Interface Between Black-footed Ferret Research And Operational Conservation.

Dean E. Biggins
U.S. Geological Survey, National Ecology Research Center, Fort Collins, CO

Travis M. Livieri
Prairie Wildlife Research

Stewart W. Breck
USDA/APHIS/WS National Wildlife Research Center, stewart.w.breck@aphis.usda.gov

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Dean E. Biggins,* Travis M. Livieri, and Stewart W. Breck

United States Geological Survey, Fort Collins Science Center, 2150 Centre Avenue, Building C, Fort Collins, CO 80526-8118, USA (DEB)
Prairie Wildlife Research, P.O. Box 308, Wellington, CO 80549-0308, USA (TML)
United States Department of Agriculture—Wildlife Services—National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521, USA (SWB)

** Correspondent: dean_biggins@usgs.gov*

Questions and problems that emerged during operational conservation of black-footed ferrets (*Mustela nigripes*) have been addressed by a wide variety of studies. Early results from such studies often were communicated orally during meetings of recovery groups and in written form using memoranda, unpublished reports, and theses. Typically, implementation of results preceded their publication in widely distributed journals. Many of these studies eventually were published in journals, and we briefly summarize the contents of 8 volumes and special features of journals that have been dedicated to the biology of ferrets and issues in ferret recovery. This year marks the 30th anniversary of rediscovery of the black-footed ferret, and the 7 papers of the following Special Feature summarize data collected over nearly that span of time.

Key words: adaptive management, attitudes, captive breeding, communication, *Cynomys*, endangered species, *Mustela nigripes*, plague, prairie dog, reintroduction

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In the mid-1800s 2 well-known American naturalists 1st described the black-footed ferret (*Mustela nigripes*) to the scientific world (Audubon and Bachman 1851), but by early in the next century, the black-footed ferret already was suffering from human persecution of prairie dogs (*Cynomys*) on which it depended (see Miller and Cully [2001] and the accompanying *Journal of Mammalogy* Special Feature). In the words of Seton (1929:573), ''Now that the big Demon of Commerce has declared war on the Prairie-dog, that merry little simpleton of the Plains must go … and with the passing of the Prairie-dog, the Ferret, too, will pass.'' Just 50 years later Seton's prophecy was nearly fulfilled when the last black-footed ferret of the 1st captive-breeding effort died (Carpenter 1985; Poessel et al. 2011) and free-ranging ferrets could no longer be found (Gilbert 1980). But in 1981 hope was restored when a ranch dog killed a ferret near Meeteetse, Wyoming.

The rediscovery of ferrets quickly resulted in studies to learn more about this poorly understood mustelid (Fagerstone and Biggins 2011). Although protection of the population of ferrets at Meeteetse was given highest priority, the population was at risk due to its limited size and available habitat. Plans for a small captive-breeding effort evolved, with a goal of creating a 2nd population of ferrets to provide redundancy and ferrets for release into other habitats, but those plans were diverted into an emergency effort to salvage ferrets when the wild Meeteetse population began to collapse in 1985 due to diseases (Biggins et al. 2006). By winter 1985 only 10 ferrets were known to exist (6 in captivity and 4 in the wild). The 2nd captive-breeding program produced no offspring during 1986, but 2 females left in the wild reproduced. All remaining wild ferrets that could be found ($n = 12$) were removed to a captive-breeding facility by early 1987, and eventually 15 of the 18 ferrets in captivity bred. The 2nd captive-breeding program ultimately fared much better than the 1st, producing >6,000 ferrets by 2008 (Jachowski and Lockhart 2009) and supporting reintroductions at 19 sites in 10 states and provinces by 2009. The estimated population by summer of 2008 included a core breeding population of about 240 adults maintained in captivity (Marinari and Kreeger 2006) and an estimated 824 ferrets in free-ranging populations (Jachowski and Lockhart 2009).

