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The importance of thinking big: Large-scale prey conservation drives black-footed ferret reintroduction success

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ABSTRACT

Objective evaluations of wildlife reintroductions are vital for increasing the success of future efforts to re-establish endangered species. Attempts to reintroduce one of the most endangered mammals in North America, the black-footed ferret (*Mustela nigripes*), have been ongoing for 18 years with no quantitative assessment of factors related to reintroduction success. We examined relationships between ferret reintroduction success and factors associated with disease outbreaks, release strategies, and the distribution and abundance of their primary prey, prairie dogs (*Cynomys* sp.), at 11 reintroduction sites. The most important factor related to ferret reintroduction success was a cumulative metric incorporating both size of the area occupied by prairie dogs and density of prairie dog burrows within that area. Each of the four successful sites had prairie dog populations that occupied an area of at least 4300 ha. No sites with <4300 ha of prairie dogs were successful in maintaining ⩾30 adult individual ferrets over multiple years without augmentation even if they had a high prairie dog burrow density. The overarching importance of the availability of high-quality habitat suggests managers should prioritize actions that maintain and enhance the availability of large areas with high prairie dog burrow density, which are becoming increasingly rare due to anthropogenic impacts and disease outbreaks.

1. Introduction

Successful reintroductions are essential for the conservation and recovery of many endangered species (Griffith et al., 1989), but reintroduction attempts often fail (Beck et al., 1994; Armstrong and Seddon, 2008). Despite this lack of success, few attempts have been made to evaluate factors that differentiate successful and unsuccessful reintroductions (Griffith et al., 1989; Wolf et al., 1996, 1998; Fischer and Lindenmayer, 2000). Further examinations of these factors are essential because objective evaluations of reintroduction attempts strengthen our understanding of reintroduction biology and provide important information for decision-makers (Sarrazin and Barbault, 1996; IUCN, 1998). Such examinations can help conservation biologists prioritize future reintroduction efforts so that available funding is focused on recovery sites and strategies that have a high likelihood of success (Gusset et al., 2008a).

Evaluations of carnivore reintroductions are particularly important given the political and biological challenges involved with these species. For example, many carnivore reintroductions face public opposition due to economic cost and perceived threats to human activities or interests (Reading and Clark, 1996; Breitenmoser et al., 2001). Availability of suitable sites and feasibility of re-establishing populations are limited because carnivore species often are characterized by low population densities (Carbone and Gittleman, 2002), large home ranges (Woodroffe and Ginsberg, 1998), sensitivity to habitat fragmentation (Schadt et al., 2002), complex social structures (Gusset et al., 2008a; Somers and Gusset, 2009), and dependence on specific prey species (Steury and Murray, 2004). These complexities underscore the importance of evaluating factors that might influence success of carnivore reintroduction attempts. However, data often are insufficient for thorough evaluation of individual reintroduction attempts, and factors affecting reintroduction success throughout the range of a species might not be evident in results from a single site. Consequently, comparative approaches can be insightful when reintroductions have been attempted at multiple sites (Gusset et al., 2008a).

The black-footed ferret (*Mustela nigripes*, hereafter referred to as the ferret), among the most endangered mammals in North America (Clark, 1987), has been the subject of one of the highest profile reintroduction programs (Lockhart et al., 2006). Following the capture of the last 18 wild ferrets and subsequent captive breeding in 1987, reintroduction attempts were initiated (Thorne and

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Williams, 1988; Seal et al., 1989; Clark, 1997) and implemented through a cooperative effort with the Black-footed Ferret Recovery Implementation Team (BFFRIT), a group composed of federal, state, tribal, and private stakeholders. There have been 18 attempts to reintroduce ferrets during the last 18 years (Jachowski and Lockhart, 2009). Although >2900 ferrets have been released, results across release sites have been mixed. Most reintroduced populations have not grown consistently, but a few attempts have established relatively large populations of ferrets (Livieri, 2006; Grenier et al., 2007). Factors differentiating successful and unsuccessful reintroductions have not been evaluated.

