Recent Directions in Black-footed Ferret Recovery

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Black-footed ferrets (*Mustela nigripes*) remain one of the world's most endangered mammals despite 15 years of conservation efforts. Although the number of captive animals has increased and ferrets have been reintroduced into four sites within their former range, no wild population, apart from reintroductions, is known. This article briefly reviews the history of ferret decline and early recovery efforts, discusses recent successes and failures, and concludes with a discussion of future recovery challenges.

A Brief History of Ferret Decline and Early Recovery Efforts

Black-footed ferrets are obligate associates of prairie dogs (*Cynomys* spp.), upon which they depend for food and shelter (Forrest et al. 1985). Ferret decline began as prairie dog numbers and distribution declined throughout the short and mid-grass prairies of North America. Large-scale conversion to agriculture, prairie dog eradication, and the effects of plague (*Yersinia pestis*), an exotic disease (Miller et al. 1990c), contributed to the loss of prairie dogs. Prairie dog eradication continues despite range science studies which question the extent of competition between prairie dogs and livestock (O'Meilia et al. 1984; Uresk & Paulson 1989), economic analyses that indicate that eradication programs are not cost effective (Collins et al. 1984), and ecological research that illustrates the importance of prairie dogs as ecosystem regulators (Krueger 1988; Whicker & Detling 1988; Reading et al. 1989). As a result, complexes of prairie dog colonies cover less than 2% of their former range (Miller et al. 1994, 1996; Roemer & Forrest 1996).

Ferret populations became small and fragmented following depletion of their prey base. They began disappearing as a result of deterministic and stochastic factors, including both plague and canine distemper (Thorne & Williams 1988). The last known wild population of ferrets was discovered near Meeteetse, Wyoming in 1981. This population was studied until 1985 when both plague and canine distemper drove it to near extinction (Clark 1989). Eighteen ferrets, many closely related, were captured just prior to extinction of the wild population, and captive breeding was initiated (Miller et al. 1988). Captive propagation succeeded in increasing ferret numbers, and today over 350 individuals are distributed among 7 facilities in the United States and Canada. The Black-footed Ferret Recovery Plan, drafted after the Meeteetse population crash, calls for establishing at least 10 separate populations of 30 or more over-wintering adults with a minimum of 1,500 total individuals (U.S. Fish and Wildlife Service 1988).

Reintroduction of ferrets bred in captivity began in 1991 with release of young of the year into Shirley Basin, Wyoming. Reintroduction has since expanded to sites in Montana, South Dakota, and Arizona. Some advances in reintroduction techniques have occured, and some wild born animals have survived to reproduce. Although progress has occurred, ferrets remain far from recovered, and the program has been plagued by unproductive conflict and policy and organizational problems (May 1986; Clark & Harvey 1988; Clark 1989 in press; Seal et al. 1989; Reading & Miller 1994; Miller et al. 1996).

Recent Developments

Captive Breeding

After a relatively slow start in the mid-1980s, the captive population began increasing before leveling off in

Year	Females in Captivity	Litters Whelped	# Kits Born	# Kits Born per Litter	# Kits Weaned	# Kits Weaned per Litter
1987-1989	59	40	132	3.3+-1.6	105	2.6+-1.8
1990	56	32	90	2.8+-1.1	66	2.1+-1.3
1991	93	59	219	3.7+-1.6	143	1.5+-1.9
1992	126	76	250	3.3+-1.8	192	2.5+-2.0
1993	173	87	276	3.2+-1.7	116	1.3+-1.6
1994	192	75	266	3.5+-1.8	180	2.4+-2.1
1995	165	88	325	3.7+-1.7	185	2.1+-1.9

Table 1. Black-footed ferret captive breeding summary.

the early 1990s (see Table 1). As the captive population grew, it was eventually split, with about half the animals remaining in the National Black-Footed Ferret Conservation Center (NBFFCC) at Sybille, Wyoming. The remainder were maintained and bred in several sites, including the Omaha Zoo, Nebraska; the National Zoo's breeding facility at Front Royal, Virginia; the Toronto Zoo, Ontario; the Phoenix Zoo, Arizona; the Louisville Zoo, Kentucky; and the Cheyenne Mountain Zoo in Colorado Springs, Colorado. Although the captive population has been stabilized, productivity has varied somewhat (see Table 1).

