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Effect of Coyotes and Release Site Selection on Survival and Movement of Translocated Swift Foxes in the Badlands Ecosystem of South Dakota

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EFFECT OF COYOTES AND RELEASE SITE SELECTION ON SURVIVAL AND MOVEMENT OF TRANSLOCATED SWIFT FOXES IN THE BADLANDS ECOSYSTEM OF SOUTH DAKOTA

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

EFFECT OF COYOTES AND RELEASE SITE SELECTION ON SURVIVAL AND MOVEMENT OF TRANSLOCATED SWIFT FOXES IN THE BADLANDS ECOSYSTEM OF SOUTH DAKOTA

Greg M. Schroeder

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Success of different release strategies for swift fox (*Vulpes velox*) translocation was evaluated in the Badlands Ecosystem in southwestern South Dakota. Release site selection (outside coyote [*Canis latrans*] core-use areas compared to random release sites) and release method (i.e., hard, semi-hard, and soft) were examined to determine effects on swift fox survival and movements at 50 days post-release. I hypothesized that swift foxes released outside of coyote core-use areas would survive at a higher rate than foxes released at random sites. From 2003-2006, 16 adult coyotes were fitted with Global Positioning System (GPS) radio collars and monitored during the pup rearing season (May-August). Coyote core-use areas were calculated and used in selecting sites where swift foxes would be released in September. Swift foxes were captured in Colorado or Wyoming and transported to Badlands National Park (BNP) for release. A total of 114 swift foxes (51 males, 63 females) were released from 2003-2006. All foxes were fitted with VHF radio collars before release. Mean home range size during the pup rearing season did not differ between male (14.2 ± 1.0 km^2) and female (14.9 ± 2.0 km^2)

($P > 0.75$) coyotes. Mean home range size for coyotes located within (15.2 ± 2.9 km^2) and outside (14.3 ± 1.0 km^2) of BNP was similar ($P > 0.78$). Size of core-use areas for male (1.4 ± 0.2 km^2) and female (1.3 ± 0.2 km^2) coyotes did not differ ($P > 0.65$) from one another. Core-use areas for coyotes located within BNP (1.0 ± 0.6 km^2) or adjacent to BNP (1.5 ± 0.6 km^2) did not differ ($P > 0.11$) from one another. Mean nighttime movement rates (km/hr) differed among female coyotes occupying areas within BNP (0.65 ± 0.02 km/hr), female coyotes outside of BNP (0.88 ± 0.02 km/hr), and male coyotes outside of BNP (0.78 ± 0.02 km/hr; $P < 0.001$). Backward elimination in the Survival Cox Regression demonstrated that release site ($P = 0.89$), release method ($P = 0.38$), age ($P = 0.91$) and gender ($P = 0.23$) were not significant predictors of swift fox survival. Mean distance moved from release site ($P = 0.001$) was the only variable that contributed to the final model. Straight-line distance moved from release site at 50 days differed ($P = 0.01$) for swift foxes that survived (22.6 ± 4.2 km) versus swift foxes that died (10.5 ± 1.2 km). For swift foxes that survived, distance from release site at 50 days did not differ by gender ($P = 0.12$), age ($P = 0.29$), release year ($P = 0.11$), release site ($P = 0.39$), or release method ($P = 0.08$). Movement was affected by release method ($P < 0.01$) and age ($P = 0.07$). Swift fox translocations should continue with wild animals. Juveniles are the preferred age class of swift fox translocation candidates, but survivorship of all released foxes can be improved with short-term soft release techniques.

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Chapter 1

Introduction and Study Area

INTRODUCTION

The swift fox (*Vulpes velox*) is a key species native to the shortgrass and mixed-grass prairies of the Great Plains of North America. Historically, this small fox (~2 kg) occurred in all or portions of North Dakota, South Dakota, Montana, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas, and the southern prairie region of Alberta, Manitoba, and Saskatchewan (Hall 1981, Scott-Brown et al. 1987, Sovada and Scheick 1999, Allardyce and Sovada 2003). Swift foxes were abundant throughout much of their range until the late 1800s to the early 1900s. Records from the American Fur Company report trading of over 10,000 swift fox pelts between 1835 and 1838 at the American Fur Company's Upper Missouri Outfit (Johnson 1969) and the Hudson's Bay Company traded over 100,000 pelts between 1853 and 1877 (Rand 1948).

With European settlement of the plains, swift fox populations declined dramatically by the late 1800s (Zumbaugh and Choate 1985, Allardyce and Sovada 2003). The decline has been attributed to factors including conversion of native prairie to agriculture and the associated declines in prey species (Egoscue 1979), unregulated hunting and trapping, rodent control programs, and predator control programs aimed at larger carnivores (Kilgore 1969, Samuel and Nelson 1982, Carbyn et al. 1994). Perhaps the most important direct cause of swift fox population decline was inadvertent poisoning from strychnine-laced bait targeted at wolves (*Canis lupus*) and sodium monofluoracetate (compound 1080) bait stations (Young 1944, Robinson 1953, Scott-Brown et al. 1987, Allardyce and Sovada 2003). Swift foxes readily accepted poisoned baits and thus, died by the thousands (Bailey 1926, Young 1944). Swift fox declines were greatest in their northern range, being extirpated from Canada and North Dakota (Soper 1964, Sovada and Scheick 1999, Allardyce and Sovada 2003) and remaining in scattered, remnant populations in South Dakota, Nebraska, and Montana (Allardyce and Sovada 2003).

