

Species Status Assessment Report for the Black-footed Ferret (*Mustela nigripes*)



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Version 1.0
December 12, 2019

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Acknowledgements

We would like to thank the following individuals for providing substantial information and insights for this SSA report: Tyler Abbott (U.S. Fish and Wildlife Service), Nichole Bjornlie (Wyoming Game and Fish Department), Kristy Bly (World Wildlife Fund), Robyn Bortner (U.S. Fish and Wildlife Service), David Eads (U.S. Geological Survey), Steve Forrest (Defenders of Wildlife), Shaun Grassel (Lower Brule Sioux Tribe), Lauri Hanauska-Brown (Montana Fish, Wildlife, and Parks), Holly Hicks (Arizona Game & Fish Department), Tina Jackson (Colorado Parks and Wildlife), Chris Keefe (Bureau of Land Management), Silka Kempema (South Dakota Game, Fish, and Parks), Travis Livieri (Prairie Wildlife Research), David Lucas (U.S. Fish and Wildlife Service), Randy Matchett (U.S. Fish and Wildlife Service), Brian Maxfield (Utah Division of Wildlife Resources), Matt Peek (Kansas Department of Wildlife, Parks, and Tourism), Rachel Santymire (Lincoln Park Zoo), Greg Schroeder (National Park Service), Dan Tripp (Colorado Parks and Wildlife), and Rachel Williams (U.S. Fish and Wildlife Service). We thank Sarah Backsen, Julie Reeves, and Justin Shoemaker of the U.S. Fish and Wildlife Service with their assistance in conducting an expert workshop to solicit stakeholder perspectives. We would also like to thank everyone who reviewed initial drafts of the report and provided helpful comments, as well as the two peer reviewers.

Executive Summary

This report summarizes the results of a Species Status Assessment (SSA) that the U.S. Fish and Wildlife Service (Service) has completed for the black-footed ferret (*Mustela nigripes*). The black-footed ferret is the only ferret species native to North America, and its historic distribution overlapped with the distributions of three prairie dog species: the black-tailed prairie dog (*Cynomys ludovicianus*), Gunnison's prairie dog (*C. gunnisonii*), and the white-tailed prairie dog (*C. leucurus*). This SSA report summarizes the current and projected future conditions of the black-footed ferret to assess the overall viability of the species now and into the future. For the purposes of this SSA, we define viability as the ability of the black-footed ferret to sustain populations in the wild into the future. Additionally, since the continued persistence of the black-footed ferret depends heavily on the ability to release captive-reared individuals into the wild in order to establish new reintroduction sites and maintain existing reintroduction sites throughout its potential range, we also evaluate the viability of the captive population to provide individuals for these purposes into the future.

To assess the current status, future status, and overall viability of the black-footed ferret, we used the conservation biology principles of resiliency, redundancy, and representation (collectively, the 3Rs). Specifically, we identified the ecological requirements of the black-footed ferret at the individual, population, and species levels, and described the stressors influencing the viability of the species. The black-footed ferret needs multiple, resilient populations distributed across its range in a variety of ecological settings to persist into the future and to avoid extinction. For our analyses, we divided the wild (i.e., reintroduced) black-footed ferret population into 29 analysis units that correspond to locations where the species has been purposely reintroduced. The captive population was divided into six analysis units that correspond to the captive breeding facilities currently participating in the black-footed ferret recovery program. For the wild population, we evaluated the resiliency of each analysis unit using the metrics of five-year mean number of breeding adults, the five-year average ferret family rating (an index of habitat suitability encompassing area and prairie dog density), annual plague management level, annual ferret vaccination level, ferret population persistence, and level of prairie dog population protection. These metrics either directly or indirectly addressed four primary stressors of concern: sylvatic plague, drought, prairie dog poisoning and shooting, and declining genetic fitness, with declining genetic fitness defined as increased inbreeding and declining genetic diversity. For the captive population, we evaluated the resiliency of each analysis unit using the metrics of percent whelping success, mean number of kits born per litter, and percentage of kits weaned to assess breeding success, animal condition, animal husbandry effectiveness, and declining genetic fitness.

The historical condition of the black-footed ferret is difficult to quantify due to a lack of reliable historical data and the secretive nature of the species. At present, the species has been reintroduced to a small portion of its historic range, with 29 discrete reintroduction sites being established since recovery efforts began in 1991. As of 2019, 14 of 29 reintroduction sites are active, with an estimated wild population of approximately 340 individuals. The captive

population is divided between six captive breeding facilities, and numbers 301 individuals. Using the metrics referenced above, we determined that two reintroduction sites were in high condition (high resiliency), eight were in moderate condition (moderate resiliency), four were in low condition (low resiliency), and 15 were extirpated. For the captive population, we determined that one facility was in high condition, four were in moderate condition, and one was in low condition. We should note that considerable management inputs (primarily plague management and population augmentation with captive-reared animals for the wild population and managed breeding for the captive population) are required to maintain the of resiliency of each population, and most if not all of the reintroduction sites that are extirpated became so due to the effects of sylvatic plague. Currently, the wild black-footed ferret population is found within all of the ecological settings it occupied historically (black-tailed, Gunnison's, and white-tailed prairie dog habitat), although its representation within Gunnison's prairie dog habitat is limited to only one site.

We predicted the future viability of the black-footed ferret by forecasting the conditions of our metrics for each analysis unit under five potential future scenarios. Our future scenarios varied based on four main stressors, sylvatic plague, drought, prairie dog poisoning and shooting, and declining genetic fitness, as well as levels of conservation efforts. We forecasted each scenario to two time periods, approximately 10 and 20 years into the future. The projected future condition of each population varied by scenario, but we predicted that both populations would decline in viability under every scenario except for scenarios where conservation efforts increased relative to current levels. Overall, we predict that the effects of sylvatic plague and the lack of suitable habitat will continue to limit the viability of the black-footed ferret, and management inputs will continue to be required in order to maintain current levels of viability. Moreover, management inputs will need to be expanded and improved in effectiveness in order to increase viability for the species. We acknowledge that our assessment of future conditions is a projection involving uncertainty. However, our future scenarios are designed to capture the full range of future conditions that could plausibly occur, and we used the best available science for our analyses and acknowledged any key assumptions and uncertainties throughout this SSA report.

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Chapter 1. Introduction

This report summarizes the results of a Species Status Assessment (SSA) conducted by the U.S. Fish and Wildlife Service (Service) for the black-footed ferret (*Mustela nigripes*). The black-footed ferret is a medium-sized carnivore historically found in the Great Plains and Intermountain West states of Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming, as well as the Canadian province of Saskatchewan and the Mexican state of Chihuahua. The species was thought to be extinct in 1979, until it was rediscovered in 1981 in Meeteetse, Wyoming. A captive breeding program was established using individuals from this population, and all extant ferrets are descendants of this captive population. At present, the black-footed ferret is found only in a reintroduced population at multiple sites in the states of Arizona, Colorado, Kansas, Montana, New Mexico, South Dakota, Utah, and Wyoming, and a captive population housed at facilities located in Arizona, Colorado, Kentucky, Virginia, and Ontario, Canada.

We used the SSA framework (Smith et al. 2018) to develop a comprehensive analysis of the black-footed ferret's biology, the stressors affecting its status, its current biological status, and to project the future status of the species under various future scenarios. This SSA report summarizes the results of our analysis, and provides a means of assessing the viability of the black-footed ferret. As new information becomes available, we intend to revise this SSA as needed so it can serve as a foundational document for all functions of the Service's Ecological Service program, such as consultation and recovery planning.

The purpose of this SSA report is to provide a scientific foundation for the Service's 5-year status review of the listing status of the black-footed ferret under the Endangered Species Act of 1973, as amended (Act) (16 U.S.C. 1531 *et seq.*). Importantly, this SSA report is not a decision document, but instead provides the scientific information needed to support future decisions made by the Service under the Act. The 5-year review finding will be made by the Service after reviewing this SSA report and all relevant laws, regulations, policies, and conservation efforts, and the Service will announce its finding independently.

1.1 Listing History and Previous Federal Actions

The black-footed ferret was listed as an endangered species in 1967 (32 FR 4001, March 11, 1967) and again in 1970 (35 FR 8491, June 2, 1970) under early endangered species legislation and was "grandfathered" as an endangered species under the Act in 1973. Black-footed ferrets are exempt from the requirement to designate critical habitat because they were listed prior to the 1978 amendments to the Act requiring critical habitat. The first recovery plan for the black-footed ferret was published in 1978 (Linder et al. 1978), and was revised in 1988 (USFWS 1988)

and again in 2013 (USFWS 2013a). A 5-year review was issued concurrently with the 2013 recovery plan revision, and retained the endangered status for the species.

1.2 The Species Status Assessment (SSA) Framework

This SSA report summarizes the results of our in-depth review of the black-footed ferret's biology and stressors, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. For the purposes of this assessment, we define viability as the ability of the species to sustain populations in the wild into the future in a biologically meaningful timeframe, which is 10-20 years for our analysis. We chose this relatively short timeframe due to the high population turnover rates of the black-footed ferret and its primary prey, prairie dogs, the sudden and chronic effects of sylvatic plague, and the small population sizes at many reintroduction sites that are vulnerable to short-term stochastic effects. Since the viability of this species in the wild is also dependent on the presence of a captive population, we also assess the ability of the species to sustain a captive population over the same timeframe.

Using the SSA Framework (Figure 1), we evaluated what the black-footed ferret needs to be viable into the future by characterizing the current and future statuses of the species using the concepts of resiliency, redundancy, and representation (the "3Rs") from conservation biology (Shaffer and Stein 2000, Smith et al. 2018).

Resiliency is the ability of populations to tolerate natural, annual variation in their environment and to recover from periodic or random disturbances, known as stochastic events. Resiliency can be measured using metrics like vital rates, such as annual births and deaths, and population size. In general, populations with high abundance and stable or increasing population trends are more resilient than those with limited resources or declining populations. Populations with high resiliency can better withstand stochastic changes in demography or their environment due to natural or anthropogenic disturbances.

Redundancy is the ability of a species to withstand catastrophic events, such as a rare, destructive natural event that affects multiple populations. Redundancy is measured by the duplication and distribution of populations across the range of the species. The more redundant a species, or the greater number of populations a species has distributed over a larger landscape, the better able it is to recover from catastrophic events. Redundancy helps "spread the risk" and ensures that not all populations are extirpated at once due to a catastrophic event.

Representation is the ability of a species to adapt to changing physical (climate, habitat) and biological (diseases, predators) conditions. Representation can be measured by looking at the genetic, morphological, behavioral, and ecological diversity within and between populations

across a species' range. The more representation, or diversity, a species has, the more likely it is to be able to adapt and persist with natural or human-caused changes to its environment.

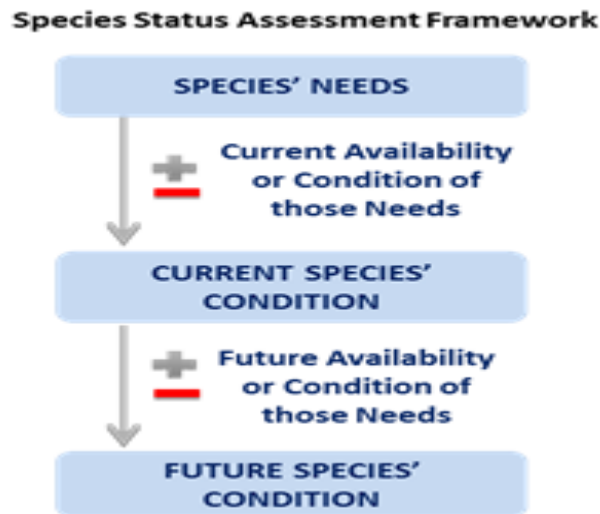


Figure 1. The three phases of the SSA Framework used to guide this analysis. To assess the viability of the black-footed ferret, we evaluated the species' needs, the current availability and condition of those needs, and the current condition of the species. We then predicted the future condition of the species based on the projected future availability and condition of the identified needs of the species.

For the purpose of this SSA, viability is defined as the ability of the species to sustain populations in the wild into the future in a biologically meaningful timeframe. Viability is not a single state; rather, there are degrees of viability. In other words, a Species Status Assessment does not determine if a species is or is not viable. Instead, we characterize the resiliency, redundancy, and representation a species currently exhibits and predict how these characteristics may change in the future. Generally speaking, species with higher resiliency, redundancy, and representation are more protected from environmental changes, can better tolerate stressors and adapt to changing conditions, and are thus more viable than species with low levels of the 3Rs.

To assess the viability of the black-footed ferret, we analyzed its ecology, historic and current conditions, and projected the viability of the species under a number of future scenarios, all in the context of the 3Rs and using the best scientific data available. Chapter 2 of this SSA report summarizes the biology, ecology, and needs of the black-footed ferret at the individual, population, and species levels. Chapter 3 examines the stressors and conservation measures that affect the resiliency of wild and captive black-footed ferret populations and analyzes the historical and current conditions of the species. Chapter 4 projects the future condition of the species under five scenarios. In Chapter 5, we summarize all of the information presented in this SSA and analyze the overall viability of the black-footed ferret.

1.3 Summary of Recent Information

Since the 2013 publication of the revised Black-footed Ferret Recovery Plan (USFWS 2013a), we have evaluated new peer-reviewed literature and solicited new information from partner agencies and organizations throughout the historic range of the black-footed ferret, including, but not limited to, state wildlife management agencies, tribes, non-governmental conservation organizations, the U.S. Forest Service, Bureau of Land Management, and National Park Service. These organizations are members of the Black-footed Ferret Recovery Implementation Team (BFFRIT), which serves as an expert source of up-to-date demographic and distribution data for the species. Specifically, we requested information on the following topics:

- The species' distribution, population levels, and population trends in the wild (i.e. at reintroduction sites);
- The species' population levels and trends in captive settings;
- The magnitude and severity of sylvatic plague and other diseases at various reintroduction sites;
- Other potential threats to the species, including, but not limited to, inbreeding depression, energy development, agricultural conversion, recreational shooting of prairie dogs (*Cynomys spp.*), and poisoning;
- Updates to laws, regulations, policies, or management plans that may apply to the species; and
- Any ongoing conservation actions for the species and its habitats.

Our literature review and data solicitation found that there was new information for wild populations on sylvatic plague dynamics and management, development of additional black-footed ferret reintroduction sites through the Black-footed Ferret Programmatic Safe Harbor Agreement (USFWS 2013b), and conservation efforts undertaken by individual states and tribes through the use of state-or-tribe-specific black-footed ferret management plans. New information obtained for the captive population included information on the production of kits from captive breeding partners under the auspices of the Black-footed Ferret Species Survival Plan® (SSP®). New information was also obtained for the emerging role of genomics in the potential management both the captive and reintroduced populations. In addition, several pertinent peer-reviewed papers have been published since 2013 investigating the application and efficacy of the insecticide deltamethrin, the systemic pulicide fipronil, and oral Sylvatic Plague Vaccine (SPV) to manage the non-native bacterium *Yersinia pestis* that causes deadly epizootics of sylvatic plague, as well as potential application of genomics to aid both captive and wild populations.

We incorporated these data, which include spatial data, peer-reviewed literature, reports, and personal communications with experts, into various parts of the SSA, including the analysis of

the current population levels and distribution of the black-footed ferret and the severity of stressors and related conservation actions. If we lacked specific data for some aspect of our analysis, we used information obtained through communication with experts at various meetings of BFFRIT subcommittees, including the Conservation Subcommittee, Related Species Subcommittee, Disease Subcommittee, and Managed Care Subcommittee.

Chapter 2. Species Ecology and Needs

In this chapter, we provide basic biological information about the black-footed ferret, including its taxonomic history and relationships, morphological description, physical environment, and reproductive and other life history traits. We then describe the needs of the black-footed ferret at the individual, population, and species levels. This chapter is not an exhaustive review of the species' natural history, but rather provides the biological basis for the SSA analyses in this report.

2.1 Life History

2.1.1 Taxonomy and Description

The black-footed ferret is in the Order Carnivora, Family Mustelidae, Genus *Mustela*, and Subgenus *Putorius*. No subspecies are recognized (Hillman and Clark 1980, Anderson et al. 1986). The species is one of four members of the genus *Mustela* in North America that also includes the ermine (*M. erminea*), long-tailed weasel (*M. frenata*), and least weasel (*M. nivalis*) (Wilson and Ruff 1999, Kurose et al. 2008). The black-footed ferret is the only ferret species native to the Americas. Other ferret species in the subgenus are the Siberian polecat (*M. eversmannii*) and the European ferret (*M. putorius*) (Hillman and Clark 1980, Anderson et al. 1986), which has been domesticated and sold as a pet. The black-footed ferret is most closely related to the Siberian polecat (Hillman and Clark 1980, Anderson et al. 1986). The earliest fossil record of the black-footed ferret is from approximately 100,000 years ago and the species was first formally described in 1851 by J.J. Audubon and J. Bachman (Anderson et al. 1986, Clark 1986).

The black-footed ferret is a medium-sized mustelid, typically weighing 645–1125 grams (1.4-2.5 pounds) and measuring 479–600 millimeters (19-24 inches) in total length. Upper body parts are yellowish buff, occasionally whitish; feet and tail tip are black; and a distinctive black “mask” occurs across the eyes (Hillman and Clark 1980, Anderson et al. 1986)

2.1.2 Habitat and Distribution

The black-footed ferret was historically found throughout the Great Plains, mountain basins, and semi-arid grasslands of North America, and its distribution coincided with the ranges of the black-tailed prairie dog (*Cynomys ludovicianus*), Gunnison's prairie dog (*C. gunnisonii*), and

white-tailed prairie dog (*C. leucurus*) (Hillman and Clark 1980, Figure 2). There has been no documented occurrence of the ferret within the range of either the Utah prairie dog (*C. parvidens*) or the Mexican prairie dog (*C. mexicanus*), whose ranges are small and disjunct from other prairie dog species (Lockhart et al. 2006). The species was common historically; however, its secretive habits (nocturnal and often underground) probably made it difficult to observe (Forrest et al. 1985, Anderson et al. 1986, Clark 1989). Anderson et al. (1986) stated that prairie dog habitat 100 years ago may have supported 500,000-1,000,000 black-footed ferrets given a conservative estimate of 41,000,000 hectares (ha) of prairie dog colonies and one ferret per 40-60 ha (Forrest et al. 1985).

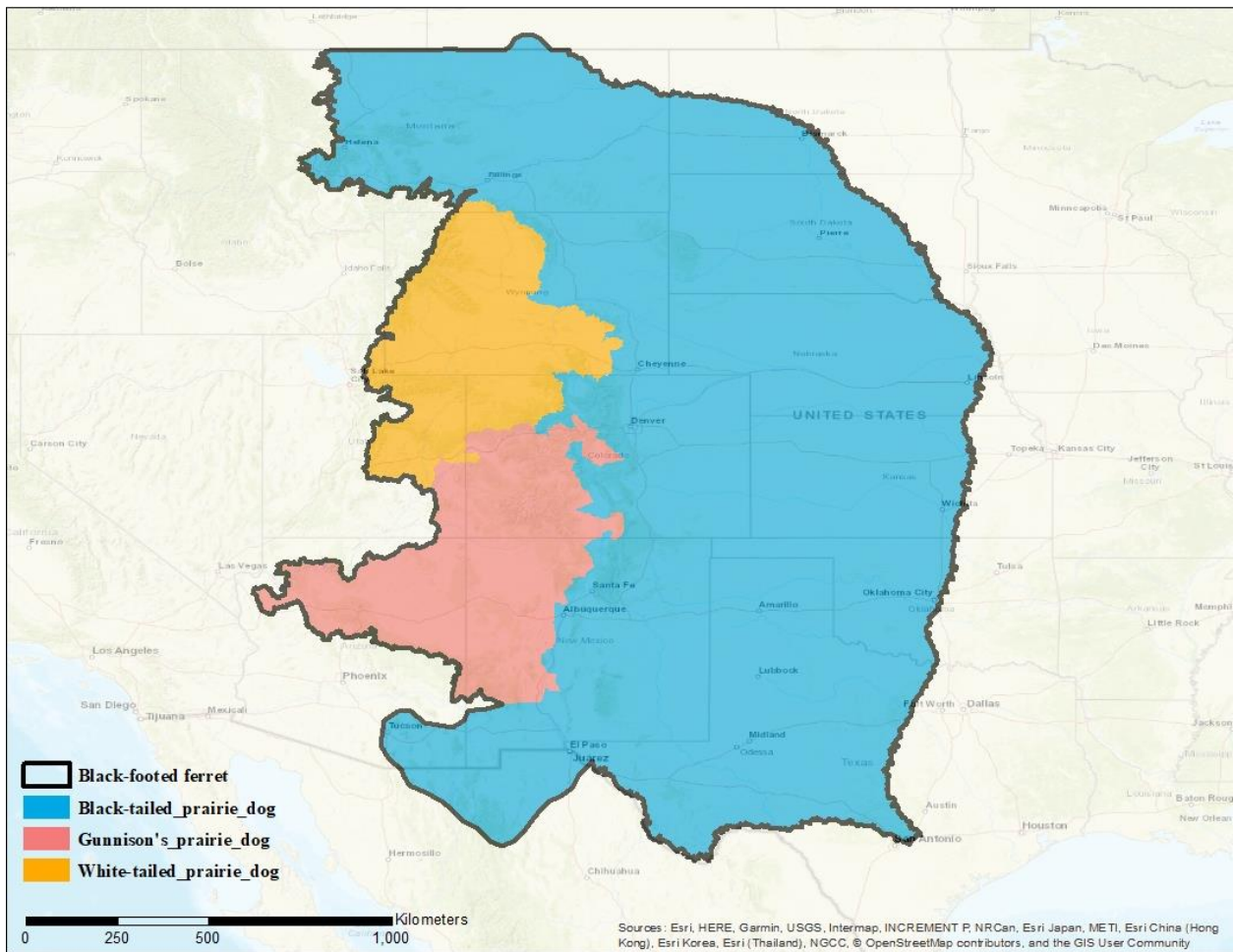


Figure 2. Historical distribution of the black-footed ferret and the distribution of black-tailed, Gunnison's, and white-tailed prairie dogs.

2.1.3 Feeding Habits

The black-footed ferret depends almost exclusively on prairie dogs for food and on prairie dog burrows for shelter (Hillman 1968, Biggins et al. 2006c). Recent data suggest that the diet of

black-footed ferrets may be slightly more plastic than previously thought, with adult females consuming up to 33% of non-prairie dog prey (mice, voles, and other small mammals) on an annual basis (Brickner et al. 2014). The researchers suggested that adult females killed prairie dogs and provisioned them for dependent young, while meeting their own energetic demands by consuming alternate prey. In contrast, the diet of adult males and juveniles of both sexes consisted of approximately 75% prairie dogs on an annual basis. Regardless of differing food habits between sexes at different times of the year, black-footed ferrets remain highly specialized predators that are obligate associates of prairie dogs (Hillman and Clark 1980).

2.1.4 Life Cycle and Reproduction

The black-footed ferret is solitary, except for breeding and the period when mother and young are together (Forrest et al. 1985). The ferret breeds at approximately one year of age from mid-March through early April in the wild (Wilson and Ruff 1999), and adult sex ratio is approximately one male to two females (Forrest et al. 1988). Gestation is about 42–45 days and parturition (whelping) takes place below ground with an average litter size of 3.5 individuals (Wilson and Ruff 1999). The kits are born altricial (helpless and requiring parental care) and develop quickly with the black mask becoming apparent after 16-18 days, eyes opening at 37 days, and nearly reaching adult weight after 125 days (Vargas and Anderson 1996). The kits are mobile enough to appear above ground in July and are generally ready to disperse from their mother by September or October.

Dispersal, defined as a permanent movement away from the natal area, occurs in the fall months among the young of the year, although a few instances of adults making permanent moves in the fall have been recorded (Forrest et al. 1988). Dispersal distances and movements up to 49 kilometers (km) have been recorded (Biggins et al. 1999) in newly released captive born animals and dispersal of more than 20 km in wild-born ferrets. Males tend to move greater distances than females.

2.1.5 Activity Patterns

The black-footed ferret is generally a nocturnal predator, appearing above ground at irregular intervals and for irregular durations (Clark et al. 1986). In the post-breeding period ferrets tend to be most active on nights when the moon is above the horizon (Eads et al. 2012a), but ferrets have been observed during the day (Clark et al. 1986, Eads et al. 2010, Livieri et al. 2013). The ferret is an extreme specialist that depends on prairie dogs for food and shelter (Biggins et al. 2006c). Ferrets occupy prairie dog burrows and do not dig their own burrows. They will modify burrows, dig out hibernating prairie dogs or remove a soil plug in a behavior called trenching (Eads et al. 2012b).

2.1.6 Home Range and Territoriality

Black-footed ferret densities at the last known wild population near Meeteetse, Wyoming, were linearly correlated with white-tailed prairie dog colony size, with an average density of one adult ferret per 40–60 ha of occupied prairie dog habitat (Forrest et al. 1985). Information on ferret life expectancy is sparse. In the wild, females have reached 5 years of age and males have reached 4 years. However, mustelids typically have short mean life expectancies and 50 percent or greater juvenile mortality (Clark 1989). The mean life expectancy of free-ranging ferrets in the Meeteetse population was 0.9 years (Biggins et al. 2006a). Annual survival rates for the Conata Basin, South Dakota population were 70% for juvenile females, 50% for adult females and 38% for males regardless of age (McDonald et al. 2005). The juvenile age class comprises approximately 60-67% of the population and has the largest effect on population growth (Forrest et al. 1988, McDonald et al. 2005).

Black-footed ferrets generally conform to a typical mustelid spacing pattern with some overlap between female home ranges and nearly complete overlap between male and female home ranges (Powell 1979, Livieri and Anderson 2012). Ferrets select for areas within prairie dog colonies that contain high burrow densities and thus high densities of prairie dogs (Biggins et al. 2006c, Eads et al. 2011, Jachowski et al. 2011b, Livieri and Anderson 2012). Home ranges of female ferrets occupying high density black-tailed prairie dog habitat average approximately 60 ha whereas males average approximately 130 ha (Jachowski et al. 2010, Livieri and Anderson 2012). Territories, a defended area within an animal's home range, average 13 ha for females and 36 ha for males and contain higher burrow densities than the rest of the home range (Livieri and Anderson 2012).

2.2 Black-footed Ferret Needs

A species can only be viable if its basic ecological needs are satisfied. In this section, we translate our knowledge of the black-footed ferret's biology and ecology into its needs at the individual, population, and species levels. For individual black-footed ferrets, we describe the resources and habitat conditions that adults, juveniles, and kits need to complete each stage of their life cycle. We then describe the habitat and demographic conditions that black-footed ferret populations need to be resilient. Finally, we describe what the species needs in order to be viable in terms of resiliency, redundancy, and representation (Figure 3).

2.2.1 Individual Needs

As obligate predators of prairie dogs, black-footed ferrets typically need large, contiguous (≤ 7 km apart; Biggins et al. 1993) prairie dog colonies to meet their individual needs. Prairie dogs are the predominant prey taken by black-footed ferrets (Sheets et al. 1972, Campbell et al. 1987),

and most explicit observations of black-footed ferrets mention prairie dog colonies (Biggins et al. 2006c). Black-footed ferrets do not excavate their own extensive burrow systems, but instead rely on the burrow systems constructed by prairie dogs for shelter (Forrest et al. 1988). Black-footed ferrets utilize prairie dog burrow systems for whelping, and young emerge aboveground at approximately 60 days of age. As juvenile black-footed ferrets disperse from their natal burrows at approximately 100 days of age, they adopt the same food habits and shelter requirements of adult black-footed ferrets.

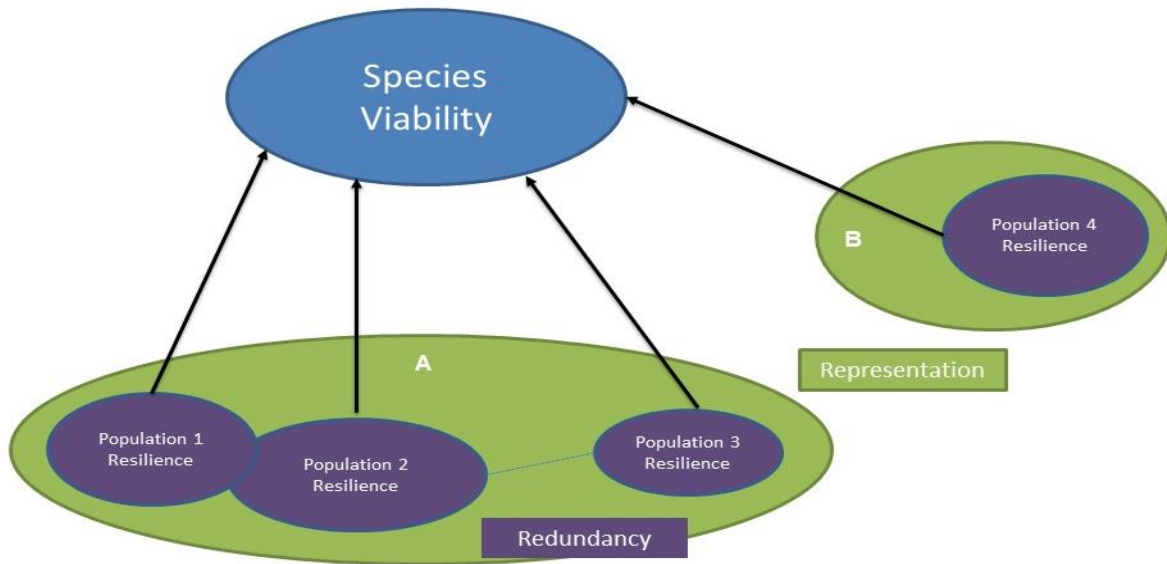


Figure 3. Illustration of how resiliency, redundancy, and representation influence what a species needs for viability.

2.2.2 Population Needs

Black-footed ferrets currently exist in the wild only at isolated reintroduction sites, which may contain both captive-bred and wild-born ferrets, may contain ferrets translocated from other sites, and are not necessarily equivalent to biological populations as they may have existed historically. Ferrets are also maintained in a captive setting at six widely separated captive rearing facilities. For the purpose of this SSA, we consider all wild (reintroduced) black-footed ferrets to constitute one “population”, and all captive black-footed ferrets to constitute another “population”. We further subdivide these populations into analysis units (subpopulations or reintroduction sites are each considered an “analysis unit” for the wild population, and each captive breeding facility is considered an “analysis unit” for the captive population). We use these terms interchangeably throughout the document. These rather simplistic definitions are an artifact of the black-footed ferret being extirpated from the wild in 1987 to initiate a captive breeding program (Lockhart et al. 2006), and subsequent occurrence in the wild for the species is the result of purposeful reintroduction efforts at discrete reintroduction sites.

The 1988 Black-footed Ferret Recovery Plan (USFWS 1988) and subsequent revisions (USFWS 2013a) established a minimum criterion of 30 breeding adults for a black-footed ferret subpopulation to count toward recovery goals. This criterion was derived from the study of the last free-ranging ferret population discovered at Meeteetse, Wyoming in 1981, which averaged approximately 25 breeding adults throughout intensive demographic studies from 1982 to 1985. Since this population apparently persisted for a considerable amount of time prior to its discovery in 1981, it was assumed that 25 breeding adults provided a stable basis for population persistence (USFWS 1988). In developing a conservative estimate of black-footed ferret habitat requirements based on known female ferret spacing (Biggins et al. 1993, 2006b), USFWS (2013a) estimated that 90 ha of black-tailed prairie dog habitat was required to support one black-footed ferret female, and 150 ha of Gunnison's or white-tailed prairie dog habitat was required to support one black-footed ferret female. Assuming a 1:2 sex ratio and overlapping male and female home ranges (Biggins et al. 1993), a population of 30 breeding adult black-footed ferrets would require 1,800 ha of black-tailed prairie dog habitat, and 3,000 ha of Gunnison's or white-tailed prairie dog habitat. Biggins et al. (1993, 2006c) describes methodologies based on bioenergetics requirements used to derive these estimates.

When individual black-footed ferrets have access to ample food and habitat (defined here as abundant prairie dog prey), the species is capable of a high reproductive rate and can readily colonize unoccupied habitat (Grenier et al. 2007). At the population level, juvenile production and survival drives black-footed ferret population growth (Forrest et al. 1988), and high juvenile production is correlated with the availability of prairie dog pups as a food resource (Biggins et al. in preparation).

Connectivity between discrete reintroduction sites encourages dispersal of individuals and maintains gene flow, which prevents extirpation due to low genetic diversity and accelerated genetic drift (Lacy 1987). Larger, less isolated subpopulations are also more resilient and less likely to be extirpated by a stochastic event (Frankel and Soulé 1981, Smith et al. 2018). Because black-footed ferrets were not widely studied prior to the onset of substantial population declines (Hillman 1968, Forrest et al. 1988) and the extirpation of the species from the wild (Lockhart et al. 2006), the importance of connectivity to the maintenance of genetic fitness is poorly understood. Given the species' obligate association with prairie dogs, it is likely that individual black-footed ferret populations associated with larger, less fragmented prairie dog colonies exhibit greater resiliency and are less likely to be extirpated by stochastic events than those associated with smaller, fragmented colonies (Miller et al. 1994, Jachowski et al. 2011a).

2.2.3 Species Needs

As a species, the black-footed ferret needs multiple resilient populations (i.e., redundancy) that display a breadth of ecological and genetic diversity (i.e., representation) across its historic range

(12 present-day states and across three species of prairie dogs; USFWS 2013a). One source suggests that the black-footed ferret needs a minimum of 20 resilient populations to meet these criteria (Lacy and Clark 1989). Since recovery of the black-footed ferret is heavily dependent on the availability of captive-reared animals for release at reintroduction sites, the sustainability of the captive breeding program and the ability to translocate wild-born black-footed ferret kits to new reintroduction sites is of utmost importance (Garelle et al. 2014). Establishment of additional reintroduction sites is key to increase both ecological and genetic diversity (representation), while meeting established recovery goals (USFWS 2013a).

The duplication and distribution of resilient black-footed ferret populations across the landscape enhances redundancy, and the presence of populations in a diversity of ecological settings (in the case of the black-footed ferrets, the presence of populations in black-tailed, Gunnison's, and white-tailed prairie dog habitats) increases representation. Representation is also evidenced by genetic variation, and given the black-footed ferret's very limited number of founder animals (N=7) and extirpation in the wild in 1987 (Lockhart et al. 2006), genetic representation will likely remain a challenge for the species well into the future (Wisely 2006).

2.2.4 Summary of Species Needs in terms of the 3Rs

As described above, at the individual level, the primary requirement for all black-footed ferret life stages is prairie dogs. At the population level, black-footed ferret populations need at least 30 breeding adults, which requires at least 1,800 ha of black-tailed prairie dog habitat or 3,000 ha of Gunnison's or white-tailed prairie dog habitat (USFWS 2013a). Populations also need some level of connectivity, a sufficient rate of juvenile survival, and larger, less fragmented prairie dog colonies to maintain resiliency to stochastic events. At the species level, the black-footed ferret needs multiple (≥ 20), resilient populations (i.e., redundancy) that display a breadth of ecological and genetic diversity (i.e., representation) across its historic range, including black-tailed, Gunnison's, and white-tailed prairie dog habitats. A captive breeding population is also needed to provide individuals for release at reintroduction sites, thereby increasing resiliency of those populations, and to provide additional redundancy in the case of catastrophic events that could affect reintroduction sites, as well as to maintain the genetic diversity that is needed for the species to adapt to changing conditions (representation).

Chapter 3. Influences, Historical Condition, and Current Condition

In this chapter, we summarize the historical and current conditions of the black-footed ferret at the population and species levels. To do this, we introduce the stressors that have and continue to influence the species' condition as well as current conservation efforts which address some of these stressors. We then detail how black-footed ferret abundance and distribution has changed over time. Finally, we put the species' historical and current conditions in the context of the 3Rs

to assess its current viability. The viability of the black-footed ferret is inextricably linked with the viability of black-tailed, Gunnison's, and white-tailed prairie dogs, as it is an obligate associate of these species. At the species level, the black-footed ferret needs multiple, resilient populations within the range of these three prairie dog species in order to be viable (Chapter 2).

3.1 Range of the Black-footed Ferret

As noted in Chapter 2, the historic range of the black-footed ferret coincided with the historic range of black-tailed, Gunnison's, and white-tailed prairie dogs. For the purposes of this SSA, we compiled spatial data delineating the current ranges of the three species of prairie dogs in order to develop a potential range for the black-footed ferret. At present, black-footed ferrets have been purposely reintroduced at 29 discrete sites within the potential range (Figure 4). We do not expect that black-footed ferrets could occur throughout the entire potential range, as prairie dog colony size and configuration are important determinants of black-footed ferret habitat suitability (Biggins et al. 1993, Bevers et al. 1997, Biggins et al. 2006d), and unsuitable habitats for both prairie dogs and ferrets exist within the potential range as currently defined. Unsuitable habitats can include wetlands, cultivated areas, developed areas, and areas where soils and topography are not suitable for prairie dogs (Ernst et al. 2006). A more spatially refined analysis of the potential range is needed to determine where additional black-footed ferrets can potentially be established. Preliminary efforts at finer-scale analyses can be found in Luce (2006).