We developed hypotheses about biological conditions and release strategies that might contribute to successful reintroduction, and used results of ferret reintroduction attempts to test our hypotheses. Ferrets are extremely specialized carnivores, occurring only on prairie dog (*Cynomys sp.*) colonies (Henderson et al., 1969; Biggins et al., 2006a), and depending on prairie dogs for >90% of their diet (Sheets et al., 1972; Campbell et al., 1987). Therefore, we hypothesized that success of reintroduction attempts would be greater at sites where abundance of prairie dogs was high, as measured by the total area occupied by prairie dogs, prairie dog density, or a combination of both metrics. Ferrets are extremely vulnerable to an exotic disease, sylvatic plague (hereafter referred to as plague), which acts as a catastrophic stochastic factor within the ecosystem (Williams et al., 1994; Rocke et al., 2008). In addition to the direct effect of plague on ferrets, plague epizootics result in 85–100% declines in prairie dog populations (Rayor, 1985; Ubico et al., 1988; Cully and Williams, 2001; Pauli et al., 2006). Once a plague epizootic has occurred in an area, outbreaks are likely to reoccur at 5–10 year intervals (Barnes, 1982). Therefore, we hypothesized that successful sites have not had an epizootic occur or have had fewer incidences of epizootic plague.

Reintroduction efforts must assess how many animals need to be released to establish a population (Armstrong and Seddon, 2008) and when to halt releases (Schaub et al., 2009). Sometimes, sustained release of individuals is unlikely to contribute to population persistence and reintroduction success (Griffith et al., 1989; Steury and Murray, 2004). However, the release of too few individuals might result in populations that do not persist due to demographic stochasticity or Allee effects (Armstrong and Seddon, 2008; Somers et al., 2008). The continued release of animals over multiple years might augment populations and overcome these effects (Smith and Clark, 1994; Gusset et al., 2009). Therefore, we hypothesized that the number of animals released and the number of years reintroductions took place at a site are positively correlated with reintroduction success.

2. Methods

2.1. Study areas

From 1991 to 2008, approximately 2964 captive-born ferrets were released and 157 wild ferrets were translocated to initiate or supplement populations of ferrets at 18 sites in the United States and one site in Mexico (Jachowski and Lockhart, 2009), all within the historical range of the species. Reintroduction sites were identified by the BFFRIT based on habitat conditions, a local commitment to monitoring and management of ferrets, and socio-political conditions favorable to their conservation. Sites typically were geographically isolated from each other such that movement of ferrets between sites was rare or non-existent. We limited our analyses to those reintroduction sites where >5 years had elapsed from the initial release of ferrets until December 2008 ($n = 11$) (Fig. 1). This 5-year threshold is consistent with general recommendations for evaluating carnivore reintroductions (Breitenmoser et al., 2001) and is appropriate for ferrets given their short generation time and potential for rapid population growth (Grenier et al., 2007), making it biologically plausible for a ferret population to grow fast enough to meet the threshold for being considered "recovered" (see Section 2.3 below) after 5 years.

2.2. Field monitoring

To evaluate reintroduction attempts, we used data provided by BFFRIT members responsible for overseeing the post-release monitoring of ferrets at each reintroduction site. The BFFRIT expected site managers to conduct annual standardized spotlight surveys to assess the status of ferret populations (Biggins et al., 2006b). During spotlight surveys, ferrets were located, captured in traps, anesthetized and uniquely marked with passive-integrated-transponder microchips (Fagerstone and Johns, 1987; Grenier et al., 2009). Survey results were used to calculate an index of ferret abundance, expressed as the minimum number known alive (Krebs, 1966). Although this index does not account for incomplete and variable detectability, the field protocol generally is believed to detect >82% of the adult ferrets present, making this index adequate for our examination (Biggins et al., 2006b).

Habitat quantity and quality at reintroduction sites were assessed using standardized techniques to measure the maximum extent of prairie dog colonies (aggregations of prairie dog family groups defined by the maximum extent of burrow systems) (Hoogland, 1995) and the mean burrow density of prairie dogs through density transects (Biggins et al., 1993). The standardized monitoring of prairie dog populations also provided an indirect in-

