FINAL REPORT

Black-footed Ferret

Population Management Planning Workshop

June 10-13, 2003
Denver, Colorado

Black-footed ferret
Species Survival Plan

Black-footed Ferret Population Management Planning Workshop

10-13 June 2003
Denver, Colorado

FINAL REPORT

JANUARY 2004

A Collaborative Workshop:

United States Fish & Wildlife Service
Black-footed Ferret Recovery Implementation Team
The Conservation Breeding Specialist Group (SSC/IUCN)

Cover photos courtesy of Dean Biggins, US Geological Survey; Luray Parker, Wyoming Game and Fish Department; Jessie Cohen, Smithsonian National Zoological Park and Randy Matchett, USFWS.

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CBSG. 2004. *Black-footed Ferret Population Management Planning Workshop. FINAL REPORT*. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, MN.

Additional copies of *Black-footed Ferret Population Management Planning Workshop. FINAL REPORT,* can be ordered through the CBSG office. www.cbsg.org, office@cbsg.org, 952-997-9800.

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Section 1
Executive Summary

Executive Summary

Black-footed Ferret Recovery Program

The black-footed ferret (ferret) is one of the most endangered mammals in North America, having been reduced to only 18 individual animals by 1987. To save the species, a fledgling captive breeding program was initiated and remarkable progress has been made in species recovery. From a "founder" population of only 7 animals, over 4,000 ferrets have been produced in captivity and reintroduction efforts were initiated in 1991 that have included 8 areas over six western states and one site in Chihuahua, Mexico. The recovery program is represented by numerous state and federal agencies, zoos, conservation organizations, private landowners, and Tribes across the U.S., Canada and Mexico. Many dedicated biologists, zoo staff, land managers, and administrators have collectively contributed to the success of the recovery program to date.

Although much program progress has been realized, significant obstacles to recovery remain and the reestablishment of enough viable wild populations to achieve recovery objectives is far from assured. Severe habitat limitations persist and the introduction of an exotic disease severely threatens continued recovery. Only through renewed commitments from current recovery partners, expanded involvement of new partners, careful evaluation of program progress, continued effective management of captive breeding efforts and continued research can the black-footed ferret be restored to native habitats across North America.

Workshop Justification

The Conservation Breeding Specialist Group (CBSG) of the Species Survival Commission of the World Conservation Union was instrumental in the development of the original captive breeding and ferret recovery recommendations of 1987. Recent issues raised about captive breeding efficiency, potential genetic effects on captive and wild ferret populations, evaluation of reintroduction progress and the need to critically examine and model various program management applications indicated a need for further program analyses. Presentations by CBSG staff and BFFRIT representatives were made to the BFFRIT Executive Committee and Conservation Subcommittee in late 2002/early 2003. At those meetings, and a subsequent U. S. Fish and Wildlife Service (Service) briefing, it was determined that identified program evaluation and management questions were of high priority to overall species recovery and a Black-footed Ferret Population Management Workshop was organized. Invitations were extended to all members of the Executive Committee, Conservation Subcommittee and the Species Survival Plan (SSP) Subcommittee. This was a timely and important workshop that resulted in significant findings and recommendations to help further species recovery. The findings of this workshop are also important to the development of a new Black-footed Ferret Recovery Plan that is currently under preparation and should be completed by late 2004 or early 2005.

The Workshop Process

This workshop was organized, at the request of the Service and BFFRIT in collaboration with CBSG, to assist the Service and the black-footed ferret recovery program partners in answering a series of technical questions of concern to the future of the Program and recovery of the species. Participants with expertise in both captive and wild black-footed ferret population management were invited from a variety of organizations including the Service, participating SSP facilities, reintroduction sites, partner agencies and individuals and organizations that had expressed interest.

The goals of this workshop were to: 1) identify and explore key questions facing the Program with regard to recovery of the black-footed ferret; 2) bring all available data to bear on these questions; and 3) determine specific management recommendations based on the results of these deliberations. This report presents the results of the efforts and energy the participants contributed to the workshop. Editing of the draft report was done with the assistance of workshop participants. Outside review by non-participants was not part of the process. No content changes were made by the editors and participants checked to ensure that accurate representations were made of their workshop products.

This intensive, 3 ½ day workshop was conducted June 10-13, 2003 in Denver, CO. There were twenty-six participants with most present the entire duration of the workshop. This provided for sustained interactions and the benefit of full attention to the goals and process of the workshop. The workshop began with participant introductions. Individuals were asked to introduce themselves and write out and then read aloud answers to three introductory questions: what is your personal goal for this workshop; what do you hope to contribute to the black-footed ferret population management planning process; and what do you see as the key question facing the program with regard to recovery of the black-footed ferret? This process allows for expression of individual perspectives without being immediately influenced by previous responses, indicates potential areas of common ground and can provide a first insight into the diversity of perceived issues present in the group. It also provides a check on whether workshop deliberations respond to the concerns and issues raised. Answers to these questions can be found in Appendix I of this report.

A series of overview presentations were then given to ensure that everyone in the room was up to speed on the current status of the captive and wild populations (see Appendix II). Next, to develop the specific agenda items for the workshop, participants were asked to identify what are, in their opinions, the key questions facing the Program with regard to recovery of the black-footed ferret. These questions were captured on flip charts and added to a set of discussion questions sent out to participants in advance of the workshop, as well as questions elicited from the group during the overview presentations. The combined list of questions was themed into four categories: pen management, SSP management, habitat and reintroduction/translocation.

After this question formulation session, participants in the workshop self-selected into two working groups, one focused on questions related to SSP and pen management and the other addressing question surrounding habitat, reintroduction/translocation and disease issues. With the exception of periodic plenary sessions for presentation of progress reports and cross pollination of the work of the two groups, the remainder of the workshop was spent in separate working groups. Each group identified individuals to serve as Working Group Facilitator (to keep the discussions focused and ensure that each person wanting to speak is heard), Recorder (to keep track of group discussion on computer), Timekeeper (to keep the group aware of the time remaining for each working group session) and Presenter (to deliver the working group report in plenary).

The groups were tasked with defining, sorting and prioritizing their key questions and then analyzing the root cause of each problem upon which the questions are based. Day two was dedicated to bringing all available data to bear on the questions facing recovery of the black-footed ferret. CBSG's quantitative resource team, with a number of computer modeling tools at their disposal, helped evaluate the scientific and management hypotheses and management alternatives that each group developed. Based on the answers to each group's questions, a set of detailed management recommendations was developed to address the root cause of the problem addressed by the question. To increase the potential for implementation, the recommendations were written to meet the "SMART" criteria: Specific, Measurable, Achievable, Results-oriented and Time-fixed.

Each group produced a report on their discussion and conclusions. Those reports can be found in Sections 2 and 3 of this document.

Priority Outcomes

The **SSP/Pen Management Working Group** identified 18 specific, prioritized recommendations. All recommendations are listed in Section 2 of this report. The three top ranking recommendations are:

1. The group evaluated the recent management decision to remove individuals over two years of age from the SSP population, thereby breeding only one- and two-year-old ferrets in an attempt to increase kit production. The resulting accelerated loss of gene diversity due to a shorter generation time was estimated to outweigh the estimated potential increase in production. Therefore, the working group recommended changing the proposed age structure within the SSP by retaining an even distribution of one-, two-, and three-year-olds and some four-year-olds. Only four-year-olds that have bred before and are genetically valuable will be retained in the SSP.

2. Recent reproductive evaluations of male black-footed ferrets suggest a decline in sperm quality in captivity. It is important to evaluate sperm quality of wild-caught males. There is some indication that diet may be a contributing factor. It is recommended that a diet study be designed and conducted to evaluate the effect of diet on sperm quality.

3. A widespread decline in sperm quality and associated decrease in fertility could be devastating to the ferret population. Management strategies to deal with this problem will depend upon the relative contribution of genetic and environmental factors on sperm quality. To

develop appropriate management actions, it is important to determine if sperm quality traits are heritable.

The **Reintroduction/Translocation and Habitat Working Group** developed detailed recommendations in 3 categories: Habitat, Disease and Reintroduction. The top ranking recommendation in each category is listed below:

Habitat
In order to achieve existing recovery objectives for distributing sufficient numbers of black-footed ferret populations across the historical range of the species at least two suitable recovery planning areas, of sufficient size to effectively support a black-footed ferret population, should be identified within the jurisdictional boundaries of each western state. Suitable recovery areas should be identified and/or maintained in Mexico and Canada. Habitats within identified recovery sites should be managed to promote large and healthy prairie dog complexes needed to support ferret populations. Agencies should consider development of ferret recovery sites in the next round of their associated land management planning processes; and/or consider amending existing plans by no later than FY2006 to address ferret recovery needs.

Disease
Sylvatic plague remains a primary factor in black-footed ferret habitat destruction. Work with appropriate partners to identify the funding, regulatory and other obstacles hindering development of a plague vaccine and write a plague vaccine development plan. Use the plan to reduce or remove obstacles to vaccine development so that field application can begin as soon as possible.

Reintroduction
To achieve black-footed ferret recovery objectives, program partners involved in ferret reintroduction projects should continue to support and manage established reintroduction sites as long range ferret recovery areas, whether reintroduction efforts are presently active or not. In addition, new partnerships are encouraged to expand reintroduction opportunities across the historical range of the species — into additional sites, other states, Tribal lands, and Canada. The translocation of wild-born ferrets is a valuable tool that may promote more rapid and efficient establishment of reintroduced ferret populations. Workshop modeling results indicate that up to 30 percent of the kits produced annually at an established reintroduction site (i.e. Conata Basin, South Dakota) can be captured and translocated to new sites without adversely affecting the donor population (see model results below). Full tests and adequate monitoring are needed to determine the success and effects of translocations on donor and recipient sites.

Next Steps

The recommendations made by the participants at this workshop include timelines for, and identify parties responsible for championing, their implementation. A draft of this document was distributed to all members of the Executive Committee and a presentation of the results was made at their annual meeting in December 2003. In addition, the report was distributed to the

Conservation Subcommittee and the Education and Outreach Subcommittee. The Executive Committee will be asked for assistance in prioritization and implementation of workshop recommendations.

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Section 2
SSP and Pen Management
Working Group Report

SSP/Pen Management Working Group Report

Process Overview

The SSP/Pen Management Working Group was comprised of individuals from Federal and State agencies as well as the international zoo community. All members of the group have black-footed ferrets entrusted to them as part of the Black-footed Ferret Species Survival Plan® (SSP) or pen facility populations. Researchers in reproductive physiology and genetics also formed the group. A Conservation Breeding Specialist Group (CBSG) representative was assigned to the working group to analyze data using PM2000, SIMPOP and MateRx computer software tools. Additionally, CBSG participation helped concentrate discussions on our main objectives, thus avoiding individual biases and personal or institutional agendas.

Preliminary Issues and Discussion

The working group began by highlighting all captive management-related topics discussed in the preliminary sessions and on the question/issue list generated prior to and during the workshop. Flipcharts were used to list all topics related to SSP and pen facility management. Commonalities were determined between SSP and pen discussion points, and the group discussed additional points related to future management of captive ferrets not identified on our preliminary list of issues.

Four key subject areas encompassed the discussion questions and issues. These included: balancing the conservation of remaining genetic variability with the production required for reintroduction; reproductive physiology issues; SSP structure and function; and pen management issues. These four fundamental headings would be the topics of our remaining discussions.

Deepening the Issues

Group members posed questions pertaining to captive management issues and the group asked “why?” in order to determine the root cause of each. This was essential in order to tease out as much underlying information as possible and thereby decrease the likelihood that participant concerns were based on personal feelings. Additionally, with persistent analysis of each question, a more direct and specific recommendation could be developed that would lead to better management of captive animals. The group further developed three possible management scenarios: population management designed to maximize retention of genetic diversity over time, production of as many kits as possible with no regard to genetic concerns, and a combined approach of the two aforementioned schemes. Discussions concerning each management strategy were deliberated, and the working group chose the combined management approach, thereby supporting continued genetic management of both the SSP and pen populations while producing sufficient numbers of kits for the annual reintroduction efforts.

Development and Prioritization of Recommendations

A total of 18 recommendations were identified by the SSP/Pen Management Working Group based upon issues generated in earlier discussions. These recommendations addressed the root cause of the problem to which each issue referred. The question adopted as the group's primary driving force was: What is the most effective way to balance genetic concerns and kit production in the captive management of black-footed ferrets? Additionally, we adopted the "SMART" criteria with each recommendation, striving for them to be Specific, Measurable, Achievable, Results-oriented and Time-fixed. Since one recommendation was completed during the course of the workshop, a total of 17 recommendations were prioritized using the paired ranking method. The criterion for prioritization was the effectiveness in balancing genetic concerns and kit production. Discussion following the prioritization exercise acknowledged that some group members may have been viewing certain recommendations differently during prioritization, which probably impacted their ranking. Below is the list of recommendations in order of descending priority. Each recommendation is also presented and discussed in the appropriate topic section of this report (note: some recommendations are applicable to more than one section and therefore may be discussed more than once).

Summary of Working Group Recommendations

1. Change the proposed age structure within the SSP by retaining an even distribution of one-, two-, and three-year-olds and some four-year-olds. Only four-year-olds that have bred before and are genetically valuable will be retained in the SSP. *Responsibility: P Marinari to design the even age structure by the SSP meeting in September 2003.*

2. Design and conduct a diet study to evaluate the effect of diet on sperm quality. *Responsibility: Study design to be developed by P Marinari, S Wisely, JG Howard, R M Santymire and J Kreeger by 1 October 2003; study to be initiated by 1 November 2003; reproductive evaluations of sperm quality to be conducted by R M Santymire, P Marinari and J Kreeger in spring 2004.*

3. Use existing data to determine if there is evidence that sperm quality traits are heritable. Continue to monitor data as information becomes available, and investigate the logistics and expense of conducting a conclusive heritability study. *Responsibility: Existing data to be analyzed by JG Howard and R M Santymire by 1 July 2003 (completed; see Tables 11 & 12 for data summary). Feasibility of study to be investigated by the Black-footed Ferret SSP and reported to the Executive Committee.*

4. Continue to send low-ranked animals (those with high mean kinship values) out for release and keep the most genetically valuable animals in the SSP. When sending out litters for reintroduction, do not split the litters to keep one-half in the SSP but send out the entire litter. Divide littermates among different reintroduction sites to increase the likelihood that released animals will not mate with first-order relatives. *Responsibility: U.S. Fish and Wildlife Service to implement recommendation during annual allocation distributions (beginning August 2003).*

5. Increase number of animals available for release from pen facilities through husbandry and management practices that promote reproduction and kit survival. Site-specific pen breeding recommendations for increasing kit survival are currently being incorporated into management plans. Data comparing multiple years and facilities will be presented at the 2004 Conservation Subcommittee meeting, at which time recommendations for pen breeding will be discussed. *Responsibility: To be presented by P Marinari in February 2004.*

6. Send a larger proportion of one-year-old males to pens or to facilities with outdoor light (Conservation and Research Center, and the new Ferret Conservation Center). This may increase the experience of naïve animals, increase breeding opportunities for one-year-olds, and potentially increase genetic diversity at reintroduction sites. Once bred, animals provided to pen breeding facilities could be returned to the SSP population, if genetically valuable. Evaluation of breeding success utilizing one-year-old males will be determined following the 2004 breeding season and compared to production in previous years. *Responsibility: U.S. Fish and Wildlife Service to implement during annual allocation process (beginning August 2003).*

7. Balance the distribution of proven animals (animals that have reproduced before) among SSP facilities so that each institution has the ability to increase production. Additionally, each institution should maintain unproven animals and recognize the importance of breeding unproven and/or genetically valuable animals to recovery objectives. *Responsibility: To be implemented by SSP prior to the 2003 SSP meeting in September.*

8. Design and implement a standard SSP Annual Facility Report (see SSP Structure and Function section for report outline). *Responsibility: To be designed by D Garelle and P Marinari by 1 August for review and approval at the September 2003 SSP meeting.*

9. Evaluate relatedness of potential breeding pairs in pens and develop more specific breeding recommendations. Currently the only criterion for forming pairs in pen breeding facilities is to prohibit pairing of nuclear family members (i.e., parent-offspring or siblings). Selection of males to be transferred to pen facilities for breeding will be selected based on the best possible mating choices to minimize inbreeding. *Responsibility: U.S. Fish and Wildlife Service to implement recommendation as part of annual allocation process (beginning Fall 2003).*

10. Consider increasing SSP population size to increase production potential as well as promote retention of gene diversity. *Responsibility: The Black-footed Ferret SSP will compile a list of strategies to enable the maintenance of a larger SSP population and will report back to the Executive Committee for discussion.*

11. Obtain training in studbook keeping and captive population management for current black-footed ferret studbook keeper. *Responsibility: P. Marinari to request funding for training by 1 July 2003.*

12. Develop a matrix of data for individual animals in order to determine which factors affect reproductive success. Measures to be recorded include age, inbreeding coefficient, breeding

opportunities, breeding behavior, status of sperm checks, sperm quality, litter size, kit survival, facility, and various husbandry factors. Data can also be used to assess inbreeding depression in the population. *Responsibility: Format to be developed and data to be collated by P Marinari and intern H Branvold in September 2003*.

13. Increase dialog between the current SSP genetic advisor and the SSP coordinator and studbook keeper. If the current advisor's time commitments are too constrained, a new genetic advisor should be identified. *Responsibility: D Garelle and P Marinari to discuss with Jon Ballou by 1 July 2003*.

14. Measure and increase light intensity as needed at indoor breeding facilities. Each facility must measure light intensity and keep it above 25 foot candles, a minimum intensity previously found to be critical for synchrony of male and female breeding. *Responsibility: D Garelle to collect data from each institution by September 2003; will implement study at Cheyenne Mountain Zoo by increasing light in 2004 for comparison with 2003 data*.

15. Design a light study to demonstrate the effects of light intensity on reproduction. *Responsibility: Summary of light intensity in ferret cages at SSP facilities to be collected by D Garelle and presented at the 2003 SSP meeting in September. SSP will determine if further light intensity studies are warranted and, if so, a study will be designed to determine influence of light intensity on reproductive success.*

16. Continue using advanced photoperiod at Toronto and Phoenix Zoos for the time being. *Responsibility: SSP; subsequent discussions with these facilities negated the need to maintain advanced photoperiods, leading to the cancellation of this recommendation.*

17. Continue communication between the BFF SSP and the BFFRIT to align kit production and the need to supply animals for reintroduction efforts. *Responsibility: Ongoing; Black-footed Ferret SSP and BFFRIT.*

18. Change the definition of survival to age of weaning from 90 days to 60 days with reference to calculation of Expected Productivity Rate (EPR). *Responsibility: Approved by D Garelle, SSP Coordinator on 12 June 2003; further discussion is anticipated at SSP meeting in September 2003.*

Balancing Genetic Diversity and Production

The Black-footed Ferret Species Survival Plan (SSP) is unusual among SSPs in that its goals are to both minimize the loss of genetic diversity and to produce the maximum number of kits for release into the wild. These goals can at times conflict with each other; methods used to maximize production may not retain genetic diversity, while strategies that maintain genetic diversity may greatly reduce productivity. Challenges to the recovery of the black-footed ferret are numerous; for the captive breeding program these include animal husbandry of a difficult species to breed in captivity and a small number of founding animals (seven). Maintenance of genetic diversity is important to the population for several reasons: 1) to maintain genetic diversity so that wild reintroduced populations have the potential to adapt to a changing environment; and 2) to limit the amount of inbreeding and inbreeding depression. Ancillary to the goal of maintaining genetic diversity is minimizing artificial selection via selection for the captive environment or unintentional selection for maladaptive traits. Maximizing production of kits for release into the wild provides each reintroduction site with enough animals to augment populations that are not yet self-sustaining or provides founders for new release sites. Past management of the SSP population has been successful in retaining gene diversity from the original seven founding animals and minimizing inbreeding while producing animals to supply reintroduction efforts (Figures 1 & 2).

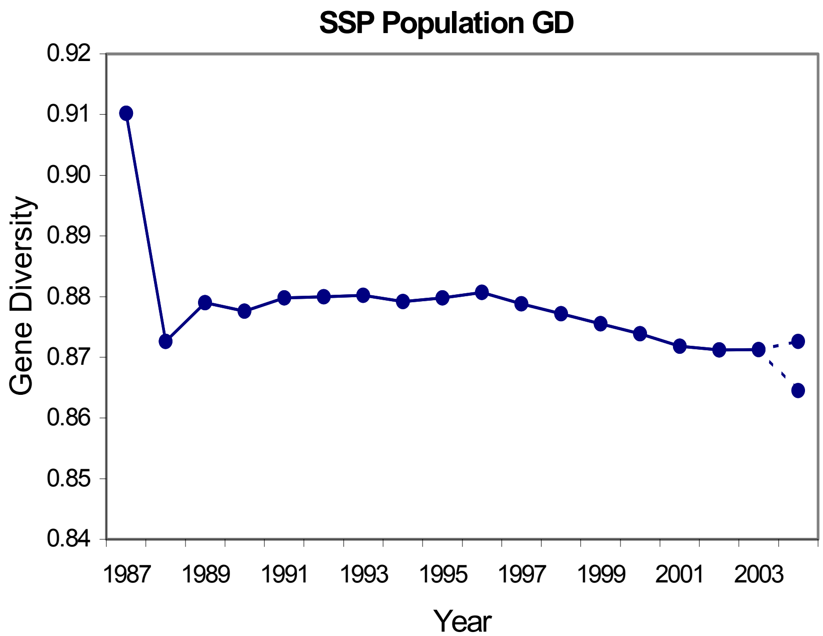

Figure 1. Gene diversity retained in the captive black-footed ferret SSP population over time (1987-2003) based upon gene drop simulations using PM2000 and the historical studbook data. Founders were included in gene diversity calculations.

Best-case and worst-case scenarios are projected for 2004. The best-case scenario represents iterative pairing of the top-ranked male and female based upon mean kinship value, with no restriction in the number of pairings per male (simulating the ability to use natural and AI reproduction). The worst-case scenario represents pairing of the lowest-rank male and female, limiting each male to four pairings. For each scenario 62% of all females ages 1-3 were bred and produced three surviving offspring. After all breedings were completed, all individuals were advanced one year in age, and individuals older than 3 years were removed.

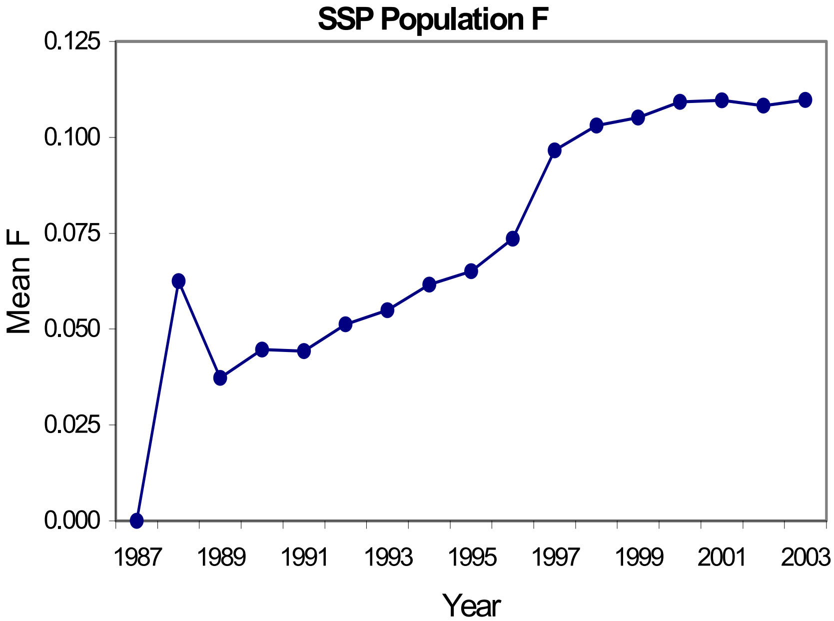

Figure 2. Mean inbreeding coefficient in the captive black-footed ferret SSP population over time (1987-2003) based upon gene drop simulations using PM2000 and the historical studbook data. The observed increase in inbreeding in 1997 is likely a result of a shift in management to exclude older, post-reproductive animals from the defined SSP population.

Recent biomedical surveys of the captive population suggest that physiological changes have occurred in captivity. Sperm quality has declined in the captive population in recent years. The percent of normal sperm produced by males has decreased and percent of abnormal acrosomes has increased (see Reproductive Physiology section). In 2003, five cryptorchid animals were observed, and animals with heart and kidney defects have been observed sporadically since the commencement of captive breeding. These abnormalities mirror changes that have been seen in other carnivore species with low overall genetic diversity, including the Florida panther and giant panda. Causes for these changes are unknown but could include both genetic and environmental factors.

Management of any captive population is a dynamic process, and recently changes to ferret management have been proposed and implemented. Because some males are easier to breed than others, there has been a tendency to breed only animals with a successful history of breeding (proven breeders). SSP facilities that have had low productivity request proven breeders. These proven breeders (typically males) then get shipped from facility to facility and become genetically overrepresented in the population. This strategy is a form of line breeding that may increase productivity in the short term, but will reduce genetic diversity and increase inbreeding and possibly inbreeding depression over time (see Figures 3 & 4). Line breeding has been used in the past to increase the genetic representation of an underrepresented founder (Annie), but the goal of this strategy was to actually increase the overall genetic diversity of the captive population by reducing variation in the founder representation. Additionally, it has been recommended that only the most fecund age classes (one- and two-year-olds) be maintained in the captive population for breeding in order to increase the productivity in captivity.

In an attempt to more fully understand the dynamics of current and proposed management strategies we considered two extreme cases of genetic management: 1) managing solely for maximum retention of genetic diversity; and 2) managing solely for maximum production of kits. We then examined commonalities between the two strategies to develop a management plan that would incorporate both goals of maintaining genetic diversity and maintaining a productive population that would provide kits for release.

Strategy for Managing for Maximum Retention of Genetic Diversity

The most commonly used strategy in captive populations for maintenance of genetic diversity is the strategy of minimizing mean kinship (MK). Using this method, the mean kinship of each animal is calculated and ranked. Animals with low mean kinship values are ranked high (i.e., genetically valuable) because they contain genes from the least represented founders. High-ranking males are hypothetically paired with high-ranking females, and if inbreeding coefficients of their putative offspring are acceptably low, then the animals are in fact paired for breeding. The intended result is an even representation of genes from the founders, which maximizes the retention of genetic diversity (see Figure 3). Ultimately, finding a new founder, or augmenting the captive population with genes from a different subspecies, would be the surest way to increase genetic diversity in this population. Extreme caution must be taken when considering the incorporation of alternative taxa into the captive population as outbreeding depression may result.

Under this strategy, reproductive efficiency of high-ranking animals should be increased so that their genetic representation is ensured. Good animal husbandry practices, optimal environmental conditions, and assisted breeding are ways to increase efficiency. If a male with a high rank has problems breeding (typically behavioral problems including aggression or improper positioning), sperm is collected and used to artificially inseminate a high-ranking female. Artificial insemination (AI) is a valuable technique to ensure that high-ranking animals breed. Because sperm can be frozen and stored, sperm from dead animals can be used to genetically augment a population.

Increasing the population size would also reduce the loss of genetic diversity through random loss of alleles via genetic drift and cushion the population against the risks of unfavorable stochastic demographic events. Given a specific population size, only enough animals needed to perpetuate the captive population should be maintained. Alternatively, additional animals could be produced if those at the bottom of the mean kinship list (i.e., those that contain genes from overrepresented founders) are culled from the population. Generation time should be maximized because loss of genetic diversity is inevitable with each generation. To achieve a long generation time in a species with overlapping generations, breeding preference should be given to older animals provided that they have a relatively low MK value.

A Species Survival Plan (SSP) should be in place to coordinate and direct the often complicated breeding plan needed to implement genetic management using mean kinship. Past genetic management of this captive population through the Black-footed Ferret SSP has managed to capture and retain much of the genetic diversity of the original seven founders and slow the loss of gene diversity and accumulation of inbreeding over time (see Figures 1 & 2). Projections for 2004 indicate the ability of genetic management to either counteract or exacerbate the effects of genetic drift, depending on the breeding strategy employed.

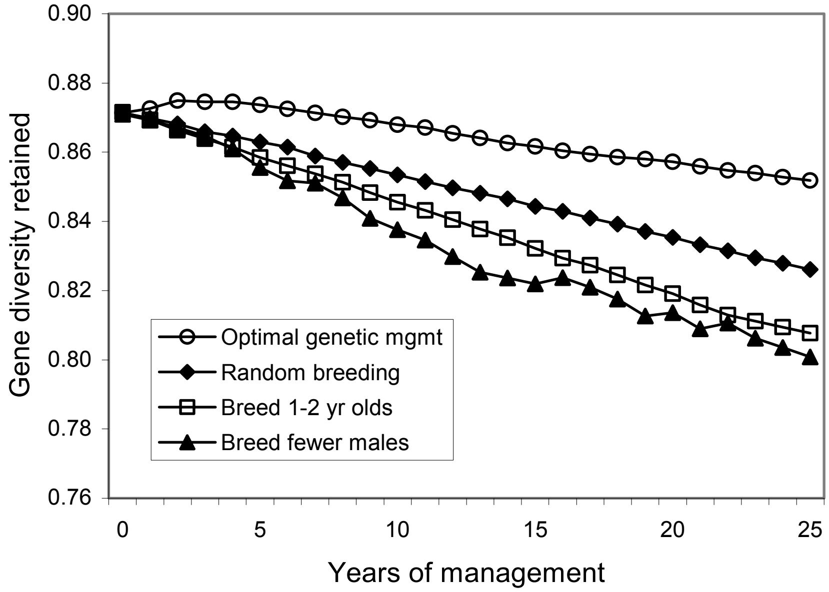

Figure 3. Projected gene diversity retained in the captive black-footed ferret SSP population over the next 25 years for four different management scenarios. Results are based upon 500 iterations using the SIMPOP simulation model and using a simulated population, not actual pedigree data. All females were paired, and breeding success (% whelping) was modeled as 62%. Reproductive lifespan for both sexes was 1-3 years of age (except for strategy #3). Animals were paired randomly for breeding (except for strategy #1). The adult population was held at approximately 250 individuals, with excess kits removed randomly each year for recovery needs.

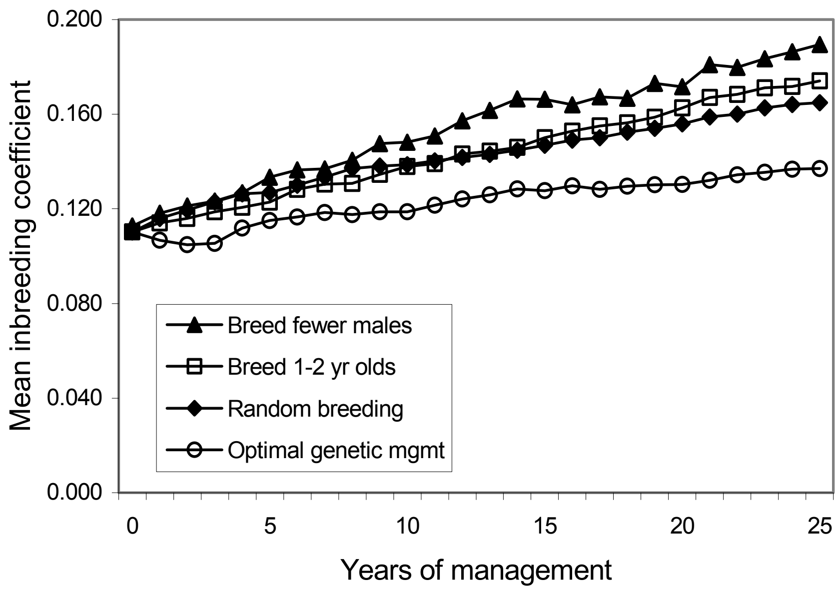

Figure 4. Projected mean inbreeding coefficient in the captive black-footed ferret SSP population over the next 25 years for four different management scenarios. Results are based upon 500 iterations using the SIMPOP simulation model and using a simulated population, not actual pedigree data. All females were paired, and breeding success (% whelping) was modeled as 62%. Reproductive lifespan for both sexes was 1-3 years of age (except for strategy #3). Animals were paired randomly for breeding (except for strategy #1). The adult population was held at approximately 250 individuals, with excess kits removed randomly each year for recovery needs.

The four management scenarios modeled are: 1) optimal genetic management (females paired with top-ranking male based on an iterative ranked mean kinship list); 2) random breeding; 3) animals are bred at 1-2 years of age, with 3+ year old animals removed from the population; and 4) additional male kits are removed from the population to form a female-biased breeding structure, approximately a strategy whereby fewer males are used for breeding. Note that population extinctions were very high for strategy #4 due to the nature of the model; therefore, the results of this strategy should be viewed cautiously but indicate a trend of increased rate of inbreeding.

Strategy for Managing for Maximum Production of Kits

The goal of managing for kit production is to provide animals for preconditioning, which typically starts at 60 days of age. Black-footed ferrets vary in their ability to produce kits; a perception among captive breeding managers is that animals that previously produced a litter tend to produce litters in the future while animals that do not produce litters in one year will have a lower probability the following year. Thus, animals that are "proven" should have their reproductive potential maximized. If it is assumed that this ability is maximized, then the offspring of these animals should also be preferentially bred. Skewing the sex ratio so that many more females are in the population would increase production as would breeding only the most fecund age classes.