Ferret reproduction and kit survival have been quite successful in 1996 with 316 kits born in 89 litters and 234 kits surviving to weaning. Approximately 125 of these animals were allocated for reintroduction into the three active release sites (Montana, South Dakota, and Arizona), and 106 kits (the most genetically valuable) were retained in the captive breeding program.

Older animals, which contribute little to reproduction, now comprise a substantial portion of the captive population, creating problems of space for younger, more reproductively valuable animals. The increase in numbers of older ferrets permitted allocation of some for exhibit at zoological parks, and today eleven zoos, in addition to those breeding animals, display ferrets.

The captive breeding program has produced many kits; however, problems associated with inbreeding may develop. There are only 7 genetic founders represented in the breeding pool. Genetic analyses initially recommended maintaining 200 breeding animals in captivity to maintain 80% of the genetic diversity of founders for over 200 years (Ballou & Oakleaf 1989); this was later increased to 240 adults. To increase the productive capacity of breeding animals, captive management strives to maintain a ratio of 3 males:5 females. Emphasis is placed on genetic management of the captive population because of the comparative ease of managing its genetics relative to wild populations (Russell et al. 1994), and because mortality of reintroduced animals is high. Therefore, only genetically "surplus" animals (i.e., high inbreeding coefficients and high representation in the captive population) and numbers produced in excess of those needed to replace loss of captive animals are available for reintroduction (Godbey & Biggins 1994). Genetic studies to determine relatedness of "founders" were called for in 1985 but never conducted and ferret lineages remain estimates based on the locations of animals captured from the wild. In addition, animals of disputed paternity entered the breeding population in 1987-88. As a result, genetic management has been compromised.

Reintroduction Research

A variety of research has occured on captive animals, the results of which have contributed substantially to ferret recovery efforts. Studies directed at increasing the captive productivity of ferrets examined reproductive physiology (Seal et al. 1989; Carvalho et al. 1991; Williams et al. 1991, 1992), artificial insemination (Howard et al. 1991, 1996), reproductive behavior (Miller 1988; Miller et al. 1996), developmental biology (Vargas 1994; Miller et al. 1996; Vargas & Anderson 1996a, 1996b), and captive management (Miller et al. 1988, 1996; Williams et al. 1991). The risk of disease (Thorne & Williams 1988; Williams et al. 1994) led to disease prevention protocols and studies directed at developing vaccinations (Williams et al. in press). Additional studies examined methods for increasing chances of post-release survival. Studies included raising animals in enriched environments and in arenas with resident prairie dogs to simulate a more natural environment (Miller et al. 1990a, 1990b; Biggins et al. 1991, 1993a; Vargas 1994), providing young with opportunities to kill prey (Miller et al. 1990a; Vargas 1994; Vargas & Anderson 1996a), providing aversive stimuli in the presence of potential predators (Miller et al. 1990b), and exploring the possibility of food im-

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printing (Vargas & Anderson 1996b). These latter studies were conducted in collaboration with test reintroductions of closely related Siberian polecats (*M. eversmanni*) and actual reintroductions of black-footed ferrets to examine effects on survivorship.

Prior to reintroducing black-footed ferrets, biologists experimented with trial releases of Siberian polecats to improve techniques. Siberian polecats which had experience killing prey, which had less contact with people, and which were raised in arenas as opposed to cages were better predators and exhibited more developed predator avoidance behaviors (Biggins et al. 1991, 1993a; Miller et al. 1990a, 1990b). Similarly, more recent releases of black-footed ferrets found that animals raised in enriched environments and those with previous experience killed prey more effectively (Vargas 1994). Nevertheless, only recently were these techniques incorporated into reintroduction protocols (Miller et al. 1996).

Other research focused on reintroduction sites. Research on prairie dogs examined colony dynamics and habitat preferences (Reading et al. 1989; Reading 1993) and developed standardized monitoring and evaluation methods for complexes of prairie dog colonies (Biggins et al. 1993b). Other studies assessed and monitored populations of potential ferret predators (Reading 1993) and sampled resident carnivores for disease, especially canine distemper and plague. Local support is crucial for conservation efforts. An evaluation of local values and attitudes found that people were often antagonistic toward ferrets, due to the perception that prairie dogs compete with livestock for forage and from the fact that ferrets are listed as endangered, which elicited fears of loss of control over public grazing lands and of restrictions on land uses (Reading 1993; Reading & Kellert 1993; Reading et al. in review). Results of these and other studies permitted site ranking on a number of biological and social science criteria and development of proactive strategies to improve a site's suitability for ferret reintroduction.

