2 dated January or May 1996. Comparisons may be made across the data tables of files with the same file number (but a different letter prefix) whose parameter values are the same except for the specific parameters being tested and reported in that table.

Sample Input File

A sample input file used to initialize the model for one of the base scenarios for the farmland cheetah population is included at the end of this section (Table 1). The information input for each request and the question are shown in the order in which they appear in the program.

Results

Deterministic Results

We list the stochastic 'r' values for each scenario in the tables. The stochastic r values are usually lower, but never higher, than the deterministic r values, which are not reported here. Deterministic outputs in each scenario included values for the growth rate of the population (r, lambda, and Ro), the generation times for males and females, the stable age distribution, and the adult male-to-female sex ratio (Table 2). The deterministic growth rate was calculated by a Leslie matrix algorithm. Positive values of 'r' are necessary for a population to survive or grow, and, in principle, a zero value characterizes a stable population. Sustained negative values inevitably lead to extinction. The deterministic growth rate is not sensitive to differences in starting population size, K, or environmental variation, but varies with level of mortality, reproductive values, and the additional mortality imposed by catastrophes. The generation times for female cheetah varied from 5.0 to 5.5 years and from 6.6 to 7.0 years for males. This value is a function of age of first reproduction, maximal breeding age, and interbirth interval. Thus, there are about 17 to 20 cheetah generations in 100 years. The male to female sex ratio of adults varied between 0.49 and 0.54 depending upon imposed male mortality rates.

Stochastic Results

Base scenario

Means (and SD for r and N), calculated over the 200 iterations at 100 years, are given for stochastic population growth rates (r stoc), probabilities of extinction (Pe), final population size (N), retention of genetic heterozygosity (Het) and mean time to extinction (Te) (Tables 3-9, Figs. 3-14). Stochastic population growth rates and the probability of extinction are sensitive to the values and the variances entered for each of the demographic and reproductive parameters.

A first approximation for a baseline scenario was constructed with *natural mortality* of 10% in the > 1 year female and male age classes with no catastrophe (Figure 3; Table 3 a, #38) and including a catastrophe of 5% frequency and 0.65 severity effect on survival and no effect on reproduction of the survivors (Table 3 a, # 032; Figure 4). The proportion of females with no litter was set at 40%, mean litter size was 3.5, starting population size (N) and carrying capacity (K) were set at 2,500, and first year mortality was 46%. The set of conditions with no catastrophe yielded an r = 0.179 and with inclusion of the 5% catastrophe yielded a projected mean stochastic 'r' of 0.156 or a population growth rate of about 17% per year. Both scenarios yielded a zero probability of extinction at 100 years, mean 100 year population size at the carrying capacity of 2500 and the loss of less than 1% of heterozygosity in 100 years. The populations, under these conditions, have the potential to double in size in 4 - 5 years, if growth is unrestrained. Alternatively, these populations might sustain the removal of 200-300 animals, of the appropriate age and sex structure, each year and still remain at the target size of 2,500 animals. The current removal rate is estimated at about 250 animals per year and the population is thought to have been stable at about 2,500 animals in recent years so this base scenario (with female mortality at 20%), (Table 3 a, #s 036 & 042 and Figures 3 & 4) may approximate current conditions.

Since this is a relatively fecund, polygynous species, the mortality rate of adult females will be a critical rate limiting factor on the population growth rate, as shall be demonstrated in latter scenarios. Since adult (breeding age) females comprise about 27% of the population, under these conditions, then the removal of adult females from the population would need to be limited to about 60 - 70 females per year as their proportional share of the 200 - 300 animals that might be removed while maintaining a stable target population.

We explored the effects on these population growth characteristics of varying the number, frequency and severity of catastrophes (Tables 3 & 4), varying adult mortality (Tables 3 - 9), varying the ratio of adult male-to-female mortality (Tables 4 - 6), varying the starting population size (Table 9), and varying carrying capacity (Table 9). Parameter values resulting in a significant probability of extinction or low or negative population growth rates or sustained reduction in population size provide an idea of the limits of the resilience of the cheetah population in response to catastrophes, conditions needed for management of a stable target population, and the rate and composition of removals that might be needed to maintain a stable population size.

Probability of Extinction

Projected 100 year probabilities of population extinctions with total adult female average annual mortality of 20% or lower were zero except in the extreme scenarios with a 20% catastrophe frequency and a reduction in survival of 50% in these catastrophes. Scenarios with 30% adult female mortality had probabilities of extinction ranging from 14% to 100% depending upon the frequency and severity of the catastrophes (Figure 5). However, if the population continues to decline at the 4 to 7% annual rate experienced until recently, there is a 50 to 100% probability of extinction in the next 100 years. The population appears to have a robust growth potential of 10 to 15% per year if it is subjected to only natural mortality. Under these conditions of no human induced mortality the population could double in size in 5 to 7 years if undisturbed. Analysis of the model outputs, from scenarios using different sets of parameter values,

Stochastic Growth Rate

<u>Mortality effects</u>

Population growth rates are sensitive to 'natural' mortality rates in each of the age and sex classes, to the added effects of environmental variation on mortality rates, to human-induced added mortality, and to added catastrophe-induced mortality.

With all other conditions the same as in the base scenario, a 30% adult female mortality rate resulted in a high probability of extinction, Pe = 0.48, (Table 3 a), negative population growth rate, r = -0.058, and a declining population size even with no catastrophe included in the scenario (Figure 3). Increasing the starting population size to 6,000, on the assumption that the Namibian cheetah population is closely connected to the one in Botswana and using the high end assumption of population sizes does not alter the negative growth rate or the rapid rate of population decline (Figures 5 & 6). The probability of extinction at 100 years is lower (Pe = 0.22) but the population sizes of the surviving populations are low and still in decline so that final extinction of all populations would be only a matter of time. The risk of extinction would be further increased if during this time additional catastrophes occurred. The demographic and genetic impact on the Namibian population of the connection with the Botswana population depends upon the rate of exchange between the two populations. Low rates of exchange (<0.05% per year) could sustain gene flow between the populations and keep them essentially panmictic but would not provide demographic support in a rapid decline. If one population were declining, it would tend to act as a 'demographic sink' for the other population and possibly contribute to its decline as well if there were a significant differential rate of movement (2 - 5% per year) from one to the other. To be demographically significant this movement would have to include females.

Interactions of adult mortality and catastrophe frequency on a scenario with a catastrophe of 0.65 severity on survival (35% increase in mortality in the year of the catastrophe) yielded a family of curves for projected stochastic population growth rate (Figure 7)(Tables 3 a & 3 b, Files 032 - 037 and B32 - B37). Results indicate that 15 to 25% average annual adult mortality is the maximum that can be sustained with a catastrophe of this severity and these frequencies. Variation of catastrophe severity (0.5, 0.65, 0.8, and 1.0) on survival at a 5% frequency indicated a proportional decline in population growth rates with an increase in severity of the catastrophe even though they occurred with only a 5% probability or at an average frequency of 5 times in 100 years (Figure 9). Similarly population size declines significantly at adult mortality rates greater than 20% per year (Figure 10) even with no catastrophe effects (severity = 1.0) included in the scenario. A 5% increase in female mortality reduces the 'r' value by 0.040 to 0.045 in the range of positive values of 'r'. An increase in catastrophe severity of 0.15, at 5% frequency, on a female mortality rate of 0.15 decreases the value of 'r' by 0.010 to 0.012.

Wide variations in male mortality rates had little effect on the growth rate of the population, as expected in a polygynous species. Data on animals killed indicate that consistently more males than females are removed from the farmland population (Marker-Kraus et al. 1996). The possible demographic impact of these selective male removals was examined by varying the ratio of the male to female mortality rates. The scenarios tested included variable female mortalities with a constant male mortality rate of 30% (Tables 4 a & 4 b; Figures 11 & 12), with the male mortalities 1.5 times the female rates as the female rates were varied from 5 to 30% (Table 5), and with male mortality rates 2.0 times the female rate (Table 6). These scenarios yielded a family of 'r' value curves identical with those observed with male rates equal to female rates (Figure 7). These results indicate that the demographic characteristics of this cheetah population are relatively insensitive to a wide variation in male mortality rates. The increase in proportional male mortality has a small effect of 0.5 to 1.0% on the retention of heterozygosity in the populations at 100 years. Thus under extreme conditions the rate of heterozygosity loss might approximately double. The magnitude of this loss would be a function of population size.

Increasing the frequency of catastrophes from 5% to 10% (Tables 3 b and 4 b), or even higher (Figures 7 & 8) as suggested in some of the disease scenarios, effectively increases the average mortality, decreased the population growth rate, produced more rapid population declines and increased the probability of extinction depending upon the mortality rate of females due to other causes. This means that progressively lower female mortality rates can be allowed at higher catastrophe probabilities if the population is to be sustained at the target levels. At a 10 year average catastrophe frequency, average annual female mortality in the range of 20 to 25% can result in declining population growth (Figures 14).

Reproduction rate effects

Reproductive rates are sensitive to age of first reproduction, mean litter size, and proportion of females with litter size = 0 each year (interbirth interval). Each of these rates is also susceptible to the effects of environmental variation.

We did not model changes in the age of first reproduction or in mean litter size. Increasing the reproductive rate by increasing the proportion of females that produce a litter each year to 75% (25% of females not producing a surviving litter from 40% not reproducing in most of the scenarios) increases the population growth rate (r) by 0.05 to 0.07 (about 5 to 7% per year) and would enable the population to sustain a higher female mortality rate under any given set of catastrophe conditions. Thus a 25 to 28% female mortality rate when the catastrophe frequency is 5% (Tables 7 & 8) would still allow the populations to survive. Interbirth interval may become shorter under optimal habitat conditions during a wet period but this is not considered likely under the prevailing dry conditions so the value of 40% of females with no litter in a given year was used in most of the scenarios.

Catastrophes

The recent CDV epidemic in the Serengeti and the concern for the vulnerability of cheetah to FIV, anthrax, and other diseases prompted modeling of potential disease catastrophes over a range of frequencies and severities (Tables 3 - 9; Figures 7, 8, 13, & 14). Simulation results indicate that the growth rate of the cheetah population is affected by catastrophes occurring at average frequencies (probabilities of occurrence) as low as 5% depending on the severity of their effects on survival and reproduction. A minimum catastrophe risk of 5% with severity effects of 0.8 on both mortality and reproduction (a 20% reduction in reproduction and in survival in the year of the event) would reduce the annual population growth rate in the base scenario with 10% natural adult mortality from about 17% to about 16% per year. This would have no detectable effect on average population size. There would be no detectable effect of such catastrophes on average population size over 100 years at total female mortalities up to 20% (natural plus human induced). A 20% reduction in population size would be restored in 2 to 5 years with average annual female mortality rates of 10 - 20%. The adverse effects of more severe catastrophes on population size and growth rate, whether due to drought or disease, could be ameliorated by reducing the rates of removals from the population or specifically by reducing the rate of killing of females while the population is recovering. It is not clear what level of mortality from a disease event would be detected with current monitoring capabilities or through reporting by the farmers.

Carrying capacity and starting population size effects

Variation in carrying capacity and the starting population size over the range of 1,500 to 6,000 had no effect on the stochastic or deterministic population growth rate (r) with or without the inclusion of catastrophe events (Table 9). There was no effect on growth rate of setting the starting population size either equal to or less than the carrying capacity. Variation of K from year to year by inclusion of an environmental variation effect also had no effect on the population growth rate (Table 9). These results are as expected since the carrying capacity simply places a limit on the allowed maximum population size by randomly removing animals proportionately across all age classes in any year when this limit is exceeded.

Population Size

Comment

Projected mean surviving population size with its standard deviation at 100 years in relation to the set carrying capacity provides an indicator of the impact of the interaction of all of the parameters and their variation on the population. Thus monitoring of population size or some average density estimate and of human induced added mortality provide a basis for management. Population models provide a tool to evaluate the monitoring information against projections and provide a basis for testing the effects of selected management options. The models are subject to continued testing and modification in the same process with collection of new data. Widely fluctuating population sizes during the time course of the simulations, as indicated by the magnitude of the standard deviation, suggest greater uncertainty about the outcome in individual populations and the need for closer monitoring of the real population. Populations may stabilize, on average, at levels below the set carrying capacity with the occurrence of catastrophes or with widely fluctuating environmental variance.

Historical observations

An estimated 6,800 cheetah were removed from the wild from 1980 to 1991 according to compiled data. During the same time period it is estimated that the cheetah population declined about 50% to about 2,500 animals. This 50% decline in the cheetah population implies an annual negative growth rate of about 4 to 7%. Since no evidence was presented for a natural catastrophe during that time or for an increase in natural mortality, it is likely that the documented rate of cheetah removal exceeded the rate of replacement of the population by reproduction and immigration. Natural mortality rates of 10% combined with an additional 20% mortality, imposed by shooting and capture for export, to yield a 30% or greater total annual female mortality rate and a comparable or greater loss of males would produce negative growth rates in the range of 4 - 7% and account for the population decline. This excess mortality could be accomplished by removal of 800 to 1000 animals per year from a population of 5-6,000 at the beginning of the decline with the absolute number removed each year declining as the population size declined. Thus the recorded rate of cheetah removal from the population (Figure 2) and the estimated magnitude of the population decline with the estimated rate negative growth rate were simulated by the scenario with a total annual female mortality rate of 30% ± 7% and without the inclusion of any catastrophe events. Reproductive rates in this scenario were the same as in the base scenario. The reproductive rates were estimated from independent data as was first year mortality. These results provide an internal consistency check on the parameter values selected for the base scenario.