The present contiguous range of the swift fox extends from Wyoming south through eastern Colorado, western Kansas, eastern New Mexico, Oklahoma panhandle and extreme northern Texas. Small, fragmented populations exist in South Dakota and Nebraska (Allardyce and Sovada 2003). An isolated, but expanding, population exists in southern Canada and northern Montana as a result of the Canadian Wildlife Service's swift fox reintroduction program (Giddings 1998). The only significant expansion of the swift fox distribution in the northern part of their historic range has occurred because of reintroduction programs (Carbyn 1998).

The first successful reintroduction program for swift foxes began in 1983. The Canadian Wildlife Service and cooperators began a swift fox reintroduction, focusing their efforts largely on private lands in Alberta and Saskatchewan, Canada (Carbyn et al. 1994). The success of the Canadian swift fox relocation program has sparked a surge in efforts to restore swift fox populations into unoccupied, yet suitable habitat within their historic range. These efforts include a reintroduction (i.e., release of captive reared foxes, see Kleiman 1989 for definitions) on the Blackfeet Reservation in Montana from 1999-2002 (Ausband and Foresman 2007) and four translocations (i.e., capture and transfer of free-ranging foxes from one part of historic range to another) currently in progress. Three translocations are being conducted in South Dakota, one on the Bad River Ranches

(Turner Endangered Species Fund) and one on Lower Brule Sioux Tribal Land (Lower Brule Sioux Tribe Department of Wildlife, Fish and Recreation and the Maka Foundation) and the one herein, at Badlands National Park. One translocation project is ongoing in Montana, at Fort Peck.

Several strategies are being applied to restoration efforts. For example, on the Blackfeet Reservation in Montana, captive reared foxes were released (Ausband and Foresman 2007), whereas at other sites wild foxes are being translocated from one part of their historic range to another (e.g., Bad River Ranches, South Dakota, Turner Endangered Species Fund; Honness et al. 2005). The Canadian program used both captive reared and translocated foxes. Evaluating and understanding the successes and failure of the different approaches to reintroductions are essential for improving reintroduction strategies and for conserving the species (Wolf et al. 1998, Fischer and Lindenmayer 2000).

Coyotes have been identified as the principal cause of swift fox mortality throughout their distribution (Sovada et al. 1998, Kitchen 1999, Olsen and Lindzey 2002). The Canadian Wildlife Service did not apply coyote control measures to help swift fox populations become established, however, private ranchers did control coyotes on their lands where swift foxes were reintroduced (Carbyn et al. 1994). Yet, coyotes greatly influenced the survival rates of the reintroduced population in Canada (Carbyn et al. 1994). Questions were raised in the 2000 Swift Fox Conservation Team Meeting regarding the need to control coyotes before a swift fox reintroduction (Swift Fox Conservation Team 2000). A clear decision could not be made on whether coyote control was needed, but knowledge of coyote core areas and densities prior to release of swift foxes was determined to be valuable information when deciding where to release swift foxes. Swift foxes tend to set up home ranges outside of coyote core-use areas (50% use area) (Kamler et al. 2003). Furthermore, red foxes (*Vulpes vulpes*; a species with similar relationships to coyotes) living sympatrically with coyotes maintain home ranges on the periphery of coyote territories and do not venture into the core areas used by coyotes (Sargeant et al. 1987, Harrison et al. 1989). The objectives of this project were to 1) examine the effect of release site (sites outside coyote 50% use area versus randomly selected sites) on survival and movements of translocated swift foxes and 2) examine the effect of release method (hard, semi-hard, and soft) on survival and movements of translocated swift foxes.

Study Area

Badlands National Park (BNP) is located in southwestern South Dakota (Figure 1). The 1846-km^2 study area included the north unit of BNP and the surrounding area. Twenty three percent of the area was managed by the National Park Service, 34% by United States Forest Service, and 43% was privately-owned (Figure 2). Less than 1% of the study area was used for row-crop agriculture. The major industry in the region was cattle (*Bos taurus*) production; thus, the majority of the study area outside of BNP was grazed by cattle. Within BNP, moderate-to-low intensity grazing occurred by bison (*Bison bison*) in 52% of the north unit. Substantial grazing did not occur in the remaining 48% of the north unit.