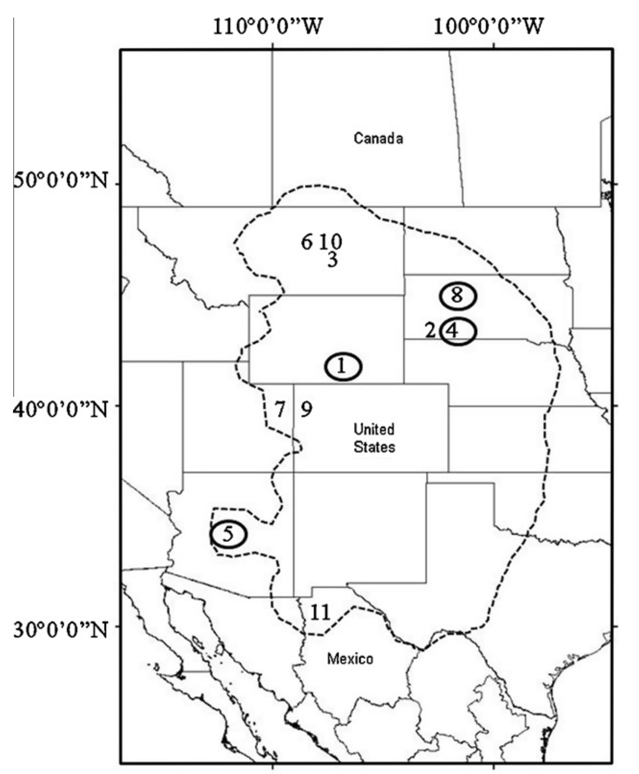

Fig. 1. Great Plains of North America, with state and international boundary lines, showing the historical range of the black-footed ferret (*Mustela nigripes*) (dashed line). The 11 ferret reintroduction sites that we used in our analysis (i.e. all reintroduction sites where ⩾5 years had elapsed from the initial release of ferrets until December 2008) are numbered in sequential order based on year of first release: (1) Shirley Basin, (2) Badlands, (3) UL Bend, (4) Conata Basin, (5) Aubrey Valley, (6) Ft. Belknap, (7) Coyote Basin, (8) Cheyenne River, (9) Wolf Creek, (10) 40-Complex, and (11) El Cuervo. Sites where reintroduction met our criteria for success are circled.

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dex of epizootic outbreaks of plague, which were apparent due to rapid, large-scale mortality of prairie dog populations (Collinge et al., 2005; Wagner et al., 2006). We used this information to determine if a plague epizootic had occurred following a reintroduction attempt and tallied the number of years epizootic outbreaks were observed since reintroduction.

2.3. Data analyses

We established biological criteria for defining reintroduction success based on the concept that the principal aim of a species reintroduction project is to establish a self-sustaining population that requires minimal long-term intervention (IUCN, 1998). The goal of the current ferret recovery plan for down-listing the species from Endangered to Threatened status is the establishment of 1500 free-ranging, breeding adult ferrets distributed in >10 populations over the historical range of the species, with ⩾30 breeding adults in each population (US Fish and Wildlife Service, 1988). Therefore, we categorized a reintroduction site as successful if it directly contributed to down-listing by maintaining a population of ⩾30 adult ferrets. We further refined this definition by requiring sites to have documented the ability to maintain a population of ⩾30 adult ferrets for >2 years without augmentation of captive-bred or translocated animals prior to December 2008.

We examined how 11 variables differed between successful and unsuccessful reintroduction sites (Table 1). We focused on variables in three categories: (1) variables related to prairie dogs (area occupied by prairie dogs, colony number, colony size, prairie dog burrow density, a composite index based on both area occupied by prairie dogs and burrow density, and species); (2) disease or plague-related variables (epizootic plague occurrence and the number of epizootics); and (3) ferret reintroduction variables (number of years released, number of years since initial reintroduction, and cumulative total number released).

In this analysis, our composite index of prairie dog biomass was calculated by multiplying the total area occupied by prairie dogs in each site by the average density of prairie dog burrows per ha, a metric we termed the prairie dog index. Prior to conducting analyses, we hypothesized that this index would be a more accurate measure of the total prey base for ferrets than either area occupied by prairie dogs or density alone. For example, black-tailed prairie dogs (*Cynomys ludovicianus*) typically occur at higher densities than white-tailed (*C. leucurus*) or Gunnison's prairie dogs (*C. gunnisoni*) (Cully and Williams, 2001), while the areas occupied were much larger, on average, at reintroduction sites occupied by one of the latter two species. The prairie dog index standardized total prey biomass across reintroduction sites regardless of which one of these species was present. We calculated a prairie dog index for each year at sites where both the area occupied by prairie dogs and burrow density data were available. Because data were not available for each metric every year for some sites, we averaged all recorded data across years to generate a single mean value of each metric for each site. We used site averages versus a summary parameter that down-weighted extreme values (e.g., median) because a year of especially high or low prairie dog abundance could have a disproportionately strong effect in determining whether the population achieved a sufficient minimum population size to escape limiting effects of demographic stochasticity and other extinction factors.