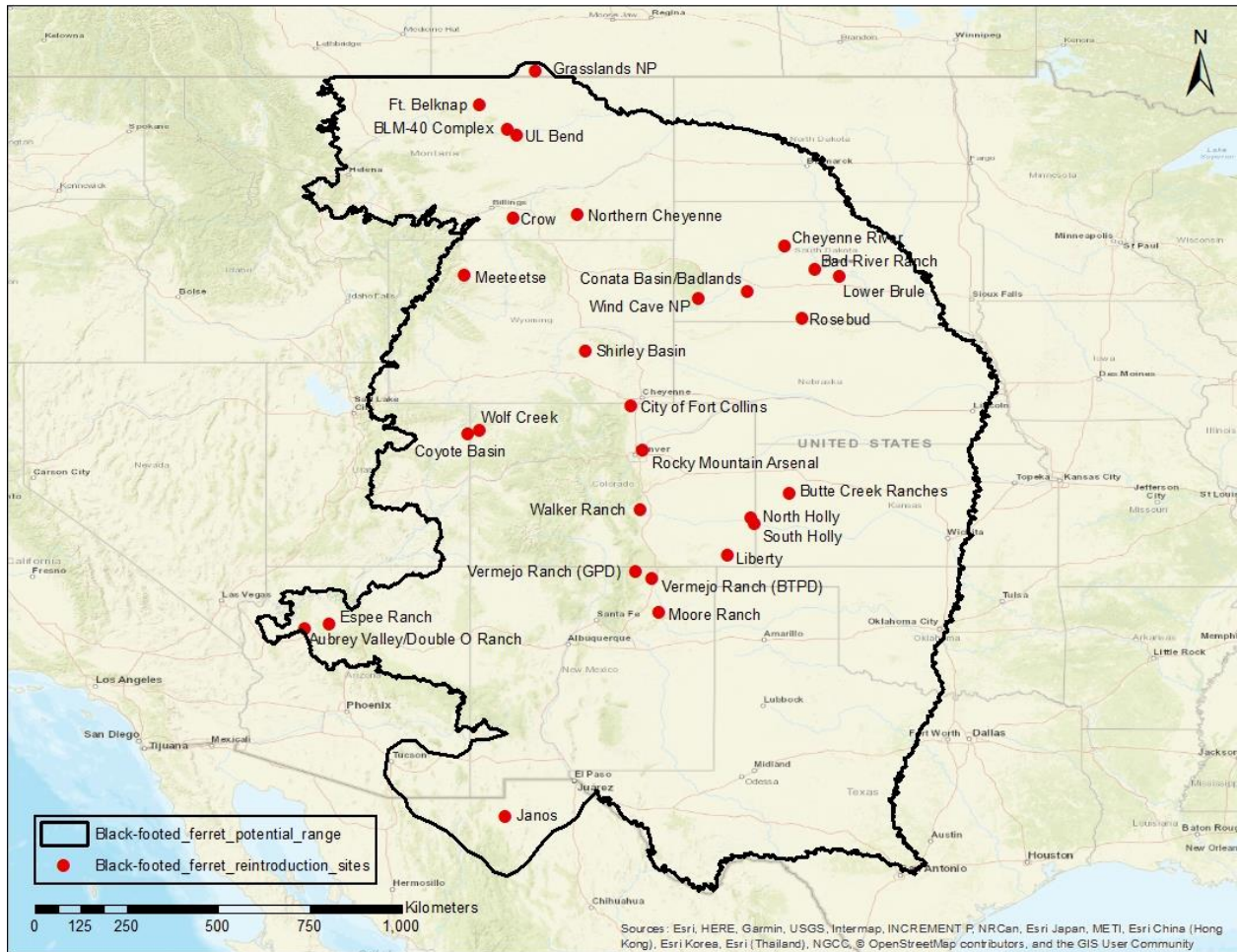


Figure 4. Black-footed ferret potential range and locations of reintroduction sites. The potential range represents the outer boundary of areas where black-footed ferrets occur or could occur, but not all areas within the potential range are occupied or provide potentially suitable habitat. The potential range encompasses approximately 231,425,000 ha.

3.2 Factors Influencing Black-footed Ferret Condition

In this section, we discuss the external factors (stressors) that may influence the 3Rs, and thus the viability, of the black-footed ferret (Figure 5). Through careful review of available literature on the black-footed ferret, black-tailed prairie dog, Gunnison’s prairie dog, and white-tailed prairie dog, we chose to evaluate stressors for which there is broad consensus on the potential to affect black-footed ferret viability at the species-wide level. These include disease, genetic fitness, drought, agricultural land conversion, recreational shooting of prairie dogs, poisoning of prairie dogs, range management, urbanization, and energy development. Although the magnitude and scale of effects of these stressors varies, the importance of these stressors is supported by other recent reviews of black-footed ferret viability (USFWS 2013a, Belant et al. 2015). We did consider other possible stressors in the course of our analysis, such as predation (USFWS

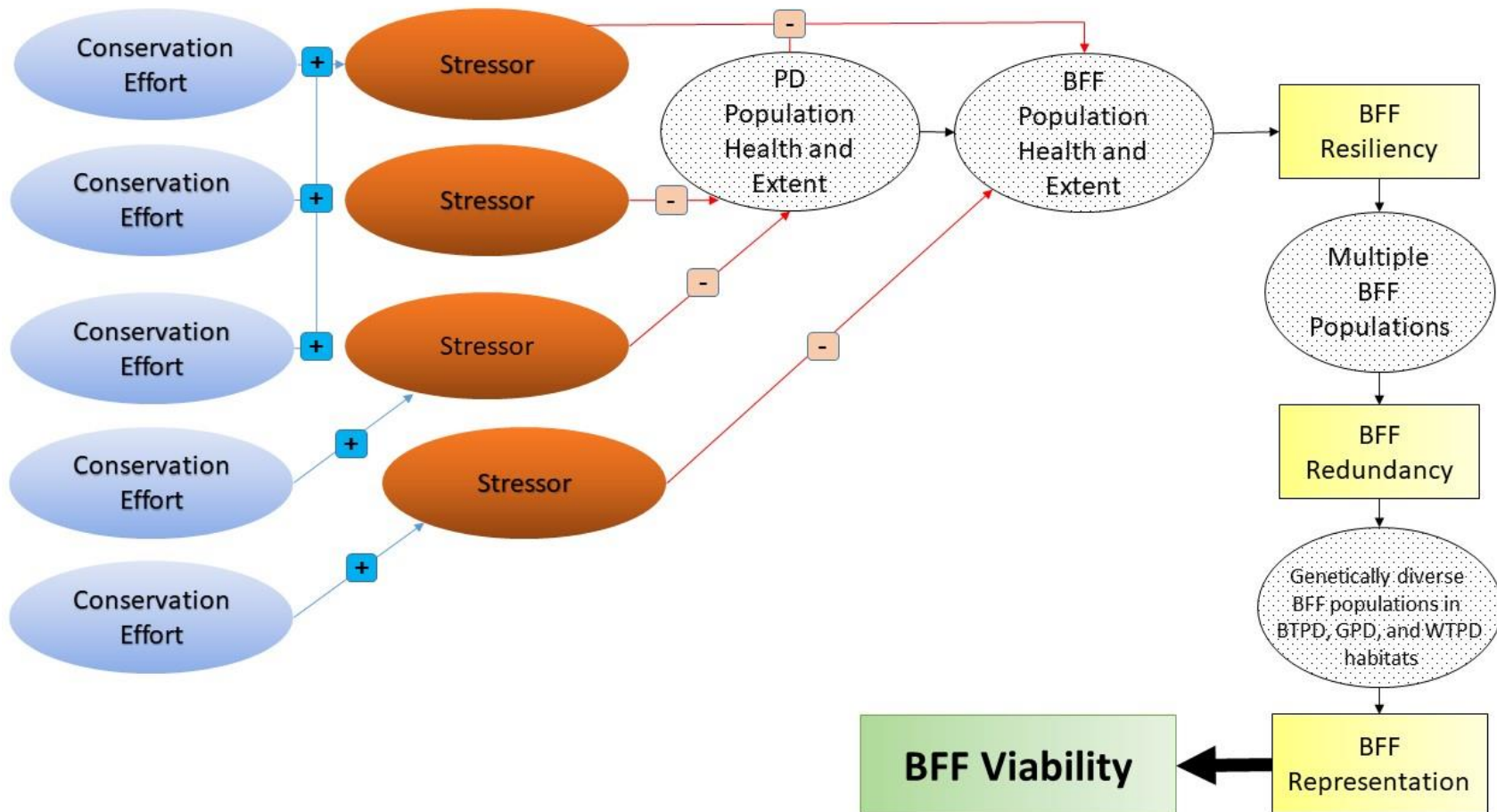


Figure 5. A general influence diagram modeling how stressors and conservation efforts can affect the resilience of black-footed ferret populations. Stressors (orange polygons) decrease the health and extent of prairie dog populations and black-footed ferret populations. Conservation efforts (blue polygons) increase both prairie dog and black-footed ferret population health, and increase black-footed ferret population resiliency. The presence of multiple resilient black-footed ferret populations that are genetically diverse and located in diverse habitat types increases redundancy and representation, and overall black-footed ferret viability.

2013a), but found no credible support that these stressors, either individually or cumulatively, could have population-level effects. We largely excluded these stressors from further analysis in this SSA report. For those factors considered further, we include a description, a current quantification of the magnitude of the stressor (if possible given the data available), and a summary of ongoing and/or potential conservation measures that may ameliorate these effects.

3.2.1 Disease

Native canine distemper and non-native sylvatic plague have seriously affected both wild and captive populations of the black-footed ferret. Several other native diseases, including coccidiosis, cryptosporidiosis, and hemorrhagic syndrome also affect captive populations (Hutchins et al. 1996), but are not common in the wild.

3.2.1.1 Canine Distemper

Description

Canine distemper can have significant adverse effects on the black-footed ferret. This disease was originally believed to have been the primary cause of the demise of the last wild population of ferrets at Meeteetse, Wyoming, in the mid-1980s (Clark 1989). At that time, it was believed that plague did not directly affect the species because many carnivore species, including other ferret species, were resistant to the disease (Cully 1993, Godbey et al. 2006). However, epizootics of both canine distemper and plague were likely responsible for the decline of the Meeteetse ferrets (Lockhart et al. 2006).

The canine distemper virus causes a systemic disease that is highly virulent to carnivore species, including the black-footed ferret. It is endemic in the United States and initially challenged the reintroduction of ferrets (Wimsatt et al. 2006). Efforts in 1972 to breed ferrets from the Mellette County, South Dakota population were ultimately unsuccessful due to vaccine-induced canine distemper. Although safe in domestic ferrets, the vaccine induced fatal distemper in four of six vaccinated black-footed ferrets that were removed from the wild Mellette County population for captive breeding purposes (Lockhart et al. 2006). Some ferrets in the Meeteetse population also succumbed to distemper in the mid-1980s (Clark 1989). Today, an effective commercial distemper vaccine is widely employed in both the captive and reintroduced ferret populations (Marinari and Kreeger 2006). Canine distemper vaccination can substantially reduce the threat of catastrophic population losses of ferrets. However, it is not practical to vaccinate all wild-born ferrets to protect them from periodic distemper events. Accordingly, wild populations may require monitoring and periodic augmentation.

Summary of Effects on the 3Rs

While canine distemper was partially responsible for the decline in the last free-ranging black-footed ferret population in Meeteetse, WY, in 1985, no canine distemper epizootics have been

observed since reintroduction efforts began in 1991 (USFWS 2016a). Due to its reduced prevalence and vaccination efforts in both wild and captive settings (USFWS 2016a, USFWS 2017), at present canine distemper does not appreciably affect black-footed ferret resiliency, redundancy, and representation.

Current and Suggested Conservation Measures

Vaccination of captive and wild-born black-footed ferrets has proven to be a useful strategy to prevent canine distemper epizootics, although limited resources prevent more intensive monitoring to assess its effectiveness in the wild (Wimsatt et al. 2006, USFWS 2016a, USFWS 2017). Care must be taken to select the appropriate vaccines for this disease, as mortalities have occurred through the use of modified-live vaccine constructs (Wimsatt et al. 2006, USFWS 2017).

3.2.1.2 Sylvatic Plague

Description

Sylvatic plague infections are caused by the bacterium *Yersinia pestis*. Fleas acquire the bacterium from biting infected animals and can then transmit it to other animals in a similar manner. The disease can also be transmitted pneumonically (via the respiratory system) among infected animals or via the consumption of contaminated tissues (Godbey et al. 2006, Abbott and Rocke 2012). Recovery efforts for the black-footed ferret are hampered because both ferrets and prairie dogs are extremely susceptible to plague (Barnes 1993, Gage and Kosoy 2006). Plague can affect ferrets directly via infection and subsequent mortality. It can also indirectly affect ferrets through the disease's effects on prairie dogs and the potential for dramatic declines in the ferret's primary prey base (Barnes 1993, Biggins and Kosoy 2001).

Sylvatic plague did not exist on the North American continent prior to 1900, when it was inadvertently introduced into San Francisco (Gage and Kosoy 2006). It was first observed in prairie dogs in 1932 in Arizona (Cully 1993) and detected in all states within the historical range of the black-footed ferret by 2005 (Abbott and Rocke 2012). The disease is currently present throughout the entire range of white-tailed and Gunnison's prairie dogs and in at least the western two-thirds of the range of black-tailed prairie dogs (Barnes 1993, Lockhart et al. 2006, Abbott and Rocke 2012). In addition, plague is very likely to be present in many counties where it has not yet been documented (Biggins 2013).

Sylvatic plague can be present in a prairie dog colony in either an enzootic (persistent, low level of mortality) or epizootic (swift, large-scale die-offs) state. Most of the information we have regarding effects from plague has been collected during epizootic events. However, two recent studies have expanded our understanding of enzootic plague and its effects on black-footed ferret recovery. In Montana, black-footed ferret survival significantly improved when plague vaccinations (Rocke et al. 2006, Rocke et al. 2008) were given to ferrets or when the insecticide

deltamethrin was applied as a prophylactic treatment (Seery et al. 2003, Seery 2006) to control fleas in prairie dog burrows. These results were achieved even in the absence of a discernable die-off of prairie dogs (Matchett et al. 2010). The researchers concluded that increased ferret mortality associated with enzootic plague was hindering ferret recovery and fleas were a key component in transmission. A wider-scale study using prophylactic deltamethrin treatments in Montana and Utah (Biggins et al. 2010) suggested that the enzootic phenomenon was present in black-tailed prairie dogs, white-tailed prairie dogs, and Utah prairie dogs, and that vector control improved the survival of all three prairie dog species.

The factors responsible for the eruption of epizootics and the maintenance of enzootic plague are not well understood. Researchers have identified prairie dog density (Cully and Williams 2001), colony connectivity (Savage et al. 2011), landscape composition (Johnson and Collinge 2004, Collinge et al. 2005, Brinkerhoff et al. 2010), other organisms functioning as short-term reservoirs (Webb et al. 2006, Markman et al. 2018), and local climatic conditions (Snall et al. 2008, Eads and Biggins 2017) as potential influential factors. Regardless of the mechanism (or more likely, combination of mechanisms) involved, sylvatic plague remains an important disruptor of prairie ecosystems (Eads and Biggins 2015, Biggins and Eads 2019).

Summary of Effects on the 3Rs

In general, larger populations exhibit higher resiliency and are better able to withstand stochastic events. While canine distemper epizootics are relatively rare and occur in localized settings (Williams and Thorne 1996), the likelihood of entire populations of black-footed ferrets being extirpated during sylvatic plague epizootics is high (Shoemaker et al. 2014), and the effects of plague can be exacerbated by other stressors such as drought and recreational shooting (see **Sections 3.2.2 and 3.2.4**, below). Further, stressors such as drought and recreational shooting can create positive feedback loops where the effects of plague are magnified (Biggins and Eads 2019). The loss of individual populations due to plague reduces redundancy and representation, particularly if populations occurring in different habitat types (e.g., black-tailed, Gunnison's, and white-tailed prairie dogs) succumb to plague simultaneously. Given the black-footed ferret's low level of genetic diversity, plague represents an additive stressor that further diminishes the species' ability to adapt to changing environmental conditions (Wisely et al. 2002).

Current and Suggested Conservation Measures

Current plague management efforts aim to minimize the effects of plague on black-footed ferrets by reducing flea loads on prairie dogs through vector control, immunizing individual black-footed ferrets against the disease, immunizing individual prairie dogs against the disease, or a combination of these strategies. Applying the insecticide deltamethrin to individual prairie dog burrows ("dusting"; Seery et al. 2003, Seery et al. 2006) effectively reduces flea loads and increases both prairie dog and black-footed ferret survival by reducing the likelihood and rate of plague transmission (Godbey et al. 2006, Biggins et al. 2010, Matchett et al. 2010). Drawbacks to dusting include effects to non-target invertebrates and high labor and materials costs

(Jachowski et al. 2011c). Flea resistance to deltamethrin has also been documented at sites where the insecticide has been applied on an annual basis for < 10 years (Eads et al. 2018), and managers should attempt to utilize other products using an integrated pest management paradigm so that resistance issues can be avoided (Eads and Biggins 2019). A potential new plague mitigation product is the systemic pulicide fipronil. When incorporated into grain baits, researchers found significant short-term control of fleas (3 months) in black-tailed prairie dog colonies in Colorado and South Dakota (Poche et al. 2017, Eads et al. 2019). The cost of this product is equivalent to that of deltamethrin dusting, and while in theory its non-target effects should be lower (Borchert et al. 2009), additional evaluation is needed in this regard.

Rocke et al. (2006) developed a vaccine (F1-V) to prevent plague in black-footed ferrets. Ferrets immunized by a series of two subcutaneous injections had significantly higher antibody titers than un-immunized animals. Eleven of 16 vaccinated individuals survived when challenged with plague 6 months after immunization. All eight control animals died. The 11 survivors were again challenged by ingestion of a plague-infected mouse 2 months later and all survived. The F1-V vaccine is now used operationally (Abbott and Rocke 2012, USFWS 2016a), and most captive ferrets, including all of those provided for reintroduction, are currently vaccinated for plague. Many ferret kits at the Conata Basin-Badlands reintroduction site and several other reintroduction sites are also vaccinated annually in an effort to minimize effects from the ongoing plague epizootic. Recent experience at this site indicates that dusting alone is insufficient to maintain ferret populations during a plague epizootic and that vaccination increases the survival of ferrets on dusted colonies; without both dusting and vaccination the population at Conata Basin-Badlands would likely have perished (Livieri 2019). However, maximum protection is difficult to achieve in wild ferrets, which must be trapped twice, two to four weeks apart, to receive two effective doses of the vaccine.

Another vaccine under development, the sylvatic plague vaccine (SPV), is delivered via treated baits to prairie dogs, and may eventually be useful in protecting ferrets from habitat reduction due to plague. This vaccine has been effective in a laboratory setting (Rocke et al. 2010, Abbott and Rocke 2012), and a recent broad-scale experiment involving four species of prairie dogs to test effectiveness in the field found that SPV prevented complete colony collapse in instances where plague epizootics were documented (Rocke et al. 2017). However, some prairie dogs on these colonies still died from plague because researchers were not able to attain either a 100% vaccination rate or a sufficient vaccination response to impart herd immunity (Rocke et al. 2017).

In a black-tailed prairie dog population in Colorado, the effectiveness of SPV was found to be highly influenced by temporal variation in treatment, as well as temporal variation in the eruption of plague epizootics (Tripp et al. 2017). The authors found that neither dusting nor SPV provided colonies with complete protection, but repeated annual application of SPV well in advance (> 30 days) of a plague epizootic stabilized survival rates in adult prairie dogs exposed

to an epizootic. To maximize effectiveness, Tripp et al. (2017) suggested that SPV should be applied in non-epizootic conditions, and should be administered over large, contiguous areas in late summer or fall to ensure vaccination of juvenile prairie dogs. Further research is needed to determine if SPV can limit plague transmission by limiting the role of prairie dogs as a reservoir, and if it is an effective means of mitigating the overall effects of sylvatic plague on black-footed ferrets and associated species.

Vector control (i.e., dusting and/or fipronil grain baits) and SPV use in conjunction with vigilant plague epizootic monitoring may provide the most effective way to reduce the range-wide effects of plague (Antolin et al. 2002, Abbott et al. 2012, Tripp et al. 2017). However, the widespread use of these prophylactics across the species' range is logistically and financially challenging. To address this concern, a new method of manufacturing has made SPV bait production quicker and more cost effective (Corro et al. 2017), and recent tests have explored the utility of using drones and all-terrain vehicles equipped with mechanical dispensers to distribute SPV over larger areas (USFWS 2016b). These technologies are also being used to develop application techniques for other plague management practices, such as the application of systemic insecticides (Matchett 2019). Information provided by recent studies on plague management techniques may help managers gain the most benefit from limited, but targeted, conservation efforts. Vaccination rates of 50 to 80 percent of individuals in a colony using SPV may be necessary to control plague epizootics (Tripp et al. 2014). Broadcasting SPV-laden baits at high densities during the fall, as opposed to the spring, may be the best way for managers to reach these vaccination goals (Tripp et al. 2014, Tripp et al. 2017).

While the goal of vector control practices such as dusting should be to dust entire colonies for maximum plague prevention, dusting even a portion of a colony can buffer it against the effects of a plague epizootic for some time (Tripp et al. 2017). Flea abundance rebounded to high levels 12 months after dusting treatment on plots that were adjacent to large blocks of untreated habitat, so managers may consider dusting more frequently or at least annually to effectively suppress plague on small, disjunct colonies in larger habitat areas; however, in some instances dusting provided significant flea reduction for up to two years (Eads and Biggins 2019). A single dusting event on an entire colony would theoretically suppress flea abundance for a longer period of time. Preventative dusting is also more effective than dusting in response to an observed plague epizootic (Tripp et al. 2016).

Plague management activities including vector control and SPV distribution are ongoing at most, but not all, black-footed ferret reintroduction sites (Table 1). Intensive, long-term plague management has occurred at the Conata Basin-Badlands reintroduction site in South Dakota since 2008, when epizootic plague was first documented (USFWS 2013a). Prior to the epizootic, Conata Basin-Badlands had provided a surplus of kits for translocation to other reintroduction sites since 2000 (Livieri 2006). Plague was detected in prairie dogs approximately 40 km south

Table 1. Summary of plague management activities at black-footed ferret reintroduction sites, 2014-2018.

Site Name and Location*	Size in 2018 (ha)	2014 dusting (ha)	2015 dusting (ha)	2016 dusting (ha)	2016 SPV (ha)	2017 dusting (ha)	2017 SPV (ha)	2018 dusting (ha)	2018 SPV (ha)
Conata Basin-Badlands, SD	5,494	4,446	4,282	3,418	405	3,589	405	3,399	411
UL Bend NWR, MT	202	0	0	0	486	0	486	0	364
Aubrey Valley/Double O Ranch, AZ	26,485	0	0	0	0	0	0	256	248
Ft. Belknap Reservation, MT	688	0	157	116	0	116	0	75	0
Coyote Basin, CO/UT	10,117	0	0	0	0	0	0	0	1,214
Lower Brule Reservation, SD	723	0	101	267	0	0	0	0	506
Wind Cave National Park, SD	739	0	207	102	0	98	0	243	486
<i>Espee Ranch, AZ</i>	8,811	0	0	0	0	0	0	65	251
<i>Northern Cheyenne Reservation, MT</i>	324	0	0	0	0	401	0	9	0
<i>Grasslands National Park, SK</i>	769	0	472	139	0	101	0	351	0
<i>Walker Ranch, CO</i>	340	0	0	405	0	293	293	0	340
City of Fort Collins, CO	746	1,000	1,000	622	0	405	676	405	693
<i>North Holly, CO</i>	55	0	728	1,012	0	66	55	0	55
<i>Liberty, CO</i>	93	0	304	142	0	16	32	0	93
Rocky Mountain Arsenal NWR, CO	1,214	0	1,046	809	405	1,212	405	0	615
Crow Reservation, MT	1,985	N/A	525	710	0	470	0	221	0
<i>South Holly, CO</i>	120	N/A	0	607	0	93	101	0	81
Meeteetse, WY	2,236	N/A	N/A	2,032	0	1,165	0	1,189	405
<i>Bad River Ranch, SD</i>	121	N/A	N/A	N/A	N/A	364	253	61	6
Moore Ranch, NM	164	N/A	N/A	N/A	N/A	N/A	N/A	0	164
TOTALS	61,426	5,446	8,822	10,381	1,296	8,389	2,706	6,274	5,932

*Sites shown in italics are no longer occupied by black-footed ferrets as of 2018

of Conata Basin in 2005. Approximately 1,600 kilograms (kg) were dusted on 2,800 ha of prairie dog colonies in known ferret habitat during the late summer and fall of 2005 in an effort to control fleas. Despite continued dusting efforts, plague was identified at Conata Basin in May 2008.

Following detection of plague at Conata Basin-Badlands, several Federal agencies undertook a dusting effort that targeted approximately 4,000 ha of prairie dog colonies (Griebel 2008). Approximately 4,000 ha of untreated prairie dog colonies were affected by plague (Griebel 2008). Plague in Conata Basin-Badlands continued into 2009 and removed approximately 2,000 additional hectares of prairie dogs for a two-year reduction in occupied prairie dog habitat from 12,600 ha to 6,500 ha (Griebel 2009). Dusting at Conata Basin-Badlands has continued annually to the present. The Conata Basin-Badlands reintroduction used dusting and vaccination to actively manage black-footed ferret habitat in the midst of this plague outbreak and have maintained approximately 4,455 ha of prairie dog colonies occupied by ferrets (Griebel 2009). The precise extent of ferret mortality at Conata Basin is not known, but is presumed to be as much as 75 percent of the pre-epizootic population, based upon survey data and the number of acres affected at this site (USFWS 2013a).

In one instance, black-footed ferrets appear to have prospered despite the prior presence of plague. In 1991, Shirley Basin, Wyoming, was the first site where ferrets were reintroduced. White-tailed prairie dogs occupy this site. Ferret releases at Shirley Basin were suspended in 1994 due to prairie dog population declines caused by plague. By 1997, only five ferrets were observed (Grenier et al. 2007). However, 52 ferrets were observed in 2003 and thereafter, the Shirley Basin ferret population received additional augmentation of captive-born animals and grew rapidly (Lockhart et al. 2006, Grenier et al. 2007). White-tailed prairie dog complexes are less densely populated than typical complexes of black-tailed or Gunnison's prairie dogs, and some authors have suggested that prairie dog colony size and density play a key role in determining the severity and duration of plague epizootics (Cully 1989, Cully and Williams 2001, Collinge et al. 2005). It is possible that scattered populations of prairie dogs avoided contracting plague and were able to sustain a small ferret population. However, ferrets and white-tailed prairie dogs at other reintroduction sites have been continuously or repeatedly affected by plague (Holmes 2008, McDonald et al. 2011), and recent research suggests that vector densities rather than host densities may be the most important factors in determining plague transmission rates (Biggins and Eads 2019).

Despite ongoing plague mitigation efforts at several black-footed ferret reintroduction sites, plague remains the most significant challenge to ferret population resiliency. Frequent, successive plague epizootics, as well enzootic plague, prevent both prairie dog and ferret populations from reaching their biological potential (Augustine et al. 2008, Eads and Biggins 2015). Ameliorating the effects of plague on black-footed ferrets and the prairie dog population

that they rely upon will require rangewide, strategic use of available plague management tools (Tripp et al. 2017).

3.2.2 Genetic Fitness

Description

Genetic fitness of the black-footed ferret has been a concern in the captive breeding program due to the extreme bottleneck that the species experienced (Groves and Clark 1986, U.S. Fish and Wildlife Service 1988, CBSG 1992, Hutchins et al. 1996, CBSG 2004, Garelle et al. 2006, Howard et al. 2006, Wisely 2006). The current captive breeding program began with the genetic equivalent of seven founder animals from the last wild population at Meeteetse, Wyoming (Hutchins et al. 1996, Wisely 2006). The magnitude of loss of genetic fitness was exacerbated by the especially isolated nature of this last population, which is located on the periphery of the historical ferret range and was likely a refugium during the last glacial period that subsequently remained isolated (Wisely 2006). Both natural history (especially limited dispersal capabilities relative to other carnivores) and the ebb and flow of Pleistocene glaciers likely served to induce genetic drift within black-footed ferret populations, which created marked genetic differentiation among populations (Wisely et al. 2002).

Two types of genetic effects can affect a population's survival and overall genetic fitness: (1) inbreeding depression, caused by increased genetic homozygosity (uniformity) and the subsequent expression of deleterious genes; and (2) genetic drift, the random loss of genetic diversity in small populations (Clark 1989). In some species, genetic diversity of less than 90 percent of that in founder populations has been associated with compromised reproduction due to low birth weights, small litter size, and high neonatal mortality (Soulé et al. 1986). Genetic diversity in the current black-footed ferret population is estimated to be 85.66 percent of that in the founder population, with an average loss of 0.17 percent per year (Graves et al. 2018). A primary goal of the SSP® is to optimize genetic management of the captive population by maintaining 80 percent of the genetic diversity present in the founder population for the next 25 years (Marinari and Kreeger 2006). Some periodic abnormalities observed in captive ferrets (renal aplasia and kinked tails) may be a result of inbreeding (Hutchins et al. 1996, Howard et al. 2006), and more recently researchers have noted decreasing sperm motility and an increasing incidence of sperm structural abnormalities in the captive ferret population (Santymire et al. 2019). These abnormalities appear to be associated with inbreeding, and may be partially responsible for declining reproductive success in the captive population (Santymire et al. 2019).

The genetic uniformity of the black-footed ferret is unprecedented and rivaled by perhaps only one other carnivore, the African cheetah (*Acinonyx jubatus*) (Wisely 2006). However, carnivores typically have less genetic diversity than other mammalian taxa (Kilpatrick et al. 1986). Felines are more susceptible to inbreeding than most taxa (Wisely 2006), and yet the

cheetah continues to survive in the wild. The use of artificial insemination in ferret captive breeding programs has been effective and has helped preserve genetic diversity from an underrepresented male lineage (Howard et al. 2006). Approximately 9,300 ferret kits have been produced at captive breeding facilities to date (Graves et al. 2018). Wild ferret populations appear to flourish despite reduced genetic diversity where ample plague-free habitat exists, likely due to behavioral responses linked to inbreeding avoidance (Wisely 2006). In a comparison of three reintroduction sites, Wisely et al. (2008) found that two sites (Aubrey Valley, AZ and Conata Basin-Badlands, SD) maintained similar genetic diversity as the captive population due to rapid population growth after population augmentation ceased (Conata Basin-Badlands) and annual augmentation from the captive population (Aubrey Valley). One population (Shirley Basin, WY) did experience a loss of genetic diversity and concomitant morphological changes due to a lack of augmentation and a population decline attributed to a sylvatic plague epizootic (Wisely et al. 2008). Through periodic population augmentation efforts, the black-footed ferret will likely persist with continued careful management of remaining genetic resources (Wisely 2006), although stressors such as sylvatic plague and other stochastic processes associated with small populations may create periodic bottlenecks that result in the loss of genetic diversity (Wisely et al. 2008).

Successful reproduction has been documented in black-footed ferrets at almost all reintroduction sites. In 1999, a study detected no difference in genetic diversity between captive-reared releases and their wild descendants at the UL Bend, Montana and Conata Basin-Badlands, South Dakota reintroduction sites (Wisely 2006), although the molecular-based techniques used in this study may not adequately assess short-term changes in genetic diversity (Morin et al. 2009). Additionally, ferrets at Conata Basin were able to maintain genetic diversity levels after releases of captive-reared animals ceased (Cain et al. 2011). Nevertheless, the translocation of wild-born ferrets that have been exposed to natural selection processes that do not occur in captivity may aid overall recovery and is utilized at some new reintroduction sites. Ferret reintroduction efforts have emphasized releasing captive-bred animals to the wild as quickly as possible, but also have encouraged the translocation of wild-born ferrets to initiate new recovery sites (USFWS 2013a).

Summary of Effects on the 3Rs

Reduced genetic fitness is the result of increased inbreeding and declining genetic diversity, which causes inbreeding depression and the expression of deleterious alleles (Frankel and Soulé 1981). This can cause a reduction in individual animal fitness, which can reduce the ability of a species to adapt to changing environments (Hoffman et al. 2003), or representation. Reduced genetic fitness may therefore reduce the resilience of black-footed ferret populations, and redundancy in turn is reduced if the establishment of new populations is curtailed. Reduced genetic fitness also reduces representation, as the extant populations of black-footed ferrets can trace their lineage to only seven founder animals from one geographically isolated population. Collectively, these factors serve to reduce the overall viability of the black-footed ferret.

Current and Suggested Conservation Measures

Given the black-footed ferret's history of near-extinction and the resultant small founder captive breeding population, conservation measures have emphasized retention of remaining genetic diversity through the use of the mean kinship strategy augmented by line breeding (Ballou and Oakleaf 1989). This strategy, implemented whenever logistically feasible, selects breeding pairs that maximize the representation of the most unrepresented founders of the captive population. These efforts have largely been successful, and molecular-based estimates have shown no loss in allelic diversity from the founder population to the present day captive population (Wisely et al. 2003). However, molecular-based estimates may not adequately predict short timescale changes in genetic diversity (Morin et al. 2009), and as a result, uncertainty exists as to the magnitude of the loss of genetic fitness experienced by the reintroduced black-footed ferret population. Wisely et al. (2015) state that given the small size of the reintroduced black-footed ferret population and declining genetic fitness, a productive captive population will be needed for at least the next 50 years while suitable habitat is restored and additional reintroduction sites are developed.

Despite the success in establishing and maintaining both captive and reintroduced black-footed ferret populations, conservation and possibly expansion of genetic diversity remain important considerations in black-footed ferret recovery efforts. Wisely et al. (2015) suggested that the black-footed ferret could serve as a case study to evaluate the effectiveness of interspecies somatic cell transfer (iSCNT), and efforts are underway to evaluate extant genetic material to use for these purposes (USFWS 2018a). By enabling the production of individuals via reproductive cloning using cells other than germ cells, iSCNT could help address the persistent erosion of genetic diversity via genetic drift, and may extend the useful life of the captive black-footed ferret population by incorporating genetic material from two cryopreserved founder animals from the Meeteetse population not represented in the current captive population (Wisely et al. 2015).

3.2.3 Drought

Description

Drought is defined as a deficiency in precipitation over an extended period, which reduces water supply, water quality, and range productivity, and affects social and economic activities (Woodhouse and Peck 1998, National Weather Service 2008). Although drought is recognized as a normal process, and local conditions may vary from year to year, the western United States overall has been in what is characterized as a significantly harsh drought in recent years (Woodhouse and Peck 1998; National Oceanic and Atmospheric Administration (NOAA) 2018). The last time the western United States experienced a “megadrought” of this magnitude was in the latter half of the 16th century (Woodhouse and Peck 1998). Recent studies of Gunnison's prairie dog and black-tailed prairie dog colonies have attributed observed decreases in body

condition, reproductive rates, and adult and juvenile survival to the recent drought period (Facka et al. 2010, Davidson et al. 2014, Stephens et al. 2018).

Reduced precipitation due to drought decreases primary productivity and limits the amount of succulent vegetation available to prairie dogs, which in turn negatively affects obligate predators such as the black-footed ferret. Increased primary productivity at a site leads to higher prairie dog densities, increased mating success, and larger litters (Hoogland 2001). Additionally, abundant vegetation allows hibernating prairie dog species such as white-tailed prairie dogs to accumulate the large amounts of fat they need to survive hibernation (Seglund et al. 2006). Prairie dogs may become dormant or enter hibernation as early as July in dry years, extending the time they spend underground (Tileston and Lechleitner 1966, Clark 1977, Andelt et al. 2009). If hibernating prairie dogs do not have access to high quality forage and do not build sufficient fat stores prior to hibernation, they may emerge from their burrows during the winter and die from starvation (Seglund et al. 2004). For non-hibernating prairie dog species such as the black-tailed prairie dog, lack of abundant vegetation can suppress reproduction and decrease juvenile survival rates (Facka et al. 2010, Stephens et al. 2018). Since black-footed ferrets preferentially prey on prairie dog pups to feed their young at critical times of the year (Biggins et al. 2019 in preparation), factors negatively affecting prairie dog reproduction have similar effects on ferrets.

The effects of drought on the frequency and severity of plague are complex and difficult to assess. Researchers have hypothesized contradictory effects of drought on plague epizootics, with studies concluding that drought may contribute to decreased (Parmenter et al. 1999, Stapp et al. 2004, Snäll et al. 2008, Snäll et al. 2009) or increased incidences of plague (Eads and Hoogland 2016, Eads et al. 2016). In wet years or areas, flea abundance can increase due to higher primary productivity and increased soil moisture, leading to increased plague risk for a prairie dog colony (Parmenter et al. 1999, Snäll et al. 2008). In contrast, low primary productivity associated with dry years or areas can lead to decreased prairie dog body condition, increased flea loads, and higher plague risk (Eads and Hoogland 2016, Eads et al. 2016). The complex interplay of annual precipitation variability over multiple years, primary productivity, and prairie dog densities may ultimately explain colony vulnerability to plague epizootics (Eads and Biggins 2017). More research is needed to better understand how precipitation, or lack thereof, influences the frequency of plague epizootics (Eads and Biggins 2017).

Summary of Effects on the 3Rs

As an obligate predator of prairie dogs, the effects of stressors such as drought have cascading effects on the black-footed ferret. Prairie dog populations affected by drought exhibit lower abundance, reproduction, and survival. This makes both prairie dog and black-footed ferret populations less resilient and more vulnerable to other stochastic events. If drought decreases the density of individual prairie dog colonies and reduces the availability of suitable dispersal corridors, black-footed ferrets are forced to range farther during foraging activities, which

negatively affects their survival and overall population resiliency. Such populations will also exhibit decreased resiliency through the limitation of immigration and gene flow. This combination of factors can lead to the loss of populations across the range and decrease the redundancy of the species, making it more susceptible to wide scale, catastrophic events. The effects of drought may be amplified if it occurs in concert with other stressors, such as a plague epizootic (Seglund et al. 2006, Lupis et al. 2007, Eads et al. 2016).

Current and Suggested Conservation Measures

We are not aware of any ongoing conservation measures involving prairie dogs, black-footed ferrets, and drought. Ensuring that prairie dog habitat is in high condition may help buffer colonies from additional vegetation losses due to drought (Seglund et al. 2006). High condition habitat is free from invasive weeds and has appropriate grazing utilization levels (Mack et al. 2017). In non-drought years, moderate grazing and the use of prescribed fire may help achieve these habitat conditions. In extreme cases, supplemental feeding by managers may help colonies persist during periods of extended drought (Davidson et al. 2014)

3.2.4 Agricultural Land Conversion

Description

Agricultural land conversion is the change in land use from a previous use to an agricultural use, including cropland and pastureland (single-species plantings grown for livestock grazing and/or hay production). At a large scale, agricultural land conversion represents a permanent loss of habitat for black-footed ferrets and their prairie dog prey (Knowles 2002, Ceballos et al. 2010). However, its effects on ferrets and prairie dogs may be mixed. In some instances, agricultural lands can benefit prairie dogs by providing a source of highly nutritious forage (Crocker-Bedford 1976, Seglund 2002, Seglund and Schnurr 2010). Roads and fences associated with agricultural conversion can fragment contiguous prairie dog habitat (Seglund and Schnurr 2010), but it is possible that agricultural lands sometimes facilitate prairie dog dispersal (Sackett et al. 2012).