Reintroduction Efforts

Reintroduction began in 1991 with the release of 49 ferret kits into Shirley Basin, Wyoming. All animals were young of the year, released during autumn when young ferrets normally disperse. The kits were acclimated for a minimum of ten days in raised cages, given access to cages post release, and provided with supplementary food (Wyoming Game and Fish Department 1991). At least 4 ferrets survived the winter, with 2 producing litters.

An additional 90 kits were reintroduced into the same site in 1992. Seventeen of the animals released were raised in outdoor arenas. These pre-conditioned animals dispersed less and survived significantly longer than cage-reared animals (Biggins et al. 1993a; Vargas 1994). A minimum of 8 animals survived the winter and at least 4 litters were born the following summer.

A second site in Montana was biologically ready to receive ferrets in 1992, but political pressure at the state governors' level delayed release (Reading & Miller 1994; Miller et al. 1996). By 1993 field preparations for a third release site in South Dakota were also completed. However, a large decline in captive production precluded releases in either Montana or South Dakota, thus Shirley Basin, Wyoming received all 48 animals in 1993. By late 1993, an estimated 24 ferrets survived. By October 1994 about 10 adults and kits of unknown origin (none were captured) were observed.

Black-footed ferrets were reintroduced into all three sites in 1994: 41 into Wyoming, 36 into the Conata Basin of South Dakota, and 40 into south Phillips County, Montana. The fate of ferrets released in Wyoming is unknown. In South Dakota at least 8 ferrets were still alive by early December 1994 and, by July 1995, at least 4 surviving ferrets produced 5 kits in 2 litters. In Montana at least 9 animals survived the winter, producing a minimum of 5 kits in 3 litters the following summer. The Montana reintroduction included intensive telemetric monitoring of all animals and an experimental design to test preconditioning. Assessment of data from all three reintroduction sites showed a highly significant effect of pre-conditioning on short-term and long-term survival (Biggins et al. in review).

To test the potential contribution of adult reintroductions to the overall recovery effort, two releases in South Dakota used 4- and 5-year-old animals. Only the second group of 14 animals was monitored with telemetry; 12 were found dead soon after release and the other 2 signals were lost. Because of the high losses, this technique was canceled.

Plague, coupled with a flooding event, reduced white-tailed prairie dogs (*C. leucurus*) in Shirley Basin, Wyoming during 1994-95. Due to the greatly depleted prey base no additional animals were released into the site in 1995 or 1996. However, at least 5 ferrets, including kits, were discovered in Wyoming during spotlighting surveys during the summer of 1996. Researchers were hopeful that these animals survived by producing antibodies for plague, but blood tests on 2 animals did not support this hypothesis.

Thirty-three young ferrets were released in South Dakota in the fall of 1995. By late November/early December at least 16 ferrets had survived, including 9 animals reintroduced in 1995, 2 released in 1994, 3 kits born in 1995, and 2 unidentified animals. This showed an increase in the number of animals known to be alive through December from 22% in 1994 to 30% in 1995. An additional 7 animals were released into the South Dakota site in February 1996 in an attempt to reduce over-winter mortality. Spotlighting surveys during the summer of 1996 found a minimum of 9 adults with at least 5 litters and 8 kits. Of significant interest is the fact that animals born in the wild in 1995 produced litters in 1996. South Dakota released an additional 67

kits and 4 adult females during the fall of 1996.

Thirty-seven animals were reintroduced into Montana in 1995. Both lethal control of coyotes and temporary electric fences were used to reduce predation during the first couple of weeks after release. All ferrets were intensively monitored using radio telemetry for several weeks and then monitored periodically using spotlights. Thirty-day survivorship increased from 26% in 1994 to 58% in 1995. By December 1995, a minimum of 28 ferrets survived and by May 1996, a minimum of 19 animals were identified. Although coyote control and electric fences increased short-term survival, long-term survival was not affected. The timing of pre-release conditioning may be the most important variable affecting survival. Survival was greatest for ferrets raised in large, dirt filled pens or transferred into these pens at an early age. In 1996, a minimum of 10 females produced litters with at least 15 kits, including litters from wild-born females. Four kits produced in 1995 (67%) survived to the 1996 breeding season. An additional 43 ferrets were released onto Montana prairie dog colonies unoccupied by ferrets in the fall of 1996.