We focused on univariate comparisons of each variable between successful and unsuccessful reintroduction sites due to the low number of reintroduction sites available ($n = 11$). For numeric variables we used the Wilcoxon Rank–Sum test to examine whether the distributions of each variable differed between successful and unsuccessful sites, and we computed 90% nonparametric confidence intervals for the difference in the location parameter for the two distributions (R Core Development Team, 2008). For non-numeric variables, we used univariate logistic regression to examine whether there was evidence that the proportion of successful sites differed among categories of each variable. We used a likelihood ratio test to determine if there was a statistically significant effect of each categorical variable (i.e., by comparing the univariate model to an intercept-only null model). Our sample size was constrained by the number of existing ferret reintroduction sites, but such low sample sizes characterize almost all reintroduction efforts (Seddon et al., 2007). To appropriately balance our ability to detect relationships of conservation significance *vs*. our need to minimize Type I error, we set $\alpha = 0.10$ for

Table 1
Summary (mean value or percentage of sites and standard deviation) and parameter estimate contrasting successful and unsuccessful reintroduction sites (with 90% confidence intervals and significance) of variables hypothesized to influence reintroduction success of black-footed ferrets (*Mustela nigripes*) at 11 sites in North America.

Parameter	Successful sites[a]	Unsuccessful sites	Estimate [b]	90% CI		*P*
				Lower bound	Upper bound	
Habitat						
Average size of area occupied by prairie dogs (ha)	9406.6 (4681.0)	3879.6 (3427.1)	5530	161	11,079	0.07
Average number of colonies	54.9 (75.9)	23.3 (21.6)	3.9	−11.4	144.0	0.92
Average colony size (ha)	619.4 (680.9)	1431.1 (3435.4)	220	−279	1336	0.40
Average prairie dog density (burrows/ha)	47.2 (29.8)	50.9 (33.8)	−1.6	−46.6	40.0	0.92
Average total prairie dog index	346127.1 (176652.8)	97551.1 (55,926.2)	207,563	90,158	486,044	0.02
Prairie dog species (number of sites)	*Cynomys ludovicianus* (2) *C. leucurus* (1) *C. gunnisoni* (1)	*C. ludovicianus* (5) *C. leucurus* (2)	0.4 [c]	0.05	3.42	0.48
Disease						
Number of sylvatic plague epizootics	1.8 (2.9)	0.9 (1.5)	0.0	−1.0	5.0	0.75
Occurrence of sylvatic plague epizootic	50% had plague epizootic	40% had plague epizootic	1.3	0.2	10.6	0.82
Ferret releases						
Total years released	7.3 (2.5)	5.1 (2.2)	2.2	0.0	6.0	0.20
Years since 1st reintroduction	12.3 (3.7)	9.7 (3.1)	3.0	−2.0	7.0	0.29
Total ferrets released	294.0 (161.6)	216.3 (64.1)	60.9	−72.0	274.0	0.57

[a] Success was defined by documented ability of a site to maintain a population of ⩾30 adults more than 2 years after halt of augmentation. Successful reintroduction sites included Aubrey Valley (Arizona), Shirley Basin (Wyoming), Cheyenne River (South Dakota), and Conata Basin (South Dakota).
[b] For Prairie dog species and Plague epizootic, results are based on univariate logistic regression models for the probability that a site is successful, including the estimated odds ratio (odds of being a successful site for the first category of each variable/odds for the second category), confidence interval for this odds ratio, and significance of a likelihood ratio test comparing a logistic regression model with the variable included to an intercept-only model. For other variables, results are the difference (successful–unsuccessful sites), confidence interval for this difference, and significance of the difference based on the Wilcoxon Rank Sum non-parametric analog of the 2-sample *t*-test.
[c] Comparing black-tailed prairie dogs (*Cynomys ludovicianus*) to both white-tailed (*C. leucurus*) and Gunnison's prairie dogs (*C. gunnisoni*).

evaluating statistical significance and we focused on 90% confidence intervals for evaluating biological significance.

3. Results

Four of the 11 reintroduction sites we examined met our criteria of success as of December 2008. Successful sites were located in Arizona, South Dakota and Wyoming, on privately and publicly-owned lands (Fig. 1). Of the seven sites that did not meet our criteria for success, two no longer contained ferrets by December 2008 (40-Complex and Ft. Belknap Indian Reservation), while the remaining five sites contained small populations or were periodically augmented with captive-reared or translocated individuals (i.e., UL Bend, Coyote Basin, Wolf Creek, El Cuervo, and Badlands).

