Assessing the risk of plague to black-footed ferrets in Conata Basin, South Dakota

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Abstract
The endangered black-footed ferret (*Mustela nigripes*) is an obligate carnivore of prairie dogs (*Cynomys* spp.) and both are highly susceptible to plague, a non-native bacterial disease. In Conata Basin the reintroduced population of black-footed ferrets was once the largest, self-sustaining population ever documented until plague was documented in the ecosystem in 2008. Federal agencies responded by applying insecticide into prairie dog burrows to kill fleas, a vector of plague, to effectively maintain prairie dog colonies in the presence of a plague epizootic. Studies in Montana suggested that dusting alone may be sufficient to protect both ferrets and prairie dogs in the presence of plague. We vaccinated ferrets against plague as a secondary measure to protect the population. Ferret populations continued to decline on prairie dog colonies treated annually with insecticide while plague continued to persist in the ecosystem. Our objectives were to evaluate the effects of plague presence on black-footed ferret re-encounter rates, a surrogate for survival, and investigate the effect of vaccination on re-encounter rates of ferrets occupying dusted prairie dog colonies. We used multiple logistic regression to construct models of black-footed ferret re-encounter rates 2004-2012 and their associated variables (spotlight effort, sex, age, plague presence, vaccine status) and interactions. Models were ranked using Akaike's Information Criterion (AIC). Re-encounter rates of black-footed ferrets were strongly influenced by spotlight effort, sex and plague presence. Spotlight effort, sex, age and vaccination status were strongly associated with ferret re-encounter rates on dusted prairie dog colonies while plague was present in the ecosystem. Spotlight effort was included in all top models and served as a control for detectability of black-footed ferrets. Vaccination mostly influenced re-encounter rates of male adults and female kits. Plague continues to influence black-footed ferrets in Conata Basin despite the extensive efforts to dust prairie dog colonies. Full vaccination (two shots) of ferrets with plague vaccine is needed to offset the influence of plague and to ensure population persistence during a plague epizootic. We strongly recommend continued dusting of prairie dog colonies combined with vaccination of ferrets in areas with known plague presence.

Introduction

Black-footed ferrets (*Mustela nigripes*) are endangered mustelids that rely upon prairie dogs (*Cynomys* sp.) as prey and use their burrow systems (Biggins et al. 2006*b*). Ferrets were extirpated from South Dakota by 1974 and subsequently reintroduced from captive stock beginning in 1994 within the state (Lockhart et al. 2006). Since 1994 black-footed ferrets have been released at six location in South Dakota; Badlands National Park, Buffalo Gap National Grassland (Conata Basin), Cheyenne River Sioux Tribe, Rosebud Sioux Tribe, Lower Brule Sioux Tribe, and Wind Cave National Park. Historically South Dakota had some of the best habitat for ferrets, partially due to a lack of sylvatic plague.

Plague is caused by the bacterium *Yersinia pestis* and not native to North America. Many rodent species, felines and black-footed ferrets are highly susceptible to plague (Abbott and Rocke 2012). Plague was not known in South Dakota until it was detected in a coyote in western Custer County in 2004. In 2005 plague was verified in Shannon County on Pine Ridge Reservation where it infected ~50,000 acres of prairie dogs. By that time Conata Basin had a well-established black-footed ferret population that was self-sustaining (i.e. no longer required reintroduction), was a source of ferrets for other reintroduction sites, and was the largest ferret population ever documented (Livieri 2006). Fears that plague may reach Conata Basin prompted several federal agencies (US Fish & Wildlife Service, USDA Wildlife Services, and National Park Service) to prophylactically apply DeltaDust® (0.05% deltamethrin; Bayer, Montvale, NJ), an insecticide dust to kill fleas, a vector of plague (Seery et al. 2003). Approximately 7,000 acres of prairie dog colonies were treated with DeltaDust® in Conata Basin in 2005. The US Fish & Wildlife Service continued dusting approximately 1,000 acres of high quality ferret habitat in 2006-2007 despite a lack of known plague.