Arizona became the recovery program's fourth reintroduction site when 4 ferrets were released into large (980 m^2) fenced enclosures on a reintroduction site in Coconina County's Aubrey Valley in March 1996. Thirty-five ferrets were later released into ten on-site enclosures, each sub-divided into four smaller pens, constructed to exclude terrestrial predators. The site received an additional 15 kits in the fall of 1996 and the state will strive to compare behaviors and survival of kits with those of adults.

Program Organization and Management

Organization and management of ferret recovery efforts has been the subject of intense research and analysis (May 1986; Clark & Harvey 1988; Clark 1989 in press; Thorne & Oakleaf 1991; Godbey & Biggins 1994; Reading & Miller 1994; Miller et al. 1996). Despite broad recognition of many of the program's organizational problems, participants interpreted the underlying reasons for these problems differently, and the problems have been given little explicit attention despite many recommendations.

The U.S. Fish and Wildlife Service (FWS) designated Wyoming Game and Fish Department the lead agency for ferret recovery soon after discovery of the Meeteetse, Wyoming population in 1981 (Clark 1989). The state agency vigorously managed and controlled the program from 1981-1985, when the FWS took the lead in what had become a large, complex, and multi-organizational program. The program has continued to grow as the number of captive facilities and reintroduction sites has grown. At the same time, however, Congressional allocations for endangered species recovery programs have declined.

After 15 years, participants requested the FWS assume greater involvement in the ferret recovery program due in part to unresolved organizational problems, an increasingly national (even international) recovery program, and reduced funding. This, coupled with lingering uncertainty about the success of the Wyoming reintroductions, led to several changes in the mangementof the program (Miller et al. 1996). In early 1995, the FWS formed a body composed of agency representatives to oversee recovery efforts. In early 1996, the FWS assumed direct responsibility for the captive breeding facility at Sybille, Wyoming and assigned captive breeding and reintroduction specialists to assist a new part-time Recovery Coordinator. To improve coordination and management of recovery efforts, the FWS established a formal recovery implementation team in July 1996.

The FWS contracted the American Zoo and Aquarium Association (AZA) in 1995 to conduct a programmatic evaluation of the ferret recovery program. The AZA held a series of meetings on captive breeding, reintroduction and habitat conservation, and program administration and accountability. The working documents produced from these meetings are intended to help the FWS improve the program, guide recovery efforts, and draft a new recovery plan (Hutchins & Wiese 1996).

Future Challenges

Black-footed ferrets appear to be moving toward recovery, but numerous challenges, both biological and non-biological, remain. Perhaps the largest biological obstacle to recovery is posed by disease epizootics, including canine distemper and plague. Ferrets are highly and fatally susceptible to canine distemper (Williams et al. 1988). A temporary vaccine for canine distemper is now available and a vaccine for lifetime immunity is being researched (Williams et al. in press). Perhaps of greater concern is plague. Ferrets, until recently, were thought not to be susceptible to plague. However, the loss of several ferrets at two separate captive facilities has dramatically proven otherwise (Williams et al. 1994).

Reduced numbers of prairie dogs also poses a threat to ferret conservation. Prairie dogs continue to suffer marked declines across most of their range from exotic disease and other causes (e.g., poisoning and shooting). Plague epidemics have already affected the reintroduction sites in Wyoming and Montana and have periodically affected most known complexes of prairie dog colonies, with the notable exceptions of South Dakota and perhaps Mexico. Combating plague probably poses the most significant biological challenge to the conservation of ferrets and the entire prairie dog ecosystem. The FWS is coordinating research directed at decreasing plague occurence within and around ferret reintroduction sites.

Captive breeding continues to produce relatively large numbers of kits for reintroduction, but inbreeding could lead to problems with fertility, survivorship and deformities. Unfortunately, options are limited by

the extremely small number of founders: only five are currently represented. Resolving issues of relatedness by performing the requisite genetic studies might aid the situation. The recovery program should also develop contingency plans in case inbreeding depression begins to affect the captive population.

Several non-biological challenges also face ferret recovery. Antipathy for prairie dogs remains prevalent among some people, especially relevant groups such as ranchers and many employees of agriculture, wildlife, and public land management agencies (Miller et al. 1990c; Reading 1993; Reading et al. in review). Inducing these people to support, or at least not to oppose, ferret and prairie dog conservation programs is crucial to long-term success. Similarly, several groups actively oppose endangered species conservation programs because of real and perceived restrictions associated with the Endangered Species Act (ESA). Anger and fears associated with several sensitive issues, including private property rights, states' rights versus federalism, and public land management, have produced a strong backlash against the ESA and individual recovery programs (Reading & Kellert 1993; Reading et al. in review). Successful, long-term conservation requires addressing these concerns effectively.