Under this strategy only captive males with good quality sperm should be paired with females to ensure reproductive success. There is the potential to capture and/or collect and freeze semen from wild-born males if sperm quality is found to be better in the wild population.

Maximizing the reproductive success of animals chosen for breeding would increase productivity. Natural light or increased indoor light intensity increases the synchrony of sperm production in males and ovulation in females. To increase the number of animals in natural light, more animals could be placed in outdoor pens for breeding, but then returned indoors for whelping and weaning. Although it has been found that natural light increases the success of pregnancy, whelping and weaning success is lower in outdoor cages, hence strategies for increasing juvenile survivorship would need to be developed.

Electroejaculation of males lets captive managers know if a male is maximally spermic while vaginal cytology can verify when a female is ready to ovulate. Consistent use of these two techniques would increase the synchrony of individual pairings. An alternative method is to "fast track" males, whereby males are quickly paired with females, removing them if they are not behaviorally ready to breed, and trying another male.

Diet may affect sperm quality in males (see Reproductive Physiology section, Table 13); preliminary results show that animals on a whole carcass diet may have better sperm quality than animals on the Toronto diet. The change in diet of the captive population in January 2001 may be related to the observed decline in sperm quality (Figure 5). Animals prior to 2001 were given the 60/40 diet while animals since then have been given the Toronto diet. Potentially, the Toronto diet may negatively affect sperm quality. By switching diets from Toronto diet to 60/40 or some other diet, sperm quality may increase with the hopes of increasing production.

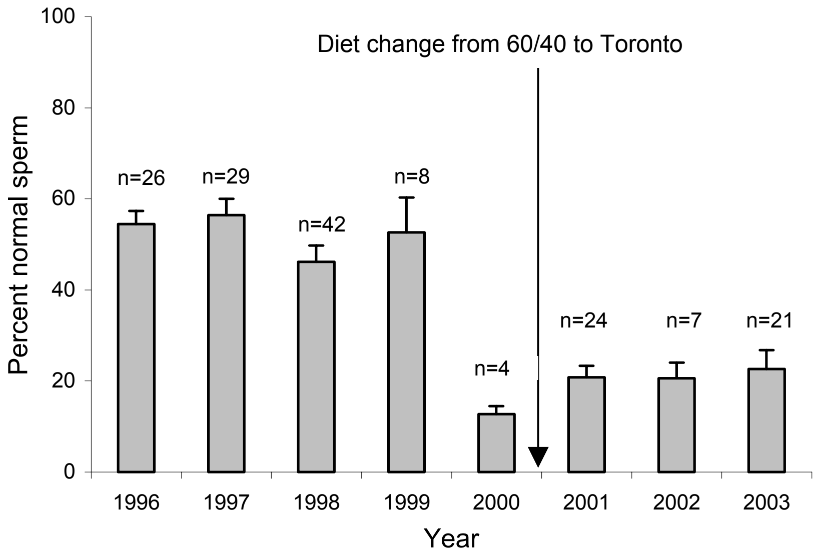

Figure 5. Percent normal sperm observed in electroejaculated captive black-footed ferrets over time.

Finally, by increasing the space available for captive breeding, the captive population could be expanded to allow more kits to be produced. If Siberian polecat x black-footed ferret matings are fertile, male Siberian polecats could be used to inseminate black-footed ferret females in the event that black-footed ferret sperm quality drops below some critical level needed for maximum reproductive output.

The Compromise Breeding Strategy

We found three common aspects of these two breeding strategies: incorporating new genetic lines, increasing reproductive efficiency, and increasing population size. We dismissed using Siberian polecats in the current breeding plan as a source of new genetic material because of legal, biological and political implications that would likely ensue. Siberian polecats have not evolved in North America. Furthermore, the implications of outbreeding depression that may not be observed in captivity could decrease the fitness of free-ranging animals. Adding new black-footed ferret founders would be desirable and would be the most viable option (should extant populations be discovered).

Increasing the reproductive efficiency of genetically valuable animals through the use of AI and better husbandry would maximize retention of genetic diversity and would increase the output of kits. If sperm quality of top-ranked males is unacceptably low, then sperm stored in the Genome Resource Bank (sperm collected and frozen from now dead animals) could be used to augment genetic diversity of the living population. Care must be taken, however, when using valuable sperm, because genetic diversity will decrease through time and new genes infused into the population will be subject to genetic drift. To maximize the retention of those new genes, they should be used with discretion, perhaps when inbreeding depression is observed.

Better husbandry practices throughout the captive population would increase the number of kits produced. Increasing juvenile survival, increasing the number of breeding females or increasing pregnancy rate would increase kit production (see Figure 6). Increasing the success rate of naïve or unsuccessful breeders would both increase genetic representation and increase production. Increased light intensity, assessing sperm quality prior to pairing, physical exams, and increased technician training could increase the quality of husbandry.

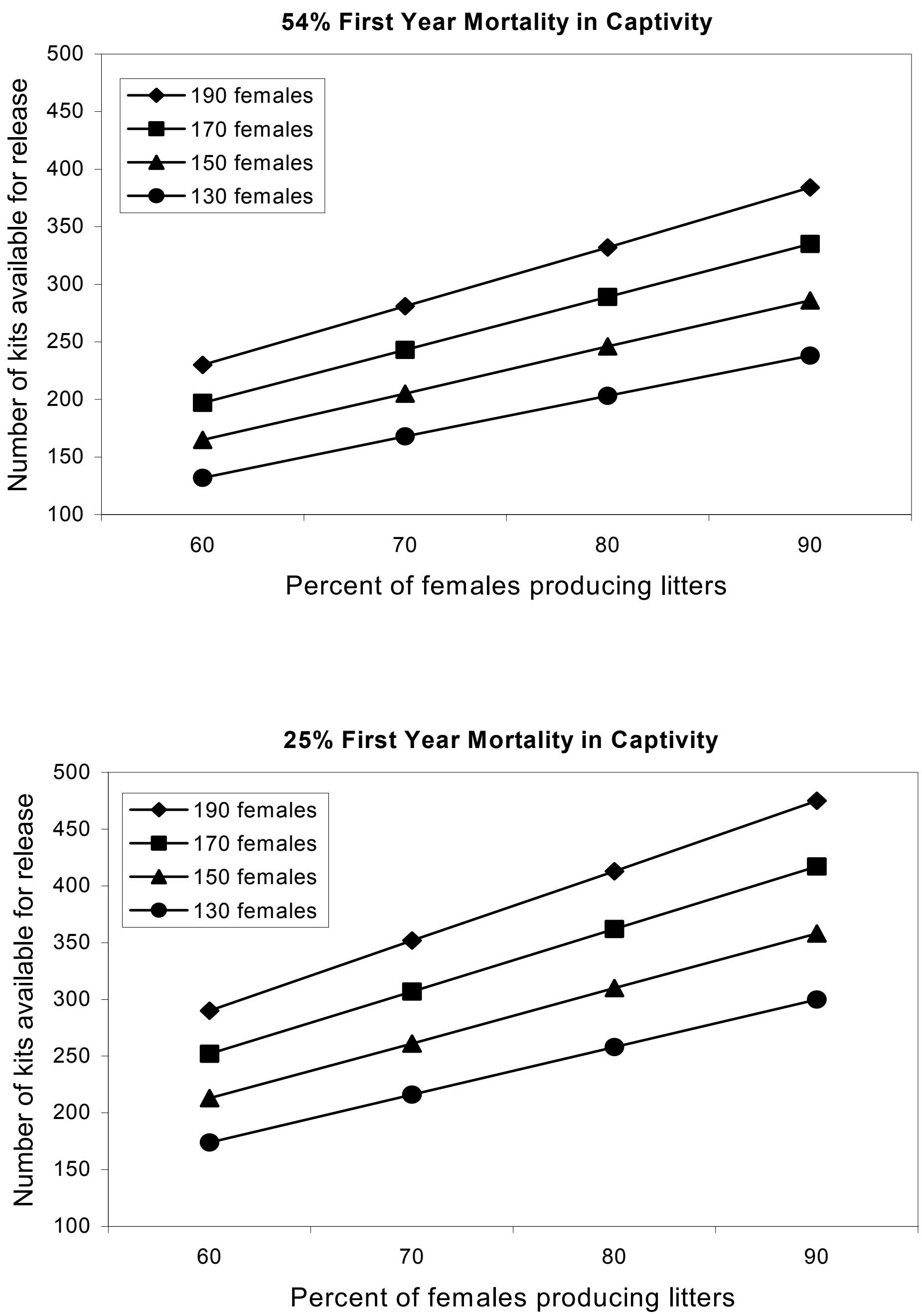

Figure 6. Annual number of excess kits produced (i.e., available for release) as a function of breeding success, number of breeding females, and first-year mortality. PM2000 was used to determine the expected captive population size after one year for each set of values and given the birth and death rates observed in the SSP over the past five years. The number of animals that are excess to the maintenance of a stable SSP population was then calculated to reach an estimate of the number of kits available for recovery efforts. Increased productivity of kits is associated with increased number of adult females, increased percentage of females reproducing, and increased survival of kits. Between 132 and 475 kits are expected to be available for the recovery program on an annual basis within the range of values explored.

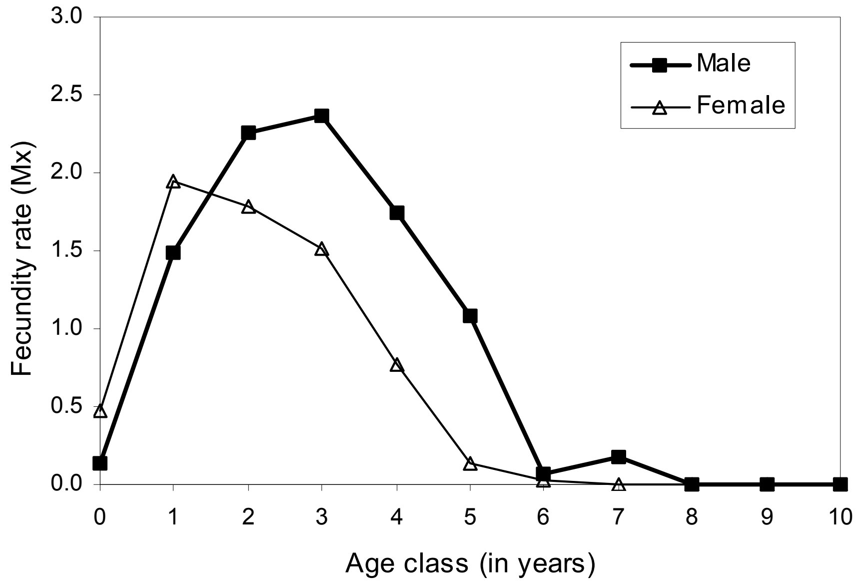

Figure 7. Male and female fecundity for historical captive black-footed ferret population (taken from SPARKS studbook data and calculated using PM2000 analytical software). Data based on past reproduction given both biological and management constraints (i.e., opportunities to breed).

Increasing the generation time of black-footed ferrets would maximize retention of genetic diversity (see Figure 3) and could potentially increase production. A reexamination of fecundity by age structure illustrates that three- and four-year-olds have only slightly reduced fecundity (see Figure 7). By retaining three- and four-year-old animals, a compromise between genetics and production could be achieved.

Gene diversity is lost more quickly from small populations. Increasing the population size of the SSP would not only promote the retention of genetic diversity, but by increasing the number of breeding females also promote increased production (see Figure 6). This could be accomplished through expansion of the number of facilities and/or number of cage spaces within existing facilities.

A compromise strategy needs to weigh the relative importance of strict management using mean kinship for this population. MK values are typically presented in ordered MK lists for each sex, with genetically valuable individuals at the top of the list (see Appendix I for current MK list).

Breeding preference is given to genetically valuable individuals, often in order of rank. However, other factors also need to be considered, such as the likelihood of success based upon behavior, health, age and other factors, as well as the risks and costs associated with the transfer of animals among institutions. Due to the small number of founders obtained at the same time and subsequent genetic management of the captive population, the relative distribution of mean kinship values is fairly clumped, with a few relatively underrepresented and overrepresented individuals and most of the population of moderate value over a small range of MK scores (see Figure 8). Many individuals have the same MK score, although they appear "ranked" on the MK list. It is therefore important to consider an individual's MK value rather than its MK rank when weighing costs and benefits in the formation of breeding pairs within a breeding season. Efforts should be make to breed those few individuals with relatively low MK values and to avoid breeding those with high MK values. Less genetic benefit is to be gained by preferential breeding of individuals with small differences in MK values in the middle of the MK list; for these pairings, greater consideration might be given to other factors such as behavior and location to promote breeding success.

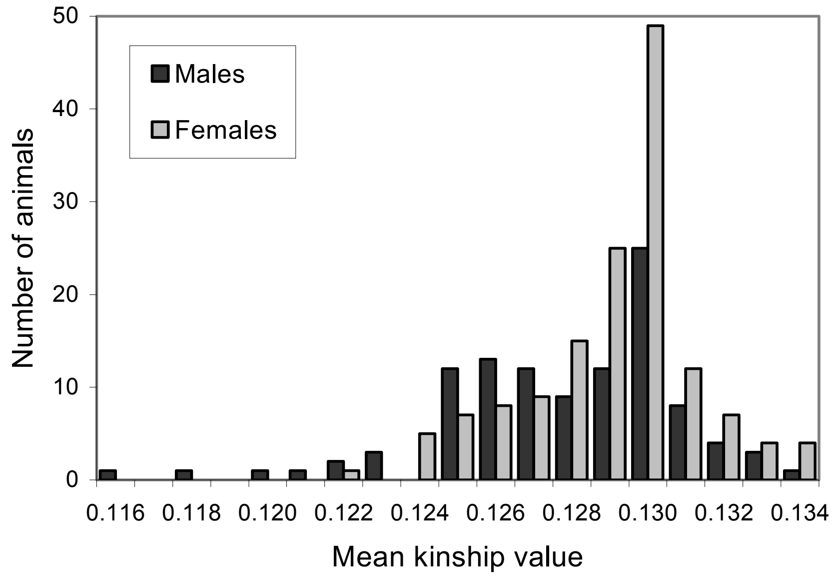

Figure 8. Distribution of mean kinship (MK) values in current black-footed ferret SSP population (as of 15 April 2003).

Breeding Strategy Recommendations

1. Change the proposed age structure within the SSP by retaining an even distribution of one-, two- and three-year-olds and some four-year-olds. Only four-year-olds that have bred before and are genetically valuable will be retained in the SSP. USFWS/SSP requested to implement changes at the SSP meeting in September 2003.

2. Send a larger proportion of one-year-old males to pens or to facilities with outdoor light (CRC and new FCC). There is evidence that one-year-olds are spermic later than older animals in artificial light, which decreases their availability for breeding when females are ovulating. Natural light synchronizes breeding and increases reproductive success. By housing one-year-olds in natural light facilities, we may increase the experience of naïve animals, increase breeding opportunities for one-year-olds (which are perceived as difficult breeders by some facilities), and potentially increase genetic diversity at reintroduction sites. Once bred, these animals could be returned to the SSP population if deemed to be genetically valuable. Risks to one-year-olds will be considered. Animals will be quarantined if returned to the SSP population. Transfer of animals will only be done in the fall prior to sperm production or after confirmation of adequate sperm production to ensure that shipping does not compromise fertility. Because one-year-olds are more difficult to breed, pen facilities will be asked to do positive sperm checks on females post breeding and to electroejaculate males prior to breeding to ensure that males are optimally spermic. Evaluation of breeding success utilizing one-year-old males will be

determined following the 2004 breeding season and compared to production in previous years. U.S. Fish and Wildlife Service requested to implement by August 2003.

3. Balance the distribution of proven animals (animals that have bred successfully) among SSP facilities so that each institution has the ability to increase production. Additionally, each institution should maintain unproven animals (animals that have not bred before). SSP facilities that breed previously unbred animals or genetically valuable animals will be given incentive to continue with better husbandry by receiving a higher rank. A higher rank ensures a larger number of transferred animals will be given to the facility the following year (see SSP Structure and Function for a complete description of the incentives program). A balanced distribution of proven animals should be identified by the 2003 SSP meeting, so that appropriate transfers can be scheduled prior to the 2004 breeding season.

4. Obtain studbook and population management training for current black-footed ferret studbook keeper P. Marinari, including use of SPARKS and PM2000. A request for funding for training will be submitted to the SSP and USFWS by 1 July 2003.

5. Increase routine dialog between the current SSP genetic advisor and the SSP coordinator and studbook keeper. If the current advisor's time commitments are too constrained, a new genetic advisor should be identified. A job description should be prepared with desired qualifications (e.g., familiarity with PM2000). D. Garelle and P. Marinari will discuss with Jon Ballou by 1 July 2003.

6. Measure and increase light intensity as needed at indoor breeding facilities. Each facility should measure their light intensity and keep it above 25 foot candles, a minimum intensity previously found to be critical for synchrony of male and female breeding. D. Garelle will be responsible for collecting data from each institution. Additionally, Cheyenne Mountain Zoo will implement a study by increasing light in 2004 to compare with 2003.

Relationship Among Mean Kinship, Sperm Quality and Productivity

Because animals at the bottom of the ranked MK list are the most genetically over-represented, they are often animals that have produced the most offspring. Conversely, animals that are the most genetically valuable (at the top of the MK list) typically have produced the fewest kits. Because of this relationship, there has been concern that the SSP is sending its most fecund animals for release and retaining "poor breeders" in the SSP.

In year by year comparisons, we found sperm quality to increase with increasing MK value, i.e., animals that were the most genetically valuable had the poorest sperm quality

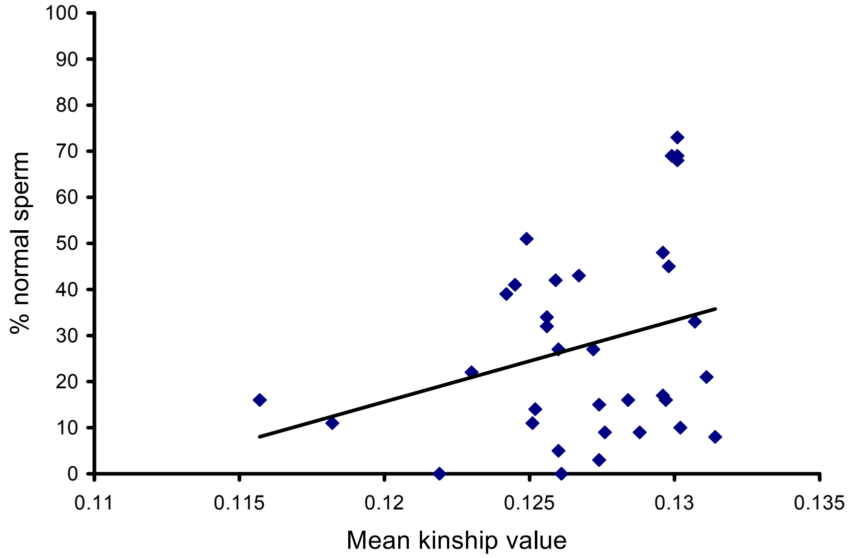

Figure 8.5. Regression of percent normal sperm on mean kinship value for captive black-footed ferrets from CRC in 2003 only. We found a marginally significant relationship between the variables ($F = 3.0$, $P = 0.09$). As MK value increased so did percent normal sperm.

When we combined analyses for a multi-year comparison, however, we found the reverse relationship: the lower the MK value (the more genetically valuable) the better the sperm quality (Figure 9). We believe this second observation to be spurious because MK value was highly correlated with year; MK has increased over time as animals become more related to one another ($r = 0.64$, $P < 0.001$), yet sperm quality has decreased through time giving the impression that animals with lower MK value have better sperms. Thus, we believe this correlation is driven by the year effect instead of MK value. In multi-year studies which incorporate a relatedness parameter such as MK, we recommend that rank be used and not the value.

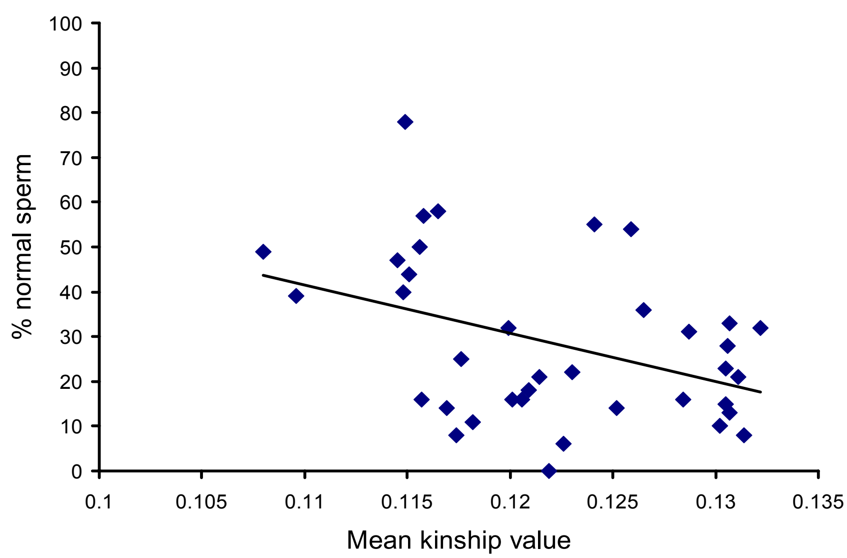

Figure 9. Regression of percent normal sperm on mean kinship value for captive black-footed ferrets from CRC from 1996 to 2003. We found a significant relationship between the variables ($F = 6.8$, $P = 0.01$, $n = 36$). However, we believe this relationship to be spurious due to the high correlation between MK value and year.

Several questions emerge from these data and observations. Is fecundity heritable? Is sperm quality heritable or is it driven by environmental factors such as diet or light? If sperm quality is heritable, the concern has been expressed that the MK method of genetic management may select for poor sperm quality by preferential breeding of animals at the top of the MK list. In fact, the MK method will not select for poor sperm quality, but neither will it keep it out of the population. Minimizing mean kinship results in the retention of genes in the population at the same level as in the initial founding population, counteracting selection either for or against certain genes. Most SSP programs acknowledge that "bad" genes will be maintained along with good genes but accept this risk rather than eliminate all of the genetic diversity added by that founder. Additionally, genes that may cause poor sperm quality in captivity may not have the same effect in the wild (genes x environment effect).

Additional MK Recommendations

1. Continue to send low-ranked animals (those with high MK values) out for release and keep the most genetically valuable animals in the SSP. Do not retain low-ranked MK litters and do not split the litters and keep half in the SSP.

2. Split litters for reintroduction among different reintroduction sites to increase the likelihood that released animals will not mate with first-order relatives.

3. Develop a matrix of data for individual animals in order to determine which factors affect reproductive success. Measures to be recorded include age, inbreeding coefficient, breeding opportunities, breeding behavior, status of sperm checks, sperm quality, litter size, kit survival, facility, and various husbandry factors. Data also will be used to evaluate how these factors correlate to inbreeding depression. These data will be collated by intern, Heather Branvold in September 2003.

Reproductive Physiology and Assisted Reproduction

The Black-footed Ferret Recovery Plan emphasized species preservation through natural breeding and the use of assisted reproductive technology. Reproductive biotechnology offers many advantages for enhancing reproduction and maintaining genetic diversity in small populations. The use of techniques such as artificial insemination (AI: deposition of sperm into a female) provides an approach for improving reproductive efficiency in animals with poor breeding performance. An extensive review of reproductive history in black-footed ferrets revealed that numerous factors influence male reproductive failure, including improper breeding position, poor testes development and excessive aggression (Wolf et al. 2000). The strategy of assisted reproduction combats behavioral incompatibility between individuals and helps ensure reproduction in genetically valuable animals. These techniques especially benefit species like black-footed ferrets that are propagated under the auspices of a genetic management plan such as the Species Survival Plan (SSP). The SSP provides breeding recommendations in an attempt to equalize genetic representation of the few original wild-caught founders, and cooperating institutions breed animals on the basis of genetic value and how related an individual is to the rest of the population, termed 'mean kinship' (see Balancing Genetic Diversity and Production section) (Ballou and Lacy 1995). The use of AI offers an alternative to natural breeding when recommended pairings fail to reproduce.

The potential of assisted reproduction is enhanced further by sperm cryopreservation, which saves valuable genetic material for future generations. The development of a Genome Resource Bank (GRB: a repository of cryopreserved sperm) offers a feasible strategy for infusing germ plasm into a genetically stagnant population or transferring sperm between geographically separated populations (Wildt et al. 1997). In species that have short life spans (like the black-footed ferret), the use of cryopreserved sperm extends the reproductive life of an individual. In the Black-footed Ferret Recovery Program, assisted reproductive techniques have been demonstrated to be effective. To date, more than 100 black-footed ferret kits have been born from AI with fresh or cryopreserved semen. This technology is currently being utilized in the management of this endangered species to prevent the loss of valuable genetic material and provide additional kits for reintroduction each year.

Strategies to maintain gene diversity in small populations include: equalizing founder representation, maximizing generation time and minimizing inbreeding. Although the mean kinship strategy (designed to achieve these goals) has been used for propagating black-footed ferrets, abnormal traits have been detected in the current population that are similar to those observed in other small populations of carnivores, such as the Florida panther. The currently observed traits in black-footed ferrets include: a higher percentage of abnormal sperm, kinked tail, cryptorchidism, heart murmur, kidney aplasia and uterine horn aplasia. It is now necessary to summarize these data to begin determining if etiology is due to selection or inbreeding depression. These following questions will assist in summarizing the data:

Question 1: Have sperm traits changed over time in male black-footed ferrets at FCC and CRC?

Over the past eight years (1996 – 2003), the percent motile sperm has not changed drastically (Figure 10). A dramatic decline in percent normal sperm was observed beginning in 2000 (Figure 11). Similarly, the percent of sperm with abnormal acrosomes dramatically increased beginning in 2000 (Figure 12). A high percentage of abnormal acrosomes may lead to fertility problems.

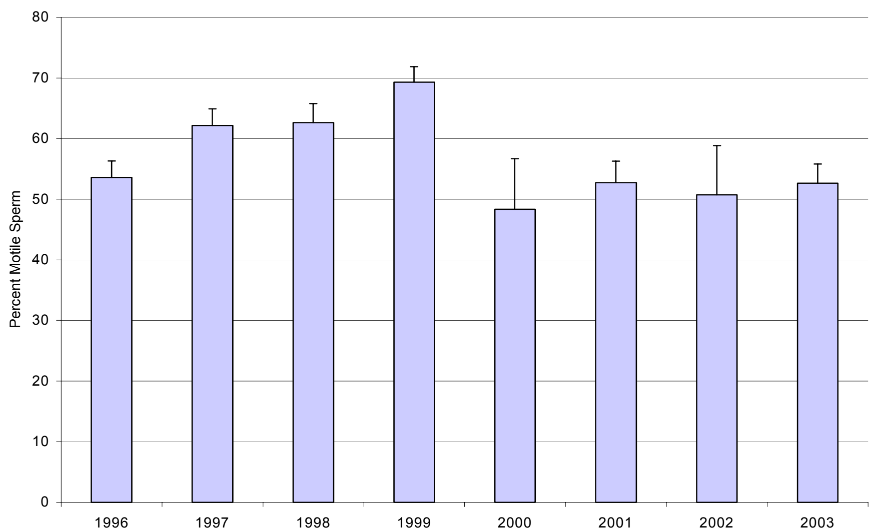

Figure 10. Percent motile sperm in black-footed ferrets at FCC and CRC during 1996 – 2003. Overall mean (+ sem) percent is 57.7 + 1.4, with a range from 48.3 + 8.3 to 69.3 + 3.3.

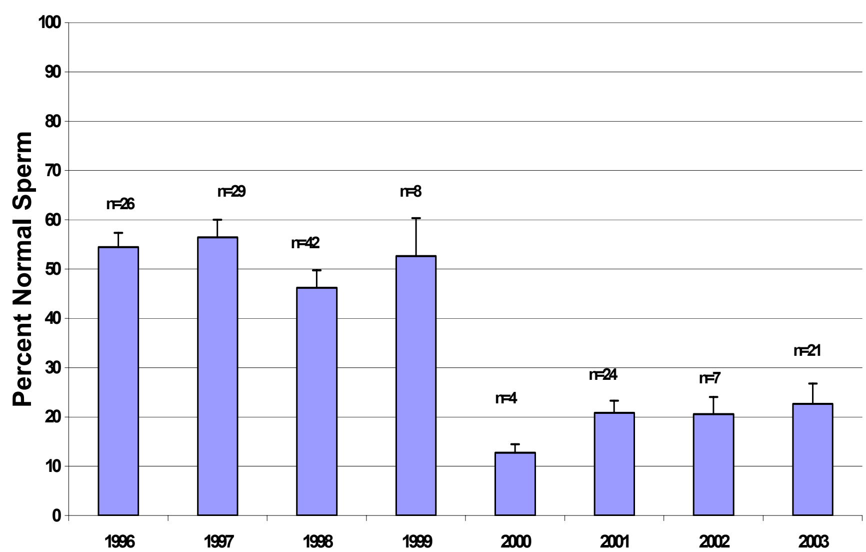

Figure 11. Percent normal sperm in black-footed ferrets at FCC and CRC during 1996 – 2003. Overall mean (+ sem) percent is 40.9 + 1.9, with a range from 12.8 + 1.7 to 56.4 + 3.6.

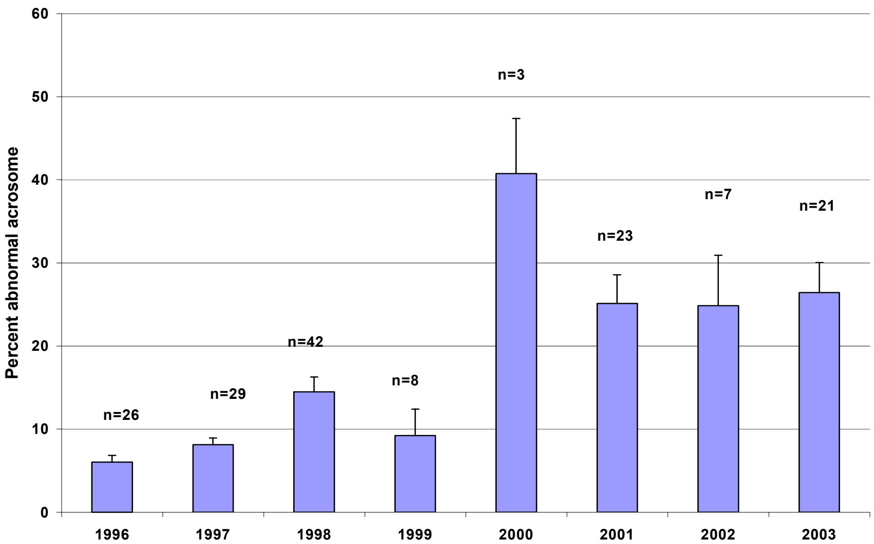

Figure 12. Percent abnormal acrosomes in black-footed ferrets at FCC and CRC during 1996 – 2003. The mean (+ sem) percent from 1996 – 1999 was 10.2 + 0.9, while the mean from 2000 to 2003 was 26.7 + 2.2.

Question 2: Have sperm traits changed over time in male black-footed ferrets at CRC only?

Semen evaluations in males at FCC could be influenced by numerous factors including time of year, time of visit during the breeding season (early vs late season), light cycle (advanced vs natural vs outdoor) and asynchrony in one-year-old males. Therefore, FCC data were removed for analyses of CRC males only during the same time period.

A similar pattern of results was observed when only CRC males are examined. The mean percent motile sperm did not change significantly over the years ($p > 0.05$) (Figure 13).

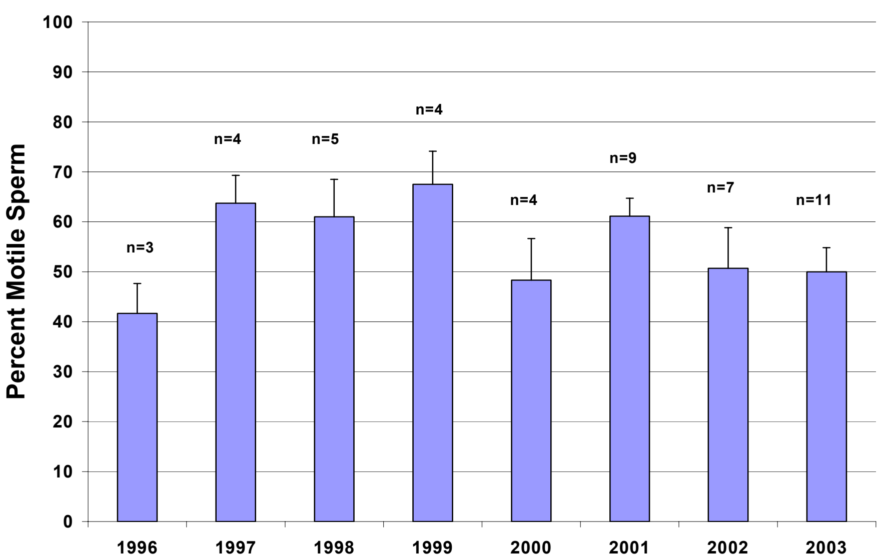

Figure 13. Percent motile sperm in black-footed ferrets at CRC during 1996 – 2003. Overall mean (+ sem) percent is 55.5 + 2.3, with a range from 41.7 + 6.0 to 67.5 + 6.6.