Successes of conservation efforts to date are due in large part to the dedication and on-the-ground decisions of a large

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team of individuals. Progress also has been a product of science. With this Special Feature we are commemorating the 30th year of the rediscovery of black-footed ferrets and the mix of science and management activities that extracted ferrets from the edge of extinction. Although scientific underpinnings exist for many management activities involved in ferret conservation, we define operational conservation as management activities that are not linked directly to testing of hypotheses or conducting experiments. Operational conservation included tasks such as searching for extant populations of ferrets, captive-breeding operations, manipulations of habitat, and releasing ferrets to establish populations. The problems that emerged during operational conservation of black-footed ferrets have motivated much of the research on this species. Understanding the complex social dynamics between personnel involved in operational conservation and research provides a context for understanding the trajectory of research. We briefly review this history in the next section. As additional background, we follow this discussion of social context with a section containing brief summaries of former groups of papers published collectively in various volumes.

Research in Support of Operational Conservation

Lessons from observing the interface between black-footed ferret research and operational conservation suggest that such a partnership can be effective but might not be without controversy. Presumably, biologists involved in a project that focuses on conservation of a critically endangered species share a common goal of species recovery, but various backgrounds and philosophies can lead to differing views on the most appropriate means to achieve that end result. Disagreements and compromises are inevitable. Given the nearly universal limitations of funding, resources, and numbers of animals available, not all proposed research can be accommodated, and what is approved often must be narrowly focused. Experimental designs can be less than perfect due to operational constraints and management needs. For example, sample sizes, allocations of sexes, timing of releases, and other attributes of an experiment might need adjustment to accommodate requirements of the captive-breeding operation. Uncertainties regarding outcomes associated with different proposed methods can mean that plans associated with operational conservation need to accommodate experimental or comparative approaches that put animals at varying risk. Ultimately, it is especially important to allow applied research (i.e., addressing questions) to take priority over other objectives (e.g., reaching site-specific population targets) when problems of survival become apparent or questions have broadscale implications. For example, reintroduction sites with low population densities of ferrets or with population growth rates that were low or negative were used as laboratories for research that led to important discoveries critical to the recovery program. In the words of Miller et al. (1994:462), ''High mortality is not a failure unless biologists do not learn enough to increase survival in future reintroductions.''

One of the communication challenges at the interface of research and management is balancing the need by resource management agencies for rapid access to the latest information and the need for researchers to publish their results in peer-reviewed outlets, which can be a slow process. The United States Fish and Wildlife Service and other agencies must make timely decisions on the best available science (Brosnan and Groom 2006), especially when addressing endangered species concerns. The best available science might include information that is unpublished at the time decisions are needed. Thus, initial communication of important research results for ferrets often was accomplished orally within groups that had representatives from multiple institutions (e.g., federal, state, and local agencies that manage land and wildlife, in addition to private landowners and conservation groups); groups were given names such as the Black-footed Ferret Advisory Team, later supplanted by the Black-footed Ferret Interstate Coordinating Committee, and finally succeeded by the Black-footed Ferret Recovery Implementation Team and its Conservation Subcommittee (Lockhart et al. 2006). From the perspective of researchers, presentations at such groups often became a lively and vigorous form of peer review (Miller et al. 1996). Early examples were the series of meetings to decide the fate of the Meeteetse ferret population in 1985. Researchers presented data in 1985 showing a precipitous decline in the population, ultimately resulting in the decision in 1986 to remove all ferrets to a captive population, but those data were not published until 2 years later (Forrest et al. 1988). For situations seemingly in need of expeditious (but not necessarily immediate) attention, oral communications at meetings often were supplemented with memoranda, unpublished reports, theses, and dissertations.