Organizational challenges have significantly affected program performance in the past and a number of issues remain unresolved. Among the most fundamental of these problems is an inability to learn more effectively, to utilize the potential of high performance teams and to prototype (Westrum 1994; Clark 1996). While some issues are being addressed in the current programmatic evaluation and re-organization effort, many important organizational challenges remain (e.g., an effective decision-making process, see Clark & Brunner 1996). Several past problems had their origins in differing biases of participants and were manifest individually and organizationally in differing values, organizational cultures, operating philosophies, goals, and control issues. These variables must be successfully addressed to reduce further polemics, goal displacement, and unproductive conflict (Miller et al. 1996; Clark in press).

On a more positive note, the world's largest prairie dog complex in Chihuahua, Mexico, is being incorporated into a new protected area. This complex could, theoretically, support over 1,200 black-footed ferret families (Ceballos et al. 1993) and is currently being assessed more fully by biologists from the Universidad Naciónal Autonomá de México. In addition, research during reintroductions and captive breeding continues to refine methods, improving chances for future success at lower costs. Finally, many dedicated professionals are committed to the recovery of this charismatic ambassador of the threatened prairie dog ecosystem, substantial progress has been made, and hopes remain high that wild, free-ranging populations of black-footed ferrets will once again roam the prairies of North America.

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Literature Cited

Ballou, J. D. and B. Oakleaf. 1989. Demographic and genetic captive-breeding recommendations for black-footed ferrets. Pages 247-267 in U. S. Seal, E. T. Thorne, M. A. Bogan, and S. H. Anderson, editors. Conservation biology of the black-footed ferret. Yale University Press, New Haven, CT.

Biggins, D. E., L. H. Hanebury, B. J. Miller, R. A. Powell, and C. Wemmer. 1991. Release of Siberian ferrets (*Mustela eversmanni*) to facilitate reintroduction of black-footed ferrets. U.S. Fish and Wildlife Service Report (unpublished), Fort Collins, CO.

Biggins, D. E., K. Godbey, and A. Vargas. 1993a. Influence of pre-release experience on reintroduced black-footed ferrets (*Mustela nigripes*). U.S. Fish and Wildlife Service Report, 27 May 1993. Ft. Collins, CO.

Biggins, D. E., B. Miller, L. Hanebury, B. Oakleaf, A. Farmer, R. Crete, and A. Dood. 1993b. A system for evaluating black-footed ferret habitat. U.S. Fish & Wildlife Service. Biological Report **13**:73-92.

Biggins, D. E., J. Godbey, L. H. Hanebury, R. Luce, P. Marinari, R. Matchett, and A. Vargas. In review. Survival of reintroduced black-footed ferrets. Journal of Wildlife Management.

Carvahlo, C. F., J. G. Howard, L. Collins, C. Wemmer, M. Bush, and D. E. Wildt. 1991. Captive breeding of black-footed ferrets (*Mustela nigripes*) and comparative reproductive efficiency in 1-year old versus 2-year old animals. Journal of Zoo Wildlife Medicine **22**:96-106.

Ceballos, G., E. Mellink, and L. R. Hanebury. 1993. Distribution and conservation status of prairie dogs *Cynomys mexicanus* and *Cynomys ludovicianus* in Mexico. Biological Conservation **63**:105-112.

Clark, T. W. 1989. Conservation biology of the black-footed ferret, *Mustela nigripes*. Wildlife Preservation Trust Special Scientific Report No. 3. 175pp.

Clark, T. W. 1996. Learning as a strategy for improving endangered species conservation. Endangered Species UPDATE **13**(1&2):5-6,22-24.

Clark, T. W. In press. Averting extinction: Reconstructing the endangered species process. Yale University Press, New Haven, CT.

Clark, T. W. and A. H. Harvey. 1988. Implementing endangered species recovery policy: Learning as we go? Endangered Species UPDATE **5**:35-42.

Clark, T. W. and R. D. Brunner. 1996. Making partnerships work in endangered species conservation: An introduction to the decision process. Endangered Species UPDATE **13**(9):1-5.