The average total area occupied by prairie dogs and the prairie dog index value were higher on successful than unsuccessful sites (Table 1). Four of the five sites with a prairie dog index >150,000 were successful (Table 1, Fig. 2). None of the reintroductions on sites where prairie dog populations occupied <4300 ha were successful even if the site had a high density of prairie dogs (Fig. 2). Average colony size, prairie dog burrow density, and species of prairie dog did not differ between successful and unsuccessful sites (Table 1). Successful reintroductions included sites occupied by each of the three prairie dog species.

The documented occurrence of plague epizootics and the number of epizootics did not differentiate successful and unsuccessful sites (Table 1). Two of the four successful reintroduction sites had at least one plague epizootic, but their ferret populations persisted or recovered sufficiently to meet our criteria of success. Successful and unsuccessful sites were not differentiated by the number of ferrets released, the number of years in which releases occurred, or the number of years since first reintroduction. Both successful and unsuccessful sites on average received over 200 captive-reared ferrets over approximately 10 years (Table 1).

4. Discussion

We evaluated how successful and unsuccessful ferret reintroduction sites differed in spatial extent and burrow density of prairie dogs, occurrence of plague epizootics, and the intensity of ferret release efforts. Successful reintroductions occurred on sites where the total area occupied by prairie dogs was large and the total relative biomass of prairie dogs was high. These metrics directly measure habitat availability and quality for ferrets because ferrets require prairie dogs as prey and use their burrows for security and denning (Forrest et al., 1988; Jachowski et al., 2010). Therefore, our results show that habitat characteristics were the most important factor affecting success of reintroduction attempts for ferrets.

Our findings support a common paradigm in reintroduction biology that emphasizes habitat quantity and quality as critical factors determining whether self-sustaining populations can be reestablished and avoid extinction (Griffith et al., 1989; Kleiman, 1989; Wolf et al., 1996). The availability of high-quality habitat is essential for conserving endangered carnivores (Wikramanayake et al., 1998; Dinerstein et al., 2007) and predicting extinction risk (Woodroffe and Ginsberg, 1998). Our work suggests that such metrics similarly are important for reintroduction success. For ferrets, the best measure of habitat quality integrates the spatial extent of suitable habitat and the density of the primary prey. Prairie dog density alone, as indexed by burrow density, did not differentiate successful and unsuccessful sites. Rather than focusing solely on area of suitable habitat (Woodroffe and Ginsberg, 1998) or density of prey within a defined area (Steury and Murray, 2004; Hetherington and Gorman, 2007), managers should consider both the size and quality of the habitat when potential ferret reintroduction sites are being evaluated.

In contrast to the general assumption that increasing the number of animals released improves the likelihood of carnivore reintroduction success (Breitenmoser et al., 2001), the number of ferrets and duration of release attempts did not differ between successful and unsuccessful sites. Most endangered large carnivores are characterized by high longevity, long generation time, and small litter sizes (Purvis et al., 2000). In contrast, ferrets have exhibited a high potential rate of increase that has resulted in rapid population growth from relatively small (5–25 individual) founder populations when high-quality habitat is available (Grenier et al., 2007). Ferrets and possibly other small carnivores with high potential intrinsic rates of increase may increase in abundance rapidly if habitat quality and quantity are sufficient. The rapid population growth possible when habitat is sufficient can allow a reintroduced population to increase rapidly to a level at which demographic and genetic stochastic processes and factors such as Allee effects pose little threat to the population's persistence. Further, our findings suggest that the number of individuals released at most ferret reintroduction sites might have been high enough such that habitat availability was the primary factor determining likelihood of success. This would indicate that there are diminishing returns with continued releases.