Current removal rates

Using the same base scenario values for parameter values, the current population of 2,500 animals might sustain an annual removal rate of 10% of adult females and 10 - 20% of adult males per year (above the natural mortality rate of 10% and assuming no natural catastrophes during the periods of removal) and still maintain a positive growth rate. Since about 27% of the population in these scenarios is estimated to be adult females, removal of about 60 to 70 adult females per year would be the maximum annual harvest rate this population would likely be able to sustain. This rate should allow maintenance of a stable population size and a margin of positive growth potential to buffer against annual environmental variation in natural reproduction and mortality. However, the occurrence of any catastrophic events would require downward adjustment of this rate of removal until the population had regained its target size.

If female cheetah exchange (migration) with neighboring populations in Botswana is occurring then population growth rates in Namibia might be buffered from higher losses depending upon the rate and direction of migration of females. If average migration rates of 5-10% of the population are occurring then the two populations could function as a single demographic unit. Estimates of the possible rate of exchange or migration into Namibia would allow a closer estimate of the demographic reinforcement from Botswana that might occur. Much lower rates (less than 0.1% per year) are needed to provide sufficient gene flow for sustaining a panmictic population, assuming that breeding of some of the exchanged individuals occurs.

Population growth rate effects

The average surviving cheetah population size projected to 100 years, starting from 2,500 animals (with 40% ± 10% of females not producing a litter each year), declines when adult female average annual mortality is 20% or greater for all values of catastrophe severity and frequency (Tables 3- 9; Figs. 4, 6, 8, 10, 12, & 14). If no catastrophe events are included in the model, populations can sustain about 20 - 25% female mortality and maintain a positive growth rate. Addition of any catastrophes at an average frequency of 5% (once in 20 years) reduces the sustainable level of annual female mortality to less than 25%. The risk of extinction over 100 years rises rapidly when these mortality rates are exceeded. Variations of male mortality rates up to double those of female mortality rates had no effect on the population size. Thus management of adult female mortality rates is critical for managing population size through management of population growth rates. Changing management based removals in response to catastrophic population losses or declines would assist population recovery. Monitoring of animals removed from the population or killed will need to include information on the sex of the animals and general age class (cub, juvenile, adult) if these data are to be most useful for management directed at maintaining the target population size.

Carrying capacity and target population size

Increasing the population size delays the median time to extinction under any given scenario conditions. Thus larger population sizes potentially have a longer time and greater capacity to recover from periods of increased mortality whether due to climatic factors, loss of prey, reduction in carrying capacity, or human induced mortality. Retention of heterozygosity and accumulation of new heterozygosity by mutation through time are also functions of population size as a determinant of effective population size. Each of these factors needs to be considered when selecting the target population size for management.

Retention of Heterozygosity

There was 1% or less loss of heterozygosity over 100 years in the populations, ranging in size from 1,500 to 6,000, with stochastic growth rates of 2% or more (Tables 3 - 9). This reflects the fact that randomly breeding populations of these sizes and with these growth rates are sufficiently large to minimize losses due to random drift effects. This rate of heterozygosity loss would be less than 0.05% per generation and would result in no detectable additional adverse inbreeding effects over the 100 year time span. Projected populations that did not grow or that declined in size lost 3% or more of their heterozygosity over 100 years which amounts to 0.1 to 0.3 % per generation. Heterozygosity values in these scenarios may underestimate the rate of heterozygosity loss depending upon the breeding structure of the population, the proportion of breeding males available, and the distribution of life-time reproductive success of males and females.

Summary and Recommendations

1. Manage the cheetah population on the farmlands so that 10% or less of the adult females and 20% or less of males are removed annually. For a population size of approximately 2,500 animals this would be about 60 to 70 adult females per year. This would provide a margin of safety for uncertainties in estimates of density, uncertainties in knowledge of natural female mortality rates, in female reproductive rates, in directions and rates of migration, and in estimates of fluctuations in natural mortality.

2. Removal of males needs to continue to be given preference over the removal of females in the control of problem animals in the farmland population. Population viability and growth rates are not as sensitive to male mortality rates over a wide range. Total annual adult male mortality rates of 30-35% will have no effect on population growth rates. It will be useful to further evaluate the genetic consequences of such a strategy.

2. Improve the estimates of annual female natural and especially removal mortality rates as a guide to possible population growth rate impacts and to provide management guidance on the number of removals that can be allowed and sustain a viable population. Reporting by the farmers of removals by sex will provide a useful estimate.

4. Improve estimates of the proportion of females not producing a litter (that survives to the age of 3-4 months) each year. This estimate and estimates of cub survival (observed litter size) to the age of about 1 year can serve as an indicator of environmental variation effects on reproduction. Correlation with environmental or habitat (prey density) data may provide a useful management index.

5. Evaluate the impact of continued excess loss of adult females during the dry phase years on stability of population size and on the management target for the population.

6. Estimate the confidence limits of the methods used to estimate population density, available habitat, and calculated population size as a basis for estimating the magnitude of change and the number of years of change required to detect different rates of population change (decline or increase). For example, what effort, frequency of measurement, and measurement reliability would be required to detect the 4-7% annual decline in population size estimated to have occurred since 1980? Estimates of these parameters can be done with modeling and statistical methods using currently available data and theory. These estimates would provide a basis for the amount of effort required to monitor the status of the population, to detect changes in the population, and to allow adjustments of management.

Figure Legends:

Figure 1. General distribution map of cheetah in Namibia. There is some population fragmentation. The cheetah population in Etosha National Park, about 100 animals representing 5% of the total population, is relatively isolated from the farmland population of about 2,500 animals.

Figure 2. Estimated numbers of cheetah removed annually from Namibia by killing (circles) and for export based upon CITES data. The difference between the curves for killing and total (squares) represents the numbers exported.

Figure 3. Projected mean population sizes at 10 year intervals for 100 years for increasing rates of adult cheetah mortality with *no catastrophes* included in the simulations. There appears to be a break between 25 and 30% adult mortality rates.

Figure 4. Projected mean population sizes (N) at 10 year intervals for 100 years for increasing rates of adult cheetah mortality with a catastrophe of 5% frequency and a reduction in survival of 50%. There is an impact at all levels of adult mortality, but in the scenarios with 25 and 30% adult annual mortality rates the populations will become extinct.

Figure 5. Interaction of 30% adult female mortality and carrying capacity on projections of Pe, probability of extinction. The starting population size was set at the carrying capacity with K. One catastrophe at 5% probability of occurrence with the severity effect on survival and reproduction set at 0.8 (a 20% reduction for the year of occurence).

Figure 6. Interaction of 30% adult female mortality and carrying capacity on projections of N, mean surviving population size at 100 years. The starting population size was set at the carrying capacity with K = 1,500, 2,500, 4,000, or 6,000. The scenarios included one catastrophe at 5% probability of occurrence with the severity effect on survival and reproduction set at 0.8 (a 20% reduction).

Figure 7. Mean stochastic growth rates (r) as a function of interaction of adult annual mortality rates and frequency of a catastrophic event. The catastrophe survival severity was set at 0.65 for an increase in mortality of 35%. The five curves are, from top to bottom, for catastrophe frequencies of 0% (no catastrophe), 5% (20 years on average), 10% (10 years), 14% (7 years), and 20% (5 years), respectively.

Figure 8. Projected mean population sizes (N) at 100 years as a function of adult annual mortality rates and catastrophe frequency. Other parameter values for all scenarios are as in Figure 3.

Figure 9. Effects of increasing adult male and female annual mortality rates and increasing severity of a catastrophe on mortality (S = 1.0, 0.8, 0.65, or 0.5) at 5% frequency (every 20 years on average) on the mean stochastic growth rates (r). The proportion of females with no litter each year was set at 40%. The top curve (squares) is with no catastrophe.

Figure 10. Effects of increasing adult male and female mortality rates and increasing severity of a catastrophe at 5% frequency (every 20 years on average) on the projected mean population size at 100 years. The proportion of females with no litter each year was set at 40%. The top curve (squares) is with no catastrophe.

Figure 11. Effects of increasing adult female mean annual mortality rates, with the male annual mortality rates held constant at 30%, and increasing severity of a catastrophe on mortality at 5% frequency (every 20 years on average) on the stochastic growth rates. The proportion of females with no litter each year was set at 40%.

Figure 12. Effects of increasing adult female mean annual mortality rates with male mortality rates held constant at 30% and increasing severity on mortality of a catastrophe at 5% frequency (every 20 years on average) on the mean population size (N) at 100 years. The proportion of females with no litter each year was set at 40%.

Figure 13. Effects of increasing adult male and female mean annual mortality rates and increasing mortality severity of a catastrophe at 10% frequency (every 10 years on average) on the stochastic growth rates (r). The proportion of females with no litter each year was set at 40%.

Figure 14. Effects of increasing adult male and female mean annual mortality rates and increasing mortality severity of a catastrophe at 10% frequency (every 10 years on average) on the projected mean population size (N) at 100 years. The proportion of females with no litter each year was set at 40%.

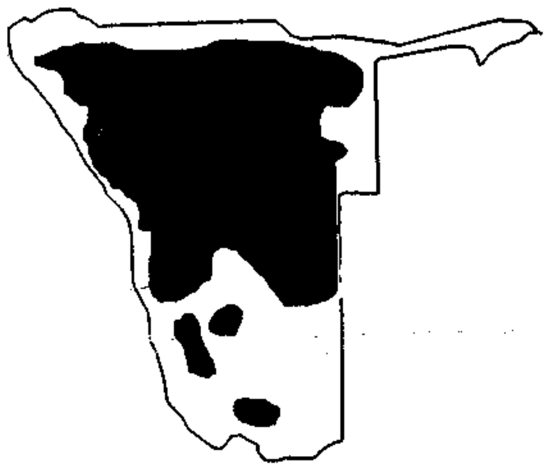

Figure 1. Generalized distribution map of cheetahs in Namibia. There are no annual census data for cheetahs in Namibia.

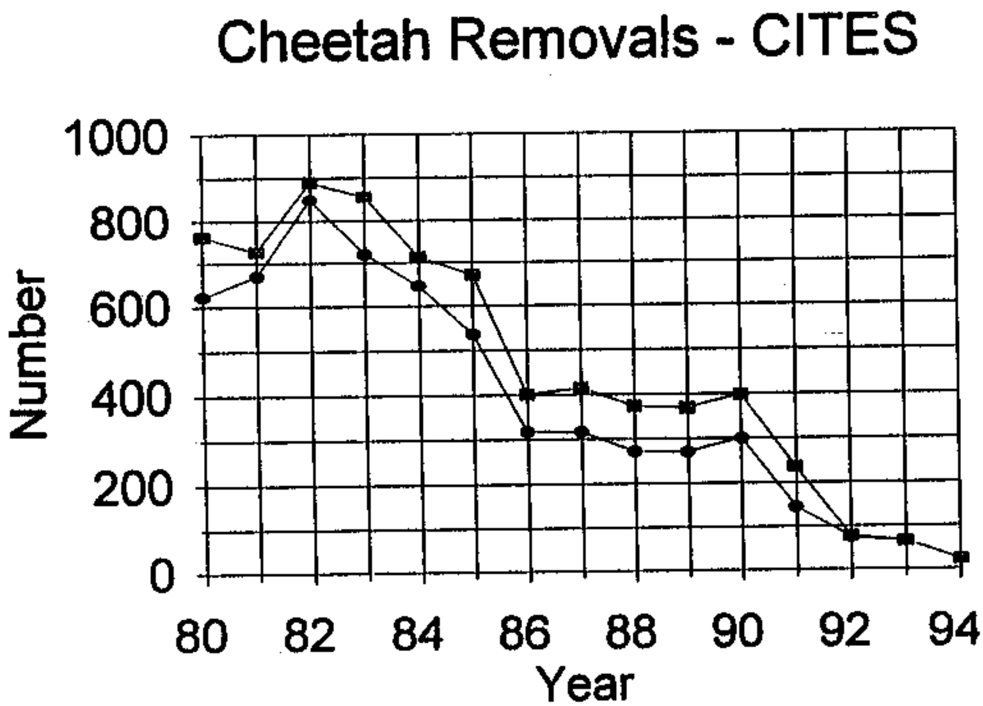

Figure 2. Numbers of cheetahs killed and exported in Namibia from 1980 to 1993 based upon CITES data. The difference between the curves for killing and total (squares) represents the numbers exported.