Collins, A. R., J. P. Workman, and D. W. Uresk. 1984. An economic analysis of black-tailed prairie dog (*Cynomys ludovicianus*) control. Journal of Range Management **37**:358-361.

Forrest, S. C., T. W. Clark, L. Richardson, and T. M. Campbell, III. 1985. Black-footed ferret habitat: Some management and reintroduction considerations. Wyoming BLM Wildlife Technical Bulletin **2**:1-49.

Godbey, J. and D. E. Biggins. 1994. Recovery of the black-footed ferret: Looking back, looking forward. Endangered Species Technical Bulletin **19**(1):10, 13.

Howard, J. G., M. Bush, C. Morton, F. Morton, and D. E. Wildt. 1991. Comparative semen cryopreservation in ferrets (*Mustela putorius furo*) and pregnancies after laparoscopic intrauterine insemination with frozen-thawed spermatozoa. Journal of Reproductive Fertility **92**:109-118.

Howard, J. G., D. R. Kwiatkowstki, E. S. Williams, R. W. Atherton, R. M. Kitchin, E. T. Thorne, M. Bush, and D. E. Wildt. 1996. Pregnancies in black-footed ferrets and Siberian polecats after laparoscopic artificial insemination with fresh and frozen-thawed semen. Proceedings: American Society of Andrology. Journal of Andrololgy. (Supplement):P-51 (abstract 115).

Hutchins, M. and R. Wiese. 1996. Black-footed ferret (*Mustela nigripes*) recovery program analysis and action plan. American Zoo & Aquarium Association, Bethesda, MD. 131pp.

Krueger, K. 1988. Prairie dog overpopulation: Value judgment or ecological reality? USDA Forest Service General Technical Report. RM-154:39-45.

May, R. M. 1986. The cautionary tale of the black-footed ferret. Nature **320**:13-14.

Miller, B. J. 1988. Conservation and behavior of the endangered black-footed ferret (*Mustela nigripes*) with a comparative analysis of reproductive behavior between the black-footed ferret and the congeneric domestic ferret (*Mustela putorius furo*). Ph.D. Dissertation, University of Wyoming, Laramie. 195pp.

Miller, B. J., S. H. Anderson, M. W. DonCarlos, and E. T. Thorne. 1988. Biology of the endangered black-footed ferret and the role of captive propagation in its conservation. Canadian Journal of Zoology **66**:765-733.

Miller, B. J., D. E. Biggins, C. Wemmer, R. A. Powell, L. Hanebury, D. Horn, and A. Vargas. 1990a. Development of survival skills in captive-raised Siberian polecats (*Mustela eversmanni*): I. Locating prey. Journal of Ethology **8**:89-94.

Miller, B. J., D. E. Biggins, C. Wemmer, R. A. Powell, L. Calve, L. Hanebury, and T. Wharton. 1990b. Development of survival skills in captive-raised Siberian polecats (*Mustela eversmanni*): II. Predator avoidance. Journal of Ethology **8**:95-104.

Miller, B. J., C. Wemmer, D. E. Biggins, and R. P. Reading. 1990c. A proposal to conserve black-footed ferrets and the prairie dog ecosystem. Environmental Management **14**:763-769.

Miller, B. J., G. Ceballos, and R. P. Reading. 1994. The prairie dog and biotic diversity. Conservation Biology **8**:677-681.

Miller, B. J., R. P. Reading, and S. C. Forrest. 1996. Prairie Night: Black-footed ferrets and the recovery of endangered species. Smithsonian Institution Press, Washington, D.C.

O'Meilia, M. E, F. L. Knopf, and J. G. Lewis. 1982. Some consequences of competition between prairie dogs and beef cattle. Journal of Range Management **35**:580-585.

Reading, R.P. 1993. Toward an endangered species reintroduction paradigm: A case study of the black-footed ferret. Ph.D. Dissertation. Yale University, New Haven, CT.

Reading, R. P., J. J. Grensten, S. R. Beissinger, and T. W. Clark. 1989. Attributes of black-tailed prairie dog colonies in northcentral Montana, with management recommendations for the conservation of biodiversity. Montana BLM Wildlife Technical Buletin **2**:13-27.

Reading, R. P. and S. R. Kellert. 1993. Attitudes toward a proposed black-footed ferret (*Mustela nigripes*) reintroduction. Conservation Biology **7**: 569-580.