In May of 2008 plague was documented in Conata Basin and federal agencies (US Forest Service, National Park Service, and US Fish & Wildlife Service responded by dusting the highest quality black-footed ferret habitat as determined by past ferret occupancy (Griebel 2008). The agencies dust more than 12,000 acres of the same prairie dog colonies annually to provide an estimated 10 months of protection per year (Biggins et al. 2010) to valuable black-footed ferret habitat in Conata Basin and the adjacent Badlands National Park. More than 20,000 acres of prairie dog colonies in Conata Basin and Badlands National Park have been impacted by plague since 2008 (Griebel 2012).

A plague vaccine, initially developed for humans, was tested on black-footed ferrets (Rocke et al. 2008) and proven effective to increase survival of free-ranging ferrets in Montana (Matchett et al. 2010). Prairie Wildlife Research began using plague vaccine experimentally on black-footed ferrets in 2005 and operationally in 2008 when plague was confirmed. Lab trials demonstrate ferrets are most protected when two shots, a primary and a booster, are administered approximately one month apart (Rocke et al. 2008). Prairie Wildlife Research, federal agencies and partners monitor black-footed ferrets annually and administer vaccine. Studies in Montana suggested that either dust or vaccine was sufficient to protect black-footed ferrets from plague but there was no further affect for using both (Matchett et al. 2010). Vaccinating ferrets does not protect the prey

base, prairie dogs, from plague thus dusting was considered by many to be the essential plague mitigation activity and vaccination less essential.

Plague mitigation activities (i.e. dusting) has maintained approximately 10,000 acres of high quality black-footed ferret habitat in Conata Basin. However, results from annual ferret monitoring efforts suggest a continuous and gradual decline in ferret numbers on dusted colonies (Figure 1). Why are ferret numbers not maintaining despite annual dusting? Our objectives were to evaluate the effect of plague, spotlight effort, age and sex on black-footed ferret survival and investigate the effect of plague vaccine, spotlight effort, age and sex on survival of black-footed ferrets on prairie dog colonies that were dusted with insecticide. Our study and analyses presented here are retrospective and were not designed as a traditional research study from the beginning.