A significant decline ($p < 0.05$) in percent normal sperm was observed when comparing data for 1996 – 1998 to that from 1999 – 2003 (Figure 14). Likewise, the number of sperm with abnormal acrosomes increased significantly from 1999 to 2000 ($p < 0.05$) and has remained high (more than 20%) for four years. A high percentage of abnormal acrosomes may lead to fertility problems.

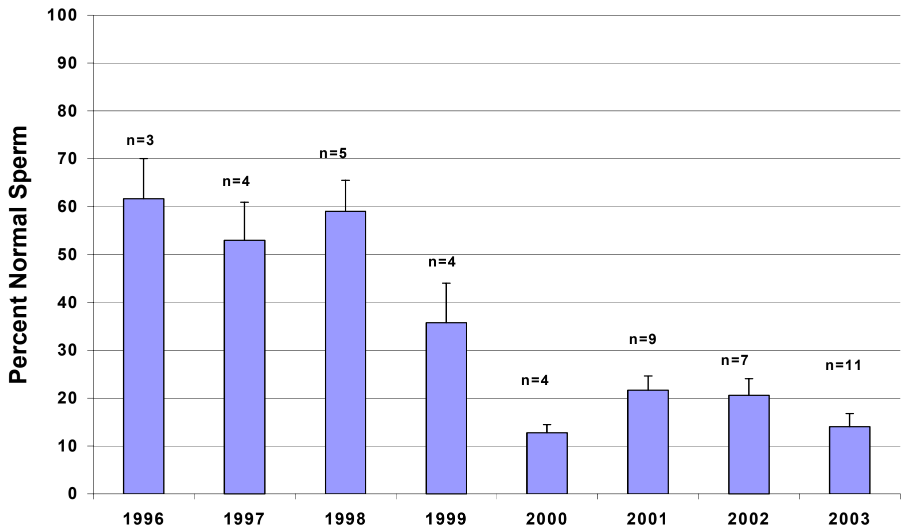

Figure 14. Percent normal sperm in black-footed ferrets at CRC during 1996 – 2003. Overall mean (± sem) percent is 29.3 ± 3.0, with a range from 12.8 ± 3.4 to 61.7 ± 8.4.

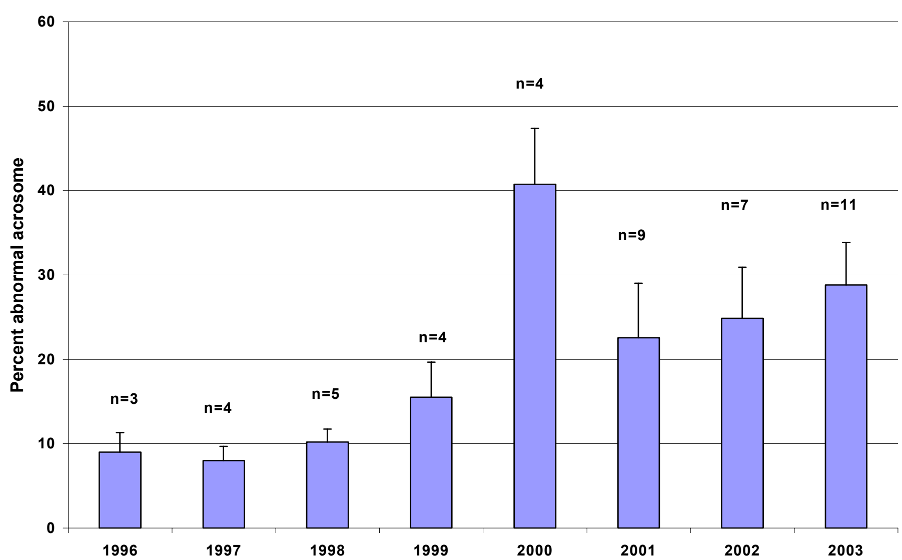

Figure 15. Percent abnormal acrosomes in black-footed ferrets at CRC during 1996 – 2003. Overall mean (± sem) percent is 21.1 ± 2.4, with a range from 8.0 ± 1.7 to 40.8 ± 5.7.

Question 3: Have whelping rates changed over time?

Preliminary data analysis has found no difference ($p > 0.05$) in the whelping success between AI and natural breeding (see Table 1).

Table 1. Whelping rates using artificial insemination (AI) and natural breeding (CRC and FCC) in black-footed ferrets in 1996 through 2002.

Year	CRC AI	CRC Natural breeders	FCC Natural breeders
1996	5/6 (83.3%)	None	36/51 (71%)
1997	6/8 (75%)	None	46/74 (62%)
1998	3/5* (60.0%)	3/4 (75%)	68/85 (80%)
1999	6/9 (66.7%)	4/8 (50%)	56/90 (62%)
2000	3/9 (33.3%)	4/8 (50%)	45/75 (60%)
2001	7/9 (77.8%)	5/8 (62.5%)	47/88 (53%)
2002	4/9 (44.4%)	5/8 (62.5%)	39/89 (44%)

* hCG problems: 4 did not ovulate

Question 4: What is the reproductive success in kits born after AI vs natural breeding?

Table 2. Reproductive success in 1-year, 2-year, 3-year and 4 –year old male and female black-footed ferrets produced by artificial insemination (AI) or natural breeding.

Year of productivity	Females born by artificial insemination	Males born by artificial insemination	Females born by natural breeding	Males born by natural breeding
1st year	43.9% n = 22	0% n = 15	48.6% n = 22	35.7% n = 10
2nd year	63.2% n = 18	50% n = 15	76.7% n = 21	69.4% n = 9
3rd year	64.8% n = 16	50% n = 5	44.4% n = 20	36.1% n = 9
4th year	n/a	66.7% n = 3	n/a	42.9% n = 7

Question 5: Are there other signs of abnormal traits?

Kinked tails, partial uterine aplasia, unilateral renal aplasia, heart murmur and cryptorchidism have been observed in black-footed ferrets (see Tables 3 - 5). Preliminary results indicate that unilateral cryptorchidism in the black-footed ferret does not inhibit sperm production (Table 6).

Table 3. Black-footed ferrets with kinked tails (detected in 7 of 87 ferrets in 2003).

SB#	Name	DOB	Sex	Inbreeding (F)	MK #, 2003	MK Rank, 2003
3891	And Dean	2002	M	0.1118	0.1288	58
3653	Eddie	2001	M	0.1045	0.1256	20
3647	Zachary	2001	M	0.0993	0.1260	26
3401	Scout	2001	F	0.1197	0.1247	6
3649	Beth	2001	F	0.0992	0.1310	116
3910	Hope	2002	F	0.1113	0.1327	140
3858	Aspen	2002	F	0.1054	0.1313	122

Table 4. List of other abnormal traits.

Abnormal Trait	Occurrence in BFF population
Partial uterine aplasia (one uterine horn missing)	Observed in the past
Unilateral renal aplasia (one kidney missing)	Founder SB #16 "Dean" (defect observed by Dr. Beth Williams)
Heart murmur (systolic murmur)	SB #2945 "Geoff"; born 1999; MK=0.1219; MK rank=5; F=0.0922 Noticed in 2003; similar to Florida panther; type of defect needs to be confirmed by necropsy

Table 5. Inbreeding (F) and MK values for cryptorchid black-footed ferrets and MK values for their sire and dam.

SB#	Name	Type*	DOB	F	MK#	MK Rank	Sire SB#	Sire MK#	Sire MK Rank	Dam SB#	Dam MK#	Dam MK Rank
3974	Zorro	I	2002	0.1011	0.1252	18	2201	0.1226	16	2855	0.1246	15
3653	Eddie	I	2001	0.1045	0.1256	20	3069	0.1235	31	2399	0.1237	27
3647	Zachary	I	2001	0.0993	0.1260	26	2698	0.1223	16	2334	0.1247	95
3644	Jacob	I	2001	0.0993	0.1260	25	2698	0.1223	16	2334	0.1247	95
3307	Mojave	T	2000	0.1232	0.1251	14	1958	0.1259	106	3032	0.1269	135

* I = inguinal; T = true

Table 6. Semen traits in cryptorchid males in 2003.

SB#	Name	MK 2003	MK Rank 2003	Sperm conc. ($x10^6$/ml)	Normal sperm (%)	Abnormal acrosomes
3307	Mojave	0.1251	14	152	11	19
3647	Zachary	0.1260	26	642	5	73
3653	Eddie	0.1256	20	50.5	32	16
Average ± SEM		0.126 ± 0.0	20.0 ± 3.5	281.5 ± 182.6	16.0 ± 8.2	36.0 ± 18.5

Question 6: Is there evidence of infertility?

Table 7. Infertility cases observed in 2002.

Artificial insemination = no pregnancies
#2420 Jack CRC used for 3 AI in 2002 and no pregnancies
Female # 3098 One Eighty Two (born 2000; 2 yr) PROVEN
Female # 3204 Zhanna (born 2000; 2 yr) = NON PROVEN
Female #2928 Tex (born 1999, 3 yr old in 2002) = PROVEN
Natural breeding = no pregnancies
#2945 Geoff LZG: multiple females, + sperm
#2302 Tashi FCC: multiple females, + sperm
#2741 Kublai FCC: multiple females, + sperm
#3335 Robinson FCC: multiple females, + sperm

Table 8. Compromised sperm quality in sperm donors for AI in 2003.

- Poor sperm quality in 4 of 5 males not used for AI
#2787 Shaggy: low # sperm, low % sperm motility, low sperm status
#2945 Geoff: low % motility, low sperm status, 0% normal sperm, 54% non-intact acrosomes
#3332 Buckshot: low # sperm, low % motility, low status
#2734 Sawyer: low # sperm
- First time: Had to use natural breeders or frozen semen
- First time: Failure to represent males

Table 9. Poor semen traits in 'dud' black-footed ferrets that could not be used for AI in 2003. While one reduced semen trait may not affect fertility, two or more reduced traits may compromise fertility, such as low sperm count combined with a low percent motile sperm and low numbers of normal sperm.

SB#	Name	MK # 2003	MK Rank 2003	Sperm Conc. ($x10^6$/ml)	Total Sperm ($x10^6$)	Sperm Motility (%)	Sperm Status (0-5; 5=best)	Normal Sperm (%)	Abnormal Acrosome (%)
2787	Shaggy	0.1230	7	109.0	3.16	30.0	2.0	8	22.0
2945	Geoff	0.1219	5	379.3	6.45	40.0	2.5	0	54.0
3332	Buckshot	0.1199	3	448.4	4.93	20.0	2.0	8	17.0
2734	Sawyer	0.1252	15	166.4	1.66	50.0	2.5	14	42.0
Average ± SEM		0.1225 ± 0.0	7.5 ± 2.6	275.8 ± 81.8	4.1 ± 1.0	35.0 ± 6.5	2.3 ± 0.1	7.5 ± 2.9	33.8 ± 8.6

Question 7: How do semen traits compare between wild-born versus captive-born kits?

Preliminary results suggest that wild-born 1-year-old males have the highest total sperm count ($p < 0.05$).

Table 10. Sperm traits from fresh semen samples in captive-born versus wild-born black-footed ferrets.

	FCC 2003 Natural breeders (n=10)	CRC Natural Breeders (n=17)	CRC AI Sperm Donors (n=28)	Wild-born 1 yr old (n=22)	Wild-born 2 & 3 yr old (n=7)
Total sperm ($x10^6$)	8.2 ± 1.9	14.7 ± 3.9	13.3 ± 2.0	25.2 ± 3.4	8.8 ± 2.5
Sperm motility (%)	55.5 ± 4.1	58.8 ± 4.5	53.8 ± 2.7	62.7 ± 1.2	53.6 ± 4.0
Sperm status (0 to 5; 5=best)	2.8 ± 0.2	2.3 ± 0.3	2.8 ± 0.1	3.0 ± 0.04	2.4 ± 0.2
Normal sperm (%)	32.1 ± 7.2	28.3 ± 4.5	30.6 ± 4.1	41.3 ± 2.7	19.9 ± 5.8
Abnormal acrosomes (%)	23.8 ± 5.3	16.4 ± 3.1	24.2 ± 3.1	19.2 ± 2.8	25.6 ± 7.3

Question 8: Have semen traits changed within an individual male?

Due to confounding factors such as facility, light, diet and time of year, analysis of individual semen trait changes over time is difficult to assess accurately (see Table 11).

Question 9: Are semen traits heritable and has sperm quality changed over generations?

Again, because of confounding factors such as facility, light, diet and time of year, analysis of heritability of semen traits among grandfather, father and son is difficult to assess accurately. Preliminary results found a lack of correlation between generations (see Table 12).

Question 10: Are semen traits influenced by diet?

No concrete results were obtained from the diet study in 2003 (see Tables 13a & b). Therefore, another diet study is planned in 2004 to be conducted with 50 animals at FCC.

Table 13a. Semen traits in male black-footed ferrets on preliminary diet study (Toronto diet versus prairie dogs) conducted at FCC in 2003.

	Toronto diet Indoors (n=13)	Prairie dog diet Indoors (n=5)	Prairie dog diet Outdoors (n=2)
Sperm concentration ($x10^6$/ml)	641.1 ± 169.2	465.5 ± 228.1	208.1 ± 33.1
Sperm motility (%)	55.5 ± 4.1	59.0 ± 2.4	67.5 ± 2.5
Sperm status (0 to 5; 5=best)	2.8 ± 0.2	2.8 ± 0.2	3.0 ± 0.0
Normal sperm (%)	31.8 ± 5.7	44.0 ± 10.8	55.5 ± 13.5
Abnormal acrosomes (%)	22.8 ± 4.6	26.6 ± 7.3	17.0 ± 6.0
Mean kinship rank (for 2003)	46.0 ± 6.9	49.8 ± 13.6	54.0 ± 30.0

Table 13b. Semen traits in male black-footed ferrets on preliminary diet study (Toronto diet versus prairie dogs) conducted at FCC in 2003 (indoor and outdoor data combined).

	Toronto diet Indoors (n=13)	Prairie dog diet Indoors and Outdoors (n=7)
Sperm concentration ($x10^6$/ml)	641.1 ± 169.2	391.9 ± 164.6
Sperm motility (%)	55.5 ± 4.1	61.4 ± 2.4
Sperm status (0 to 5; 5=best)	2.8 ± 0.2	2.9 ± 0.1
Normal sperm (%)	31.8 ± 5.7	47.3 ± 8.3
Abnormal acrosomes (%)	22.8 ± 4.6	23.9 ± 5.5
Mean kinship rank (for 2003)	46.0 ± 6.9	44.7 ± 6.6

Are Traits Heritable or Environmental?

To continue assessing the etiology of the sperm defects and other abnormalities, further research may be needed to determine if causes of spermic and morphologic changes are genetic or environmental. The working group made the following recommendations and actions to further assess the impact of diet and light on reproductive traits.

Reproduction Recommendations

1. Design a diet study to determine if sperm quality is affected by diet. The design of this study will be developed by P. Marinari, S. Wisely, JG. Howard, R. Moreland and J. Kreeger by 1 October 2003, and the study will be initiated by 1 November 2003. In the spring of 2004, reproductive evaluations of sperm quality will be conducted by R. Moreland, P. Marinari and J. Kreeger.

2. Use existing data to determine if there is evidence that sperm quality traits are heritable. This task will be difficult due to the limited amount of data; however, existing data on sperm traits over generations will be summarized. Continue to monitor data as information becomes available. Investigate the logistics and expense of conducting a conclusive heritability study. Existing data will be analyzed by JG. Howard and R.M. Santymire by 1 July 2003 (completed; see Tables 11 & 12 for data summary). The feasibility of conducting a more conclusive study will be investigated by the Black-footed Ferret SSP and reported to the Executive Committee.

3. Design a light study to demonstrate the effects of light intensity on reproduction. A summary of light intensity in ferret cages (at floor level) at SSP facilities will be conducted by D. Garelle and presented at the 2003 SSP meeting. Based on these findings, a light intensity study will be designed to see if light intensity influences reproductive success.

Other suggestions that were discussed at the workshop were: to continue the use of AI using fresh and/or cryopreserved sperm as a management tool to maintain genetic diversity (selecting top-ranking, non-proven ferrets that have had several opportunities to breed); and to determine if AI has been useful for maintaining genetic diversity and management of black-footed ferrets (by removing kits produced by AI and all of their descendants from the studbook to assess the impact on gene diversity; to be completed by JG. Howard and K. Traylor-Holzer by 1 July 2003).

Table 11. Sperm traits in individual black-footed ferrets over time. Highlighted sections reflect data collected on same individuals both before and after the decline in sperm quality.

SB #	NAME	DATE COLL	DOB	LOCATION	Tot Sperm mill	% MOT	Status 0-5	% NORM	AB ACR
732	Lyle	4/3/96	4/12/93	NBFFCC	17.60	65	3.0	76	5.0
732	Lyle	3/16/97	4/12/93	NBFFCC	2.40	75	4.0	27	4.0
732	Lyle	3/4/98	4/12/93	NBFFCC	4.72	50	3.0	61	12.0
562	Ralph	4/3/96	5/31/92	NBFFCC	8.71	40	3.0	48	6.0
562	Ralph	5/2/97	5/31/92	CRC	18.00	50	3.0	49	4
562	Ralph	5/4/98	5/31/92	NBFCC	6.01	20	2.0	10	52.0
639	Sony	4/4/96	7/4/92	NBFFCC	17.90	60	2.5	58	11.0
639	Sony	5/6/97	7/4/92	CRC	6.25	60	3.0	40	7.0
639	Sony	3/3/98	7/4/92	NBFFCC	0.87	15	1.5	2	52.0
256	Buckwheat	4/4/96	4/12/91	NBFFCC	21.70	60	2.5	53	6.0
256	Buckwheat	3/11/97	4/12/91	NBFFCC	21.72	60	3.0	60	0.0
1078	Anton	4/8/96	5/21/94	NBFFCC	7.86	70	4.0	69	2.0
1078	Anton	3/14/97	5/21/94	NBFFCC	5.96	80	3.5	66	6.0
1078	Anton	3/4/98	5/21/94	NBFFCC	8.40	50	3.0	6	40.0
294	Darwin	4/5/96	5/3/91	NBFFCC	20.32	60	3.5	56	2.0
294	Darwin	3/12/97	5/3/91	NBFFCC	4.08	60	3.0	43	3.0
296	Lowane	4/6/96	5/3/91	NBFFCC	2.78	50	3.5	40	12.0
296	Lowane	3/14/97	5/3/91	NBFFCC	6.31	50	3.0	32	9.0
733	Lucifer	4/7/96	4/12/93	NBFFCC	22.00	70	4.0	62	2.0
733	Lucifer	5/9/97	4/12/93	NBFFCC	2.51	60	3.0	55	4.0
733	Lucifer	4/9/98	4/12/93	NBFFCC	1.55	80	3.5	58	6.0
1301	Taylor	5/7/97	5/9/95	NBFFCC	5.01	75	3.5	55	9.0
1301	Taylor	4/10/96	5/9/95	CheyMtZoo	3.70	35	3.0	48	8.0
1044	Burroughs	5/1/96	5/12/94	CRC	10.63	45	2.5	50	13.0
1044	Burroughs	3/16/97	5/12/94	NBFFCC	1.90	40	2.5	71	7.0
1044	Burroughs	4/7/98	5/12/94	NBFFCC	4.69	70	3.0	44	18.0
731	Snooker	5/1/96	4/12/93	CRC	10.80	50	3.0	78	5.0
731	Snooker	3/16/97	4/12/93	NBFFCC	0.92	35	2.5	44	8.0
1047	Danny	5/1/96	5/12/94	CRC	3.04	30	2.5	57	9.0
1047	Danny	5/7/97	5/12/94	NBFFCC	1.95	70	0.0	76	9.0
1323	Butch	5/6/97	5/14/95	NBFFCC	5.00	65	3.0	65	16.0
1323	Butch	3/10/98	5/14/95	CRC	6.46	50	3.0	39	11.0
1323	Butch	5/14/99	5/14/95	CRC	18.70	50	3.0	17	27
1323	Butch	5/25/00	5/14/95	CRC	26.29	40	2.5	18	n/a
718	Bouncer	3/17/97	8/10/92	NBFFCC	38.40	50	3.0	78	10.0
718	Bouncer	4/9/98	8/10/92	NBFFCC	27.70	70	3.5	38	5.0
1343	Abraham	5/10/97	5/22/95	NBFFCC	11.90	75	3.0	83	3.0
1343	Abraham	4/10/98	5/22/95	CRC	17.10	60	3.0	58	6.0
1343	Abraham	5/7/99	5/22/95	CRC	10.60	75	3.5	28	16.0
1348	Marty	5/7/97	5/23/95	NBFFCC	4.87	75	3.5	81	9.0

SB #	NAME	DATE COLL	DOB	LOCATION	Tot Sperm mill	% MOT	Status 0-5	% NORM	AB ACR
1348	Marty	5/8/98	5/23/95	NBFFCC	1.30	80	3.5	56	10.0
1311	Jared	3/13/97	5/12/95	NBFFCC	4.80	75	4.0	63	7.0
1311	Jared	4/6/98	5/12/95	NBFFCC	6.79	75	3.0	42	14.0
1338	Rascal	5/10/97	5/23/95	NBFFCC	8.40	60	3.0	56	17.0
1338	Rascal	4/8/98	5/23/95	NBFFCC	13.70	65	3.5	40	13.0
1598	Othello	5/5/97	5/9/96	NBFFCC	10.60	70	3.0	77	13.0
1598	Othello	3/2/98	5/9/96	NBFFCC	0.63	45	2.5	81	5.0
1583	Bowman	3/15/97	5/2/96	NBFFCC	12.30	75	3.0	55	5.0
1583	Bowman	4/9/98	5/2/96	NBFFCC	5.74	85	3.5	77	9.0
641	Travis	5/6/97	5/9/92	CRC	5.37	75	3.5	47	12.0
641	Travis	3/10/98	5/9/92	CRC	1.56	40	2.0	64	8.0
1637	Reid	5/20/97	5/21/96	NBFFCC	2.94	??	??	56	4
1637	Reid	5/11/00	5/21/96	CRC	11.07	40	2.5	14	50
1647	Joseph	5/7/97	5/23/96	NBFFCC	0.94	70	3.0	22	6.0
1647	Joseph	5/12/98	5/23/96	CRC	13.00	80	4.0	79	11.0
1647	Joseph	5/4/99	5/23/96	CRC	22.16	80	3.0	44	11.0
1828	Clifford	4/23/99	6/2/96	HenryDoorly	11.48	70	3.0	77.0	5.0
1828	Clifford	4/24/00	6/2/96	CRC	10.27	65	2.5	16.0	24.0
2201	Winkin	5/1/01	6/16/97	CRC	n/a	50	2.0	25	18.0
2201	Winkin	5/24/02	6/16/97	CRC	36.74	65	3.0	13	46.0
2423	Augustus	6/22/01	6/4/98	CRC	35.49	60	3.0	13	23
2423	Augustus	5/30/02	6/4/98	CRC	8.50	10	1.0	12	48
2420	Jack	4/2/01	6/4/98	NBFFCC	8.78	60	3.0	19	31.0
2420	Jack	5/14/02	6/4/98	CRC	45.85	35	2.5	18	18.0
3280	Hasin	4/4/01	4/13/00	NBFFCC	6.67	60	3.0	56	18.0
3280	Hasin	6/25/02	4/13/00	CRC	23.69	65	3.0	31	16.0
2176	Austin	5/1/01	5/23/97	CRC	15.31	40	2.5	32	38.0
2176	Austin	5/9/02	5/23/97	CRC	36.50	50	2.5	18	24.0
2486	Hildatsa	6/19/02	5/23/98	CRC	22.78	60	3	16	16
2486	Hildatsa	4/22/03	5/23/98	CRC	12.10	50	2.5	3	40.0
3626	Kupper	5/9/02	6/11/01	CRC	13.30	65	3.0	0	30.0
3626	Kupper	4/8/03	6/11/01	FCC	25.30	65	3.0	41	39.0
3335	Robinson	3/9/02	6/4/00	NBFFCC	5.41	60	3.0		
3335	Robinson	4/23/03	6/4/00	CRC	14.20	50	2.5	11	50.0
2766	Gloop	3/9/02	5/27/99	NBFFCC	10.62	55	2.5	26	6
2766	Gloop	4/11/03	5/27/99	NBFFCC	1.06	60	3.0	27	15.0
3410	Otoson	3/13/02	3/30/01	NBFFCC	4.36	60	3	10	14
3410	Otoson	4/11/03	3/30/01	NBFFCC	3.92	60	3.0	69	17.0

Table 12. Comparison of sperm traits within pedigrees.

SB #	Name	Relationship	Date Collect	DOB	Sperm mill/ml	TotSperm mill	Motil %	Status 0-5	Normal %	% Abn Acros
3636	Shandro	Son	4/10/03	06/21/01	612.9	15.94	60	3.5	39	20
2201	Winkin	Father	2/12/02	06/16/97	27.6	1.08	50	2.0	28	16
639	Sony	Grandfather	5/6/97	07/04/92	284.0	6.25	60	3.0	40	7
3626	Kupper	Son	4/8/03	06/11/01	1150.0	25.30	65	3.0	41	39
2176	Austin	Father	5/1/01	05/23/97	528.0	15.31	40	2.5	32	38
3615	Embo	Son	4/8/03	05/27/01	578.8	15.30	65	3.5	51	12
2176	Austin	Father	5/1/01	05/23/97	528.0	15.31	40	2.5	32	38
3340	Badger	Son	4/29/03	06/10/00	130.6	2.74	65	3.0	16	28
1323	Butch	Father	5/14/99	05/14/95	812.3	18.70	50	3.0	17	27
3335	Robinson	Son	4/23/03	06/04/00	748.7	14.20	50	2.5	11	50
1828	Clifford	Father	6/1/00	06/02/96	326.1	10.76	60	4.0	22	16
1047	Danny	Grandfather	4/12/96	05/12/94	705.0	6.34	65	3.5	69	0
305	Dot	Great grandfather	4/6/96	05/08/91	2193.0	17.54	35	2.5	16	14
3332	Buckshot	Son	5/14/03	06/04/00	448.4	4.93	20	2.0	8	17
1828	Clifford	Father	6/1/00	06/02/96	326.1	10.76	60	4.0	22	16
1047	Danny	Grandfather	4/12/96	05/12/94	705.0	6.34	65	3.5	69	0
305	Dot	Great grandfather	4/6/96	05/08/91	2193.0	17.54	35	2.5	16	14
2205	Daniel	Son	4/4/01	06/18/97	121.0	2.66	40	2.5	0	8
562	Ralph	Father	5/2/97	05/31/92	619.0	18.00	50	3.0	49	4
1831	Oliver	Son	3/27/97	06/11/96	48.4	0.43	70	2.5	24	16
731	Snooker	Father	5/1/96	04/12/93	1080.0	10.80	50	3.0	78	5
1829	Mellors	Son	4/8/98	06/03/96	117.0	1.52	80	3.0	48	11

SB #	Name	Relationship	Date Collect	DOB	Sperm mill/ml	TotSperm mill	Motil %	Status 0-5	Normal %	% Abn Acros
1047	Danny	Father	4/12/96	05/12/94	705.0	6.34	65	3.5	69	0
1828	Clifford	Son	6/1/00	06/02/96	326.1	10.76	60	4.0	22	16
1047	Danny	Father	4/12/96	05/12/94	705.0	6.34	65	3.5	69	0
305	Dot	Grandfather	4/6/96	05/08/91	2193.0	17.54	35	2.5	16	14
1825	Comet	Son	3/15/97	05/06/96	24.0	0.38	30	2.0	20	12
1047	Danny	Father	4/12/96	05/12/94	705.0	6.34	65	3.5	69	0
305	Dot	Grandfather	4/6/96	05/08/91	2193.0	17.54	35	2.5	16	14
2734	Sawyer	Son	4/29/03	05/02/99	166.4	1.66	50	2.5	14	42
2238	Mica	Father	6/12/01	03/30/98	n/a	n/a	60	n/a	32	4
1311	Jared	Grandfather	3/13/97	05/12/95	301.0	4.80	75	4.0	63	7
295	Franklin	Great grandfather	4/6/96	05/03/91	636.0	3.81	65	3.5	58	5
2945	Geoff	Son	4/29/03	06/14/99	379.3	6.45	40	2.5	0	54
1603	Alexei	Father	4/10/97	05/09/96	171.7	0.50	100	3.5	n/a	n/a
733	Lucifer	Great grandfather	4/7/96	04/12/93	2201.0	22.00	70	4.0	62	2
2787	Shaggy	Son	4/11/03	05/31/99	210.0	4.60	30	2.0	22	36
1986	Popeye	Father	5/4/98	05/26/97	279.0	6.98	75	3.5	50	10
1311	Jared	Grandfather	3/13/97	05/12/95	301.0	4.80	75	4.0	63	7
295	Franklin	Great grandfather	4/6/96	05/03/91	636.0	3.81	65	3.5	58	5
3465	Odell	Son	4/11/03	05/23/01	369.2	7.39	60	3.0	48	14
2650	Osiris	Father	4/1/01	03/30/99	318.0	6.36	60	3.0	33	19
2128	Navajo	Grandfather	5/8/98	06/11/97	597.0	20.00	85	3.5	73	6
3307	Mojave	Son	4/11/03	05/08/00	152.0	2.13	60	2.5	11	19
1583	Bowman	Grandfather	4/9/98	05/02/96	174.0	5.74	85	3.5	77	9

SB #	Name	Relationship	Date Collect	DOB	Sperm mill/ml	TotSperm mill	Motil %	Status 0-5	Normal %	% Abn Acros
732	Lyle	Great grandfather	4/3/96	04/12/93	2201.0	17.60	65	3.0	76	5
3404	Jonah	Son	4/10/03	05/22/01	263.2	8.15	60	3.0	27	26
767	Guy	Grandfather	3/5/98	04/25/93	170.0	3.91	70	3.5	31	20
3258	Quentin	Son	4/9/03	03/21/00	640.0	14.60	60	3.0	9	22
731	Snooker	Great grandfather	4/12/96	04/12/93	1428.0	5.71	60	3.5	84	3
3876	John-Boy	Son	4/9/03	05/30/02	40.1	0.64	60	2.5	73	7
2423	Augustus	Grandfather	6/22/01	06/04/98	507.0	35.49	60	3.0	13	23
1142	Sunchief	Great grandfather	3/4/98	05/18/94	508.0	12.70	40	2.5	21	16
3886	George	Son	4/9/03	05/31/02	37.0	0.89	50	2.5	3	26
2205	Daniel	Father	3/11/02	06/18/97	376.7	6.47	60	3.0	4	80
562	Ralph	Grandfather	5/2/97	05/31/92	619.0	18.00	50	3.0	49	4
3653	Eddie	Son	4/9/03	06/02/01	50.5	0.12	20	1.0	32	16
1647	Joseph	Grandfather	5/12/98	05/23/96	1300.0	13.00	80	4.0	79	11
3877	Jim Bob	Son	4/9/03	05/30/02	869.5	20.9	60	3.0	68	13
2423	Augustus	Grandfather	6/22/01	06/04/98	507.0	35.49	60	3.0	13	23
1142	Sunchief	Great grandfather	3/4/98	05/18/94	508.0	12.70	40	2.5	21	16
3753	Damen	Son	4/8/03	05/05/02	330.6	6.2	60	2.5	17	45
1647	Joseph	Grandfather	5/12/98	05/23/96	1300.0	13.00	80	4.0	79	11
3830	Plaster	Son	4/8/03	05/25/02	614.5	11.5	60	3.0	60	7
3366	Stucco	Father	3/10/02	07/07/00	308.3	10.33	70	3.0	10	26
1993	Stuart	Great grandfather	3/3/98	05/27/98	367.5	8.82	80	3.5	67	7

SSP Structure and Function

Management Issues

The primary challenge identified by the SSP and Pen Management Working Group for captive management of black-footed ferrets is to develop methods to increase breeding success while minimizing loss of genetic diversity in the SSP population. Variability in breeding success among facilities and within some facilities has raised concerns about the usefulness of some facilities. Furthermore, some facilities deviate from the SSP-approved animal husbandry guidelines in an effort to increase production. These facilities have produced high numbers of kits by "fast tracking" – pairing and/or using limited number of proven males to maximize the number of kits produced. The "fast-tracking" method refers to a shortened pairing time per male due to lack of positive sperm check. This method successfully increases production but greatly limits the number of parents represented in the gene pool of the offspring, thus reducing genetic diversity. Many facilities prefer to breed only "proven" males – males that have produced kits in the past and are therefore known to have bred successfully. The working group was concerned that this bias toward proven males will also reduce genetic diversity because the number of males bred each year will be smaller than the optimum (see Balancing Genetic Diversity and Production section and Figure 3).

The working group recognized the important political and biological contributions that multiple breeding facilities bring. Ultimately more animals can be produced, catastrophic epizootics can be averted and more partners can participate in the process of recovery of an endangered species. It was thus decided that increasing production at facilities while maintaining genetic diversity be a goal for every facility, not just the FCC facility. Ultimately, it was recognized that increasing the number of animals in the SSP (with or without increasing the number of facilities) will enhance both the maintenance of genetic diversity and the production of kits for reintroduction.