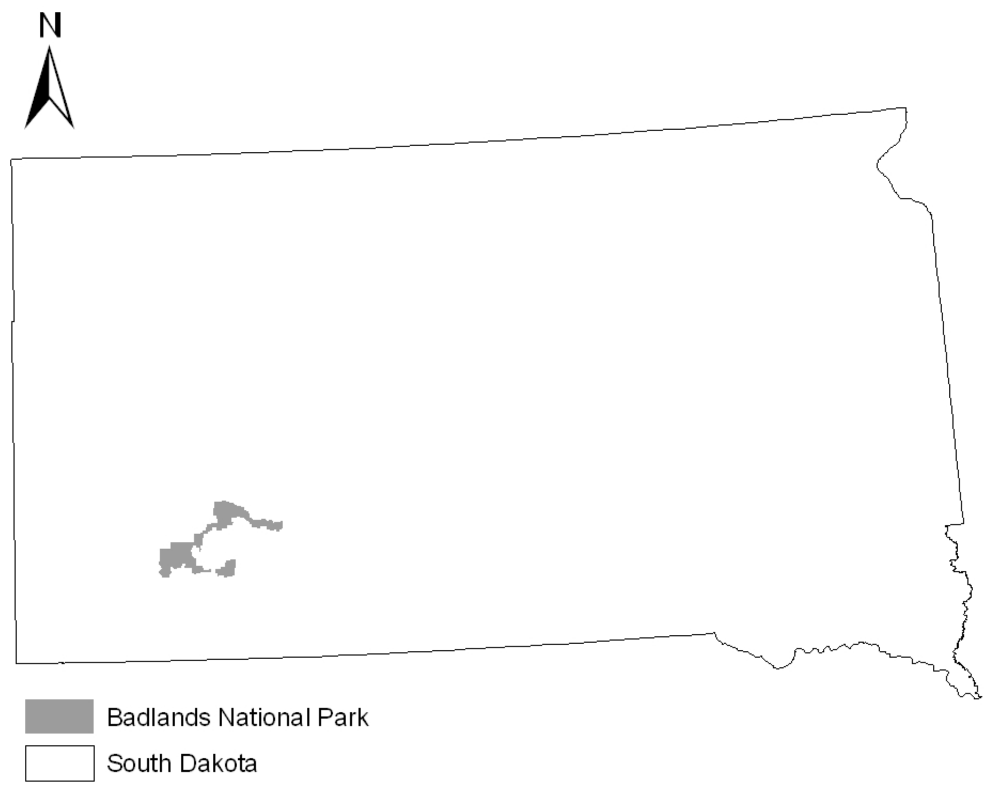

Figure 1. Badlands National Park located in southwestern South Dakota, USA.

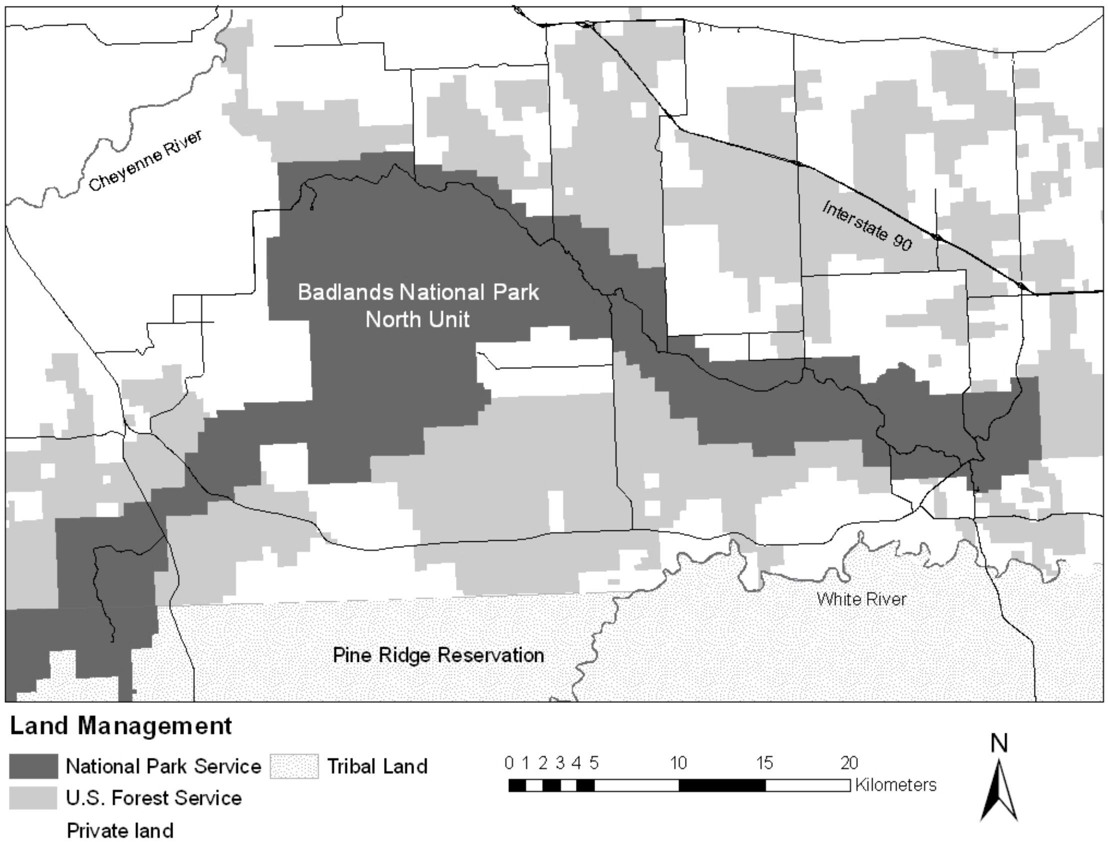

Figure 2. Study area map delineating land management jurisdiction, rivers, and primary roads. Study area was located in southwestern South Dakota, USA.

Typical of continental climates, dramatic seasonal variation in temperature occurred within this area. Mean annual temperature was 10.1°C, varying from a January mean low temperature of -11.7 °C to a July mean high temperature of 33.3°C. Mean precipitation over the past 45 years was 42.9 cm, varying from 29.4 cm to 68.8 cm (Fahnestock and Detling 2002, Badlands National Park unpublished data; Figure 3).