Published Collections of Earlier Research

The requirements for rapid communication and response during management of endangered species do not obviate the need to publish results in outlets that are widely distributed. Doing so allows others to synthesize information regarding ferret biology within novel contexts, different scales of time and space, and various levels of taxonomy. Moreover, research on black-footed ferrets clearly addresses theoretical questions in ecology and also has broader applications in conservation biology. Although results often were published separately in a wide variety of outlets, collections of papers addressing the results of research efforts periodically were grouped into proceedings of symposia and workshops, books, and special features of journals (Fig. 1). The 1st workshop on black-footed ferrets and prairie dogs (Linder and Hillman 1973) summarized the status of ferrets and prairie dogs at the time the current Endangered Species Act became law (1973) and recognized the link between prairie dog conservation and the future of the ferret. These proceedings led to greater interest in searching for extant ferret populations and helped

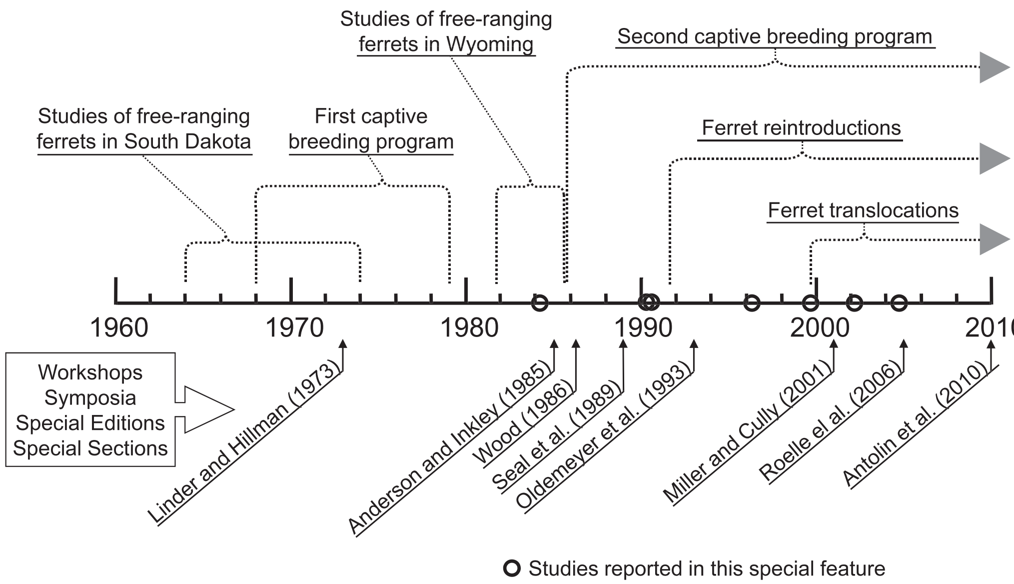

Fig. 1.—Time line relating symposia, workshops, special publications, and research reported in the 7 other papers presented in this Special Feature to noteworthy events and periods in the conservation of black-footed ferrets.

guide the course of action that followed the discovery of black-footed ferrets in 1981 near Meeteetse, Wyoming. The Meeteetse population presented a renewed opportunity to learn about ferret ecology. At a 2nd prairie dog and ferret workshop (Anderson and Inkley 1985) some initial findings from studies at Meeteetse were reported, agency responsibilities for ferrets were discussed, and survey techniques for studying the species were refined. Research reported in Wood (1986) evaluated museum specimens and systematics of ferrets, ferret behavior and ecology, and for the 1st time attempted to estimate genetic variation.

The focus of research in Seal et al. (1989) was on captive-breeding and reproductive techniques because by then all extant black-footed ferrets lived in captivity, although consideration also was given to management of small populations that might be discovered or reestablished. Oldemeyer et al. (1993) reported on research into the ecological roles of prairie dogs, the importance of sylvatic plague, and coarse-scale habitat assessment for reintroduction of black-footed ferrets, which already had begun. The limited amount of prairie dog habitat available for reintroduction of black-footed ferrets helped raise questions about viability of prairie dog populations. A 1998 petition by the National Wildlife Federation to list black-tailed prairie dogs (*Cynomys ludovicianus*) as a threatened species spurred research and reviews on the range-wide conservation status and factors influencing prairie dog persistence (reported in a Special Feature of the *Journal of Mammalogy*—Miller and Cully 2001).