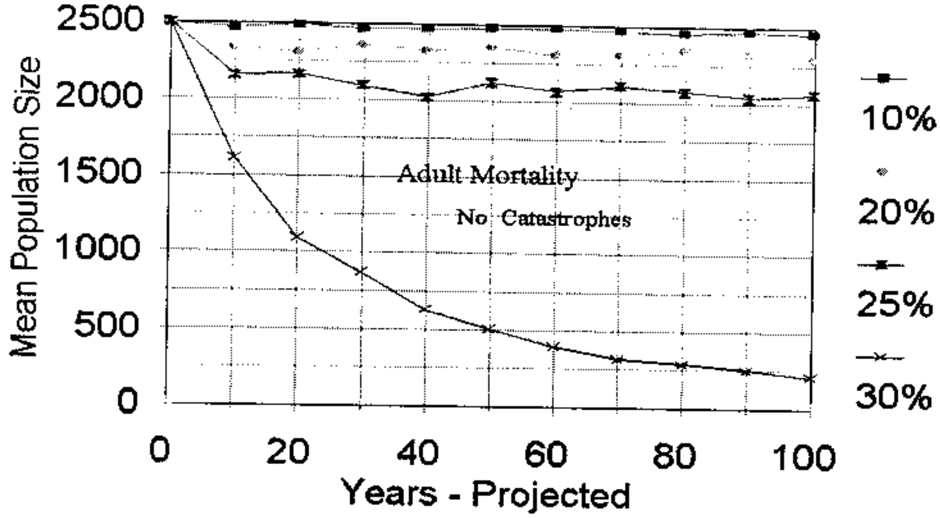

Figure 3. Effects of adult cheetah mean annual mortality (10, 20, 25, and 25%) on 'N', projected mean population size over 100 years. No catastrophes.

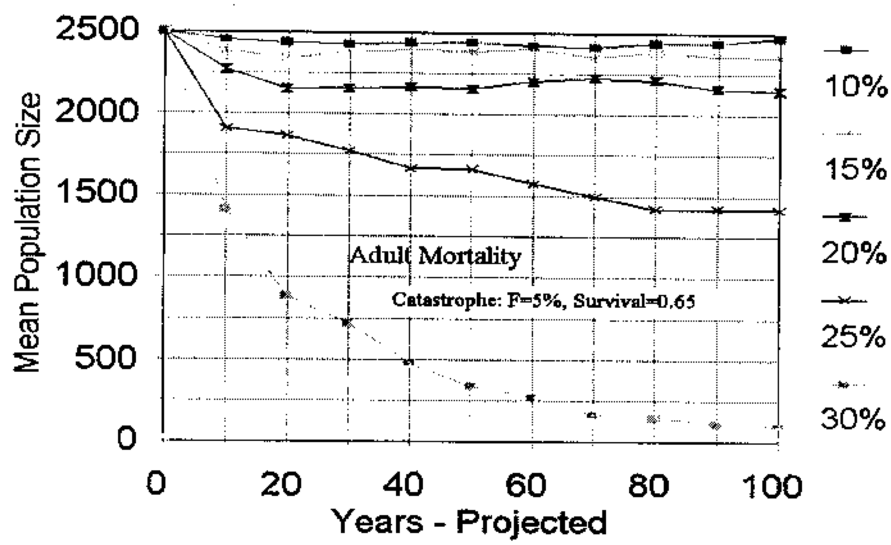

Figure 4. Effects of adult mean annual mortality (10, 20, 25, and 25%) on 'N', projected mean population size at 10 year intervals over 100 years. Catastrophe frequency of 5% (20 years) with 50% reduction in survival.

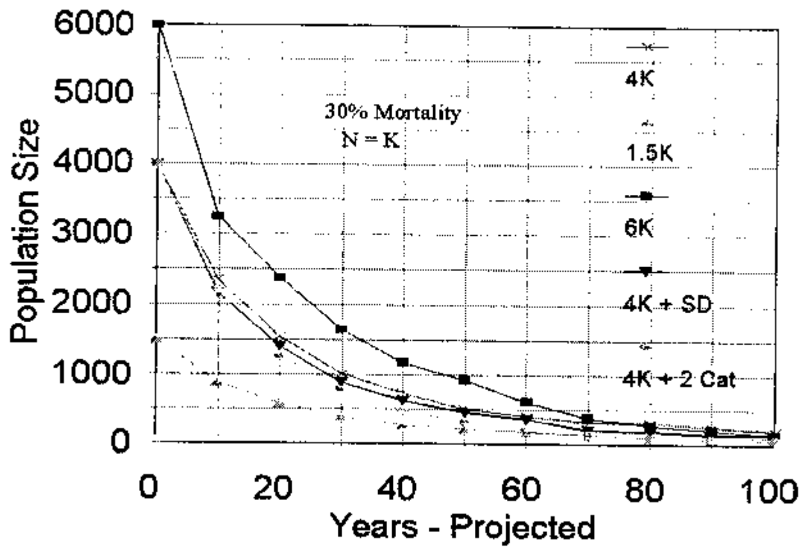

Figure 5. Interaction of 30% adult female mortality and carrying capacity on projections of Pe, probability of extinction. The starting population size was set at the carrying capacity with K. One catastrophe at 5% probability of occurrence with the severity effect on survival and reproduction set at 0.8 (a 20% reduction for the year of occurrence).

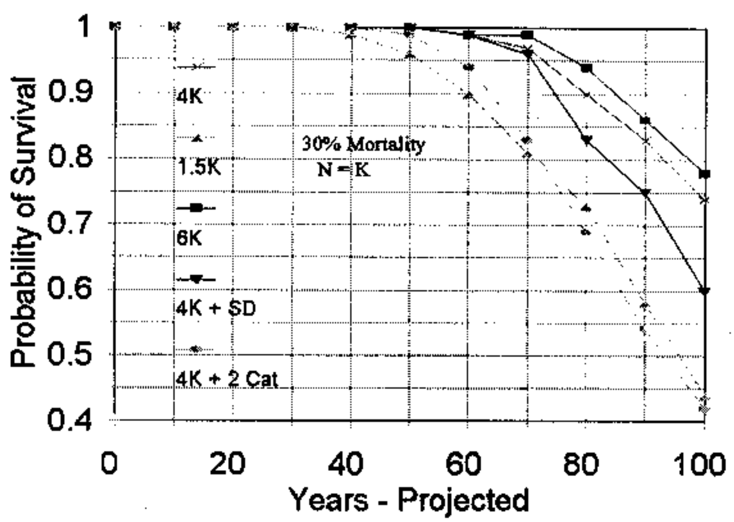

Figure 6. Interaction of 30% adult female mortality and carrying capacity on projections of N, mean surviving population size at 100 years. The starting population size was set at the carrying capacity with K = 1,500, 2,500, 4,000, or 6,000. The scenarios included one catastrophe at 5% probability of occurrence with the severity effect on survival and reproduction set at 0.8 (a 20% reduction).

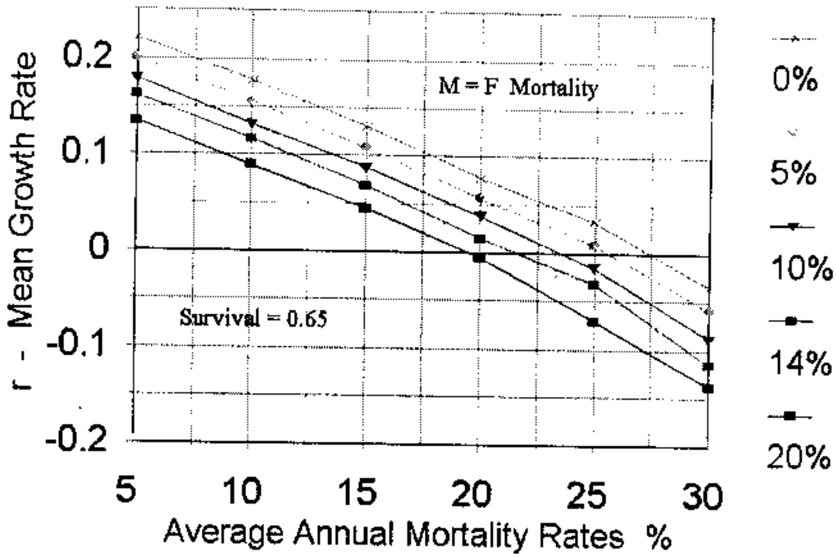

Figure 7. Interaction of adult mortality and frequency of catastrophe with a 35% increase in mortality on 'r', (mean stochastic population growth rate). Male=Female mortality. Catastrophe frequency set at 0, 5, 10, 14, or 20% (0, 20, 10, 7, or 5 years on average). Zero equals no catastrophe.

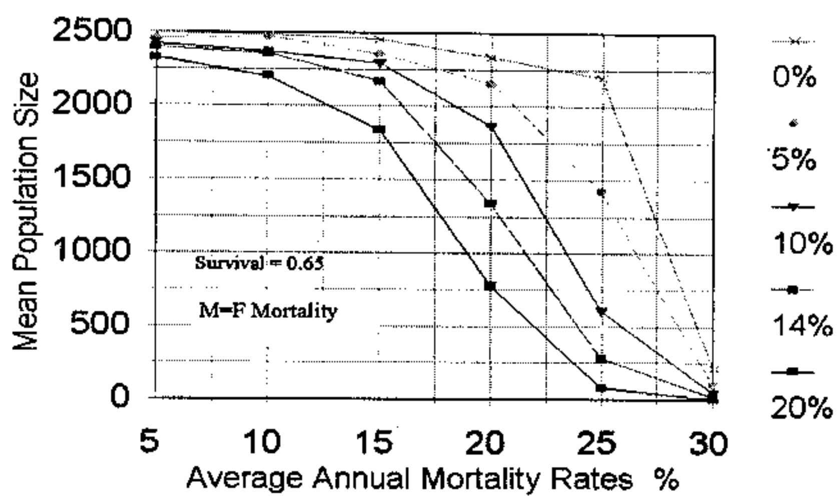

Figure 8. Interaction of adult mortality and frequency of catastrophe with 35% increase in mortality on 'N', mean surviving population size at 100 years. Male=Female mortality. Catastrophe frequency set at 0, 5, 10, 14, or 20% (0, 20, 10, 7, or 5 years on average).

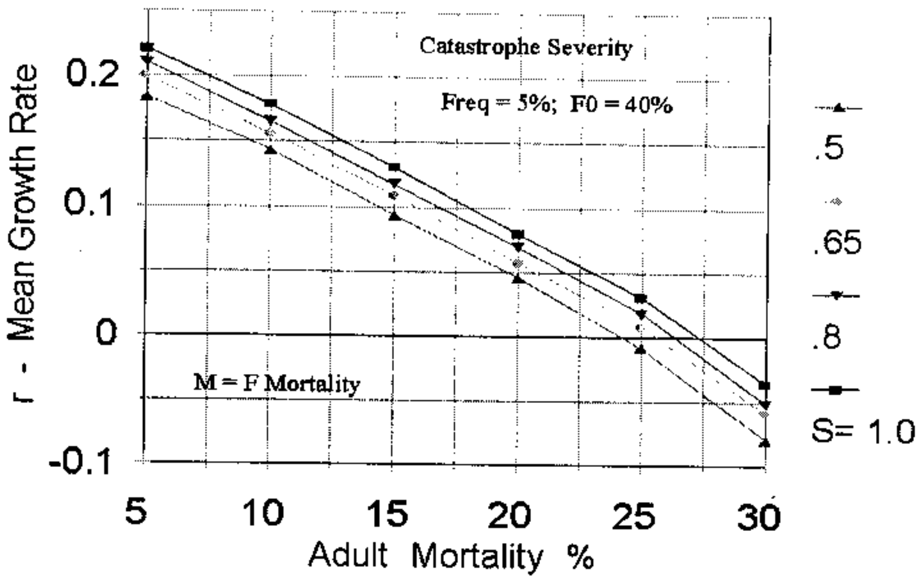

Figure 9. Interaction of increasing adult mean annual mortality (5-30%) and a catastrophe (5% frequency with 50, 35, 20 or 0% increase in mortality) on 'r' mean stochastic growth rate.