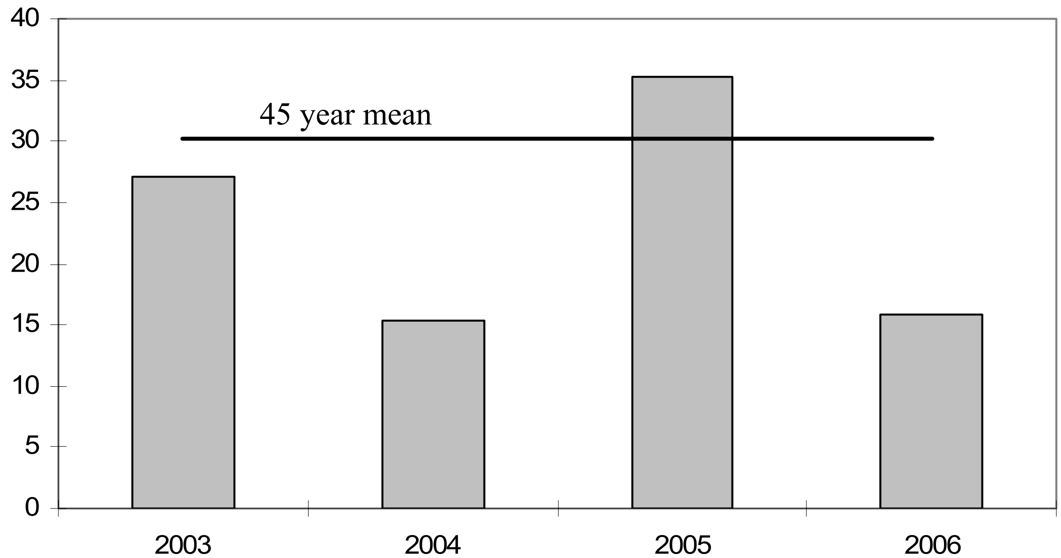

Figure 3. Precipitation (cm) for April – August at Badlands National Park, South Dakota (2003-2006)

Topography of the region was diverse. Elevation ranged from 691 to 989 m above mean sea level. The area within BNP was typified by highly eroded cliffs and spires over 100 m in height. Outside BNP, the terrain was less rugged and typified by rolling prairies. Vegetation in the region was dominated by mixed-grass prairie species including buffalo grass (*Buchloe dactyloides*), western wheatgrass (*Pascopyrum smithii*), and plains prickly-pear (*Opuntia polyacantha*); the region is mostly void of tree and brush species. The Cheyenne and White rivers form the western and southern boundaries of the study area, respectively.

Literature Cited

Allardyce, D., and M.A. Sovada. 2003. A review of the ecology, distribution, and status of swift foxes in the United States. Pages 3-18 *in* M.A. Sovada and L.N. Carbyn, editors. The swift fox: ecology and conservation of swift foxes in a changing world. Canadian Plains Research Center, University of Regina, Saskatchewan, Canada.

Ausband, D.E., and K.R. Foresman. 2007. Dispersal, survival and reproduction of wild-born, yearling swift foxes in a reintroduced population. Canadian Journal of Zoology 85: 185-189.

Bailey, V. 1926. A biological survey of North Dakota. North American Fauna 49:1-226.

Bunker, C.D. 1940. The kit fox. Science 92:35-36.

Carbyn, L. 1998. COSEWIC status report on the swift fox. Committee on the status of endangered wildlife in Canada. Canadian Wildlife Service, Ottawa, Canada.

Carbyn, L., H. J. Armbuster, and C. Mamo. 1994. The swift fox reintroduction program in Canada from 1983 to 1992. *in* M.L. Bowles and C.J. Whelan. Restoration of endangered species: conceptual issues, planning and implementation. Cambridge University Press.

Egoscue, H. J. 1979. *Vulpes velox*. Mammalian Species 122:1-5.

Fahnestock, J.T., and J.K. Detling. 2002. Bison-prairie dog-plant interactions in North American mixed-grass prairie. Oecologia 132:86-95.

Fischer, J., and D.B. Lindenmayer. 2000. An assessment of the published results of animal relocations. Biological Conservation 96:1-11.

Giddings, B. 1998. Swift fox management activities in Montana. Pages 18-22 *in* C. Roy, editor. Annual report of the Swift fox Conservation Team 1998. Kansas Department of Wildlife and Parks, Emporia, Kansas, USA.

Hall, E.R. 1981. The mammals of North America. Volume 2, pages 601-1181-90. John Wiley and Sons, Inc. New York, New York, USA.

Harrison, D. J., D. A. Bissonette, and J. A. Sherburne. 1989. Spatial relationships between coyotes and red foxes in eastern Maine. Journal of Wildlife Management 53:181-185.

Honness, K. M., K.E. Kunkel, and M. K. Phillips. 2005. Swift fox restoration in west central South Dakota: 2004 Annual Progress Report. Turner Endangered Species Fund Conservation Report 04-01.

Johnson, D.R. 1969. Returns of the American Fur Company. 1835-1839. Journal of Mammalogy 50:836-839.

Kamler, J. F., W.B. Ballard, R.L. Gilliland, and K. Mote. 2003. Spatial relationships between swift foxes and coyotes in northwestern Texas. Canadian Journal of Zoology 81:168-172.

Kilgore, D.L. 1969. An ecological study of the swift fox in the Oklahoma panhandle. American Midland Naturalist 81: 512-534.