Since the largest portion of the black-footed ferret's historic range occurred in black-tailed prairie dog habitat (approximately 84%; Ernst 2006), agricultural conversion in these habitats constitutes the largest loss of potential black-footed ferret habitat. Due to an abundance of deep, relatively level soils, black-tailed prairie dog habitat experienced higher levels of agricultural land conversion than other habitat types within the black-footed ferret's potential range (Choate et al. 1982, Clark 1986), but we do not have information to quantify how much potential habitat was actually lost. In addition, colonies near crops and rangelands with high domestic livestock stocking rates may be subjected to more lethal control efforts than those that are not (Hoogland 2001, Knowles 2002).

Summary of Effects on the 3Rs

Although cropland and pastureland in the United States increased from 2007 to 2012, in the longer term there has been a large decrease in the amount of land being used for agricultural production since 1980. This may reflect changes related to urbanization, energy production, as well as the increase in land retirement programs (NRCS 2015; numbers do not include Federally-owned lands). While most extant prairie dog colonies are not large or contiguous enough to support black-footed ferrets at this time, the amount of available remaining habitat is likely sufficient to sustain ferret populations (USFWS 2013a) that could be resilient. If agricultural land conversion rates do not increase, redundancy of black-footed ferret populations should not be affected. Since agricultural land conversion is less of a concern in Gunnison's and white-tailed prairie dog habitat (USFWS 2013a), representation likewise should not be affected. In summary, at present agricultural land conversion does not constitute a significant stressor with regard to black-footed ferret resiliency, redundancy, and representation.

Current and Suggested Conservation Measures

While restoration activities to restore former cropland to prairie dog habitat are uncommon, the practice has occurred in some areas (Truett et al. 2006, USFWS 2013b). More relevant to the conservation of prairie dog habitat are attempts to minimize conflicts with agriculture and the development of incentive programs to increase prairie dog tolerance (Seglund and Schnurr 2010, NRCS 2014). Such conservation and incentive efforts are often at odds with state and local laws that mandate prairie dog control (Kansas Statutes Annotated 80-1201 and 80-1203), making them difficult to implement at the scale needed for black-footed ferrets. Conservation efforts may be more effective if they are focused on remaining occupied prairie dog habitat rather than restoration of former croplands, since cropland conversion no longer appreciably reduces survival of reintroduced ferrets contributing to recovery goals for the species (USFWS 2013a).

3.2.5 Recreational Shooting of Prairie Dogs

Description

Several species of prairie dogs are subjected to shooting as recreation and as a form of pest management. Depending on its intensity, shooting can negatively affect local prairie dog populations (Knowles 1988, Vosburgh and Irby 1998, Keffer et al. 2001), and the resulting loss in prey base likely affects black-footed ferret reintroduction sites (Pauli 2005, Reeve and Vosburgh 2006). These effects are more pronounced in black-tailed prairie dog colonies due to their higher densities and greater accessibility to shooters relative to Gunnison's and white-tailed prairie dog colonies (Reeve and Vosburgh 2006). Recreational shooting is potentially more of an additive source of mortality in black-tailed prairie dog colonies for these reasons (Reeve and Vosburgh 2006).

At the Conata Basin-Badlands reintroduction site, prior to the establishment of shooting closures within the designated ferret recovery area, an estimated 75 percent of the prairie dog population

was reduced in density and areal extent by recreational shooting (USFWS 1998). Recreational shooting not only reduces the number of prairie dogs in a colony, but also decreases prairie dog density (Knowles 1988), occupied acreage (Knowles and Vosburgh 2001), and reproduction (Stockrahm 1979). Juvenile and adult female prairie dogs are more susceptible to recreational shooting than adult males (Vosburgh and Irby 1998, Keffer et al. 2001), which can negatively affect black-footed ferret habitat quality due to the species' reliance on prairie dog pups as a food source (Biggins et al. 2019 in preparation). Recreational shooting of prairie dogs also leads to increased rates of emigration (Keffer et al. 2001).

In addition to indirect effects on black-footed ferrets, recreational shooting also causes direct mortality to prairie dog associated species (Knowles and Vosburgh 2001). Thus, incidental take of black-footed ferrets by prairie dog shooters is also a potential, but as yet undocumented, source of ferret mortality. Finally, recreational shooting of prairie dogs contributes to the problem of lead accumulation in wildlife food chains that include prairie dogs (Knowles and Vosburgh 2001, Pauli and Buskirk 2007, McTee et al. 2019). Killing large numbers of animals, not removing carcasses from the field, and using expanding bullets containing lead may present potentially dangerous amounts of lead to scavengers and predators of prairie dogs. Although no negative effects from ingesting lead have been reported in black-footed ferrets, the cumulative effects of recreational prairie dog shooting along with other stressors can negatively affect black-footed ferret populations.

Prairie dog populations can recover from very low numbers over time following intensive shooting (Knowles 1988, Vosburgh 1996, Dullum et al. 2005, Pauli 2005). It appears that a typical scenario is either: (1) once populations have been reduced, shooters go elsewhere and populations recover; or (2) continued shooting maintains reduced population size at specific sites (Knowles 1988, Vosburgh 1996, Dullum et al. 2005, Pauli 2005). Some landowners charge a fee for recreational shooting and such monetary gain may motivate other landowners to preserve prairie dog colonies for future shooting opportunities (Vosburgh and Irby 1998, Reeve and Vosburgh 2006).

Summary of Effects on the 3Rs

Recreational shooting is a relatively low magnitude but persistent stressor to black-footed ferret populations, especially when it is combined with other stressors such as drought and sylvatic plague (Biggins and Eads 2019). This characterization is a broad evaluation across various types of prairie dog habitat and different prairie dog species. On white-tailed and Gunnison's prairie dog ferret reintroduction sites it may not be a stressor due to relatively low shooting intensities (Reeve and Vosburgh 2006), while on black-tailed prairie dog ferret reintroduction sites it can be a significant stressor. Recreational shooting of prairie dogs likely limits the carrying capacity for ferrets at reintroduction sites, and may appreciably reduce survival and reproduction. As such, recreational shooting may decrease black-footed ferret population resiliency in localized situations, particularly at reintroduction sites located in black-tailed prairie dog habitat. If

individual prairie dog colonies are extirpated due to the additive effects of high shooting pressure and other stressors such as sylvatic plague and drought, black-footed ferret population redundancy may be reduced if this occurs over a large portion of the species' range. Since the effects of recreational shooting are most pronounced in black-tailed prairie dog colonies, the representation of black-footed ferret populations may be reduced if populations occurring within this habitat type experience reduced resiliency.

Current and Suggested Conservation Measures

Arizona, Colorado and Utah implement prairie dog shooting closures on public lands from April 1 to June 30 (Arizona), March 1 to June 14 (Colorado) and April 1 to June 15 (Utah) (Arizona Game & Fish Department 2019, Colorado Parks and Wildlife 2019, Utah Division of Wildlife Resources 2018, Regulation R657-19-6). These closures provide protection to prairie dog populations during the crucial breeding and whelping periods, and may reduce the demographic effects of shooting on colonies (Reeve and Vosburgh 2006, Seglund and Schnurr 2010). Other jurisdictions have implemented total shooting closures on prairie dog colonies specifically for the purpose of improving black-footed ferret habitat conditions (U.S. Forest Service 2012), and shooting closures are often a prerequisite for incentive programs focused on black-footed ferret recovery on non-federal lands (NRCS 2014). Since prairie dog mortality by unregulated recreational shooting can greatly exceed predation by black-footed ferrets, implementation of shooting closures is thought to increase prey availability for black-footed ferrets, particularly in instances where sylvatic plague also affects prairie dog populations (Reeve and Vosburgh 2006, Biggins and Eads 2019). Managers should avoid the reintroduction of black-footed ferrets in areas with high levels of recreational prairie dog shooting.

3.2.6 Poisoning of Prairie Dogs

Description

Poisoning of prairie dogs is a major factor in the historical declines of prairie dogs and black-footed ferrets (Forrest et al. 1985, Cully 1993, Forrest and Luchsinger 2006). Similar to many of the other stressors affecting ferret populations, poisoning can affect the ferret directly, through inadvertent secondary poisoning of the ferret caused by consumption of poisoned prairie dogs, or indirectly, through the loss of the prairie dog prey base. The historical estimate of prairie dog occupied habitat is approximately 41 million ha (Anderson et al. 1986). Concerns regarding competition for available forage between livestock and prairie dogs led to the development of extensive government sponsored prairie dog poisoning programs early in the 20th century. Organized prairie dog control gained momentum from 1916–1920, when prairie dogs were poisoned on millions of hectares of western rangeland (Bell 1921). Between 1915 and 1965, the total area poisoned across all states occupied by black-tailed prairie dogs exceeded 15 million hectares, with 1.5 million hectares poisoned in 1923 alone (Forrest and Luchsinger 2006). By the 1960s, occupied prairie dog habitat reached a low of approximately 570,000 ha in the United

States (Bureau of Sport Fisheries and Wildlife 1961, Berryman and Johnson 1973), less than 5% of their historic range (Forrest and Luchsinger 2006). The most recent estimate of prairie dog occupied habitat is approximately 1.5 million ha (74 FR 63343, December 3, 2009; 69 FR 64889, November 9, 2004; 73 FR 6660, February 5, 2008), an increase of 250 percent from its low point.

From the late 1800s to the early 1920s, strychnine was the primary poison for prairie dogs (Bell 1921). Between World War II and 1972, Compound 1080 was the preferred poison for prairie dog control (Forrest and Luchsinger 2006). In 1972, Executive Order 11643 prohibited the use of certain toxicants that might cause secondary poisoning on Federal lands or in federally funded programs. This order was revoked by Executive Order 12342 in 1982. However, poisoning prairie dogs with strychnine and Compound 1080 did not resume. Zinc phosphide became the preferred poison for prairie dog control by 1976, and its use continues to the present (Hanson 1993, Forrest and Luchsinger 2006). In recent years, manufacturers have promoted the use of the anticoagulant rodenticides chlorophacinone (Rozol[®]) and diphacinone (Kaput[®]) for control of prairie dogs (Bruening 2007, Lee and Hygnstrom 2007). These chemicals pose a much greater risk than zinc phosphide of secondary poisoning to non-target wildlife that prey upon prairie dogs, such as the black-footed ferret (Erickson and Urban 2004, Vyas et al. 2012).

In May 2009, the U.S. Environmental Protection Agency (EPA) authorized the use of Rozol[®] throughout much of the range of the black-tailed prairie dog via a Federal Insecticide, Fungicide, and Rodenticide Act Section 3 registration. Rozol[®] and Kaput-D[®] are only labeled for the control of black-tailed prairie dogs, and the labels do not allow its use in Arizona or the taking of “endangered species.” Furthermore, the EPA has established additional restrictions through the Endangered Species Protection Bulletins that ban the use of Rozol[®] in black-footed ferret recovery sites. These bulletins are considered an extension of the pesticide label, and it is a violation of federal and state law to use a pesticide in a manner inconsistent with the label.

Despite these regulations, poisoning on or adjacent to black-footed ferret recovery sites is still a concern. The legal use of Rozol[®] occurs regularly adjacent to one reintroduction site (Butte Creek Ranches, Kansas), and its illegal use occurred at another reintroduction site (Rosebud Reservation, South Dakota) (USFWS 2013a). It is not known if any ferret mortalities directly attributable to Rozol[®] use occurred at these sites. The ability to verify effects on non-target species such as the ferret is quite limited due to the fossorial nature of ferrets, vegetative cover, possible consumption of poisoned ferrets by other predators, and delayed action of the rodenticide. Only a very small percentage of animals that die from secondary poisoning are ever located. However, the loss of prairie dog occupied habitat that resulted from these poisoning activities reduced the quality and quantity of habitat available to support ferrets. The Service recommended that the EPA withdraw its registration for Rozol[®] and not issue a registration for Kaput[®] (Gober 2006, Slack 2006, Arroyo 2009). The Western Association of Fish and Wildlife

Agencies similarly requested that EPA reconsider use of anticoagulants for prairie dog control (Koch 2008). However, Rozol[®] and Kaput[®] use to control black-tailed prairie dogs is now legal in most of the western United States.

With the historical decline in prairie dogs, there was a concurrent decline in black-footed ferrets. Poisoning, if thorough enough, may result in permanent loss of prairie dogs, such as occurred in the extirpation of black-tailed prairie dogs in Arizona (Hoffmeister 1986, Arizona Game and Fish Department 1988). This loss can preclude ferret recovery opportunities. More typically, prairie dog numbers are reduced temporarily, but long enough for ferrets to disappear. Efforts to reintroduce prairie dogs, such as with the black-tailed prairie dog in southern Arizona in 2008 (Hale et al. 2013), offer opportunities to create or recreate lost habitat for ferrets.

Prairie dog control to address boundary encroachment issues from expanding prairie dog acreage at the Conata Basin-Badlands black-footed ferret reintroduction site in South Dakota began in 2004 and peaked in 2006, with a 94 percent reduction in toxicant use by 2009 (Griebel 2010). The U.S. Forest Service, in response to local concerns about the effects of drought and prairie dogs, suggested a need to poison prairie dogs in interior portions of the ferret reintroduction area at Conata Basin-Badlands in order to reduce alleged prairie dog damage to native grasslands and balance multiple use needs (U.S. Forest Service 2008). Proposed poisoning in the interior of the site could significantly reduce the viability of this ferret recovery site, as well as reducing the number of wild-born kits available for translocation to other recovery sites. However, the decision whether to allow expanded toxicant use on prairie dog colonies in the interior portion of Conata Basin-Badlands was deferred due to plague epizootics that significantly reduced occupied prairie dog habitat (USFWS 2013a).

Summary of Effects on the 3Rs

Long-term poisoning of prairie dogs can create increase colony fragmentation and reduce overall abundance, causing increased susceptibility to stochastic events and low levels of population resiliency. As an obligate predator of prairie dogs, black-footed ferrets cannot readily adapt to such situations by switching prey resources, and their populations exhibit low abundance, juvenile survival, and resiliency as a result. Extirpation or increased fragmentation of prairie dog colonies reduces black-footed ferret redundancy, as individual ferret populations are extirpated due to reduced prey availability and connectivity between populations. If poisoning is widespread, this can lead to the extirpation of black-footed ferret populations across a variety of ecological settings, reducing genetic variability and resulting in a reduction of the species' representation. However, unlike historic times, poisoning of prairie dogs today largely occurs at local scales without the goal of widespread eradication, and does not result in species-level effects (Forrest and Luchsinger 2006, Seglund et al. 2006). Still, the use of anticoagulant rodenticides remains a localized concern due to secondary poisoning effects. Such effects can occur even if anticoagulants are applied to prairie dog colonies adjacent to black-footed ferret

reintroduction sites, resulting in a potential erosion of ferret population resiliency due to edge effects. Black-footed ferret males may be particularly susceptible to these effects due to their larger home ranges relative to females.

Current and Suggested Conservation Measures

Rodenticides such as zinc phosphide are routinely used to control prairie dogs adjacent to black-footed ferret reintroduction sites, which can increase overall social tolerance of prairie dogs and black-footed ferret reintroduction efforts (Griebel 2010, USFWS 2013b). Prohibitions on the use of rodenticides are often a prerequisite for incentive programs focused on black-footed ferret recovery on non-federal lands (NRCS 2014). Zinc phosphide has fewer secondary poisoning effects than anticoagulants (Erickson and Urban 2004), and its use is often prioritized over the use of anticoagulants in black-footed ferret reintroduction areas for this reason. Anticoagulants remain an issue of conservation concern for black-footed ferret populations (USFWS 2013a, Vyas 2013). Regardless of mode of action, rodenticide use and its resultant prairie dog mortality can exacerbate the effects of sylvatic plague, as plague transmission rates can increase as infected fleas accumulate on surviving hosts (Biggins and Eads 2019).

3.2.7 Range Management

Description

Herbivory has always been a component of both the shortgrass prairie and sagebrush-steppe regions of the western United States, and prairie dogs co-evolved with native herbivores such as bison (*Bison bison*), pronghorn (*Antilocapra americana*), and mule deer (*Odocoileus hemionus*) (Osborne 1953, Koford 1958, Miller et al. 1994). In addition to native herbivores, domestic livestock grazing within the historic range of the black-footed ferret began with the arrival of European settlers in the 1800s. The effects of grazing on rangelands are influenced by stocking rate, livestock species, timing and periodicity, and other factors such as drought and fire (Vallentine 1990, Fleischner 1994).

In addition to herbivory, fire historically served as an important disturbance within prairie dog habitat, particularly within black-tailed prairie dog habitat (Augustine et al. 2007). Strong feedback effects can occur between fire and herbivory, affecting both herbivores and the plant communities on which they depend (Coppock and Detling 1986, Coppedge and Shaw 1998). The interaction between fire and herbivory was an important factor in determining the range and extent of black-tailed prairie dog populations (Uresk and Bjugstad 1983), and to a lesser extent determined distribution of white-tailed and Gunnison's prairie dogs (Baker 2006). Fire typically does not directly affect fossorial animals such as prairie dogs and black-footed ferrets (Lyon et al. 1978), but rather its effects on the vegetative community in turn affect prairie dog population dynamics.

The synergistic effects of disturbances such as herbivory and fire can have positive or negative effects on prairie dog populations, and by extension black-footed ferret populations (Fleischner 1994). For the purposes of this report, we define appropriate range management as actions that positively alter plant community composition in a way that increases the quality of prairie dog habitat. In contrast, poor range management degrades prairie dog habitat and occurs when disturbances are of a magnitude and frequency that prevents the recovery of forage plants (Vallentine 1990).

Within the black-tailed prairie dog portion of the black-footed ferret's historic range, both grazing management and fire can significantly influence vegetative community composition, and thus population resiliency of prairie dogs. Depending on precipitation and site characteristics, black-tailed prairie dogs can compete directly with domestic livestock for forage, resulting in social conflicts (Lamb and Cline 2003), and range degradation if utilization levels are not managed appropriately (Koford 1958, Uresk and Paulson 1988). The degree and severity of competition for forage between black-tailed prairie dogs and domestic livestock is extremely complex, and results have been conflicting or inconclusive (O'Melia et al. 1982, Vermeire et al. 2004, Augustine and Springer 2013, Connell et al. 2019). Regardless of the source of herbivory, overutilization of rangeland decreases habitat quality for black-tailed prairie dogs by reducing the quality and quantity of forage, resulting in lower prairie dog densities and often larger colony sizes as prairie dog territories expand as a result of forage shortages (Facka et al. 2010, Augustine and Springer 2013). This decrease in habitat quality is very similar to the effects of drought, and can result in similar demographic effects for both prairie dogs and black-footed ferrets (see **Section 3.2.2**, above). Under certain conditions, grazing can improve habitat for black-tailed prairie dogs by improving forage quality (Miller et al. 2007, Chipault and Detling 2013, Connell et al. 2019) and facilitating predator detection by reducing vegetative height (Uresk et al. 1981, Cable and Timm 1987).

The effects of range management practices on white-tailed and Gunnison's prairie dogs differ somewhat from the effects described above for black-tailed prairie dogs. In particular, fire has played a smaller role in shaping vegetative communities, as it was much less frequent historically (100 to 450 year intervals vs. 1 to 10 year intervals) in the shrub-steppe habitats occupied by these species (Baker 2006, LANDFIRE 2007). In recent years the role of fire has become more important in lower elevation habitats, as its frequency has increased due to the invasion of non-native annual grasses such as cheatgrass (*Bromus tectorum*) (Crawford et al. 2004, Baker 2006). In contrast, fire frequencies have declined in higher elevation habitats, resulting in the expansion of shrubs and trees (Miller and Rose 1999, Crawford et al. 2004, Baker 2006). These processes have degraded habitat quality for white-tailed and Gunnison's prairie dogs (Lupis et al. 2007), particularly when they are accompanied by forage overutilization (Seglund et al. 2006, Lupis et al. 2007). As is the case in black-tailed prairie dog habitat, properly-managed grazing can increase habitat quality for white-tailed and Gunnison's

prairie dogs by increasing forage quality (Pauli et al. 2006), and can be used as a management tool to increase the amount of open habitat preferred by white-tailed prairie dogs (Seglund and Schnurr 2010).

Summary of Effects on the 3Rs

Range management practices that reduce forage quantity and quality decrease prairie dog abundance, fecundity, and juvenile survival (Facka et al. 2010), which in turn makes dependent black-footed ferret populations less resilient. While these practices do not presently occur throughout the potential range of the black-footed ferret, in localized instances the redundancy of black-footed ferret populations can be reduced through loss of connectivity, since black-footed ferrets experience increased mortality when dispersing through unsuitable habitats. This phenomenon is exacerbated by stochastic events such as sylvatic plague and drought. Black-footed ferret representation is reduced if these practices take place across a variety of habitats, resulting in lower genetic variability and ecological diversity. Conversely, the implementation of appropriate range management practices enhances black-footed ferret resiliency, redundancy, and representation if prairie dog habitat quality increases as a result (Augustine and Springer 2013).

Current and Suggested Conservation Measures

Range management practices can be utilized to either maintain or improve prairie dog habitat, and by extension black-footed ferret habitat. Proper allocation of available forage resources between potentially competing herbivores can maintain vegetative communities conducive to prairie dog population resiliency, and application of tools such as prescribed fire can remove visual barriers that hinder prairie dog colony expansion (Seglund and Schnurr 2010, Augustine and Springer 2013). Range management practices that encourage a shifting mosaic of heavily grazed and lightly grazed areas to mimic the historical movement of prairie dog colonies across the landscape (Ernst 2001, Fuhlendorf and Engle 2004) can increase habitat quality for black-footed ferrets while maintaining domestic livestock production levels. Range management practices that favor prairie dog reproduction and colony maintenance can also improve black-footed ferret habitat by providing a reliable supply of prairie dog pups for black-footed ferrets (Biggins et al. 2019 in preparation).

3.2.8 Urbanization

Description

Urbanization represents a permanent loss of potential black-footed ferret habitat, and can entail the direct eradication of prairie dog prey (Hoogland 2006, Lupis et al. 2007, Seglund and Schnurr 2006). Additionally, urbanization fragments and isolates prairie dog colonies, leading to smaller colonies with higher prairie dog densities (Johnson and Collinge 2004). Approximately

1.3 million ha of historical black-footed ferret habitat have been lost to urbanization (Ernst 2001), which is approximately 0.56% of the species' potential range.

While the habitat area required by a population of 30 adult black-footed ferrets (the minimum population size counting toward currently defined recovery goals; USFWS 2013a) is relatively large ($\geq 1,800$ ha in black-tailed prairie dog habitats and $\geq 3,000$ ha in white-tailed and Gunnison's prairie dog habitats) and in most cases is not available in urban settings, notable exceptions do occur. In 2015, black-footed ferrets were reintroduced to Rocky Mountain Arsenal National Wildlife Refuge, an undeveloped 5,059 ha tract located on the east side of Denver, Colorado. Despite the presence of single-family homes and other urban development immediately adjacent to the refuge, black-footed ferrets have successfully colonized the refuge, with approximately 29 breeding adults occurring at the site on approximately 1,394 ha of high-density black-tailed prairie dog habitat (USFWS 2018b). Vehicle collisions have been a source of mortality for the ferret population, with six known mortalities reported since the site's initiation in 2015 (N. Kaczor, USFWS, personal communication). Other municipalities have expressed interest in establishing black-footed ferret populations adjacent to urban areas (Boulder County Parks and Open Space 2016). While these observations indicate that urban prairie dog colonies can provide habitat for black-footed ferrets in some instances, prairie dog populations in such colonies are subject to population loss as the degree of fragmentation increases (Magle and Crooks 2009).

Given the significant development pressures in areas such as the Front Range of Colorado, the potential exists for continued loss of potential habitat for black-footed ferrets (74 FR 63343, December 3, 2009). However, it appears that sufficient prairie habitat still occurs within the ferret's historical range to accommodate increases in prairie dog occupied habitat when the 1.3 million ha of urban lands are contrasted with the 163 million ha of current rangeland available within the black-footed ferret's potential range (USFWS 2013a). Similar to the discussion above on the stressor of agricultural land conversion (see **Section 3.2.3**), we recognize that urbanization may affect some prairie dog populations locally, which may impair their ability to potentially serve as black-footed ferret reintroduction sites.

Summary of Effects on the 3Rs

Prairie dog populations subject to the pressures of urban development may become small, isolated, and resource limited. This makes them less resilient and more vulnerable to stochastic events such as plague epizootics and extreme weather events. Decreased connectivity between colonies reduces the ability of migrants to recolonize extirpated colonies, leading to a reduction in redundancy. Given their need for large prairie dog complexes capable of supporting self-sustaining populations in the long term, black-footed ferrets are unlikely to persist in such settings unless the complexes are of sufficient size (see above) and are not subject to further development pressures. However, as discussed above, urbanization is currently affecting only

local areas, and sufficient areas of rangeland within the black-footed ferret's potential range remain.

Current and Suggested Conservation Measures

We are not aware of any conservation measures that address the loss of habitat due to urbanization, as this type of habitat conversion is usually permanent in nature. However, if prairie dog complexes large enough to serve as black-footed ferret reintroduction sites are maintained as open space, habitat can be provided for the species in urban settings.

3.2.9 Energy Development

Description

Oil and gas exploration and development as well as alternative energy development (primarily wind and solar) occur throughout the potential range of the black-footed ferret. Between 2004 and 2008, political and economic incentives increased the exploration of oil and gas resources in the Great Plains and intermountain west. The 2005 Energy Policy Act expedited the leasing and permitting of energy development on Federal lands (42 U.S.C. 13201 *et seq.*; Seglund and Schnurr 2010). U. S. energy consumption is expected to increase only slightly in the next 35 years (U. S. Energy Information Administration (EIA) 2019). However, domestic energy production is expected to greatly increase during that same time period with an emphasis on natural gas (EIA 2019). Significant oil and gas development within the black-footed ferret's potential range is expected to continue in Colorado (Seglund and Schnurr 2010), Montana (L. Hanauska-Brown, Montana Fish, Wildlife, and Parks pers. comm.), North Dakota (EIA 2019), Utah (Hersey et al. 2016), and Wyoming (Pocewicz et al. 2014). Alternative energy sources, such as wind and solar, are developing at a rapid pace in Colorado (Seglund and Schnurr 2010) and Wyoming (Pocewicz et al. 2014).

Oil and gas development includes exploration, drilling, production, and site abandonment phases (EPA 2000), each of which may potentially affect the black-footed ferret or its habitat. Seismic methods used for exploration include shot-hole surveys and vibroseis, which is the use of a truck-mounted vibrating plate that sends shock waves through the ground to locate oil sources. These exploration techniques have the potential to result in prairie dog mortality and to crush vegetation along the seismic route (Seglund et al. 2006). However, a study in Wyoming found no correlations between vibroseis activity and burrow collapse or white-tailed prairie dog declines (Menkens and Anderson 1985). Once an oil or gas source is discovered, permanent structures including access roads, well pads, pipelines and any other necessary infrastructure are constructed (EPA 2000). Wells may be in the production phase for up to 20 to 30 years for gas wells (EPA 2000) and up to 100 years for oil wells (Connelly et al. 2004). Although requirements vary by jurisdiction, after production ceases lessees are typically responsible for

reclaiming the land back to its original condition, or as close to the original condition as possible (BLM 2007, Sedivec and Saxowsky 2015).

Exploration for oil and gas may increase human activity within previously undisturbed habitats (Underwood 2007). The development of well pads and supporting infrastructure, such as roads and pipelines, reduces and fragments habitat, compacts soil, and destroys vegetation. This infrastructure also creates perches for raptors, which may increase predation pressure on prairie dog colonies near these structures (Pauli et al. 2006). New roads may increase road mortality, and prairie dog shooting may increase with increased human access (Gordon et al. 2003).

The amount of direct habitat loss and total fragmentation associated with oil and gas development varies greatly depending on well density (number of hectares per well) and spacing (distance between individual well pads). Well densities and spacing are typically designed to maximize recovery of the resource and are administered by state oil and gas agencies and the BLM on federal mineral estate. Each geologic basin has a standard spacing, but exemptions are granted (Connelly et al. 2004). Within the potential range of the black-footed ferret, well spacing can vary from 2 to 65 ha per well. Increasing wells per unit area decreases the amount of habitat available for wildlife. Increasing the number of wells per pad increases the size of the individual pad, but also decreases the amount of habitat fragmented. Directional, or horizontal, drilling also decreases the amount of habitat fragmentation by co-locating multiple wells on a single pad (Copeland et al. 2009). On BLM lands in Wyoming, single drill pads average 1.2 ha, but this estimate varies widely between projects (BLM 2007). Variation in well pad size and spacing results in variation of the intensity of effects from energy development across the potential range of the black-footed ferret. The threshold levels of oil and gas development that result in population-level effects to the black-footed ferret are unknown.

For our analysis of oil and gas development within the black-footed ferret's potential range, we applied a 1.37 ha pad scar footprint on all known producing and non-producing wells within the species' range, following the methods of Garman and McBeth (2014). This footprint more accurately describes the spatial effect of a well, rather than just the point of the well itself, because it attempts to account for the infrastructure and vegetation disturbance associated with well development. Although one may assume the amount of disturbance is less for a non-producing well than a producing well, we included them in our analysis because we cannot estimate the level of post-production restoration that has occurred on-site. Restoration of a closed well pad site to its natural condition may take up to 40 to 50 years (S. Garman, USGS, pers. comm.). Within the black-footed ferret's potential range, 429,491 ha are affected by producing and non-producing well footprints, corresponding to 0.19 percent of the species' potential range (Figure 6).

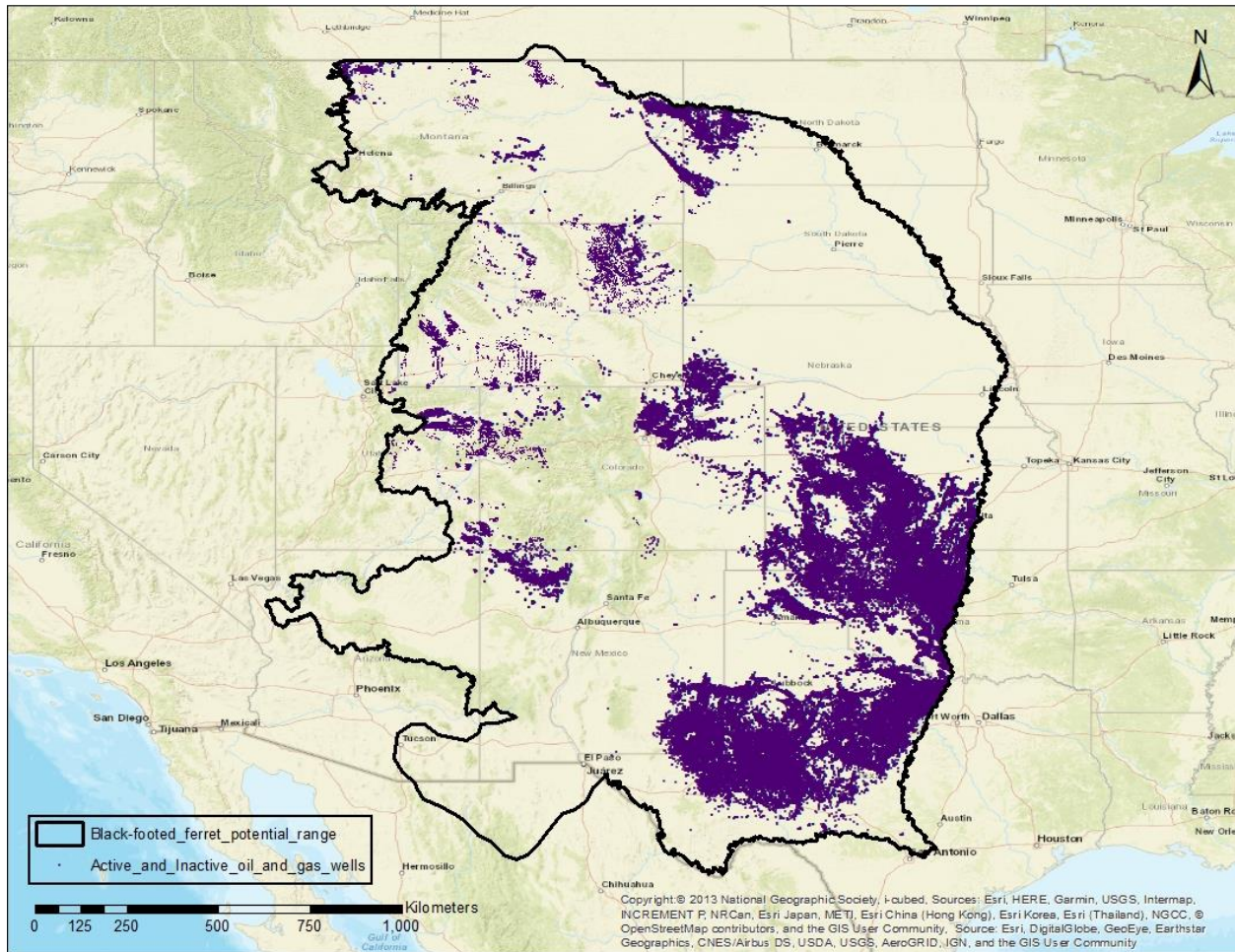


Figure 6. Map showing active (producing) and inactive (non-producing) oil and gas wells located in the potential range of the black-footed ferret. Footprints of oil and gas wells comprise 0.19 percent of the black-footed ferret’s potential range. Because of the scale of this map, the points representing oil and gas wells overestimate the true area of the well footprints, making it appear to be greater than 0.19 percent of the potential range. The footprints are displayed in this manner so the reader is better able to see concentrations of oil and gas development with the potential range of the black-footed ferret. Spatial data from IHS Markit (2019).

Like oil and gas development, wind energy development can affect black-footed ferret habitat during the construction and operation phases, and projects result in some permanent loss of habitat. On a per-megawatt basis, wind energy has a larger footprint than most forms of energy (Kiesecker et al. 2011). In an analysis of 172 existing and proposed wind energy development projects, Denholm et al. (2009) estimated direct area affected due to permanent disturbances such as roads, turbine pads, and substations, as well as the total area encompassed by the footprint of each wind project. Although estimates of total area varied widely due to differences in wind plant configuration, Denholm et al. (2009) estimated an average area requirement of 0.3 ha per MW of installed wind energy for direct area affected, and an average of 34.5 ha per MW

for the total area affected. We used the USGS U.S. Wind Energy Turbine Database (Hoen et al. 2019) to determine the installed wind energy capacity within the potential range of the black-footed ferret (Figure 7). Based on these data, there is 41,608 MW of installed wind energy in the potential range, with a direct effect of 12,482 ha and a total area affected footprint of 1,435,476 ha. These estimates comprise 0.005 percent and 0.62 percent of the potential range of the black-footed ferret, respectively. While this is a small portion of the black-footed ferret's potential range and some potential habitat is likely available within the total area of a wind plant footprint, projects can potentially have significant local effects. For example, a planned wind energy development in Shirley Basin, Wyoming is located in the center of a black-footed ferret reintroduction site, and managers are closely monitoring prairie dog and ferret abundance in the area to evaluate potential impacts (Wyoming Game and Fish Department 2018). Roads and transmission line corridors associated with wind energy developments may also increase predation on ferrets by generalist predators such as coyotes (*Canis latrans*) (Forman et al. 2003).

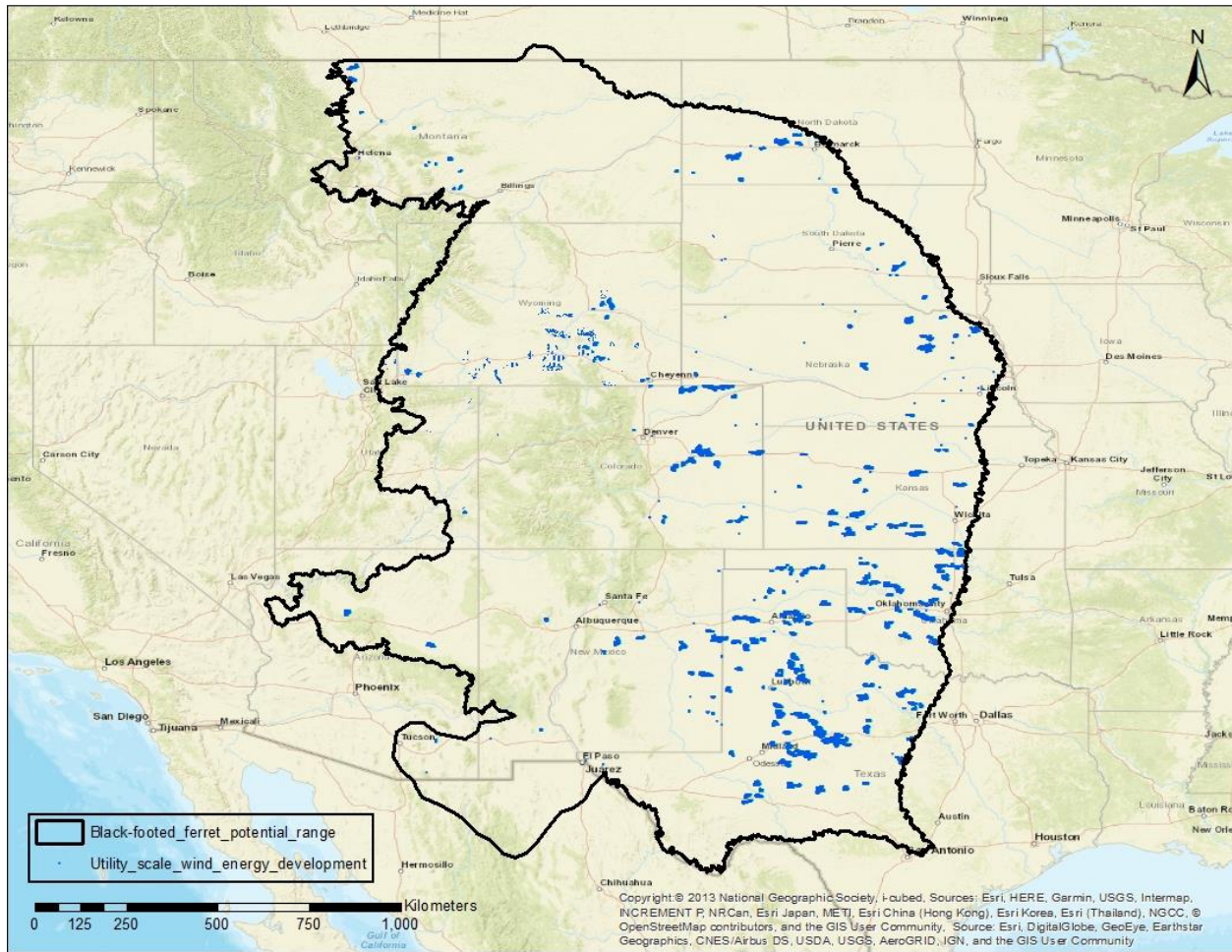


Figure 7. Map showing utility scale (> 100 kilowatts) wind energy development projects located in the potential range of the black-footed ferret. Direct loss of habitat due to placement of permanent structures comprises 0.005 percent of the black-footed ferret’s potential range, and the total summed footprints of each wind project comprise 0.62 percent of the range. Because of the scale of this map, the points representing individual wind turbines overestimate the true area of each project, making it appear to be greater than 0.62 percent of the potential range. The footprints are displayed in this manner so the reader is better able to see concentrations of wind energy development with the potential range of the black-footed ferret.