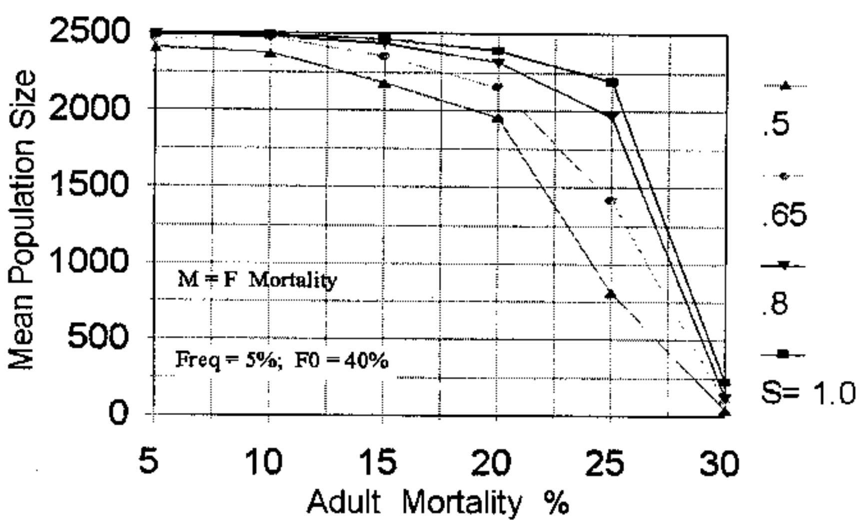

Figure 10. Interaction of increasing adult mean annual mortality (5-30%) and catastrophe (5% frequency with 50, 35, 20 or 0% increase in mortality) on 'N' the mean population size at 100 years.

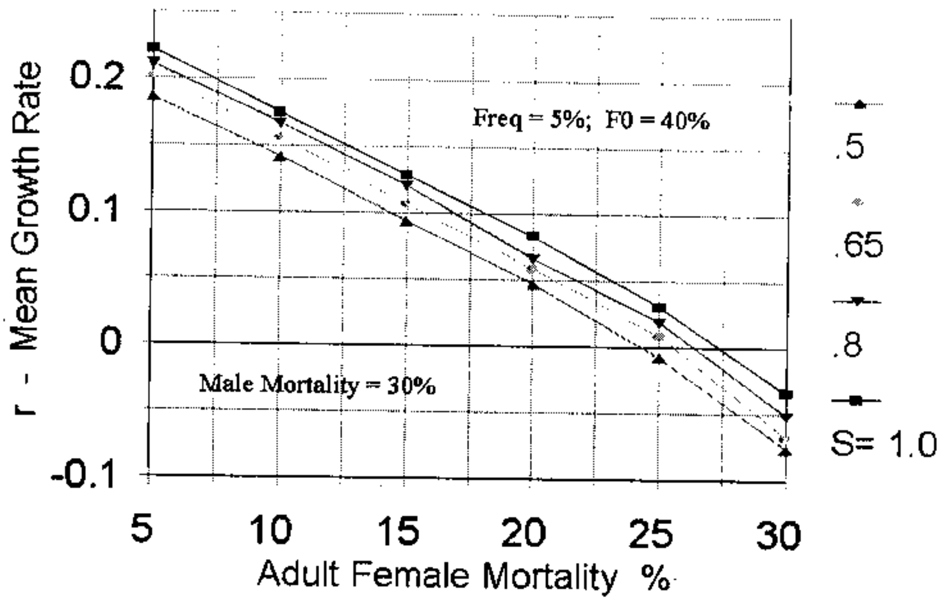

Figure 11. Interaction of increasing adult female mean annual mortality (5-30%) and catastrophe (5% frequency with 50, 35, 20 or 0% increase in mortality) on 'r', the mean stochastic growth rate. Male mortality = 30%.

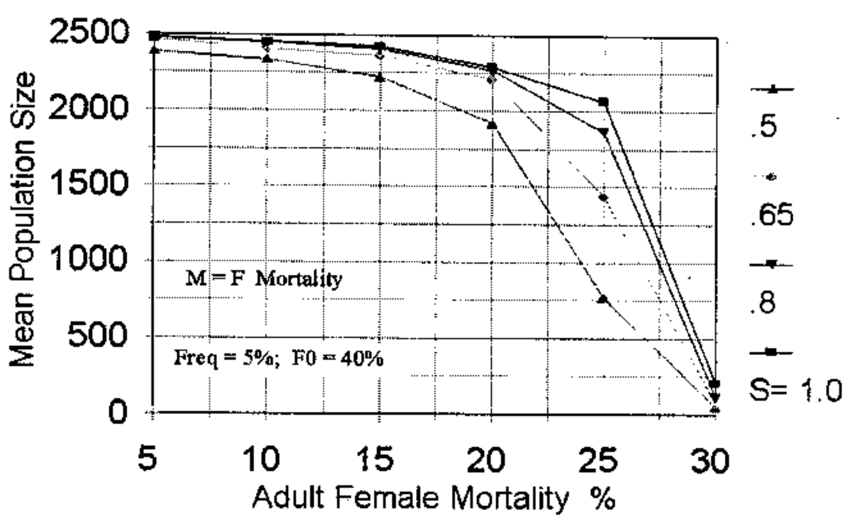

Figure 12. Interaction of increasing adult female mean annual mortality (5-30%) and catastrophe (5% frequency with 50, 35, 20 or 0% increase in mortality) on 'N', the mean population size at 100 years. Male annual mortality = 30%.

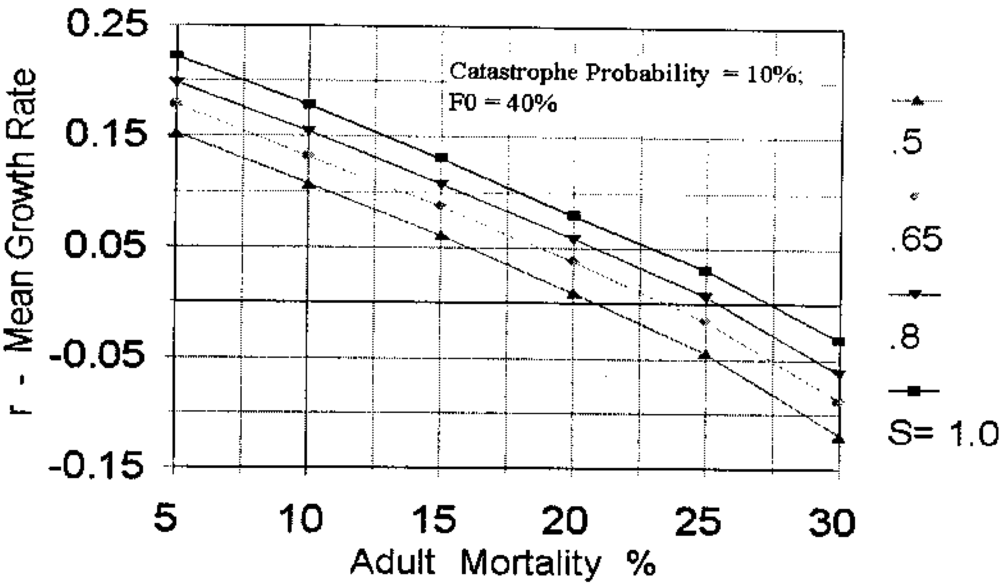

Figure 13. Interaction of increasing adult female mean annual mortality (5-30%) and catastrophe (10% frequency with 50, 35, 20 or 0% increase in mortality) on 'r' mean stochastic growth rate. Male mean annual mortality = female mortality.

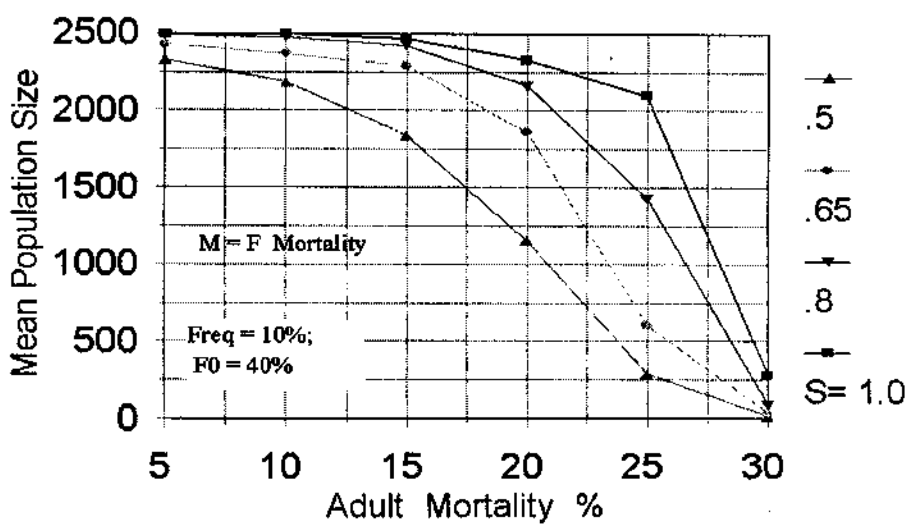

Figure 14. Interaction of increasing adult female mean annual mortality (5-30%) and catastrophe (10% frequency with 50, 35, 20 or 0% increase in mortality) on 'N', mean 100 year population size. Male mean annual mortality = female mortality.

Table 1. VORTEX input file for the base scenario.

CHEETAH.032 ***Output Filename***
Y ***Graphing Files?***
N ***Each Iteration?***
Y ***Screen display of graphs?***
100 ***Simulations***
100 ***Years***
10 ***Reporting Interval***
1 ***Populations***
N ***Inbreeding Depression?***
Y ***EV correlation?***
1 ***Types Of Catastrophes***
P ***Monogamous, Polygynous, or Hermaphroditic***
3 ***Female Breeding Age***
5 ***Male Breeding Age***
10 ***Maximum Age***
0.500000 ***Sex Ratio***
5 ***Maximum Litter Size***
N ***Density Dependent Breeding?***
40.000000 ***Population 1: Percent Litter Size 0***
0.000000 ***Population 1: Percent Litter Size 1***
0.000000 ***Population 1: Percent Litter Size 2***
30.000000 ***Population 1: Percent Litter Size 3***
30.000000 ***Population 1: Percent Litter Size 4***
0.000000 ***Population 1: Percent Litter Size 5***
12.500000 ***EV--Reproduction***
46.000000 ***Female Mortality At Age 0***
12.500000 ***EV--FemaleMortality***
10.000000 ***Female Mortality At Age 1***
3.000000 ***EV--FemaleMortality***
10.000000 ***Female Mortality At Age 2***
3.000000 ***EV--FemaleMortality***
10.000000 ***Adult Female Mortality***
3.000000 ***EV--AdultFemaleMortality***
46.000000 ***Male Mortality At Age 0***
12.500000 ***EV--MaleMortality***
10.000000 ***Male Mortality At Age 1***
3.000000 ***EV--MaleMortality***
10.000000 ***Male Mortality At Age 2***
3.000000 ***EV--MaleMortality***
10.000000 ***Male Mortality At Age 3***

3.000000 ***EV--MaleMortality***

10.000000 ***Male Mortality At Age 4***
3.000000 ***EV--MaleMortality***
10.000000 ***Adult Male Mortality***
3.000000 ***EV--AdultMaleMortality***
5.000000 ***Probability Of Catastrophe 1***
1.000000 ***Severity--Reproduction***
0.6500000 ***Severity--Survival***
N ***All Males Breeders?***
Y ***Answer--A--Known?***
66.000000 ***Percent Males In Breeding Pool***
Y ***Start At Stable Age Distribution?***
2500 ***Initial Population Size***
2500 ***K***
0.000000 ***EV--K***
N ***Trend In K?***
N ***Harvest?***
N ***Supplement?***
Y ***AnotherSimulation?***

Table 2. Partial output file for the base scenario from the input file of Table 1.

VORTEX -- simulation of genetic and demographic stochasticity
CHEETAH.032
Fri Feb 16 04:30:35 1996

1 population(s) simulated for 100 years, 100 iterations

No inbreeding depression

First age of reproduction for females: 3 for males: 5
Age of senescence (death): 10
Sex ratio at birth (proportion males): 0.50000

Population 1:

Polygynous mating;
66.00 percent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

40.00 (EV = 12.65 SD) percent of adult females produce litters of size 0
0.00 percent of adult females produce litters of size 1
0.00 percent of adult females produce litters of size 2
30.00 percent of adult females produce litters of size 3
30.00 percent of adult females produce litters of size 4
0.00 percent of adult females produce litters of size 5

46.00 (EV = 12.46 SD) percent mortality of females between ages 0 and 1
10.00 (EV = 3.00 SD) percent mortality of females between ages 1 and 2
10.00 (EV = 3.00 SD) percent mortality of females between ages 2 and 3
10.00 (EV = 3.00 SD) percent annual mortality of adult females (3<=age<=10)
46.00 (EV = 12.46 SD) percent mortality of males between ages 0 and 1
10.00 (EV = 3.00 SD) percent mortality of males between ages 1 and 2
10.00 (EV = 3.00 SD) percent mortality of males between ages 2 and 3
10.00 (EV = 3.00 SD) percent mortality of males between ages 3 and 4
10.00 (EV = 3.00 SD) percent mortality of males between ages 4 and 5
10.00 (EV = 3.00 SD) percent annual mortality of adult males (5<=age<=10)
EVs may have been adjusted to closest values
possible for binomial distribution.
EV in reproduction and mortality will be correlated.