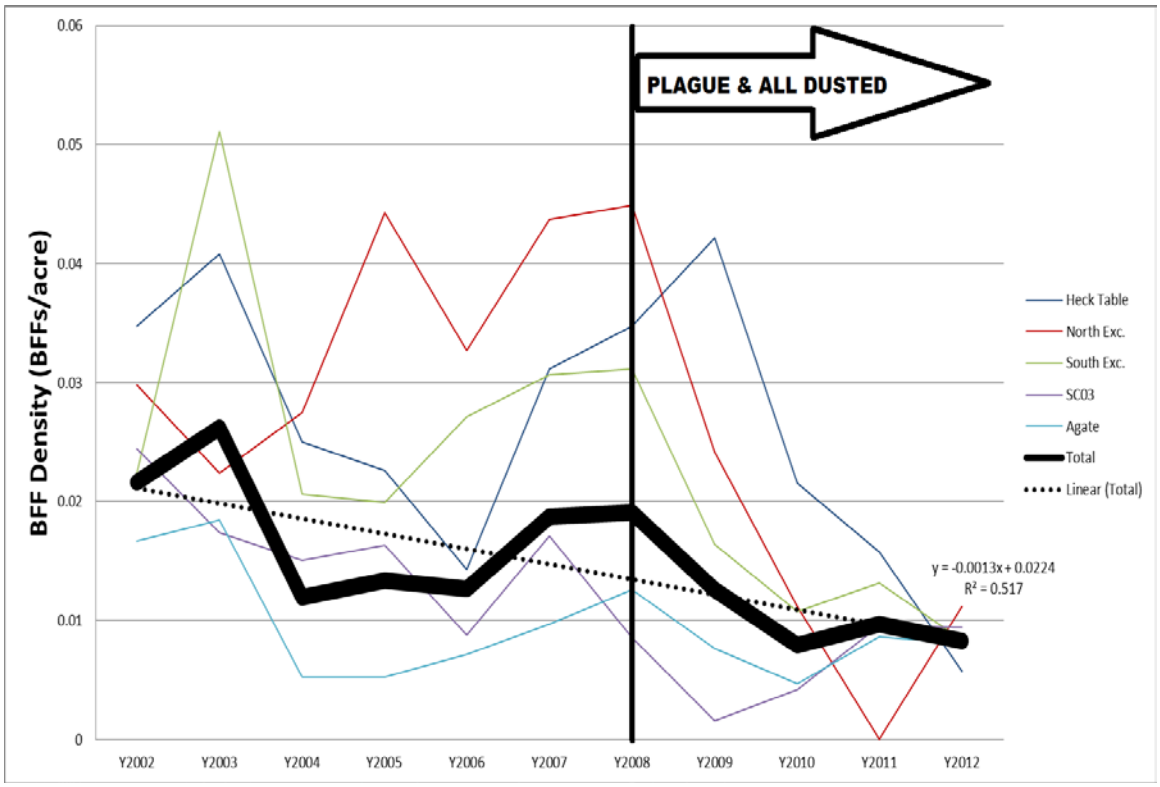

Figure 1. Black-footed ferret density on prairie dog colonies prior to plague (2008) on prairie dog colonies annually dusted in Conata Basin, South Dakota.

Methods

Study area

Conata Basin is a portion of the Buffalo Gap National Grassland in southwestern South Dakota, administered by the U.S. Forest Service and adjacent to Badlands National Park. The study area was a 29,000 ha mixed-grass prairie with vegetation dominated by western wheatgrass (*Agropyron smithii*), buffalograss (*Buchloe dactyloides*), and blue grama (*Bouteloua gracilis*). Primary land uses in the area are cattle grazing and recreation. In 2012, the area contained 4,757 ha (11,755 acres) of prairie dog colonies (Griebel 2012), mapped by driving the perimeter of the colony with a differentially

corrected Global Positioning System (GPS) and imported into Geographic Information Systems (GIS) environment. Prairie dog colony area varied throughout the study duration (2004-2012) and reached a high of 12,955 ha (32,013 acres) in 2007 prior to the discovery of plague.

Dusting
Prairie dog burrows were individually treated with ~4g of DeltaDust® using mechanical dust dispensers, Technidusters (Technicide, San Clemente, CA) with wands that fit directly into the burrow. Application occurred annually on most active (i.e. not impacted by plague) prairie dog colonies during the spring and summer months.

Plague surveillance
Visual inspection surveys to assess the presence of plague began in 2005 when plague was confirmed approximately 18.5 km (30 miles) from Conata Basin. Observers drove through prairie dog colonies once per week during the day to assess prairie dog activity levels through visual observation of prairie dogs, burrow activity (fresh diggings, scat or active burrow openings). Any dead animals, particularly prairie dogs, were safely collected and sent to Centers for Disease Control for plague diagnostic testing.

Black-footed ferret surveys and vaccinations
We used spotlight surveys to located black-footed ferrets (Biggins et al. 2006*a*). Spotlighting occurred mid-August to December each year from dusk to dawn. Black-footed ferret locations were recorded using GPS. Ferrets were trapped using methods described by Biggins et al. (2006*a*) and subcutaneously vaccinated with 0.5 mL of F1-V plague vaccine in the trap or under anesthesia. Attempts were made to capture ferrets twice in a season to administer primary and booster shots. Ferrets were identified by passive integrated transponder (PIT) tags (Fagerstone and Johns 1987).

Data analysis
Black-footed ferret locations were used to build an annual encounter history for each individual ferret. The time interval for ferret survival was 15 August – 31 December and annual survival was based upon re-encounter of an individual in the following time interval. For instance, a black-footed ferret encountered in September of 2008 and then re-encountered at any time between 15 August – 31 December 2009 is considered a survivor, marked as “1”, for that interval. If the animal was not re-encountered then it was marked as “0” and considered as not surviving that interval.

Variables that may influence black-footed ferret survival were associated with each individual ferret interval and included plague presence in the ecosystem, vaccination status, sex, age, and spotlighting effort to find that individual. To investigate the effect of plague on black-footed ferret survival from 2004-2012 we used a dichotomous variable for plague presence. If plague was known to occur in the Conata Basin area during the annual interval (15 August to 14 August the following year) then it was coded as “1” and if it was not known during that time interval then it was coded as “0”. Because black-footed ferrets were identified by PIT tags the gender and sex of individuals was known. Ferrets were considered either adults or kits at the beginning of each interval.