Utility scale solar energy developments also occur within the potential range of the black-footed ferret, but comprise a much smaller portion of the potential range than other forms of energy development. The Solar Projects Database (Solar Energy Industries Association 2019) lists 11 utility scale (10 MW or greater) project within the potential range, with an average footprint of 3.7 ha/MW. While utility scale solar projects can alter potential black-footed ferret habitat permanently, at present they occupy a negligible portion of the species’ potential range.

Summary of Effects on the 3Rs

Reduction in habitat quality and quantity due to energy development could make prairie dog populations less resilient, and preclude their availability as potential black-footed ferret habitat. Fragmentation of occupied habitat can reduce the ability of black-footed ferrets to disperse to new habitats, through either direct mortality or a reduction in gene flow and genetic fitness, leading to a reduction in population resiliency and redundancy. However, energy development represents a very small portion of the total black-footed ferret potential range, and as such does not preclude the establishment of additional reintroduction sites in most instances.

According to our analysis, energy development currently affects less than one percent of the black-footed ferret's potential range. While we recognize that energy development can have localized effects at some black-footed ferret reintroduction sites, it does not appear to be a major factor influencing the resilience of the species at this time.

Current and Suggested Conservation Measures

Conservation efforts focused on white-tailed prairie dog and Greater sage-grouse conservation in the state of Wyoming may have beneficial effects for black-footed ferrets. In 2007 the Bureau of Land Management (BLM) issued a Statewide Programmatic White-tailed Prairie Dog Biological Evaluation that recommended several conservation practices to minimize effects to white-tailed prairie habitat (BLM 2007). These practices included locating new access roads away from existing colonies, prohibiting development in occupied colonies, including conditions in oil and gas drilling permits to protect prairie dogs during the breeding season (April 1 – July 15), and encouraging the use of directional drilling. Many of these practices have also been included in Resource Management Plans (RMP) for BLM field offices throughout the range of the white-tailed prairie dog, which includes several existing and potential black-footed ferret reintroduction sites (Luce 2006).

Several restrictions on energy development in Greater sage-grouse habitat in Colorado, Utah, and Wyoming may also benefit white-tailed prairie dogs, and create or maintain black-footed ferret reintroduction sites. These restrictions include co-locating disturbance activities, prohibition of permanent surface occupancy in identified core areas, seasonal restrictions on production activities, and prohibitions on wind energy development in core areas (BLM 2019, State of Wyoming Executive Order 2015-4). Since white-tailed prairie dog habitat overlaps with Greater sage-grouse habitat in these states (Mack et al. 2017), habitat quality may be enhanced for portions of the black-footed ferret potential range as well.

3.3 Historical Condition

3.3.1 Distribution

As indicated in **Section 2.1.2**, the black-footed ferret's historical distribution coincided with the distribution of black-tailed, Gunnison's, and white-tailed prairie dogs (Figure 2). These prairie dog species collectively occupied approximately 41 million ha of intermountain and prairie grasslands extending from Canada into Mexico (Anderson et al. 1986, Biggins et al. 1997). The habitat occupied by prairie dogs existed within a range of an estimated 237 million ha (Ernst 2006). There has been no documented occurrence of the ferret within the range of either the Utah prairie dog or the Mexican prairie dog, whose ranges are small and disjunct (Lockhart et al. 2006). Ferrets from Arizona, Colorado, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, Wyoming, Alberta, and Saskatchewan have been collected as museum specimens since the late 1800s (Anderson et al. 1986). Ferrets also likely occurred in Mexico in recent times, as evidenced by: (1) the fairly contiguous historical distribution of prairie dogs in Arizona, New Mexico, and Mexico, (2) the similarity of biological communities in these areas, (3) the presence of a museum specimen from a site just north of the Mexico and U.S. border, and (4) fossil records farther south in Mexico (Anderson et al. 1986).

Ernst (2006) utilized a geographic information system database to identify the likely distribution of prairie dog habitat where the black-footed ferret probably occurred historically in the United States. Ernst concluded that 85 percent of all ferrets may have occurred in black-tailed prairie dog habitat, 8 percent in Gunnison's prairie dog habitat, and 7 percent in white-tailed prairie dog habitat. Although potential biases are possible in this characterization of the historical distribution of ferrets, most ferrets probably occurred in black-tailed prairie dog habitat based on the more expansive extent of their distribution.

3.3.2 Abundance

The black-footed ferret's close association with prairie dogs was an important factor in its decline. From the late 1800s to approximately 1960, both prairie dog occupied habitat and prairie dog numbers were reduced by: (1) habitat destruction due to conversion of native prairie to cropland, (2) poisoning, and (3) disease. The ferret population declined precipitously as a result (Lockhart et al. 2006). The ferret was considered extremely rare before a small population was located in Mellette County, South Dakota, in 1964 (Henderson et al. 1969), and no abundance data exist apart from museum specimens (Anderson et al. 1986). Breeding attempts with a few captured animals failed to produce surviving young. The last wild animals in the Mellette population were observed in the field in 1974 (Clark 1989). The last captive animal from the Mellette population died at Patuxent Wildlife Research Center in 1979 (USFWS 1988) and the ferret was presumed extinct.

In 1981, a remnant population was discovered near Meeteetse, Wyoming (Clark et al. 1986, Lockhart et al. 2006). At its peak in 1984, the Meeteetse population numbered 129 animals, with 43 adults and 86 juveniles observed (Forrest et al. 1988). Outbreaks of canine distemper and

sylvatic plague occurred at Meeteetse in the early 1980s, and all surviving wild ferrets at Meeteetse were removed during 1985–1987. These ferrets were used to initiate a captive breeding program. Of the 18 remaining ferrets captured from Meeteetse, 15 individuals, representing the genetic equivalent of seven distinct founders, produced a captive population lineage that is the foundation of present recovery efforts (Hutchins et al. 1996, Garelle et al. 2006). Extant populations, both captive and reintroduced, descend from these “founder” animals.

No wild populations of black-footed ferrets have been found following the final capture of the last known Meeteetse ferret in 1987, despite extensive and intensive searches throughout the historic range of the ferret. It is very unlikely that any undiscovered wild populations remain (Hanebury and Biggins 2006, Lockhart et al. 2006).

3.4 Current Condition

3.4.1 Distribution

Black-footed ferrets currently occur in both captive and wild populations, and have been purposefully managed as such since 1987, when the last remaining wild population in Meeteetse, Wyoming was rescued to establish a captive breeding program for the species (Lockhart et al. 2006, USFWS 2013a). The captive black-footed ferret population is guided by the Association of Zoos and Aquariums (AZA) Black-footed Ferret SSP[®] to conserve a minimum breeding population of 240 ± 35 animals of optimum sex and age ratio to maximize productivity and genetic diversity (Hutchins et al. 1996). Captive ferrets in excess of SSP[®] needs are allocated each year for reintroduction or for scientific and educational purposes. Animals used for scientific or educational purposes are often older animals that are past prime breeding age, although some kits have also been allocated for research purposes. For example, some ferrets have been used for research and development of a plague vaccine (Rocke et al. 2006). Not including non-reproductive animals housed at zoos and nature centers for outreach purposes, the captive black-footed ferret population numbers 301 animals as of 2018 and is housed at six captive breeding facilities in the United States and Canada (Table 2).

Since the reintroduction of black-footed ferrets into the wild in 1991 at Shirley Basin, Wyoming, captive ferrets in excess of SSP[®] needs have been reintroduced at 29 reintroduction sites in the western United States, Canada, and Mexico. At present, 14 sites are occupied by ferrets, with the other 15 sites being extirpated due to sylvatic plague. Table 3 provides more detailed characteristics of each reintroduction site as well as its current and past performance.

Table 2. Location and number of breeding age black-footed ferrets housed at captive breeding facilities in the United States and Canada, 2018.

Facility Name	Location	# of male BFF	# of female BFF
National Black-footed Ferret Conservation Center (NBFCC)	Carr, CO	74	106
Smithsonian Conservation Biology Institute (SCBI)	Front Royal, VA	14	19
Louisville Zoological Garden (LZG)	Louisville, KY	14	15
Cheyenne Mountain Zoo (CMZ)	Colorado Springs, CO	9	13
Phoenix Zoo (PHZ)	Phoenix, AZ	12	16
Toronto Zoo (TOR)	Toronto, ON	3	5
TOTALS		126	175

Table 3. Black-footed ferret reintroduction site characteristics and current status as of 2018.

Site Name and Location	Year(s) Initiated	PD Species ¹	Active PD Hectares	Potential PD Hectares	Active?	#BFF Fall 2018 ²	Max # Fall BFF seen (Year) ^{2,3}
Shirley Basin, WY	1991	WTPD	21,711	73,574	Yes	30	229 (2006) ⁴
Conata Basin-Badlands, SD	1994, 1996	BTPD	5,494	12,141	Yes	119	355 (2007)
UL Bend NWR, MT	1994	BTPD	202	728	Yes	1	56 (1999)
Aubrey Valley/Double O Ranch, AZ	1996, 2016	GPD	26,485	106,846	Yes	9	123 (2012)
Ft. Belknap Reservation, MT	1997	BTPD	688	3,035	Yes	11	55 (1998)
Coyote Basin, CO/UT	1999	WTPD	10,117	19,830	Yes	3	45 (2003)
Cheyenne River Sioux Tribe, SD	2000	BTPD	2,428	16,592	No	0	173 (2006)
Wolf Creek, CO	2001	WTPD	1,594	12,141	No	0	38 (2001)
BLM 40 Complex, MT	2001	BTPD	202	486	No	0	10 (2004)
Janos, MX	2001	BTPD	2,226	15,000	No	0	15 (2003)
Rosebud Sioux Tribe, SD	2003	BTPD	1,012	28,329	No	0	30 (2004)
Lower Brule Sioux Tribe, SD	2006	BTPD	723	2,226	Yes	10	29 (2010)
Wind Cave NP, SD	2007	BTPD	739	1,133	Yes	18	49 (2010)
Espee Ranch, AZ	2007	GPD	8,811	56,356	No	0	22 (2008)
Butte Creek Ranches, KS	2007	BTPD	2,145	3,157	Yes	13	79 (2011)
Northern Cheyenne Tribe, MT	2008	BTPD	324	3,440	No	0	6 (2009)
Vermejo Park Ranch (BTPD), NM	2008	BTPD	4,047	4,047	No	0	28 (2010)
Grasslands NP, SK	2009	BTPD	769	3,561	No	0	17 (2010)
Vermejo Park Ranch (GPD), NM	2012	GPD	405	1,619	No	0	5 (2013)
Walker Ranch, CO	2013	BTPD	340	1,195	No	0	3 (2014)
City of Fort Collins, CO	2014	BTPD	746	1,619	Yes	8	11 (2016)
North Holly, CO	2014	BTPD	55	1,514	No	0	1 (2015)
Liberty, CO	2014	BTPD	93	607	No	0	2 (2015)
Rocky Mountain Arsenal NWR, CO	2015	BTPD	1,214	1,214	Yes	79	79 (2018)
Crow Reservation, MT	2015	BTPD	1,985	3,316	Yes	10	22 (2017)
South Holly, CO	2015	BTPD	120	689	No	0	1 (2015)
Meeteetse, WY	2016	WTPD	2,236	2,870	Yes	26	129 (1984)
Bad River Ranch, SD	2017	BTPD	121	1,335	No	0	8 (2017)
Moore Ranch, NM	2018	BTPD	164	609	Yes	3	3 (2018)
TOTALS			97,197	379,210		340	1,623

¹WTPD=white-tailed prairie dog, BTPD=black-tailed prairie dog, GPD=Gunnison's prairie dog

²Minimum number alive (MNA) unless otherwise noted

³Numbers reported do not necessarily correspond with Active or Potential PD acres as reported in this table; area surveyed varies by year at most sites

⁴Correlated density estimate derived from 8,369 ha survey area

3.4.2 Abundance

3.4.2.1. Captive Black-footed Ferret Population

While the total captive black-footed ferret population is kept relatively stable at approximately 280 animals for reasons described above, population performance can be measured on an annual basis by comparing various measures of reproductive performance. In the context of captive breeding, whelping is defined as a female giving birth to one or more kits, either alive or stillborn (USFWS 2017). Whelping success rates for the captive population have declined in recent years (Figure 8).

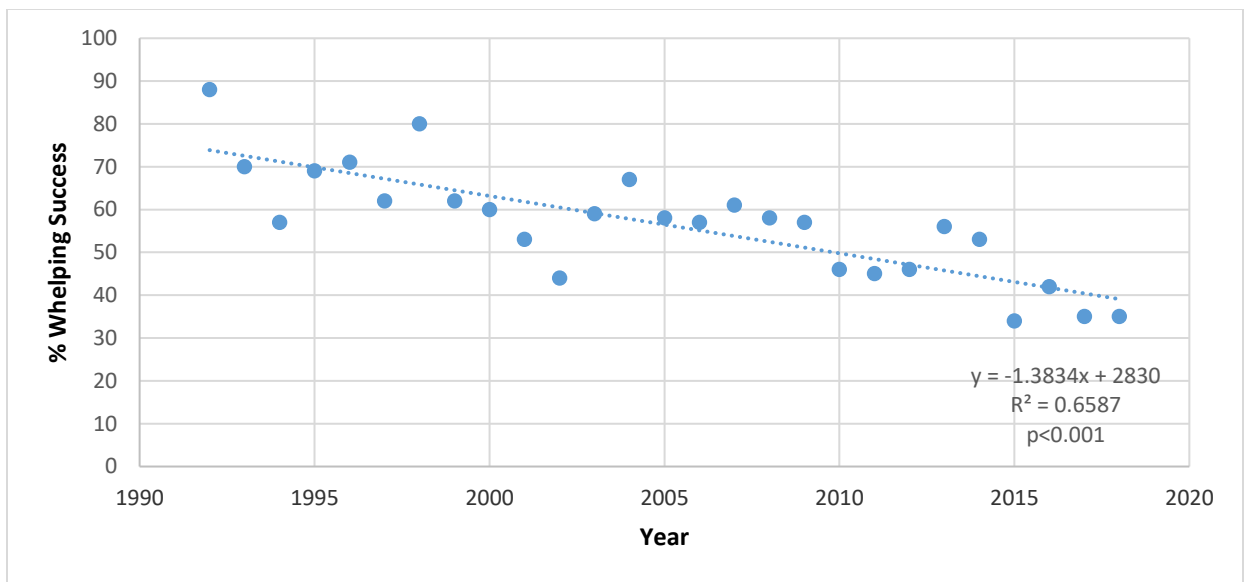


Figure 8. Overall whelping success rates for the captive black-footed ferret population (all facilities), 1992-2018.

Captive black-footed ferret population performance is also measured by the mean number of kits born per litter (Figure 9) and percentage of kits born that are successfully weaned (Figure 10). Unlike whelping rates, these measures have been stable to increasing over the life of the captive breeding program, although kit weaning percentages have declined in recent years. The increase in the mean number of kits born per litter over time may be due to the stability of food resources in the captive setting rather than hereditary factors; this phenomenon has been observed in other species reared in captivity (Jaquish et al. 1996).

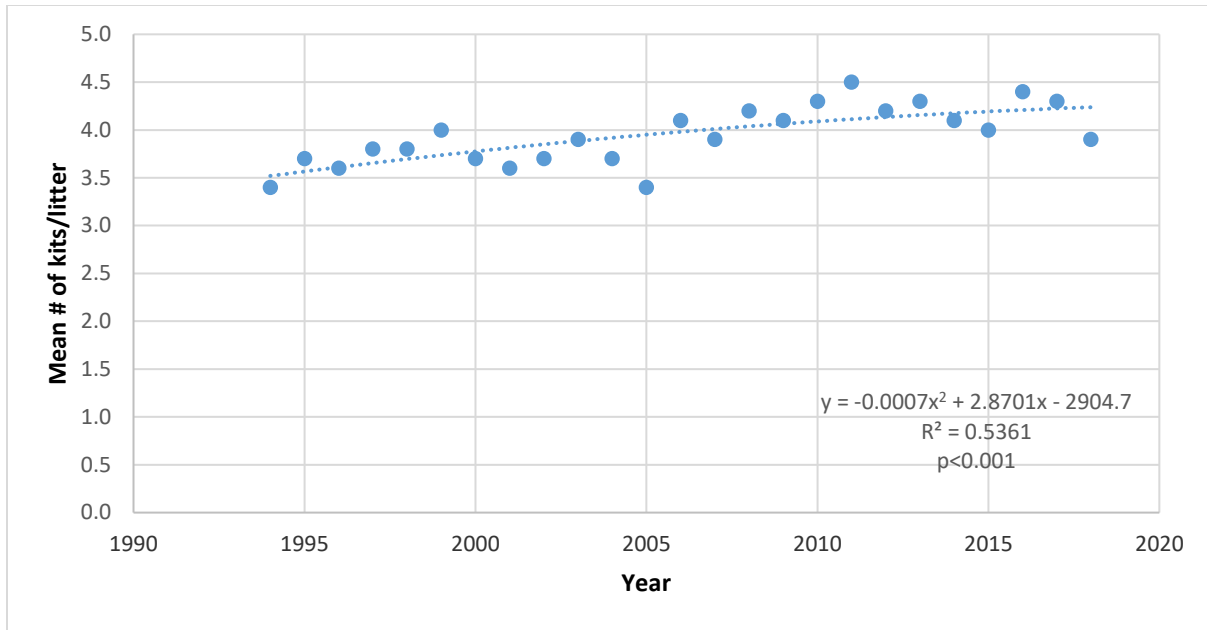


Figure 9. Mean number of kits born per litter for the captive black-footed ferret population (all facilities), 1994-2018.

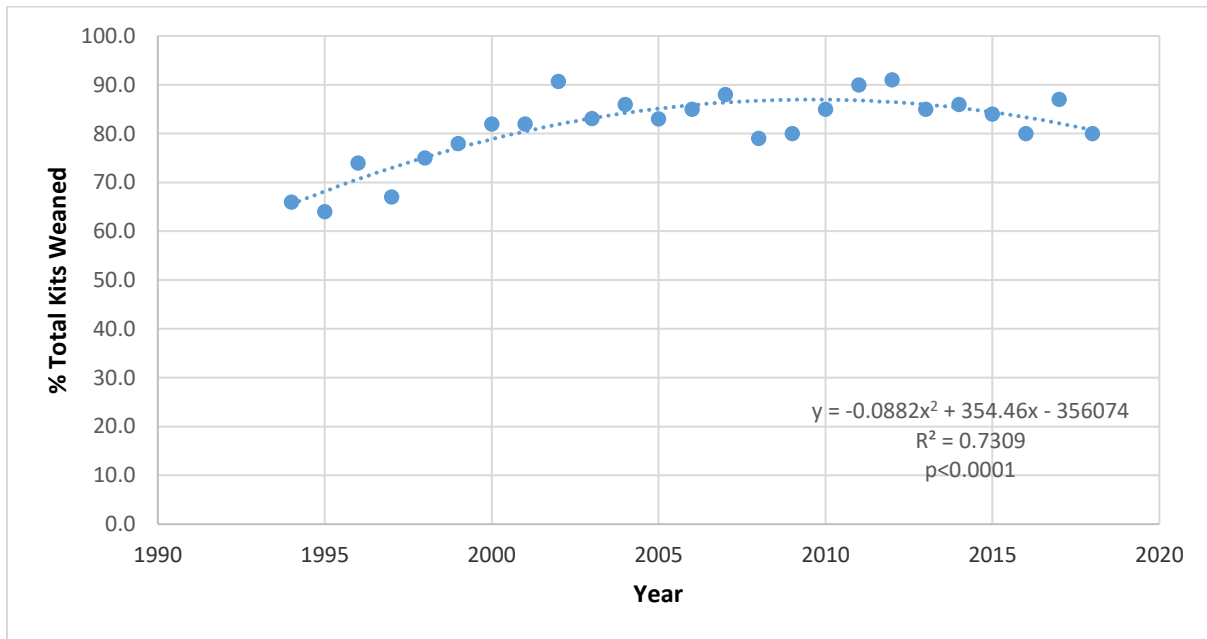


Figure 10. Percentage of total kits born and successfully weaned for the captive black-footed ferret population (all facilities), 1994-2018.

3.4.2.2 Reintroduced Black-footed Ferret Population

Accurate population estimates for the reintroduced black-footed ferret population are difficult to obtain, due to the species' reclusive nature and a lack of available resources (USFWS 2013a), which preclude comprehensive survey efforts at every reintroduction site every year. Reintroduction sites generally obtain population estimates via fall spotlight surveys that attempt to enumerate black-footed ferret adults and young of the year (Biggins et al. 2006b, USFWS 2016a). The population estimates presented herein are likely biased low due to incomplete survey efforts; however, they are useful for comparative purposes, and trend analyses provide an indicator of the relative resiliency of each reintroduction site. Population estimates reported by reintroduction sites are expressed as minimum number alive (MNA; Krebs 1966), which serves as an index of ferret abundance. Although the MNA index does not account for incomplete and variable detectability, it is generally believed to detect >82% of adult ferrets present (Forrest et al. 1988, Biggins et al. 2006b). Based on long-term data from several reintroduction sites, fall MNA data are comprised of approximately 33% adults and 67% young of the year, and overwinter survival data indicate that one-half of the fall MNA estimate is an accurate estimate of spring breeding adults (USFWS 2013a). Data presented in this report come from a variety of sources, most commonly from annual reports issued to the Black-footed Ferret Recovery Implementation Team (BFFRIT) Conservation Subcommittee. Data are available from the Service upon request.

Unlike the captive black-footed ferret population, sites within the reintroduced ferret population are subject to a high degree of year-to-year variability due to drought, sylvatic plague epizootics, and other stochastic events. These fluctuations are apparent when analyzing the overall population trend for the species, which increased steadily from the early 1990s until approximately 2007, after which it began to decline (Figure 11).

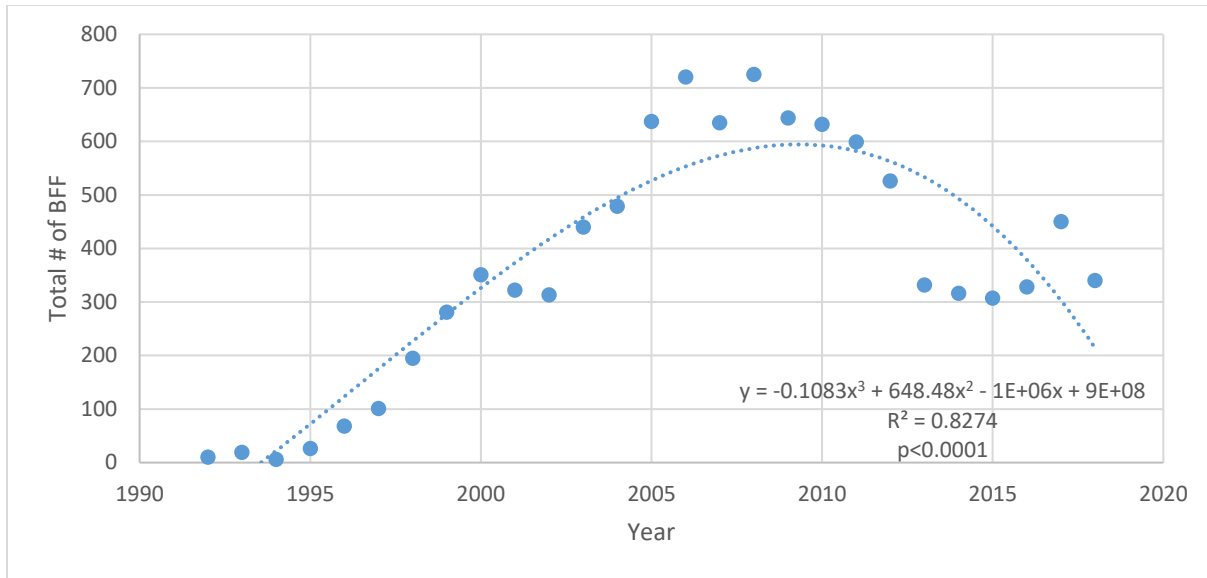


Figure 11. Overall population trend for the reintroduced black-footed ferret population, 1992-2018.

Despite the addition of several new reintroduction sites since the beginning of reintroduction efforts in 1991, population levels for the black-footed ferret reintroduced population have failed to keep pace with the rate at which new sites were developed (Figure 12). The primary reason for this phenomenon (and the extirpation of several reintroduction sites) is the occurrence of sylvatic plague epizootics. Sylvatic plague was not documented in South Dakota until 2006, after which it severely affected the Conata Basin-Badlands and Cheyenne River reintroduction sites, which were two of the largest sites in terms of total number of black-footed ferrets (USFWS 2013a).

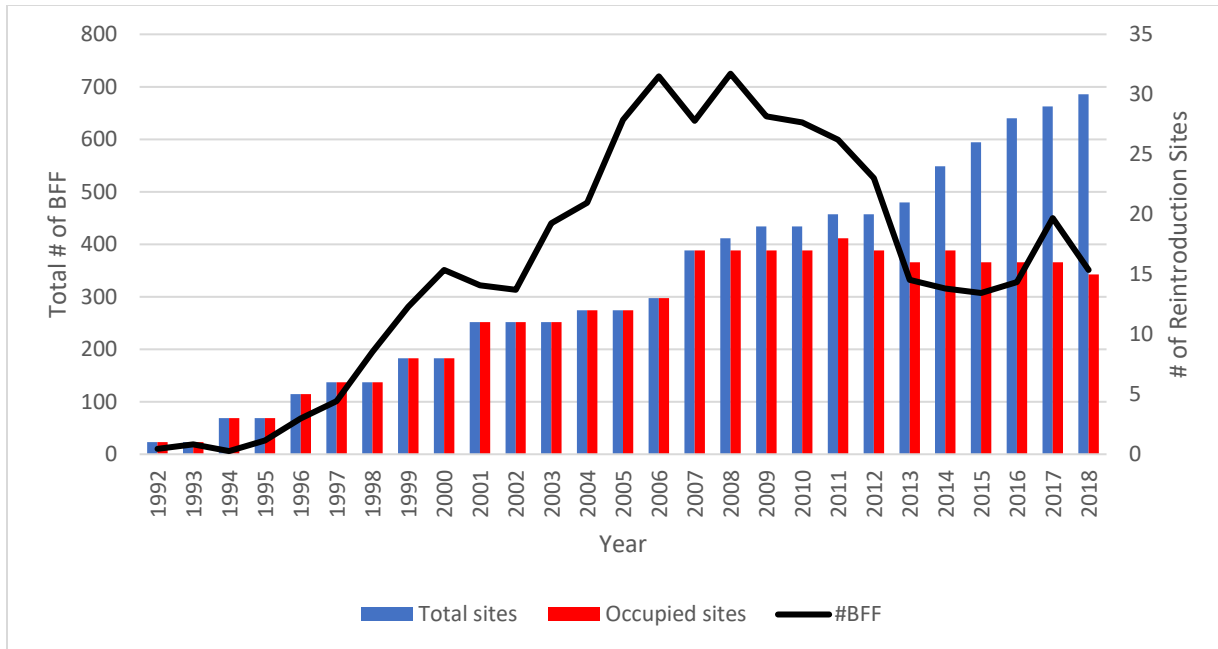


Figure 12. Black-footed ferret population levels and reintroduction site recruitment trends, 1992-2018.

The association between total number of reintroduction sites and black-footed ferret population levels was strongly positive from 1992 to 2007 ($F_{1,14}=86.42$, $r^2=0.86$, $p<0.01$), but much less so from 2008 to 2018 ($F_{1,25}=11.07$, $r^2=0.31$, $p<0.01$). This divergence noted in 2008 is likely the result of sylvatic plague epizootics at several reintroduction sites, as well as differences in the characteristics of reintroduction sites added during the periods 1992-2007 and 2008-2018.

Analysis of variance shows that reintroduction sites added during the latter period are significantly smaller in mean initial size (1,235.3 ha vs. 6,531.6 ha; $F_{1,14}=8.71$, $p<0.05$) and have fewer mean years of persistence before extirpation (3.4 vs. 8; $F_{1,14}=9.21$, $p<0.01$).

The size of reintroduction sites, along with the density of prairie dog prey, level of conservation efforts, sylvatic plague, drought, and other abiotic factors, plays a significant role in their ability to support black-footed ferret populations. A breeding population of 30 adults was established as the minimum recovery criterion (USFWS 1988, USFWS 2013a) largely based on population studies conducted at Meeteetse, Wyoming, the last free-ranging population of black-footed ferrets that formed the basis for all subsequent black-footed ferret recovery efforts. Although the Meeteetse population was studied intensively for only a short time (1981-1985), researchers assumed that it had persisted as a geographically isolated population over the long term prior to its discovery in 1981. Researchers also assumed that the observed maximum count of 43 adults and 86 juveniles in the fall of 1985 was representative of the site's potential (Forrest et al. 1985, USFWS 1988).

Considerable debate has occurred over what constitutes a minimum viable population size, and the 30 breeding adult criterion falls below the “50/500 rule” effective population size guideline that is often cited as a management goal for imperiled species (Franklin 1980, Brook et al. 2011). However, for management-intensive species such as the black-footed ferret, frequent intervention in the form of plague management (vector control and/or individual ferret vaccination) and population augmentation is required in order to prevent the extirpation of individual reintroduction sites. This paradigm follows examples cited by Garnett and Zander (2011) and Jamieson and Allendorf (2012), in which extinction risk due to invasive species and other factors is insensitive to effective population size or levels of genetic diversity, and those other factors pose a much more immediate risk of extinction. Self-sustaining black-footed ferret reintroduction sites have been established successfully in recent years, provided plague management and sufficient amounts of suitable habitat are available (Grenier et al. 2007, Jachowski et al. 2011a, USFWS 2018b). These instances suggest that availability of suitable habitat and implementation of appropriate management practices may take precedence over adherence to strict effective population size parameters, although such factors should be carefully considered in the future recovery strategy for the species, particularly in the context of reproductive fitness and evolutionary potential (Traill et al. 2010, Frankham et al. 2014). Modeling efforts have illustrated the roles of minimum population size, carrying capacity, and the need for periodic population augmentation (CBSG 2004), although these efforts have not explicitly accounted for the role of stressors such as sylvatic plague (Figure 13).

Regardless of the utility of the 30 breeding adult criterion as a minimum viable population size, black-footed ferret reintroduction sites have struggled to meet this level, and few can be considered resilient in the context of achieving stated recovery goals in the 2013 Recovery Plan (USFWS 2013a). An analysis of comprehensive survey data from the only five reintroduction sites to ever meet the minimum 30 breeding adult criterion (Aubrey Valley, Arizona; Butte Creek Ranches, Kansas; Cheyenne River Reservation, South Dakota; Conata Basin-Badlands, South Dakota; and Shirley Basin, Wyoming) showed that the amount of habitat needed by each breeding female exceeded parameters established in the 2013 Black-footed Ferret Recovery Plan (USFWS 2013a). The mean observed area per adult female for black-tailed prairie dog habitat (data from Butte Creek Ranches, Cheyenne River, and Conata Basin-Badlands), Gunnison’s prairie dog habitat (data from Aubrey Valley), and white-tailed prairie dog habitat (data from Shirley Basin) is shown in Table 4. Figure 14 depicts each reintroduction site’s maximum observed size and its projected ability to meet the 30 breeding adult criterion using the mean observed ha/female data from Table 4.

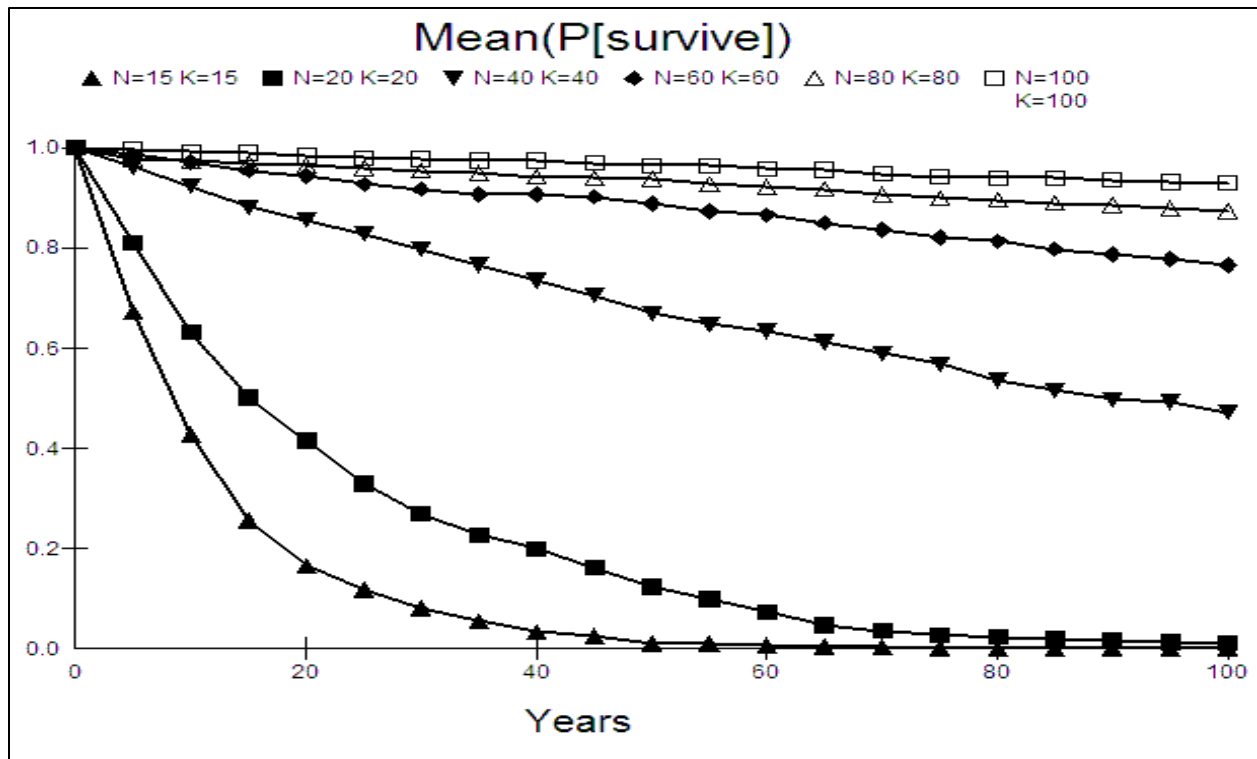


Figure 13. Mean probability of persistence for simulated black-footed ferret populations of different initial size (N), with carrying capacity (K) equal to initial size. From CBSG (2004).

Table 4. Observed area per female (hectares/female) for black-footed ferret reintroduction sites in black-tailed, Gunnison's, and white-tailed prairie dog habitats.