Frequency of type 1 catastrophes: 5.000 percent
with 1.000 multiplicative effect on reproduction
and 0.650 multiplicative effect on survival

Initial size of Population 1:
(set to reflect stable age distribution)

Age 1	2	3	4	5	6	7	8	9	10	Total	
324	246	185	141	106	80	61	46	35	26	1250	Males
324	246	185	141	106	80	61	46	35	26	1250	Females

Carrying capacity = 2500 (EV = 0.00 SD)

Deterministic population growth rate (based on females, with assumptions of no limitation of mates, no density dependence, and no inbreeding depression):

r = 0.156 lambda = 1.169 R0 = 2.357
Generation time for: females = 5.49 males = 6.93

Stable age distribution:

Age class	females	males
0	0.182	0.182
1	0.083	0.083
2	0.062	0.062
3	0.047	0.047
4	0.036	0.036
5	0.027	0.027
6	0.020	0.020
7	0.015	0.015
8	0.012	0.012
9	0.009	0.009
10	0.007	0.007

Ratio of adult (> = 5) males to adult (> = 3) females: 0.521

Population 1

Year 10
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Population size = 2450.41 (15.98 SE, 159.77 SD)
Expected heterozygosity = 0.999 (0.000 SE, 0.000 SD)
Observed heterozygosity = 1.000 (0.000 SE, 0.000 SD)

Number of extant alleles = 1411.73 (8.59 SE, 85.89 SD)

Year 100
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Population size = 2472.26 (13.25 SE, 132.48 SD)
Expected heterozygosity = 0.991 (0.000 SE, 0.001 SD)
Observed heterozygosity = 0.991 (0.000 SE, 0.002 SD)
Number of extant alleles = 209.92 (0.93 SE, 9.29 SD)

In 100 simulations of Population 1 for 100 years:
0 went extinct and 100 survived.

This gives a probability of extinction of 0.0000 (0.0000 SE),
or a probability of success of 1.0000 (0.0000 SE).

Mean final population for successful cases was 2472.26 (13.25 SE, 132.48 SD)

Age 1	2	3	4	Adults	Total	
327.64	240.67	182.14	144.09	345.00	1239.54	Males
326.95	236.12			669.65	1232.72	Females

Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was 0.1556 (0.0016 SE, 0.1636 SD)

Final expected heterozygosity was 0.9909 (0.0001 SE, 0.0008 SD)
Final observed heterozygosity was 0.9913 (0.0002 SE, 0.0022 SD)
Final number of alleles was 209.92 (0.93 SE, 9.29 SD)
****

Table 3 a. Namibian cheetah population projections - stochastic simulations.

The column headers in the tables are: **File #** = number of the VORTEX output file containing the results for this scenario; **> 1 Yr Mortal** = mean mortality rate for > 1 year age classes; **r stoc** = mean stochastic growth rate; **SD** = standard deviation of r; **Pe** = probability of extinction; **N** = mean population size of surviving populations at 100 years; **SD** = standard deviation of N; **Het** = mean heterozygosity of surviving populations at 100 years; and **Te** = mean time to extinction at 100 years.

Interaction of varying >1 year old female and male mortality from 5 to 30% and varying catastrophe survival rates on population growth rate, size, and risk of extinction. The frequency of the *catastrophe was set at 5%* (20 year average interval) with survival rate varied from 50% to 80% and with no effect on reproduction. The frequency of catastrophe is varied in Tables 1a and 1b to approximate 20, 10, 7, and 5 year average intervals.

Base scenario conditions: The age of first reproduction was set at 3 years for females and 5 years for males. Other constant parameters were: 40% of females producing no litter each year, mean litter size of 3.5, 46% 0-1 year mortality, starting population size N = 2,500, K = 2,500, 66% of males in the breeding pool, no trend in K, no density dependence of reproduction, and sex ratio at birth = 0.5. No harvests or supplementation were included. The simulations were run for 100 years with 200 repetitions.

File #	**>1 Yr Mortal**	**r stoc**	**SD**	**Pe**	**N**	**SD**	**Het**	**Te**
Catastrophe 5%: Survival = 0.500; Variable >1 year ♂ & ♀ mortality rates.								
025	5%	0.184	0.199	0.000	2405	269	99.09	0.0
020	10	0.144	0.202	0.000	2378	325	99.03	0.0
022	15	0.094	0.213	0.000	2181	463	98.91	0.0
024	20	0.046	0.219	0.000	1957	653	98.39	0.0
021	25	-0.008	0.218	0.050	810	725	94.49	75.0
023	30	-0.079	0.280	0.740	43	54	76.66	72.2

File #	>1 Yr Mortal	r stoc	SD	Pe	N	SD	Het	Te
Catastrophe 5%: Survival = 0.650; Variable >1 year ♂ & ♀ mortality rates.								
037	5%	0.200	0.155	0.000	2457	157	99.14	0.0
032	10	0.156	0.164	0.000	2472	132	99.09	0.0
034	15	0.109	0.173	0.000	2355	263	99.03	0.0
036	20	0.057	0.181	0.000	2153	434	98.91	0.0
033	25	0.008	0.178	0.010	1418	769	97.72	94.0
035	30	-0.058	0.237	0.480	96	134	83.31	77.3
Catastrophe 5%: Survival = 0.800; Variable >1 year ♂ & ♀ mortality rates.								
031	5%	0.211	0.134	0.000	2492	46	99.14	0.0
026	10	0.166	0.142	0.000	2478	88	99.11	0.0
028	15	0.118	0.152	0.000	2440	131	99.06	0.0
030	20	0.070	0.166	0.000	2316	246	98.98	0.0
027	25	0.019	0.156	0.000	1966	498	98.60	0.0
029	30	-0.051	0.221	0.360	125	163	82.38	81.2
No Catastrophe: Variable >1 year ♂ & ♀ mortality rates.								
043	5%	0.221	0.125	0.000	2497	26	99.14	0.0
038	10	0.179	0.136	0.000	2492	38	99.12	0.0
040	15	0.131	0.145	0.000	2466	106	99.09	0.0
042	20	0.080	0.157	0.000	2392	177	99.00	0.0
039	25	0.031	0.149	0.000	2196	344	98.82	0.0
041	30	-0.036	0.201	0.140	226	297	86.82	84.3

Table 3 b. Namibian cheetah population projections - stochastic simulations. Interaction of varying >1 year old female and male mortality, a *catastrophe frequency of 10%* and varying catastrophe survival rates on population growth rate, size, and risk of extinction. The frequency of the catastrophe was set at 10% with survival rate varied from 50% to 80% and with no effect on reproduction. Other conditions are as in Table 1a.

File #	>1 Yr Mortal	r stoc	S.D.	Pe	N	S. D.	Het	Te
Catastrophe 10%: Survival = 0.500; Variable >1 year ♂ & ♀ mortality rates.								
B25	5%	0.153	0.242	0.000	2329	376	99.02	0.0
B20	10	0.108	0.248	0.000	2185	524	98.85	0.0
B22	15	0.062	0.254	0.000	1840	671	98.39	0.0
B24	20	0.010	0.263	0.030	1154	892	95.28	77.0
B21	25	-0.044	0.274	0.360	290	391	87.47	77.5
B23	30	-0.119	0.328	0.950	17	20	64.02	57.1
Catastrophe 10%: Survival = 0.650; Variable >1 year ♂ & ♀ mortality rates.								
B37	5%	0.179	0.180	0.000	2426	193	99.10	0.0
B32	10	0.132	0.187	0.000	2371	278	99.07	0.0
B34	15	0.088	0.192	0.000	2291	389	98.95	0.0
B36	20	0.038	0.204	0.000	1863	579	98.46	0.0
B33	25	-0.015	0.205	0.030	606	627	93.66	81.0
B35	30	-0.088	0.271	0.830	40	51	76.12	70.3
Catastrophe 10%: Survival = 0.800; Variable >1 year ♂ & ♀ mortality rates.								
B31	5%	0.198	0.142	0.000	2487	55	99.15	0.0
B26	10	0.155	0.153	0.000	2476	70	99.11	0.0
B28	15	0.108	0.159	0.000	2424	145	99.05	0.0
B30	20	0.059	0.171	0.000	2161	377	98.93	0.0

File #	>1 Yr Mortal	r stoc	S.D.	Pe	N	S. D.	Het	Te
B27	25	0.007	0.164	0.000	1432	672	98.07	0.0
B29	30	-0.062	0.238	0.530	89	180	81.90	80.3

Table 4 a. Namibian cheetah population projections - stochastic simulations. Interaction of variable >1 year female mortality with a constant male mortality of 30% and a *5% frequency of catastrophe* with varying survival rates (0.50, 0.65, 0.80, 1.0) on population growth rate, size, and risk of extinction. The frequency of catastrophe is varied in Tables 2a and 2b to approximate 20, 10, 7, and 5 year average intervals.

Base scenario conditions: The age of first reproduction was set at 3 years for females and 5 years for males. Other constant parameters were: 40% of females producing no litter each year, mean litter size of 3.5, 46% 0-1 year mortality, starting population size N = 2,500, K = 2,500, 66% of males in the breeding pool, no trend in K, no density dependence of reproduction, and sex ratio at birth = 0.50. The simulations were run for 100 years with 200 repetitions. No harvests or supplementation were included. The simulations were run for 100 years with 100 repetitions.

File#	♀ Mort	r stoc	SD	Pe	N	SD	Het	Te
Catastrophe 5%: Survival=0.500; Variable female mortality; >1 Year Old ♂ Mortality=30%.								
049	5%	0.186	0.227	0.000	2390	288	98.36	0.0
044	10	0.142	0.229	0.000	2339	314	98.41	0.0
046	15	0.094	0.235	0.000	2222	446	98.37	0.0
048	20	0.047	0.237	0.000	1918	635	98.05	0.0
045	25	-0.007	0.238	0.030	770	627	94.64	71.7
047	30	-0.076	0.279	0.730	49	54	80.83	73.6
Catastrophe 5%: Survival = 0.650; Variable female mortality; >1 Year Old ♂ Mortality = 30%								
061	5%	0.202	0.194	0.000	2469	99	98.41	0.0
056	10	0.156	0.198	0.000	2410	221	98.53	0.0
058	15	0.107	0.200	0.000	2362	242	98.61	0.0
060	20	0.059	0.204	0.000	2206	356	98.58	0.0
057	25	0.009	0.200	0.000	1436	718	97.60	0.0
059	30	-0.068	0.246	0.640	75	126	84.30	78.3

File#	♀ Mort	r stoc	SD	Pe	N	SD	Het	Te
Catastrophe 5%: Survival = 0.800; Variable female mortality; >1 Year Old ♂ Mortality = 30%								
055	5%	0.211	0.179	0.000	2481	89	98.41	0.0
050	10	0.167	0.181	0.000	2452	140	98.58	0.0
052	15	0.121	0.183	0.000	2410	169	98.67	0.0
054	20	0.066	0.188	0.000	2266	288	98.69	0.0
051	25	0.019	0.180	0.000	1862	545	98.42	0.0
053	30	-0.051	0.218	0.380	117	149	85.96	81.9
No catastrophe; Variable female mortality; >1 Year Old ♂ mortality = 30%								
067	5%	0.222	0.170	0.000	2477	86	98.42	0.0
062	10	0.175	0.172	0.000	2454	119	98.58	0.0
064	15	0.129	0.178	0.000	2426	155	98.68	0.0
066	20	0.083	0.181	0.000	2289	234	98.74	0.0
063	25	0.031	0.174	0.000	2065	404	98.69	0.0
065	30	-0.034	0.199	0.100	211	309	88.64	86.1

Table 4b. Namibian cheetah population projections - stochastic simulations. Interaction of variable >1 year female mortality with a constant male mortality of 30%, *a catastrophe frequency of 10%*, and varying catastrop survival rates on population growth rate, size, and risk of extinction. Other conditions are as in Table 2a.

File #	**_ Mort**	**r stoc**	**S.D.**	**Pe**	**N**	**S.D.**	**Het**	**Te**
Catastrophe 10%: Survival=0.500; Variable ♀ mortality; ♂ Mortality = 30%.								
B49	5%	0.158	0.266	0.000	2312	411	98.16	0.0
B44	10	0.111	0.271	0.000	2215	483	98.09	0.0
B46	15	0.059	0.277	0.000	1718	740	97.73	0.0
B48	20	0.011	0.279	0.040	1115	833	94.72	78.2
B45	25	-0.051	0.299	0.470	334	536	87.05	73.5
B47	30	-0.110	0.324	0.960	17	18	68.54	61.3
Catastrophe 10%: Survival=0.650; Variable ♀ mortality; ♂ Mortality = 30%.								
B61	5%	0.177	0.213	0.000	2416	208	98.36	0.0
B56	10	0.132	0.220	0.000	2362	274	98.45	0.0
B58	15	0.088	0.218	0.000	2231	372	98.51	0.0
B60	20	0.038	0.226	0.000	1883	615	97.99	0.0
B57	25	-0.015	0.222	0.030	600	599	92.77	89.3
B59	30	-0.087	0.273	0.820	47	57	75.73	70.1
Catastrophe 10%: Survival=0.800; Variable ♀ mortality; ♂ Mortality = 30%.								
B55	5%	0.199	0.184	0.000	2447	127	98.43	0.0
B50	10	0.156	0.187	0.000	2461	107	98.57	0.0
B52	15	0.109	0.190	0.000	2358	250	98.64	0.0
B54	20	0.060	0.194	0.000	2201	363	98.62	0.0
B51	25	0.008	0.187	0.000	1499	701	97.86	0.0
B53	30	-0.065	0.239	0.580	81	107	79.73	79.9

Table 5. Namibian cheetah population projections - stochastic simulations. Interaction of variable > 1 year female mortality with a variable male mortality based upon a male to female ***removal ratio of 1.5*** and varying catastrophe survival rates on population growth rate, size, and risk of extinction. Catastrophe frequency was set at 5% with survival rates varied (0.50, 0.65, 0.80, 1.0). Age of first reproduction was set at 3 years for females and 5 years for males. Other constant parameters were as in Table 2a.