Reading, R. P. and B. J. Miller. 1994. The black-footed ferret recovery program: Unmasking professional and organizational weaknesses. Pages 73-100 in T. W. Clark, R. P. Reading, and A. L. Clarke, editors. Endangered species recovery: Finding the lessons, improving the process. Island Press, Washington, D.C.

Reading, R. P., B. J. Miller, and S. R. Kellert. In Review. Values and attitudes toward prairie dogs. Wildlife Society Bulletin.

Roemer, D. M. and S. C. Forrest. 1996. Prairie dog poisoning in Northern Great Plains: An analysis of programs and policies. Environmental Management **20**:349-359.

Russell, W. C., E. T. Thorne, R. Oakleaf, and J. D. Ballou. 1994. The genetic basis of black-footed ferret reintroduction. Conservation Biology **8**:263-266.

Seal, U. S., E. T. Thorne, M. A. Bogan, and S. H. Anderson, editors. 1989. Conservation biology and the black-footed ferret. Yale University Press, New Haven, CT.

Thorne, E. T. and B. Oakleaf. 1991. Species rescue for captive breeding: Black-footed ferret as an example. Pages 241-261 in J. H. W. Gipps, editor. Beyond captive breeding: Re-introducing endangered mammals to the wild. Clarendon Press, Oxford.

Thorne, E. T. and E. Williams. 1988. Diseases and endangered species: The black-footed ferret as a recent example. Conservation Biology **2**:66-73.

U.S. Fish and Wildlife Service. 1988. Black-footed ferret recovery plan. U.S. Fish and Wildlife Service, Denver, CO.

Uresk, D. W. and D. B. Paulson. 1989. Estimated carrying capacity for cattle competing with prairie dogs and forage utilization in western South Dakota. USDA Forest Service General Technical Report RM-166:387-390.

Vargas, A. 1994. Ontogeny of the endangered black-footed ferret (*Mustela nigripes*) and effects of captive upbringing on predatory behavior and post-release survival for reintroduction. Ph.D. Dissertation. University of Wyoming, Laramie, WY.

Vargas, A. and S. H. Anderson. 1996a. The effects of diet on black-footed ferret food preferences. Zoo Biology **15**:105-113.

Vargas, A. and S. H. Anderson. 1996b. Growth and development of captive-raised black-footed ferrets (*Mustela nigripes*). American Midland Nature **135**:43-52.

Westrum, R. 1994. An organizational perspective: Designing recovery teams from the inside out. Pages 327-350 in T. W. Clark, R. P. Reading, and A. L. Clarke, editors. Endangered species recovery: Finding the lessons, improving the process. Island Press, Washington, D.C.

Whicker, A. D. and J. K. Detling. 1988. Ecological consequences of prairie dog disturbances. BioScience **38**:778-785.

Williams, E. S., E. T. Thorne, M. J. G. Appel, and D. W. Belitsky. 1988. Canine distemper in black-footed ferrets (*Mustela nigripes*) in Wyoming. Journal of Wildlife Diseases **24**:385-398.

Williams, E. S., R. T. Thorne, D. R. Kwiatkwoski, S. L. Anderson, and K. Lutz. 1991. Reproductive biology and captive management of black-footed ferrets (*Mustela nigripes*). Zoo Biology **10**:383-398.

Williams, E. S., R. T. Thorne, D. R. Kwiatkwoski, K. Lutz, and S. L. Anderson. 1992. Comparative vaginal cytology of the estrous cycles of black-footed ferrets (*Mustela nigripes*), Siberian polecats (*Mustela eversmanni*), and domestic ferrets (*M. putorius furo*). Journal of Veterinarian Diagnostic Investigation **4**:38-44.

Williams, E. S., K. Mills, D. R. Kwiatkowski, E. T. Thorne, and A. Boelger-Field. 1994. Plague in a black-footed ferret (*Mustela nigripes*). Journal of Wildlife Disease **30**:581-585.

Williams, E. S., S. L. Anderson, J. Cavender, D. Lynn, K. List, C. Hearn, and M. J. G. Appel. In Press. Vaccination of black-footed ferret (*Mustela nigripes*) x Siberian polecat (*M. eversmanni*) hybrids and domestic ferrets (*M. putorius furo*) against canine distemper. Journal of Wildlife Disease.

Wyoming Game and Fish Department. 1991. Black-footed ferret reintroduction in Wyoming: Project description and protocol. Unpublished report, Cheyenne, WY.

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