One way to ensure that facilities comply with the new goals of production tempered with maintenance of genetic diversity was to standardize data collection between facilities. The Expected Reproductive Rate (EPR) is an evaluation tool used by facilities to estimate their productivity. Currently the EPR success rate is based on a 90-day survival rate, which includes a period of time after the kits have been transferred from the SSP facility to pre-conditioning pens. If an animal dies after the 60-day period but is no longer at the SSP facility, this counts against the facility's EPR for that breeding year. Updating the evaluation process to equitably assess each facility coupled with incentives to breed unproven animals and maintain genetic diversity was recommended by the working group. Additionally, a more accurate EPR will benefit reintroduction sites by giving them a more accurate assessment of the number of kits that will be allocated to them.

Several other suggestions and recommendations were made to address the goals of increased production and maintenance of genetic diversity. It was suggested that kits born under advanced photoperiod may have decreased survival. Two SSP facilities currently use advanced photoperiod protocols.

The current recommendation for age structure is an increase of one- and two-year-olds and a decrease in three-year-old females maintained in the SSP for increased pen breeding success. The previous recommendation to eliminate four-year-old females was also reevaluated. These recommendations were evaluated to determine the impacts on genetic diversity in the black-footed ferret population. Allocation of one-year-old males was also discussed to address increasing the number of proven males in the SSP.

Discussion

It was recognized that facilities have attempted to breed for numbers to produce the desired EPR number of kits, equating "high numbers" with success. The group emphasized that facilities should not focus on numbers alone, but should also focus on increasing genetic diversity by allowing unproven males a better chance to reproduce (increased pairing time and number of attempts). In addition, a "full participation rule" for the SSP Electroejaculation Protocol to determine male readiness for breeding should be implemented. It was also recognized that facility staff training is essential in implementing this protocol along with cytology, sperm checks and testes monitoring. It was noted that videos are available along with a full electroejaculation protocol in the SSP Husbandry Manual. Any further training concerns should be addressed at the annual SSP meeting and/or CRC should be contacted for further assistance and guidance. This training and standardization could maximize the full potential of both males and females in the SSP and increase overall breeding success.

It was agreed that proven males will be more evenly distributed among the SSP facilities. Because one-year-old males raised in artificial light develop sperm asynchronously from females, their contribution to the SSP has been limited, and the number of proven males is typically restricted to two- and three-year-olds. To increase the number of one-year-olds that successfully breed, a portion of genetically non-valuable one-year-old males should go to the outdoor pens for their first breeding. The natural light conditions should help these males come into breeding readiness and may assist in "proving" these males for possible future breeding back in the SSP.

Increased breeding success would assist facilities in financial justification, public education, achievement of their EPR goal, and contributing to the recovery program. In order to achieve increased success, it is recommended that a new process for rating and documenting individual facility program progress be created. A comprehensive standard Black-footed Ferret Annual Breeding Report should be submitted by all participating SSP facilities. Compliance of facilities in meeting protocols (such as the electroejaculation protocol and sperm check protocol) would be documented in the new report. The Black-footed Ferret Annual Breeding Report will be ranked to measure progress and compliance and will provide essential data to evaluate SSP program efficiency and success. To assist the overall program's goal of increased production and maintenance of genetic diversity, report rankings will reflect these goals. For example facilities that successfully use unproven males or maintain a certain level of genetic diversity in their population will be rewarded with a higher rank. Details of report content and evaluation methods will be taken to the SSP meetings in 2003 for review and implementation. The data recommended for inclusion in the new SSP report are listed below.

SSP Facility Annual Report

A: Breeding/Production Data:

- Total population size (male.female)
- Recommended pairings
- Actual pairings
- No. of kits produced
- No. of kits weaned (60 days)
- No. surviving to 120 days if preconditioned at facility
- Maximum, minimum and average inbreeding coefficient of kits
- No. unproven males used and successful
- No. proven males used and successful
- Length of time of each pairing vs. "fast tracking"
- No. of pairings for each male
- Kit transponder number(s)
- Allocation information (zoo/pen/reintroduction site)

B: Facility Protocols:

- Use of advanced photoperiod (Yes/No)
- Lighting (foot-candle levels at cage floor/natural light?)
- Electroejaculation of all males including dates, sperm counts & motility; data sent to CRC for morphology evaluation
- Staining sperm checks? type of cytology stain used
- Diet (weaning and adult)
- Pre-breeding physical exams and results
    - No vaccines at this time
    - Check for cryptorchid, heart murmurs, kinked tails
- Disease issues/problems
    - Albon use pre-/post- ship, keeper use prophylactically
    - CRC diclazuril data
    - Adult mortality/complete necropsy results (formalin for histopathology, freezing carcasses for DNA samples)
- List vaccines used and dates
- Husbandry application
- Environmental factors (temperature ranges, humidity, light intensity)
- Staff training (electroejaculation, vaginal cytology, sperm checks, etc.)
- Personnel issues or administrative changes
- Communication with SSP (reports/calls/meetings)

C: Research

- Summary, reports and/or proposals

D: Education efforts

Modeling tools (SIMPOP and PM2000) were used to demonstrate the effect of breeding success for the number of breeding females (130, 150, 170 or 190) in the SSP population and the number of excess kits that could be produced annually. Findings indicated that as you increase the number of breeding females and breeding success, you can increase the number of kits for release (see Figure 6).

The question of how many kits are needed for reintroduction impacts the size and function of the SSP. It was resolved that communication with the USFWS and release sites should continue to estimate annually the number of kits needed to be produced.

Advanced photoperiod has been used for several reasons. At FCC it was ostensibly started to help even out the workload of breeding all animals at one time. Since husbandry has been streamlined at FCC, it is possible to breed all ferrets on natural photoperiod/light cycle. Limited data from Conata Basin suggests that age of juveniles released and time of year of release affects survival. Based on these findings, Toronto Zoo will stay on advanced light cycle due to the time it takes to get CITES permits for black-footed ferret entry to the US. Phoenix Zoo will also stay on advanced photoperiod at this time due to extreme summer heat. Juvenile black-footed ferrets should not be placed on advanced photoperiod due to possible decreased fertility at less than one year of age.

It was agreed that the official weaning date definition will be changed from 90 days to 60 days to more accurately evaluate the EPR of facilities. In addition, survival to 120 days will be evaluated whether kits go to preconditioning pens or not.

SSP Management Recommendations

1. A larger portion of one-year-old males should go to the pens for breeding and possible return as proven males to the SSP (*USFWS final allocation, August 15, annually*).

2. Balance the distribution of proven males among SSP facilities (*SSP annual meeting*).

3. Design and implement a standard SSP Annual Facility Report (*D Garelle and P Marinari, by August 1 and approved by SSP at annual meeting*).

4. Consider increasing SSP population size and/or incorporating the old FCC after the new Fort Collins facility opens (*SSP/USFWS, 2006*).

5. Facilities currently using advanced photoperiod will continue at this time (*Toronto and Phoenix Zoos*).

6. Communicate with Reintroduction/Habitat Working Group to determine the maximum number of animals needed for release (*Ongoing USFWS annual allocation process, September 2003*).

7. Change definition of survival age/weaning from 90 days to 60 days (*D Garelle/SSP, completed on 12 June 2003).*

Pen Breeding

Spotlighting data of released ferrets have shown the minimum survival rate is greater in young-of-the-year ferrets exposed to a naturalistic prairie dog burrow system and live prey compared to same age cage-reared ferrets released without pen experience (Biggins et al. 1998). In 1996, BFFRIT began preconditioning all animals allocated for reintroduction. An extension of this management technique was to allow animals to breed in natural pens with placement of young-of-the-year (kits) into burrow systems early in their development. With high minimum survivorship of preconditioned animals in South Dakota's Conata Basin on-site pens, other partners decided to build breeding and/or preconditioning pens to increase not only the number of animals available for the annual allocation process, but to maximize the programs potential of producing higher quality reintroduction candidates. The USFWS, as part of the annual black-footed ferret recovery program allocation process, sends male and female ferrets to facilities for pen breeding. The primary goal of pen breeding is to maximize reproductive output by utilizing a large proportion of proven animals from the Species Survival Plan (SSP) population with high mean kinship. To date, over 370 black-footed ferrets have been produced in pen breeding operations. Breeding pairs are based solely on non-nuclear family members with little attention to the overall genetic ramifications. Due to low output (number of kits released per female), the USFWS is currently reviewing the usefulness of pen breeding as a means to augment production from SSP facilities.

Pen Management Recommendations

1. *Increase the number of animals available for release from pen facilities through husbandry and management practices that promote reproduction and kit survival*.

Production of kits through non-nuclear family pairings has been promising, although survivorship of kits following placement in the burrow system to the age at which they can be released (120-140 days) has not met expectations, and is disparate among pen facilities. During the 2000, 2001 and 2002 breeding seasons, the number of kits/female surviving to release has been 0.41, 1.0 and 1.1 respectively. The Turner Endangered Species Fund (TESF) pen facility has been the most consistent facility, with numbers of kits born per female and overall preconditioning survivorship equal to that of the SSP and other preconditioning locations. Site-specific pen breeding recommendations are currently being incorporated into management plans. P. Marinari (USFWS) presented summaries of kits made available for reintroduction from pen facilities at both the BFFRIT Executive Committee (December 2002, Phoenix) and the Conservation Subcommittee (January 2003, Fort Collins) meetings. The Colorado/Utah working group was interested in discussing and incorporating management strategies with potential for increasing kit pen survivorship during the 2003 season. Paul provided specific recommendations at the Colorado/Utah working group meeting. These recommendations include splitting large litters at 90 days of age into several pens (keeping a minimum of four animals per pen), placement of prairie dogs in pens prior to the addition of ferrets in order to "clean" and alter existing burrow systems, and releasing single adult ferrets into pens that had high kit mortality in 2002. Pen facility staff will implement these changes in 2003. Data comparing multiple years and facilities will be presented at the 2004 Conservation Subcommittee meeting at which time evaluations to continue pen breeding will be discussed.

2. *Send more one-year old males to pens and evaluate their reproductive efficiency.*

Proven males (2-4 years of age) have typically been transferred to pen facilities either prior to (November) or during the breeding season (May). These males have been retained at pens, released or, infrequently, returned to the SSP. Studies conducted at CRC and FCC documented a lag in reproductive readiness between juvenile and adult males on indoor light. However, regardless of age, all males were determined to be spermic at the time females reach reproductive readiness (Howard, pers. comm.). Most one-year-old males located at SSP facilities are not used throughout the breeding season. Workshop participants agreed that by sending some one-year-olds to pen facilities the likelihood they will get opportunities to breed should increase. In former years, older, proven males with high mean kinship have been transferred to pen breeding efforts. The incorporation of one-year-old males from across a wider range of MK values would most likely provide greater genetic diversity to wild populations through release of offspring. While workshop participants recognize there are inherent risks to one-year-old males (increased mortality in pens, decreased opportunity to electroejaculate, etc.) it is believed these risks are acceptable and will ultimately benefit the program. The U.S. Fish and Wildlife Service will coordinate the allocation of juvenile males to current pen breeding facilities (TESF, CO pens) in fall of 2003. Additionally, pen facility staff will be briefed on the necessity to include these animals in their 2004 breeding populations during scheduled conference calls (summer 2003). Evaluation of breeding success utilizing one-year-old males will be determined following the 2004 breeding season and compared to production in previous years. This information will be provided to the U.S. Fish and Wildlife Service and SSP prior to allocation timelines for 2005. All information will be summarized, presented and disseminated to program participants when available.

3. *Evaluate pen pairing inbreeding coefficients and develop more specific breeding recommendations.*

A random breeding management scheme is currently used at all pen breeding facilities. The only criteria used for this approach is that nuclear family members are not paired (see Figure 3 for comparison of random breeding vs genetic management). Workshop participants were in favor of implementing a pairing scheme that incorporates aspects of genetic management into mate selection. Selection of males transferred to pen facilities in upcoming seasons will be selected based on the best possible mating choices allowing for inbreeding coefficients below 0.1250. Although genetic diversity will decrease over time, this strategy will slow the rate of loss. During the annual allocation process (Fall 2003), Paul Marinari will develop a pool of pen facility candidates. An inbreeding coefficient table will be developed and animals will only be transferred to facilities if they are genetically suitable.

Literature Cited

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Working group participants: *Maria Franke, Della Garelle, JoGayle Howard, Cindy Maddox, Paul Marinari, Rachel Moreland Santymire, Bill Van Pelt and Samantha Wisely; Kathy Traylor-Holzer (CBSG modeler).*

Appendix I. Ordered mean kinship list by sex for Black-footed Ferret SSP population (as of 15 April 2003).

MALES

SB#	MK	%kn	Age	Location
3340	0.116	100.0	3	NZP-CRC
3335	0.118	100.0	3	NZP-CRC
3332	0.120	100.0	3	NZP-CRC
3051	0.121	100.0	4	SYBILLE
2945	0.122	100.0	4	NZP-CRC
3620	0.122	100.0	2	NZP-CRC
2486	0.123	100.0	5	NZP-CRC
2787	0.123	100.0	4	NZP-CRC
2698	0.123	100.0	4	SYBILLE
2734	0.125	100.0	4	NZP-CRC
3615	0.125	100.0	2	NZP-CRC
3636	0.125	100.0	2	NZP-CRC
3974	0.125	100.0	1	NZP-CRC
3307	0.125	100.0	3	SYBILLE
3303	0.125	100.0	3	SYBILLE
3626	0.125	100.0	2	SYBILLE
3973	0.125	100.0	1	SYBILLE
2593	0.125	100.0	5	TORONTO
3097	0.125	100.0	3	TORONTO
3361	0.125	100.0	3	TORONTO
3507	0.125	100.0	2	TORONTO
2328	0.126	100.0	5	LOUISVILL
3365	0.126	100.0	3	LOUISVILL
3833	0.126	100.0	1	LOUISVILL
2423	0.126	100.0	5	SYBILLE
3038	0.126	100.0	4	SYBILLE
3264	0.126	100.0	3	SYBILLE
3107	0.126	100.0	3	SYBILLE
3354	0.126	100.0	3	SYBILLE
3404	0.126	100.0	2	SYBILLE
3644	0.126	100.0	2	SYBILLE
3647	0.126	100.0	2	SYBILLE
3834	0.126	100.0	1	SYBILLE
3835	0.126	100.0	1	SYBILLE
3280	0.127	100.0	3	COLO SPRG
3281	0.127	100.0	3	PHOENIX
3576	0.127	100.0	2	PHOENIX
2238	0.127	100.0	5	SYBILLE
2332	0.127	100.0	5	SYBILLE
3028	0.127	100.0	4	SYBILLE
3258	0.127	100.0	3	SYBILLE
3259	0.127	100.0	3	SYBILLE
3208	0.127	100.0	3	SYBILLE
3577	0.127	100.0	2	SYBILLE
3653	0.127	100.0	2	SYBILLE
3808	0.127	100.0	1	SYBILLE
3434	0.128	100.0	2	COLO SPRG
3366	0.128	100.0	3	LOUISVILL

FEMALES

SB#	MK	%kn	Age	Location
3622	0.122	100.0	2	TORONTO
3172	0.124	100.0	3	NZP-CRC
3230	0.124	100.0	3	NZP-CRC
3231	0.124	100.0	3	NZP-CRC
3401	0.124	100.0	2	NZP-CRC
3573	0.124	100.0	2	SYBILLE
3445	0.125	100.0	2	NZP-CRC
3616	0.125	100.0	2	NZP-CRC
3628	0.125	100.0	2	NZP-CRC
2867	0.125	100.0	4	SYBILLE
3310	0.125	100.0	3	SYBILLE
3627	0.125	100.0	2	SYBILLE
3832	0.125	100.0	1	SYBILLE
3164	0.126	100.0	3	LOUISVILL
3098	0.126	100.0	3	SYBILLE
3267	0.126	100.0	3	SYBILLE
3210	0.126	100.0	3	SYBILLE
3405	0.126	100.0	2	SYBILLE
3648	0.126	100.0	2	SYBILLE
3099	0.126	100.0	3	TORONTO
3124	0.126	100.0	3	TORONTO
3165	0.127	100.0	3	LOUISVILL
3260	0.127	100.0	3	SYBILLE
3262	0.127	100.0	3	SYBILLE
3705	0.127	100.0	2	SYBILLE
3732	0.127	100.0	1	SYBILLE
3786	0.127	100.0	1	SYBILLE
3978	0.127	100.0	1	SYBILLE
3979	0.127	100.0	1	SYBILLE
3980	0.127	100.0	1	SYBILLE
3689	0.128	100.0	2	LOUISVILL
3510	0.128	100.0	2	NZP-CRC
3110	0.128	100.0	3	SYBILLE
3275	0.128	100.0	3	SYBILLE
3347	0.128	100.0	3	SYBILLE
3349	0.128	100.0	3	SYBILLE
3198	0.128	100.0	3	SYBILLE
3199	0.128	100.0	3	SYBILLE
3508	0.128	100.0	2	SYBILLE
3509	0.128	100.0	2	SYBILLE
3511	0.128	100.0	2	SYBILLE
3837	0.128	100.0	1	SYBILLE
3838	0.128	100.0	1	SYBILLE
3839	0.128	100.0	1	SYBILLE
3888	0.128	100.0	1	SYBILLE
3135	0.129	100.0	3	LOUISVILL
3670	0.129	100.0	2	LOUISVILL
3301	0.129	100.0	3	PHOENIX

MALES

SB#	MK	%kn	Age	Location
3935	0.128	100.0	1	LOUISVILL
2766	0.128	100.0	4	SYBILLE
3465	0.128	100.0	2	SYBILLE
3688	0.128	100.0	2	SYBILLE
3836	0.128	100.0	1	SYBILLE
3886	0.128	100.0	1	SYBILLE
3887	0.128	100.0	1	SYBILLE
3517	0.129	100.0	2	LOUISVILL
2687	0.129	100.0	4	NZP-CRC
3967	0.129	100.0	1	NZP-CRC
2466	0.129	100.0	5	PHOENIX
3069	0.129	100.0	4	SYBILLE
3748	0.129	100.0	1	SYBILLE
3800	0.129	100.0	1	SYBILLE
3830	0.129	100.0	1	SYBILLE
3876	0.129	100.0	1	SYBILLE
3877	0.129	100.0	1	SYBILLE
3878	0.129	100.0	1	SYBILLE
3916	0.129	100.0	1	SYBILLE
3118	0.130	100.0	3	COLO SPRG
3298	0.130	100.0	3	COLO SPRG
3680	0.130	100.0	2	LOUISVILL
3681	0.130	100.0	2	LOUISVILL
3930	0.130	100.0	1	LOUISVILL
3941	0.130	100.0	1	LOUISVILL
3232	0.130	100.0	3	NZP-CRC
3958	0.130	100.0	1	NZP-CRC
3041	0.130	100.0	4	PHOENIX
3816	0.130	100.0	1	PHOENIX
3410	0.130	100.0	2	SYBILLE
3484	0.130	100.0	2	SYBILLE
3664	0.130	100.0	2	SYBILLE
3737	0.130	100.0	1	SYBILLE
3753	0.130	100.0	1	SYBILLE
3843	0.130	100.0	1	SYBILLE
3863	0.130	100.0	1	SYBILLE
3891	0.130	100.0	1	SYBILLE
3900	0.130	100.0	1	SYBILLE
3939	0.130	100.0	1	SYBILLE
3942	0.130	100.0	1	SYBILLE
3950	0.130	100.0	1	SYBILLE
3663	0.130	100.0	2	TORONTO
3679	0.130	100.0	2	TORONTO
3817	0.130	100.0	1	TORONTO
2464	0.131	100.0	5	COLO SPRG
3197	0.131	100.0	3	LOUISVILL
3699	0.131	100.0	2	LOUISVILL
3700	0.131	100.0	2	NZP-CRC
2688	0.131	100.0	4	PHOENIX
3711	0.131	100.0	1	SYBILLE
3850	0.131	100.0	1	SYBILLE
3936	0.131	100.0	1	SYBILLE

FEMALES

SB#	MK	%kn	Age	Location
3175	0.129	100.0	3	PHOENIX
3389	0.129	100.0	2	SYBILLE
3594	0.129	100.0	2	SYBILLE
3429	0.129	100.0	2	SYBILLE
3498	0.129	100.0	2	SYBILLE
3499	0.129	100.0	2	SYBILLE
3539	0.129	100.0	2	SYBILLE
3767	0.129	100.0	1	SYBILLE
3768	0.129	100.0	1	SYBILLE
3769	0.129	100.0	1	SYBILLE
3750	0.129	100.0	1	SYBILLE
3751	0.129	100.0	1	SYBILLE
3801	0.129	100.0	1	SYBILLE
3802	0.129	100.0	1	SYBILLE
3803	0.129	100.0	1	SYBILLE
P335	0.129	100.0	1	SYBILLE
3914	0.129	100.0	1	SYBILLE
P269	0.129	100.0	1	SYBILLE
3968	0.129	100.0	1	SYBILLE
3969	0.129	100.0	1	SYBILLE
3917	0.129	100.0	1	TORONTO
3970	0.129	100.0	1	TORONTO
3234	0.130	100.0	3	COLO SPRG
3235	0.130	100.0	3	COLO SPRG
3244	0.130	100.0	3	COLO SPRG
3593	0.130	100.0	2	COLO SPRG
3121	0.130	100.0	3	LOUISVILL
3931	0.130	100.0	1	LOUISVILL
3932	0.130	100.0	1	LOUISVILL
3943	0.130	100.0	1	LOUISVILL
3944	0.130	100.0	1	LOUISVILL
3951	0.130	100.0	1	LOUISVILL
3370	0.130	100.0	3	NZP-CRC
3649	0.130	100.0	2	NZP-CRC
3533	0.130	100.0	2	NZP-CRC
3682	0.130	100.0	2	NZP-CRC
3959	0.130	100.0	1	NZP-CRC
3176	0.130	100.0	3	PHOENIX
3466	0.130	100.0	2	PHOENIX
3532	0.130	100.0	2	PHOENIX
3896	0.130	100.0	1	PHOENIX
3089	0.130	100.0	4	SYBILLE
3342	0.130	100.0	3	SYBILLE
3204	0.130	100.0	3	SYBILLE
3412	0.130	100.0	2	SYBILLE
3432	0.130	100.0	2	SYBILLE
3433	0.130	100.0	2	SYBILLE
3486	0.130	100.0	2	SYBILLE
3650	0.130	100.0	2	SYBILLE
3651	0.130	100.0	2	SYBILLE
3531	0.130	100.0	2	SYBILLE
3666	0.130	100.0	2	SYBILLE

MALES

SB#	MK	%kn	Age	Location
3654	0.132	100.0	2	COLO SPRG
3203	0.132	100.0	3	PHOENIX
3201	0.132	100.0	3	SYBILLE
3742	0.132	100.0	1	SYBILLE
3678	0.133	100.0	2	COLO SPRG
3945	0.133	100.0	1	LOUISVILL
3946	0.133	100.0	1	SYBILLE
2388	0.134	100.0	5	LOUISVILL

FEMALES

SB#	MK	%kn	Age	Location
3667	0.130	100.0	2	SYBILLE
3734	0.130	100.0	1	SYBILLE
3739	0.130	100.0	1	SYBILLE
3783	0.130	100.0	1	SYBILLE
3927	0.130	100.0	1	SYBILLE
3933	0.130	100.0	1	SYBILLE
3864	0.130	100.0	1	SYBILLE
3897	0.130	100.0	1	SYBILLE
3898	0.130	100.0	1	SYBILLE
3892	0.130	100.0	1	SYBILLE
3893	0.130	100.0	1	SYBILLE
3901	0.130	100.0	1	SYBILLE
3902	0.130	100.0	1	SYBILLE
3904	0.130	100.0	1	SYBILLE
3411	0.130	100.0	2	TORONTO
3735	0.130	100.0	1	TORONTO
3756	0.130	100.0	1	TORONTO
3784	0.130	100.0	1	TORONTO
3903	0.130	100.0	1	TORONTO
3534	0.131	100.0	2	COLO SPRG
3702	0.131	100.0	2	COLO SPRG
3683	0.131	100.0	2	LOUISVILL
3937	0.131	100.0	1	LOUISVILL
3206	0.131	100.0	3	SYBILLE
3485	0.131	100.0	2	SYBILLE
3656	0.131	100.0	2	SYBILLE
3657	0.131	100.0	2	SYBILLE
3853	0.131	100.0	1	SYBILLE
3854	0.131	100.0	1	SYBILLE
3855	0.131	100.0	1	SYBILLE
3938	0.131	100.0	1	SYBILLE
3652	0.132	100.0	2	COLO SPRG
3655	0.132	100.0	2	LOUISVILL
3858	0.132	100.0	1	NZP-CRC
3723	0.132	100.0	1	SYBILLE
3745	0.132	100.0	1	SYBILLE
3859	0.132	100.0	1	SYBILLE
3744	0.132	100.0	1	TORONTO
3947	0.133	100.0	1	LOUISVILL
3948	0.133	100.0	1	NZP-CRC
3701	0.133	100.0	2	PHOENIX
3949	0.133	100.0	1	SYBILLE
3913	0.134	100.0	1	COLO SPRG
3910	0.134	100.0	1	NZP-CRC
3911	0.134	100.0	1	SYBILLE
3912	0.134	100.0	1	SYBILLE

Black-footed Ferret
Population Management Planning Workshop

10-13 June 2003
Denver, Colorado

FINAL REPORT

Section 3
Habitat, Disease and Reintroduction Working Group Report

Habitat, Disease and Reintroduction Working Group Report

Introduction

History and Background of Black-footed Ferrets and Recovery Efforts
Black-footed ferrets (*Mustela nigripes*) are obligate predators of three species of prairie dogs (*Cynomys* spp.). Ferrets were first described to science in 1851 by Audobon and Bachman and were known to exist throughout the Great Plains into the early 20th century. They proved incapable of withstanding extensive conversion and fragmentation of native prairies into agricultural land, prairie dog poisoning campaigns, and the introduction and spread of the exotic disease, sylvatic plague, throughout much of its range.

Mellette County, South Dakota 1964-1974

By 1964,black-footed ferrets were widely considered extinct until a small population was discovered in Mellette County, South Dakota on a highly fragmented black-tailed prairie dog (*Cynomys ludovicianus*) complex. The Mellette County population was the first ferret population ever studied and much of the basic ecology of ferrets was learned from this population. Ninety individual ferrets including 11 litters were observed until 1974 when the population disappeared. Five ferrets were taken into captivity and captive breeding was unsuccessful. The last Mellette County ferret died in 1979 in captivity and the species was once again believed extinct.

Meeteetse, Wyoming 1981-1987

In 1981 a small population of black-footed ferrets was discovered near Meeteetse, Wyoming inhabiting 9,800 acres of white-tailed prairie dogs (*Cynomys leucurus*). In 1982 an incomplete surveyed observed 61 individuals. Population censuses from 1983-1985 revealed 88, 129, and 58 individual ferrets respectively. Canine distemper and sylvatic plague decimated the ferret and prairie dog populations at Meeteetse in 1985, coinciding with a precipitous decline. The last 18 ferrets were removed from Meeteetse and placed in a captive breeding program at the Wyoming Game and Fish Department's Sybille Wildlife Research Center near Wheatland, Wyoming.

Shirley Basin, Wyoming 1991-present

Captive breeding of black-footed ferrets at Sybille was successful, and by 1991 enough kits were produced to begin reintroductions back into the wild. Led by Wyoming Game and Fish Department (WYGF), Shirley Basin, near Medicine Bow, Wyoming was the first reintroduction site with the release of 49 (32m.17f) ferret kits. Shirley Basin contained approximately 57,510 acres of white-tailed prairie dogs. Soft-release techniques were used and survivorship was generally low. From 1991-1994, 228 kits were released; in 1992, 90 (55m.35f) kits, in 1993, 48 (29m.19f) kits, and in 1994, 37 (24m.13f) kits were released. Sylvatic plague impacted the prairie dog population and reintroductions were halted after 1994. Eight ferrets remained in both

1995 and 1996 with one litter documented each year. Surveys in 2000 revealed 15 ferrets including 4 litters. The most recent surveys in 2001 revealed 19 ferrets including 3 litters and 10 kits on a portion of a complex well removed from the original release site.

UL Bend National Wildlife Refuge, Montana 1994-present

Black-footed ferret reintroductions in Montana began in 1994 on the UL Bend National Wildlife Refuge, managed as part of the Charles M. Russell National Wildlife Refuge by the U.S. Fish and Wildlife Service in north-central Montana. The UL Bend site was one of five specific release sites identified in southern Phillips County within a 7 km-rule prairie dog complex area (Biggins et al. 1993). The UL Bend release area is made up of three sub-complexes of black-tailed prairie dogs as delineated by identifying all colonies within a complex where no colony is more than 1.5 km apart. The three sub-complexes, named Locke, Hawley and Valentine, contain approximately 1,000, 900 and 600 acres of black-tailed prairie dogs respectively. A total of 171 kits were released from 1994-1999 and 188 wild-born kits were observed between 1995 and 2002. Approximately 25-30 breeding adults were observed each spring from 1998-2001 and the number of wild-born kits steadily increased each summer.

The black-footed ferret population declined substantially during summer 2001 and the causes for the decline are not fully understood. Possible reasons include, too small a habitat base resulting in insufficient survival and reproduction for population establishment that was masked by continual augmentation with captive-bred animals, severe drought affecting prairie dog populations, and disease (sylvatic plague). The April 2003 spotlight survey located 3 ferrets (2m.1f). The remaining ferrets are directly related to each other with a three-year old female (4^{th} generation wild-born), her son and grandson. The population is expected to decline to zero in the near future. Additional releases are planned in 2003 concurrent with an experimental plague management study.

From 1994-2003, monitoring of black-footed ferrets at this site was intensive and reliable estimates of population size were produced. Monitoring capabilities were relatively easy compared to other sites because of vehicle access and low vegetation height.

Badlands National Park, South Dakota 1994-present

Badlands National Park (BNP) is located in southwestern South Dakota adjacent to the Conata Basin of the Buffalo Gap National Grasslands. The Conata Basin/Badlands Black-footed Ferret Experimental Population Area was designated in March 1994. Within this designated area that encompasses the park, there are approximately 3,200 acres of active black-tailed prairie dog colonies spread over 122,000 acres of the North Unit of Badlands National Park.

BNP began black-footed ferret reintroduction in 1994 with release of 32 captive-born kits (20m.12f). Releases were accomplished using the soft release method developed in Shirley Basin, WY. Short-term (30 days post-release) survivorship was 25% of the release cohort. Production in 1995 was 3 litters with 5 kits. Soft releases in 1995 were into the same prairie dog colonies as 1994 and included 37 kits (24m.13f). The release complex for 1994-95 was Hay Butte (1,011 acres). Detected wild-born production in 1996 was 5 litters with 8 kits.

Experimental release of 26 (12m.14f) black-footed ferret adults into Burns Basin (500 acres) in spring of 1996 with hard release methods showed short-term survival of 4%. One male from that release did survive after dispersing into the Agate complex on Conata Basin and was found in 1998. Additional releases in the fall of 1996 went into Burns Basin with 31 kits (16m.15f) that were a combination of pen-born, preconditioned, and cage-reared individuals. These releases were accomplished using hard release of ferrets into an area that was surrounded with predator exclusion electric fence. Kits were radio collared and tracked with base station triangulation telemetry for 30 days post release. Several of those kits dispersed into the Agate complex on Conata Basin. Short-term survivorship of the 1996 released kits was 32%. Detected wild-born production throughout the park in 1997 was one litter with one kit located in Burns Basin. These two individuals represented the known ferret population in the park before releases in fall of 1997.

Black-footed ferret releases in 1997 went into a new prairie dog complex in the park, Kocher Flats (1,268 acres). A total of 22 kits (12m.10f) were hard released. All kits received preconditioning and were released into a site with a predator exclusion electric fence and associated lethal predator management. Radio telemetry was utilized to detect minimum short-term survivorship of 62%. Detected wild-born production throughout the park in 1998 was 4 litters with 8 kits in the Kocher Flats complex.

Augmentation of the park black-footed ferret population continued in the fall of 1998 with releases in Kocher Flats and Hay Butte. A total of 43 preconditioned kits (27m.16f) were hard released (15m.10f at Hay Butte and 12m.6f at Kocher Flats). Post release, short-term survivorship at Hay Butte was 68% in vacant habitat. Short-term survivorship in occupied habitat at Kocher Flats was 33%. In an effort to track the survival of the entire ferret population, wild-born individuals were trapped and PIT tagged beginning in the summer of 1998. The minimum detected ferret population within the park was 22 (8m.13f.1unk) individuals at the end of 1998. Detected wild-born production in summer of 1999 was 2 litters with 3 kits at Hay Butte and 6 litters with 16 kits at Kocher Flats.

The final year of black-footed ferret population augmentation occurred in 1999 with releases into Kocher Flats and Middletown (135 acre satellite town in Hay Butte complex). A total of 18 preconditioned kits (6m.4f at Kocher Flats and 5m.3f at Middletown) were hard released into electric fence enclosures. Post release minimum short-term survival at Middletown was 40% of the release cohort, and at Kocher Flats was 13%. The minimum ferret population in the park was 19 (3m.12f.4unk) individuals in spring of 2000. The detected wild-born production that summer was 7 litters with 18 kits.