Spotlight effort was calculated as the cumulative effort, in minutes per hectare, on the prairie dog colony the ferret was known to occupy. For instance, the spotlight effort for a ferret encountered on Colony A in October of 2007 but found on Colony B in September of 2008 was calculated as the cumulative effort from 15 August – 31 December 2008 on Colony B. Vaccination status of an individual ferret was measured as the total number of vaccinations the ferret received during the annual interval. Ferrets received 0, 1, or 2 shots of plague vaccine during the year (15 August – 14 August the following year).

Multiple logistic regression was used to construct models of black-footed ferret re-encounters and associated variables and interactions (Table 1) that may influence re-encounter rates. Models were evaluated and ranked using Akaike's Information Criterion corrected for small sample size (AIC_c; Burnham and Anderson 2002) and Akaike weights (the relative likelihood of the model given the data). We calculated evidence ratios for the top model as a likelihood comparison with the lower ranked models (Burnham and Anderson 2002).

Table 1. Independent variables used in multiple logistic regression models of plague effect on black-footed ferret re-encounter rates (Plague model) and plague vaccine effect on black-footed ferret re-encounter rates on dusted prairie dog colonies (Vaccine model).

Variable	**Type**	**Range of values**	**Models**
Spotlight effort (minutes/hectare)	Continuous	1.3 – 167.9	Plague, Vaccine
Sex	Dichotomous	Male, Female	Plague, Vaccine
Age	Dichotomous	Kit, Adult	Plague, Vaccine
Plague present	Dichotomous	0, 1	Plague
(Plague*Sex)	Interaction	-	Plague
(Plague*Age)	Interaction	-	Plague
Vaccine status	Continuous	0 – 3	Vaccine
(Age*Sex)	Interaction	-	Vaccine
(Vaccine*Age)	Interaction	-	Vaccine
(Vaccine*Sex)	Interaction	-	Vaccine

Results

Dusting

Dusting of prairie dog colonies began prophylactically in 2005 and operationally in 2008 after plague presence in the ecosystem was confirmed (Table 2).

Plague surveillance

Plague was confirmed from dead prairie dogs in Conata Basin on May 12, 2008 by Centers for Disease Control. Thereafter we continued to test prairie dogs however visual inspection of colonies was deemed sufficient to determine plague status (see Griebel 2008, 2009 for description of techniques).

Table 2. Prairie dog colony area treated with DeltaDust® in Conata Basin study area, South Dakota, 2004-2012.

Annual interval	Hectares (acres) dusted	Total hectares (acres) in area	% Treated
2004-05	0 ha (0 ac)	10,101 ha (24,960 ac)	0.0
2005-06	2,833 ha (7,000 ac)	12,204 ha (30,156 ac)	23.2
2006-07	549 ha (1,357 ac)	12,204 ha (30,156 ac)	4.5
2007-08	623 ha (1,539 ac)	12,865 ha (31,789 ac)	4.8
2008-09	4,143 ha (10,238 ac)	8,485 ha (20,966 ac)	48.8
2009-10	4,117 ha (10,173 ac)	6,815 ha (16,839 ac)	60.4
2010-11	4,643 ha (11,474 ac)	6,160 ha (15,221 ac)	86.0
2011-12	3,332 ha (8,233 ac)	3,877 ha (9,580 ac)	85.9
2012-13	4,757 ha (11,755 ac)	4,842 ha (11,965 ac)	98.2

Black-footed ferret surveys and vaccinations

We spent 9,655 hours spotlighting prairie dog colonies for black-footed ferrets in the Conata Basin study area from 2004-2012 (Table 3). Black-footed ferrets were experimentally vaccinated against plague from 2005-2006 and operationally beginning in 2008 after plague was confirmed present in the ecosystem.

Table 3. Overall survey effort, black-footed ferret identifications and vaccinations in the Conata Basin study area, South Dakota, 2004-2012. Black-footed ferret numbers indicate only animals included in the study.