File#	**♀ Mort**	**♂ Mort**	**r sto**	**S.D.**	**Pe**	**N**	**S.D.**	**Het**	**Te**
Catastrophe 5%: Survival = 0.500; ♂ to ♀ removal ratio = 1.5									
069	15%	17.5%	0.094	0.213	0.000	2290	363	98.88	0.0
071	20	25	0.044	0.233	0.000	1829	701	98.06	0.0
068	25	32.5	-0.009	0.244	0.040	871	772	93.71	75.8
070	30	40	-0.084	0.317	0.780	74	82	77.11	68.1
Catastrophe 5%: Survival = 0.650; ♂ to ♀ removal ratio = 1.5									
077	15%	17.5%	0.110	0.177	0.000	2345	315	99.02	0.0
079	20	25	0.058	0.194	0.000	2093	490	98.81	0.0
076	25	32.5	0.011	0.204	0.000	1533	750	97.49	0.0
078	30	40	-0.070	0.285	0.670	103	147	78.06	75.1
Catastrophe 5%: Survival = 0.800; ♂ to ♀ removal ratio = 1.5									
073	15%	17.5%	0.121	0.158	0.000	2439	124	99.04	0.0
075	20	25	0.071	0.176	0.000	2284	280	98.85	0.0
072	25	32.5	0.017	0.188	0.000	1813	527	98.26	0.0
074	30	40	-0.052	0.260	0.430	179	362	79.57	80.5
No catastrophe; ♂ to ♀ removal ratio = 1.5									
081	15%	17.5%	0.131	0.150	0.000	2457	100	99.05	0.0
083	20	25	0.079	0.171	0.000	2333	234	98.90	0.0
080	25	32.5	0.029	0.180	0.000	2130	423	98.56	0.0
082	30	40	-0.038	0.243	0.160	158	298	83.55	85.1

Table 6. Namibian cheetah population projections - stochastic simulations. Interaction of >1 year female mortality with a variable male mortality of based upon a male to female ***removal ratio of 2.0*** and variable severity of catastrophes on population growth rate, size, and risk of extinction. Catastrophe frequency was set at 5% with survival rates varied (0.50, 0.65, 0.80, 1.0). Other constant parameters were as in Table 2a.

File#	♀ Mort	♂ Mort	r sto	S.D.	Pe	N	S.D.	Het	Te
Catastrophe 5%: Survival = 0.500; ♂ to ♀ removal ratio = 2.0									
085	15	20	0.095	0.221	0.000	2254	403	98.84	0.0
087	20	30	0.043	0.242	0.000	1858	707	97.77	0.0
084	25	40	-0.005	0.263	0.050	928	753	93.39	93.6
086	30	50	-0.088	0.335	0.860	110	97	74.95	63.8
Catastrophe 5%: Survival = 0.650; ♂ to ♀ removal ratio = 2.0									
093	15	20	0.109	0.184	0.000	2344	308	98.94	0.0
095	20	30	0.058	0.206	0.000	2159	422	98.53	0.0
092	25	40	0.012	0.231	0.000	1404	760	96.34	0.0
094	30	50	-0.076	0.312	0.840	106	113	81.66	73.8
Catastrophe 5%: Survival = 0.800; ♂ to ♀ removal ratio = 2.0									
089	15	20	0.119	0.165	0.000	2421	159	99.00	0.0
091	20	30	0.067	0.190	0.000	2275	293	98.70	0.0
088	25	40	0.018	0.217	0.000	1773	561	97.62	0.0
090	30	50	-0.062	0.295	0.640	191	301	76.65	75.0
No catastrophe; ♂ to ♀ removal ratio = 2.0									
097	15	20	0.131	0.157	0.000	2449	123	99.01	0.0
099	20	30	0.081	0.183	0.000	2313	295	98.74	0.0
096	25	40	0.031	0.209	0.000	1984	461	98.03	0.0
098	30	50	-0.044	0.275	0.380	253	380	82.60	78.1

Table 7. Namibian cheetah population projections - stochastic simulations. Interaction of >1 year female mortality with a variable male mortality based upon a male to female ***removal ratio of 1.5***, variable catastrophe survival, and 25% of females producing no litter each year, on population growth rate, size, and risk of extinction. Catastrophe frequency was set at 5% with survival rates varied (0.50, 0.65, 0.80, 1.0). Other constant parameters were as in Table 2a.

File#	♀ Mort	♂ Mort	r sto	S.D.	Pe	N	S.D.	Het	Te
Catastrophe 5%: Survival = 0.500; No litter=25%; ♂ to ♀ removal ratio = 1.5									
101	15	17.5	0.155	0.213	0.000	2365	369	98.85	0.0
103	20	25	0.105	0.232	0.000	2180	502	98.64	0.0
100	25	32.5	0.053	0.239	0.000	1906	693	97.98	0.0
102	30	40	-0.006	0.279	0.050	807	739	92.46	77.6
Catastrophe 5%: Survival = 0.650; No litter=25%; ♂ to ♀ removal ratio = 1.5									
109	15	17.5	0.170	0.181	0.000	2422	182	98.95	0.0
111	20	25	0.121	0.195	0.000	2376	250	98.85	0.0
108	25	32.5	0.071	0.208	0.000	2229	349	98.51	0.0
110	30	40	0.007	0.254	0.030	1270	693	95.17	81.3
Catastrophe 5%: Survival = 0.800; No litter=25%; ♂ to ♀ removal ratio = 1.5									
105	15	17.5	0.180	0.163	0.000	2462	98	98.95	0.0
107	20	25	0.132	0.181	0.000	2415	198	98.80	0.0
104	25	32.5	0.079	0.192	0.000	2316	281	98.57	0.0
106	30	40	0.023	0.233	0.000	1595	693	97.20	0.0
No catastrophe; ♂ to ♀ removal ratio = 1.5									
113	15	17.5	0.191	0.154	0.000	2475	73	98.96	0.0
115	20	25	0.142	0.171	0.000	2433	129	98.85	0.0
112	25	32.5	0.094	0.183	0.000	2410	183	98.63	0.0
114	30	40	0.032	0.227	0.000	1860	594	97.81	0.0

Table 8. Namibian cheetah population projections - stochastic simulations. Effects of 25% of females with no litter in a given year on interaction of >1 year female mortality with a variable male mortality based upon a male to female ***removal ratio of 2.0*** and variable severity of catastrophes on population growth rate, size, and risk of extinction. Catastrophe frequency was set at 5% with survival rates varied (0.50, 0.65, 0.80, 1.0). Other constant parameters were as in Table 2a.

File #	**♀ Mort**	**♂ Mort**	**r sto**	**S.D.**	**Pe**	**N**	**S.D.**	**Het**	**Te**
Catastrophe 5%: Survival = 0.500; No litter=25%; ♂ to ♀ removal ratio=2.0									
117	15	20	0.158	0.216	0.000	2333	396	98.79	0.0
119	20	30	0.105	0.239	0.000	2225	436	98.46	0.0
116	25	40	0.060	0.259	0.000	1967	658	97.54	0.0
118	30	50	-0.012	0.308	0.170	735	649	87.45	74.7
Catastrophe 5%: Survival = 0.650; No litter=25%; ♂ to ♀ removal ratio=2.0									
125	15	20	0.167	0.186	0.000	2464	118	98.89	0.0
127	20	30	0.117	0.206	0.000	2299	332	98.60	0.0
124	25	40	0.071	0.230	0.000	2175	438	97.95	0.0
126	30	50	0.008	0.273	0.010	1175	771	91.70	69.0
Catastrophe 5%: Survival = 0.800; No litter=25%; ♂ to ♀ removal ratio=2.0									
121	15	20	0.179	0.168	0.000	2446	123	98.91	0.0
123	20	30	0.129	0.192	0.000	2393	218	98.63	0.0
120	25	40	0.079	0.221	0.000	2269	309	98.09	0.0
122	30	50	0.018	0.260	0.010	1487	700	94.86	92.0
No catastrophe. No litter=25%; ♂ to ♀ removal ratio = 2.0									
129	15	20	0.190	0.161	0.000	2485	68	98.91	0.0
131	20	30	0.142	0.183	0.000	2433	142	98.64	0.0
128	25	40	0.091	0.215	0.000	2346	243	98.14	0.0
130	30	50	0.033	0.254	0.000	1832	543	96.31	0.0

Table 9. Effects of variable carrying capacity and starting population size and their interaction with a catastrophe event on 100 year projections of cheetah populations in Namibia and the interaction with a catastrophe. Simulations were done without a catastrophe and with a catastrophe at 5% probability. The catastrophe had a severity effect of 0.8 on reproduction and either 0.65 or o.8 on survival.

File ID	% Female Mortality	r stoc	SD(r)	Prob. Extinc.	Population Size N	Population Size SD	Het % Retain	Te Years
K=4000, N=2500, 5% Catastrophe; Surv =0.80, Repro =0.80								
CHEETA4.N73	10	0.167	0.148	0	3959	148	99.4	0
CHEETA4.073	15	0.119	0.161	0	3883	209	99.4	0
CHEETA4.075	20	0.069	0.181	0	3732	431	99.3	0
CHEETA4.072	25	0.018	0.187	0	2953	932	98.7	0
CHEETA4.074	30	-0.062	0.27	0.53	75	64	80.3	80.3
K=4000, N=2500, 5% Catastrophe; Surv =0.65, Repro =0.80								
CHEETA4.N77	10	0.151	0.17	0	3904	311	99.4	0
CHEETA4.077	15	0.107	0.184	0	3791	438	99.4	0
CHEETA4.079	20	0.057	0.2	0	3425	674	99.2	0
CHEETA4.076	25	0.009	0.209	0	2058	1218	98.2	0
CHEETA4.078	30	-0.069	0.284	0.67	136	199	81.5	78.6
K=4000, N=2500, No Catastrophe								
CHEETA4.N81	10	0.175	0.133	0	3983	74	99.5	0
CHEETA4.081	15	0.13	0.152	0	3941	166	99.4	0
CHEETA4.083	20	0.079	0.169	0	3689	417	99.3	0
CHEETA4.080	25	0.03	0.182	0	3306	711	99.0	0
CHEETA4.082	30	-0.034	0.242	0.17	332	385	87.9	84.6
K=1500, N=1500, 5% Catastrophe; Surv =0.80, Repro =0.80								
CHEETk15.N73	10	0.164	0.148	0	1494	43	98.5	0
CHEETk15.073	15	0.116	0.162	0	1459	96	98.4	0
CHEETk15.075	20	0.069	0.178	0	1359	177	98.2	0
CHEETk15.072	25	0.018	0.191	0	1051	361	97.1	0
CHEETk15.074	30	-0.057	0.273	0.52	92	147	78.1	72.1
K=1500, N=1500, 5% Catastrophe; Surv =0.65, Repro =0.80								
CHEETk15.N77	10	0.156	0.17	0	1458	119	98.5	0
CHEETk15.077	15	0.107	0.184	0	1425	145	98.4	0