The spring 2001 black-footed ferret population was detected at 16 (1m.4f.11unk) ferrets in the park. Summer 2001 production was 2 litters with 7 kits in the park, located at Kocher Flats. The fall 2001 population declined to 13 (5m.4f.4unk) individual ferrets. Spotlight surveys in summer 2002 detected wild-born production in the park to be 2 litters with 4 kits. The last ferret surveys in the park were conducted in the fall of 2002. The minimum ferret population was 9 (1m.4f.4unk) individuals at that time.

At BNP, the logistics and efficiency of monitoring efforts are made somewhat difficult by motorized vehicle restrictions in the ferret reintroduction area which forces spotlighting by backpacking into remote reintroduction sites.

Conata Basin, South Dakota 1996-present

Conata Basin is a portion of the Buffalo Gap National Grassland in southwestern South Dakota, administered by the US Forest Service. The Conata Basin encompasses approximately 55,000 acres of mixed grass prairie with more than 14,000 acres of black-tailed prairie dogs. There are three sub-complexes of prairie dogs, Agate (4,000+ acres), Sage Creek (8,000+ acres) and Heck Table (1,700 acres).

Reintroduction began in 1996 with the release of 33 (19m.14f) captive-born black-footed ferret kits into Agate. Eighteen of those kits were cage-reared (i.e. were not exposed to dirt burrows or live prairie dogs prior to release, a process called preconditioning). Most of the ferrets were radio-tagged and followed intensively. Survivorship was low (30%), mostly due to great horned owls, although some kits survived. Badlands National Park released a cohort of kits also in the fall of 1996 in an area adjacent to Agate and several of those ferrets dispersed into Agate, likely because of the higher habitat quality there. Two adult ferrets were released with their kits, but none survived more than 30 days.

In 1997, the US Forest Service constructed 24 black-footed ferret preconditioning pens on an existing prairie dog colony in the Agate sub-complex. Thirty-six (20m.16f) captive-born kits were preconditioned at Conata Basin and released into Sage Creek. All 36 animals were radio-tagged and survivorship was very high (86%). In Agate a minimum of 4 litters of wild-born kits were found in 1988. None of the wild-born kits were trapped and thus were not marked with PIT (Passive Integrated Transponder) microchip tags.

To augment existing populations in Agate and Sage Creek, 25 (13m.12f) and 15 (9m.6f) black-footed ferret kits, preconditioned at Conata Basin, were released respectively in 1998. No animals were radio-tagged and survivorship was initially high (80%) but dropped off in the long-term compared to the 1997 Sage Creek release. We theorized that survivorship was low because animals were released on top of an existing population and free-ranging ferrets displaced newly released animals. Across Conata Basin, 22 litters of wild-born kits were found, and in Agate, litters of wild-born kits were found from both captive-born and wild-born mothers. Sage Creek ferrets still exhibited high survivorship and many wild-born kits were found. Kits were trapped in both Agate and Sage Creek and PIT tags implanted, including the wild-born from 1997 in Agate who were now adults with their own kits.

In 1999, black-footed ferrets were released into Heck Table for the first time and into Sage Creek to augment existing populations. Eighteen (9m.9f) captive-born kits preconditioned at Conata Basin were released into Heck Table concurrently with 18 (9m.9f) wild-born kits translocated from Agate. All animals at Heck Table were radio-tagged and survivorship was high for both groups (70%). In Sage Creek, 8 adult females and 12 kits were released, all preconditioned at Conata Basin. Initially survivorship of the adults was high (60%) but only one survived in the long-term and produced a litter. Survivorship of the Sage Creek 1999 released kits was high (75%), probably due to releasing them in unoccupied areas of Sage Creek. Wild-born kits were found in 33 litters and as many kits as possible were trapped for PIT tag implantation.

At this point, it was decided Conata Basin no longer needed supplementation with captive-born black-footed ferret kits. In 2000, wild-born litters were found at all three sub-complexes with a total of 60 litters. Also, 16 wild-born kits were removed and released at the Cheyenne River Reservation in north-central South Dakota in 2000. In 2001 and 2002, 64 and 60 litters of wild-born kits were found respectively. The population is likely still growing, but the ability to monitor the population may have reached the limit given current resources and habitat base size. There are now wild free-ranging ferrets in all three sub-complexes and 99% of the population is wild-born.

Monitoring of black-footed ferrets at Conata Basin is relatively easy compared to other reintroduction sites due to level topography, low vegetation and the ability to drive a truck on all colonies. An enormous monitoring effort has been made by this site which has contributed invaluable recovery program data on reintroduction success, survival differences in age/preconditioning treatment, and partitioning of wild ferret populations.

Aubrey Valley, Arizona 1996-present

After evaluating eight Gunnison's prairie dog (*Cynomys gunnisoni*) complexes across northern Arizona, the Aubrey Valley was selected as the best site for black-footed ferret reintroduction. In 1997 prairie dog acreage estimates were 29,653 acres. With the release of 35 ferrets (9 kits, 26 adults) in 1996, Aubrey Valley became the fourth reintroduction site and the first to develop and evaluate on-site acclimation pens to pre-condition release candidates. No ferrets were released in 1997, 26 in 1998, 52 in 1999, 19 in 2000, 12 in 2001, and 6 in 2002. Survivorship has been generally low. In 2001, the first wild-born black-footed ferret kits were found in Arizona following a spring release of animals bred prior to release.

Fort Belknap Reservation, Montana 1997-2000

The Montana Department of Fish, Wildlife and Parks entered into a Memorandum of Understanding with the Fort Belknap Reservation to begin a black-footed ferret reintroduction program in 1997. The Reservation is within the north-central Montana non-essential, experimental area that includes UL Bend and other lands in between. In the early 1990's there were 50,000 acres of black-tailed prairie dogs, all interconnected and within the 7km rule area stretching from UL Bend to the Snake Butte area in the northwestern corner of the Reservation; a span of 70 miles.

A total of 167 black-footed ferret kits were released within two areas known as Snake Butte and People's Creek. The Snake Butte area includes two 1.5km sub-complexes of approximately 1,000 and 1,400 acres. The People's Creek release area was composed of a single sub-complex totaling about 5,000 acres. A plague epizootic hit People's Creek two weeks after ferrets were released in 1999, and the habitat base was reduced to a fraction of its former size over the next 2 years. No ferrets were observed post-release in the People's Creek area and a maximum of 6 ferrets were observed during spring breeding seasons in the Snake Butte area. A total of nine wild-born kits were observed at Fort Belknap and the last ferret observed alive was a single male seen during spring 2002 spotlight surveys.

Colorado/Utah 1999-present

The Colorado/Utah black-footed ferret working group coordinates ferret reintroduction efforts within the Coyote Basin and Wolf Creek prairie dog complexes. These areas are located within a series of largely interconnected white-tailed prairie dog complexes in northwestern Colorado and northeastern Utah.

The Coyote Basin Primary Management Zone consists of a 20,876 ha area in Uintah County, Utah. Land ownership within this area is 87.7% Bureau of Land Management administered by the Vernal, Utah Field Office, 11.8% Utah state trust land, and 0.5% private. Prairie dogs occupy over 25,401 acres within the primary management zone in two main colony complexes, Coyote Basin (11,224 acres) and Kennedy Wash (2,954 acres). In addition, the Coyote Basin complex contains an additional 1,307 acres located in Colorado. The Kennedy Wash complex has had active plague within the past several years, although it appears to be recovering at present. Plague is not currently present in the Coyote Basin complex, and has not been documented in the complex since the 1980's. The ferret family rating (which is an index of habitat quality) for these complexes has been greater than 50 ferret families since 1999, with a high of 86 ferret families in 2002.

The Wolf Creek Management area in Moffat County, Colorado consists of Bureau of Land Management land administered by the Meeker, Colorado Field Office, as well as state and private ownership. Prairie dogs occupy over 17,018 acres within the Wolf Creek complex. The black-footed ferret family rating for this complex has been around 30 ferret families, although in 2002 it dropped to near 13 ferret families. The cause of the decline in 2002 is not known.

Black-footed ferret reintroductions were initiated in Coyote Basin during fall 1999 with the release of 72 ferrets (53 kits, 19 adults). Releases have also occurred in 2000, 2001, and 2002 with 220 ferrets (160 kits, 60 adults) released to date. Reproduction in the wild has occurred every year since the initial release. To date, eleven wild-born ferrets have been captured and tagged in the Coyote Basin and Kennedy Wash colonies. In 2002, at least five litters were produced within the Coyote Basin colony. Ferrets have also dispersed to prairie dog complexes outside the primary management zone. The estimated ferret population in Coyote Basin at the end of 2002 was 35 ferrets (14 male, 11 female, 9 unknown). Further releases of ferrets will probably not occur in Coyote Basin during 2003.

Black-footed ferret releases were initiated in Wolf Creek during fall 2001 with the release of 35 ferrets (28 kits, 7 adults). An additional 28 ferrets were released during fall 2002 (20 kits, 8 adults). Reproduction was not documented in 2002. Post-reproductive surveys during August 2002 located one confirmed ferret, and several probable ferrets. Spotlighting in this area is very difficult and PIT tag readings were not obtained for any of the sightings. Tracks and trenching were located in two areas during winter 2002. Ferrets will be released in Wolf Creek during 2003.

Cheyenne River Reservation, South Dakota 2000-present

The Cheyenne River Reservation is located in north-central South Dakota and contains plague-free black-tailed prairie dog populations. Sixty-nine black-footed ferrets were released in 2000 into the East Moreau River Complex (EMRC) in the northeastern portion of the Reservation. The complex contains approximately 14,000 acres of prairie dogs with the core management area (following 1.5 km rule) at 5,800 acres. Prairie dog densities on this complex average 16.6 prairie dogs/acre. Sixteen of the release cohort were wild-born ferrets from Conata Basin, and proved to have 26% better survivorship than the captive born animals released (n = 53). Overall short-term survivorship was encouraging at 55%. More than 9 litters were produced in 2001 with a minimum of 29 kits of which 22 were implanted with PIT tags.

Another 39 animals were released in 2001 to augment East Moreau; short-term survivorship was 36%. Dispersal and mortality of the 2001 releases was high compared to the 2000 releases, likely due to releasing into an existing population. In 2002, 42 black-footed ferrets were released into the South Parade Complex (SPC), which is south of EMRC and encompasses approximately 6,598 acres of prairie dogs. Prairie dog densities on SPC average 10.9 prairie dogs/acre. The management area is comprised of five towns totaling 1,200 acres. Short-term survival on this complex was 31%; however, it should be noted that monitoring intensity decreased compared to previous years.

Carnivore disease sampling on the Reservation and specifically around black-footed ferret release sites has occurred since 1999. Canine distemper is present in the coyote population at relatively low titers, with occasional outbreaks cycling through the population. Tularemia titers are usually low, however a coyote with high titers has been detected on rare occasion. Plague has not been detected. Aerial gunning to reduce coyote populations in and around the release areas was conducted in 1999-2001, although coyote populations in the area remain high. Spotlighting is the primary method used to monitor ferret populations on both EMRC and SPC. Monitoring is focused mainly during late summer (July/August) through the fall until late October, and then one four day session a month until April. Snow-tracking is another method used when weather permits.

Janos-Nuevo Casas Grandes, Chihuahua, Mexico 2001-present

In September of 2001, the prairie dog colony of El Cuervo in the municipality of Janos, Chihuahua became the first black-footed ferret reintroduction site in Mexico. The area includes 48,525 acres of plague-free black-tailed prairie dogs including El Cuervo, the largest prairie dog colony in the world at 37,237 acres. In 2001-2002, 160 ferrets were released; 91 in 2001 and 69 in 2002. Monitoring efforts in 2002 revealed 7 wild-born kits and 15 ferrets from 2001-2002 release cohorts. Monitoring difficulties, including large coverage areas and vehicle restrictions, have precluded survivorship estimates. It is believed more ferrets have survived but eluded detection.

Bureau of Land Management, 40-Complex, Montana, 2001-present

The 40-Complex is located in north-central Montana on Bureau of Land Management (BLM) lands between the Fort Belknap Reservation and the UL Bend NWR black-footed ferret reintroduction areas. The 40-Complex release site was one of five identified in the 1993 North-Central Montana Black-footed Ferret Reintroduction and Management Plan and it peaked at 1,700 acres within a 1.5 km sub-complex in 1988. This area is in the middle of the 50,000-acre black-tailed prairie dog complex within a 7 km rule area that once existed on the Fort Belknap Reservation and stretched southeast to UL Bend NWR. Plague substantially reduced prairie dogs in the 40-Complex and much of Phillips County beginning in 1992. Prairie dog shooting is also thought to have hampered prairie dog recovery and complex expansion.

Twenty black-footed ferrets were released on the 40-Complex during fall 2001 on 1,100 acres of prairie dogs within a 1.5 km sub-complex. Three survived to spring breeding and produced a single litter of 2 kits. Another 25 ferrets were released during fall 2002 and 4 survived to spring 2003. March, 2003 spotlight surveys in the 40-Complex located 5 ferrets (4m.1f).

General Problem Statement

Although a tenacious and effective predator, the dependence of black-footed ferrets on prairie dogs and their associated susceptibility to habitat loss and fragmentation and poisoning brought the species perilously close to extinction. The spread of sylvatic plague further threatens ferret recovery potential today. Still, much progress has been made over the past 15 years and recovery prospects have improved substantially. Program partners have learned how to produce large numbers of animals in captivity and met many challenges involved with successfully establishing wild populations. New and unforeseeable challenges will emerge before we reach the desired goal of full recovery. The Black-footed Ferret Recovery Plan is currently under revision and will address many of the challenges facing recovery using knowledge gained from past and present ferret recovery experiences.

We identified two primary challenges affecting black-footed ferret recovery today:

1. There are not enough high quality prairie dog complexes currently in existence that would support black-footed ferret populations to achieve recovery goals.
2. The ecology of sylvatic plague is poorly understood and this disease remains a significant factor in habitat loss and affects black-footed ferret recovery potential.

Evaluation and Prioritization of Topics

Aside from captive breeding, there are many challenges associated with black-footed ferret recovery that range from technical to international socio-political issues. We identified major categories of issues facing ferret recovery and then further broke down each issue in an attempt to identify the ultimate cause of each problem. The issues were then addressed as either discussion topics or quantitative topics. After the issues were discussed or approached with data, we formulated a set of recommendations and identified responsible parties and proposed timetables when appropriate.

Discussion Topics

Discussion topics were defined as those that could not be approached empirically with existing data and sometimes were social, political or economic in nature. We realized that discussion items often were inter-related across categories, for example, the category of sylvatic plague is related to the category of habitat since plague has dramatic impacts upon prairie dog populations.

Quantitative Topics

Quantitative topics were defined as those biological aspects that could be approached with empirical data available to us at the time. Data available included black-footed ferret demographics, survivorship, prairie dog density and complex size. We used VORTEX to model populations and explore the effects of density dependence, harvest, supplementation and prairie dog complex size upon ferret persistence. The Conata Basin and UL Bend data sets were used since both had large amounts of data yet represented opposite trends in ferret population persistence, presumably due to prairie dog complex size and plague.

Discussion Results

The issues facing black-footed ferret recovery were placed into one of three broad, inter-related categories: habitat, disease and reintroduction. Issues were then prioritized in order of their importance to ferret recovery. We recognized that funding is a high priority issue that affects each category but for purposes of this workshop focused on biological issues.

Habitat

1. <u>How do we motivate Federal agencies, States, and Tribes to increase prairie dog habitat for black-footed ferrets?</u>
   Results: Black-footed ferret recovery is distinct from but inextricably linked to prairie dog conservation efforts. Prioritizing management areas for ferret recovery does not foreclose, or appreciably affect, other multiple land uses (e.g. grazing, oil and gas development, recreation). Agencies and organizations managing prairie dogs must recognize the needs of ferret recovery. Incentive programs for expanding existing habitat on private and Tribal lands need to be identified and implemented.

2. <u>How do we best manage existing black-footed ferret habitat?</u>
   Results: We debated the classic conservation biology issue of "Single Large Or Several Small" (SLOSS) in regards to the configuration of prairie dog colonies for black-footed ferret recovery. Ferrets inhabiting a range of high prairie dog density areas appear to use space according to social tolerance rather than prey density (T. Livieri, pers. comm.). This led us to model ferret populations with varying levels of ferret density dependence (see Model Results). Quantifying the effect of variable prairie dog densities on ferret spatial use will be useful in defining habitat quality for ferrets. We need to model and/or investigate the interactive metapopulation dynamics of ferrets, prairie dogs and plague (e.g. can ferrets persist in a plague-managed portion of a complex?). We also discussed the use of tools to

create or enhance prairie dog habitat, such as grazing, prescribed burns, and translocation and the conditions under which these tools are appropriate.

3. What are the characteristics of prairie dog habitat as they relate to a "self-sustaining" population of black-footed ferrets?
   Results: Characteristics we concluded relate to a "self-sustaining" population of black-footed ferrets were: total prairie dog acreage, prairie dog density, spatial configuration of colonies within a complex, prairie dog species, and presence of plague. This issue is relevant to expectations from smaller sites interested in ferret reintroduction. We debated whether smaller sites could be effectively managed as nurseries or research populations instead of putting extensive time, money, and ferrets into them to build a "self-sustaining" population. We concluded there may be value to smaller research/nursery populations if they can provide wild-produced animals to larger recovery sites. Sufficient habitat for ferret recovery does not currently exist and strategies to restore and conserve large amounts of prairie dog habitat for ferret recovery are needed. The term "self-sustaining" is often and freely used, but lacks a quantitative definition. The need for different ferret population goals on different prairie dog species was identified.

4. Funding issues
   Results: Funding will continue to be an issue for habitat needs and overall black-footed ferret recovery. Prioritization of funding is important, particularly for long range habitat restoration needed to facilitate ultimate species recovery.

Disease

1. Research needs
   Results: Sylvatic plague is a primary obstacle to black-footed ferret recovery and plague research is vital to the program. Many plague issues need further research, such as: flea ecology, mammalian reservoirs, management methods, effects on ferrets (both direct and indirect), and various methods to control fleas (i.e. growth inhibitors, biological factors, and vaccines), and effects of plague on different species of prairie dog and within species (black-tail prairie dogs in Montana and South Dakota). A list of plague researchers has been compiled with contact information, and the group felt it important to keep that list updated and exchanged with interested/involved investigators.

2. Sampling and monitoring disease
   Results: There are several methods currently employed by sites to monitor plague and other diseases. Monitoring standardization for disease was suggested but we concluded there are many unanswered questions in regards to plague and sites should continue to monitor as resources allow.

3. Transmission of disease
   Results: Inadequate quarantine and translocation of both prairie dogs and black-footed ferrets may inadvertently spread disease. The group agreed this is a concern but ranked it as a lower priority issue until more is learned about plague and transmission dangers associated with quarantine and translocation are better understood.

4. Other diseases
   Results: Canine distemper research must continue, primarily in the areas of wide spread vaccination capability and determining its effect/presence in current free-ranging wild populations of black-footed ferrets. Tularemia is a disease that to date has not been an issue for ferret recovery, but little is known about how this disease affects ferrets, and thus more research is needed. Impacts of other diseases such as West Nile virus need to be investigated but at this point are not of high priority.

5. Funding issues
   Results: Funding for disease research is an ongoing need, particularly for research agencies such as the USGS-BRD. Partnerships with universities and other research organizations should be explored.

Reintroduction

1. Black-footed ferret persistence over time at current reintroduction sites.
   Results: We need to quantitatively define the term "self-sustaining" as it pertains to black-footed ferret populations. There are currently no guidelines to determine when to cease ferret reintroduction at a site (either a "self-sustaining" population has been established or cannot be established). The translocation of wild ferrets is a powerful tool for ferret recovery although the effect upon the donor population must be investigated, including genetic effects. Release strategies should continue to be refined and investigated (e.g. one large release of ferrets vs. several small, spring vs. fall, day vs. night). "Self-sustaining" sites may need additional releases to maintain/enhance genetic diversity. We need to determine when a site counts towards recovery goals.

2. Sampling and monitoring consistencies between reintroduction sites and the allocation process.
   Results: There is a lack of consistency between sites in terms of monitoring and reporting which can be reflected in the annual allocation process. Particular areas of inconsistency include black-footed ferret survival and population monitoring, prairie dog contributions to captive breeding, and carnivore disease sampling. We deemed these issues lower priority for this workshop and are questions routinely addressed by the CS and through annual allocation processes.

3. Funding and Partnerships.
   Results: Partnerships among agencies and organizations will increase the visibility of black-footed ferret recovery efforts. We must continue to build relationships with potential release sites, even if there is little short-term assurance of achieving "self-sustaining" populations. Such sites may serve as valuable research areas.

Quantitative Model Results

We identified several quantitative issues that could be addressed with empirical data from Conata Basin and UL Bend. The captive breeding group tasked us to investigate survival of captive-born black-footed ferrets as a function of release age. If there was no difference in survival as a function of release age, then the duration of preconditioning and several program costs could be lowered. It was decided that this task could not be adequately addressed in this forum due to many confounding factors and sample size issues. Also several of these release age concerns were addressed previously by Biggins et al. (1998).

Conata Basin models

Our first goal was to construct a model that emulated black-footed ferret population growth at Conata Basin from 1996-2002, which we established as our baseline model. Next, we modeled Conata Basin with harvest to explore how many ferret kits could be removed for translocation without significantly decreasing population persistence. Third, using Conata Basin rates, we modeled variable ferret reintroduction cohort sizes and carrying capacities to determine the minimum number of ferrets and minimum prairie dog complex size required to achieve a reasonable expectation of population persistence. Then we investigated supplementation strategies to maintain a ferret population with a reasonable expectation of persistence.

UL Bend models

We also constructed a model that emulated the observed UL Bend population dynamics to be used as a comparative baseline with the Conata Basin model. The UL Bend rates must be considered very preliminary and coarse as more intensive efforts are in progress using mark-recapture statistical methods to estimate sex/age/year specific survival and a host of co-variates. Next we modified the mortality rates of UL Bend to an area of comparable prairie dog acreage in Conata Basin (Heck Table).

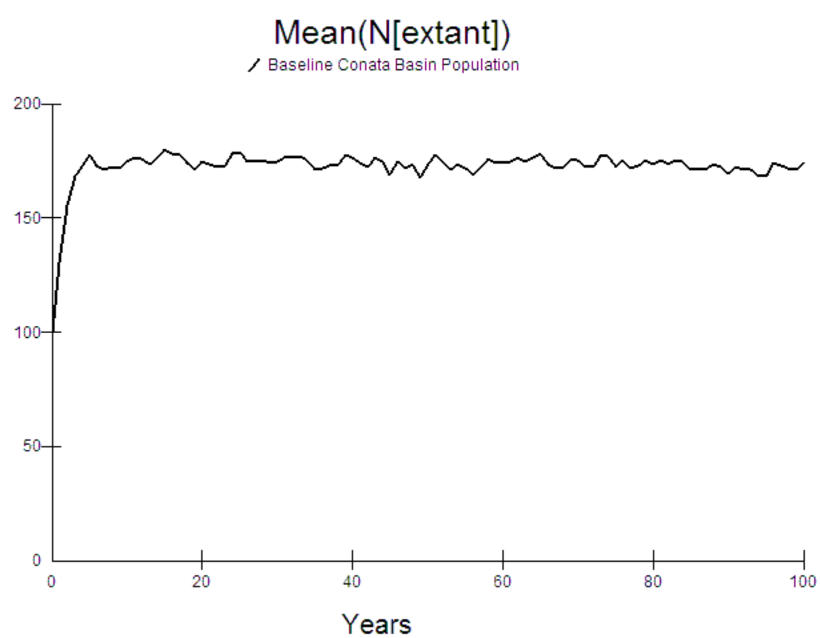

Figure 1. Mean extant population size for the baseline demographic simulation model of black-footed ferrets at Conata Basin, South Dakota. Probability of extinction for this simulated population over a 100-year timespan is 0.012. See text and Appendix for additional details on model input parameters.

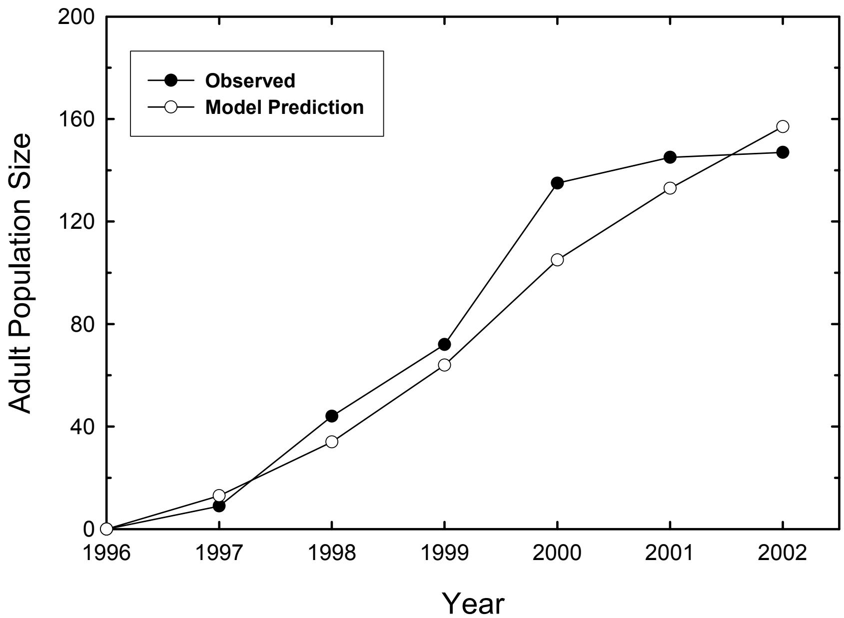

Figure 2. Retrospective VORTEX analysis of growth dynamics of the Conata Basin population of black-footed ferrets, beginning in 1996. Demographic data for model based on data from this region collected during the period 1996 – 2002. Observed data taken from spring field count estimates. See text and Appendix for additional details on model input parameters.

Results from Conata Basin Simulation Modeling

Conata Basin baseline model dynamics

For a detailed discussion of the available biological field data and their application to the parameterization of the VORTEX model, please refer to Appendix 1. The baseline model for the Conata Basin dataset produces an annual average growth rate of 0.038 over a simulation time period of 100 years. With this growth rate, the population can increase in size from an original number of 100 breeding individuals to about 160 in a short period of time, owing to density-dependent growth in the model. Once a larger population size is reached, higher density-dependent mortality is imposed and the growth rate declines until a stable population size is reached (Figure 1). Because of this rather strong opportunity for growth, the population has a low probability of extinction of just 0.012 over the 100-year simulated timeframe. Extinction typically occurs when, at higher population densities, very high mortality is randomly imposed through the inclusion of environmental variability in demographic rates, and the population rapidly declines to a very low level. Following this decline, the population can readily become extinct. Declines of smaller magnitude are not as severe since, through the inclusion of density-dependent mortality in all our models, the low population densities that result lead to lower mortality levels and greater overall growth rates.

Given this baseline result, we wanted to test this model against the actual trends in population size observed at Conata Basin over the period of demographic data collected. The baseline model for this dataset does an acceptable job of tracking the observed trend in black-footed ferret population size during the period 1996-2002 (Figure 2).

Based on the dynamics in our baseline model, we were much more comfortable exploring various management scenarios for populations displaying demographic behavior similar to that of the Conata Basin population. This population is an excellent representative of a population that is free of major disease threats such as plague, and can perhaps serve as a template for other populations that could be established in similar disease-free habitats.

Harvest analysis

Our first question centered on the issue of removal of individuals (kits) from a healthy population like Conata Basin. Removal of kits serves two primary purposes: 1) these individuals can be used to start or supplement other populations; and 2) removal of individuals will reduce population density and, theoretically, promote lower mortality and higher growth rates in the remaining source population (i.e. removal is compensatory mortality).

Results from an experiment conducted in South Dakota during initial releases of black-footed ferrets at the Heck Table colonies provided insight into translocation as a tool to establish new populations (Biggins et al. 2000). The experiment involved 36 (18♂ / 18♀) ferrets intensively monitored via radio-telemetry and spotlighting. The ferrets included 18 (9♂ / 9♀) animals captured in the Agate colonies and moved to Heck Table, and another 18 (9m.9f) captive born, preconditioned animals. Wild-born, translocated ferrets moved significantly less aboveground than their captive-born counterparts. Although the telemetry-derived survival rate for the captive-born, pre-conditioned ferrets was high (66% for 30 days), the rate for wild-born ferrets (94%) was significantly higher. Survival to 1-year was 35.2% for captive-born and 55.5% for wild-born ferrets. An effort to determine the effect of removing animals from the donor population gave inconclusive results. Minimum survival rates to 1-year for kits remaining in the donor population (48.7%) did not differ significantly from survival rates of kits in a nearby un-manipulated control population (65.2%), suggesting removal is additive mortality to the donor population rather than compensatory.

We were interested in further examination via modeling of the amount of kit harvest that could be tolerated in this population. To simulate this, we reduced mean litter size per breeding adult female by the requisite amount. Simulating "harvest" in this way was necessary as *VORTEX* does not allow the direct harvest of juveniles. Models were developed that reduced mean litter size by 30% and 40%, with all other demographic variables held constant.

The results of these analyses are shown in Figure 3 and Table 1. In the absence of harvest, the baseline model shows an annual growth rate of nearly 4%, with an extinction risk of just over 1%. It is interesting to note the increase standard deviation in mean population growth in this baseline no-harvest model, compared to those in which harvest is included. Remember that in the model, in the presence of fairly strong density-dependent mortality, approaching higher population size (and ultimately carrying capacity) leads to lower population growth through higher mortality.

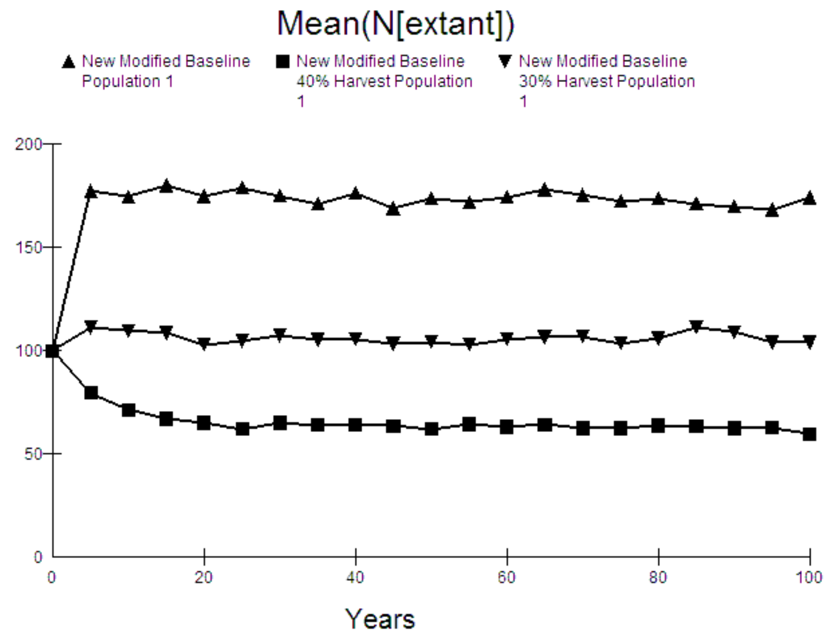

Figure 3. Average size of simulated extant populations of black-footed ferrets at Conata Basin under varying levels of kit harvest. Harvest is simulated in VORTEX as proportional reductions in mean litter size per breeding adult female. See text for additional model input parameters.

Table 1. Demographic results for harvest models of simulated Conata Basin black-footed ferret populations. See text for additional model details.

Harvest Rate	r_s (SD)	P(E)	N_{100} (SD)	T(E)
0%	0.038 (0.407)	0.012	174 (56)	56
30%	0.000 (0.266)	0.002	105 (42)	18
40%	-0.008 (0.227)	0.062	60 (26)	60

r_s (SD) – mean stochastic population growth rate (standard deviation)
P(E) – probability of population extinction over 100 years
N_{100} (SD) – mean size of extant populations after 100 years (standard deviation)
T(E) – mean time to extinction (years)

When 30% of the kits are removed annually, the population stabilizes at about 100 breeding-age individuals throughout the course of the simulation. In contrast to the no-harvest baseline, note that the annual variability in population growth rate is substantially reduced – again, a result of the reduced overall population size and elimination of high-density mortality. When harvest is increased to just 40%, overall mean population growth rate decline, extinction risk increases, and average final population size drops as well. Therefore it appears that, under the conditions modeled here using existing black-footed ferret demographic data from Conata Basin, a 30% annual harvest rate is sustainable.

Population Size and Persistence

Another major question we posed was the minimum size of prairie dog habitat necessary to support a black-footed ferret population with some reasonable probability of persistence. To address this question, we developed a set of models with initial ferret population sizes ranging from 15 to 100 breeding-age adults, with habitat carrying capacity (defined largely in terms of prairie dog acreage) defined as either equivalent to initial population size or twice the initial size. As with all other models created to this point, we used the Conata Basin dataset.