Habitat Type	Mean observed ha/female	95% CI	2013 Recovery Plan ha/female guideline
Black-tailed prairie dog	154.1	±25.7	90.0
Gunnison's prairie dog	649.9	±179.3	152.0
White-tailed prairie dog	227.1	±85.2	152.0

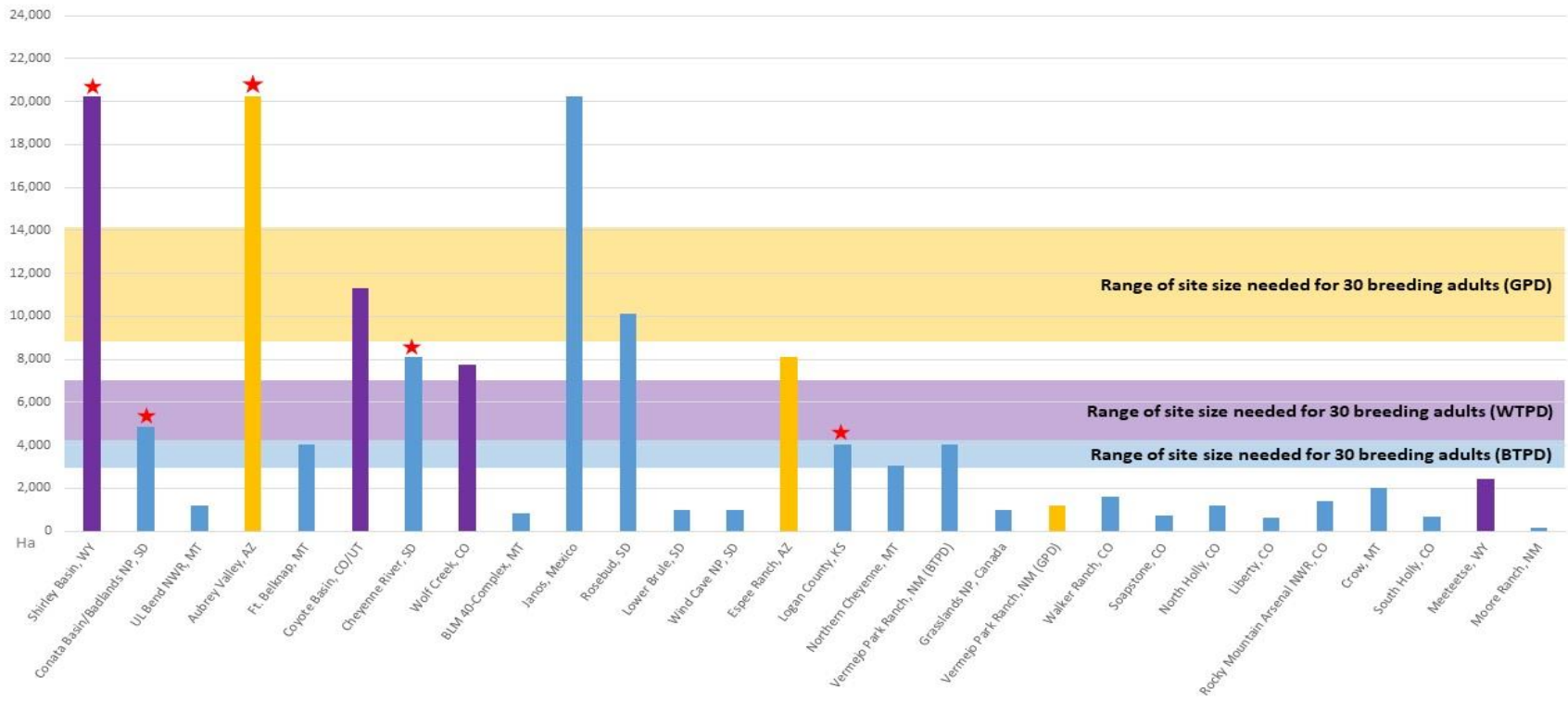


Figure 14. Maximum observed size (ha) of black-footed ferret reintroduction sites and its relationship to confidence intervals showing the range of site sizes needed to support ≥ 30 breeding adult black-footed ferrets in black-tailed (BTPD), Gunnison’s (GPD), and white-tailed (WTPD) prairie dog habitats. Sites are displayed chronologically (left to right) in the order they were initiated. Stars above bars denote sites that have reached the ≥ 30 breeding adult criterion at some point in the past.

We acknowledge that the use of observed area per female to determine minimum habitat area requirements for black-footed ferrets can be problematic, since survey efforts typically do not locate all individuals at a reintroduction site. However, the minimum number alive population estimation methodology used at several reintroduction sites accounts for >82% of all individuals present (Forrest et al. 1988, Biggins et al. 2006b), and more intensive survey data are available for some reintroduction sites that help define minimum habitat area requirements. Data from the Rocky Mountain Arsenal National Wildlife Refuge and UL Bend National Wildlife Refuge reintroduction sites (both located in black-tailed prairie dog habitat) constitute black-footed ferret censuses, and these data illustrate the utility of the suggested area per female guideline found in the 2013 Recovery Plan (USFWS 2013a). The observed area per female at Rocky Mountain Arsenal is 89 ha/female (USFWS 2018b), and the observed area per female at UL Bend is 118 ha/female (USFWS 2018c). Rather than being a conservative estimate as described in the 2013 Recovery Plan, the 90 ha/female criterion for ferrets occupying black-tailed prairie dog habitats (USFWS 2013a) may reflect actual breeding female habitat needs. The discrepancy between the 90 ha/female criterion and the earlier 30 ha/female estimate developed by Biggins et al. (1993) may be due to social behavior of female black-footed ferrets (Biggins et al. 2006d) as well as the effects of enzootic plague that may compromise habitat quality without being readily apparent (Biggins et al. 2010, Matchett et al. 2010).

Since few reintroduction sites have been able to meet the minimum 30 breeding adult criterion due to inherent biological capability and/or sylvatic plague epizootics, most active reintroduction sites have been maintained by frequent releases of captive-born animals (Table 5). Each year approximately 80-100 select kits are retained in the captive population to maintain a stable breeding age structure, and to minimize the loss of genetic diversity; any excess non-essential kits are allocated to reintroduction sites or used for research purposes (USFWS 2017). The allocation of excess kits is essential to starting new reintroduction sites, and allocations to existing reintroduction sites have utility in that they can 1) serve as a means of demographic rescue if the site is in imminent danger of extirpation and 2) ameliorate genetic drift-induced losses of genetic diversity in the short term at sites that are otherwise self-sustaining (Wisely 2006, Wisely et al. 2008). However, frequent augmentation to reintroduction sites is counterproductive to the ultimate goal of establishing self-sustaining, genetically diverse reintroduced populations that can acquire the ability to adapt to local environmental conditions and contribute to overall redundancy (Traill et al. 2010, IUCN/SSC 2013, Rosenfeld 2014). A more sustainable strategy may be to periodically augment self-sustaining reintroduced populations through translocation of other wild-born (or in some instances, captive-born) individuals (Wisely 2006, Wisely et al. 2008). Such a strategy would help foster the cultural transmission of important behaviors in reintroduced populations (Biggins 2000), as well as prevent phenotypic changes that may arise due to declines in genetic diversity (Wisely et al. 2008).

Table 5. Captive-born black-footed ferret kits allocated to active reintroduction sites for population augmentation purposes, 2009-2018 (not including initial releases during the first 3 years of site establishment).

Site	Year Established	Years Augmented	Total kits (males.females)
Shirley Basin, WY	1991	2012, 2017, 2018	26.25
UL Bend NWR, MT	1994	2009, 2013	17.9
Aubrey Valley/Double O Ranch, AZ	1996	2011, 2012, 2013, 2017, 2018	74.42
Coyote Basin, CO/UT	1999	2009, 2011, 2012, 2013, 2018	73.48
Lower Brule Reservation, SD	2006	2011, 2012, 2017, 2018	48.30
Butte Creek Ranches, KS	2007	2010, 2012, 2014, 2016, 2017	64.47
Wind Cave NP, SD	2007	2010, 2013, 2016	16.11
City of Fort Collins, CO	2014	2017, 2018	11.10
Crow Reservation, MT	2015	2018	6.4
TOTAL			335.226

Reintroduction sites vary in their ability to support black-footed ferret populations, primarily due to site size, level of conservation efforts (primarily sylvatic plague mitigation efforts), prairie dog density, drought and other abiotic factors, and the occurrence of sylvatic plague epizootics. Notably, large reintroduction sites located in white-tailed prairie dog habitat such as Shirley Basin, Wyoming, are typically not surveyed in their entirety, and actual population levels may be higher than reported (Grenier et al. 2007, Grenier et al. 2008). Sites such as Shirley Basin may be able to achieve resilience with fewer management inputs such as plague mitigation and population augmentation as a result of their large size and lower sylvatic plague transmission rates, possibly due to the low densities and loose colonial structure of white-tailed prairie dogs (Cully 1989, Cully and Williams 2001, Gasper and Watson 2001). Nonetheless, large white-tailed prairie dog reintroduction sites do experience sylvatic plague epizootics (Menkens and Anderson 1991, Anderson and Williams 1997, Seglund 2010), which can have population-level impacts on black-footed ferrets (Forrest et al. 1988, Wisely et al. 2008, Seglund 2010). Further investigations need to be conducted to assess plague dynamics, black-footed ferret persistence, and the efficacy of plague management efforts in these habitats (Biggins et al. 2010, Russell et al. 2019) to determine their resilience. Tools such as occupancy modeling (MacKenzie et al. 2003) may be more appropriate to assess black-footed ferret population levels in these habitats. See Table 3 for more detailed characteristics of each reintroduction site and its current and past performance.

3.4.3 Stressors Considered for Inclusion in Current Condition Analysis

The current condition of stressors affecting the black-footed ferret are provided in **Section 3.2 Factors Influencing Black-footed Ferret Condition**, which discussed disease, genetic fitness, drought, agricultural land conversion, recreational shooting of prairie dogs, poisoning of prairie dogs, range management, urbanization, and energy development. We did not carry forward all of these stressors into the current condition analysis. A stressor was considered in the current condition analysis if 1) the magnitude of the stressor across the potential range of the black-footed ferret was generally known, 2) a negative effect of the stressor has been quantified, and 3) the stressor was known to affect black-footed ferrets and/or their prairie dog prey at the species level, or if the stressor was known to have synergistic effects with other stressors (Table 6). These stressors are the main factors driving the current condition of the species. In some instances, stressors were combined due to their similarity of effects on black-footed ferret populations, such as prairie dog poisoning and recreational shooting of prairie dogs, as well as their similar roles as additive factors with respect to other stressors (e.g., sylvatic plague; Biggins and Eads 2019). In other cases, identified stressors were a subset of a broader category, such as sylvatic plague.

For a stressor to have a quantifiable negative effect on black-footed ferrets and/or their prairie dog prey, both exposure and response must occur. In some cases, such as energy development and urbanization, measures of exposure were available, but evidence suggests that black-footed ferrets and/or their prairie dog prey are relatively resilient to the stressor and do not exhibit a measurable negative response. A challenge unique to the black-footed ferret is a lack of data showing a link between population performance and stressor exposure, due primarily to the lack of adequate sample size needed to quantify such relationships; black-footed ferrets have been reintroduced at only 29 discrete locations, limiting the level of inference that can be achieved.

We acknowledge that some stressors likely have localized effects within some black-footed ferret reintroduction sites, but this SSA report seeks to quantify the black-footed ferret's viability at the species level. Disease (narrowly defined as sylvatic plague), genetic fitness, drought, and lethal control (a combined category of recreational shooting of prairie dogs and prairie dog poisoning) were carried forward in the current condition analysis because the magnitudes of these stressors within the potential range of the black-footed ferret are known, negative responses have been quantified, and the stressors have species-level effects, either singularly or in combination with other stressors (Figure 15). Effects from the stressors not carried forward in the current condition analysis (agricultural land conversion, range management, and urbanization) were not expected to have a measurable effect at the species level.

Table 6. Consideration of stressors for inclusion in the current condition analysis for the black-footed ferret. To be carried forward in the analysis, the magnitude of the stressor needs to be known, a negative response must be quantified, and the negative response must occur at the species level, either singularly or in combination with another stressor.

Stressor	Magnitude Known?	Negative Response Quantified?	Species-level Response?	Carried Forward in Analysis?
Plague (subset of Disease)	Yes	Yes	Yes	Yes
Genetic Fitness	Yes	Yes	Yes	Yes
Drought	Yes	Yes	Yes	Yes
Agricultural Land Conversion	Yes	Yes	No	No
Lethal Control of Prairie Dogs (combined category; see above)	Yes	Yes	Yes	Yes
Range Management	No	Yes	No	No
Urbanization	Yes	No	No	No
Energy Development	Yes	No	No	No

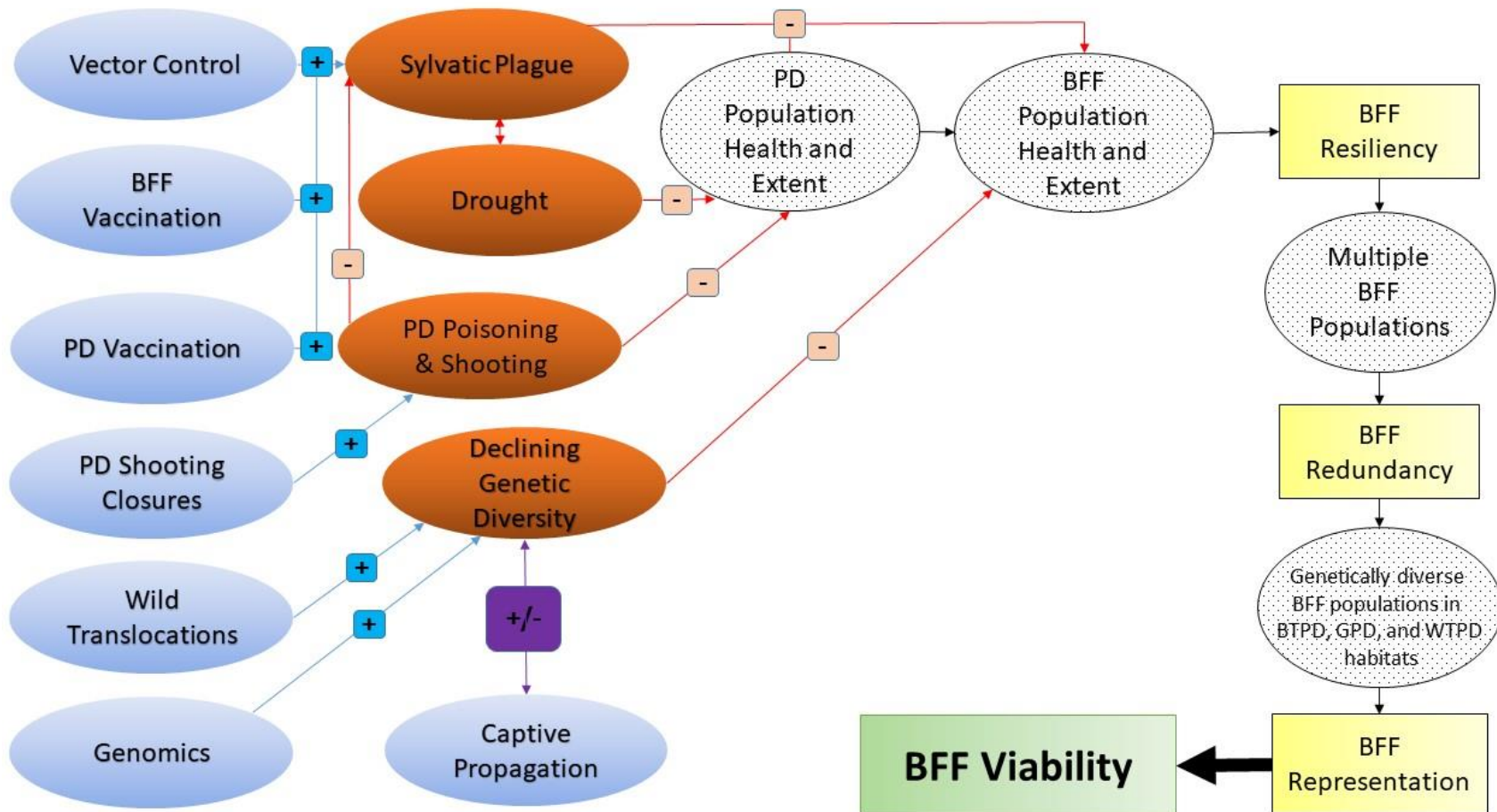


Figure 15. A detailed influence diagram modeling how key stressors and conservation efforts can affect the resilience of black-footed ferret populations. Stressors (orange polygons) decrease the health and extent of prairie dog populations and black-footed ferret populations. Conservation efforts (blue polygons) increase both prairie dog and black-footed ferret population health, and increase black-footed ferret population resiliency. The presence of multiple resilient black-footed ferret populations that are genetically diverse and located in diverse habitat types increases redundancy and representation, and overall black-footed ferret viability.

3.4.4 Analysis of Current Condition

To assist with the analysis of current condition for the black-footed ferret, we utilized an expert panel comprised of conservation professionals familiar with the conservation biology of the black-footed ferret to develop matrices describing the current resiliency of captive and reintroduced black-footed ferret populations. The matrices were developed by combining the stressors identified in **Section 3.4.3** with abundance and trend data (see **Sections 3.4.1 and 3.4.2**, above) and current and suggested conservation measures. The analysis units used in the matrices were locations of black-footed ferret captive breeding facilities (Table 2) and black-footed ferret reintroduction sites (Table 3). The categories used for the matrices are described below.

3.4.4.1 Current Resiliency of the Captive Black-footed Ferret Population

The classes used to evaluate the current resiliency of the captive black-footed ferret population are % whelping success (Figure 9), the mean number of kits born per litter (Figure 10), and the percentage of total kits weaned (Figure 12). These classes capture the level of breeding success, animal condition, and husbandry effectiveness for the six facilities housing the captive population, and were developed with the assistance of members of the Black-footed Ferret SSP[®]. While not stated explicitly, these classes are also an indirect measure of declining genetic diversity. Scores were assigned using the criteria shown in Table 7.

Table 7. Current resilience classes and scores used in the evaluation of the captive black-footed ferret population.

Parameter of Interest	Values for Score of 3 (high)	Values for Score of 2 (moderate)	Values for Score of 1 (low)
% Whelping success	>60%	40-59%	<40%
Mean # of kits/litter	>4	3-4	<3
% Kits weaned	>90%	80-89%	<80%

These classes were evaluated for each facility housing the captive population for the period 2009 to 2013 (Table 8) and 2014 to 2018 (Table 9). Scores were summed across categories to derive total resiliency class scores, which were classified as >7=high, 5-7=moderate, and <5=low. Scores generally declined in most classes for each facility between the two time periods evaluated.

Table 8. Current resiliency table for facilities housing the black-footed ferret SSP® population, 2009-2013. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	2	3	2	7
Smithsonian Conservation Biology Institute	3	3	3	9
Louisville Zoological Garden	3	3	3	9
Cheyenne Mountain Zoo	2	2	1	5
Phoenix Zoo	1	2	1	4
Toronto Zoo	2	3	2	7

Table 9. Current resiliency table for facilities housing the black-footed ferret SSP® population, 2014-2018. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	1	3	2	6
Smithsonian Conservation Biology Institute	3	3	2	8
Louisville Zoological Garden	2	2	1	5
Cheyenne Mountain Zoo	1	3	1	5
Phoenix Zoo	1	2	1	4
Toronto Zoo	1	2	2	5

3.4.4.2 Current Resiliency of the Reintroduced Black-footed Ferret Population

The classes used to evaluate the current resiliency of the reintroduced black-footed ferret population are the five-year mean number of breeding adult ferrets, the five-year mean ferret family rating (a biomass-based index of black-footed ferret habitat suitability incorporating prairie dog colony area and prairie dog density; see Biggins et al. 1993 and Biggins et al. 2006d for details), annual plague management level, annual black-footed ferret vaccination level, black-footed ferret population persistence, and level of prairie dog population protection. High, moderate, and low scores for each class are 3, 2, and 1, respectively; some classes included a

value of zero if ferrets were not present at a reintroduction site, and others were weighted. An occupancy multiplier (1 for occupied, 0 for unoccupied) was used to prevent inflation of scores for unoccupied sites. Descriptions of the classes and scoring methodology used are found in Table 10.

Resiliency classes were evaluated for 29 discrete black-footed ferret reintroduction sites for the period 2014-2018. The 5-year mean number of breeding adults and ferret population persistence classes provide a measure of demographic performance, and potentially address the stressor of declining genetic diversity. The 5-year mean ferret family rating class provides a measure of habitat suitability, and how it is influenced by the stressors of drought, sylvatic plague, and prairie dog poisoning and shooting. The annual plague management level and annual ferret vaccination level classes directly address the stressor of sylvatic plague, and the level of prairie dog protection class addresses the combined stressor of prairie dog poisoning and shooting. Due to their importance to black-footed ferret population resilience, the 5-year number of breeding adults class was weighted by a factor of 10, and the 5-year mean ferret family rating and annual plague management level classes were weighted by a factor of 5. Adjusted current resiliency class scores were classified as 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High (Table 11).

Table 10. Descriptions of resiliency class scores used in the evaluation of the reintroduced black-footed ferret population.

Class	Description and Scoring Methodology	Stressors Addressed
5-year Mean Number of Breeding Adults (from Fall surveys)	>30=high, 10-30=moderate, <10=low, 0=inactive/no value; raw score weighted by a factor of 10	Drought, sylvatic plague, declining genetic diversity
5-year Mean Ferret Family Rating	>100=high, 30-100-moderate, <30=low; raw score weighted by a factor of 5	Drought, sylvatic plague, prairie dog poisoning and shooting
Annual Plague Management Level	>50% of available acreage treated=high, ≤50% of available acreage treated or plague epizootic not documented at site=moderate, minimal or no plague management undertaken annually=low; raw score weighted by a factor of 5	Sylvatic plague
Annual Ferret Vaccination Level	>50% of population vaccinated each year=high, ≤50% of population vaccinated each year=moderate, minimal or no vaccination effort=low	Sylvatic plague
Ferret Population Persistence	self-sustaining=high, ≤1 population augmentation in 5 years=moderate, >1 population augmentation in 5 years=low, no ferrets present at site for the past 5 years=no value	Drought, sylvatic plague, declining genetic diversity
Level of Prairie Dog Protection	No lethal control permitted=high, lethal control regulated=moderate, lethal control unregulated=low	Prairie dog poisoning and shooting

Table 11. Current resiliency table for 29 black-footed ferret reintroduction sites, 2014-2018. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high). Adjusted current resiliency is a weighted value that is the result of multiplying the 5-year mean # of breeding adults class by 10 and the 5-year mean ferret family rating and annual plague management level classes by 5, and adding these values to the remaining classes. Adjusted current resiliency rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High

Site and Location	Prairie Dog Species	5-year mean # of breeding adults (10X)	5-year mean ferret family rating (5X)	Annual Plague Management Level (5X)	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD protection	Occupancy Multiplier (1 or 0)	Adjusted Current Resiliency
Conata Basin, SD	BTPD	3	3	3	3	3	3	1	69
UL Bend NWR, MT	BTPD	1	1	2	3	2	3	1	33
Ft. Belknap, MT	BTPD	1	1	2	3	1	2	1	31
Cheyenne River, SD	BTPD	1	2	1	1	1	1	0	0
BLM 40 Complex, MT	BTPD	0	1	1	1	0	1	0	0
Janos, MX	BTPD	0	2	1	1	0	1	0	0
Rosebud, SD	BTPD	1	2	1	1	1	1	0	0
Lower Brule, SD	BTPD	1	1	2	3	1	2	1	31
Wind Cave NP, SD	BTPD	1	2	2	3	1	3	1	37
Butte Creek Ranches, KS	BTPD	1	2	2	3	1	3	1	37
Northern Cheyenne, MT	BTPD	0	1	1	1	0	1	0	0
Vermejo BTPD, NM	BTPD	1	2	1	1	1	3	0	0
Grasslands NP, SK	BTPD	0	1	1	1	0	3	0	0
Walker Ranch, CO	BTPD	0	1	3	1	0	3	0	0
City of Fort Collins, CO	BTPD	1	1	3	3	1	3	1	37
North Holly, CO	BTPD	1	1	3	1	1	3	0	0
Liberty, CO	BTPD	1	1	3	1	1	3	0	0
Rocky Mountain Arsenal NWR, CO	BTPD	2	2	3	3	3	3	1	54

Site and Location	Prairie Dog Species	5-year mean # of breeding adults (10X)	5-year mean ferret family rating (5X)	Annual Plague Management Level (5X)	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD protection	Occupancy Multiplier (1 or 0)	Adjusted Current Resiliency
Bad River Ranch, SD	BTPD	1	1	2	1	1	3	0	0
Crow Reservation, MT	BTPD	1	1	2	2	1	2	1	30
South Holly, CO	BTPD	1	1	3	1	1	3	0	0
Moore Ranch, NM	BTPD	1	1	3	1	1	3	1	35
Aubrey Valley, AZ	GPD	2	3	2	2	1	2	1	50
Espee Ranch, AZ	GPD	1	2	2	1	1	2	0	0
Vermejo GPD, NM	GPD	1	1	1	1	1	3	0	0
Shirley Basin, WY	WTPD	2	3	1	2	2	2	1	46
Coyote Basin, CO-UT	WTPD	1	3	2	1	1	2	1	39
Wolf Creek, CO	WTPD	0	1	1	1	0	2	0	0
Meeteetse, WY	WTPD	1	2	3	3	1	2	0	41

3.5 Summary of Historical and Current Condition in terms of the 3Rs

According to our analysis of relevant data and through the development of condition classes to make these data comparable between analysis units, one of the six captive breeding facilities within the black-footed ferret captive population is in high condition, four are in moderate condition, and one is in low condition with respect to resiliency. Data from previous years (Table 8) suggest that the condition class values for most facilities have declined over time, and the long-term trend of declining whelping rates (Figure 9) may be the result of this phenomenon. While the overall condition of the black-footed ferret captive population can be considered resilient in that stable age structure and sex ratios have been maintained while maximizing the conservation of remaining genetic diversity (Wisely et al. 2003), recent trends may reflect a decline in the population's overall resiliency. The redundancy of the captive population (consisting of six captive breeding facilities) has remained unchanged for over 10 years. The captive population cannot increase its limited genetic representation due to its static number of founders, unless technologies such as iSCNT can be utilized to arrest the erosion of genetic diversity (Wisely et al. 2015).

Results for the reintroduced population indicate that two reintroduction sites are in high condition, eight are in moderate condition, four are in low condition with respect to resiliency, and 15 are inactive. Population trends are negative (Figure 11), and population levels have not kept pace with the rate at which new reintroduction sites have been added (Figure 12). Overall resiliency for this population is low, given the need to augment existing reintroduction sites regularly with excess animals from the captive population, and most importantly the need for continuous management inputs such as plague management and black-footed ferret vaccination to keep individual sites from succumbing to sylvatic plague epizootics. The redundancy of this population has been compromised in recent years, with only 14 of 29 reintroduction sites being classified as active. While this population does occur within the ranges of all three species of prairie dogs as it did historically, only one active population exists within Gunnison's prairie dog habitat, reducing overall population redundancy and ecological representation. Genetic representation is also limited, as ferrets that occupy most reintroduction sites are still closely related to ferrets from the captive population, primarily due to frequent population augmentations.

It is important for us to acknowledge that the black-footed ferret is a conservation-reliant species (Scott et al. 2010, Rohlf et al. 2014), and as such considerable management inputs are required to maintain both the captive and reintroduced populations of the species. These inputs include management and oversight of a captive breeding program, veterinary care and animal husbandry (USFWS 2017), maintenance of a preconditioning program (Biggins et al. 1998, USFWS 2017), and plague management and ferret vaccination programs at individual reintroduction sites. This

past and ongoing management has been crucial to maintaining the current levels of resiliency, redundancy, and representation of the black-footed ferret.

Chapter 4. Future Condition

In this chapter, we project the future condition of the six captive breeding facilities within the black-footed ferret SSP[®] population, and the 29 reintroduction sites comprising the reintroduced black-footed ferret population. This analysis includes five potential scenarios of changes in stressors (due in part to climate change) and conservation efforts. The scenarios are evaluated over two timeframes (10 years and 20 years) in an effort to predict how viability of the black-footed ferret may change in the future. These timeframes were chosen due to the short generation time of the black-footed ferret (3-4 years), the high level of variation experienced by populations in response to drought, sylvatic plague, and other factors, and the small numbers of individuals at several reintroduction sites. Many reintroduction sites have a high likelihood of experiencing local extirpations (see Figure 13) due to their small local population sizes, and as a result are often re-initiated through the release of captive-reared animals on a relatively frequent (3 to 7 years) basis. In addition, the known annual loss of genetic diversity (currently estimated to be 0.17 percent per year; see Graves et al. 2018) makes it incumbent on managers to identify potential conservation practices as quickly as possible. This high level of variability complicated analyses using longer timeframes, so we attempted to address known stressors and their effects on black-footed ferret populations using these shorter timeframes.

4.1 Climate Change

Greenhouse gas (GHG) emissions increased at an unprecedented rate during the 20th century, resulting in global climate change characterized by warming atmospheric and ocean temperatures, diminishing coverage of snow and ice, and rising sea levels (Intergovernmental Panel on Climate Change (IPCC) 2014). Scientists use a variety of climate models, which include consideration of natural processes and variability as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (Meehl et al. 2007, Ganguly et al. 2009, Prinn et al. 2011). Combinations of models and emission scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature, until approximately 2030. Although projections of the magnitude and rate of warming differ after 2030, the overall trajectory of all of the projections is one of increased surface temperature through the end of this century, even for projections based on scenarios that assume GHG emissions will stabilize or decline. Regardless of the projections in question, there is strong evidence that average surface temperatures will continue to increase through the 21st century, and the magnitude and rate of this change will be substantially influenced by the extent of GHG emissions (Meehl et al. 2007, Ganguly et al. 2009, Prinn et al. 2011, IPCC 2014).

It is important for us to include the potential effects of climate change in our analysis of the future condition of the black-footed ferret, primarily due to its effects on two primary stressors affecting black-footed ferret populations, drought and sylvatic plague (Facka et al. 2010, Eads et al. 2016). To do this, we used climate change data obtained from the USGS National Climate Change Viewer (NCCV; Alder and Hostetler 2013). The NCCV averages the results of 33 global climate change (GCM) models and provides predictions for two GHG emissions scenarios called Representative Concentration Pathways (RCP). The two scenarios (RCP4.5 and RCP8.5) are projected through three future time periods (2025 to 2049, 2050 to 2074, and 2075 to 2099), which in turn are compared against a reference period from 1981 to 2005 (Alder and Hostetler 2013). The two GHG emissions scenarios used in the NCCV come from the latest IPCC report (IPCC 2014). The RCP4.5 scenario is an intermediate emissions scenario where atmospheric CO₂ concentrations are expected to equal approximately 650 ppm by the year 2099. The RCP8.5 scenario is more aggressive, with atmospheric CO₂ concentrations rising to approximately 1370 ppm by 2099. For comparison, current atmospheric CO₂ concentrations are approximately 400 ppm (Alder and Hostetler 2013).

To evaluate climate predictions throughout the potential range of the black-footed ferret, we developed NCCV model predictions at the scale of individual counties, and selected counties where reintroduction sites for black-footed ferrets have occurred (28 counties in 8 states). For reintroduction sites in Canada and Mexico, which are close to the U.S. border, we selected the U.S. counties located closest to the reintroduction sites (2 counties in 2 states). Although this frame of analysis is somewhat restrictive, the distribution of black-footed ferret reintroduction sites covers most of its potential range (Figure 2), with the exception of the eastern portion. To address this shortcoming, we selected eight additional counties in the states of Kansas, Nebraska, North Dakota, Oklahoma, and Texas where potential reintroduction sites have been identified (Luce 2006), to enhance the geographic coverage of our analysis. A total of 38 counties located in 12 states were used to develop NCCV model predictions (Table 12). Since the end points of the two time periods of interest we identified for this report (2029 and 2039) both fall within the NCCV 2025-2049 climatology period, we differentiated between the two points by using the time series function in the NCCV. We used the time series function to identify discrete values of parameters of interest by year in the model, which allowed us to differentiate between the two points quantitatively through trend analysis. We used different emission scenarios (RCPs) depending on the parameters set forth in each of our future scenarios (see **Section 4.2.2 Descriptions of Future Scenarios**).

Table 12. United States counties used to develop National Climate Change Viewer projections of climate change within the potential range of the black-footed ferret.

State	Counties of Interest
Arizona	Coconino, Mojave
Colorado	Adams, Baca, Larimer, Moffat, Prowers, Pueblo, Weld
Kansas	Barber, Logan
Montana	Big Horn, Blaine, Phillips, Powder River, Yellowstone
Nebraska	Garden
New Mexico	Colfax, Hidalgo, Mora
North Dakota	McKenzie, Sioux
Oklahoma	Beaver
South Dakota	Custer, Dewey, Lyman, Pennington, Stanley, Todd, Ziebach
Texas	Brewster, Lipscomb, Sherman
Utah	Uintah
Wyoming	Albany, Carbon, Natrona, Park

Across both of our future climate scenarios, mean annual maximum temperature is expected to increase over time within the potential range of the black-footed ferret, with the magnitude of the increase amplified under the RCP8.5 emissions scenario. While most of the counties of interest followed the general pattern of increasing spring precipitation and decreasing summer precipitation, some counties in the southern portion of the range may experience reduced spring precipitation as well, with little to no change in summer precipitation. Across the potential range, soil water storage is expected to decrease, and evaporative deficit is expected to increase. Evaporative deficit is the difference between water availability in the soil and water lost to evapotranspiration. As evaporative deficit increases, the landscape becomes drier and drought conditions increase in severity and duration.

Because drought and plague are significant stressors in terms of their effects on black-footed ferret habitat quality, we focused on evaporative deficit instead of annual maximum temperature or precipitation levels as a measure of climate change that may have the greatest effect on the viability of the species. Plague dynamics are thought to be influenced by drought, although the mechanisms are not well understood and results are sometimes conflicting (Snall et al. 2009, Eads et al. 2016, Eads and Biggins 2017). The effects of more commonly used measures such as increased temperature and precipitation on plague can confound each other, and the effects of increased temperature override increased precipitation in some models (Stewart et al. 2004). This phenomenon explains the expected decrease in soil moisture and increase in evaporative deficit within the potential range of the black-footed ferret in the future. These effects suggest that at the potential range scale, black-footed ferret habitat may become drier in the future as a result of climate change (Stewart et al. 2004, Dai 2011). This effect is likely amplified under

increasing levels of GHG emissions (Alder and Hostetler 2013). For these reasons, we utilized measures of evaporative deficit for our predictions of drought conditions that may affect the viability of the black-footed ferret in the future.

4.2 Analysis of Future Condition

4.2.1 Acknowledgment of Uncertainty

Climate models are useful in that they allow us to make predictions of how climate may change in the future, but their results should be interpreted carefully. Models are mathematical representations of what can happen, but they do not always accurately predict future events. The accuracy of climate models has improved in recent years, but projections for precipitation remain less reliable than those for surface temperature (O’Gorman and Schneider 2009, Trenberth 2011, IPCC 2014). For our analysis of the black-footed ferret’s future condition, we acknowledge the inherent uncertainty associated with climate modeling, particularly with respect to the frequency and severity of drought, one of the primary stressors with respect to black-footed ferret habitat quality. We also recognize that these models represent some of the best available scientific data that we can utilize for projecting the species’ future condition.

Several studies have predicted an increase in precipitation variability in the future due to the effects of climate change, primarily in the form of more frequent extreme precipitation events (O’Gorman and Schneider 2009, Trenberth 2011, IPCC 2014). An increase in extreme precipitation events does not necessarily equate to a wetter environment, as this escalation is offset by increasing temperatures and rates of evapotranspiration (Trenberth 2011). Rather, this represents a redistribution of annual precipitation that leads to a drier landscape overall (Trenberth 2011). While there is good evidence for increased precipitation variability in the future, unfortunately there is not a metric available to measure this increase. This is important in the context of future condition analyses involving plague, as epizootics may follow short-term periods of dramatic variation in timing and amount of precipitation (Eads et al. 2016, Eads and Biggins 2017). Due to this limitation, we used conservative judgment and assumed that increased precipitation variability only served to increase the frequency of plague epizootics under future condition scenarios using the RCP8.5 climate change scenario.

Uncertainties also exist with respect to the efficacy of conservation efforts in the future. Due to the considerable management inputs required to maintain both the captive and reintroduced black-footed ferret populations and the species’ high susceptibility to plague, we assume that some form of plague management (a combination of vector control, oral vaccine baits, and individual ferret vaccination) is required to prevent the extirpation of the reintroduced population. As noted above (see **Section 3.4.2.2 Reintroduced Black-footed Ferret Population**), larger black-footed ferret reintroduction sites in white-tailed prairie dog habitat

may exhibit greater resiliency with respect to susceptibility to sylvatic plague, so these sites may not require the level of plague management that sites located in other habitats require. At present limited resources prevent the implementation of plague management at every reintroduction site, and we cannot predict the availability of plague management resources in the future. The plague management data presented in Table 1 is considered a baseline level of plague management, with approximately 20% of the habitat currently occupied by the reintroduced black-footed ferret receiving some form of plague management. Additionally, it is likely that the efficacy of various plague management techniques are not equal, and additional research on formulation, timing of application, and synergistic effects is needed (Tripp et al. 2014, Tripp et al. 2017).

4.2.2 Description of Future Condition Scenarios

We used the condition classes developed for the captive and reintroduced black-footed ferret populations (Tables 7 and 10, respectively) to frame our future condition analysis for both populations. These condition classes were informed by abundance and trend data for both populations (**Section 3.4.2**) and identified stressors (**Section 3.4.3**). For our future condition analysis, we constructed five scenarios focused on changes in climate, levels of conservation efforts, reintroduction site habitat quality and quantity (reintroduced population only), and production levels of black-footed ferret kits from both the captive and reintroduced populations. These scenarios are meant to represent the wide range of future conditions that could occur in the black-footed ferret's potential range. We projected each scenario to two time periods in our analysis of future condition, 10 and 20 years from the present. Depending on the scenario, the RCP4.5 or RCP8.5 emission scenarios were used for the climatology period of 2025-2049.

Continuation Scenario

This scenario is a continuation of current conditions, with management of existing reintroduction sites and captive breeding facilities continuing at the same scale and intensity. New reintroduction sites are added at the same rate as observed during the past five years (approximately two per year), and new sites are the mean size of sites added during the past five years (975 ha). The current baseline of approximately 20% of all active habitat receives plague management each year, and plague epizootics occur at their current magnitude and frequency. Ferret vaccination efforts at reintroduction sites continue at their current level, and prairie dog protection levels are unchanged. Limited incentive programs are available to encourage non-federal landowners to participate in black-footed ferret recovery. Captive population reproduction metrics (whelping success, mean number of kits born per litter, and weaning %) continue to follow current trends, and 15 wild-born kits are available each year for translocation from existing to new reintroduction sites. Greenhouse gas emissions follow the RCP4.5 scenario.

Pessimistic Scenario

Under this scenario, 10% of active habitat receives plague management each year, and plague epizootics increase in magnitude and frequency. Ferret vaccination rates do not exceed 50% for any reintroduction site, and no new reintroduction sites are developed. Prairie dog protection levels are unchanged. Incentive programs are not available for non-federal landowners. Captive population reproduction metrics decline by 10% relative to 5-year mean values, and no wild-born kits are available for translocation. Greenhouse gas emissions follow the RCP8.5 scenario.