Annual interval	Total spotlight hours	Total hectares (acres) surveyed	# BFFs identified (male.female)	# BFFs vaccinated (male.female)
2004-05	1,328	8,709 ha (21,521 ac)	189 (70.119)	0
2005-06	1,425	10,477 ha (25,889 ac)	228 (96.132)	67 (29.38)
2006-07	1,023	9,675 ha (23,907 ac)	219 (89.130)	52 (22.30)
2007-08	1,112	11,862 ha (29,311 ac)	237 (100.137)	0
2008-09	1,261	7,823 ha (19,331 ac)	180 (79.101)	155 (64.91)
2009-10	1,389	5,789 ha (14,305 ac)	130 (49.81)	102 (36.66)
2010-11	619	6,160 ha (15,221 ac)	85 (32.53)	80 (29.51)
2011-12	611	3,631 ha (8,972 ac)	71 (32.39)	71 (32.39)
2012-13	887	3,788 ha (9,360 ac)	70 (27.43)	70 (27.43)

Effect of plague on black-footed ferret re-encounter rates

We analyzed 1,262 intervals from 944 individual black-footed ferrets (418 males, 525 females) from 2004-2012 to assess the effect of plague presence in the ecosystem on ferret re-encounter rates. The top ranked model included spotlight effort, sex and plague presence as variables strongly associated with re-encounter rates (Table 4). We found moderate evidence (Δ AICc < 2.0) for an age affect and (Plague*Sex) interaction affect (Δ AICc < 3.0) to justify modeling each sex separately. When modeled separately the support for an effect of (Plague*Sex) interaction becomes weaker. Re-encounter rates

Table 4. Multiple logistic regression model rankings of the effect of plague presence in the ecosystem on black-footed ferret re-encounter rates in Conata Basin, South Dakota, 2004-2012.

Plague Model – Both Sexes	***logL***	**AICc**	**Δ AICc**	**Weight**	**Evidence**
K + Effort + Sex + Plague	-722.4	1452.8	0.000	0.519	
K + Effort + Sex + Age + Plague	-722.4	1454.8	1.946	0.196	2.65
K + Effort + Sex + Age + Plague + (Plague * Sex)	-721.6	1455.3	2.439	0.153	3.39
K + Effort + Sex + Age + Plague + (Plague * Age)	-722.3	1456.8	3.936	0.073	7.16
K + Effort + Sex + Age + Plague + (Plague * Sex) + (Plague * Age)	-721.5	1457.2	4.361	0.059	8.85
K + Sex + Plague	-731.9	1469.8	16.957	0.0001	4810.23
K + Effort + Plague	-732.9	1471.9	19.039	3.810E-05	13622.80
K + Effort + Sex	-733.0	1472.1	19.237	3.451E-05	15040.47
K + Effort + Age + Plague	-732.9	1473.8	21.012	1.421E-05	36534.05
K + Effort + Sex + Age	-733.0	1474.0	21.166	1.316E-05	39458.31
K + Effort	-743.7	1491.4	38.598	2.157E-09	240685100.5
Plague Model – Males Only	***logL***	**AICc**	**Δ AICc**	**Weight**	**Evidence**
K + Effort + Plague	-260.046	526.1	0.000	0.624	
K + Effort + Age + Plague	-260.016	528.1	1.971	0.233	2.68
K + Effort + Age + Plague + (Plague * Age)	-259.504	529.1	2.985	0.140	4.45
K + Effort	-266.896	537.8	11.675	0.002	342.92
K + Effort + Age	-266.721	539.5	13.350	0.0008	792.35
Plague Model – Females Only	***logL***	**AICc**	**Δ AICc**	**Weight**	**Evidence**
K + Effort + Plague	-461.585	929.2	0.000	0.607	
K + Effort + Age + Plague	-461.407	930.9	1.666	0.264	2.30
K + Effort + Age + Plague + (Plague * Age)	-461.344	932.8	3.567	0.102	5.95
K + Effort	-466.090	936.2	6.994	0.018	33.02
K + Effort + Age	-465.800	937.6	8.430	0.009	67.69

with plague present in the ecosystem were much lower than when plague was not present (Figure 2).