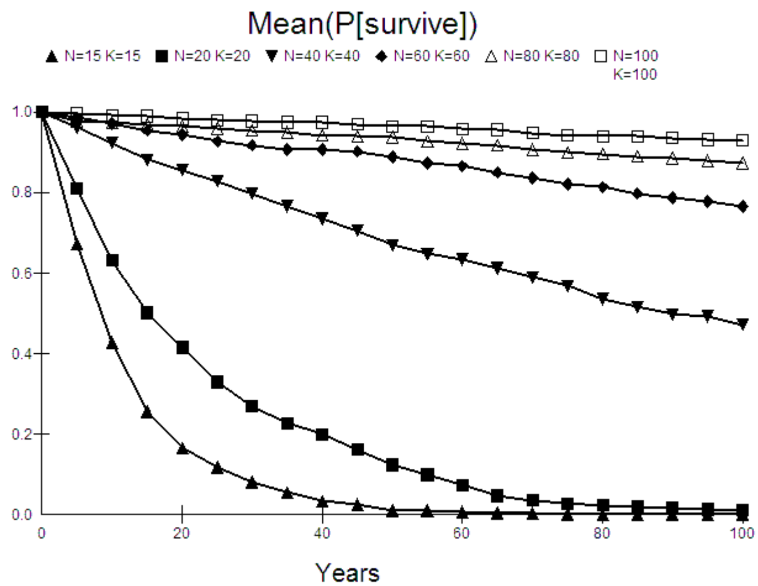

Figure 4. Mean probability of persistence for simulated black-footed ferret populations of different initial size, with carrying capacity equal to initial size. Demographics of each population are based on the Conata Basin dataset. See text and Appendix for additional detail on model input parameters.

The results of these models are shown in Figures 4 and 5 and Table 2. The simulations clearly show that very small ferret populations – for example, those with N<40, are highly susceptible to extinction with 30 – 50 years in the absence of intensive management. Larger populations show a much greater degree of persistence, with growth rates ranging from 3% to 4% per year and extinction risks less than 10% over 40 years and less than 20% over 100 years.

Table 2. Demographic results for population persistence models of simulated Conata Basin black-footed ferret populations. See text for additional model details.

N0	K	r_s (SD)	P(E)	N_{100} (SD)	T(E)
15	15	0.000 (0.407)	0.998	8 (--)	12
	30	0.040 (0.439)	0.814	19 (8)	39
20	20	0.018 (0.462)	0.990	14 (6)	22
	40	0.038 (0.430)	0.506	26 (10)	45
40	40	0.031 (0.436)	0.528	27 (9)	43
	80	0.038 (0.416)	0.118	56 (19)	49
60	60	0.034 (0.426)	0.234	40 (15)	50
	120	0.038 (0.416)	0.046	83 (27)	52
80	80	0.033 (0.423)	0.126	54 (19)	46
	160	0.038 (0.411)	0.030	110 (36)	54
100	100	0.032 (0.418)	0.070	68 (23)	49
	200	0.037 (0.412)	0.030	137 (46)	61

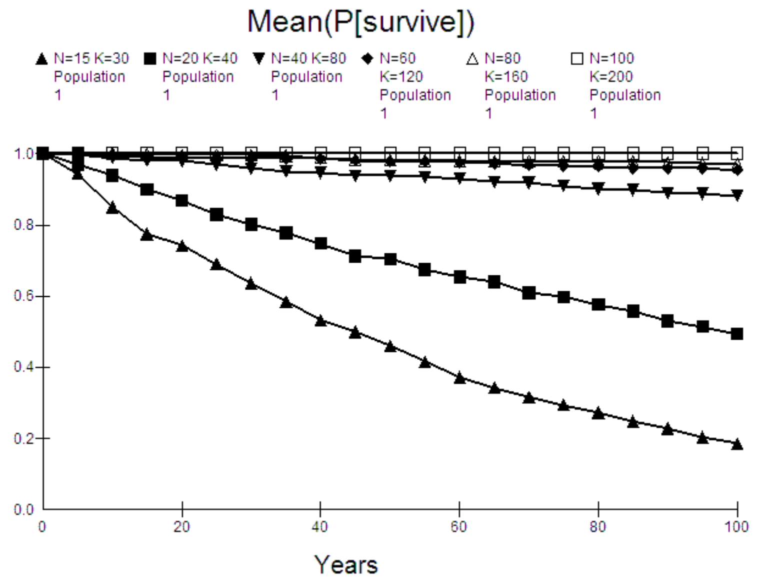

Figure 5. Mean probability of persistence for simulated black-footed ferret populations of different initial size, with carrying capacity equal to twice the initial population size. Demographics of each population are based on the Conata Basin dataset. See text and Appendix for additional detail on model input parameters.

When black-footed ferret populations have an opportunity to grow to a larger carrying capacity, the growth rates increase, extinction probabilities decrease, and general population stability is enhanced. However, these simulations clearly demonstrate the susceptibility of very small ferret populations to random extinction through unpredictable variability in demographic rates – even when those demographic rates are expected to show long-term population growth.

An Analysis of Supplementation Strategies

After observing the considerable extinction risk facing small black-footed ferret populations occupying isolated fragments of prairie dog habitat, we were interested in gaining a better understanding of how these small ferret populations can be maintained. We therefore developed a set of models including supplementation of a specified number of 1-year old individuals at determined intervals. VORTEX structure would not allow direct supplementation of kits. Our initial models focused on a population of 20 ferrets that saturates a given area of habitat; in other words, habitat carrying capacity was also set at 20 animals.

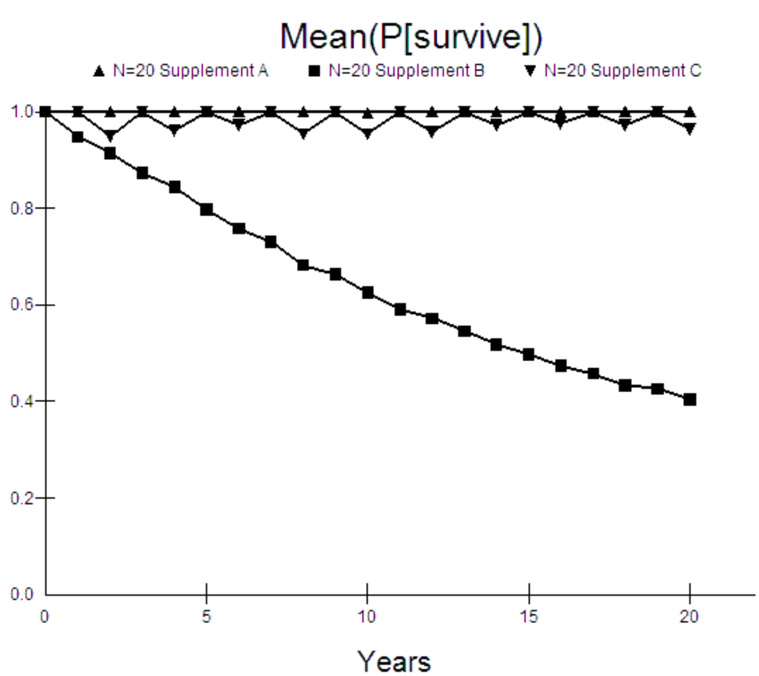

Figure 6. Persistence probabilities for a small population of black-footed ferrets (N_0 = 20) with different levels of supplementation of 1-year-old individuals:
Strategy A: Annual supplementation of 5 animals (3 ♀, 2 ♂)
Strategy B: No supplementation
Strategy C: Supplementation of 5 animals every other year. See text and Appendix for additional details of model input parameters.

The results of this analysis are seen in Figure 6. In the absence of supplementation, this small population has a considerable risk of extinction within 10 to 20 years. However, when 5 individuals aged 1 year are added to this population annually for 20 years, the population is greatly stabilized and extinction is prevented. When supplementation is implemented every other year, there is a risk that animals will be added to an empty habitat; in other words, local extinction may occur in a given year before the supplementation event. In any case, the risk of extinction in this particular case remains low and this particular strategy remains attractive.

It may be more efficient with respect to resources to impose a density dependence on supplementation. For example, supplementation could be imposed only when the population density dips below a threshold value such as 50%. This was done in another modeling exercise, and the results (not displayed here) show high levels of population stability, similar to that seen when supplementation occurs every year – even at high population densities when supplementation is unnecessary. As a result, frequent monitoring of small populations will be necessary to determine when supplementation should occur.

UL Bend Simulation Modeling
A smaller set of models was developed based on Randy Matchett's data on black-footed ferrets at UL Bend, Montana. This demographic dataset is characterized by a reduced reproductive output per breeding female, higher levels of mortality, and smaller population size compared to Conata Basin. This provides a considerable contrast to the data from Conata Basin and serves as an interesting point of comparison to the South Dakota population and extinction probabilities. The demographic rates used in this analysis are both preliminary and coarse in their assumptions and will likely change with more intensive analyses using mark-recapture statistical techniques to estimate sex/age/year specific survival and a host of co-variates.

The results of the UL Bend analysis are shown in Figure 7. Applying observed data directly to VORTEX, the population shows a rapid rate of decline, approaching 19% per year, with extinction occurring in just 20 years. This is considerably better than rough growth rate estimates from field data which suggest a 38% annual population decline and field observations of extinction within 5 years of the last release of captive ferrets.

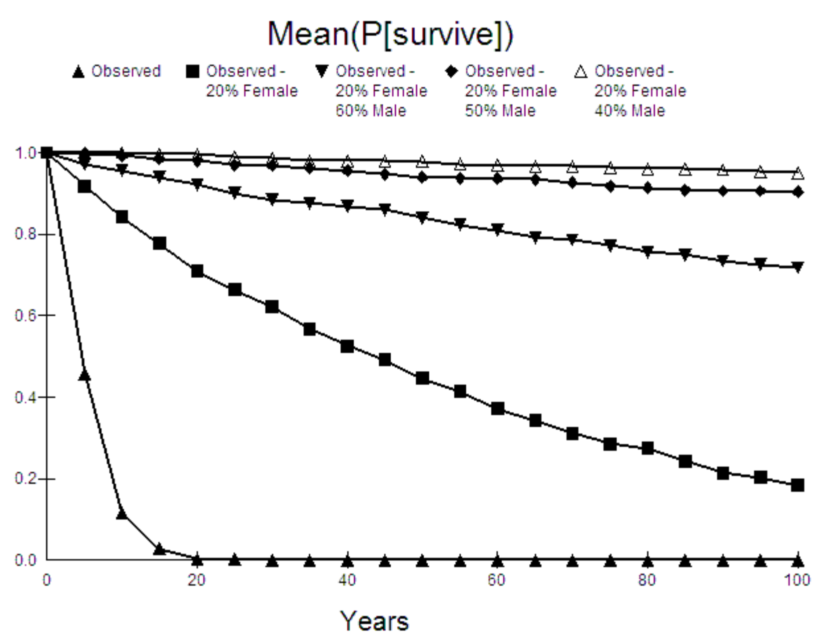

Figure 7. Results of VORTEX models for the UL Bend (Montana) population dataset. Alternative models show persistence probabilities for various combinations of female and male kit mortalities. See text and Appendix for additional details on model input parameters.

We were interested in applying other mortality rates to this baseline model in order to observe demographic responses. To begin with, we applied 20% 0-1 year old female kit mortality rates (UL Bend observations suggest 65%) that are similar to the rates observed at Heck Table in the Conata Basin. This modification was seen as appropriate as part of a larger sensitivity analysis. While this modification reduced the rate of population decline, the probability of population persistence remains low. Ultimately we discovered that, given the lower levels of reproductive output seen in this population (2.4 kits per breeding female compared to 3.1 kits at Conata Basin) and the higher levels of mortality, a maximum level of 50% male kit mortality is necessary in the presence of 20% female kit mortality to reduce the probability of population extinction to less than about 10%.

Demographic estimates for the UL Bend black-footed ferret population were based on spotlight observations from 1994-2000. Intensive spotlight surveys are conducted each year in April (spring breeding season), September (to mark wild-born kits) and in November or December to estimate short-term survival of released animals and post-marking for wild-born individuals. Individual identity (pit-tags) of virtually 100% of all animals has been maintained throughout the study period. Initial results from mark-recapture analyses estimate detection rates of over 90%. Initial estimates of survival by sex and age class were based on these observations. During this same period, 50 litters were observed on which productivity estimates were based.

<u>A preliminary analysis of plague and its potential impacts</u>

While the direct cause of the rapid population decline among black-footed ferrets at UL Bend is not known with certainty, plague may be involved along with a very small habitat base. At this point in time, and for reasons not yet fully understood, the Conata Basin populations of prairie dogs and black-footed ferrets appear to be free of the devastating impacts of plague. However, it is important from a proactive management perspective to evaluate the potential effect that introduction of this disease might have on previously unaffected populations. To achieve this, we developed a pair of scenarios derived for our baseline Conata Basin population but with the inclusion of a catastrophic outbreak of plague.

Specifically, these scenarios simulate an outbreak of plague within the prairie dog colony in Conata Basin. We concluded that this would be a more tractable scenario to simulate, as we could define the consequence of this disease event as a severe reduction in "effective" ferret carrying capacity. We recognize that plague can also directly affect ferrets, but the dynamics of infection among both prairie dogs and ferrets, and the ways in which infection in one species can influence infection in the other, were beyond the scope of current modeling exercise.

Based on direct observation of prairie dog acreages over a period of years, it is apparent that these colonies can easily be reduced by 50-75% through disease outbreaks in a very short period of time. In addition, the relatively low reproductive potential of this species means that population recovery can require 5 – 10 years or more. Using this information, we developed two different scenarios in which the carrying capacity of the Conata Basin black-footed ferret population was reduced by either 50% or 75% of its original baseline value of 250 breeding individuals. We assumed that such an event would occur, on average, every 20 years. Following this catastrophe, we simulated a linear increase in carrying capacity over a period of six years to the original baseline value. This trajectory in K was accomplished in VORTEX using the function editing routine for input of carrying capacity.

The results of these models are given in Table 3 and Figure 8. It is clear from these models that, under the conditions simulated here, a dramatic reduction in the size of prairie dog colonies (and, consequently, ferret carrying capacity) can have a significant impact on the viability of black-footed ferret populations associated with them. When plague leads to a 50% reduction in ferret K, the risk of population extinction climbs dramatically to more than 80%. Extinction is virtually guaranteed within 30 years when K is reduced by 75% due to an outbreak. As discussed earlier, the high levels of annual environmentally-induced variation in ferret demographic rates can lead to considerable instability in population growth, making random extinction much more likely when population size is small (i.e., plague reduces K to low levels). It is interesting to note that the mean stochastic growth rate is actually *higher* in the presence of plague compared to the plague-free baseline model. This is due to the increased opportunity for strong population growth following the catastrophic reduction in K and its steady return to the baseline level. Assuming that stochastic forces do not lead to immediate extinction following the plague outbreak, a simulated population can grow quite vigorously (refer to Figure 1). With frequent drops in K due to plague, positive ferret population growth can also occur more frequently thereby resulting in a larger mean population growth rate. However, despite this greater opportunity for population growth, the risk of major reductions in the size of affected ferret populations is considerable. Judging from these simple results, seemingly healthy (plague-free) ferret populations such as at Conata Basin are no longer viable in the presence of plague.

It is important to remember that this is a preliminary attempt to model the impacts of a complex disease event with uncertain epidemiology and transmission dynamics. We also know that plague can directly impact ferret survival – an observation that was not incorporated into these models of plague in prairie dogs. It is clear that a greater understanding of the direct and indirect affects of plague on black-footed ferrets is needed. Armed with this enhanced knowledge, we will be able to construct more sophisticated models of the demographic impacts of plague in both species, and the ways in which species-specific interactions are linked.

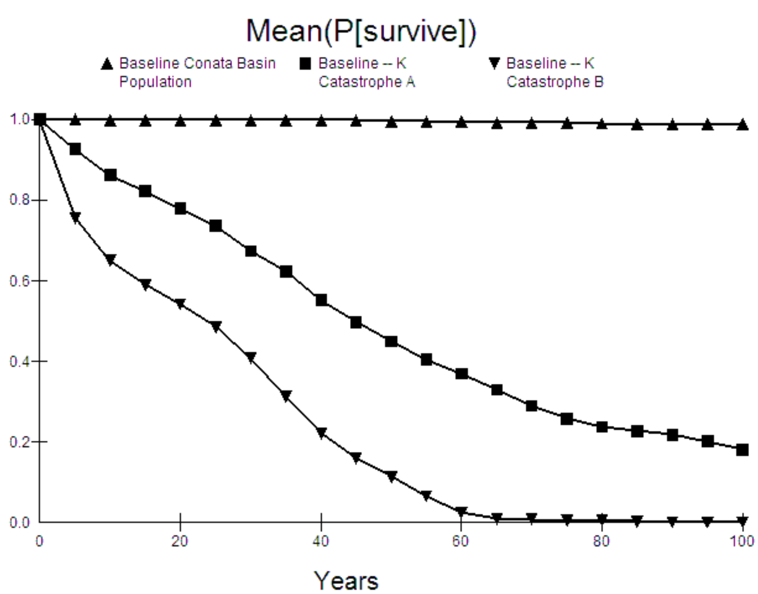

Figure 8. Persistence probabilities for simulated Conata Basin black-footed ferret populations impacted by catastrophic incidence of plague among associated prairie dog colonies. In this analysis, plague is assumed to reduce ferret carrying capacity (K) by 50% (Catastrophe A) or 75% (Catastrophe B), with a 6-year recovery time to original baseline level (250 breeding individuals). See text for additional details.

Table 3. Demographic results for population persistence models of simulated Conata Basin black-footed ferret populations impacted by catastrophic plague outbreaks. See Table 1 for column heading definitions, and text for additional model details.

% Decline in K	r_s (SD)	P(E)	N_{100} (SD)	T(E)
0 (Baseline)	0.038 (0.407)	0.012	174 (56)	56
50	0.043 (0.452)	0.818	159 (62)	40
75	0.047 (0.452)	0.998	115 (--)	25

Analysis

It is important to understand the derivation of data used in these simulations. The vast majority of the data used in the simulations were derived from spotlighting, thus the parameters represent minimum known rates. Conata Basin and UL Bend represent black-tailed prairie dog habitats and further modeling is needed to investigate black-footed ferrets on white-tailed and Gunnison's prairie dog habitats. Future models should employ Meeteetse data.

The Meeteetse population of wild origin black-footed ferrets was studied from 1981-1986. That population of ferrets, ancestral to all present captive and reintroduced black-footed ferret populations, existed on a complex of white-tailed prairie dogs. It is useful to review demographic data from the Meeteetse population because ferrets are being reintroduced onto white-tailed prairie dog habitats, and because those data can serve as a baseline against which reestablished populations can be compared.

White-tailed prairie dog densities at the Meeteetse complex were estimated with visual counts from 1981-1983 on a colony that supported high densities of black-footed ferrets (East Core) (Clark 1989). The mean count density (7.5/ha) should be expanded to account for sightability of prairie dogs. Sightability of these prairie dogs was 0.495, derived from comparison of visual counts and capture-recapture estimates (Fagerstone and Biggins 1986) done on 12.96-ha plots. Sightability may have been higher on Clark's 1.5-ha plots, but prairie dog densities likely were 10-15/ha on the ferret habitat in the East Core prior to the plague outbreak of 1985.

Counts of black-footed ferrets from spotlighting surveys during 1983-1985 provided much of the data for the demographic summaries of Forrest et al. (1988). Although the surveys were intensive, involving the work of many observers during July and August, and enthusiasm remained high during searches, the cumulative counts must be regarded as minimum estimates. Due to this confounding factor in spotlighting data, any condition that influences the efficiency of spotlighting effort (e.g., terrain, vegetation, weather, ferret activity rates) will influence estimates of minimum population and survival rates. Although utility of spotlight survey data in general is reduced by this drawback, the situation is not hopeless. With reasonable assumptions and careful experimental designs that emphasize comparisons of groups within sites, these data are useful (see Biggins et al. 1998). For modeling of population dynamics and persistence, however, the variation in estimates due to sampling efficiency are more problematic. Unlike more recent surveys done at many of the release sites, systematic replication of searching was coupled with marking at Meeteetse in a manner that enabled separation of capture probabilities from survival rates. Thus, at Meeteetse, we gained some confidence in the spotlighting technique from cross checks using radio-telemetry, snow tracking, mark-recapture, and an evaluation of the increase in cumulative count with cumulative effort (Forrest et al. 1988). Nevertheless, interpretations stemming from any modeling exercise with these or other black-footed ferret data should be well-infused with qualifications about the consequences of data collection strategies and habitat conditions discussed above.

With these precautions in mind, Meeteetse data (Forrest et al. 1988) may prove interesting to reevaluate, but present problems of their own. For an overall rate of loss of black-footed ferrets, the data from the intensive work on Colony 25E or the cumulative data from telemetry are likely the most reliable. These suggest an annual survival rate of about 40%, combining all sexes and ages. This was an established population that may have been at or near saturation of habitat. Mortality rates should be lower in growing populations under our density dependent analyses previously discussed. It is difficult to imagine, however, that recapture rates given by Forrest et al. (e.g., 37% for adults, 11 % for juveniles) are high enough to maintain a stable population (they are not consistent with the overall 40% survival rate). As one alternative, it is possible that the probability of capture was lower than previously thought. It would not be inconceivable, for example that the annual survival rates for adult females were as high as 65%, with adult male rates at 45% (as suggested by the ratio of captures), juvenile male survival at 8% and juvenile females at 24% (3-fold greater than males). VORTEX modeling efforts to evaluate the demographic impacts of these different vital rates may prove valuable.

As another alternative, the population may not have been stable in the years it was studied. If plague were present before the major epizootic of 1985, as suggested by the late George Menkens (pers. comm.), it may have had a direct influence on the black-footed ferret population. Interestingly, no marked juveniles from 1984 were recaptured in 1985, the span during which plague became obvious in the Meeteetse colonies. During the same span, the recovery rate for marked adults was 20%, down from the previous year's 35% but obviously better than the juvenile rate. Plague possibly affected juveniles more than adults because the juveniles are forced into poorer quality habitat during dispersal, which may be the habitat most affected by plague. This would further exacerbate the difficulties the Meeteetse ferrets already faced. However, this is an hypothesis that is yet to be tested and so therefore must be recognized as highly speculative.

Recommendations

The endangered status of the black-footed ferret is the result of epic degradation of its primary habitat — prairie dog colonies — through decades of conversion of native prairie to cultivated lands and extensive prairie dog control programs. Species recovery has been further compromised by the introduction and spread of the exotic disease, sylvatic plague, which has devastating effects on both prairie dog and reintroduced ferret populations.

Since the early 1980's, program partners from many state and federal agencies, zoos, conservation organizations, Tribes, and private interest groups have invested enormous resources in recovery of this species. And although significant recovery progress has been made, the black-footed ferret remains perilously endangered. Habitat availability remains the primary limiting factor in reestablishing viable, wild populations of ferrets.

Recommendations presented here are derived from discussions and quantitative model simulations. Within each category, recommendations are listed in priority order and, where appropriate, specific recommended tasks and timelines are presented.

Habitat

Recommendation 1

In order to achieve existing recovery objectives for distributing sufficient numbers of black-footed ferret populations across the historical range of the species, Federal and State land management and wildlife agencies, Tribes, and private interest groups within the historical ranges of black-tailed, white-tailed and Gunnison's prairie dogs need to proactively target specific, large, recovery areas that can be managed as long term black-footed ferret reintroduction sites.

> *Proposed Action:* Within the jurisdictional boundaries of the western states of Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah and Wyoming, identify at least two suitable recovery planning areas, of sufficient size to effectively support a black-footed ferret breeding population. Suitable recovery areas should also be identified and/or maintained in Mexico and Canada. Agencies and Tribes should consider development of ferret recovery sites in the next round of their associated land management planning processes; and/or consider amending existing plans by no later than FY2006 to address ferret recovery needs. Plans for development of recovery areas should include proposed timelines, methods, and funding needs.

– Although the best remaining prairie dog habitats in North America should be identified and prioritized as ferret recovery areas, many other sites currently supporting only small prairie dog population colonies could ultimately be managed/developed into suitable ferret reintroduction areas. It must be recognized that development of suitable reintroduction sites could take many years to accomplish and requires long range planning.

– CBSG participants acknowledge that prioritizing management areas for ferret recovery should not foreclose, or appreciably affect, other major land uses (e.g. grazing, oil and gas development, recreation).

– Data from existing reintroduction projects indicate that relatively large, closely distributed blocks of prairie dog habitat are needed to support "self-sustaining" black-footed ferret populations. Based on modeling simulations of Conata Basin population structure and growth, we estimate that 120 breeding adults is needed to sustain a ferret population with >90% probability of persistence over 100 years (see Model Results). By applying an estimate of acreage required by adult male and female ferrets (T. Livieri, unpubl. data) and the relative ratio of 1:2 males:females in a population, our modeling efforts suggest a complex of 6,030 acres of high quality habitat (i.e. Conata Basin) is needed to support a population of 120 adults ferrets (a complex is defined as a cluster of prairie dog towns each of which is no farther than 1.5 km from the border of another). Given the level of success and rapid ferret population growth at Conata Basin (supporting a prairie dog complex of some 13,000 acres of high density, black-tailed prairie dog habitat), we suggest that development of targeted complexes of 10,000 acres or more of similar habitat quality are needed to more reasonably achieve recovery objectives. Greater complex sizes would be needed in areas of lesser prairie dog population density, particularly for white-tailed and Gunnison's prairie dog species.

– While it is important to acknowledge that larger prairie dog complexes would contribute to more rapid and assured ferret recovery, it is also recognized that few areas of such large, high-value habitat currently exist in North America. Although agencies and Tribes are encouraged to establish long range goals for development of ferret recovery sites with a larger complex base, reintroduction efforts on smaller, or developing complexes (<5,000 acres) are also essential for continued species recovery. It is crucial to establish and maintain as many ferret populations as possible in native habitats. In cases where the habitat base is smaller, or subject to periodic effects of plague for example, more on-going human intervention and management may be required to maintain populations. These populations may also play an important role in establishing nursery stocks which could be exchanged between reintroduction areas to maximize genetic diversity and improve overall survival and health of wild ferret populations.

– Identified ferret recovery areas should be managed to restore and maintain sufficient habitat for ferrets; and as such, potentially adverse affects on habitat quality should be minimized (e.g. major land conversion, prairie dog shooting, etc.). Efforts to enhance recovery areas and to ameliorate any negative affects on private land owners should be pursued (e.g. land exchanges, incentives). See Recommendation 5 below.

Responsible Parties and Timetable: State and Federal land and wildlife management agencies, and Tribes, have ultimate authority and responsibility for implementing habitat conservation measures needed to recover the ferret. Partners involved in the Black-footed Ferret Recovery Implementation Team should identify processes by which this recommendation can be addressed by their respective agencies and Tribes. The EC should encourage their respective organizations and agencies to address these recommendations in their management planning processes. This is a critical, on-going program recommendation that requires periodic evaluation of recovery opportunities and progress. Finally, the Service should include a provision in the revised Black-footed Ferret Recovery Plan for designating an appropriate number and distribution of targeted reintroduction/ferret population areas to achieve both down-listing and delisting goals (as will defined in a pending revision of the Black-footed Ferret Recovery Plan).

Recommendation 2

The best remaining prairie dog habitats and potential ferret recovery areas in North America occur on Tribal lands. Workshop participants encourage the development of close working partnerships and management plans with Tribes across the United States and long term conservation of prairie dog habitats to promote ferret recovery and native prairie management. Participants further recommend that the role of Tribal liaisons (both within tribes and agencies) be strengthened to help facilitate on-the-ground development of ferret recovery actions on Tribal lands and promote other wildlife initiatives deemed beneficial by Tribes.

Responsible Parties: The Tribes bear ultimate responsibility for approval and development of grassland conservation and ferret recovery initiatives on their lands. The BFFRIT should promote development of additional cooperative black-footed ferret management programs and long-term funding mechanisms with Tribes. The development of cooperative programs is a dynamic process and largely depends on the potential for partnerships between state and federal agencies, conservation organizations or other private interests and individual Tribes. The BFFRIT can play an active role in helping allay concerns, identifying potential benefits of ferret recovery, and potential funding sources. The Bureau of Indian Affairs and involved Tribal members in the BFFRIT could have a particularly important role in helping develop cooperative programs with other Tribes.

Proposed Action: BFFRIT should devise specific outreach plans to investigate cooperative management opportunities with those Tribes that could potentially support ferret recovery projects. It is understood that considerable sensitivities and mistrust may exist within Tribal governments about ferret recovery and great care is needed to ensure full consultation with Tribal leadership and through appropriate contacts. These issues should be debated by the BFFRIT and tasks and schedules developed, as warranted.

Recommendation 3

To date, black-footed ferret reintroduction projects have predominantly occurred on federal public lands (i.e. Bureau of Land Management, Forest Service, National Park Service, Fish and Wildlife Service) or Tribal lands. The development of ferret recovery partnerships with more private landowners is essential to the ultimate recovery of the species. Pursuant to Habitat Recommendation 1 above, CBSG participants recommend that BFFRIT members and land and wildlife management agencies investigate opportunities to develop habitats and cooperative reintroduction efforts with private landowners in western states.

Responsible Parties: Incentive programs to manage prairie dogs and other non-game/endangered wildlife on private lands are evolving and are subject to congressional appropriations and specific program development (e.g. State Wildlife Grants, Farm Bill). It is incumbent on both federal and state agencies within the boundaries of each of the eleven western states to identify potential recovery sites and investigate available mechanisms for gaining private landowner support. This recommendation has an on-going, long term life and can be best facilitated through partner agencies of the BFFRIT. As a first step, the BFFRIT should make a concerted effort to get those states and other appropriate entities not currently involved in ferret recovery, to participate in the BFFRIT process and help examine both habitat development and private partnership possibilities. These issues should be debated during the upcoming BFFRIT meetings and appropriate tasks and schedules developed.

Recommendation 4

Black-footed ferret recovery is inextricably linked to the conservation and management of prairie dog populations. Although individual and multi-state prairie dog working groups and planning processes are independent and have somewhat different focus, it is critical that prairie dog habitat management groups are aware of black-footed ferret habitat needs and recovery goals; and, where possible, that planning efforts are coordinated to meet the needs of each species.

Proposed Action/Responsible Parties: Close and on-going coordination should be maintained between the Service, BFFRIT and prairie dog management groups. In addition, as black-footed ferret recovery planning documents and program evaluations are accomplished (i.e. revised Black-footed Ferret Recovery Plan, CBSG report) these products should be widely distributed to groups interested in prairie dog planning. The Service's Black-footed Ferret Recovery Coordinator is responsible for ensuring that the recovery plan, CBSG reports or other pertinent products dealing with black-footed ferret habitat needs are provided to key agency, Tribal, and organization contacts dealing with prairie dog management and conservation.

Recommendation 5

There are many potential tools available to State and Federal land management and wildlife agencies to enhance prairie dog habitats for black-footed ferret recovery (e.g. grazing regimes, prairie dog shooting restrictions/seasons, burning, weed/non-native vegetation control, translocation). To date, there are no comprehensive guidelines for "best management practices" that would develop and enhance habitats for the species of prairie dogs important to black-footed ferret recovery (black-tailed, white-tailed, Gunnison's). Development of such guidance would be helpful for both prairie dog and ferret conservation and is recommended.

Proposed Action/Responsible Parties: Partner agencies within the Black-footed Ferret Recovery Implementation Team and the western states prairie dog management team have the expertise to develop recommended guidelines for enhancement of habitats for the three prairie dog species. Development of a useable guideline publication could perhaps be best accomplished through, and funded by, a state/federal multi agency approach. Moreover, such guidelines should be dynamic and allow for periodic updates. The BFFRIT should address this recommendation at the upcoming 2003 and 2004 meetings and establish appropriate tasks and timetables for completion.

Recommendation 6

Some impacted prairie dog complexes (disease or controlled) consistently remain at low densities and have not recovered to historical population levels. The occurrence of plague is thought to be one major factor causing continued, cyclical degradation of habitat. There are likely other complex causes, and answers may be difficult to obtain. This is an important issue in long term development and/or restoration of ferret habitat.

> *Proposed Action/Responsible Parties:* Some proposed disease management recommendations provided below could provide insight into this question. As yet, there are no specific data gathered which would likely yield definitive information on other biological or climatic causes of prairie dog population suppression. Although largely academic and experimental, additional research should be devised to examine these questions with a goal of developing long range measures to improve prairie dog habitat. Review of available information and concept development should be conducted by BFFRIT partners and prairie dog management working groups; and, should ultimately result in preliminary proposals which could be submitted to appropriate research entities for consideration and funding. This topic should be placed on the agenda of upcoming BFFRIT meetings.

Recommendation 7

Simulation models constructed at this workshop covered only two sites, both of which are found on black-tailed prairie dog complexes. Further modeling is needed to determine white-tailed and Gunnison prairie dog acreage needed to support a black-footed ferret population with a reasonable chance of persistence. Models should incorporate Meeteetse and perhaps Shirley Basin data, and assess the potential effects of plague. In addition, models could be reexamined as other data become available from other reintroduction sites.

> *Proposed Action/Responsible Parties:* Conduct modeling exercises using existing Meeteetse data (and available data from other sites) to investigate the amount of acreage needed to support ferrets on white-tailed and Gunnison prairie dog complexes. Explore different colony configurations with and without plague to prescribe optimal configurations within a complex. The BFFRIT should examine data availability in upcoming meetings and task additional modeling exercises and recommendations from technical staff. The schedule for product development and periodic follow-up revisions should be addressed by the BFFRIT.