File ID	% Female Mortality	r stoc	SD(r)	Prob. Extinc.	Population Size N	Population Size SD	Het % Retain	Te Years
CHEETk15.079	20	0.056	0.198	0	1282	289	97.9	0
CHEETk15.076	25	0.008	0.212	0.01	839	418	95.8	99
CHEETk15.078	30	-0.069	0.294	0.73	57	60	74.4	72.3
K=1500, N=1500, No Catastrophe								
CHEETk15.N81	10	0.175	0.134	0	1494	24	98.6	0
CHEETk15.081	15	0.13	0.154	0	1470	71	98.4	0
CHEETk15.083	20	0.079	0.171	0	1379	143	98.2	0
CHEETk15.080	25	0.031	0.183	0	1221	238	97.7	0
CHEETk15.082	30	-0.039	0.251	0.26	115	132	79.2	80.7
K=6000, N=2500; 5% Catastrophe, Surv =0.8, Repro =0.8								
CHEETk60.N73	10	0.164	0.146	0	5913	262	99.6	0
CHEETk60.073	15	0.115	0.163	0	5846	321	99.6	0
CHEETk60.075	20	0.07	0.179	0	5582	568	99.5	0
CHEETk60.072	25	0.015	0.193	0	3818	1614	99.0	0
CHEETk60.074	30	-0.058	0.262	0.46	99	130	81.8	80.8
K=6000, N=2500; 5% Catastrophe, Surv =0.65, Repro =0.8								
CHEETk60.N77	10	0.154	0.169	0	5843	507	99.6	0
CHEETk60.077	15	0.111	0.183	0	5467	909	99.6	0
CHEETk60.079	20	0.056	0.198	0	5119	1150	99.4	0
CHEETk60.076	25	0.005	0.211	0	2735	1812	98.1	0
CHEETk60.078	30	-0.065	0.283	0.53	74	83	77.7	77.8
K=6000, N=2500; No Catastrophe								
CHEETk60.N81	10	0.177	0.133	0	5981	66	99.6	0
CHEETk60.081	15	0.133	0.151	0	5893	276	99.6	0
CHEETk60.083	20	0.08	0.169	0	5662	523	99.5	0
CHEETk60.080	25	0.03	0.182	0	5033	1046	99.3	0
CHEETk60.082	30	-0.034	0.239	0.13	411	760	89.1	85.1
K=4000, N=2500; SD K = 600; 5% Catastrophe, Surv =0.8, Repro =0.8								
CHEETk20.N73	10	0.166	0.147	0	3811	571	99.4	0
CHEETk20.073	15	0.117	0.163	0	3574	603	99.3	0
CHEETk20.075	20	0.069	0.18	0	3378	652	99.2	0
CHEETk20.072	25	0.018	0.188	0	2458	939	98.7	0
CHEETk20.074	30	-0.057	0.262	0.44	116	141	78.8	79

File ID	% Female Mortality	r stoc	SD(r)	Prob. Extinc.	Population Size N	SD	Het % Retain	Te Years
K=4000, N=2500; SD K = 600; 5% Catastrophe, Surv =0.65, Repro =0.8								
CHEETk20.N77	10	0.154	0.171	0	3652	665	99.4	0
CHEETk20.077	15	0.108	0.183	0	3468	733	99.3	0
CHEETk20.079	20	0.057	0.196	0	3154	727	99.1	0
CHEETk20.076	25	0.009	0.211	0	1971	1067	98.2	0
CHEETk20.078	30	-0.069	0.285	0.66	117	178	78.0	75.8
K=4000, N=2500; SD K = 600; No Catastrophe								
CHEETk20.N81	10	0.178	0.134	0	3780	553	99.4	0
CHEETk20.081	15	0.132	0.153	0	3799	557	99.3	0
CHEETk20.083	20	0.08	0.168	0	3421	645	99.2	0
CHEETk20.080	25	0.03	0.183	0	3014	741	98.9	0
CHEETk20.082	30	-0.034	0.241	0.17	291	301	87.3	88.9
K=4000, N=2500; Two 5% Catastrophes, Surv =0.8, Repro =0.8								
CHEE2CAT.N73	10	0.152	0.157	0	3901	256	99.4	0
CHEE2CAT.073	15	0.103	0.172	0	3831	296	99.4	0
CHEE2CAT.075	20	0.052	0.191	0	3358	749	99.2	0
CHEE2CAT.072	25	0.005	0.201	0	1923	1171	98.1	0
CHEE2CAT.074	30	-0.076	0.281	0.71	70	82	76.4	74.3
K=4000, N=2500; Two 5% Catastrophes, Surv =0.65, Repro =0.8								
CHEE2CAT.N77	10	0.141	0.18	0	3753	540	99.4	0
CHEE2CAT.077	15	0.093	0.191	0	3736	448	99.4	0
CHEE2CAT.079	20	0.044	0.207	0	2968	998	99.1	0
CHEE2CAT.076	25	-0.008	0.221	0	1205	1093	95.3	0
CHEE2CAT.078	30	-0.087	0.301	0.84	73	115	69.8	70.8
K=4000, N=2500; No Catastrophes								
CHEE2CAT.N81	10	0.178	0.133	0	3986	67	99.4	0
CHEE2CAT.081	15	0.131	0.15	0	3944	154	99.4	0
CHEE2CAT.083	20	0.083	0.169	0	3717	408	99.3	0
CHEE2CAT.080	25	0.031	0.18	0	3360	612	99.1	0
CHEE2CAT.082	30	-0.034	0.244	0.12	260	281	87.5	84.2
N=K Runs								

File ID	% Female Mortality	r stoc	SD(r)	Prob. Extinc.	Population Size N	Population Size SD	Het % Retain	Te Years
K=4000, N=4000; 5% Catastrophe, Surv =0.8, Repro =0.8								
CHEExA4.072	25	0.017	0.189	0	2804	990	98.9	0
CHEExA4.074	30	-0.047	0.255	0.26	201	358	83.0	0
K=1500, N=1500; 5% Catastrophe, Surv =0.8, Repro =0.8								
CHEExk15.072	25	0.019	0.193	0	1119	331	97.0	0
CHEExk15.074	30	-0.057	0.275	0.56	95	133	77.4	96
K=6000, N=6000; 5% Catastrophe, Surv =0.8, Repro =0.8								
CHEExk60.072	25	0.018	0.19	0	4093	1530	99.3	0
CHEExk60.074	30	-0.049	0.253	0.22	153	175	83.8	0
K=4000, N=4000; SD = 600; 5% Catastrophe, Surv =0.8, Repro =0.8								
CHEExk20.072	25	0.018	0.193	0	2552	856	98.7	0
CHEExk20.074	30	-0.053	0.261	0.4	142	192	82.6	0
K=4000, N=4000; Two Catastrophes: 5% Catastrophes, Surv =0.8, Repro =0.8								
CHEx2CAT.072	25	0.004	0.202	0	2193	1215	98.3	0
CHEx2CAT.074	30	-0.07	0.271	0.58	69	59	79.0	93

Disease Working Group Report - Cheetahs

Betsy Fox, Linda Munson (facilitators), David Balford, Mitch Bush, Mark Jago, Lynn Kramer, Jock Orford, Rosemary Orford, Melody Roelke-Parker, Hermann Scherer, Byron Stein, Christian Walzer, Kumiko Yoneda

Problems:

1. There was consensus that disease is a potential threat to Namibian cheetah population viability.

2. There was consensus that we lack sufficient information on disease prevalence in Namibian cheetahs to develop long-term management recommendations to minimize disease threats.

3. There was consensus that the biomedical laboratories in Namibia need additional training, equipment and supplies to conduct priority disease surveillance for cheetahs.

Defining the Diseases that are a Threat:

1. Infectious Diseases in Wild Cheetahs

Anthrax:

Anthrax is present throughout Namibia, but the threat to cheetahs depends on the concentration of susceptible prey and patterns of rainfall and drought. Anthrax has caused the death of several cheetahs in the limestone plains region of Etosha since 1993 (P. Lindeque, personal communication) and historically. Because cheetahs appear susceptible, significant mortalities could occur in regions where wild ungulate deaths from anthrax are concentrated. In Etosha, approximately half the cheetah population lives in these Anthrax areas. On Namibian farmland wild ungulates are sufficiently concentrated on 25% of the land to create an anthrax risk, whereas on 75% of the land, domestic cattle are vaccinated against anthrax. Increased game ranching will increase this threat. The threat of anthrax to cheetah populations also may increase during a wet cycle following a dry cycle when susceptible wild species and cheetahs return to the limestone plains regions of Etosha. However, the number of lion on the plains also would increase during a wet cycle and drive the cheetahs to lower anthrax risk areas.

Feline Coronavirus (FCoV):

Disease surveillance by the Cheetah Conservation Fund has revealed that 40% of healthy farmland cheetahs in several regions of the country have antibodies to FCoV. The prevalence in wild cheetahs of the clinical diseases of enteritis or feline infectious peritonitis (FIP) associated with this virus is unknown. Clinical FIP has been documented in captive Namibian cheetahs. Because coronavirus has caused serious epidemics in three captive facilities (U.S., Japan and Ireland), and because coronavirus has been isolated from a cheetah cub with ataxia during the recent upsurge of ataxia in cheetahs of Europe, this virus is considered a potential threat.

Canine Distemper Virus (CDV):

The potential for a catastrophic CDV epidemic is great if the Serengeti biotype arises in Namibia. Transmission to cheetahs most likely will occur from CDV-infected domestic dogs or susceptible wildlife.

Feline Immunodeficiency Virus (FIV):

The potential for developing a persistently FIV-infected population is great, and cheetahs may develop clinical disease if infected with the lion (or other species) biotype. Maintaining an FIV-negative population also would increase the potential economic value of Namibian cheetahs. At present, all cheetahs tested have been negative.

Rabies:

A periodic threat is anticipated because rabies is endemic in Namibia.

Feline panleukopenia virus (Parvovirus), feline herpesvirus 1, tuberculosis, feline leukemia virus, feline calicivirus, hemoparasites, ectoparasites, endoparasites, and toxoplasmosis all could cause morbidity and mortality in cheetahs. The degree of threat presently is unknown. However, disease surveillance by the Cheetah Conservation Fund has disclosed that some farmland cheetahs around the country have antibodies to parvovirus, herpesvirus, and calicivirus, indicating that these viruses are present in the region and wild cheetahs have been exposed to these pathogens.

2. Diseases of Captive Cheetahs

The three most common diseases in the captive population, veno-occlusive disease, glomerulosclerosis, and gastritis, have not been identified in wild cheetahs surveyed by the Cheetah Conservation Fund (L. Munson, personal communication). Therefore, these diseases are unlikely to affect significantly the Namibian population, which is predominantly free ranging. Optimizing the management of captive-held Namibian cheetahs to minimize stress will deter development of these three diseases.

3. Impact of Translocations and Animal Transfers on Diseases:

Transfer of animals between sites could increase pathogen transmission between captive facilities and between ecosystems. Also, common holding sites for translocating wild cheetahs will concentrate pathogens, exposing these cheetahs to unnaturally high doses which may overwhelm natural resistance. Therefore, unregulated animal movements may increase the prevalence of infectious diseases in both captive and wild populations.

What is Needed to Address the Problems:

1. Know the prevalence of infectious diseases in Namibia.

2. Know the pathogenicity of strains of infectious diseases in Namibia (e.g., FIV and CDV).

3. Train Namibian veterinarians and laboratory personnel in procedures to diagnose cheetah diseases (ante- and post-mortem).

4. Train farmers and field personnel to collect the biomaterials needed for disease monitoring (ante- and post-mortem).

5. Define the applied research projects to identify effective preventative measures.

6. Create a captive management plan to minimize disease.

7. Identify funding to meet the needs for surveillance, *in situ* training and applied research.

Immediate Action Plan Recommendations:

1. Actions to Define Disease Threats

a. Inform Namibian veterinarians during the Namibian Veterinary Workshop (17-18 February 1996) of the proposed disease-monitoring program for cheetahs in Namibia.

b. Determine the current exposure to FIV and anthrax in Namibian cheetahs by conducting appropriate testing on previously archived frozen serum samples.

i. FIV antibodies should be assessed in all available Namibian cheetah sera by Western blot analysis, currently the most reliable available method. The Western blot test is more sensitive and specific than the IDEXX CITE-Combo^R test that results in false negative and positive results. Western blot tests for FIV are by Dr. Margaret Barr (U.S.A.) and Dr. Stephen O'Brien (U.S.A.).

ii. Anthrax antibody titers should be determined to assess any preexisting immunity to anthrax in farmland cheetahs. Most Etosha cheetahs tested lack anthrax antibodies (P. Lindeque, personal communication). If no cheetahs have anthrax antibodies, then the entire population will be considered susceptible and the anthrax threat to the population will be considered greater than would be true if immune populations existed. Anthrax antibody levels can be detected by ELISA methods using an assay developed by Dr. P.C.B. Turnbull in England. The Etosha Ecological Institute can conduct the test. Testing will be restricted to selected samples from different farmland regions, because limited quantities of reagents are available.

c. Determine historic patterns of infectious diseases in predators and their prey in Namibia and of infectious diseases in domestic pets which are transmissible to cheetahs.

i. All unpublished data from Etosha, the Central Veterinary Laboratory and agricultural records should be combined with all available published reports to define the history of infectious diseases of cheetahs in Namibia. This summary will provide the basis for immediate disease control strategies.

ii. We propose completing this task during 1996 with student volunteers supervised by Namibian veterinarians.

d. Initiate prospective disease monitoring programs for Namibian cheetahs.

i. Begin collecting, banking, and evaluating biomaterials from all cheetahs that are handled or that die. Due to limited funding, the first year will focus on forming an effective network throughout Namibia to collect and store biomaterials. All available fixed tissues should be evaluated by histopathology without delay, and selected serology (e.g., for FIV, CDV, and anthrax) should be conducted. Costs for diagnostic procedures hopefully will be waived during the first year while funding sources are identified.

ii. The proposed network for biomaterials collection and storage will include veterinarians in private practice, Ministry of Environment and Tourism personnel, the Cheetah Conservation Fund, Africat, and possibly field researchers.

iii. Biomaterials recommended for collection and storage include fixed and frozen tissues, hair, whole blood, serum, plasma, blood smears, and semen.

e. Evaluate habitat and environmental factors that concentrate pathogens.

i. Determine the effect of dry/wet cycles and seasons on pathogen concentrations in the ecosystem.

ii. Determine the effects of wildlife and livestock management practices, such as the construction of artificial water holes, on the concentration of pathogenic agents.

f. After 3 years, collate all prospective and retrospective data to redefine disease threats to Namibian cheetahs.

i. Utilize these results to re-assess disease threats to Namibian cheetah populations and define new priorities for surveillance and research.

ii. Communicate results to all concerned parties. Ongoing communications should occur at meetings and through the publications of regional farmer, hunter, and veterinary associations, and in the scientific literature.