Emerging infectious diseases pose a severe threat to reintroduced wildlife populations (Daszak, 2000), and carnivore reintroductions in particular (Scheepers and Venzke, 1995; Schmidt-Posthaus et al., 2002; Wild et al., 2006). Epizootic outbreaks of sylvatic plague were not related to ferret reintroduction success during our period of study, but future management of reintroduced ferret populations requires a better understanding of the long-term impacts of this emerging infectious disease. In particular, results to date suggest that subsequent examinations of ferret reintroduction attempts should examine the hypothesis that there is an interaction between habitat availability and the threat posed by plague. Of the three ferret reintroduction sites with a longer history of exposure to sylvatic plague, two small reintroduction sites (Ft. Belknap and 40-Complex) suffered massive prairie dog die-offs and the extirpation of ferret populations (Antolin et al., 2002; Jachowski and Lockhart, 2009). In contrast, a single large site (Shirley Basin) persisted through a plague epizootic without management intervention and subsequently supported a large ferret population (Grenier et al., 2007). Persistence of ferrets at the Shirley Basin site suggests that the effects of plague epizootics can be overcome without intervention when sufficient habitat is

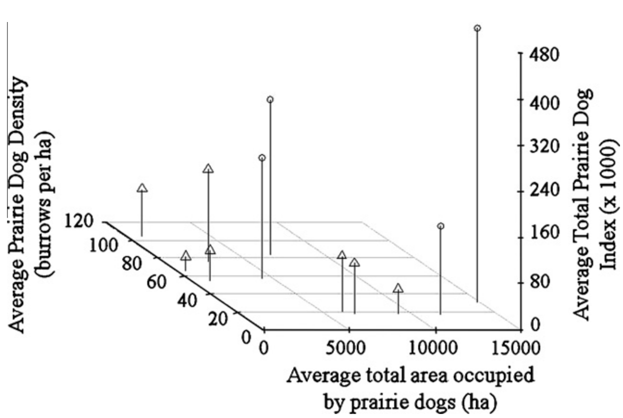

Fig. 2. The average total prairie dog (*Cynomys sp.*) index value (calculated as the area that the prairie dog population covers multiplied by burrow density) shown in relation to the average total area (ha) occupied by prairie dogs and the average density of prairie dog burrows per ha for 11 black-footed ferret (*Mustela nigripes*) reintroduction sites in North America. Unsuccessful sites are denoted by triangles. Successful sites, denoted by circles, contained prairie dog index values greater than 150,000 and were greater than 4000 ha in size.

available. However, there are additional complications in assessing past effects and the relative threat posed by plague and its interaction with habitat. For example, ferrets at the Conata Basin site likely persisted during recent plague epizootics due to management intervention via flea control (Greibel, 2009). In addition, new research has suggested that plague persists between epizootic outbreaks at an enzootic level which has a limiting effect on prairie dog (Biggins et al., 2010) and ferret (Matchett et al., 2010) populations. Therefore, further work is needed to assess the need for and effectiveness of plague intervention in large prairie dog populations, the sustainability of such intervention, and the long-term effects of this disease as it spreads to new areas and re-occurs in epizootic and inter-epizootic (i.e. enzootic) forms in areas where it already is present. We are not saying plague is unimportant; rather our results indicate that habitat availability is of overriding importance when compared with epizootic outbreaks, given information to date.

Efforts to increase success of carnivore reintroductions typically focus on improving release strategies (Rodriguez et al., 1995) and managing small populations of reintroduced individuals to address competition, conflict with humans, and disease (Vucetich and Creel, 1999; Gusset et al., 2008a). In the 18 years since the ferret reintroduction program began, a great deal of attention and funding for enhancing ferret reintroduction success has focused on captive breeding and preconditioning of ferrets prior to release (Biggins et al., 1999), potential consequences of low genetic diversity (Wisely et al., 2008), and development of vaccines for ferrets (Williams et al., 1996; Rocke et al., 2008). However, if insufficient habitat is present, the probability of success is low regardless of the availability of strategies for intensive management of ferret populations. When determining whether to attempt reintroductions at sites with a low probability of success, program managers need to consider whether the benefits in terms of public relations, partnerships or conservation (e.g., research or the establishment of populations that could be used to augment other populations decimated by a catastrophe) make the effort a worthwhile use of resources.