As captive breeding of ferrets became refined and reintroductions achieved success in reestablishing wild populations, fine-scale habitat relationships were explored and tools to mitigate disease emerged (Roelle et al. 2006). Biologically, the greatest threat to prairie dog viability and black-footed ferret recovery is the deadly disease plague (caused by the bacterium *Yersinia pestis*). A recent symposium on plague (Antolin et al. 2010) presented research on the role of enzootic plague in survival of black-footed ferrets (Matchett et al. 2010) and prairie dogs (Biggins et al. 2010) and on the efficacy of vaccines against plague (Rocke et al. 2010).

This Special Feature

The 30th anniversary of the rediscovery of black-footed ferrets will occur on 26 September of this year, and the 7 papers of this Special Feature span research over much of that 30-year period (Fig. 1). The 1st study reported in the pages that follow (Fagerstone and Biggins 2011) was conducted during 1983–1984 on the ancestral population of ferrets at Meeteetse (Fig. 1). That study focused on gaining a better understanding of basic ecological relationships using radiotelemetry, a technique that had been recommended 10 years earlier (Erickson 1973) to study this reclusive semifossorial and nocturnal species. In 1985 plague began to have devastating effects on both the prairie dog and the ferret populations at Meeteetse, and a 2nd disease, canine distemper (caused by *Morbillivirus*) also appeared to be affecting the ferret population (Williams et al. 1988), ultimately resulting in the decision to rescue all remaining ferrets at Meeteetse.

After 4 years of breeding and rearing ferrets in captivity a sufficient number of ferrets was available to begin reintroductions in 1991 (Fig. 1). During the initial phases of captive breeding much of the research attention had been devoted to ferret reproduction (Seal et al. 1989), but soon other experiments and field trials were directed toward developing strategies for rearing ferrets in a manner that would allow them to be returned successfully to their native habitat. Many kinds of research were impossible to implement directly on black-footed ferrets during the early years of captive breeding, leading to use of closely related Siberian polecats (*Mustela eversmanii*) as surrogates for black-footed ferrets. The efficacy of using this purported ecological equivalent as an ecological surrogate, the results from trial releases of polecats, and comparative results from the initial release of ferrets are subjects of the 2nd and 3rd papers in this Special Feature (Biggins et al. 2011b, 2011c).

The last 4 papers of this Special Feature involve research conducted on reintroduced populations of ferrets (Fig. 1). Predation on ferrets was quickly identified as the major cause of mortality during the 1st several months postrelease. The 4th paper (Poessel et al. 2011) uses data collected on radiotagged ferrets released in the Conata Basin of South Dakota during 1996–1997 and identifies landscape features that correlate with mortality of ferrets due to predation. By 1998 enough had been learned about rearing ferrets with appropriate stimuli in captivity and conditioning them in outdoor pens to increase their postrelease survival by an order of magnitude (Biggins et al. 1998), but the question remained whether wild-born ferrets that were translocated would have even better survival skills. A study of ferret translocation in 1999 in South Dakota provided data for the 5th paper of this Special Feature (Biggins et al. 2011a). Considering the small number of founders from which all extant ferrets descended, discussions and evaluations of genetics have been ongoing during captive-breeding and reintroduction efforts (Seal et al. 1989). During 2001–2003 the Conata Basin population of ferrets had become self-sustaining, providing an opportunity to examine retention of allelic diversity in a population of free-ranging ferrets (6th paper—Cain et al. 2011). In the early years of reintroductions quality of ferret habitat was judged and ranked at individual sites prior to release of ferrets using a broadscale model based on ferret energetics (Biggins et al. 1993). In recent years increased attention has been given to habitat relationships assessed at finer scales, namely dispersion of prairie dog burrows (and prairie dogs as an assumed correlate) within prairie dog colonies. The 7th paper of this Special Feature (Eads et al. 2011) examines habitat relationships within that context. We hope the articles published in this Special Feature will serve not only to inform a broader community of biologists of the progress with black-footed ferret conservation but also will contribute to an understanding of the evolution of these specialist carnivores and suggest additional tools for conservation and management of endangered species.