2. Actions to Identify Funding for Disease Monitoring and Applied Research

a. Submit a grant to NGOs and other private funding sources within 1 year for a comprehensive, long-term disease-monitoring project for Namibian cheetahs. Initial costs of this program will be high due to the need for equipment (estimated at N$25,000 to 40,000) to collect, store, and evaluate biomaterials and to enhance regional laboratory capabilities through training (N$150,000). Subsequently, funding will be required only for supplies (N$5,000/year) and costs for diagnostic tests (N$155,000/year). Funds also will be needed for a Curator of Biomaterials (N$36,000) and for regional travel (N$100,000). Funds will be managed locally through the Veterinary Clinicians Forum.

b. Once disease-monitoring programs are established, then seek funding for applied research projects, such as an anthrax vaccine trial on cheetahs.

3. Actions to Standardize Disease Surveillance Programs and Preventative Measures

a. Design protocols for consistent collection and storage of biomaterials. Regional veterinarians will review protocols for feasibility within Namibia. Protocols to be used by non-veterinary personnel will include illustrations of tissues and collecting procedures. Non-veterinarians will receive instruction from veterinarians on methods of biomaterial collection. A curator of biomaterials will be designated to maintain inventories and monitor access to the biomaterial banks. Protocols for processing, labeling, and storing samples will be consistent with CBSG Genome Resource Bank recommendations.

b. Designate sites and techniques for evaluating cheetah biomaterials in Namibia. Sites will be chosen based on the abilities of existing personnel to perform the optimal tests and quality assurance from the laboratories. Considerable concern was expressed about the ability of existing laboratories in Namibia to perform these tests.

c. Create a communication network on the cheetah diseases involving all concerned parties. It was recognized that the veterinary community has a strong, pre-existing communication network for domestic animal diseases that involves veterinarians, farmers and the Ministry. This network should assist in communicating above wildlife disease threats.

d. Design protocols for translocations. The feasibility of these protocols should consider the constraints of:

i. need to immediately move animals from traps to a holding site.

ii. delay inherent in comprehensive infectious disease screening. Translocation protocols will include shipping and quarantine standards, required tests for infectious diseases and the acceptable results, vaccination and anti-parasiticide recommendations, housing standards, and minimum standards for physical examinations and medical records.

e. Design protocols for captive management. The Medical Procedures section of the Cheetah Species Survival Plan Husbandry Manual of the American Zoo and Aquariums Association should be adapted to meet specific needs of Namibian cheetahs.

f. Enhance existing vaccination programs for domestic cats and dogs in regions with cheetah populations. Supplement current rabies vaccination programs with vaccination against CDV in dogs and parvovirus, herpesvirus, and calicivirus in cats. The program should include education concerning the benefits of vaccinating pets. This should be an ongoing program that is initiated within 2 years.

g. Design an epidemic response plan for cheetahs that includes veterinarians, Ministry officials, and other concerned parties. Recommendations for the response plan include designing strategies for defining the extent of a given epidemic and containing the epidemic, designating routes of communication, devising strategies for vaccination of endangered wildlife, isolating threatened populations, and collection/banking of gametes to assist in 'insuring' populations population extinction.

h. Initiate collection and banking of infectious disease-free semen to assure against catastrophic loss of the population from disease. Semen can be managed through a regional Genome Resource Bank.

4. Immediate Actions to Conserve the Current Health Status of Namibian Cheetahs

a. Test all cheetahs that are to be moved (within or out of the country) for FIV antibodies. Any FIV-positive animal should not be translocated, and strict quarantine standards should be imposed.

b. Test all cheetahs that are to be moved within or into the country for FCoV antibodies. Cheetahs with positive titers should not be translocated between facilities.

c. Strict quarantine standards should be observed during translocations.

Models of Disease Threats to Namibian Cheetah Populations for the PHVA VORTEX Model

1. Anthrax: Based on the current anthrax mortality in free-ranging cheetahs from Etosha, current farming practices, current numbers and distribution of cheetahs in Namibia, and historic dry/wet cycles of 10 yr/5 yr, the model predicts that:

a. For Etosha, following a 10 year dry cycle, up to 25% of cheetahs living in the plains areas (50% of the population) would die and up to 10% of cheetah living where vaccinated livestock predominate (75% of the total population) would die. Total estimated losses would be 17.5% in the plains areas and 12.5% in farmlands.

2. CDV: Based on the Serengeti CDV epidemic in lion and assuming that the Serengeti CDV biotype was the infectious agent, and assuming that all cheetahs in the population lacked neutralizing antibodies to this biotype, then a 50% mortality can be predicted.

3. Rabies: Based on historical data from Etosha, a model would predict a 5 to 7% mortality every 15 to 20 years in cheetahs.

Genetics Working Group Report - Cheetahs

Stephen O'Brien, Jan Martenson (facilitators), Kristin Nowell, Tom Priesser, Joelle Wentzel

Problems:

1. There is a lack of understanding of the management consequences of having small founder populations of cheetahs on game farms/reserves.

Solution/strategy: Develop practical guidelines for selecting founders of known origin and for managing small populations based on demographic simulation models.

2. Physical/health problems have been observed in free-ranging cheetahs.

   a. abnormal spermatozoal characteristics (developmental in origin)
   b. tooth/jaw anomalies
   c. kink in tail vertebrae

Are these anomalies indicative of inbreeding depression, infectious diseases, poison, or other factors? Are these factors on the increase?

Solution/strategy: Assess and recognize components of relative fitness that may reflect historic or recent inbreeding. Namibia has a special advantage for monitoring fitness parameters for two reasons:

   a. Constant supply of readily captured cheetahs due to their preference for play trees.
   b. CCF researchers are in place and actively monitor general health.
   (Note of Caution: animals with physiological problems may be more likely to become problem animals, be captured, and give a sampling bias of higher numbers of health problems than are prevalent in the actual wild population.)

Evaluation and reality: It would be useful to be able to recognize health problems which may be analogous to those associated with reduced genetic diversity in other animals (e.g., undescended testicles in the genetically compromised Florida panther). Given the field research programs currently in place in Namibia, and the amount of data gathered thus far, analysis of physical/health problems should be quite straight-forward, requiring more energy and computer time than money. Should any disorders be thought to be genetic in origin, the feline genome-mapping project in S. O'Brien's laboratory could aid in identifying the responsible gene(s).

The reality is that any genetic disorder may not be treatable other than by removing the carriers of the defective genes from the breeding population. Health problems found to be non-genetic in basis would need to be addressed according to cause (poor nutrition, poisoning, infectious disease).

3. The Namibian cheetah is a national treasure and has been and continues to be a fascinating subject for genetic research. However, there is a lack of indigenous capacity (geneticists with access to molecular biology technologies and funding) to investigate these questions.

Solution/strategy: Encouragement and sponsorship of interested Namibian students/interns to train in genetics under the guidance of experienced wildlife geneticists outside of Namibia and then return and apply their training to the study of indigenous species.

4. There exist several documented physiological traits, correlated with genetic uniformity, that may be reduced through maximizing outbreeding.

Solution/strategy:

a. Test geographically isolated populations for the extent of phylogenetic distinctiveness.

i. Candidate geographic isolates include:
- *A. jubatus jubatus,* Southern Africa
- *A. jubatus raineyi,* East Africa
- *A. jubatus hecki,* West Africa
- *A. jubatus venaticus,* Egypt
- *A. jubatus venaticus,* Iran

ii. Obtain genetic samples from Egypt, Iran and Niger for analysis.

b. In captive settings, establish controlled matings between animals from geographically distinct populations, initially between *A. j. jubatus* and *A. j. raineyi*. Evaluate the offspring for fitness components observed in cheetahs. [This recommendation concurs with one made by the captive breeding working group.] Some data currently exist for the *jubatus* and *raineyi* subspecies (see Marker-Kraus, 1996). Captive (or wild-caught animals unsuitable for rehabilitating) from north and west African and Iranian cheetahs would be needed to complete this study.

c. There exists a proven sensitivity of the cheetah's ancestors, and possibly the current population, to demographic reduction and genetic homogenization.

Solution/strategy: Identify the cause of the historic bottleneck in order to anticipate and/or avoid a similar event in the future.

Evaluation and reality: Investigation into the cause(s) of a major cheetah population reduction(s) 10 to 20,000 years ago have thus far yielded only conjectures as to the cause. A final answer may never be possible with today's technologies.

Captive Populations
Working Group Report - Cheetahs

Jack Grisham (facilitator), Karl Ammann, Bruce Davidson, Claudia Feiss, Mike Fouraker, Cheryl Green, JoGayle Howard, Mandy Schumann, Tarren Wagener

Goal:- Develop a management plan for captive populations that will include all animals held in captivity. Programs should network with the international community to enhance long-term species management, including both range countries and captive populations.

Defining the Namibian captive population: For the purpose of this document, a captive population is comprised of non-free-ranging animals that are managed on an individual basis and are not self-sufficient. There are two types of captive-held animals: (1) permanently held in captivity (i.e., pets, tourism); or (2) held temporarily before translocation. There are 50 to 80 cheetahs in Namibia held in permanent captivity. The majority of these are pets, with the remainder used for exportation and tourism. Most of these have origins as 'problem' animals. Namibia currently has minimum legislation regulating facilities that hold cheetahs.

Action Steps:

1. Current legislation and policy should be reviewed in the light of the recommendations contained within the final PHVA document. Namibia is developing an Action Plan for the Cheetah which should include the captive population. A coordinating body should be established that controls the fate of animals moving into and within captivity. This body should be responsible for the administration and approval of all permits for the capture and/or transportation of cheetahs. A basic principle should be minimal movement of animals from point of origin. All protocols should be developed and reviewed by the central, representative coordinating body, a 'commission'.

a. There need to be standards established the in law to control the handling and housing of animals moving into and within captivity, emphasizing (among others) the following factors (see Appendix VI for more details):

> Husbandry standards including, (but not limited to) enclosure size, water source, shade, enrichment (play tree, rocks, platforms, etc.), fencing type, enclosure location

(close to other animals or visitors), hygiene.

Nutrition, including quantity, variety and type of feed, supplementation and feeding schedules.

Health, including infectious disease status and vaccination protocols).

Breeding guidelines, including gestation, litter size, special care, housing (maternity den) hand-raising guidelines and birth control.

b. Controlling movement of captive animals (especially those temporarily held) through a coordinating body (commission) will require:

A central organization for assimilating and coordinating supply and demand and discouraging random advertisements by international zoos and hunters.

Cooperation of international zoos and hunters (i.e., suppliers and demanders) by having fair representation on the commission.

Regional "rapid response teams" consisting of volunteers who willingly will quickly locate and collect problem animals.

Central or regional holding points for screening, quarantine, housing and permanently identifying animals while awaiting decisions on fate.

Legislation to support the powers of the central commission that ultimately should approve applications for permits to capture and export cheetahs.

2. Management goals for the captive Namibian cheetah populations are:

Develop a genome resource bank (GRB) (see Appendix V for more details).

Provide a source of animals for reintroduction/relocation, tourism, education, research, export and other highly worthwhile enterprises.

3. Within Namibia, a captive research population using East African-derived and Namibian-derived cheetahs should be established to allow selective and controlled inter-crossing between geographical isolates. Offspring should be assessed for the effects of inter-crossing on genotype, phenotype, disease resistance, survival and adaptive capabilities.

Recommendations Summary:

1. The Namibian Government should consider appointing a commission, comprised of representative parties (MET, farmers, hunters, veterinarian, NGOs, among others), in the next 6 months to examine existing regulations and then advise about promulgating new legislation deciding the appropriate handling and dispensation of cheetahs brought into captivity.

2. The Namibian government should consider implementing a cheetah policy using the information generated from this PHVA process for the ultimate purpose of creating a national cheetah management plan.

3. The Namibian government should consider establishing a central representative coordinating body within the next 12 months, whose function will be to set standards for captive cheetah management In the interim, the government should consider establishing a program to assess the general health and disease status of the existing captive cheetah population

4. Captive Namibian cheetahs may serve as a valuable resource of genetic material for long-term conservation purposes and as a hedge against catastrophe. Therefore, a genome resource banking action plan (GRB) is recommended. Such a plan should be developed and implemented within the next 12 months.