Disastrous Scenario

This scenario represents a significant loss in management intervention capability, with only 5% of active habitat receiving plague management each year. Plague epizootics increase in magnitude and frequency. Ferret vaccination rates do not exceed 25% for any reintroduction site, and no new reintroduction sites are developed. Prairie dog protection levels decrease, with no reintroduction sites except for those associated with National Parks and National Wildlife Refuges having complete prohibitions on lethal control. Incentive programs are not available for non-federal landowners. Captive population reproduction metrics decline by 50% relative to 5-year mean values, and no wild-born kits are available for translocation. Greenhouse gas emissions follow the RCP8.5 scenario.

Optimistic Scenario

This scenario represents an increase in management intervention capability, with $\geq 50\%$ of active habitat receiving plague management each year. Five new reintroduction sites capable of supporting ≥ 30 breeding adults each are added to the reintroduced population by the year 2029. Prairie dog protection levels are unchanged, and $> 50\%$ of new reintroduction sites added have complete prohibitions on lethal control of prairie dogs. Incentive programs for non-federal landowners are available throughout the potential range. Captive population reproduction metrics increase by 20% relative to 5-year mean values, and ≥ 30 wild-born kits are available for translocation each year. Greenhouse gas emissions follow the RCP4.5 scenario.

Transformation Scenario

This scenario includes technological breakthroughs and increased resource availability for management intervention. Plague management is implemented annually on $\geq 75\%$ of active habitat due to the development of additional cost-effective management tools, and five new reintroduction sites capable of supporting ≥ 100 breeding adults each are added to the reintroduced population by the year 2029. Prairie dog protection levels are unchanged, and $> 75\%$ of new reintroduction sites added have complete prohibitions on lethal control of prairie dogs. Incentive programs for both non-federal landowners as well as lessees of federal lands are available. Captive production metrics increase by 30% relative to 5-year mean values, and captive-reared animals exhibit some resistance to plague through the use of genomic

technologies. At least 50 wild-born kits are available for translocation each year. Greenhouse gas emissions follow the RCP4.5 scenario.

4.2.3 Predicting Future Condition

We predicted the future conditions of each analysis unit (6 captive breeding facilities and 29 reintroduction sites) based on a combination of current population trends and variations of stressors and conservation efforts specified in our future scenarios. Specifically, we predicted how these factors influenced the three classes developed for our current resiliency analysis for the captive black-footed ferret population (Table 7), and the six classes developed for our current resiliency analysis for the reintroduced black-footed ferret population (Table 10). For the three classes associated with the captive population, we considered current population trends, conservation efforts, and the stressor of genetic fitness. For the six classes associated with the reintroduced population, we considered current population trends, conservation efforts, and the stressors of plague, genetic fitness, lethal control of prairie dogs, and drought.

Drought and its effects on black-footed ferret habitat quality and plague occurrence were assessed by looking at future projections of evaporative deficit in each of the scaled-down climate models described in **Section 4.1 Climate Change**. Although the scope of our analysis (conditions at 2029 and 2039) falls within the same NCCV climatology period (2025-2049), we discerned changes in evaporative deficit between the two points by using the time series function in the NCCV. Use of the time series function enabled us to identify discrete values of evaporative deficit by year in the model, which enabled us to differentiate between the two points quantitatively through trend analysis for each of our counties of interest. We also evaluated trend for evaporation deficit over the entire 2019-2039 interval, and noted instances where model results changed in significance between different climate scenarios (1981-2010, RCP4.5, and RCP8.5).

We scored each of the resiliency classes in our future condition analysis in the same manner as our current resiliency analyses for the both the captive and reintroduced black-footed ferret populations. For the reintroduced population, we weighted resiliency classes in the same manner as the current resiliency analysis (see **Section 3.4.4.2** and Tables 10 and 11). For future scenarios that included the addition of reintroduction sites, we did not add them as discrete analysis units to the 29 current units in our evaluation of resiliency; rather, we evaluated their contribution in a qualitative sense to overall species redundancy and representation.

4.2.4 Results of Future Condition Analysis

In this section, we present the results of our future condition analysis under five scenarios, 10 and 20 years into the future. These analyses follow the same scoring methodologies described in

Sections 3.4.4.1 and 3.4.4.2, and results are summarized in Tables 13 and 14 below. Full future condition tables with results for each condition class, under each scenario and at each time point, are included in the Appendix.

Table 13. Summary of future condition analysis results for the captive black-footed ferret population under five scenarios during two time periods. Numbers denote resiliency class scores (<5=low, 5-7=moderate, and >7=high).

Facility	Continuation Scenario		Pessimistic Scenario		Disastrous Scenario		Optimistic Scenario		Transformation Scenario	
	2029	2039	2029	2039	2029	2039	2029	2039	2029	2039
National Black-footed Ferret Conservation Center	6	6	4	4	3	3	8	9	9	9
Smithsonian Conservation Biology Institute	8	7	5	5	3	3	9	9	9	9
Louisville Zoological Garden	5	4	5	4	3	3	8	8	9	9
Cheyenne Mountain Zoo	5	5	4	4	3	3	8	8	9	9
Phoenix Zoo	3	3	3	3	3	3	5	6	9	9
Toronto Zoo	5	4	4	4	3	3	8	8	9	9

Table 14. Summary of future condition analysis for the reintroduced black-footed ferret population under five scenarios during two time periods. Numbers in each cell denote adjusted future resiliency class scores (0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High; see Table 11 for description of scoring methodology)

Site and Location	Prairie Dog Species	Continuation Scenario		Pessimistic Scenario		Disastrous Scenario		Optimistic Scenario		Transformation Scenario	
		2029	2039	2029	2039	2029	2039	2029	2039	2029	2039
Conata Basin, SD	BTPD	69	69	48	48	41	41	69	69	69	69
UL Bend NWR, MT	BTPD	33	33	0	0	0	0	53	53	54	54
Ft. Belknap, MT	BTPD	31	31	0	0	0	0	46	46	69	69
Cheyenne River, SD	BTPD	0	0	0	0	0	0	46	46	69	69
BLM 40 Complex, MT	BTPD	0	0	0	0	0	0	35	35	44	44
Janos, MX	BTPD	0	0	0	0	0	0	0	0	69	69
Rosebud, SD	BTPD	0	0	0	0	0	0	45	45	69	69
Lower Brule, SD	BTPD	31	31	30	30	0	0	37	37	52	52
Wind Cave NP, SD	BTPD	37	37	31	31	0	0	43	43	54	54
Butte Creek Ranches, KS	BTPD	37	37	31	31	0	0	53	53	63	63
Northern Cheyenne, MT	BTPD	0	0	0	0	0	0	28	28	46	46
Vermejo BTPD, NM	BTPD	0	0	0	0	0	0	45	30	69	69
Grasslands NP, SK	BTPD	0	0	0	0	0	0	36	36	43	43
Walker Ranch, CO	BTPD	0	0	0	0	0	0	35	35	53	53
City of Fort Collins, CO	BTPD	37	37	31	31	0	0	37	37	44	44
North Holly, CO	BTPD	0	0	0	0	0	0	0	0	43	43
Liberty, CO	BTPD	0	0	0	0	0	0	0	0	43	43
Rocky Mountain Arsenal NWR, CO	BTPD	54	54	47	47	41	41	54	54	64	64
Crow Reservation, MT	BTPD	30	0	0	0	0	0	30	30	46	46
South Holly, CO	BTPD	0	0	0	0	0	0	0	0	37	37
Bad River Ranch, SD	BTPD	0	0	0	0	0	0	30	30	54	54
Moore Ranch, NM	BTPD	0	0	0	0	0	0	0	0	37	37
Aubrey Valley, AZ	GPD	45	45	36	35	0	0	61	51	53	68
Espee Ranch, AZ	GPD	0	0	0	0	0	0	35	30	52	52
Vermejo GPD, NM	GPD	0	0	0	0	0	0	0	0	53	53
Shirley Basin, WY	WTPD	46	46	37	41	35	35	51	51	68	68
Coyote Basin, CO-UT	WTPD	39	33	29	24	0	0	51	46	53	68
Wolf Creek, CO	WTPD	0	0	0	0	0	0	34	34	52	57
Meeteetse, WY	WTPD	41	41	35	35	23	0	52	52	68	68

Results: Continuation Scenario

A continuation of current management practices but under increasing levels of GHG under the RCP4.5 scenario leads to continued declines in resiliency for the reintroduced black-footed ferret population, while declining genetic fitness contributes to lower levels of resiliency for the captive black-footed ferret population. By extrapolating current trends, in 10 years we project that the Phoenix Zoo will decline from moderate to low condition in mean number of kits born per litter, but overall resiliency condition class does not change. Over a 20-year timeframe, we project that the Toronto Zoo will move from moderate to low resiliency condition due to continued declines in mean number of kits born per litter, and the Smithsonian Conservation Biology Institute will move from high to moderate condition due to declining whelping success.

For the reintroduced black-footed ferret population, in 10 years we project that the effects of increased drought will cause one site (Aubrey Valley/Double O Ranch) to decline in 5-year mean family ferret rating, reducing its overall score but keeping it in the moderate resiliency class. Increased drought will also hinder the recovery of extirpated sites in the southern portion of the potential range (Vermejo Ranch BTPD, Walker Ranch, North Holly, South Holly, and Liberty), preventing their reestablishment using captive-born or wild translocated animals. Due to drought and its vulnerability to demographic stochasticity because of its small size, we project that the Moore Ranch site will become inactive. In 20 years, we predict that increasing drought effects will reduce ferret family rating values at the Coyote Basin reintroduction site, reducing its overall score but keeping it in the moderate resiliency class. During this time period, we also predict that the Crow Reservation site becomes inactive, due a lack of availability of captive-born kits (see discussion below) for population augmentation, and erosion of ferret family rating due to increasing drought effects.

This scenario calls for the establishment of an average of two reintroduction sites per year averaging 975 ha. Given drought effects and declining availability of captive-born kits, this rate of reintroduction site recruitment is likely not sustainable even in a 10-year planning horizon, regardless of the availability of incentives for non-federal landowners. Moreover, sites of this size are unlikely to contribute appreciably to long-term redundancy and representation due to their demonstrably high extinction rates (see **Section 3.4.4.2**).

Synopsis: Continuation Scenario

In the Continuation Scenario, both the captive and reintroduced black-footed ferret populations will continue to persist during both timeframes, albeit with slightly reduced resiliency and redundancy. Current trends, coupled with predicted declines in genetic fitness, will cause a reduction the resiliency of the captive population, due primarily to declines in whelping success and mean number of kits per litter. For the reintroduced population, drought will erode ferret family rating values, but sites will maintain their current resiliency levels for the most part. Smaller, less resilient sites may become extinct due to demographic stochasticity and a lack of

availability of captive-born kits for augmentation purposes, but wild-born kits from sites such as Rocky Mountain Arsenal NWR may be able to partially meet reintroduction site augmentation needs. Overall, both the captive and reintroduced black-footed populations retain some degree of resiliency, with some loss of redundancy in the reintroduced population due to site extinctions. Representation is largely unchanged, although the continued erosion of genetic diversity in the captive population reduces overall representation in a genetic context.

Results: Pessimistic Scenario

This scenario represents a general increase in the level of stressors, as well as a decrease in conservation efforts and captive population performance. Under the 10-year planning horizon, the resiliency scores for the captive black-footed ferret population are reduced markedly, with only two of the six facilities in moderate condition and the remaining four facilities in low condition. The captive population would not be able to provide any kits for release at reintroduction sites, and facilities would be challenged to maintain appropriate sex and age structure and mean kinship criteria under this scenario. At 20 years, the Louisville Zoological Garden moves from moderate to low condition, leaving the Smithsonian Conservation Biology Institute as the only facility in moderate condition with respect to resiliency.

For the reintroduced population, plague would greatly increase in magnitude as a stressor, given reduced resources to implement plague management, a lower ferret vaccination rate, and increased year-to-year variability in precipitation causing more frequent epizootics. For the 10-year planning horizon, no sites are in high resiliency condition, four sites are in moderate condition, six sites are in low condition, and 19 sites are inactive. Conditions worsen for the 20-year planning horizon as drought conditions, particularly in the southern and western portions of the potential range, continue to erode mean ferret family rating. With increasing precipitation variability, plague epizootics become more frequent. At 20 years, the numbers remain the same for all resiliency condition classes, but overall scores of individual sites continue to decline.

Synopsis: Pessimistic Scenario

In the Pessimistic Scenario, the captive black-footed ferret population experiences a significant decline in population performance, with no kits available for release at reintroduction sites and the beginnings of demographic breakdown due to a limited number of kits available for retention in the breeding population. For the reintroduced population, the effects of limited conservation efforts, declining habitat quality due to drought, and more frequent plague epizootics reduce the reintroduced population to only 10 active reintroduction sites, with most of these sites in the low resiliency condition category. While both populations retain a degree of resiliency, it is greatly reduced relative to the continuation scenario. Redundancy remains the same for the captive population, but declines for the reintroduced population due to site extinctions. As genetic diversity continues to decline in the captive population and few reintroduction sites remain in

Gunnison's and white-tailed prairie dog habitat, ecological and genetic representation likewise continue to decline.

Results: Disastrous Scenario

This scenario represents a virtual end to conservation efforts, and an inability to maintain viable populations in either captive or reintroduced settings. Under this scenario at both 10 and 20-year benchmarks, all of the facilities within the captive population are in low resiliency condition, and production levels are no longer sufficient to maintain a stable sex and age structure. No captive-born kits are available for release at reintroduction sites. For the reintroduced population, the combined effects of declining habitat quality due to drought and increased lethal control of prairie dogs, more frequent plague epizootics due to increased precipitation variability, and low ferret vaccination rates render this population functionally extinct, with only the Conata Basin-Badlands, Rocky Mountain Arsenal, Shirley Basin, and Meeteetse sites remaining active in 2029. Due to its smaller size, reduced ferret family rating, and more frequent epizootics of plague, we project that the Meeteetse site becomes inactive by 2039.

Synopsis: Disastrous Scenario

The Disastrous Scenario represents a significant challenge to black-footed ferret recovery efforts, with a severely compromised captive population that can no longer meet genetic diversity maintenance goals (Ballou and Oakleaf 1989). In this scenario, the reintroduced population in effect becomes the founder population, albeit with low genetic diversity and limited representation, as evidenced by occurrence in only black-tailed and white-tailed prairie dog habitat. For both populations, resiliency and redundancy are greatly reduced, as some of the captive facilities may not be able to breed ferrets successfully, and only three reintroduction sites remain active.

Results: Optimistic Scenario

This scenario represents a turnaround in population performance for the captive breeding population, with five facilities reaching high resiliency condition and one facility in moderate condition by 2029. This is the result of a 20% increase in whelping success, mean number of kits born per litter, and percentage of kits weaned. These improvements, due in part to revised husbandry and pairing methodologies and higher success of assisted reproductive technologies such as artificial insemination, continue through 2039, improving the overall resiliency scores for the National Black-footed Ferret Conservation Center and the Phoenix Zoo.

For the reintroduced population, targeted allocation of increased levels of plague management resources enable managers to reinitiate recovery efforts at 10 existing reintroduction sites, and increase the biological potential of existing active sites by 2029. Under this scenario, eight sites are in high resiliency condition, 12 are in moderate condition, and three sites are in low condition. Six sites remain inactive, due to allocation of resources to other sites having greater

potential to meet the minimum recovery criterion of ≥ 30 breeding adults. The addition of five new reintroduction sites meeting this criterion increases the redundancy of the reintroduced population as well as its genetic and ecological representation, and is made possible by the availability of kits from both the captive population as well as translocations from existing reintroduction sites. The gains made in the overall condition of the reintroduced population are offset somewhat by increasing drought, particularly in the southern and western portions of the potential range. These effects become more evident by 2039, with the Espee Ranch and Vermejo BTPD reintroduction sites moving from moderate to low resiliency condition, and the Coyote Basin reintroduction site moving from high to moderate condition.

Synopsis: Optimistic Scenario

The Optimistic Scenario represents gains in resiliency and representation for the captive black-footed ferret population, and gains in resiliency, redundancy, and representation for the reintroduced population. These gains are realized through the availability of resources for conservation efforts, but are tempered somewhat by worsening drought conditions in portions of the potential range.

Results: Transformation Scenario

This scenario entails significant gains in population performance for both the captive and the reintroduced black-footed ferret populations, made possible by technological advances in captive breeding techniques and plague management. Gene pool enrichment, made possible through iSCNT, brings all captive breeding facilities into high overall resiliency condition by 2029, and these gains are maintained through 2039 due to evolving technologies.

For the reintroduced population, the greater availability of effective plague management tools enables managers of most reintroduction sites to implement plague management, and overall resiliency increases as a result. Larger sites capable of supporting ≥ 30 breeding adults are prioritized for plague management, and plague management is also implemented on smaller sites with research or cultural values. Widespread implementation of plague management, availability of incentive programs, and high levels of prairie dog population protection bring 20 reintroduction sites into high resiliency condition, with the remaining 9 sites in moderate condition. The addition of five new reintroduction sites capable of supporting ≥ 100 breeding adults increases redundancy and representation for the reintroduced population, and is made possible by the availability of kits from both the captive population as well as translocations from existing reintroduction sites. These gains in population viability are offset slightly by increasing drought, particularly in the southern and western portions of the potential range; by 2039 the Aubrey Valley, Espee Ranch, Vermejo BTPD, Vermejo GPD, Coyote Basin, and Wolf Creek reintroduction sites all decline in overall condition, but retain their overall condition classes.

Synopsis: Transformation Scenario

The Transformation Scenario represents a “best case” scenario in that technological advances greatly enhance the ability to manage both the captive and reintroduced populations, and sufficient resources are available to implement these advances. The resiliency of both populations is greatly enhanced, and redundancy in the reintroduced population is increased substantially. Representation is increased through the inclusion of new genetic material in the captive population, as well as through the addition of new reintroduction sites and the reinitiation of formerly inactive sites throughout the potential range of the species.

Chapter 5. Species Viability

This report describes what the black-footed ferret needs to achieve viability (Chapter 2), and evaluates the current condition of the species in relation to those needs (Chapter 3). This report also forecasts how the condition of the black-footed ferret may change in relation to those needs under five different scenarios (Chapter 4). In this chapter, we synthesize the results from our historical, current, and future analyses and discuss the potential future viability of the black-footed ferret. We assess the viability of the species by evaluating its ability to persist into the future in the context of the 3Rs.

5.1 Resiliency

For a species that nearly became extinct (Lockhart et al. 2006), black-footed ferret populations have displayed remarkable resiliency in the face of numerous stressors. This resiliency has been achieved through considerable management inputs, including intensive and extensive captive breeding and reintroduction programs. The most significant challenges to black-footed ferret viability in the wild are sylvatic plague, and a lack of suitable habitat (CBSG 2004). Sylvatic plague is a non-native disease that is lethal to ferrets and their prairie dog prey, and requires management intervention in order to prevent the extirpation of the black-footed ferret reintroduced population. The current conditions of individual reintroduction sites, the analysis units we used for the reintroduced population, illustrate the challenges posed by plague. Since reintroduction efforts began in 1991, black-footed ferrets have been reintroduced at 29 discrete reintroduction sites. Of these 29 sites, two are currently in high resiliency condition, eight are in moderate condition, four are in low condition, and 15 are inactive. With the exception of the two sites in high condition and one site in moderate condition, periodic releases of animals from the captive population are needed to maintain active reintroduction sites. The inactive sites experienced plague epizootics, which eliminated habitat and resulted in direct black-footed ferret mortality. Black-footed ferret population resiliency, at least in the case of the reintroduced population, depends heavily on management interventions in the form of plague management and population augmentation using captive-born animals. Since most black-footed ferret reintroduction sites currently contain relatively small numbers of animals (range of 1 to 119; see

Table 3) and many are found in sub-optimal habitat, their ability to tolerate natural, annual variation in their environment in their current condition is limited.

Although it is buffered from external stressors such as plague and variable environmental conditions, the captive black-footed ferret population also exhibits limited resiliency due to its small (N=7) founder population and resultant low genetic diversity. The captive population, which numbers 301 animals, and is split between six captive breeding facilities (Table 2), currently has one facility in high resiliency condition, four in moderate condition, and one in low condition. Like the reintroduced population, the captive population requires significant management intervention for its maintenance.

Since the black-footed ferret is a conservation-reliant species, our analysis of future resiliency centered on the requirement for ongoing management of both the captive and reintroduced populations, and the degree to which management intervention might vary under differing circumstances. Resiliency for individual analysis units (reintroduction sites and captive breeding facilities) improved in the Optimistic and Transformation scenarios, while the Continuation, Pessimistic, and Disastrous scenarios resulted in losses of resiliency relative to current conditions. The only scenario in which management intervention is potentially reduced is the Transformation scenario, where advances in genomics may potentially offset the need for annual plague management activities.

5.2 Redundancy

As noted above, black-footed ferret populations were formerly widespread, occurring in conjunction with three species of prairie dogs in 12 present-day states. Although exact numbers of individual populations are not known, black-footed ferret specimens have been recorded from 128 of 513 counties within the historic range of the three species of prairie dogs (Anderson et al. 1986). While counties do not equate to populations, black-footed ferrets occurred in several discrete locations historically. At present, black-footed ferrets are found at six captive breeding facilities, and 14 reintroduction sites. The number of projected reintroduction sites in our analysis of future redundancy ranged from 10 (Disastrous Scenario, 20 year timeframe) to 34 (Transformation Scenario, 20-year timeframe) for the reintroduced population, and remained at six breeding facilities for the captive population in all scenarios. In the latter instance, some of the captive breeding facilities under the Disastrous Scenario may lose the ability to produce any black-footed ferrets in captivity, although the exact number is not known.

Climate effects and availability of conservation measures influenced the level of redundancy observed for the reintroduced black-footed ferret population, and genetic diversity influenced the level of redundancy for the captive population. Under all scenarios, at least some analysis units persisted, but their resiliency is questionable.

5.3 Representation

A species' representation is measured by evaluating its genetic, morphological, behavioral, and ecological diversity within and among populations across its range. Data generated from the study of the last wild black-footed ferret population near Meeteetse, Wyoming and analysis of museum specimens suggests that isolation of subpopulations likely occurred throughout the range of the black-footed ferret (Wisely 2006), which may explain why the species is able to survive and reproduce successfully despite low levels of genetic diversity. While the species appears to be tolerant of reduced genetic diversity, the long-term effects of reduced diversity are unknown, and could manifest themselves in a loss of ability to adapt to changing environments (Hoffman et al. 2003, Traill et al. 2010). Because many reintroduction sites are maintained through frequent augmentation with captive-reared animals, the reintroduced population remains virtually indistinguishable genetically from the captive population. Representation in the context of genetic diversity remains low, and frequent augmentation limits the cultural transmission of important behaviors in the reintroduced population (Biggins 2000).

Since all extant black-footed ferrets are descendants of seven founder animals, their genetic representation is understandably limited. In our future condition analysis, we projected genetic representation will not change for the captive population, with the exception of the Optimistic and Transformation Scenarios, where incorporation of new genetic material was introduced as a possibility. Similarly, we projected that genetic representation will not change for the reintroduced population, although it is possible that long-term reintroduction sites such as Conata Basin-Badlands, South Dakota, and Shirley Basin, Wyoming may differentiate themselves genetically during longer timeframes under the Optimistic and Transformation Scenarios.

Ecological representation in our future condition analysis did not change appreciably with respect to the reintroduced population, as active sites were maintained within the habitat of all three species of prairie dogs, with the exception of the Disastrous Scenario in 2039. This is likely the effect of changing climate reducing the resiliency of Gunnison's prairie dog reintroduction sites in the southern portion of the black-footed ferret's potential range.

5.4 Synopsis of Viability

The black-footed ferret currently exhibits moderate to low levels of resiliency, redundancy, and representation, which are maintained with the assistance of significant management inputs. The viability of both populations is dependent on the continued availability of resources for management, which in the case of the reintroduced population are diminished in effectiveness due to climate change, and in the case of both populations may be diminished due to declining genetic fitness. Importantly, a continuation of current conditions into the future is projected to lead to a decline in overall condition for most analysis units in both populations, underscoring

the need to maintain and improve upon management inputs to retain current levels of viability. Management inputs will need to be refined and expanded in scope in order to overcome the challenges of decreasing genetic diversity, sylvatic plague, and lack of suitable habitat to increase the overall viability of the black-footed ferret.

Literature Cited

- Abbott, R.C., and T.E. Rocke. 2012. Plague. U.S. Geological Survey Circular 1372. 79 pages.
- Abbott, R. C., J. E. Osorio, C. M. Bunck, and T. E. Rocke. 2012. Sylvatic plague vaccine: a new tool for conservation of threatened and endangered species? *EcoHealth* 9(3): 243-250.
- Alder, J.R., and S.W. Hostetler. 2013. USGS National Climate Change Viewer. U.S. Geological Survey https://www2.usgs.gov/climate_landuse/clu_rd/nccv.asp doi:10.5066/F7W9575T. Accessed 6 July 2019.
- Andelt, W. F., G. C. White, P. M. Schnurr, and K. W. Navo. 2009. Occupancy of random plots by white-tailed and Gunnison's prairie dogs. *Journal of Wildlife Management* 73: 35-44.
- Anderson, E., S.C. Forrest, T.W. Clark, and L. Richardson. 1986. Paleobiology, biogeography, and systematics of the black-footed ferret, *Mustela nigripes* (Audubon and Bachman), 1851. Pages 11-62 in S.L. Wood, editor. Great Basin Naturalist Memoirs No. 8: The Black-footed Ferret. Brigham Young University, Provo, Utah.
- Anderson, S.H., and E.S. Williams. 1997. Plague in a complex of white-tailed prairie dogs and associated small mammals in Wyoming. *Journal of Wildlife Diseases* 33:720-732.
- Antolin, M. F., P. Gober, B. Luce, D. E. Biggins, W. E. Van Pelt, D. B. Seery, M. Lockhart, and M. Ball. 2002. The influence of sylvatic plague on North American wildlife at the landscape level, with special emphasis on black-footed ferret and prairie dog conservation. Pages 104-127 in Transactions of the 67th North American Wildlife and Natural Resources Conference, Dallas, Texas. 30 pages.
- Arizona Game & Fish Department. 1988. Threatened native wildlife in Arizona. Arizona Game & Fish Department Publication. Phoenix, Arizona. 32 pages.
- Arizona Game & Fish Department. 2019. 2019-20 Arizona hunting regulations. Arizona Game & Fish Department Publication, Phoenix, Arizona. 144 pages

- Arroyo, B. 2009. Request to EPA dated Sept. 9, 2009 to withdraw Rozol registration for prairie dog control. In litt.
- Augustine, D.J., J.F. Cully, Jr., and T.L. Johnson. 2007. Influence of fire on black-tailed prairie dog colony expansion in shortgrass steppe. *Rangeland Ecology and Management* 60: 538- 542.
- Augustine, D. J., M. R. Matchett, T. P. Toombs, J. F. Cully, Jr, T. L. Johnson, and J. G. Sidle. 2008. Spatiotemporal dynamics of black-tailed prairie dog colonies affected by plague. *Landscape Ecology* 23: 255-267.
- Augustine, D.J., and T.L. Springer. 2013. Competition and facilitation between a native and a domestic herbivore: trade-offs between forage quantity and quality. *Ecological Applications* 23:850-863.
- Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. *Wildlife Society Bulletin* 34: 177–185.
- Ballou, J.D., and R. Oakleaf. 1989. Demographic and genetic captive-breeding recommendations for black-footed ferrets. Pages 247-267 in *Conservation biology and the black-footed ferret*, U.S. Seal, E.T. Thorne, M.A. Bogan, and S.H. Anderson, editors. Yale University Press, New Haven, Connecticut.
- Barnes, A. M. 1993. A review of plague and its relevance to prairie dog populations and the black-footed ferret. Pages 28-37 in *Management of Prairie Dog Complexes for the Reintroduction of the Black-footed Ferret*. J.L. Oldemeyer, D.E. Biggins, B.J. Miller, and R. Crete, editors. Biological Report No. 13, U.S. Fish and Wildlife Service, Washington D.C.
- Belant, J. D. Biggins, D. Garelle, R.G. Griebel, and J.P. Hughes. 2015. *Mustela nigripes*. The IUCN Red List of Threatened Species. 2015: e.T14020A45200314. 10 pages.
- Bell, W. 1921. Death to the rodents. Pages 421-438 in *U.S. Department of Agriculture, 1920 Yearbook*.
- Berryman, J.H, and N.C. Johnson. 1973. Ferret and prairie dog programs on public lands: a perspective and some facts. Pages 109-125 in *Proceedings of the Black-footed Ferret and Prairie Dog Workshop, Sept 4-6, Rapid City, South Dakota*.

- Beyers, M., J. Hof, D.W. Uresk, and G.L. Schenbeck. 1997. Spatial optimization of prairie dog colonies for black-footed ferret recovery. *Operations Research* 45:495-507.
- Biggins, D.E. 2000. Predation on black-footed ferrets (*Mustela nigripes*) and Siberian polecats (*Mustela eversmannii*) – conservation and evolutionary implications. Ph.D dissertation, Colorado State University, Fort Collins, Colorado. 185 pages.
- Biggins, D.E. 2013. Peer review of draft revised recovery plan. In litt.
- Biggins, D.E., and D.A. Eads. 2019. Prairie dogs, persistent plague, flocking fleas, and pernicious positive feedback. *Frontiers in Veterinary Science* 6:1-12.
- Biggins, D.E, D.A. Eads, S. Ramakrishnan, A.A. Goldberg, S.L. Eads, J. Hardin, and D. Konkel. 2019. Prey selection by the black-footed ferret (*Mustela nigripes*). In preparation.
- Biggins, D. E., J. L. Godbey, K. L. Gage., L. G. Carter, and J. A. Montenieri. 2010. Vector control improves survival of three species of prairie dogs (*Cynomys*) in areas considered enzootic for plague. *Vector-Borne and Zoonotic Diseases* 10: 17-26.
- Biggins, D.E., J.L. Godbey, L.H. Hanebury, B. Luce, P.E. Marinari, M.R. Matchett, and A. Vargas. 1998. The effect of rearing methods on survival of reintroduced black-footed ferrets. *Journal of Wildlife Management* 62:643-653.
- Biggins, D.E, J.L. Godbey, T.M. Livieri, M.R. Matchett, and B.D. Bibles. 2006a. Postrelease movements and survival of adult and young black-footed ferrets. Pages 191-200 in J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. *Recovery of the black-footed ferret – progress and continuing challenges*. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Biggins, D.E., J.L. Godbey, M.R. Matchett, L.R. Hanebury, T.M. Livieri, and P.E. Marinari. 2006b. Monitoring black-footed ferrets during reestablishment of free-ranging populations: discussions of alternative methods and recommended minimum standards. Pages 155-174 in J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. *Recovery of the black-footed ferret – progress and continuing challenges*. U.S. Geological Survey Scientific Investigations Report 2005-5293.

- Biggins, D.E., J.L. Godbey, M.R. Matchett and T.M. Livieri. 2006c. Habitat preferences and intraspecific competition in black-footed ferrets. Pages 129-140 in J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. Recovery of the black-footed ferret – progress and continuing challenges. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Biggins, D. E., and M.Y. Kosoy. 2001. Influences of introduced plague on North American mammals: implications from ecology of plague in Asia. *Journal of Mammalogy* 82: 906-916.
- Biggins, D.E., J.M. Lockhart, and J.L. Godbey. 2006d. Evaluating habitat for black-footed ferret: revision of an existing model. Pages 143-150 in J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. Recovery of the black-footed ferret – progress and continuing challenges. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Biggins, D.E., B.J. Miller, T.W. Clark, and R.P. Reading. 1997. Management of an endangered species: the black-footed ferret. Pages 420-436 in *Principles of Conservation Biology*. G.K. Meffe and C.R. Carroll, editors.
- Biggins, D. E., B. J. Miller, L. R. Hanebury, B. Oakleaf, A. H. Farmer, R. Creete and A. Dood. 1993. A technique for evaluating black-footed ferret habitat. Pages 73-88 in *Proceedings of the Symposium on the Management of Prairie Dog Complexes for the Reintroduction of the Black-footed Ferret*. J. L. Oldemeyer, D. E. Biggins, B. J. Miller, and R. Creete, editors. Biological Report 13, U. S. Fish and Wildlife Service, Washington, D. C.
- Biggins, D.E., A. Vargas, J.L. Godbey and S.H. Anderson. 1999. Influence of prerelease experience on reintroduced black-footed ferrets (*Mustela nigripes*). *Biological Conservation* 89:121-129.
- Borchert, J.N., R.M. Davis, and R.M. Poché. 2009. Field efficacy of rodent bait containing the systemic insecticide imidacloprid against the fleas of California ground squirrels. *Journal of Vector Ecology* 34:92-98.
- Boulder County Parks and Open Space. 2016. Prairie dog habitat element of the grassland and shrubland management policy. 87 pages.
- Brickner, K.M., M.B. Grenier, A.E. Crosier, and J.N. Pauli. 2014. Foraging plasticity in a highly specialized carnivore, the endangered black-footed ferret. *Biological Conservation* 169:1–5.

- Brinkerhoff, R.J., S.K. Collinge, C. Ray, and K.L. Gage. 2010. Rodent and flea abundance fail to predict a plague epizootic in black-tailed prairie dogs. *Vector-Borne and Zoonotic Diseases* 10:47-52.
- Brook, B.W., C.J.A. Bradshaw, L.W. Traill, and R. Frankham. 2011. Minimum viable population size: not magic, but necessary. *Trends in Ecology and Evolution* 26:619-620.
- Bruening, J.J. 2007. Field efficacy of Kaput-D® prairie dog bait for controlling black-tailed prairie dogs (*Cynomys ludovicianus*). Scimetrics Ltd. Corporation, Wellington, CO. 108 pages.
- Bureau of Land Management. 2007. Final Statewide Programmatic White-tailed Prairie Dog (*Cynomys leucurus*) Biological Evaluation. Wyoming State Office, Cheyenne, Wyoming. 60 pages.
- Bureau of Land Management 2019. Northwest Colorado greater sage-grouse record of decision and Resource Management Plan amendment. 71 pages.
- Bureau of Sport Fisheries and Wildlife. 1961. 1961 Prairie Dog Inventory. Unpublished report by Bureau of Sport Fisheries and Wildlife. Washington D.C.
- Cable, K.A. and R.M. Timm. 1987. Efficacy of deferred grazing in reducing prairie dog reinfestation rates. Pages 46-49 in *Great Plains Wildlife Damage Control Workshop Proceedings*. University of Nebraska, Lincoln, Nebraska.
- Cain, C.M., T.M. Livieri, and B.J. Swanson. 2011. Genetic evaluation of a reintroduced population of black-footed ferrets (*Mustela nigripes*). *Journal of Mammalogy* 92:751-759.
- Campbell, T.M., III, T.W. Clark, L. Richardson, S.C. Forrest, and B.R. Houston. 1987. Food habits of Wyoming black-footed ferrets. *American Midland Naturalist* 117:208-210.
- CBSG. 1992. Black-footed ferret recovery plan review. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, Minnesota. 44 pages.
- CBSG. 2004. Black-footed ferret population management planning workshop. Final Report. IUCN/SSC Conservation Breeding Specialist Group: Apple Valley, Minnesota. 130 pages.

- Ceballos, G., A. Davidson, R. List, J. Pacheco, P. Manzano-Fischer, G. Santos-Barrera, J. Cruzado. 2010. Rapid decline of a grassland system and its ecological and conservation implications. *PLOS One* 5(1):e8562.
- Chipault, J.G., and J.K. Detling. 2013. Bison selection of prairie dog colonies on shortgrass steppe. *Western North American Naturalist* 73:168-176.
- Choate, J.R., E.K. Boggess, and F.R. Henderson. 1982. History and status of the black-footed ferret in Kansas. *Transactions of the Kansas Academy of Science* 85:121-132.
- Clark, T.W. 1977. Ecology and ethology of the white-tailed prairie dog (*Cynomys leucurus*). *Milwaukee Public Museum Publication in Biology and Geology* 3:1-96.
- Clark, T.W. 1986. Technical introduction. Pages 8-10 *in* Great Basin Naturalist Memoirs No. 8 The Black-footed Ferret. S.L. Wood, editor. Brigham Young University, Provo, Utah.
- Clark, T.W. 1989. Conservation biology of the black-footed ferret *Mustela nigripes*. Wildlife Preservation Trust Special Scientific Report No. 3. 175 pages.
- Clark, T.W., S.C. Forrest, L. Richardson, D.E. Casey, and T.M. Campbell. 1986. Description and history of the Meeteetse black-footed ferret environment. Pages 72-84 *in* Great Basin Naturalist Memoirs No. 8 The Black-footed Ferret. S.L. Wood Editor. Brigham Young University, Provo, Utah.
- Collinge, S.K., W.C. Johnson, C. Ray, R. Matchett, J. Grentsen, J.F. Cully, Jr., K.L. Gage, M.Y. Kosoy, J.E. Loye, and A.P. Martin. 2005. Landscape structure and plague occurrence in black-tailed prairie dogs on grasslands of the western USA. *Landscape Ecology* 20:941-955.
- Colorado Parks and Wildlife. 2019. 2019 Colorado Small-Game Hunting. Colorado Parks and Wildlife, Denver, Colorado. 25 pages.
- Connell, L.C., L.M. Porensky, and J.D. Scasta. 2019. Prairie dog (*Cynomys ludovicianus*) influence on forage quantity and quality in a grazed grassland-shrubland ecotone. *Rangeland Ecology and Management* 72:360-372.
- Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies, Cheyenne, Wyoming, 610 pages.