Recommendation 8

Despite being a highly endangered and charismatic species, the plight of the black-footed ferret is not broadly recognized. Issues surrounding the conservation and management of the ferret's essential prey and habitat base, prairie dog populations, are particularly vexing, controversial and/or not well understood. Moreover, some habitat conservation strategies targeted toward other wildlife species or improved rangeland may limit the potential of prairie dog colony expansion and inadvertently affect ferret recovery. Both public and political (and hence financial) support of habitat development needs and overall ferret recovery could be strengthened through educational opportunities and programs.

Proposed Action/Responsible Parties: Continue to support and expand the BFFRIT educational program and examine other potential educational outlets to ensure broad distribution of (1) pertinent ferret recovery analyses and planning documents (e.g. CBSG report, Black-footed Ferret Recovery Plan), (2) recovery program progress and successes, (3) technical research results, and (4) accurate information on the affect of reintroduction projects on area land uses and other points of program controversy. The BFFRIT should strive to develop additional contacts and exchange of information/views with other non-partner conservation groups as well as agricultural and recreational organizations. Individual partner organizations are encouraged to continue to publicize their own ferret recovery activities whenever possible (i.e. in state wildlife publications) and address larger ferret/prairie dog recovery and conservation principles. This is an ongoing, long term program need. However, updated program brochures and educational packets are needed and should be revised on a semi-annual basis. The BFFRIT should reexamine the funding and capabilities of the Educational Outreach Subcommittee and focus more attention and product development on priority information needs for the program.

NOTE: Some of the recommendations identified under the Reintroduction Recommendation Sections (Numbers 2, 3, and 7) also affect questions of overall habitat quality and may ultimately have some bearing on how lands should be managed to promote prairie dog habitats capable of supporting ferret populations. In addition, sylvatic plague is an inescapable part of much of the western landscape and significantly impacts prairie dog/ferret habitat. Consequently, addressing plague related recommendations under the Disease Section below could also significantly benefit long-term habitat restoration and management.

Disease

Recommendation 1

Sylvatic plague is the primary factor limiting black-footed ferret habitat today. A plague vaccine is under development by the National Wildlife Health Lab in Madison, Wisconsin. Early trials of the vaccine have shown promise, but full development of an effective vaccine for ferrets and as a bait delivery system for prairie dogs may be years away. Development of this vaccine has enormous implications for the future management of prairie dog habitats and ultimate recovery of the ferret. The BFFRIT and U.S. Fish and Wildlife Service should recognize plague vaccine development as one of the highest priorities of the ferret recovery program today, and should do all possible to help overcome any funding, regulatory, or other constraints potentially hindering plague vaccine development.

Proposed Action/Responsible Parties: BFFRIT partners should work closely with staff of the National Lab to identify any obstacles and prepare, as warranted, a vaccine briefing paper and resolution. These parties should initiate appropriate political and scientific outreach to help facilitate vaccine development and field trials. This is a developing and ongoing issue which should be routinely addressed by the BFFRIT. Key USGS staff involved with vaccine development should be invited to BFFRIT meetings, when available and as warranted.

Recommendation 2

Several methods have shown promise in the interdiction of plague on prairie dog complexes. A major limitation in development and evaluation of plague management capabilities is funding for adequate testing over multiple years. Plague interdiction research is very important to black-footed ferret recovery and should be supported by BFFRIT partners, especially on existing ferret reintroduction areas.

> *Proposed Action/Responsible Parties:* Continued research on promising control agents and technology should be promoted and funding sought for evaluations on the efficacy of insecticides (DeltaDust, fiprinil), insect growth hormone regulators (pyriproxifen, lufenuron), and bio-control (fungus). Research should also address potential effects of agents on non-target species, prairie dogs and ferrets. USGS-BRD has been a lead agency involved with this research, particularly those dealing with applications for recovery of endangered species. Funding for the USGS-BRD has been diminishing and threatens completion of important on-going investigations on several ferret reintroduction areas. The BFFRIT and Service should ensure that the priority and importance of USGS-BRD's plague research is understood and acknowledged in applicable federal budgetary processes. In addition, the BFFRIT and Service should help define additional plague management needs to universities and other research institutions that may be involved in plague issues. USGS-BRD should update study status and projected research needs at next BFFRIT meetings.

Recommendation 3

Despite varying levels of ongoing plague research, the ecology of plague in prairie dog communities is not well understood. Research into the ecology of plague in prairie dog communities should be expanded to help identify reservoir hosts, determine factors in the geographic expansion of plague, measure transmission modes and speed, determine differential susceptibility among hosts, and investigate the varying roles of differing fleas in plague ecology.

> *Proposed Action/Responsible Parties*: These are important but technically difficult and expensive questions to address. The BFFRIT and Service should encourage ongoing research by USGS-BRD, universities, and other institutions, and examine potential funding opportunities. No specific tasks are addressed here but USGS-BRD should keep the BFFRIT apprized of any progress or potential research opportunities.

Recommendation 4

Current plague detection methods may not detect low, background levels of plague (i.e. false negatives). BFFRIT should encourage and/or support efforts to refine plague detection methods and investigate new technologies such as genetic/PCR analysis.

> *Proposed Action/Responsible Parties:* No specific tasks are defined here but the BFFRIT and Service should support any ongoing research by USGS-BRD,

universities, and other research institutions and be vigilant for other proposed study opportunities and potential funding.

Recommendation 5

Currently there are many agencies, institutions and individuals researching various aspects of plague. In order to minimize duplication of efforts, the Service had originally identified a need to coordinate these studies and develop a clearinghouse/repository of plague data. The Service and BFFRIT should promote continued coordination of plague research and data sources.

> *Proposed Action/Responsibilities:* An initial list of ongoing plague studies was compiled by Mike Antolin, Colorado State University (Appendix 2). The list of studies and available reports needs to be updated, and currently no agency/body is coordinating ongoing studies and using available data to help define further research needs. This role likely appropriately rests with the USGS, National Wildlife Health Lab. The Service and BFFRIT should renew discussions with the Health Lab to investigate the potential for taking on this task. Pete Gober of the Service's, South Dakota Field Office had originally developed this clearinghouse concept and should be asked to reinitiate discussions with USGS-BRD staff. This issue should be addressed at upcoming BFFRIT meetings.

Recommendation 6

An effective canine distemper vaccine has been developed and is in widespread use in the ferret recovery program, both in captivity and in the field. Canine distemper is no longer considered as serious a threat to ferret populations as it once was, but still warrants management. In particular, development of other potential vaccine delivery methods or reduction of exposure risk in wild ferrets warrants further investigation.

> *Proposed Action/Responsible Parties:* BFFRIT should address these issues in upcoming meetings and determine whether additional research in these areas warranted. These questions should be addressed through Beth Williams (WY State Vet. Lab) and USGS-BRD who have been primarily involved in distemper vaccine work on black-footed ferrets.

Recommendation 7

The effects of other diseases (e.g. tularemia, West Nile virus, monkey pox) on prairie dog and black-footed ferret population stability is relatively unknown. BFFRIT partners should be vigilant to outbreaks of other infectious diseases in prairie dogs and ferrets and, where appropriate and warranted, conduct disease monitoring to ascertain the level of impact and/or investigate the ecology of other diseases and effects on ferret recovery.

> *Proposed Action/Responsible Parties:* Maintain coordination with the National Wildlife Health Lab, CDC, FDA, USGS-BRD, universities, and other research institutions to follow-up on any case histories of disease outbreaks in prairie dog populations and ferret recovery areas. Field biologists should characterize the extent of effect and recovery of any areas affected by other diseases. In cases

experiencing significant losses, additional background investigations should be considered and should be coordinated through universities and agencies with expertise in disease research.

Recommendation 8

While the ecology of plague is poorly understood, there is value in using existing and developing data to model the effects of plague on prairie dog and black-footed ferret populations. BFFRIT partners involved in ferret reintroduction efforts in plague-affected areas should consolidate available prairie dog and ferret data for further impact analyses.

Proposed Action/Responsible Parties: The Conservation Subcommittee of the BFFRIT should be tasked with collating existing plague data to construct simulation models using tools such as OUTBREAK (a disease epidemiology modeling tool currently under development by CBSG). BFFRIT partner members involved in the CBSG meeting could help facilitate further plague modeling exercises with existing data and help identify information deficiencies for future development of more refined models. This issue should be discussed and tasked at the BFFRIT CS meeting in January 2004.

Reintroduction

Recommendation 1

For the foreseeable future, recovery of the black-footed ferret hinges on maintaining a viable captive population and reintroducing both captive-reared and wild born ferrets into suitable habitats within the historical range of the species. To date, black-footed ferrets have been reintroduced in Arizona, Colorado/Utah, Mexico, Montana (2 different sites), South Dakota (two sites), and Wyoming with varying degrees of success and population establishment. These efforts have involved many state and federal agencies, Tribes, zoos, conservation organizations and private landowners are essential to long range species recovery. The Service and BFFRIT partners should continue to support and manage established black-footed ferret reintroduction sites as long range ferret recovery areas, whether reintroduction efforts are presently active or not. In addition, new partnerships are encouraged to expand reintroduction opportunities across the historical range of the species — into additional sites, other states, Tribal lands, and Canada.

Proposed Action/Responsible Parties: Site specific suggestions for existing reintroduction areas are a functional element of this recommendation and are addressed individually below. Beyond existing reintroduction projects, there are plans in varying stages of development to initiate ferret reintroduction in only a few other areas of the northern plains states and Canada. Pursuant to habitat development recommendations above, the Service and BFFRIT are encouraged to develop and maintain an ongoing dialog with agencies and Tribes in other, currently non-participating states to develop habitat units of sufficient size to support ferret populations. The upcoming revision of the Black-footed Ferret Recovery Plan will address these issues in more depth. Moreover, as part of the initial recovery plan discussions, the Service presented these management concepts to wildlife agencies from all western states historically occupied by ferrets. This recommendation is long-term in nature and will require periodic review by the BFFRIT and Service. These issues should be discussed in upcoming BFFRIT meetings to identify any new opportunities and develop associated tasks and schedules, as warranted.

Recommendation 2

The Conata Basin/Badlands ferret recovery area represents the most successful reintroduction area to date and currently serves as an essential donor site for supplying wild-produced, founder stock to other ferret recovery sites. Development of a considerable on-site preconditioning capability in Conata Basin has significantly bolstered overall program recovery by increasing preconditioning capacity and helping enhance survival of ferrets released within the Conata Basin/Badlands area and other reintroduction sites in South Dakota and Montana. The Forest Service and National Park Service are commended for ongoing recovery contributions and management of this site. These agencies are encouraged to maintain and enhance existing habitat conditions to the fullest extent possible in order to promote continued species expansion and recovery.

Responsible Parties/Proposed Action: The Forest Service and National Park Service are encouraged to recognize the critical importance of this area to both short range and long term ferret recovery and the need for continued program funding to maintain effective levels of population monitoring and habitat management. Continued management of this area will help facilitate any future recovery efforts on both Forest Service and National Park Service lands. CBSG participants also recommend that BFFRIT develop a specific "resolution" to (1) outline the background and importance of the Conata Basin/Badlands site to the recovery program, (2) recommend support of continued funding and management of the Conata Basin/Badlands program over the near term, and (3) promote greater outreach for program support to agency heads and through appropriate political channels. Finally, and similar to efforts in 2003, BFFRIT partners are encouraged to develop innovative means of cross-program assistance to help with monitoring and field work needed to facilitate preconditioning and/or translocation of ferrets from the Conata Basin/Badlands site to other reintroduction areas. These issues should be addressed at upcoming meetings of the BFFRIT and specific tasks and timetables established.

Recommendation 3

In keeping with Recommendation 1 above, the Service and BFFRIT partners are further encouraged to support reintroduction programs and address specific projects needs as follows (projects are listed in order by year of first reintroduction):

Shirley Basin, Wyoming (1991) — The Wyoming Game and Fish Department, Bureau of Land Management, and U.S. Fish and Wildlife Service should remain committed to long range management of the Shirley Basin, Wyoming area as an important black-footed ferret recovery site and should examine potential means to restart reintroduction efforts as soon as practicable. Meeting participants recognize that plague, development of private landowner partnerships/incentives, and other proactive prairie dog management measures are important elements of any renewed recovery efforts in Shirley Basin.

Conata Basin/Badlands National Park, South Dakota (1994) — Reintroduction efforts were first started in Badlands National Park and extended into the Conata Basin Grasslands in 1996. Reintroduction efforts on this experimental population have resulted in the largest wild population of ferrets today and has great importance to overall recovery efforts across North America. The importance of this site and recommendations to maintain an active recovery effort are addressed in Recommendation 2 above.

Phillips County, Montana (1994) — Agencies involved in Montana reintroduction efforts should recognize the importance, and commit to, ongoing plague management research on reintroduction sites. In addition, further commitments are needed to expand and/or consolidate habitat values in 4 - 5 core prairie dog "focus areas" with the intent of blocking-up larger, more closely distributed colony complexes. Land exchanges and incentives should be pursued to prioritize specific core areas that can be managed principally for the recovery of the ferret by encouraging prairie dog growth and expansion (e.g. shooting restrictions, grazing, etc. – see recommendation 6 below). The Bureau of Land Management and Fish and Wildlife Service are further encouraged to initiate or amend existing land use plans to accommodate management of concentrated prairie dog acreage in designated focal areas within Phillips County; and, to revise the former 7 km management approach emphasis to minimize recovery affects on other land uses.

Aubrey Valley, Arizona (1996) — The Arizona black-footed ferret reintroduction site is located Aubrey Valley and is one of the best remaining Gunnison's prairie dog complexes in North America. In addition, the Arizona site is the only reintroduction site to occur entirely on private, state and tribal lands. This is an important precedent to consider. By releasing ferrets in Aubrey Valley, it demonstrates to the public the flexibility of the Endangered Species Act and actions under the Act that do not negatively impact land uses, life styles, or incomes. Although the Arizona program has not met with the level of population success as other projects, some practical management and reintroduction strategies are being tested. Moreover, there has been more recent success in the production of wild ferrets following trials of spring releases. From the context of overall recovery plan objectives (distribution of ferret populations over the historical ranges of three prairie dog species), Aubrey Valley represents an important recovery site and the Arizona Game and Fish Department and other involved parties are encouraged to continue to support recovery efforts. Research on endemic plague presence, and other potential site limiting factors should be expanded to determine if and why ferret population growth has not met expectations.

Fort Belknap Reservation, Montana (1997) — Although portions of the Ft. Belknap recovery areas are within Phillips County Montana, the site is distant from efforts on BLM and FWS lands in South Phillips County and considered a completely separate reintroduction area. The Fort Belknap Reservation supports some of the best remaining prairie dog/black-footed ferret habitat potential in the state of Montana and was the first formal ferret reintroduction on Tribal lands in the U.S. Although ferret reintroduction efforts initiated in 1997 were suspended in 1999 (due to sylvatic plague impacts on core release areas), the Fort Belknap Reservation continues to have long term potential as a ferret recovery site. The Assiniboine and Gros Ventre Tribes are commended for their foresight and efforts to help recover ferrets on Fort Belknap Tribal lands and are encouraged to consider the long range management potential of Tribal lands to support ferret populations. Program partners should work closely with the Tribes of Fort Belknap to reexamine ferret reintroduction possibilities as prairie dog populations rebound and/or new plague management capabilities develop.

Colorado/Utah (1999) — By September 2003, and through an evaluation process initiated at the CBSG workshop, determine the minimum core area (colony size/density of prairie dogs) within an appropriate metapopulation configuration that fosters persistence of 30 black-footed ferrets for at least 20 years for the CO/UT reintroduction area. Using this analysis, establish "plague-managed" core release areas on the CO/UT reintroduction area starting with releases in 2003. In addition, agencies involved in the CO/UT program need to commit to active monitoring of ferret populations with the recognition that viable populations may not be possible at the present time (given the influence of plague, and early development phases of plague management capabilities). CBSG modeling efforts indicate that augmentation of the population with 10+ kits is necessary whenever the pre-breeding population of ferrets is at or below 10 individuals on core recovery sites.

Cheyenne River Sioux Tribal Lands, South Dakota (2000) — The CRST was the first Tribe to develop a comprehensive "Prairie Management Plan" which included a ferret reintroduction project as a principal element. The CRST ferret reintroduction effort has become highly successful, may be quickly reaching a self-sustaining population level, and could potentially soon serve as a second donor site for wild born translocations. The CRST is encouraged to maintain an active ferret recovery program and continue to enhance habitat values in support of expanding ferret populations.

Janos-Nuevo Casas Grandes, Chihuahua, Mexico (2001) — This project is the first international ferret reintroduction effort and also represents the first wild reintroduction of an extirpated species into Mexico. A prairie dog colony on the Mexico reintroduction area is the largest remaining single colony of black-tailed prairie dogs in North America. Initial surveys of reintroduced ferrets have been promising and both long term survival (of the 2001 cohort of released animals) and wild reproduction have been documented. Acceptance of the project by the local communities and ranchers has been key to program success. However, some long-term habitat conservation concerns remain. Representatives from the Mexico Institute of Ecology and University of Mexico are trying to secure permanent protection for the remaining prairie dog habitats in Chihuahua, through establishment of a protected preserve designation. CBSG participants encourage continued, full support of ferret reintroduction and habitat conservation measures in Mexico. Disease and ferret population monitoring is challenging due to the inability to collect carnivore samples, the prairie dog complex size, and off-road travel restrictions. Continued development of partnerships to increase monitoring levels is encouraged to help address the status of this effort.

Rosebud Sioux Tribal Lands, South Dakota (pending) — The Rosebud Sioux Tribe (RST) has been interested in ferret recovery for many years and all associated authorizations for implementing a reintroduction project have been recently completed (Tribal Resolution, ESA section 10j final rulemaking). The RST supports perhaps the largest contiguous "complex" area of prairie dog colonies left in North America and is expected to rapidly achieve a self-sustaining population of ferrets. The RST program would be a significant contribution to ferret recovery and the Service and BFFRIT are encouraged to support the Tribe's effort to the fullest extent possible.

Recommendation 4

Translocation of wild-born black-footed ferret kits to new reintroduction sites is expected to be increasingly important as a tool for ferret recovery. The potential effects of ferret removal on a donor population and the benefits of translocation of wild animals into other recovery areas are essential program information needs. Modeling Conata Basin data, we determined that a simulated annual removal of up to 30% of the annual kit production could be accomplished without decreasing mean population growth rates (see Model Results). Our simulations assumed that removal is a compensatory loss to the donor population, although results from translocations at Conata Basin suggest kit removal may be additive mortality (Biggins et al. 2000). As set forth under BFFRIT direction, recovery partners should continue to conduct experimental wild translocations of ferrets.

Proposed Action/Responsible Parties: We recommend initial testing of our simulation model by removing 30% of the kits from a black-footed ferret population. Program partners need to ensure adequate monitoring of donor, recipient and control populations in order to make these tests meaningful. Translocation tests and the specific means of monitoring and data analyses should be prescribed in annual ferret allocation proposals submitted to the Service, and be subject to BFFRIT peer review. We encourage multiple trials with well-developed test and control evaluation procedures. Accepted translocation efforts will involve many partner agencies from recipient sites and, to date, the Forest Service and Tribes of South Dakota as donor sites. This is an ongoing recommendation, which will require annual evaluations and reporting. Publication of meaningful results in scientific journals is encouraged.

<u>Recommendation 5</u>
Black-footed ferret reintroduction sites face different problems in monitoring ferret populations (e.g. wilderness areas limited to backpacks, inability to drive off-road, rolling terrain, heavy vegetation). Although these difficulties can affect monitoring quality, some level of standardization of survey methods increases opportunities for comparisons between sites, years, and other variables of interest. Standards are needed in order to: 1) define expectations for those desiring to nominate future sites for ferret reintroduction, 2) provide guidance for prospective sites regarding methods and associated limitations, 3) assures the FWS that participants will provide consistent feedback on progress, 4) make limited data maximally useful for broad-scale interpretation, 5) and may stimulate further refinement of methods to examine population levels when standard techniques prove ineffective (e.g. radio-telemetry, dog searches, aerial survey and snow-tracking).

> *Proposed Action/Responsible Parties:* Typically, reintroduction projects perform a series of 2 - 3 spotlight monitoring surveys/year in an attempt to determine short term survival of released ferrets, long term survival rates and production. However, the timing, intensity and duration of efforts vary substantially. At this stage in the history of the recovery program, involved reintroduction partners should be able to critically evaluate and compare relative capabilities and success to determine what minimum levels of monitoring are appropriate, and how best to standardize those procedures. USGS-BRD and several other BFFRIT partners were preparing a monitoring technique manual for recovery uses, which has yet to be completed. It would be helpful to revisit this issue and address the practicality of standardizing approaches to population monitoring for both prairie dog and ferret populations. The CS should address this issue again at the January 2004 meeting and develop tasks and schedules, as warranted.

<u>Recommendation 6</u>
An adaptive management approach has proven effective in black-footed ferret recovery over the past 15 years and reintroduction proponents are encouraged to develop experimental approaches to addressing key recovery questions. Expanded research may be warranted in addressing why some releases are less successful than others when no obvious reasons stand out.

> *Proposed Action/Responsible Parties:* The Service and BFFRIT should continue to apply priority in allocating ferrets that have strong experimental investigations of release techniques (day/night, spring), survival, disease management, etc. Proponents should ensure that proposed treatment and control tests will be adequately addressed and monitoring completed in order to produce meaningful results.

<u>Recommendation 7</u>
The allocation of ferrets for reintroduction sites is largely based on habitat quality in the proposed release area. To date, the principal technique for determining how many ferrets can be supported by a given prairie dog complex is to survey “active” prairie dog burrows by standardized roller tape transects, estimate how many prairie dogs are

present, and in turn estimate how many ferret families could exist (Biggins et al. 1993). This technique was based on an energetics model and data from the Meeteetse white-tailed prairie dog complex. Central to the questions of reintroduction success and habitat development (see Recommendations under Habitat) is an understanding of the relationship of prairie dog density and the associated spatial use of prairie dog complexes by ferrets.

> *Proposed Action/Responsible Parties:* The Service and BFFRIT should encourage recovery partners and research organizations to more fully investigate these questions on different reintroduction areas and within complexes of different species of prairie dogs.

<u>Recommendation 8</u>
Access to prairie dogs as ferret food and for preconditioning juvenile ferrets is an essential part of the black-footed ferret recovery program. To date, prairie dogs have been supplied by ferret reintroduction proponents (in an allocation process which prescribes the number of prairie dogs needed/year/allocated ferret). However vital, this task redirects limited resources of reintroduction projects and may detract from other important monitoring activities. The BFFRIT and Service should identify additional opportunities and resources to secure prairie dogs to meet captive breeding needs and alleviate this burden on reintroduction sites.

> *Proposed Action/Responsible Parties:* With construction of a new quarantine facility in northern Colorado, the Service should pursue partnerships with resource developers along the front range of Colorado, and elsewhere, to supply prairie dogs to the SSP, which would otherwise be destroyed. BFFRIT members and the Service should be vigilant for opportunities to obtain prairie dogs and forward any information/recommendations to the Recovery Coordinator.

<u>Recommendation 9</u>
The BFFRIT has been successful in helping set recovery direction and resolving program conflicts. The organization and operations of the committees have changed over time, and their effectiveness and meeting success has varied. It is important to maintain a strong and effective BFFRIT and improve overall coordination between program partners. Communication and participation are essential to BFFRIT success and ferret recovery.

> *Proposed Action/Responsible Parties:* The structure and operations of BFFRIT should be periodically reviewed and appropriate changes implemented. The CS should reinstate routine conference calls (at least quarterly) and meetings for both the CS and EC should be better organized and facilitated. The BFFRIT should explore the possibility of a listserve or message board. Meeting and conference call participation by designated representatives, and for the duration of meetings is very important and should be reemphasized. Meetings should only be held if there are important business items that need to be addressed. These issues should be discussed more fully at upcoming BFFRIT meetings.

Working group participants: Doug Albertson, National Park Service; Brent Bibles, Utah State University; Dean Biggins, US Geological Survey; Peter Dratch, National Park Service; Susan Linner, US Fish & Wildlife Service; Travis Livieri, Prairie Wildlife Research; Mike Lockhart, US Fish & Wildlife Service; Randy Matchett, US Fish & Wildlife Service; Phil Miller, Conservation Breeding Specialist Group; Bill Perry, US Forest Service; US Fish and Wildlife Service/ Reindl, South Dakota State University; Pamela Schnurr, Colorado Division of Wildlife; Joe Truett, Turner Endangered Species Fund.

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APPENDIX I. VORTEX input values for black-footed ferret population models.

See Model Results text for additional information. "*" indicates a value identical to BASELINE.

Parameter	BASELINE	BART	HARV	PRK	PR2K	SUPP	ULBE	DISEASE
Inbreeding depression	No	*	*	*	*	*	*	*
Reproduction correlated with survival	No	*	*	*	*	*	*	*
No. of catastrophes	0	*	*	*	*	*	*	*
Breeding system	Polygynous	*	*	*	*	*	*	*
Age at first breeding, ♀♀	1	*	*	*	*	*	*	*
Age at first breeding, ♂♂	1	*	*	*	*	*	*	*
Maximum breeding age	4	*	*	*	*	*	5	*
Maximum no. progeny/year	5	*	*	*	*	*	6	*
Sex ratio at birth in % ♂♂	50	*	*	*	*	*	*	*
Density dependent reproduction	No	*	*	*	*	*	*	*
% Adult ♀♀ breeding	98	*	*	*	*	*	90	*
SD in % adult ♀♀ breeding	2	*	*	*	*	*	5	*
Mean litter size	-	*	1.837,2.143	*	*	*	-	*
SD in mean litter size	-	*	0.3	*	*	*	-	*
% of litters size = 1	0	*	*	*	*	*	22	*
% of litters size = 2	22.1	*	*	*	*	*	40	*
% of litters size = 3	54.9	*	*	*	*	*	18	*
% of litters size = 4	17.7	*	*	*	*	*	16	*
% of litters size = 5	5.3	*	*	*	*	*	2	*
% of litters size = 6	-	*	*	*	*	*	2	*
% mortality of ♀♀ from 0-1	35+(30*(N/K))[a]	*	*	*	*	*	65,20	*
SD % mortality ♀♀ from 0-1	10+(9*(N/K))[a]	*	*	*	*	*	12.5	*
% mortality ♀♀ 1+	40+(20*(N/K))[a]	*	*	*	*	*	50	*
SD % mortality ♀♀ 1+	6+(3*(N/K))[a]	*	*	*	*	*	10	*
% mortality ♂♂ from 0-1	65+(15*(N/K))[a]	*	*	*	*	*	87,70,60,50,40	*
SD % mortality ♂♂ from 0-1	9+(3*(N/K))[a]	*	*	*	*	*	15	*
% mortality ♂♂ 1+	40+(30*(N/K))[a]	*	*	*	*	*	60	*

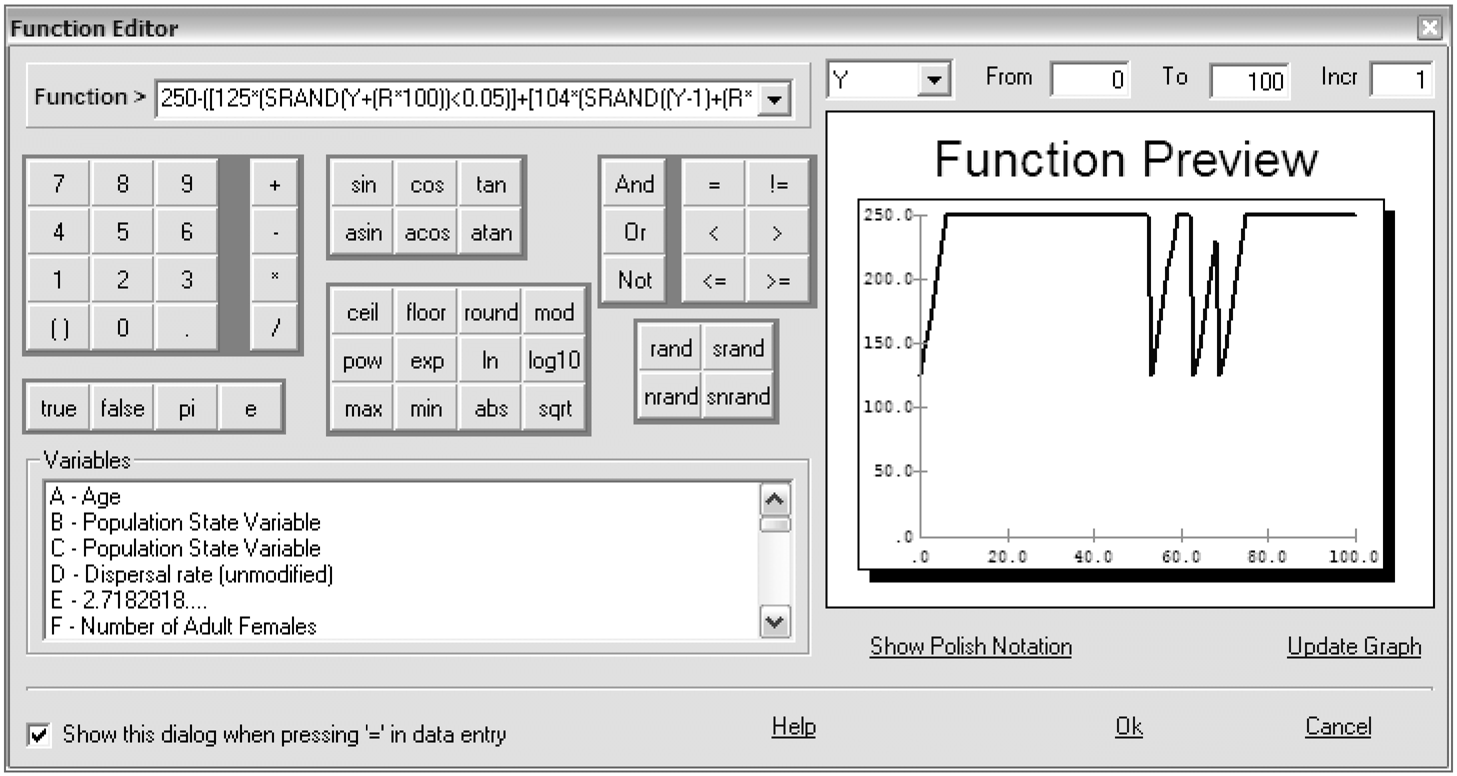
Parameter	BASE	BART	HARV	PRK	PR2K	SUPP	ULBE	DISEASE
SD % mortality ♂♂ 1+	6+(4*(N/K))[a]	*	*	*	*	*	10	*
% ♂♂ in breeding pool	100	*	*	*	*	*	69.3	*
Initial population size	100	0	*	15,20,40,60,80,100	15,20,40,60,80,100	20	28	*
No. ♀♀ age 1	40	0	*	10,13,26,40,53,67	10,13,26,40,53,67	13	10	*
No. ♀♀ age 2	17	0	*	0	0	0	6	*
No. ♀♀ age 3	7	0	*	0	0	0	3	*
No. ♀♀ age 4	3	0	*	0	0	0	2	*
No. ♂♂ age 1	23	0	*	5,7,14,20,27,33	5,7,14,20,27,33	7	4	*
No. ♂♂ age 2	7	0	*	0	0	0	2	*
No. ♂♂ age 3	3	0	*	0	0	0	1	*
No. ♂♂ age 4	0	0	*	0	0	0	0	*
Carrying capacity (K)	250	*	*	15,20,40,60,80,100	30,40,80,120,160,200	20	30	c
SD in K	0	*	*	*	*	*	2.5	
Population harvest	No	*	*[b]	*	*	*	*	
First year of harvest	-	*	*	*	*	*	*	
Last year of harvest	-	*	*	*	*	*	*	
Interval between harvests	-	*	*	*	*	*	*	
Harvest threshold	-	*	*	*	*	*	*	
No. ♀♀ harvested	-	*	*	*	*	*	*	
No. ♂♂ harvested	-	*	*	*	*	*	*	
Population supplementation	No	Yes	*	*	*	Yes	*	
First year of supplementation	-	1	*	*	*	1	*	
Last year of supplementation	-	4	*	*	*	20	*	
Interval between supplementation	-	1	*	*	*	1,2	*	
Criterion for supplementation	-	*	*	*	*	*	*	
No. ♀♀ supplemented	-	9	*	*	*	3	*	
No. ♂♂ supplemented	-	4	*	*	*	2	*	

BASE = Conata Basin baseline model from observed rates; **BART** = Conata Basin retrospective model; **HARV** = Conata Basin harvest model at 40%,30%; **PRK** = Conata Basin population size and persistence models where K=N; **PR2K** = Conata Basin population size and persistence models where K=2N; **SUPP** = Conata Basin supplementation models; **ULBE** = UL Bend baseline from observed rates and modified mortality rates.
[a] Density dependent mortality rates derived from Conata Basin data.

[b] Harvest was imposed through reduction in litter size since VORTEX does not allow direct harvest of juveniles.
c Sylvatic plague outbreak in prairie dogs was thought to impact ferrets through a reduction in ferret carrying capacity. The following functional form for K was implemented in VORTEX:

K =250-([125*(SRAND(Y+(R*100))<0.05)]+[104*(SRAND((Y-1)+(R*100))<0.05)]+[83*(SRAND((Y-2)+(R*100))<0.05)]+[62*(SRAND((Y-3)+(R*100))<0.05)]+[41*(SRAND((Y-4)+(R*100))<0.05)]+[20*(SRAND((Y-5)+(R*100))<0.05)])

This formula gives the following graphical output:



APPENDIX II. VORTEX input data sheet with information and justification for various black-footed ferret population.