Kitchen, A. M. 1999. Resource partitioning between coyotes and swift foxes: space, time, and diet. Thesis. Utah State University, Logan, Utah, USA.

Kleiman, D.G. 1989. Reintroduction of captive mammals for conservation. BioScience 39:152-161.

Olson, T. L., and F. G. Lindzey. 2002. Swift fox survival and production in southeastern Wyoming. Journal of Mammalogy 83:199-206.

Rand, A.L. 1948. Mammals of the eastern Rockies and western plains of Canada. National Museum of Canada Bulletin 108:1-237.

Robinson, W.B. 1953. Population trends of predators and fur animals in 1080 station areas. Journal of Mammalogy 76:723-729.

Samuel, D.E., and B.B. Nelson. 1982. Foxes. Pages 475-490 *in* J.A. Chapman and G.A. Feldhammer, editors. Wild mammals of North America: Biology, Management, and Economics. John Hopkins Univ. Press, Baltimore, Maryland, USA. 1147 pp.

Sargeant, A. B., S. H. Allen, and J. O. Hastings. 1987. Spatial relations between sympatric coyotes and red foxes in North Dakota. Journal of Wildlife Management 51:285-293.

Scott-Brown, J.M., S Herrero, and J. Reynolds. 1987. Swift fox. Pages 432-441 in M. Novak, J.A. Baker, M.E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Trappers Association, North Bay. Ontario, Canada.

Soper, J.D. 1964. The mammals of Alberta. The Hamley Press Ltd. Edmonton, Alberta, Canada.

Sovada, M. A., C. C. Roy, J. B. Bright, and J. R. Gillis. 1998. Causes and rates of mortality of swift foxes in western Kansas. Journal of Wildlife Management 62:1300-1306.

Sovada, M. A., and B. K. Scheick. 1999. Preliminary report to the swift fox conservation team: historic and recent distribution of swift foxes in North America. Pages 80-147 + appendix *in* C. G. Schmitt, editor. 1999 Annual report of the Swift Fox Conservation Team. New Mexico Department of Game and Fish, Albuquerque, New Mexico, USA.

Swift Fox Conservation Team Annual Report. 2000. C. G. Schmitt and B. Oakleaf, editors. 2001. New Mexico Department of Game and Fish, Albuquerque, New Mexico, USA.

Wolf, C.M., T. Garland, and B. Griffith. 1998. Predictors of avian and mammalian translocation success: reanalysis with phylogenetically independent contrasts. Biological Conservation 86:243-255.

Young, S.P. 1944. Their history, life habits, economic status, and control. Part 1. Pages 1-386 *in* The wolves of North America. The American Wildlife Institute, Washington, D.C.

Zumbaugh, D. M., and J. R. Choate. 1985. Historical biogeography of foxes in Kansas. Transactions of the Kansas Academy of Science 88:1-13.

Chapter 2

Coyote Home Ranges and Movements in the Badlands Ecosystem

INTRODUCTION

Coyotes have been identified as the principal cause of swift fox mortality in several studies (Kitchen 1999, Olson and Lindzey 2002, Sovada et al. 1998), and greatly influenced the survival rates of the reintroduced population in Canada (Carbyn et al. 1994). Questions were raised at the 2000 Swift Fox Conservation Team Meeting regarding the need to control coyotes before a swift fox reintroduction (Swift Fox Conservation Team 2000). A clear decision could not be made on whether coyote control was needed, but knowledge of coyote core areas and densities prior to release of swift foxes was determined to be valuable information when deciding where to release swift foxes.

Two studies of the spatial relationship of coyote and swift fox home ranges have reported divergent results. Kamler et al. (2003) documented swift fox home ranges occurring near the periphery or outside of coyote home ranges and swift fox home ranges did not overlap or slightly overlapped coyote core-use areas. Kitchen (1999) found no spatial avoidance of coyotes by swift foxes; however Kitchen (1999) did not exam the overlap of swift fox home ranges and coyote core-use areas. Red foxes (*Vulpes vulpes*; a species with similar relationships to coyotes) living sympatrically with coyotes maintain home ranges on the periphery of coyote territories and do not venture into the core areas used by coyotes (Sargeant et al. 1987, Harrison et al. 1989). Territorial boundaries tend to have less coyote activity than core areas of use (Sargeant et al. 1987); thus, encounters between the species should be fewer than in high-use areas. The purpose of this study was to document coyote core home ranges and movements to aid in selecting release sites for translocated swift foxes.

METHODS

Coyotes were captured from February 2003 to June 2006, in winter and/or early spring in coordination with a study of coyote epizootics in the Badlands National Park (BNP) ecosystem. Capture and handling methods followed standard protocols developed by the National Park Service (Badlands National Park 2000) and were approved by the USGS Northern Prairie Wildlife Research Center's Animal Care and Use Committee and the Institutional Animal Care and Use Committee at South Dakota State University (Assurance #A3958-01). Coyotes were captured with No. 3 Victor Soft Catch® (Woodstream Corp., Lititz, PA, USA) leg-hold traps modified with the Paws-I-Trip™ pan tension device (M-Y Enterprises, Homer City, PA, USA) or live-catch snares (The Snare Shop, Carroll, IA, USA). All traps and snares were checked daily. Each coyote was anesthetized with a medetomidine/ketamine combination (0.08mg/kg, 4.0 mg/kg) and antagonized with atipamezole (0.4 kg/mg) developed for wolves (*Canis lupus*, Kreeger 1999). Coyotes were ear-tagged, aged, sexed, and a blood sample was collected for disease analysis. Captured coyotes were fitted with a Global Positioning System (GPS) collar (< 350g, GPS 3300, Lotek Wireless Inc., Newmarket, Ontario, Canada or G2110, Advanced Telemetry Systems, Inc., Isanti, MN, USA). Coyotes were released at the point of capture.