- Copeland, H. E., K. E. Doherty, D. E. Naugle, A. Pocewicz, and J. M. Kiesecker. 2009. Mapping oil and gas potential in the U.S. intermountain west and estimating impacts to species. *PLoS ONE* 4(10): e7400.
- Coppedge, B.R., and J.H. Shaw. 1998. Bison grazing patterns on seasonally burned tallgrass prairie. *Journal of Range Management* 51:258-264.
- Coppock, D.L., and J.K. Detling. 1986. Alteration of bison and black-tailed prairie dog grazing interaction by prescribed burning. *Journal of Wildlife Management* 50:452-455.
- Corro, L.M., D.W. Tripp, S.A. Stelting, and M.W. Miller. 2017. Using off-the-shelf technologies to mass manufacture oral vaccine baits for wildlife. *Journal of Wildlife Diseases* 3:1-5.
- Crawford, J. A., R. A. Olson, N. E. West, J. C. Mosley, M. A. Schroeder, T. D. Whitson, R. F. Miller, M. A. Gregg, and C. S. Boyd. 2004. Ecology and management of sage-grouse and sage-grouse habitat. *Journal of Range Management* 57: 2–19.
- Crocker-Bedford, D.C. 1976. Food interaction between Utah prairie dogs and cattle. M.S. Thesis. Utah State University, Logan, Utah. 102 pages.
- Cully, J.F., Jr. 1989. Plague in prairie dog ecosystems: importance for black-footed ferret management. Pages 47-55 *in* T.W. Clark, D. Hinkley, and T. Rich, editors. *The Prairie Dog Ecosystem: Managing for Biological Diversity*. Montana Bureau of Land Management Technical Bulletin 2. 55 pages.
- Cully, J.F., Jr. 1993. Plague, prairie dogs, and black-footed ferrets. Pages 38-49 *in* *Proceedings of the Symposium on the Management of Prairie Dog Complexes for the Reintroduction of the Black-footed Ferret*. U.S. Fish and Wildlife Service Biological Report 13.
- Cully, J. F. Jr., and E.S. Williams. 2001. Interspecific comparisons of sylvatic plague in prairie dogs. *Journal of Mammalogy* 82: 894-905.
- Dai, A. 2011. Drought under global warming: a review. *WIREs Climate Change* 2: 45-65.
- Davidson, A.D., M.T. Friggens, K.T. Shoemaker, C.L. Hayes, J. Erz, and R. Duran. 2014. Population dynamics of reintroduced Gunnison's prairie dogs in the southern portion of their range. *Journal of Wildlife Management* 78:429-439.

- Denholm, P., M. Hand, M. Jackson, and S. Ong. 2009. Land-use requirements of modern wind power plants in the United States. National Renewable Energy Laboratory Technical Report NREL/TP-6A2-45834. 46 pages.
- Dullum, J.L.D., K.R. Foresman, and M.R. Matchett. 2005. Efficacy of translocations for restoring populations of black-tailed prairie dogs. *Wildlife Society Bulletin* 33:842–850.
- Eads, D.A., and D.E. Biggins. 2015. Plague bacterium as a transformer species in prairie dogs and the grasslands of western North America. *Conservation Biology* 29:1086-1093.
- Eads, D.A., and D.E. Biggins. 2017. Paltry past precipitation: predisposing prairie dogs to plague? *Journal of Wildlife Management* 81:990-998.
- Eads, D.A., and D.E. Biggins. 2019. Plague management of prairie dog colonies: degree and duration of deltamethrin flea control. *Journal of Vector Ecology* 44:40-47.
- Eads, D.A., D.E. Biggins, J. Bowser, J.C. McAllister, R.L. Griebel, E. Childers, T.M. Livieri, C. Painter, L.S. Krank, and K. Bly. 2018. Resistance to deltamethrin in prairie dog (*Cynomys ludovicianus*) fleas in the field and in the laboratory. *Journal of Wildlife Diseases* 54:745-754.
- Eads, D.A., D.E. Biggins, J. Bowser, K. Broerman, T.M. Livieri, E. Childers, P. Dobesh, and R.L. Griebel. 2019. Evaluation of five pulicides to suppress fleas on black-tailed prairie dogs: encouraging long-term results with systemic 0.005% fipronil. *Vector-Borne and Zoonotic Diseases* 19:400-406.
- Eads, D.A., D.E. Biggins, D.S. Jachowski, T.M. Livieri, J.J. Millspaugh and M. Forsberg. 2010. Morning ambush attacks by black-footed ferrets on emerging prairie dogs. *Ethology Ecology & Evolution* 22:345-352.
- Eads, D. A., D. E. Biggins, D. H. Long, K. L. Gage, and M. F. Antolin. 2016. Droughts may increase the susceptibility of prairie dogs to fleas: incongruity with hypothesized mechanisms of plague cycles in rodents. *Journal of Mammalogy* 97: 1044-1053.
- Eads, D.A., D.E. Biggins, D. Marsh, J.J. Millspaugh, and T.M. Livieri. 2012b. Black-footed ferret digging activity in summer. *Western North American Naturalist* 72:140-147.
- Eads, D. A., and J. L. Hoogland. 2016. Factors that affect parasitism of black-tailed prairie dogs by fleas. *Ecosphere* 7:1-12.

- Eads, D.A., D.S. Jachowski, J.J. Millspaugh, and D.E. Biggins. 2012a. Importance of lunar and temporal conditions for spotlight surveys of adult black-footed ferrets. *Western North American Naturalist* 72:179-190.
- Eads, D.A., J.J. Millspaugh, D.E. Biggins, T.M. Livieri and D.S. Jachowski. 2011. Postbreeding resource selection by adult black-footed ferrets in the Conata Basin, South Dakota. *Journal of Mammalogy* 92:760-770.
- Energy Information Agency. 2019. Annual energy outlook. #AEO2019. 83 pages.
- Environmental Protection Agency 2000. Profile of the oil and gas extraction industry. EPA office of compliance sector notebook project. 165 pages.
- Erickson, W., and D. Urban. 2004. Potential risks of nine rodenticides to birds and nontarget mammals: a comparative approach. U.S. Environmental Protection Agency. 225 pages.
- Ernst, A.E. 2001. Changes in black-tailed prairie dog towns on the Texas panhandle determined by a GIS. Masters Thesis, Texas Tech University, Lubbock, Texas. 106 pages.
- Ernst, A.E., A.L. Clark, and D.R. Gober. 2006. A habitat-based technique to allocate black-footed ferret recovery among jurisdictional entities. Pages 89-95 *in* Recovery of the Black-footed Ferret: Progress and Continuing Challenges. J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Facka, A. N., G. W. Roemer, V. L. Mathis, M. Kam, and E. Geffen. 2010. Drought leads to collapse of black-tailed prairie dog populations reintroduced to the Chihuahuan Desert. *Journal of Wildlife Management*. 74: 1752-1762.
- Fleischner, T. L. 1994. Ecological costs of livestock grazing in western North America. *Conservation Biology* 8: 629-644.
- Forman, R.T.T., D. Sperling, J.A. Bissonette, A.P. Clevenger, C.D. Cutshall, V.H. Dale, L. Fahrig, R.L. France, C.R. Goldman, K. Heanue, J. Jones, F. Swanson, T. Turrentine, and T.C. Winter. 2003. Road Ecology. Island Press, New York, New York. 504 pages.
- Forrest, S.C., D.E. Biggins, L. Richardson, T.W. Clark, T.M. Campbell III, K.A. Fagerstone, and E.T. Thorne. 1988. Population attributes for the black-footed ferret (*Mustela nigripes*) at Meetetse, Wyoming, 1981–1985. *Journal of Mammalogy* 69:261–273.

- 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 No. 2. 49 pages.
- Forrest, S.C., and J. Luchsinger. 2006. Past and current chemical control of prairie dogs. Pages 115-128 *in* Conservation of the Black-tailed Prairie Dog. J. Hoogland, editor. Island Press, Washington, D.C.
- Frankel, O.H., and M.E. Soulé. 1981. Conservation and evolution. Cambridge University Press, New York, New York. 327 pages.
- Frankham, R., C.J.A. Bradshaw, and B.W. Brook. 2014. Genetics in conservation management: revised recommendations for the 50/500 rules, Red List criteria and population viability analyses. *Biological Conservation* 170:56-63.
- Franklin, I.R. 1980. Evolutionary change in small populations. Pages 135-150 in *Conservation biology: an evolutionary-ecological perspective*. M.E. Soulé and B.A. Wilcox, editors. Sinauer Associates, Sunderland, Massachusetts.
- Fuhlendorf, S.D., and D.M. Engle. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. *Journal of Applied Ecology* 41:604-614.
- Gage, K.L. and M.Y. Kosoy. 2006. Recent trends in plague ecology. Pages 209-227 *in* Recovery of the Black-footed Ferret: Progress and Continuing Challenges. J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Ganguly, A., K. Steinhäuser, D. Erickson, M. Branstetter, E. Parish, N. Singh, J. Drake, and L. Buja. 2009. Higher trends but larger uncertainty and geographic variability in 21st century temperature and heat waves. *Proceedings of the National Academy of Sciences* 106: 15555–15559.
- Garelle, D., P. Marinari, and C. Lynch. 2006. Black-footed ferret species survival plan. American Zoo and Aquarium Association Population Management Center. 29 pages.
- Garelle, D., P. Marinari, and C. Lynch. 2014. Population analysis and breeding and transfer plan. Black-footed ferret (*Mustela nigripes*). Association of Zoos and Aquariums Population Management Center, Lincoln, Nebraska.

- Garman, S. L. and J. L. McBeth. 2014. Digital representation of oil and natural gas well pad scars in southwest Wyoming. U.S. Geological Survey, Data Series 800. 7 pages.
- Garnett, S.T., and K.K. Zander. 2011. Minimum viable population limitations ignore evolutionary history. *Trends in Ecology and Evolution* 26:618-619.
- Gasper, P.W., and R.W. Watson. 2001. Plague and yersiniosis. Pages 313-329 *in* E.S. Williams and I.K. Barker, editors. *Infectious Diseases of Wild Mammals*. Iowa State University Press, Ames, Iowa. 560 pages.
- Gober, P. U.S. Fish and Wildlife Service. 2006. Letter to South Dakota Department of Agriculture dated January 24, 2006. In litt.
- Godbey, J.L., D.E. Biggins, and D. Garelle. 2006. Exposure of captive black-footed ferrets to plague and implications for species recovery. Pages 233-237 *in* Recovery of the Black-footed Ferret: Progress and Continuing Challenges. J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Gordon, K. M., K. C. Keffer, and S. H. Anderson. 2003. Impacts of recreational shooting on black-tailed prairie dog behavior, population, and physiology: final report. Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie, Wyoming. 24 pages.
- Graves, G., R. Santymire, P. Marinari, and C. Lynch. 2018. Population analysis and breeding and transfer plan – black-footed ferret (*Mustela nigripes*). AZA Species Survival Plan[®] Yellow Program. AZA Population Management Center, Chicago, Illinois. 29 pages.
- Grenier, M.B., S.W. Buskirk, and R. Anderson-Sprecher. 2008. Population indices versus correlated density estimates of black-footed ferret abundance. *Journal of Wildlife Management* 73:669-676.
- Grenier, M.B., D.B. McDonald, S.W. Buskirk. 2007. Rapid population growth of a critically endangered carnivore. *Science* 317:779.
- Griebel, R.G. 2008. Wall Ranger District 2008 plague management report. Unpublished Report. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Nebraska National Forest, Wall Ranger District, Wall, South Dakota. 11 pages.

- Griebel, R.G. 2009. Wall Ranger District 2009 plague management report. Unpublished Report. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Nebraska National Forest, Wall Ranger District, Wall, South Dakota. 13 pages.
- Griebel, R.G. 2010. Wall Ranger District boundary and interior management zone report 2009 Monitoring Report. Unpublished Report. U.S. Department of Agriculture, Forest Service, Rocky Mountain Region, Nebraska National Forest, Wall Ranger District, Wall, South Dakota. 6 pages.
- Groves, C.R. and T.W. Clark. 1986. Determining minimum population size for recovery of the black-footed ferret. Pages 150-159 *in* Great Basin Naturalist Memoirs No. 8 The Black-footed Ferret. S.L. Wood, editor. Brigham Young University, Provo, Utah.
- Hale, S.L., J.L. Koprowski, and H. Hicks. 2013. Review of black-tailed prairie dog reintroduction strategies and site selection: Arizona reintroduction. Pages 310-315 in G.J. Gottfried, P.F. Ffolliott, B.S. Gebow, L.G. Eskew, and L.C. Collins, editors. Merging science and management in a rapidly changing world: Biodiversity and management of the Madrean Archipelago III and 7th Conference on Research and Resource Management in the Southwestern Deserts. 593 pages.
- Hanebury, L.R. and D.E. Biggins. 2006. A history of searches for black-footed ferrets. Pages 47-65 *in* Recovery of the Black-footed Ferret: Progress and Continuing Challenges. J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Hanson, R. 1993. Control of prairie dogs and related developments in South Dakota. Pages 5-7 *in* Proceedings of the Symposium on the Management of Prairie Dog Complexes for the Reintroduction of the Black-footed Ferret. U.S. Fish and Wildlife Service Biological Report 13.
- Henderson, F.R., P.F. Springer and R. Adrian. 1969 (revised 1974). The black-footed ferret in South Dakota. South Dakota Dept. of Game, Fish and Parks Technical Bulletin No. 4. 37 pages.
- Hersey, K., A. Wright, B. Maxfield, and A. Brewerton. 2016. An assessment of anthropogenic impacts and landscape features on white-tailed prairie dog occupancy in Utah 2008-2016. Utah Division of Wildlife Resources, Salt Lake City, Utah. 24 pages.
- Hillman, C.N. 1968. Field observations of black-footed ferrets in South Dakota. Transactions of the North American Wildlife and Natural Resources Conference 33:433-443.

- Hillman, C.N. and T.W. Clark. 1980. *Mustela nigripes*. Mammalian Species No. 126. The American Society of Mammalogists. 3 pages.
- Hoen, B.D., Diffendorfer, J.E., Rand, J.T., Kramer, L.A., Garrity, C.P., Hunt, H.E. 2019. United States Wind Turbine Database. U.S. Geological Survey, American Wind Energy Association, and Lawrence Berkeley National Laboratory data release: USWTDB V2.1 (July 15, 2019). <https://eerscmap.usgs.gov/uswtodb>.
- Hoffman, A.A., R.J. Hallas, J.A. Dean, and M. Schiffer. 2003. Low potential for climatic stress adaptation in a rainforest *Drosophila* species. *Science* 301:100-102.
- Hoffmeister, D.F. 1986. Mammals of Arizona. The University of Arizona Press and The Arizona Game and Fish Department. 602 pages.
- Holmes, B. E. 2008. A predictive model of white-tailed prairie dog (*Cynomys leucurus*) and black-footed ferret (*Mustela nigripes*) habitat in northwest Colorado. Bureau of Land Management and Colorado Division of Wildlife, Meeker, Colorado. 22 pages.
- Hoogland, J. L. 2001. Black-tailed, Gunnison's, and Utah prairie dogs reproduce slowly. *Journal of Mammalogy* 82:917-927.
- Hoogland, J.L. 2006. Saving prairie dogs: Can we? Should we? Pages 261-266 in *Conservation of the black-tailed prairie dog*. J.L. Hoogland, editor. Island Press, Washington, D.C.
- Howard, J., R.M. Santymire, P.E. Marinari, J.S. Kreeger, L. Williamson, and E.E. Wildt. 2006. Use of reproductive technology for black-footed ferret recovery. Pages 28-36 in *Recovery of the Black-footed Ferret: Progress and Continuing Challenges*. J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Hutchins, M, R.J. Wiese, and J. Bowdoin. 1996. Black-footed ferret recovery program analysis and action plan. American Zoo and Aquarium Association. 137 pages.
- IHS Markit. 2019. Spatial data showing current producing and non-producing oil and gas wells in the United States. <http://www.ihsmarkit.com>. Accessed 20 July 2019.
- Intergovernmental Panel on Climate Change. 2014. Climate change 2014: synthesis report. Eds. Core Writing Team, R. K. Pauchari, and L. A. Meyer. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland. 151 pp.

IUCN/SSC. 2013. Guidelines for reintroductions and other conservation translocations. Version 1.0. IUCN Species Survival Commission, Gland, Switzerland. 66 pages.

Jachowski, D.S., J.J. Millspaugh, D.E. Biggins, T.M. Livieri and M.R. Matchett. 2010. Home-range size and spatial organization of black-footed ferrets *Mustela nigripes* in South Dakota, USA. *Wildlife Biology* 16:66-76.

Jachowski, D.S., R.A. Gitzen, M.B. Grenier, B. Holmes, and J.J. Millspaugh. 2011a. The importance of thinking big: large-scale prey conservation drives black-footed ferret reintroduction success. *Biological Conservation* 144:1560-1566.

Jachowski, D.S., J.J. Millspaugh, D.E. Biggins, T.M. Livieri, M.R. Matchett and C.D. Rittenhouse. 2011b. Resource selection by black-footed ferrets in South Dakota and Montana. *Natural Areas Journal* 31:218-225.

Jachowski, D. S., S. Skipper, and M. E. Gompper. 2011c. Field evaluation of imidacloprid as a systematic approach to flea control in black-tailed prairie dogs, *Cynomys ludovicianus*. *Journal of Vector Ecology* 36: 100-107.

Jamieson, I.G., and F.W. Allendorf. 2012. How does the 50/500 rule apply to MVPs? *Trends in Ecology and Evolution* 27:578-584.

Jaquish, C.E., J.M. Cheverud, and S.D. Tardif. 1996. Genetic and environmental impacts on litter size and early infant survival in three species of callitrichids. *Journal of Heredity* 87:74-77.

Johnson, W.C., and S.K. Collinge. 2004. Landscape effects on black-tailed prairie dog colonies. *Biological Conservation* 115:487-497.

Keffer, K., K. Gordon, and S. Anderson. 2001. Effects of recreational shooting on behavior of black-tailed prairie dogs. 2000 progress report. Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, Laramie. 15 pages.

Kiesecker, J.M., J.S. Evans, J. Fargione, K. Doherty, K.R. Foresman, T.H. Kunz, D. Naugle, N.P. Nibbelink, and N.D. Niemuth. 2011. Win-win for wind and wildlife: a vision to facilitate sustainable development. *PLoS ONE* 6(4): e17566.doi:10.1371/journal.pone.0017566

Kilpatrick, C.W., S.C. Forrest, and T.W. Clark. 1986. Estimating genetic variation in the black-footed ferret-a first attempt. *Great Basin Naturalist Memoirs* 8:145-149.

- Knowles, C. 1988. An evaluation of shooting and habitat alteration for control of black-tailed prairie dogs. Pages 53-56 in Eighth Great Plains Wildlife Damage Control Workshop Proceedings, April 28–30, 1987, Rapid City, South Dakota, D.W. Uresk, G.L. Schenbeck, and R. Cefkin, editors. U.S. Forest Service General Technical Report RM-154. Pp. 53–56.
- Knowles, C. 2002. Status of white-tailed and Gunnison's prairie dogs. National Wildlife Federation, Missoula, Montana and Environmental Defense, Washington, D.C. 30 pages.
- Knowles, C.J., and T.C. Vosburgh. 2001. An evaluation of the impacts of recreational shooting on black-tailed prairie dogs. Draft manuscript prepared for Montana Department of Fish, Wildlife and Parks and Montana Department of Natural Resources and Conservation. 27 March 2001. 20 pages.
- Koch, D. 2008. Letter from WAFWA to U.S. EPA regarding use of anticoagulants for prairie dog control, August 19, 2008. In litt.
- Koford, C.B. 1958. Prairie dogs, whitefaces, and blue grama. *Wildlife Monographs* 3:1-78.
- Krebs, C.J. 1966. Demographic changes in fluctuating populations of *Microtus californicus*. *Ecological Monographs* 36:239-273.
- Kurose, N., A.V. Abramov, R. Masuda. 2008. Molecular phylogeny and taxonomy of the genus *Mustela* (Mustelidae, Carnivora), inferred from mitochondrial DNA sequences: new perspectives on phylogenetic status of the back-striped weasel and American mink. *Mammal Study* 33: 25–33.
- Lacy, R.C. 1987. Loss of genetic diversity from managed populations: interacting effects of drift, mutation, immigration, selection, and population subdivision. *Conservation Biology* 1:143-158.
- Lacy, R.C., and T.W. Clark. 1989. Genetic variability in black-footed ferret populations: past, present, and future. Pages 83-103 in *Conservation biology and the black-footed ferret*, U.S. Seal, E.T. Thorne, M.A. Bogan, and S.H. Anderson, editors. Yale University Press, New Haven, Connecticut.
- Lamb, B.L., and K. Cline. 2003. Public knowledge and perceptions of black-tailed prairie dogs. *Human Dimensions of Wildlife* 8:127-143.

- LANDFIRE. 2007. Public Landfire National Reference Database.
https://www.landfire.gov/lfrdb_data.php. Accessed 7/31/19.
- Lee, C.D. and S.E. Hygnstrom. 2007. Field efficacy and hazards of rozol bait for controlling black-tailed prairie dogs (*Cynomys ludovicianus*). Liphatech, Inc., Milwaukee, Wisconsin. 56 pages.
- Linder, R.L., M.E. Anderson, E.M. Brigham, III, C.N. Hillman, D.L. Lengkeek, A.L. Lovaas, J.K. McDowell, and W.W. Paintner. 1978. Black-footed ferret recovery plan. U.S. Fish and Wildlife Service. 146 pages.
- Livieri, T.M. 2006. Ten-year history of the Conata Basin black-footed ferret population: 1996-2005. Prairie Wildlife Research, Wall, South Dakota. 49 pages.
- Livieri, T.M. 2019. Prairie Wildlife Research. Presentation at Black-footed Ferret Recovery Implementation Team Related Species Subcommittee meeting, April 9, 2019. In litt.
- Livieri, T.M. and E.M. Anderson. 2012. Black-footed ferret home ranges in Conata Basin, South Dakota. *Western North American Naturalist* 72:196-205.
- Livieri, T.M., D.S. Licht, B.J. Moynahan and P.D. McMillan. 2013. Prairie dog aboveground aggressive behavior towards black-footed ferrets. *American Midland Naturalist* 169:422-425.
- Lockhart, J.M., E.T. Thorne, and D.R. Gober. 2006. A historical perspective on recovery of the black-footed ferret and the biological and political challenges affecting its future. Pages 6-19 *in* Recovery of the Black-footed Ferret: Progress and Continuing Challenges. J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Luce, R.J. 2006. Areas where habitat characteristics could be evaluated to identify potential black-footed ferret reintroduction sites and develop conservation partnerships. Pages 69-88 *in* Recovery of the Black-footed Ferret: Progress and Continuing Challenges. J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Lupis, S.A., K.D. Bunnell, T.A. Black, and T.A. Messmer. 2007. Utah Gunnison's prairie dog and white-tailed prairie dog conservation plan. Utah Division of Wildlife Resources, Salt Lake City, Utah. 94 pages.

- Lyon, L.J., H.S. Crawford, E. Czuhai, R.L. Fredricksen, R.F. Harlow, L.J. Metz, and H.A. Pearson. 1978. Effects of fire on fauna: a state of knowledge review. General Technical Report WO-6. U.S. Department of Agriculture, Forest Service. 22 pages.
- Mack, E., D. Keinath, J. Lindstrom, C. Hansen, J. Shoemaker, K. Newlon, K. Novak, A. Nicholas, and T. Abbott. 2017. Species status assessment report for the white-tailed prairie dog (*Cynomys leucurus*). Final draft, version 1. U.S. Fish and Wildlife Service Mountain-Prairie Region, Denver, Colorado. 145 pages.
- MacKenzie, D.I., J.D. Nichols, J.E. Hines, M.G. Knutson, and A.B. Franklin. 2003. Estimating the occupancy, colonization, and local extinction probabilities when a species is detected imperfectly. *Ecology* 84:2200-2207.
- Magle, S. B. and K. R. Crooks. 2009. Investigating the distribution of prairie dogs in an urban landscape. *Animal Conservation* 12:192-203.
- Marinari, P.E., and J.S. Kreeger. 2006. An adaptive management approach for black-footed ferrets in captivity. Pages 23-27 in *Recovery of the Black-footed Ferret: Progress and Continuing Challenges*. J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Markman, D.W., M.F. Antolin, R.A. Bowen, W.H. Wheat, M. Woods, and M. Gonzalez-Juarrero. 2018. *Yersinia pestis* survival and replication in potential ameba reservoir. *Emerging Infectious Diseases* 24:294-302.
- Matchett, M.R. 2019. Presentation at Black-footed Ferret Recovery Implementation Team Related Species Subcommittee meeting, April 9, 2019. In litt.
- Matchett, M.R., D.E. Biggins V. Carlson, B. Powell and T. Rocke. 2010. Enzootic plague reduces black-footed ferret (*Mustela nigripes*) survival in Montana. *Vector Borne Zoonotic Diseases* 10:27-35.
- McDonald, D.B., D. Albertson, T. Livieri and S.W. Buskirk. 2005. Demographic analysis of the black-footed ferret in the Conata Basin – Badlands National Park, South Dakota. Unpublished report. University of Wyoming, Laramie. 15 pages.
- McTee, M., B. Hiller, and P. Ramsey. 2019. Free lunch, may contain lead: scavenging shot small mammals. *Journal of Wildlife Management* 83:1466-1473.

- Meehl, G. A., T. F. Stocker, W. D. Collins, P. Friedlingstein, A. T. Gaye, J. M. Gregory, A. Kitoh, R. Knutti, J. M. Murphy, A. Noda, S. C. B. Raper, I. G. Watterson, A. J. Weaver, and Z. C. Zhao. 2007. Global Climate Projections. Pages 747-845 in S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, editors. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom, and New York, New York.
- Menkens, G. E., and S.H. Anderson. 1985. The effects of vibroseis on white-tailed prairie dog populations on the Laramie plains of Wyoming. #WY910-IA2-1187 Final Report, Wyoming Cooperative Fishery and Wildlife Unit, Laramie, Wyoming. 22 pages.
- Menkens, G.E., and S.H. Anderson. 1991. Population dynamics of white-tailed prairie dogs during an epizootic of sylvatic plague. *Journal of Mammalogy* 72:328-331.
- Miller, B.M., G. Ceballos, and R. Reading. 1994. The prairie dog and biotic diversity. *Conservation Biology* 8:677-681.
- Miller, B.M., R. Reading, and D.E. Biggins. 2007. Prairie dogs: an ecological view and current biopolitics. *Journal of Wildlife Diseases* 71:2801-2810.
- Miller, R. F. and J. A. Rose. 1999. Fire history and western juniper encroachment in sagebrush steppe. *Journal of Range Management* 52:550-559.
- Morin, P.A., K.K. Martien, and B.L. Taylor. 2009. Assessing statistical power of SNPs for population structure and conservation studies. *Molecular Ecology Resources* 9:66-73.
- National Oceanic and Atmospheric Administration. 2018. State of the Climate: Drought for Annual 2018. National Centers for Environmental Information <https://www.ncdc.noaa.gov/sotc/drought/201813#national-overview>. Accessed 31 July 2019.
- Natural Resources Conservation Service. 2014. Black-footed ferret special effort in Colorado. <https://www.nrcs.usda.gov/wps/portal/nrcs/detail/co/programs/landscape/?cid=nrcseprd429653>. Accessed 31 July 2019.
- Natural Resources Conservation Service. 2015. 2012 National Resources Inventory Summary Report. U. S. Department of Agriculture, Washington D. C. 210 pages.

- O’Gorman, P. A. and T. Schneider. 2009. The physical basis for increases in precipitation extremes in simulations of 21st-century climate change. *Proceedings of the National Academy of Sciences* 106: 14773-14777.
- O’Melia, M.E., F.L. Knopf, and J.C. Lewis. Some consequences of competition between prairie dogs and beef cattle. *Journal of Range Management* 35:580-585.
- Osborne, D. 1953. Archaeological occurrences of pronghorn antelope, bison, and horse in the Columbia Plateau. *The Scientific Monthly* 77: 260-269.
- Parmenter, R. P., E. P. Yadav, C. A. Parmenter, P. Ettestad, and K. L. Gage. 1999. Incidence of plague associated with increased winter-spring precipitation in New Mexico. *American Journal of Tropical Medicine and Hygiene* 61:814-821.
- Pauli, J.N. 2005. Ecological studies of the black-tailed prairie dog (*Cynomys ludovicianus*): implications for biology and conservation. Masters thesis. University of Wyoming. 77 pages.
- Pauli, J.N. and S.W. Buskirk. 2007. Recreational shooting of prairie dogs: a portal for lead entering wildlife food chains. *Journal of Wildlife Management*. 71:103–108.
- Pauli, J. N., R. M. Stephens, and S. H. Anderson. 2006. White-tailed prairie dog (*Cynomys leucurus*): a technical conservation assessment. Report for U. S. Forest Service, Rocky Mountain Region. University of Wyoming Department of Zoology and Physiology, Laramie, Wyoming. 43 pp.
- Pocewicz, A., H.E. Copeland, M.B. Grenier, D.A. Keinath, and L.M. Waskoviak. 2014. Assessing the future vulnerability of Wyoming’s terrestrial wildlife species and habitats. Report prepared by The Nature Conservancy, Wyoming Game and Fish Department, and Wyoming Natural Diversity Database. 57 pages.
- Poché, D.M., D. Hartman, L. Polykova, and R.M. Poché. 2017. Efficacy of a fipronil bait in reducing the number of fleas (*Oropsylla* spp.) infesting wild black-tailed prairie dogs. *Journal of Vector Ecology* 42:171-177.
- Powell, R.A. 1979. Mustelid spacing patterns: variations on a theme by *Mustela*. *Zeitschrift fur Tierpsychologie* 50:153-165.

- Prinn, R., S. Paltsev, A. Sokolov, M. Sarofim, J. Reilly, and H. Jacoby. 2011. Scenarios with MIT integrated global systems model: significant global warming regardless of different approaches. *Climatic Change* 104: 515–537.
- Reeve, A.F. and T.C. Vosburgh. 2006. Shooting prairie dogs. Pages 119-128 *in* Recovery of the Black-footed Ferret: Progress and Continuing Challenges. J.E. Roelle, B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Rocke, T.E., K.P. Iams, S. Dawe, S.R. Smith, J.L. Williamson, D.M. Heisey, and J.E. Osorio. 2010. Further development of raccoon poxvirus-vectored vaccines against plague (*Yersinia pestis*). *Vaccine* 28:338-344.
- Rocke, T. E., P. Nol, P. E. Marinari, J. S. Kreeger, S. R. Smith, G. P. Andrews, and A. W. Friedlander. 2006. Vaccination as a potential means to prevent plague in black-footed Ferrets. Pages 243-247 *in* Proceedings of the Symposium on the Status of the Black-footed Ferret and its Habitat. J. E. Roelle, B. J. Miller, J. L. Godbey, and D. E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Rocke, T.E., S. Smith, P. Marinari, J. Kreeger, J. Enama, and B. Powell. 2008. Vaccination with F1-V fusion protein protects black-footed ferrets (*Mustela nigripes*) against plague upon oral challenge with *Yersinia pestis*. *Journal of Wildlife Diseases* 44:1-7.
- Rocke, T. E., D. W. Tripp, R. E. Russell, R. C. Abbott, K. L. D. Richgels, M. R. Matchett, D. E. Biggins, R. Griebel, G. Schroeder, S. M. Grassel, D. R. Pipkin, J. Cordova, A. Kavalunas, B. Maxfield, J. Boulerice, and M. W. Miller. 2017. Sylvatic plague vaccine partially protects prairie dogs (*Cynomys* spp.) in field trials. *EcoHealth* 14:438-450.
- Rohlf, D.J., C. Carroll, and B. Hartl. 2014. Conservation-reliant species: toward a biology-based definition. *BioScience* 64:601-611.
- Rosenfeld, J.S. 2014. 50/500 or 100/1000? Reconciling short-and long-term recovery targets and MVPs. *Biological Conservation* 176:287-288.
- Russell, R.E., D.W. Tripp, and T.E. Rocke. 2019. Differential plague susceptibility in species and populations of prairie dogs. *Ecology and Evolution*.
<https://onlinelibrary.wiley.com/doi/10.1002/ece3.5684>. Accessed 10 October 2019.

- Sackett, L. C., T.B. Cross, R.T. Jones, W.C. Johnson, K. Ballare, C. Ray, S.K. Collinge, and A.P. Martin. 2012. Connectivity of prairie dog colonies in an altered landscape: inferences from analysis of microsatellite DNA variation. *Conservation Genetics* 13: 407-418.
- Santymire, R.M., E.V. Lonsdorf, C.M. Lynch, D.E. Wildt, P.E. Marinari, J.S. Kreeger, and J.G. Howard. 2019. Inbreeding causes decreased seminal quality affecting pregnancy and litter size in the endangered black-footed ferret. *Animal Conservation* 22:331-340.
- Savage, L.T., R.M. Reich, L.M. Hartley, P. Stapp, and M.F. Antolin. 2011. Climate, soils, and connectivity predict plague epizootics in black-tailed prairie dogs (*Cynomys ludovicianus*). *Ecological Applications* 21:2933-2943.
- Scott, J.M., D.D. Goble, A.M. Haines, J.A. Wiens, and M.C. Neel. 2010. Conservation-reliant species and the future of conservation. *Conservation Letters* 3:91-97.
- Sedivec, K., and D. Saxowsky. 2015. Reclamation of oil and gas industry-impacted land: a guide and checklist. North Dakota State University. 4 pages.
- Seery, D.B. 2006. Use of pesticides to mitigate the effects of plague. Pages 238-242 in *Proceedings of the Symposium on the Status of the Black-footed Ferret and its Habitat*. J. E. Roelle, B. J. Miller, J. L. Godbey, and D. E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Seery, D.B., D.E. Biggins, J.A. Montenieri, R.E. Enscoe, D.T. Tanda, and K.L. Gage. 2003. Treatment of black-tailed prairie dog burrows with deltamethrin to control fleas (Insecta: Siphonaptera) and plague. *Journal of Medical Entomology* 40:718-722.
- Seglund, A. 2002. White-tailed and Gunnison's prairie dog colony mapping, southeastern Utah, 2002. Utah Division of Wildlife Resources, Price, Utah. 7 pages.
- Seglund, A. 2010. Wolf Creek Management Area black-footed ferret reintroduction site summary of activities. Report to the Black-footed Ferret Recovery Implementation Team Conservation Subcommittee. 5 pages.
- Seglund, A. E., A. E. Ernst, M. Grenier, B. Luce, A. Puchniak, and P. Schnurr. 2004. White-tailed Prairie Dog Conservation Assessment. Western Association of Fish and Wildlife Agencies, Boise, Idaho. 157 pages.

- Seglund, A. E., A. E. Ernst, M. Grenier, B. Luce, A. Puchniak, and P. Schnurr. 2006. White-tailed prairie dog conservation assessment. Western Association of Fish and Wildlife Agencies, Laramie, Wyoming. 137 pages.
- Seglund, A. E. and P. M Schnurr. 2010. Colorado Gunnison's and white-tailed prairie dog conservation strategy. Colorado Division of Wildlife, Denver, Colorado. 311 pages.
- Shaffer, M. L., and B. A. Stein. 2000. Safeguarding our precious heritage. Pages 299-321 *in* Precious Heritage: the Status of Biodiversity in the United States. Eds. B. A. Stein, L. S. Kutner, and J. S. Adams. Oxford University Press, New York, New York.
- Sheets, R.G., R.L. Linder, and R.B. Dahlgren. 1972. Food habits of two litters of black-footed ferrets in South Dakota. *American Midland Naturalist* 87:249-251.
- Shoemaker, K.T., R.C. Lacy, M.L. Verant, B.W. Brook, T.M. Livieri, P.S. Miller, D.A. Fordham, and H. Resit Akçakaya. 2014. Effects of prey metapopulation structure on the viability of black-footed ferrets in plague-impacted landscapes: a metamodelling approach. *Journal of Applied Ecology* 51:735-745.
- Slack, J. U.S. Fish and Wildlife Service. 2006. Letter to U.S. EPA dated May 5, 2006. In litt.
- Smith, D.R., N.L. Allan, C.P. McGowan, J.A. Szymanski, S.R. Oetker, and H.M. Bell. 2018. Development of a species status assessment process for decisions under the U.S. Endangered Species Act. *Journal of Fish and Wildlife Management* 9:1-19.
- Snäll, T., R. E. Benestad, and N. C. Stenseth. 2009. Expected future plague levels in a wildlife host under different scenarios of climate change. *Global Change Biology* 15:500-507.
- Snäll, T., R.B. O'Hara, C. Ray, and S.K. Collinge. 2008. Climate-driven spatial dynamics of plague among prairie dog colonies. *American Naturalist* 171: 238-248.
- Solar Energy Industries Association. 2019. Utility-scale solar projects in the United States. <http://solarprojects.anl.gov/>. Accessed 31 July 2019.
- Soulé, M.E., M. Gilpin, W. Conway, and T. Foose. 1986. The millennium ark: how long a voyage, how many staterooms, how many passengers? *Zoo Biology* 5:101-113.
- Stapp, P., M. F. Antolin, and M. Ball. 2004. Patterns of extinction in prairie dog metapopulations: plague outbreaks follow El Nino events. *Frontiers in Ecology and the Environment* 2:235-240.

- State of Wyoming Executive Department Executive Order 2015-4. 2015. Greater Sage-Grouse Core Area Protection. Issued 29 July 2015.
- Stephens, T., S.C. Wilson, F. Cassidy, D. Bender, D. Gummer, D.H.V. Smith, N. Lloyd, J.M. McPherson, and A. Moehrenschrager. 2018. Climate change impacts on the conservation outlook of populations on the poleward periphery of species ranges: a case study of Canadian black-tailed prairie dogs (*Cynomys ludovicianus*). *Global Change Biology* 24: 836-847.
- Stewart, I. T., D. R. Cayan, and M. D. Dettinger. 2004. Changes in snowmelt runoff timing in western North America under a “business as usual” climate change scenario. *Climatic Change* 62:217-232.
- Stockrahm, D.M. 1979. Comparison of population structure of black-tailed prairie dog towns in southwestern North Dakota. Masters thesis, University of North Dakota, Grand Forks, North Dakota. 103 pages.
- Tileston, J. V. and R. R. Lechleitner. 1966. Some comparisons of the black-tailed and white-tailed prairie dogs in north-central Colorado. *The American Midland Naturalist* 75:292-316.
- Trall, L.W., B.W. Brook, R.R. Frankham, and C.J.A. Bradshaw. 2010. Pragmatic population viability targets in a rapidly changing world. *Biological Conservation* 143:28-34.
- Trenberth, K. E. 2011. Changes in precipitation with climate change. *Climate Research* 47:123-138.
- Tripp, D. W., T. E. Rocke, J. P. Runge, R. C. Abbott, and M. W. Miller. 2017. Burrow dusting or oral vaccination prevents plague-associated prairie dog colony collapse. *EcoHealth* 14:451-462.
- Tripp, D. W., T. E. Rocke, S. P. Streich, N. L. Brown, J. Rodriguez-Ramos Fernandez, and M. W. Miller. 2014. Season and application rates affect vaccine bait consumption by prairie dogs in Colorado and Utah, USA. *Journal of Wildlife Diseases* 50:224-234.
- Tripp, D. W., S. P. Streich, D. A. Sack, D. J. Martin, K. A. Griffin, and M. W. Miller. 2016. Season of deltamethrin application affects flea and plague control in white-tailed prairie dog (*Cynomys leucurus*) colonies, Colorado, USA. *Journal of Wildlife Diseases* 52:553-561.