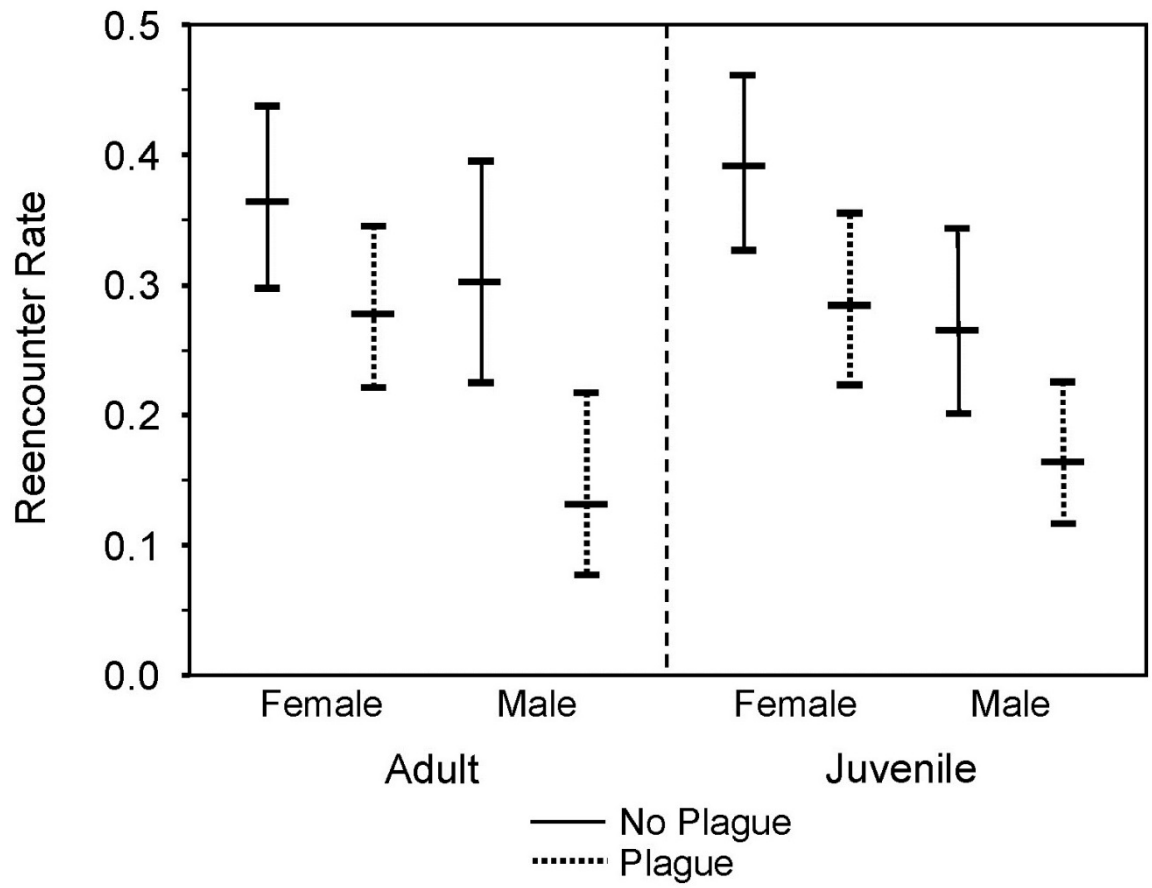

Figure 2. Evaluation of plague absence (2004-2006) and presence (2007-2011) on reencounter rates of black-footed ferrets in Conata Basin, South Dakota.

Effect of vaccination on black-footed ferret re-encounter rates on dusted colonies
We analyzed 442 intervals from 362 individual black-footed ferrets (166 males, 196 females) from 2007-2012 to assess the effect of plague vaccine on re-encounter rates of ferrets occupying dusted colonies while plague was present in the ecosystem. Although plague was first detected in May of 2008 it occurred within the 2007-08 annual interval (15 August 2007 – 14 August 2008). The top ranked models all included spotlight effort, sex, age and some combination of all three interactions strongly associated with re-encounter rates (Table 5). Re-encounter rates for male adults and female kits were most influenced by increasing vaccinations (Figure 3).

Table 5. Multiple logistic regression model ranking of the effect of plague vaccine on re-encounter rates of black-footed ferrets occupying dusted colonies with plague present in the ecosystem in Conata Basin, South Dakota, 2007-2012.