GPS collars were programmed with one of two schedules. Collars placed on coyotes captured in the spring were programmed to collect hourly locations each day (24 location attempts/day). For coyotes captured in the fall, collars were programmed to record locations every 4 hours from 0600-1800 and every hour from 1800-0600 (15 location attempts/day). These schedules maximized the number of locations collected during the expected duration of the GPS collars. Collars included a timed-release mechanism programmed to activate in August, causing the collar to fall off of the coyote to allow retrieval and analysis of data prior to release of foxes in the fall. Each collar included a VHF frequency programmed to function 24 hours a day to facilitate relocating coyotes and collar recovery.

Coyotes were captured in areas identified with suitable habitat for swift fox releases (Sovada and Schroeder 2004). Within these areas, capture of one adult coyote per family was considered adequate for documenting home range and movements because behavior of individual coyotes approximates that of the family (Bowen 1982, Sargeant et al. 1987, Kitchen 1999).

Coyote home range varies by season (Laundre and Keller 1984); so telemetry locations were separated by the four life seasons defined by Smith et al. (1981): pair formation/breeding (1 January – 15 March), gestation (16 March – 30 April), pup rearing (1 May – 31 July), and dispersal (1 August – 31 December). We adjusted the dispersal period to 1 September – 31 December, which was more appropriate for northern latitudes (Laundre and Keller 1984, Sovada et al. 2003). Data from adult coyotes collected during the pup rearing season was used to calculate coyote home ranges and core-use areas.

Home ranges were calculated with ArcGIS 9.x (ERSI, Redlands, CA, USA) and Home Range Tools (Rodgers et al. 2005), by use of default resolution grids and percent volume contours. Adaptive kernel analysis (Worton 1989) was used to define the 95% and 50% volume contours calculated by using the *ad hoc* bandwidth method (*h_ad hoc*). The *h_ad hoc* bandwidth was created by reducing the reference bandwidth (*h_ref)* by 10% in successive steps until the 95% contour fractured into 2 or more polygons (Kie and Ager 2007). The *h_ad hoc* bandwidth was the bandwidth chosen just prior to fracturing of the home range outer contour. This process is functionally similar to least-squares cross validation, which also decreases *h_ref* in incremental units until reaching a local minimum (Hemson et al. 2005). Both contours (95% and 50%) were determined with the same smoothing parameter. Coyote home ranges were grouped by the administrative land management agency (National Park Service, U.S. Forest Service, private) that encompassed > 50 % of home range size. U.S. Forest Service and private lands were combined because land use was similar and coyotes were legally harvested on these lands. National Park Service lands are grazed by bison, rather than cattle and coyote harvest/control is not allowed.

Sequential hourly locations were used for movement analyses. Distances (km) moved between hourly locations were calculated with Home Range Tools (Rodgers et al. 2005). Mean daily (07:00-1700) and nightly (18:00-06:00) movement rates (km/hr) were calculated for statistical comparison.

Data Analysis

All analyses were performed with SYSTAT 11.0 (Wilkinson 1990). I used analysis of variance (ANOVA) to test for differences in home range size and core-use areas by year. Comparisons by sex and land management agency were made with t-tests.

Nightly movement rates (km/hr) of male and female coyotes outside of BNP and female coyotes within BNP were compared using ANOVA. If a significant difference was detected, a Bonferoni multiple comparison test was conducted to detect differences among all possible paired comparisons.

RESULTS

Forty-six coyotes were captured during 4,892 trap-nights (9.4 coyotes/1000 trap-nights) from February 2003 to June 2006. Forty-one of these coyotes were fitted with GPS collars. Of these, 32 (78%) collars were recovered. Twenty-two radio-marked coyotes were adults (9 males, 13 females) and 10 were yearlings (1 male, 9 females). For all years, 55,811 GPS locations were recorded. Of these, 22,535 GPS locations were collected during the pup rearing period. Data from yearlings and transients was not used for determining coyote core-use areas.

Data were collected from 16 adult coyotes (7 male, 9 female) during the pup rearing season (Figure 4). Six coyotes (1 male, 5 female) occupied areas within BNP and 10 coyotes (6 males, 4 female) occupied areas on USDA Forest Service/private land (BGNG/P). Mean number of locations obtained per coyote during the pup rearing season was 1,274 ± 88 (± SE).

Mean home range size and core-use areas did not differ by year ($F = 0.64$, $P = 0.60$; $F = 0.23$, $P = 0.88$; respectively); therefore, data were pooled in all analyses. Mean home range size during the pup rearing season did not differ between males (14.2 ± 1.0 km^2) and females (14.9 ± 2.0 km^2) ($t = 0.31$, df = 14, $P = 0.75$). Mean home range sizes for coyotes located within (15.2 ± 2.9 km^2) and outside (14.3 ± 1.0 km^2) of BNP were similar (t = -0.29, df = 14, P = 0.73). Size of core-use areas for males (1.4 ± 0.2 km^2) and females (1.3 ± 0.2 km^2) did not differ (t = -0.46, df = 14, P = 0.65) from one another. Further, core-use areas for coyotes located within BNP (1.0 ± 0.6 km^2) or adjacent to BNP (1.5 ± 0.6 km^2) did not differ (t = 1.76, df = 14, P = 0.11) from one another.