- Truett, J.C., K. Bly-Honess, D.H. Long, and M.K. Phillips. 2006. Habitat restoration and management. Pages 97-109 Proceedings of the Symposium on the Status of the Black-footed Ferret and its Habitat. J. E. Roelle, B. J. Miller, J. L. Godbey, and D. E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Underwood, J. 2007. Interagency management plan for Gunnison's prairie dogs in Arizona. Nongame and Endangered Wildlife Program. Arizona Game and Fish Department, Phoenix, Arizona. 74 pages.
- Uresk, D.W., and A.J. Bjugstad. 1983. Prairie dogs as ecosystem regulators on the northern high plains. Pages 91-94 in Proceedings of the Seventh North American Prairie Conference, 4-6 August 1980. Southwest Missouri State University, Springfield, Missouri. 321 pages.
- Uresk, D.W., J.G. MacCracken, and A.J. Bjugstad. 1981. Prairie dog density and cattle grazing relationships. Great Plains Wildlife Damage Control Workshop Proceedings 5:199-210.
- Uresk, D.W., and D.D. Paulson. 1988. Estimated carrying capacity for cattle competing with prairie dogs and forage utilization in western South Dakota. Pages 387-390 in Management of amphibians, reptiles, and small mammals in North America: Proceedings of the Symposium. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM 166. Fort Collins, Colorado. 458 pages.
- U.S. Fish and Wildlife Service. 1988. Black-footed ferret recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado. 154 pages.
- U.S. Fish and Wildlife Service. 1998. Memorandum re: Ferret reintroduction area, Buffalo Gap Forest Service National Grasslands, South Dakota, July 1998. 2 pages.
- U.S. Fish and Wildlife Service. 2013a. Recovery plan for the black-footed ferret (*Mustela nigripes*). U.S. Fish and Wildlife Service, Denver, Colorado. 157 pages.
- U.S. Fish and Wildlife Service. 2013b. Black-footed ferret programmatic safe harbor agreement. U.S. Fish and Wildlife Service Black-footed Ferret Recovery Program, Carr, Colorado. 54 pages.
- U.S. Fish and Wildlife Service. 2016a. Black-footed ferret field operations manual. U.S. Fish and Wildlife Service Black-footed Ferret Recovery Program, Carr, Colorado. 89 pages.
- U.S. Fish and Wildlife Service. 2016b. Partnerships, innovation, (and peanut butter) give new hope for America's most endangered mammal. <https://www.fws.gov/mountain-prairie/pressrel/2016/10182016-Partnerships-Innovation-and-Peanut-Butter-Give-New-Hope-for-Americas-Most-Endangered-Mammal.php>. Accessed 27 July 2019.

- U.S. Fish and Wildlife Service. 2017. Black-footed ferret managed care operations manual. U.S. Fish and Wildlife Service Black-footed Ferret Recovery Program, Carr, Colorado. 220 pages.
- U.S. Fish and Wildlife Service. 2018a. Finding of no significant impact for the proposed issuance of a recovery permit for black-footed ferret interspecies somatic cell nuclear transfer and genome editing research. U.S. Fish and Wildlife Service Black-footed Ferret Recovery Program, Carr, Colorado. 3 pages.
- U.S. Fish and Wildlife Service. 2018b. Rocky Mountain Arsenal National Wildlife Refuge report to the Black-footed Ferret Recovery Implementation Team Conservation Subcommittee. 3 pages.
- U.S. Fish and Wildlife Service. 2018c. UL Bend National Wildlife Refuge report to the Black-footed Ferret Recovery Implementation Team Conservation Subcommittee. 5 pages.
- U.S. Forest Service. 2008. Record of Decision on final environmental impact statement for black-tailed prairie dog management on the Nebraska National Forest and associated units. 22 pages.
- U.S. Forest Service. 2012. Forest Service expands shooting closure in Conata Basin. <https://www.fs.usda.gov/detail/nebraska/news-events/?cid=STELPRDB5381632>. Accessed 9 August 2019.
- Utah Division of Wildlife Resources. 2018. R657-19-6 Taking nongame animals. <https://wildlife.utah.gov/index.php/r657-19.html> Accessed 8 August 2019.
- Vallentine, J. F. 1990. Grazing Management. Academic Press, San Diego, California. 659 pages.
- Vargas, A. and S.H. Anderson. 1996. Growth and physical development of captive-raised black-footed ferrets (*Mustela nigripes*). American Midland Naturalist 135:43-52.
- Vermeire, L. T., R. K. Heitschmidt, P. S. Johnson, and B. F. Sowell. 2004. The prairie dog story: do we have it right? BioScience 54:689-695.
- Vosburgh, T. 1996. Impacts of recreational shooting on prairie dog colonies. M.S. Thesis. Montana State University, Bozeman. 50 pages.
- Vosburgh, T. C., and L. R. Irby. 1998. Effects of recreational shooting on prairie dog colonies. Journal of Wildlife Management 62:363-372.

- Vyas, N.B. 2013. Untested pesticide mitigation requirements: ecological, agricultural, and legal implications. *Drake Journal of Agricultural Law* 18:335-348.
- Vyas, N.B., C.S. Hulse, and C.P. Rice. 2012. Chlorophacinone residues in mammalian prey at a black-tailed prairie dog colony. *Environmental Toxicology and Chemistry* 31:2513-2516.
- Webb, C. T., C. P. Brooks, K. L. Gage, and M. F. Austin. 2006. Classic flea-borne transmission does not drive plague epizootics in prairie dogs. *Proceedings of the National Academy of Sciences* 103:6236-6241.
- Williams, E.S., and E.T. Thorne. 1996. Infectious and parasitic diseases of captive carnivores, with special emphasis on the black-footed ferret (*Mustela nigripes*). *Reviews in Science and Technology* 15:91-114.
- Wilson, D.E. and S. Ruff. 1999. Pages 168-175 in *The Smithsonian book of North American mammals*. Smithsonian Institution Press, Washington, D.C.
- Wimsatt, J., D.E. Biggins, E.S. Williams, and V.M. Becerra. 2006. The quest for a safe and effective canine distemper virus vaccine for black-footed ferrets. Pages 248-266 in *Recovery of the Black-footed Ferret: Progress and Continuing Challenges*. Roelle, J.E., B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Wisely, S.M. 2006. The genetic legacy of the black-footed ferret: past, present, and future. Pages 37-43 in *Recovery of the Black-footed Ferret: Progress and Continuing Challenges*. Roelle, J.E., B.J. Miller, J.L. Godbey, and D.E. Biggins, editors. U.S. Geological Survey Scientific Investigations Report 2005-5293.
- Wisely, S.M., M.A. Fleming, D.B. McDonald, S.W. Buskirk, and E.A. Ostrander. 2002. Genetic diversity and fitness in black-footed ferrets before and during a bottleneck. *Journal of Heredity* 93:231-237.
- Wisely, S.M., D.B. McDonald, and S.W. Buskirk. 2003. Evaluation of the species survival plan and captive breeding program for the black-footed ferret. *Zoo Biology* 22:287-298.
- Wisely, S.M., O.A. Ryder, R.M. Santymire, J.F. Engelhardt, and B.J. Novak. 2015. A road map for 21st century genetic restoration: gene pool enrichment of the black-footed ferret. *Journal of Heredity* 106:581-592.

- Wisely, S.M., R.M. Santymire, T.M. Livieri, S.A. Mueting, and J. Howard. 2008. Genotypic and phenotypic consequences of reintroduction history in the black-footed ferret (*Mustela nigripes*). *Conservation Genetics* 9:389-399.
- Woodhouse, C. A. and J. T. Peck. 1998. 2,000 Years of drought variability in the central United States. *Bulletin of the American Meteorological Society* 79:2693-2714.
- Wyoming Game and Fish Department. 2018. Monitoring effects and supplemental releases for black-footed ferrets (*Mustela nigripes*) in the Shirley Basin reintroduction area. Report to the Black-footed Ferret Recovery Implementation Team Conservation Subcommittee. 17 pages.

Appendix – Future Condition Tables

Appendix Table 1. Future condition table for facilities housing the captive black-footed ferret population, continuation scenario, 10 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	1	3	2	6
Smithsonian Conservation Biology Institute	3	3	2	8
Louisville Zoological Garden	2	2	1	5
Cheyenne Mountain Zoo	1	3	1	5
Phoenix Zoo	1	1	1	3
Toronto Zoo	1	2	2	5

Appendix Table 2. Future condition table for facilities housing the captive black-footed ferret population, continuation scenario, 20 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	1	3	2	6
Smithsonian Conservation Biology Institute	2	3	2	7
Louisville Zoological Garden	2	1	1	4
Cheyenne Mountain Zoo	1	3	1	5
Phoenix Zoo	1	1	1	3
Toronto Zoo	1	1	2	4

Appendix Table 3. Future condition table for 29 black-footed ferret reintroduction sites, continuation scenario, 10 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	3	3	3	3	3	3	18	1	69
UL Bend NWR, MT	BTPD	1	1	2	3	2	3	12	1	33
Ft. Belknap, MT	BTPD	1	1	2	3	1	2	10	1	31
Cheyenne River, SD	BTPD	1	2	1	1	1	1	7	0	0
BLM 40 Complex, MT	BTPD	0	1	1	1	0	1	4	0	0
Janos, MX	BTPD	0	2	1	1	0	1	5	0	0
Rosebud, SD	BTPD	1	2	1	1	1	1	7	0	0
Lower Brule, SD	BTPD	1	1	2	3	1	2	11	1	31
Wind Cave NP, SD	BTPD	1	2	2	3	1	3	12	1	37
Butte Creek Ranches, KS	BTPD	1	2	2	3	1	3	12	1	37
Northern Cheyenne, MT	BTPD	0	1	1	1	0	1	4	0	0
Vermejo BTPD, NM	BTPD	1	2	1	1	1	3	9	0	0
Grasslands NP, SK	BTPD	0	1	1	1	0	3	6	0	0
Walker Ranch, CO	BTPD	0	1	3	1	0	3	8	0	0
City of Fort Collins, CO	BTPD	1	1	3	3	1	3	12	1	37
North Holly, CO	BTPD	1	1	3	1	1	3	10	0	0
Liberty, CO	BTPD	1	1	3	1	1	3	10	0	0
Rocky Mountain Arsenal NWR, CO	BTPD	2	2	3	3	3	3	16	1	54
Crow Reservation, MT	BTPD	1	1	2	2	1	2	9	1	30
South Holly, CO	BTPD	1	1	3	1	1	3	10	0	0
Bad River Ranch, SD	BTPD	1	1	2	1	1	3	9	0	0

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	3	1	1	3	10	0	0
Aubrey Valley, AZ	GPD	2	2	2	2	1	2	11	1	45
Espee Ranch, AZ	GPD	1	2	2	1	1	2	9	0	0
Vermejo GPD, NM	GPD	1	1	1	1	1	3	8	0	0
Shirley Basin, WY	WTPD	2	3	1	2	2	2	11	1	46
Coyote Basin, CO-UT	WTPD	1	3	2	1	1	2	10	1	39
Wolf Creek, CO	WTPD	0	1	1	1	0	2	5	0	0
Meeteetse, WY	WTPD	1	2	3	3	1	2	12	0	41

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**

Appendix Table 4. Future condition table for 29 black-footed ferret reintroduction sites, continuation scenario, 20 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	3	3	3	3	3	3	18	1	69
UL Bend NWR, MT	BTPD	1	1	2	3	2	3	12	1	33
Ft. Belknap, MT	BTPD	1	1	2	3	1	2	10	1	31
Cheyenne River, SD	BTPD	1	2	1	1	1	1	7	0	0
BLM 40 Complex, MT	BTPD	0	1	1	1	0	1	4	0	0
Janos, MX	BTPD	0	2	1	1	0	1	5	0	0
Rosebud, SD	BTPD	1	2	1	1	1	1	7	0	0
Lower Brule, SD	BTPD	1	1	2	3	1	2	11	1	31
Wind Cave NP, SD	BTPD	1	2	2	3	1	3	12	1	37
Butte Creek Ranches, KS	BTPD	1	2	2	3	1	3	12	1	37
Northern Cheyenne, MT	BTPD	0	1	1	1	0	1	4	0	0
Vermejo BTPD, NM	BTPD	1	2	1	1	1	3	9	0	0
Grasslands NP, SK	BTPD	0	1	1	1	0	3	6	0	0
Walker Ranch, CO	BTPD	0	1	3	1	0	3	8	0	0
City of Fort Collins, CO	BTPD	1	1	3	3	1	3	12	1	37
North Holly, CO	BTPD	1	1	3	1	1	3	10	0	0
Liberty, CO	BTPD	1	1	3	1	1	3	10	0	0
Rocky Mountain Arsenal NWR, CO	BTPD	2	2	3	3	3	3	16	1	54
Crow Reservation, MT	BTPD	1	1	2	2	1	2	9	0	0
South Holly, CO	BTPD	1	1	3	1	1	3	10	0	0
Bad River Ranch, SD	BTPD	1	1	2	1	1	3	9	0	0

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	3	1	1	3	10	0	0
Aubrey Valley, AZ	GPD	2	2	2	2	1	2	11	1	45
Espee Ranch, AZ	GPD	1	2	2	1	1	2	9	0	0
Vermejo GPD, NM	GPD	1	1	1	1	1	3	8	0	0
Shirley Basin, WY	WTPD	2	3	1	2	2	2	11	1	46
Coyote Basin, CO-UT	WTPD	1	2	2	1	1	2	9	1	33
Wolf Creek, CO	WTPD	0	1	1	1	0	2	5	0	0
Meeteetse, WY	WTPD	1	2	3	3	1	2	12	0	41

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**

Appendix Table 5. Future condition table for facilities housing the captive black-footed ferret population, pessimistic scenario, 10 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	1	2	1	4
Smithsonian Conservation Biology Institute	2	2	1	5
Louisville Zoological Garden	2	2	1	5
Cheyenne Mountain Zoo	1	2	1	4
Phoenix Zoo	1	1	1	3
Toronto Zoo	1	2	1	4

Appendix Table 6. Future condition table for facilities housing the captive black-footed ferret population, pessimistic scenario, 20 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	1	2	1	4
Smithsonian Conservation Biology Institute	2	2	1	5
Louisville Zoological Garden	2	1	1	4
Cheyenne Mountain Zoo	1	2	1	4
Phoenix Zoo	1	1	1	3
Toronto Zoo	1	2	1	4

Appendix Table 7. Future condition table for 29 black-footed ferret reintroduction sites, pessimistic scenario, 10 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	2	2	2	2	3	3	14	1	48
UL Bend NWR, MT	BTPD	1	1	1	2	0	3	9	0	0
Ft. Belknap, MT	BTPD	1	1	1	2	0	2	7	0	0
Cheyenne River, SD	BTPD	1	2	1	1	1	1	7	0	0
BLM 40 Complex, MT	BTPD	0	1	1	1	0	1	4	0	0
Janos, MX	BTPD	0	2	1	1	0	1	5	0	0
Rosebud, SD	BTPD	1	2	1	1	1	1	7	0	0
Lower Brule, SD	BTPD	1	1	2	2	1	2	9	1	30
Wind Cave NP, SD	BTPD	1	1	2	2	1	3	10	1	31
Butte Creek Ranches, KS	BTPD	1	1	2	2	1	3	10	1	31
Northern Cheyenne, MT	BTPD	0	1	1	1	0	1	4	0	0
Vermejo BTPD, NM	BTPD	1	2	1	1	1	3	9	0	0
Grasslands NP, SK	BTPD	0	1	1	1	0	3	6	0	0
Walker Ranch, CO	BTPD	0	1	2	1	0	3	7	0	0
City of Fort Collins, CO	BTPD	1	1	2	2	1	3	10	1	31
North Holly, CO	BTPD	1	1	2	1	1	3	9	0	0
Liberty, CO	BTPD	1	1	2	1	1	3	9	0	0
Rocky Mountain Arsenal NWR, CO	BTPD	2	2	2	2	2	3	14	1	47
Crow Reservation, MT	BTPD	1	1	1	1	1	2	7	0	0
South Holly, CO	BTPD	1	1	2	1	1	3	9	0	0
Bad River Ranch, SD	BTPD	1	1	2	1	1	3	9	0	0

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	2	1	1	3	9	0	0
Aubrey Valley, AZ	GPD	2	2	1	2	1	2	10	1	36
Espee Ranch, AZ	GPD	1	1	1	1	1	2	7	0	0
Vermejo GPD, NM	GPD	1	1	1	1	1	3	8	0	0
Shirley Basin, WY	WTPD	2	2	1	2	2	2	11	1	37
Coyote Basin, CO-UT	WTPD	1	2	1	1	1	2	8	1	29
Wolf Creek, CO	WTPD	0	1	1	1	0	2	5	0	0
Meeteetse, WY	WTPD	1	2	2	2	1	2	10	0	35

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**

Appendix Table 8. Future condition table for 29 black-footed ferret reintroduction sites, pessimistic scenario, 20 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	2	2	2	2	3	3	14	1	48
UL Bend NWR, MT	BTPD	1	1	1	2	0	3	9	0	0
Ft. Belknap, MT	BTPD	1	1	1	2	0	2	7	0	0
Cheyenne River, SD	BTPD	1	2	1	1	1	1	7	0	0
BLM 40 Complex, MT	BTPD	0	1	1	1	0	1	4	0	0
Janos, MX	BTPD	0	2	1	1	0	1	5	0	0
Rosebud, SD	BTPD	1	2	1	1	1	1	7	0	0
Lower Brule, SD	BTPD	1	1	2	2	1	2	9	1	30
Wind Cave NP, SD	BTPD	1	1	2	2	1	3	10	1	31
Butte Creek Ranches, KS	BTPD	1	1	2	2	1	3	10	1	31
Northern Cheyenne, MT	BTPD	0	1	1	1	0	1	4	0	0
Vermejo BTPD, NM	BTPD	1	2	1	1	1	3	9	0	0
Grasslands NP, SK	BTPD	0	1	1	1	0	3	6	0	0
Walker Ranch, CO	BTPD	0	1	2	1	0	3	7	0	0
City of Fort Collins, CO	BTPD	1	1	2	2	1	3	10	1	31
North Holly, CO	BTPD	1	1	2	1	1	3	9	0	0
Liberty, CO	BTPD	1	1	2	1	1	3	9	0	0
Rocky Mountain Arsenal NWR, CO	BTPD	2	2	2	2	2	3	14	1	47
Crow Reservation, MT	BTPD	1	1	1	1	1	2	7	0	0
South Holly, CO	BTPD	1	1	2	1	1	3	9	0	0
Bad River Ranch, SD	BTPD	1	1	2	1	1	3	9	0	0

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	2	1	1	3	9	0	0
Aubrey Valley, AZ	GPD	2	1	1	2	1	2	9	1	35
Espee Ranch, AZ	GPD	1	1	1	1	1	2	7	0	0
Vermejo GPD, NM	GPD	1	1	1	1	1	3	8	0	0
Shirley Basin, WY	WTPD	2	2	1	2	2	2	11	1	41
Coyote Basin, CO-UT	WTPD	1	1	1	1	1	2	7	1	24
Wolf Creek, CO	WTPD	0	1	1	1	0	2	5	0	0
Meeteetse, WY	WTPD	1	2	2	2	1	2	10	0	35

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**

Appendix Table 9. Future condition table for facilities housing the captive black-footed ferret population, disastrous scenario, 10 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	1	1	1	3
Smithsonian Conservation Biology Institute	1	1	1	3
Louisville Zoological Garden	1	1	1	3
Cheyenne Mountain Zoo	1	1	1	3
Phoenix Zoo	1	1	1	3
Toronto Zoo	1	1	1	3

Appendix Table 10. Future condition table for facilities housing the captive black-footed ferret population, disastrous scenario, 20 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	1	1	1	3
Smithsonian Conservation Biology Institute	1	1	1	3
Louisville Zoological Garden	1	1	1	3
Cheyenne Mountain Zoo	1	1	1	3
Phoenix Zoo	1	1	1	3
Toronto Zoo	1	1	1	3

Appendix Table 11. Future condition table for 29 black-footed ferret reintroduction sites, disastrous scenario, 10 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	2	2	1	1	3	2	11	1	41
UL Bend NWR, MT	BTPD	1	1	1	1	1	3	8	0	0
Ft. Belknap, MT	BTPD	1	1	1	1	1	1	6	0	0
Cheyenne River, SD	BTPD	1	1	1	1	1	1	6	0	0
BLM 40 Complex, MT	BTPD	0	1	1	1	0	1	4	0	0
Janos, MX	BTPD	0	1	1	1	0	1	4	0	0
Rosebud, SD	BTPD	1	1	1	1	1	1	6	0	0
Lower Brule, SD	BTPD	1	1	1	1	1	1	6	0	0
Wind Cave NP, SD	BTPD	1	1	1	1	1	3	8	0	0
Butte Creek Ranches, KS	BTPD	1	1	1	1	1	3	8	0	0
Northern Cheyenne, MT	BTPD	0	1	1	1	0	1	4	0	0
Vermejo BTPD, NM	BTPD	1	1	1	1	1	1	6	0	0
Grasslands NP, SK	BTPD	0	1	1	1	0	3	6	0	0
Walker Ranch, CO	BTPD	0	1	1	1	0	1	7	0	0
City of Fort Collins, CO	BTPD	1	1	1	1	1	1	6	0	0
North Holly, CO	BTPD	1	1	1	1	1	1	6	0	0
Liberty, CO	BTPD	1	1	1	1	1	1	6	0	0
Rocky Mountain Arsenal NWR, CO	BTPD	2	2	1	1	2	3	11	1	41
Crow Reservation, MT	BTPD	1	1	1	1	1	1	6	0	0
South Holly, CO	BTPD	1	1	1	1	1	1	6	0	0
Bad River Ranch, SD	BTPD	1	1	1	1	1	1	6	0	0

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	1	1	1	1	6	0	0
Aubrey Valley, AZ	GPD	1	1	1	1	1	1	6	0	0
Espee Ranch, AZ	GPD	1	1	1	1	1	1	6	0	0
Vermejo GPD, NM	GPD	1	1	1	1	1	1	6	0	0
Shirley Basin, WY	WTPD	2	2	1	1	2	1	9	1	35
Coyote Basin, CO-UT	WTPD	1	1	1	1	1	1	6	0	0
Wolf Creek, CO	WTPD	0	1	1	1	0	1	4	0	0
Meeteetse, WY	WTPD	1	1	1	1	1	1	6	1	23

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**

Appendix Table 12. Future condition table for 29 black-footed ferret reintroduction sites, disastrous scenario, 20 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	2	2	1	1	3	2	11	1	41
UL Bend NWR, MT	BTPD	1	1	1	1	1	3	8	0	0
Ft. Belknap, MT	BTPD	1	1	1	1	1	1	6	0	0
Cheyenne River, SD	BTPD	1	1	1	1	1	1	6	0	0
BLM 40 Complex, MT	BTPD	0	1	1	1	0	1	4	0	0
Janos, MX	BTPD	0	1	1	1	0	1	4	0	0
Rosebud, SD	BTPD	1	1	1	1	1	1	6	0	0
Lower Brule, SD	BTPD	1	1	1	1	1	1	6	0	0
Wind Cave NP, SD	BTPD	1	1	1	1	1	3	8	0	0
Butte Creek Ranches, KS	BTPD	1	1	1	1	1	3	8	0	0
Northern Cheyenne, MT	BTPD	0	1	1	1	0	1	4	0	0
Vermejo BTPD, NM	BTPD	1	1	1	1	1	1	6	0	0
Grasslands NP, SK	BTPD	0	1	1	1	0	3	6	0	0
Walker Ranch, CO	BTPD	0	1	1	1	0	1	7	0	0
City of Fort Collins, CO	BTPD	1	1	1	1	1	1	6	0	0
North Holly, CO	BTPD	1	1	1	1	1	1	6	0	0
Liberty, CO	BTPD	1	1	1	1	1	1	6	0	0
Rocky Mountain Arsenal NWR, CO	BTPD	2	2	1	1	2	3	11	1	41
Crow Reservation, MT	BTPD	1	1	1	1	1	1	6	0	0
South Holly, CO	BTPD	1	1	1	1	1	1	6	0	0
Bad River Ranch, SD	BTPD	1	1	1	1	1	1	6	0	0

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	1	1	1	1	6	0	0
Aubrey Valley, AZ	GPD	1	1	1	1	1	1	6	0	0
Espee Ranch, AZ	GPD	1	1	1	1	1	1	6	0	0
Vermejo GPD, NM	GPD	1	1	1	1	1	1	6	0	0
Shirley Basin, WY	WTPD	2	2	1	1	2	1	9	1	35
Coyote Basin, CO-UT	WTPD	1	1	1	1	1	1	6	0	0
Wolf Creek, CO	WTPD	0	1	1	1	0	1	4	0	0
Meeteetse, WY	WTPD	1	1	1	1	1	1	6	0	0

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**

Appendix Table 13. Future condition table for facilities housing the captive black-footed ferret population, optimistic scenario, 10 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	2	3	3	8
Smithsonian Conservation Biology Institute	3	3	3	9
Louisville Zoological Garden	3	3	2	8
Cheyenne Mountain Zoo	2	3	3	8
Phoenix Zoo	2	2	1	5
Toronto Zoo	2	3	3	8

Appendix Table 14. Future condition table for facilities housing the captive black-footed ferret population, optimistic scenario, 20 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	3	3	3	9
Smithsonian Conservation Biology Institute	3	3	3	9
Louisville Zoological Garden	3	3	2	8
Cheyenne Mountain Zoo	2	3	3	8
Phoenix Zoo	2	2	2	6
Toronto Zoo	2	3	3	8

Appendix Table 15. Future condition table for 29 black-footed ferret reintroduction sites, optimistic scenario, 10 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	3	3	3	3	3	3	18	1	69
UL Bend NWR, MT	BTPD	2	2	3	3	2	3	15	1	53
Ft. Belknap, MT	BTPD	2	2	2	2	2	2	12	1	46
Cheyenne River, SD	BTPD	2	2	2	2	2	2	12	1	46
BLM 40 Complex, MT	BTPD	1	1	3	2	1	2	10	1	35
Janos, MX	BTPD	1	2	2	1	1	1	8	0	0
Rosebud, SD	BTPD	2	2	2	1	2	2	11	1	45
Lower Brule, SD	BTPD	1	1	3	3	2	2	12	1	37
Wind Cave NP, SD	BTPD	1	2	3	3	2	3	14	1	43
Butte Creek Ranches, KS	BTPD	2	2	3	3	2	3	15	1	53
Northern Cheyenne, MT	BTPD	1	1	2	1	1	1	7	1	28
Vermejo BTPD, NM	BTPD	2	2	2	1	1	3	11	1	45
Grasslands NP, SK	BTPD	1	1	3	2	1	3	11	1	36
Walker Ranch, CO	BTPD	1	1	3	1	1	3	10	1	35
City of Fort Collins, CO	BTPD	1	1	3	3	1	3	12	1	37
North Holly, CO	BTPD	1	1	3	1	1	3	10	0	0
Liberty, CO	BTPD	1	1	3	1	1	3	10	0	0
Rocky Mountain Arsenal NWR, CO	BTPD	2	2	3	3	3	3	16	1	54
Crow Reservation, MT	BTPD	1	1	2	2	1	2	9	1	30
South Holly, CO	BTPD	1	1	3	1	1	3	10	0	0
Bad River Ranch, SD	BTPD	1	1	2	1	1	3	9	1	30

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	2	1	1	3	9	0	0
Aubrey Valley, AZ	GPD	3	2	3	2	2	2	14	1	61
Espee Ranch, AZ	GPD	1	2	2	2	1	2	10	1	35
Vermejo GPD, NM	GPD	1	1	1	1	1	3	8	0	0
Shirley Basin, WY	WTPD	2	3	2	2	2	2	13	1	51
Coyote Basin, CO-UT	WTPD	2	3	2	2	2	2	13	1	51
Wolf Creek, CO	WTPD	1	2	2	2	1	2	10	1	34
Meeteetse, WY	WTPD	2	2	3	3	2	2	14	0	52

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**

Appendix Table 16. Future condition table for 29 black-footed ferret reintroduction sites, optimistic scenario, 20 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	3	3	3	3	3	3	18	1	69
UL Bend NWR, MT	BTPD	2	2	3	3	2	3	15	1	53
Ft. Belknap, MT	BTPD	2	2	2	2	2	2	12	1	46
Cheyenne River, SD	BTPD	2	2	2	2	2	2	12	1	46
BLM 40 Complex, MT	BTPD	1	1	3	2	1	2	10	1	35
Janos, MX	BTPD	1	2	2	1	1	1	8	0	0
Rosebud, SD	BTPD	2	2	2	1	2	2	11	1	45
Lower Brule, SD	BTPD	1	1	3	3	2	2	12	1	37
Wind Cave NP, SD	BTPD	1	2	3	3	2	3	14	1	43
Butte Creek Ranches, KS	BTPD	2	2	3	3	2	3	15	1	53
Northern Cheyenne, MT	BTPD	1	1	2	1	1	1	7	1	28
Vermejo BTPD, NM	BTPD	2	1	2	1	1	3	10	1	30
Grasslands NP, SK	BTPD	1	1	3	2	1	3	11	1	36
Walker Ranch, CO	BTPD	1	1	3	1	1	3	10	1	35
City of Fort Collins, CO	BTPD	1	1	3	3	1	3	12	1	37
North Holly, CO	BTPD	1	1	3	1	1	3	10	0	0
Liberty, CO	BTPD	1	1	3	1	1	3	10	0	0
Rocky Mountain Arsenal NWR, CO	BTPD	2	2	3	3	3	3	16	1	54
Crow Reservation, MT	BTPD	1	1	2	2	1	2	9	1	30
South Holly, CO	BTPD	1	1	3	1	1	3	10	0	0
Bad River Ranch, SD	BTPD	1	1	2	1	1	3	9	1	30

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	2	1	1	3	9	0	0
Aubrey Valley, AZ	GPD	2	2	3	2	2	2	13	1	51
Espee Ranch, AZ	GPD	1	1	2	2	1	2	9	1	30
Vermejo GPD, NM	GPD	1	1	1	1	1	3	8	0	0
Shirley Basin, WY	WTPD	2	3	2	2	2	2	13	1	51
Coyote Basin, CO-UT	WTPD	2	2	2	2	2	2	12	1	46
Wolf Creek, CO	WTPD	1	2	2	2	1	2	10	1	34
Meeteetse, WY	WTPD	2	2	3	3	2	2	14	0	52

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**

Appendix Table 17. Future condition table for facilities housing the captive black-footed ferret population, transformation scenario, 10 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	3	3	3	9
Smithsonian Conservation Biology Institute	3	3	3	9
Louisville Zoological Garden	3	3	3	9
Cheyenne Mountain Zoo	3	3	3	9
Phoenix Zoo	3	3	3	9
Toronto Zoo	3	3	3	9

Appendix Table 18. Future condition table for facilities housing the captive black-footed ferret population, transformation scenario, 20 years into the future. Numbers denote resiliency class scores (1=low, 2=moderate, and 3=high).

Facility	% Whelping success	Mean # kits/litter	% Kits weaned	TOTAL SCORE
National Black-footed Ferret Conservation Center	3	3	3	9
Smithsonian Conservation Biology Institute	3	3	3	9
Louisville Zoological Garden	3	3	3	9
Cheyenne Mountain Zoo	3	3	3	9
Phoenix Zoo	3	3	3	9
Toronto Zoo	3	3	3	9

Appendix Table 19. Future condition table for 29 black-footed ferret reintroduction sites, transformation scenario, 10 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	3	3	3	3	3	3	18	1	69
UL Bend NWR, MT	BTPD	2	2	3	3	3	3	16	1	54
Ft. Belknap, MT	BTPD	3	3	3	3	3	3	18	1	69
Cheyenne River, SD	BTPD	3	3	3	3	3	3	18	1	69
BLM 40 Complex, MT	BTPD	1	2	3	3	3	3	15	1	44
Janos, MX	BTPD	3	3	3	3	3	3	18	1	69
Rosebud, SD	BTPD	3	3	3	3	3	3	18	1	69
Lower Brule, SD	BTPD	2	2	3	3	2	2	14	1	52
Wind Cave NP, SD	BTPD	2	2	3	3	3	3	16	1	54
Butte Creek Ranches, KS	BTPD	3	2	3	3	2	3	17	1	63
Northern Cheyenne, MT	BTPD	2	2	2	2	2	2	12	1	46
Vermejo BTPD, NM	BTPD	3	3	3	3	3	3	18	1	69
Grasslands NP, SK	BTPD	1	2	3	3	2	3	15	1	43
Walker Ranch, CO	BTPD	2	2	3	3	2	3	15	1	53
City of Fort Collins, CO	BTPD	1	2	3	3	3	3	15	1	44
North Holly, CO	BTPD	1	2	3	3	2	3	14	1	43
Liberty, CO	BTPD	1	2	3	3	2	3	14	1	43
Rocky Mountain Arsenal NWR, CO	BTPD	3	2	3	3	3	3	17	1	64
Crow Reservation, MT	BTPD	2	2	2	2	2	2	12	1	46
South Holly, CO	BTPD	1	1	3	3	1	3	12	1	37
Bad River Ranch, SD	BTPD	2	2	3	3	3	3	16	1	54

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	3	3	1	3	12	1	37
Aubrey Valley, AZ	GPD	2	2	3	3	3	2	17	1	53
Espee Ranch, AZ	GPD	2	2	3	3	2	2	14	1	52
Vermejo GPD, NM	GPD	2	2	3	3	2	3	15	1	53
Shirley Basin, WY	WTPD	3	3	3	3	3	2	17	1	68
Coyote Basin, CO-UT	WTPD	2	2	3	3	3	2	17	1	53
Wolf Creek, CO	WTPD	2	2	3	3	2	2	15	1	52
Meeteetse, WY	WTPD	3	3	3	3	3	2	17	0	68

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**

Appendix Table 20. Future condition table for 29 black-footed ferret reintroduction sites, transformation scenario, 20 years into the future. Numbers denote resiliency class scores (0=inactive, 1=low, 2=moderate, and 3=high).

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Conata Basin, SD	BTPD	3	3	3	3	3	3	18	1	69
UL Bend NWR, MT	BTPD	2	2	3	3	3	3	16	1	54
Ft. Belknap, MT	BTPD	3	3	3	3	3	3	18	1	69
Cheyenne River, SD	BTPD	3	3	3	3	3	3	18	1	69
BLM 40 Complex, MT	BTPD	1	2	3	3	3	3	15	1	44
Janos, MX	BTPD	3	3	3	3	3	3	18	1	69
Rosebud, SD	BTPD	3	3	3	3	3	3	18	1	69
Lower Brule, SD	BTPD	2	2	3	3	2	2	14	1	52
Wind Cave NP, SD	BTPD	2	2	3	3	3	3	16	1	54
Butte Creek Ranches, KS	BTPD	3	2	3	3	2	3	17	1	63
Northern Cheyenne, MT	BTPD	2	2	2	2	2	2	12	1	46
Vermejo BTPD, NM	BTPD	3	3	3	3	3	3	18	1	69
Grasslands NP, SK	BTPD	1	2	3	3	2	3	15	1	43
Walker Ranch, CO	BTPD	2	2	3	3	2	3	15	1	53
City of Fort Collins, CO	BTPD	1	2	3	3	3	3	15	1	44
North Holly, CO	BTPD	1	2	3	3	2	3	14	1	43
Liberty, CO	BTPD	1	2	3	3	2	3	14	1	43
Rocky Mountain Arsenal NWR, CO	BTPD	3	2	3	3	3	3	17	1	64
Crow Reservation, MT	BTPD	2	2	2	2	2	2	12	1	46
South Holly, CO	BTPD	1	1	3	3	1	3	12	1	37
Bad River Ranch, SD	BTPD	2	2	3	3	3	3	16	1	54

Site and Location	Prairie Dog Species	5-year mean # of breeding adults	5-year mean ferret family rating	Annual Plague Management Level	Annual Ferret Vaccination Level	Ferret Population Persistence	Level of PD Population Protection	Current Resiliency (Subtotal)	Occupancy Multiplier (1 or 0)	Adjusted Current Condition (weighted)*
Moore Ranch, NM	BTPD	1	1	3	3	1	3	12	1	37
Aubrey Valley, AZ	GPD	3	3	3	3	3	2	17	1	68
Espee Ranch, AZ	GPD	2	2	3	3	2	2	14	1	52
Vermejo GPD, NM	GPD	2	2	3	3	2	3	15	1	53
Shirley Basin, WY	WTPD	3	3	3	3	3	2	17	1	68
Coyote Basin, CO-UT	WTPD	3	3	3	3	3	2	17	1	68
Wolf Creek, CO	WTPD	2	3	3	3	2	2	15	1	57
Meeteetse, WY	WTPD	3	3	3	3	3	2	17	0	68

***Adjusted Current Condition** is a weighted value that is the result of multiplying the 5-year mean # of breeding adults condition class by 10 and the 5-year mean ferret family rating and annual plague management level condition classes by 5, and adding these values to the remaining condition classes. **Condition class rankings are as follows: 0 = Inactive, ≤ 33 = Low, > 33 and ≤ 50 = Moderate, > 50 = High**