Given the continued decline and fragmentation of prairie dog populations in most areas throughout North America (Miller and Cully, 2001), managers concerned with recovering black-footed ferret populations should focus on increasing the size and density of prairie dog populations. Prairie dogs historically were among the most abundant mammals in North America (Forrest, 2005), but numbers have declined to the point that the black-tailed prairie dog, Gunnison's prairie dog and white-tailed prairie dog have been petitioned repeatedly for listing under the US Endangered Species Act. While successful ferret reintroductions occurred on all three prairie dog species, no successful reintroduction sites contained prairie dog populations occupying areas that were less than 4300 ha in size. Beyond this threshold, habitat quality appeared to be determined by the interaction of relative prairie dog burrow density and the size of the area occupied by prairie dogs. Successful sites included those where prairie dogs occupied large areas at low relative density, and moderately large areas where prairie dogs occurred at fairly high relative densities. However, there were no successful sites where prairie dogs occupied small areas at high densities. Therefore, management for higher local prairie dog densities is of low utility except, perhaps, where the area occupied by prairie dogs is >4000 ha in size. Areas occupied by black-tailed prairie dogs, which typically contain moderate densities of prairie dogs burrows (30–80 per ha), likely need to be large in spatial extent (>4000 ha) to meet minimum biological requirements for successful ferret populations. Areas occupied by Gunnison's prairie dogs and white-tailed prairie dogs, which typically contain lower densities of prairie dog burrows (10–30 per ha), likely need to be even larger. However, prairie dog populations that occupy an area >4000 ha are exceedingly rare (Proctor et al., 2006), with only two such sites identified by the BFFRIT that have not already hosted ferret reintroduction attempts. Therefore, in order to reach the recovery goal of establishing 10 populations of >30 adult ferrets, managers need to increase the number of large prairie dog populations beyond what is currently available.

Although increasing the size and density of prairie dog populations might seem like a straightforward objective, it would be highly controversial and difficult to implement. Most evaluations of social-political aspects of carnivore reintroduction focus on negative local attitudes toward the carnivores themselves (Wilson, 2004; Lindsey et al., 2005; Gusset et al., 2008b). However, ferret reintroductions face the unique problem that the prey on which they depend, rather than the ferrets themselves, are widely regarded as pests (Reading and Kellert, 1993; Miller et al., 2007). Therefore, improving the suitability of reintroduction sites for ferrets, and ultimately recovering the species in the wild, only can be achieved by changing public attitudes and management policies related to their declining prey. Government-sponsored subsidies recently have been made available to local landowners to protect prairie dogs on public and private land (Miller and Reading, 2006). However, such approaches are slow to succeed at a large scale when faced with widespread and deeply ingrained prejudice against prairie dogs by many private landowners (Miller et al., 2007). Although the ecological role of prairie dogs in grassland systems is well-documented (Koford, 1958; Sharps and Uresk, 1990; Miller et al., 1994; Hoogland, 1995; Ceballos et al., 1999), the ethical, sociological, and economic arguments that have been developed and used to help justify protection for charismatic carnivores (e.g., such as increasing tourism; Hayward et al., 2007), also need to be applied to prairie dogs. When the prey on which an endangered carnivore depends is itself at risk, conservation of that prey is essential to the long-term success of recovery efforts for the carnivore.

Ferret recovery efforts, whether biological or socio-political in nature, depend on a foundation of scientific information. This study faced low sample sizes that typify most reintroduction situations. Yet, managers need to learn from experience despite these statistical limitations. Our analyses of broad patterns across all reintroduction sites complements the results of more detailed analyses at the few individual recovery sites where more detailed information permits finer-scale assessments (e.g. Holmes, 2008; Grenier et al., 2007). However, our ability to examine relationships in greater detail was hindered by the lack of data based on more rigorous and structured monitoring. For improving our conservation effectiveness, conservation activities need to be continually re-assessed in an adaptive management approach that involves testing a priori hypotheses in an iterative fashion (Armsrtong et al., 2007; Gusset et al., 2009). Our results should lead to refined hypotheses about factors affecting recovery success – and help managers identify specific monitoring goals to evaluate such refined hypotheses and advance ferret recovery.

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Dakota Game and Fish Department, New Mexico Department of Game and Fish, South Dakota Department of Game, Fish and Parks, Utah Department of Natural Resources, Wyoming Game and Fish Department, Grasslands National Park Canada, Instituto de Ecologia Mexico, Cheyenne River Sioux Tribe, Gros Ventre and Assiniboine Tribes, Lower Brule Sioux Tribe, Northern Cheyenne Tribe, Rosebud Sioux Tribe, Navajo Nation, Hualapai Tribe, Cheyenne Mountain Zoological Park, National Zoological Park, Phoenix Zoo, Calgary Zoo, Toronto Zoo, Henry Doorly Zoo, Louisville Zoo, Defenders of Wildlife, National Wildlife Federation, Prairie Wildlife Research, Turner Endangered Species Fund, The Nature Conservancy, World Wildlife Fund, and Association of Zoos and Aquariums.

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