Model	***logL***	**AICc**	**Δ AICc**	**Weight**	**Evidence**
K + Effort + Sex + Age + Vaccine + (Age * Sex) + (Vaccine * Age)	-216.5	447.2	0.000	0.362	
K + Effort + Sex + Age + Vaccine + (Vaccine * Age)	-217.8	447.8	0.564	0.273	1.33
K + Effort + Sex + Age + Vaccine + (Vaccine * Sex) + (Vaccine * Age) + (Sex * Age)	-216.5	449.3	2.050	0.130	2.79
K + Effort + Sex + Age + Vaccine	-219.8	449.8	2.563	0.101	3.60
K + Effort + Sex + Vaccine	-221.1	450.4	3.167	0.074	4.87
K + Effort + Sex + Age + Vaccine + (Vaccine * Sex)	-219.7	451.7	4.483	0.039	9.41
K + Effort + Sex	-223.9	453.9	6.736	0.012	29.02
K + Effort + Sex + Age	-223.4	454.8	7.632	0.008	45.42
K + Effort + Vaccine	-230.9	467.9	20.728	1.14E-05	31697.72
K + Effort + Age + Vaccine	-230.7	469.5	22.255	5.33E-06	68016.12
K + Effort	-234.1	472.3	25.086	1.29E-06	280127.5
K + Effort + Age	-234.1	474.3	27.096	4.74E-07	765282.3

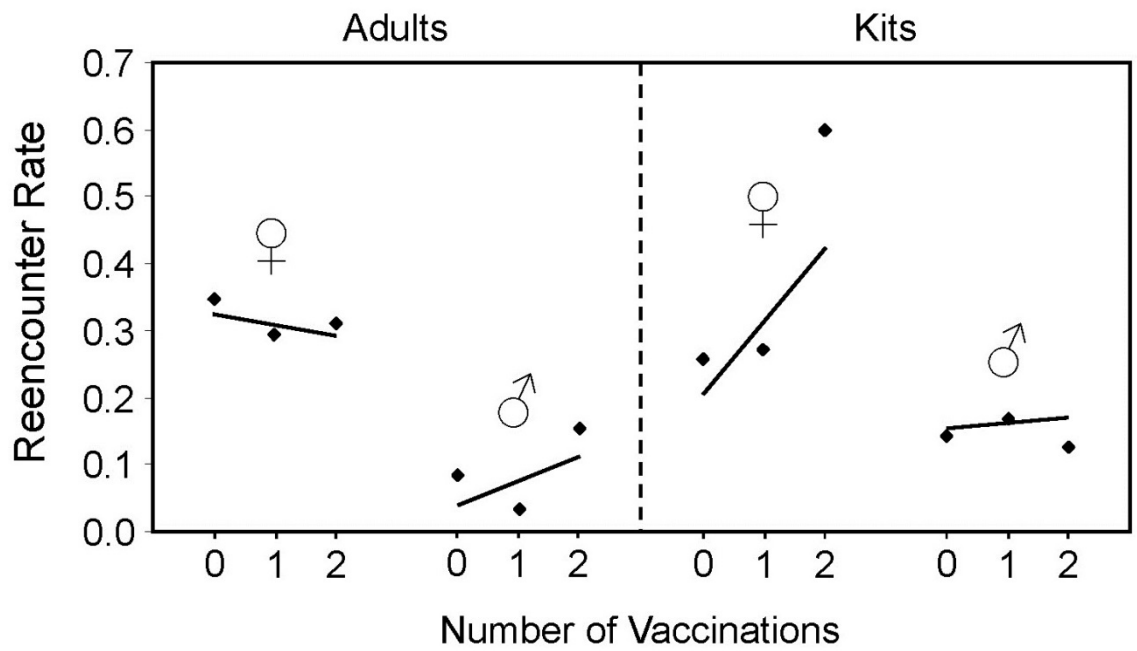

Figure 3. Effect of plague vaccination on re-encounter rate of black-footed ferrets occupying dusted prairie dog colonies while plague was present in Conata Basin, South Dakota, 2007-2012.

Discussion

Effect of plague on black-footed ferret re-encounter rates

We found strong evidence that plague affected re-encounter rates (i.e. survival) of black-footed ferrets in Conata Basin. Survival of black-footed ferrets, particularly males, decreased noticeably when plague was present in the ecosystem (Figure 2). Males may be more susceptible to plague because they tend to move farther than females and thus have a higher probability of encountering plague. This increased loss of males due to plague could lead to a reduction in pregnancies and kit production because older, more experienced males are more efficient breeders than younger males. In 2012 we observed a high number of adult females that were not lactating or simply were not bred (Livieri 2013).