1) *Do you want to incorporate inbreeding depression?*
Yes, if you think inbreeding might cause a reduction in fertility or survival
No, if you think inbreeding would not cause any negative impact
If you answered, "Yes" to Question 1), then we need to specify the severity of the impacts of inbreeding by answering the following two questions:

No. While we could have incorporated captive black-footed ferret data, no data on inbreeding depression in wild populations exists. If there is inbreeding depression in the wild then we have no evidence of reduced fertility or survival. Thus we did not use this option in any model during this workshop.

1a) *How many lethal equivalents exist in your population?*
"Lethal equivalents" is a measure of the severity of effects of inbreeding on juvenile survival. The median value reported by Ralls et al. (1988) for 40 mammal populations was 3.14. The range for mammals reported in the literature is from 0.0 (no effect of inbreeding on survival) to about 15 (most inbred progeny die).

We did not use this option in any model during the workshop.

1b) *What proportion of the total lethal equivalents is due to recessive lethal alleles? This question relates to how easily natural selection would remove deleterious genes if inbreeding persisted for many generations (and the population did not become extinct). In other words, how well does the population adapt to inbreeding? The question is really asking this: what fraction of the genes responsible for inbreeding depression would be removed by selection over many generations? Unfortunately, little data exist for mammals regarding this question; data on fruit flies and rodents, however, suggest that about 50% of the total suite of inbreeding effects are, on average, due to lethal alleles.*

We did not use this option in any model during the workshop.

2) *Do you want environmental variation in reproduction to be correlated with environmental variation in survival?*
Answering "Yes" would indicate that good years for breeding are also good years for survival, and bad years for breeding are also bad years for survival. "No" would indicate that annual fluctuations in breeding and survival are independent.

No. We have no evidence that reproduction is related to survival. If females survive, they almost always reproduce. Nearly every female seen in August-September at Conata Basin had a litter. This also seemed to be the case at Meeteetse (Clark 1989) and UL Bend. Of the females detected alive in spring at Badlands NP, only 72% survived to produce a litter that summer and all adult females found in the summer had litters.

3) *Breeding system: Monogamous or Polygynous?* Polygynous.

4) *At what age do females begin breeding?* 1

5) *At what age do males begin breeding?* 1

For each sex, we need to specify the age at which the typical animal produces its first litter. The age at which they "begin breeding" refers to their age when the offspring are actually born, and not when the parents mate.

Black-footed ferrets are sexually mature in the first year of their lives.

6) *Maximum breeding age?*
When do they become reproductively senescent? VORTEX will allow them to breed (if they happen to live this long) up to this maximum age.

2-5 years old, dependent upon the site. At Conata Basin, only two 4-year old females have been observed, both of whom reproduced. At Meeteetse, many of the ferrets true ages were unknown but they observed only one female at 2 yrs. old, which reproduced (Forrest et al. 1988). At UL Bend reproduction was observed in 5-year old females and at Badlands NP the maximum observed age was 3 yrs. old.

7) *What is the sex ratio of offspring at birth?*
What proportion of the year's offspring are males?

1:1 is approximately the ratio observed at Conata Basin, UL Bend, and Badlands NP. At Meeteetse, they observed juvenile male:female ratio of 1:0.80, which statistically did not differ from 1:1 (Forrest et al. 1988).

8) *What is the maximum litter/clutch size?*

5 observed at Conata Basin, UL Bend, and Meeteetse (Forrest et al. 1988). 4 observed at Badlands NP.

9) *In the average year, what proportion of adult females produces a litter/clutch?*
98% is approximately the rate observed at Conata Basin, i.e. almost every adult female observed in the summer had a litter. For those females not observed with a litter, we suspected they had litters but were unable to confirm it. Spring surveys were not conducted every year, thus we cannot calculate the proportion of adult females alive at breeding that had a litter in the summer and neither did Meeteetse. At Meeteetse, they observed all females in summer with litters (Forrest et al. 1988). At UL Bend and Badlands NP approximately 85% and 72% of the females observed in spring survived to summer and produced a litter.

10) *How much does the proportion of females that breed vary across years?*

Ideally, we need this value specified as a standard deviation (SD) of the proportion breeding. If long-term quantitative data are lacking, we can estimate this variation in several ways. At the simplest intuitive level, in about 67% of the years the proportion of adult females breeding would fall within 1 SD of the mean, so (mean value) + SD might represent the breeding rate in a typically “good” year, and (mean value) – SD might be the breeding rate in a typically “bad” year.

Zero. Again, nearly every female seen in August or September at Conata Basin, UL Bend, Badlands NP, and Meeteetse had a litter. The few females seen alone were usually not found until later in the season and likely had a litter due to unmarked kits in her vicinity.

11) *Of litters that are born in a given year, what percentage have litters/clutches of ...*

% of litters	Captive-CB	Wild-CB	All-CB	BNP	UL BEND	Meeteetse
1 offspring	0	0	0	26	22	1.5
2 offspring	25	20	22.1	32	40	17.6
3 offspring	45.8	61.5	54.9	32	18	38.2
4 offspring	18.8	16.9	17.7	10	16	35.3
5 offspring	10.4	1.5	5.3	0	4	7.4

Captive-CB = Captive-born released ferrets at Conata Basin; Wild-CB = Wild-born ferrets at Conata Basin; All-CB = All ferrets at Conata Basin; BNP = Badlands NP; Meeteetse (Forrest et al. 1988)

12) *What is the percent survival (and SD) of females ...*

% survival of females	Captive-CB	Wild-CB	All-CB	BNP
From birth to 1 year of age	58.8 (25.4)	46.4 (11.0)	48.4 (15.0)	28.2 (27.2)
From age 1 to age 2	36.7 (10.6)	53.3 (3.1)	49.2 (9.3)	14.2 (5.6)
From age 2 to age 3	45.4 (7.8)	39.3 (19.9)	41.0 (17.5)	17.0 (3.9)
From age 3 to age 4	0.0 (0.0)	33.3 (51.6)	20.0 (40.0)	0.0 (0.0)

Captive-CB = Captive-born released ferrets at Conata Basin; Wild-CB = Wild-born ferrets at Conata Basin; All-CB = All ferrets at Conata Basin; BNP = Badlands NP

For Conata Basin, only pre-conditioned kits and wild-born animals were used to calculate survival rates. Naïve and adult animals were excluded from analysis due to the fact that we had few naïve animals, and the program no longer releases naïve animals. Adults did not contribute much to the Conata Basin population. These survival rates were derived as means across years weighted by cohort size in each year.

At Meeteetse “limited cohort data prevented us from developing a life table” and during the Meeteetse studies, animals present at the beginning of the study were of unknown ages (Forrest et al. 1988, Clark 1989). The overall annual mortality rates for females was 47.7% (SD = 16.6) or survival rate of 53.3 (SD = 16.6). We were unable to differentiate juvenile and adult survival rates from the data presented.

13) *What is the percent survival (and SD) of males …*

% survival of males	Captive-CB	Wild-CB	All-CB	BNP
From birth to 1 year of age	30.0 (17.0)	26.7 (10.7)	27.4 (12.3)	13.3 (12.9)
From age 1 to age 2	20.0 (13.4)	45.3 (13.2)	38.4 (17.4)	11.8 (2.7)
From age 2 to age 3	0.0 (0.0)	31.3 (12.2)	25.0 (16.8)	0.0 (0.0)
From age 3 to age 4	0.0 (0.0)	50.0 (70.7)	50.0 (70.7)	0.0 (0.0)

Captive-CB = Captive-born released ferrets at Conata Basin; Wild-CB = Wild-born ferrets at Conata Basin; All-CB = All ferrets at Conata Basin; BNP = Badlands NP

See the description under females for justification and derivation of survival rates at Conata Basin. At Meeteetse, see the description under females for citations and data derivation. For all males at Meeteetse, the annual observed mortality rate was 78.3 (SD = 17.7), or survival rate of 21.7 (SD = 17.7).

14) *How many types of catastrophes should be included in the models?*
You can model disease epidemics, or any other type of disaster, which might kill many individuals or cause major breeding failure in sporadic years.

We did not explore catastrophes to a large extent during this workshop but we recognized that catastrophes exist. Potential catastrophes include plague, canine distemper, severe drought, failure of an age class, severe winter, increased predation rates and others. The probability and effects of these catastrophes are largely unknown. The catastrophes identified here could affect black-footed ferrets in two ways: first is the effect upon prairie dogs, thus reducing the prey base for black-footed ferrets and second is the direct effect upon black-footed ferrets (e.g. plague is fatal to black-footed ferrets).

15) *For each type of catastrophe considered in Question 15, what is the probability of occurrence?*
(i.e., how often does the catastrophe occur in a given time period, say, 100 years?)
What is the reproductive rate in a catastrophe year relative to reproduction in normal years?
(i.e., 1.00 = no reduction in breeding; 0.75 = 25% reduction; 0.00 = no breeding)
What is the survival rate in a catastrophe year relative to survival in normal years?
(i.e., 1.00 = no reduction in survival; 0.75 = 25% reduction; 0.00 = no survival: population extinction)

See #14.

16) *Are all adult males in the "pool" of potential breeders each year? Yes or No*
(Are there some males that are excluded from the group of available breeders because they are socially prevented from holding territories, are sterile, or otherwise prevented from having access to mates?)

Yes. At least we assume so at Conata Basin. No data exists on this parameter, but based on home range sizes calculated for ferrets at Conata Basin (Livieri and Perry, in prep.), we determined one breeding male per two breeding females. At Badlands NP, not all males are in the breeding pool because they occupy colonies without females and quite a distance away from females.

17) *If you answered "No" to Question 17), then answer at least one of the following:*
What percentage of adult males is available for breeding each year? or
What percentage of adult males typically sires a litter each year? or
How many litters are sired by the average breeding male (of those that sired at least one litter)?

Our best guess for Conata Basin is two, based on our findings of approximately 1:2 ratio of males:females during the breeding season. Also, the mean home range size of a male is approximately 150 acres and 75 acres for a female, thus it conveniently makes sense. At Badlands NP, the best estimate is that 75% of all males are in the breeding pool.

18) *What is the current population size?*

(We will assume that the population starts at a "stable age distribution", rather than specifying ages of individual animals in the current population.)

At Conata Basin, the breeding population size is approximately 100 animals (34♂ / 66♀). At Meeteetse, the current population size is 0. At UL Bend, current population size is 3 (2♂ / 1♀). At Badlands NP, current population size is 9 (1♂ / 4♀ / 4??).

19) *What is the habitat carrying capacity (K)?*
How many animals could be supported in the existing habitat?
(We will assume that the habitat is not fluctuating randomly in quality over time.)

We really don't know what K is for Conata Basin. We estimate 261 breeding adults (87♂ / 174♀). That estimate is based on the approximate home range size of each sex (150 acres for males, 75 acres for females) divided into the total prairie dog acreage of Conata Basin (13,052 acres). At Meeteetse, K was assumed to be 129, which was the maximum population size including kits in 1984. At Badlands NP, total acreage is 4,800, with approximately 3,200 in the primary ferret area. At Badlands NP, observed home range size for a litter was 165 acres.

20) *Will habitat be lost or gained over time?*

At Conata Basin, habitat will remain relatively static at 13,000-15,000 acres. At Meeteetse, the habitat base was 7,400 acres. At Badlands NP, prairie dog growth is continuing and encouraged. Observed rates at Badlands NP are 4% increase in total prairie dog acreage per year.

21) *Over how many years will habitat be lost or gained?*

Conata Basin should remain static. At Badlands NP, habitat will continue to grow but at an unknown rate. The rates at Badlands NP may vary from year to year due to different management practices (e.g. prescribed burns), but prairie dogs are allowed to fluctuate by natural processes.

22) *What percentage of habitat will be lost or gained each year?*

Difficult to estimate and is highly dependent upon grazing rates, precipitation, disease, prescribed burning and other factors that cannot be or are difficult to manage.

23) *Will animals be removed from the wild population (to bolster captive stocks or for other reasons)?*
If "Yes", then,
At what annual interval?
For how many years?
How many female juveniles? 1-2 year old females? 2-3 year old females? adult females? will be removed each time.
How many male juveniles? 1-2 year old males? 2-3 year old males? adult males? will be removed each time.

24) *Will animals be added to the population (from captive stocks, etc.)?*
If "Yes", then,
At what annual interval?
For how many years?
How many female juveniles? 1-2 year old females? 2-3 year old females? adult females? will be added each time.
How many male juveniles? 1-2 year old males? 2-3 year old males? adult males? will be added each time

APPENDIX III. Current status of black-footed ferret reintroduction sites.

Table III-1. Estimated current status of black-footed ferret populations and site potential

	Potential maximum individuals (spring)	Current # (individuals)	Complex Size (Ac)	Prairie Dog species	Years since initiation
Conata Basin/Badlands	310	125 and 7	13,052 and 3,200	BTPB	7 and 9
Montana –PCO ULBEND/BLM	20 / 10	3 / 5	1,850 / 1,230	BTPD	9 / 2
Montana – FB	10	0 ?	1,300	BTPD	6
CRST	466	57	6,598 and 14,257	BTPD	3
Mexico	462	35	37,252	BTPD	2
CO/UT		34 and 5	16,926 and 17,018	WTPD	4 and 2
Shirley Basin		18 (2001)	48,000 *	WTPD	12
Arizona		10	10,000	Gunn.PD	7

*estimate unclear based on plague presence

Appendix IV. Simulation Modeling and Population Viability Analysis

Jon Ballou – Smithsonian Institution / National Zoological Park
Bob Lacy – Chicago Zoological Society
Phil Miller – Conservation Breeding Specialist Group (IUCN / SSC)

A model is any simplified representation of a real system. We use models in all aspects of our lives, in order to: (1) extract the important trends from complex processes, (2) permit comparison among systems, (3) facilitate analysis of causes of processes acting on the system, and (4) make predictions about the future. A complete description of a natural system, if it were possible, would often decrease our understanding relative to that provided by a good model, because there is "noise" in the system that is extraneous to the processes we wish to understand. For example, the typical representation of the growth of a wildlife population by an annual percent growth rate is a simplified mathematical model of the much more complex changes in population size. Representing population growth as an annual percent change assumes constant exponential growth, ignoring the irregular fluctuations as individuals are born or immigrate, and die or emigrate. For many purposes, such a simplified model of population growth is very useful, because it captures the essential information we might need regarding the average change in population size, and it allows us to make predictions about the future size of the population. A detailed description of the exact changes in numbers of individuals, while a true description of the population, would often be of much less value because the essential pattern would be obscured, and it would be difficult or impossible to make predictions about the future population size.

In considerations of the vulnerability of a population to extinction, as is so often required for conservation planning and management, the simple model of population growth as a constant annual rate of change is inadequate for our needs. The fluctuations in population size that are omitted from the standard ecological models of population change can cause population extinction, and therefore are often the primary focus of concern. In order to understand and predict the vulnerability of a wildlife population to extinction, we need to use a model which incorporates the processes which cause fluctuations in the population, as well as those which control the long-term trends in population size (Shaffer 1981). Many processes can cause fluctuations in population size: variation in the environment (such as weather, food supplies, and predation), genetic changes in the population (such as genetic drift, inbreeding, and response to natural selection), catastrophic effects (such as disease epidemics, floods, and droughts), decimation of the population or its habitats by humans, the chance results of the probabilistic events in the lives of individuals (sex determination, location of mates, breeding success, survival), and interactions among these factors (Gilpin and Soulé 1986).

Models of population dynamics which incorporate causes of fluctuations in population size in order to predict probabilities of extinction, and to help identify the processes which contribute to a population's vulnerability, are used in "Population Viability Analysis" (PVA) (Lacy 1993/4). For the purpose of predicting vulnerability to extinction, any and all population processes that impact population dynamics can be important. Much analysis of conservation issues is conducted by largely intuitive assessments by biologists with experience with the system. Assessments by experts can be quite valuable, and are often contrasted with "models" used to evaluate population vulnerability to extinction. Such a contrast is not valid, however, as *any* synthesis of facts and understanding of processes constitutes a model, even if it is a mental model within the mind of the expert and perhaps only vaguely specified to others (or even to the expert himself or herself).

A number of properties of the problem of assessing vulnerability of a population to extinction make it difficult to rely on mental or intuitive models. Numerous processes impact population dynamics, and many of the factors interact in complex ways. For example, increased fragmentation of habitat can make it more difficult to locate mates, can lead to greater mortality as individuals disperse greater distances across unsuitable habitat, and can lead to increased inbreeding which in turn can further reduce ability to attract mates and to survive. In addition, many of the processes impacting population dynamics are intrinsically probabilistic, with a random component. Sex determination, disease, predation, mate acquisition -- indeed, almost all events in the life of an individual -- are stochastic events, occurring with certain probabilities rather than with absolute certainty at any given time. The consequences of factors influencing population dynamics are often delayed for years or even generations. With a long-lived species, a population might persist for 20 to 40 years beyond the emergence of factors that ultimately cause extinction. Humans can synthesize mentally only a few factors at a time, most people have difficulty assessing probabilities intuitively, and it is difficult to consider delayed effects. Moreover, the data needed for models of population dynamics are often very uncertain. Optimal decision-making when data are uncertain is difficult, as it involves correct assessment of probabilities that the true values fall within certain ranges, adding yet another probabilistic or chance component to the evaluation of the situation.

The difficulty of incorporating multiple, interacting, probabilistic processes into a model that can utilize uncertain data has prevented (to date) development of analytical models (mathematical equations developed from theory) which encompass more than a small subset of the processes known to affect wildlife population dynamics. It is possible that the mental models of some biologists are sufficiently complex to predict accurately population vulnerabilities to extinction under a range of conditions, but it is not possible to assess objectively the precision of such intuitive assessments, and it is difficult to transfer that knowledge to others who need also to evaluate the situation. Computer simulation models have increasingly been used to assist in PVA. Although rarely as elegant as models framed in analytical equations, computer simulation models can be well suited for the complex task of evaluating risks of extinction. Simulation models can include as many factors that influence population dynamics as the modeler and the user of the model want to assess. Interactions between processes can be modeled, if the nature of those interactions can be specified. Probabilistic events can be easily simulated by computer programs, providing output that gives both the mean expected result and the range or distribution of possible outcomes. In theory, simulation programs can be used to build models of population dynamics that include all the knowledge of the system which is available to experts. In practice, the models will be simpler, because some factors are judged unlikely to be important, and because the persons who developed the model did not have access to the full array of expert knowledge.

Although computer simulation models can be complex and confusing, they are precisely defined and all the assumptions and algorithms can be examined. Therefore, the models are objective, testable, and open to challenge and improvement. PVA models allow use of all available data on the biology of the taxon, facilitate testing of the effects of unknown or uncertain data, and expedite the comparison of the likely results of various possible management options.

PVA models also have weaknesses and limitations. A model of the population dynamics does not define the goals for conservation planning. Goals, in terms of population growth, probability of persistence, number of extant populations, genetic diversity, or other measures of population performance must be defined by the management authorities before the results of population modeling can be used. Because the models incorporate many factors, the number of possibilities to test can seem endless, and it can be difficult to determine which of the factors that were analyzed are most important to the population dynamics. PVA models are necessarily incomplete. We can model only those factors which we understand and for which we can specify the parameters. Therefore, it is important to realize that the models probably underestimate the threats facing the population. Finally, the models are used to predict the long-term effects of the processes presently acting on the population. Many aspects of the situation could change radically within the time span that is modeled. Therefore, it is important to reassess the data and model results periodically, with changes made to the conservation programs as needed (see Lacy and Miller (2002), Nyhus et al. (2002) and Westley and Miller (in press) for more details).

The *VORTEX* Population Viability Analysis Model

For the analyses presented here, the *VORTEX* computer software (Lacy 1993a) for population viability analysis was used. *VORTEX* models demographic stochasticity (the randomness of reproduction and deaths among individuals in a population), environmental variation in the annual birth and death rates, the impacts of sporadic catastrophes, and the effects of inbreeding in small populations. *VORTEX* also allows analysis of the effects of losses or gains in habitat, harvest or supplementation of populations, and movement of individuals among local populations.

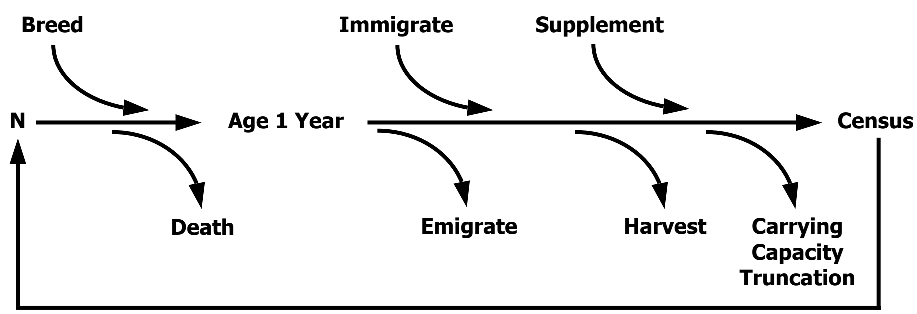
Density dependence in mortality is modeled by specifying a carrying capacity of the habitat. When the population size exceeds the carrying capacity, additional morality is imposed across all age classes to bring the population back down to the carrying capacity. The carrying capacity can be specified to change linearly over time, to model losses or gains in the amount or quality of habitat. Density dependence in reproduction is modeled by specifying the proportion of adult females breeding each year as a function of the population size.

VORTEX models loss of genetic variation in populations, by simulating the transmission of alleles from parents to offspring at a hypothetical genetic locus. Each animal at the start of the simulation is assigned two unique alleles at the locus. During the simulation, *VORTEX* monitors how many of the original alleles remain within the population, and the average heterozygosity and gene diversity (or "expected heterozygosity") relative to the starting levels. *VORTEX* also monitors the inbreeding coefficients of each animal, and can reduce the juvenile survival of inbred animals to model the effects of inbreeding depression.

VORTEX is an *individual-based* model. That is, *VORTEX* creates a representation of each animal in its memory and follows the fate of the animal through each year of its lifetime. *VORTEX* keeps track of the sex, age, and parentage of each animal. Demographic events (birth, sex determination, mating, dispersal, and death) are modeled by determining for each animal in each year of the simulation whether any of the events occur. (See figure below.) Events occur according to the specified age and sex-specific probabilities. Demographic stochasticity is therefore a consequence of the uncertainty regarding whether each demographic event occurs for any given animal.

VORTEX requires a lot of population-specific data. For example, the user must specify the amount of annual variation in each demographic rate caused by fluctuations in the environment. In addition, the frequency of each type of catastrophe (drought, flood, epidemic disease) and the effects of the catastrophes on survival and reproduction must be specified. Rates of migration (dispersal) between each pair of local populations must be specified. Because *VORTEX* requires specification of many biological parameters, it is not necessarily a good model for the examination of population dynamics that would result from some generalized life history. It is most usefully applied to the analysis of a specific population in a specific environment.

VORTEX Simulation Model Timeline



Events listed above the timeline increase N, while events listed below the timeline decrease N.

Further information on *VORTEX* is available in Miller and Lacy (1999) and Lacy (2000).

Dealing with Uncertainty

It is important to recognize that uncertainty regarding the biological parameters of a population and its consequent fate occurs at several levels and for independent reasons. Uncertainty can occur because the parameters have never been measured on the population. Uncertainty can occur because limited field data have yielded estimates with potentially large sampling error. Uncertainty can occur because independent studies have generated discordant estimates. Uncertainty can occur because environmental conditions or population status have been changing over time, and field surveys were conducted during periods which may not be representative of long-term averages. Uncertainty can occur because the environment will change in the future, so that measurements made in the past may not accurately predict future conditions.

Sensitivity testing is necessary to determine the extent to which uncertainty in input parameters results in uncertainty regarding the future fate of the pronghorn population. If alternative plausible parameter values result in divergent predictions for the population, then it is important to try to resolve the uncertainty with better data. Sensitivity of population dynamics to certain parameters also indicates that those parameters describe factors that could be critical determinants of population viability. Such factors are therefore good candidates for efficient management actions designed to ensure the persistence of the population.

The above kinds of uncertainty should be distinguished from several more sources of uncertainty about the future of the population. Even if long-term average demographic rates are known with precision, variation over time caused by fluctuating environmental conditions will cause uncertainty in the fate of the population at any given time in the future. Such environmental variation should be incorporated into the model used to assess population dynamics, and will generate a range of possible outcomes (perhaps represented as a mean and standard deviation) from the model. In addition, most biological processes are inherently stochastic, having a random component. The stochastic or probabilistic nature of survival, sex determination, transmission of genes, acquisition of mates, reproduction, and other processes preclude exact determination of the future state of a population. Such demographic stochasticity should also be incorporated into a population model, because such variability both increases our uncertainty about the future and can also change the expected or mean outcome relative to that which would result if there were no such variation. Finally, there is "uncertainty" which represents the alternative actions or interventions, which might be pursued as a management strategy. The likely effectiveness of such management options can be explored by testing alternative scenarios in the model of population dynamics, in much the same way that sensitivity testing is used to explore the effects of uncertain biological parameters.

Results

Results reported for each scenario include:

Deterministic r -- The deterministic population growth rate, a projection of the mean rate of growth of the population expected from the average birth and death rates. Impacts of harvest, inbreeding, and density dependence are not considered in the calculation. When $r = 0$, a population with no growth is expected; $r < 0$ indicates population decline; $r > 0$ indicates long-term population growth. The value of r is approximately the rate of growth or decline per year.

The deterministic growth rate is the average population growth expected if the population is so large as to be unaffected by stochastic, random processes. The deterministic growth rate will correctly predict future population growth if: the population is presently at a stable age distribution; birth and death rates remain constant over time and space (i.e., not only do the probabilities remain constant, but the actual number of births and deaths each year match the expected values); there is no inbreeding depression; there is never a limitation of mates preventing some females from breeding; and there is no density dependence in birth or death rates, such as a Allee effects or a habitat "carrying capacity" limiting population growth. Because some or all of these assumptions are usually violated, the average population growth of real populations (and stochastically simulated ones) will usually be less than the deterministic growth rate.

Stochastic r -- The mean rate of stochastic population growth or decline demonstrated by the simulated populations, averaged across years and iterations, for all those simulated populations that are not extinct. This population growth rate is calculated each year of the simulation, prior to any truncation of the population size due to the population exceeding the carrying capacity. Usually, this stochastic r will be less than the deterministic r predicted from birth and death rates. The stochastic r from the simulations will be close to the deterministic r if the population growth is steady and robust. The stochastic r will be notably less than the deterministic r if the population is subjected to large fluctuations due to environmental variation, catastrophes, or the genetic and demographic instabilities inherent in small populations.

P(E) -- the probability of population extinction, determined by the proportion of, for example, 500 iterations within that given scenario that have gone extinct in the simulations. "Extinction" is defined in the VORTEX model as the lack of either sex.

N -- mean population size, averaged across those simulated populations which are not extinct.

SD(N) -- variation across simulated populations (expressed as the standard deviation) in the size of the population at each time interval. SDs greater than about half the size of mean N often indicate highly unstable population sizes, with some simulated populations very near extinction. When SD(N) is large relative to N, and especially when SD(N) increases over the years of the simulation, then the population is vulnerable to large random fluctuations and may go extinct even if the mean population growth rate is positive. SD(N) will be small and often declining relative to N when the population is either growing steadily toward the carrying capacity or declining rapidly (and deterministically) toward extinction. SD(N) will also decline considerably when the population size approaches and is limited by the carrying capacity.
H -- the gene diversity or expected heterozygosity of the extant populations, expressed as a percent of the initial gene diversity of the population. Fitness of individuals usually declines proportionately with gene diversity (Lacy 1993b), with a 10% decline in gene diversity typically causing about 15% decline in survival of captive mammals (Ralls et al. 1988). Impacts of inbreeding on wild populations are less well known, but may be more severe than those observed in captive populations (Jiménez et al. 1994). Adaptive response to natural selection is also expected to be proportional to gene diversity. Long-term conservation programs often set a goal of retaining 90% of initial gene diversity (Soulé et al. 1986). Reduction to 75% of gene diversity would be equivalent to one generation of full-sibling or parent-offspring inbreeding.

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Black-footed Ferret
Population Management Planning Workshop

10-13 June 2003
Denver, Colorado

FINAL REPORT

Appendix I
Participant Introductory Questions

Participant Introductory Questions

Question 1: What is your personal goal for this workshop?

- To gain insight into how my research can be applied to monitoring/management and get a better feel for the overall recovery process and how all parts relate.
- To provide at least a little information useful to this review and future planning.
- To obtain broad input on status of recovery program and lay out issues facing management of black-footed ferret population in captivity and the wild.
- To learn more about the captive breeding program and discuss issues facing reintroduction efforts; learn more about Vortex model.
- To kick start the research questions, design and analysis of field reintroduction data; to identify problems that can be solved.
- Develop road map to prevent black-footed ferret extinction and estimate several, self-sustaining wild black-footed ferret populations.
- To work several scenarios through Vortex to see outcomes.
- Decide how to effectively manage the SSP population to decrease incidence of poor reproductive traits and decrease inbreeding.
- A better understanding about the issues facing the black-footed ferret such as fertility and, if there is a problem, what may be causing a decline in breeding success.
- To assist and be assisted by others here to start to understand changes that are occurring to the captive population, predict future changes and predict their effects on the reintroduced populations.
- Obtain more information on the release component of the recovery plan for future release of black-footed ferrets into Canada; captive management strategy, pairings, maintenance of genetic integrity.
- Explore, develop and identify a plan for continued successful captive breeding and recovery of the black-footed ferret.
- Population management planning that places more emphasis on the biological needs of the species, less emphasis on socio-political issues.
- Learn more about the population analysis process and concerns from other reintroduction sites.
- Understand how captive breeding can lead to successful restoration.
- Learn how best to develop habitat for ferret occupancy on 2 private, Turner-owned ranches, one in South Dakota and one in New Mexico.
- To assist with identifying AZ role in the national ferret program.
- To determine whether SSP management should be on the basis of genetic diversity or production and to think out side the box.

Question 2: What do you hope to contribute to the Black-footed Ferret Population Management Planning process?

- Information on additional ways to monitor reintroduced populations.
- Long term goal is to gain insight into plague ecology, such that answers might allow management of the disease at least at black-footed ferret reintroductions sites.
- Help assimilate information into specific management recommendations for the recovery program.
- Knowledge of reintroduction challenges facing Colorado.
- Foster exchange of ideas and a more collaborative and coordinated effort to field recovery.
- Summarize all wild reintroduction efforts; describe habitat management problems – at least from Montana perspective.
- Small wild population demographic, survivorship and habitat data from plague free site experiencing decline.
- Advisor on reproduction for the program, effects of inbreeding in carnivores, assisted reproduction (how it can help manage the ex situ and in situ populations.
- A better understanding of fertility issues by presenting data and hopefully getting some good feedback.
- My understanding of genetics, both of the captive and reintroduced populations.
- Contribute captive management component from Toronto Zoo perspective.
- Insight from zoo perspective and captive breeding experience.
- Based on limited experience, contribute to habitat and reintroduction/translocation issues.
- Knowledge of field aspects/concerns of ferret reintroduction on white-tailed prairie dog colonies.
- Understanding of population genetics of small populations, National Park Service T & E Species Restoration Program.
- Data and experience in growing prairie dogs; willingness to develop ferret habitat on private lands.
- Involved with the AZ ferret program sine 1991 with site evaluation and eventual reintroduction.
- Knowledge of captive (SSP and pen) management and overall program
- How to implement translocation of wild born individuals to other sites in order to achieve as many self sustaining populations as quickly as possible

Question 3: What do you see as the key question facing the Program with regard to recovery of the black-footed ferret?

- How to maintain/expand habitat and keep reintroduced populations going?
- How will plague influence reintroduced ferret populations (indirectly and directly)?
- How to develop sufficient habitat base to recover the species (with all the attendant problems and political issues)?
- How to manage plague in reintroduced sites or proposed sites?
- How to find/build the habitat base for free-ranging wild populations? Habitat is the primary issue.
- Failure of wild population establishment and mechanisms to create more habitat and mange/understand plague.
- Is recovery realistic with current prairie dog habitat status in North America?
- Develop management strategies to slow effects of inbreeding; will bringing wild ferrets from South Dakota into SSP population help? Can artificial insemination help in management strategy?
- How to pair individuals? How to maintain genetic diversity?
- Do we have enough prairie dog populations to sustain viable populations of ferrets and how is plague affecting habitat quality? It doesn't matter how many ferrets we produce in captivity if we have no place to put them.
- What are the details of the captive management component of the program and breeding strategies?
- How can we recover and make available high quality habitat for the black-footed ferret?
- Habitat for reintroduction? Genetics reproductive fitness?
- How to establish viable population of ferrets in areas outside the current highly successful sites (e.g. white-tailed and Gunnison's colonies, marginal black-tail colonies)?
- How small a plague-free prairie dog population is still suitable for ferret restoration?
- How will we convince land managers and landowners that dedication of landscapes to prairie dogs and ferrets has top priority?
- Can reintroduction sites within the plague area really establish a self sustaining population of ferrets?

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Appendix II
List of Participants

Black-footed Ferret Population Management Planning Workshop
Participant List

June 10-13, 2003
Denver, Colorado

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