Future Directions

The future of ferret conservation is jeopardized by limited availability of prairie dog habitat (Jachowski and Lockhart 2009) that stems from 2 chief causes. Seton (1929:573) astutely identified one of the causes as human persecution of prairie dogs, but his lucid prose was more prescient than he could have imagined. The ''war'' on prairie dogs actually included flanking assaults from 2 sides. In addition to the agricultural development advancing westward from the eastern United States, the ''big demon of commerce'' also involved trade between eastern Asia and the west coast of North America. Ships with rats and their fleas brought plague from Asia to the west coast of North America. The disease rather quickly (1900–1950) invaded eastward, causing extensive losses of all 3 species of prairie dogs comprising ferret habitat (*Cynomys leucurus*, *C. gunnisoni*, and *C. ludovicianus*). Perceptions of the threat posed by plague have changed since the epizootic at Meeteetse in 1985. At that time ferrets were considered to be resistant to plague, and the disease (Williams et al. 1991) was not thought to reside in prairie dog colonies as a persistent threat (Barnes 1993). Ferrets are now known to be directly susceptible to the disease (Godbey et al. 2006), and nonepizootic levels of plague transmission appear to cause substantial mortality in prairie dogs (Biggins et al. 2010) and ferrets (Matchett et al. 2010).

Without changes in human attitudes about prairie dogs as vermin (Lockhart et al. 2006) and effective tools to manage plague, ferret recovery will be problematic. Management actions such as increasing prairie dog populations on public lands and enabling payment programs for prairie dog occupancy of private lands might provide more habitat for ferret reintroductions. Plague is the most pressing problem needing biological research. In the complex process of plague maintenance and transmission the fleas as vectors are an important component. To date, methods to reduce flea abundance have provided the only stand-alone tools that are operationally effective for managing plague in the ferret–prairie dog community (i.e., use of various insecticides for flea control). Flea control on large scales has been costly and time-consuming, and it is likely that the insecticides used affect some nontarget organisms. Studies of flea ecology, other products for flea control, and timing of management actions might improve the efficiency of vector-control methods. A vaccine for ferrets has been effective, but the present version must be administered by injection (Rocke et al. 2006), and this method does not protect the prey on which ferrets depend. An orally deliverable vaccine for prairie dogs might provide the most pragmatic solution and is being tested (Rocke et al. 2010).

Although the interplay between operational conservation and research has at times been difficult, the qualified successes of ferret recovery should be considered a tribute to the efforts to maintain an active and adaptable research program in conjunction with on-the-ground management of ferrets. Anthropogenic changes that seem irreversible (e.g., inadvertent introduction of plague to western North America) have created a challenging environment for black-footed ferret conservation. Nevertheless, thriving populations are being maintained with intensive management, suggesting that reestablishment of this species in the wild is possible if social values generate the resolve to do so. It is our hope that in another 30 years black-footed ferrets will no longer be endangered but will once again be a sustainable treasure of the North American fauna.

Acknowledgments

We emphasize that the acknowledgments sections of the accompanying papers are (due to space limitations) woefully inadequate. For example, we would like to mention by name all of the crew members who collected field data, but the list is much too long. The list, however, also should reach far beyond those who were involved directly in day-to-day field activities. There would have been little research on ferrets without the many governmental agencies, private institutions, and individuals involved in the operational conservation program that it serves. We are grateful that the ferret recovery program has grown to involve 19 reintroduction sites in 10 states and provinces (including 1 in Mexico and 1 in Canada) and has a federal facility and 5 zoos maintaining and producing ferrets for release, but the size and complexity of the program now make proper recognition of contributions difficult (Jachowksi and Lockhart 2009). We are taking a small step to show our appreciation to the many collaborators by creating a comprehensive listing of them that will appear elsewhere (http://www.prairiewildlife.org/). Finally, we thank J. F. Cully, T. J. O'Shea, and J. L. Godbey for helpful reviews of this introductory synopsis.

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