Spotlight effort occurred in each of the top models indicating the influence of our survey efforts (i.e. how often and how much we look for ferrets) on re-encounter rates. We interpret the prominence of spotlight effort as a suitable control variable for the detectability of black-footed ferrets.

Effect of vaccination on black-footed ferret re-encounter rates on dusted colonies

Vaccination of black-footed ferrets with plague vaccine influenced the re-encounter rates on dusted prairie dog colonies when plague was known to be present in the ecosystem. Matchett et al. (2010) suggested that dusting alone may be sufficient to maintain black-footed ferrets in the presence of plague although their study was conducted when plague was enzootic (Abbott and Rocke 2012). In Conata Basin we documented an epizootic of plague beginning in 2008 and it is likely that the dusting efforts maintained prairie dog

colonies and prevented them from completely succumbing to plague. Our results suggest that during an epizootic of plague that dusting and vaccination of ferrets are needed to maintain survival of black-footed ferrets.

Again, spotlight effort was influential in the top models as a control variable for detectability of black-footed ferrets. Full vaccination (2 shots) appears to be most effective for adult males and juvenile females (Figure 3) which, for males, may be support for the higher probability of encountering plague due to greater movements than females.

Management recommendations

Our results strongly suggest that during an epizootic of plague and when plague is known to be present in the ecosystem that both dusting of prairie dog burrows with DeltaDust® and fully vaccinating black-footed ferrets with plague vaccine are needed to maintain black-footed ferret populations. Dusting without ferret vaccinations may lead to extirpation of a ferret population. Costs associated with dusting, approximately $17.31 per acre of colony (Griebel 2012), may seem expensive but in comparison to costs to control wildfires or noxious weeds it is not so unusual and provides many conservation benefits. We recommend continued dusting of prairie dog colonies and vaccination of black-footed ferrets until suitable plague mitigation alternatives are developed.

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Literature Cited

Abbott, R. C., and T. E. Rocke. 2012. Plague. US Geological Survey Circular No. 1372. 79 p.

Biggins, D. E., J. L. Godbey, K. L. Gage, L. G. Carter, and J. A. Montenieri. 2010. Vector control improves survival of prairie dogs (*Cynomys*) in areas considered enzootic for plague. Vector-Borne and Zoonotic Diseases 10:17-26.

Biggins, D. E., J. L. Godbey, M. R. Matchett, L. R. Hanebury, T. M. Livieri, and P. E. Marinari. 2006*a*. Monitoring black-footed ferrets during reestablishment of free-

ranging populations: discussion 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. 2006*b*. 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.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and multi-model inference. Springer-Verlag Inc., New York, NY. 496p.

Fagerstone, K. A., and B. E. Johns. 1987. Transponders as permanent identification markers for domestic ferrets, black-footed ferrets, and other wildlife. Journal of Wildlife Management 51: 294-297.

Griebel, R. L. 2008. Wall Ranger District, Conata Basin 2008 plague control report. Unpublished report. Nebraska National Forest, Buffalo Gap National Grassland, Wall Ranger District, Wall, South Dakota. 11 p.

Griebel, R. L. 2009. Wall Ranger District, 2009 plague management report. Unpublished report. Nebraska National Forest, Buffalo Gap National Grassland, Wall Ranger District, Wall, South Dakota. 13 p.

Griebel, R. L. 2012. Conata Basin/Badlands Area 2012 plague management report. Unpublished report. Nebraska National Forest, Buffalo Gap National Grassland, Wall Ranger District, Wall, South Dakota. 10 p.

Livieri, T. M. 2006. Ten-year history of the Conata basin black-footed ferret population: 1996-2005. Unpublished report. Prairie Wildlife Research, Wall, SD. 49 p.

Livieri, T. M. 2013. Conata Basin black-footed ferret monitoring report Summer/Fall 2012. Unpublished report. Prairie Wildlife Research, Wellington, CO. 15 p.

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 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.

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 and Zoonotic Diseases 10: 27-35.

Rocke, T. E., S. Smith, P. Marinari, J. Kreeger, J. T. Enama, and B. S. 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.

Seery, D. B., D. E. Biggins, J. A. Montenieri, R. E. Enscore, 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.