Mean nighttime movement rates (km/hr) differed among female coyotes occupying areas within BNP (0.65 ± 0.02 km/hr), female coyotes outside of BNP (0.88 ± 0.02 km/hr), and male coyotes outside of BNP (0.78 ± 0.02 km/hr; $F_{2, 1104}$ = 28.1, P < 0.001). Males living within BNP were not included in analyses because of low sample size (Table 1). Mean daytime movement rates were calculated, but not used in analyses because of low sample sizes (Table 1).

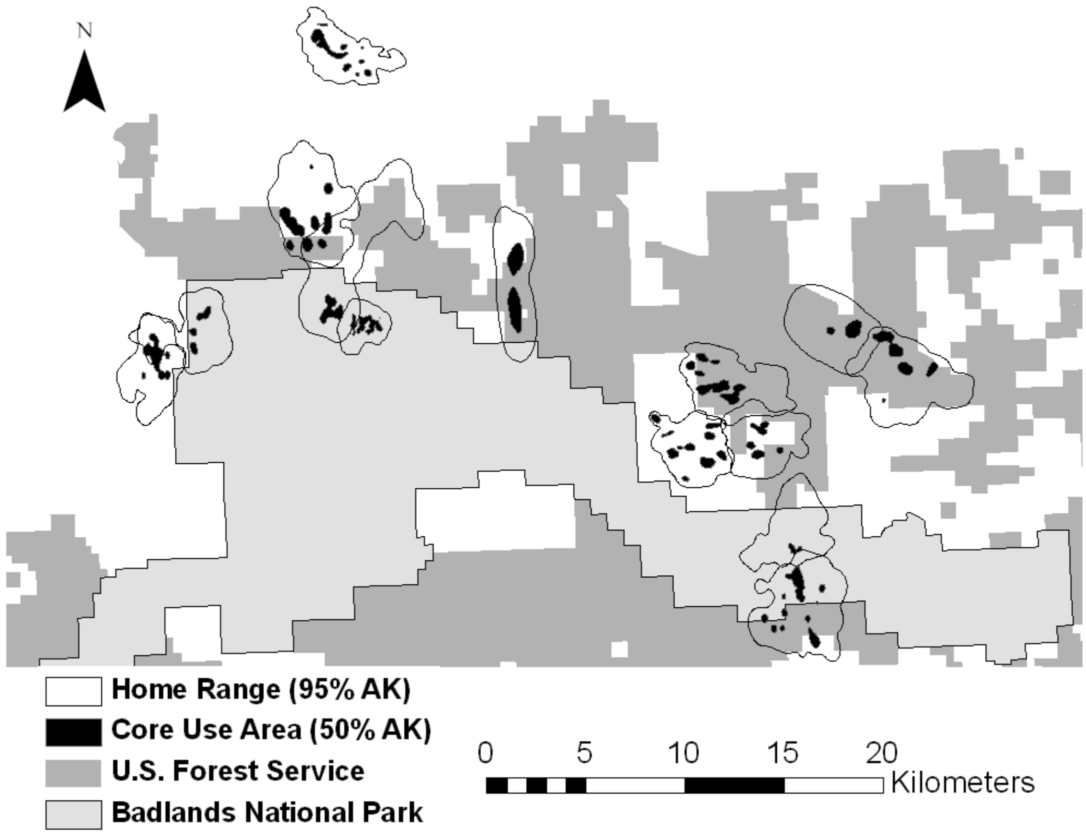

Figure 4. Home range (95% Adaptive Kernel) and core-use area (50% Adaptive Kernel) for adult coyotes during the pup rearing season (1 May – 31 August), 2003-2006, Badlands National Park and adjacent lands (Buffalo Gap National Grasslands and private land holdings), South Dakota, USA.

Table 1. Mean nighttime (1800-0600) and daytime (0700-1700) movement rates (km/hr) of adult male and female coyotes occupying areas within and adjacent to Badlands National Park. Buffalo Gap National Grasslands and privately owned land comprised area adjacent to the park, 2003-2006, South Dakota, USA.

	No. Locations	Sex (N)	Movement rates Mean	SE
Badlands National Park				
Nighttime	318	F (5)	0.65	0.02
	56	M (1)	0.66	0.04
Daytime	225	F (4)	0.48	0.02
	49	M (1)	0.26	0.04
Buffalo Gap/private land				
Nighttime	330	F (4)	0.88	0.02
	459	M (6)	0.78	0.02
Daytime	82	F (1)	0.41	0.03
	56	M (1)	0.23	0.03

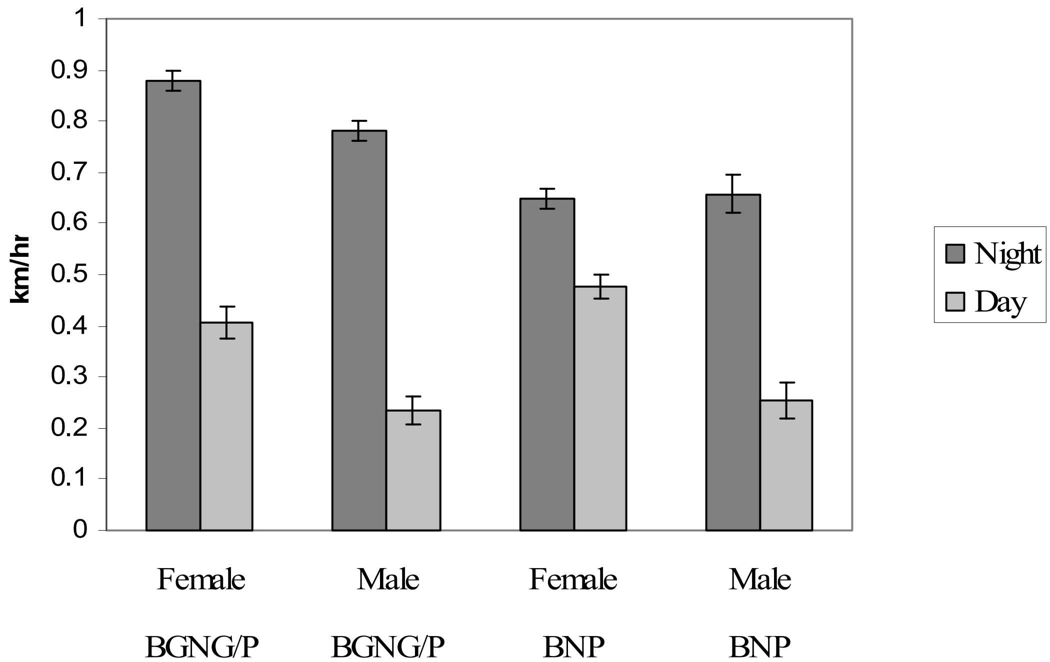

Figure 5. Mean nighttime (1800-0600) and daytime (0700-1700) movement rates (km/hr) of adult coyotes on Buffalo Gap National Grasslands/Private land (BGNG/P) and Badlands National Park (BNP), South Dakota, USA.

DISCUSSION

Home range size of coyotes in the Badlands National Park ecosystem was similar to studies of coyotes on the prairie in Colorado (Gese et al. 1988), western South Dakota (Chronert et al. 2007), and Alberta (Bowen 1982).

Despite differences in land use inside and outside of the park, home range size and core use area of coyotes did not differ. Home range sizes were larger for exploited versus unexploited coyotes in Colorado (Kitchen et al. 2000), but prey abundance was higher during the unexploited coyote study period. Prey abundance influenced the size of home ranges for mountain lions *(Puma concolor,* Grigione et al. 2000). Gese et al.

(1998) found coyote home ranges vary by habitat type, but not within habitat type. Most coyotes in this study were in one habitat type, prairie, and therefore, I did not expect home ranges to vary inside or outside of Badlands National Park. Home ranges and core-use areas did not differ by gender, which supported results of other studies (Andelt and Gipson 1979, Laundre and Keller 1984, Young et al. 2006)

Coyote are mostly nocturnal (Andelt and Gibson 1979, Laundre and Keller 1984, Kitchen et al. 2000) with limited daily movement in exploited areas; whereas coyotes were equally active during the day and night in undisturbed areas (Litvaitis and Shaw 1980, Major and Sherman 1987, Tremblay et al. 1998, Kitchen et al. 2000). Our data generally supports this, but unexploited coyotes moved more at night than during the day. This is probably the result of the spatial arrangement of home ranges of coyotes within BNP. While >50 % of the home range was in BNP, most coyotes did have a portion of their home range outside of BNP where human exploitation was possible.

Most studies have reported a lack of gender related differences in movement rates of coyotes during the pup rearing season (Andelt 1985, Kitchen et al. 2000, Servin et al. 2003). However, Holzman et al. (1992) and Chamberlain et al. (2000) documented females moving more than males at night. Outside of BNP, female coyotes moved more than males during the day and night. Within BNP, this pattern held true for a mated pair of coyotes.

Further research is in need to verify 1) females move more than males (day and night) 2) nocturnally, exploited coyotes (males and females) move more than unexploited coyotes.

Literature Cited

Andelt, W.F. 1985. Behavioral ecology of coyotes in south Texas. Wildlife Monographs No. 94.

Andelt, W.F., and P.S. Gipson. 1979. Home range, activity, and daily movements of coyotes. Journal of Wildlife Management 43:944-951.

Badlands National Park. 2000. Coyote capture and immobilization protocol. G.M. Schroeder and D.D. Albertson, editors. Badlands National Park, Interior, SD 57750. 12 pp.

Bowen, W.D. 1982. Home range and spatial organization of coyotes in Jasper National Park, Alberta. Journal of Wildlife Management 46:201-216.

Carbyn, L., H. J. Armbuster, and C. Mamo. 1994. The swift fox reintroduction program in Canada from 1983 to 1992. *in* M.L. Bowles and C.J. Whelan. Restoration of endangered species: conceptual issues, planning and implementation. Cambridge University Press.

Chamberlain, M.J., C.D. Lovell, and B.D. Leopold. 2000. Spatial-use patterns, movements, and interactions among adult coyotes in central Mississippi. Canadian Journal of Zoology 78:2087-2095.

Chronert, J.M., J.A. Jenks, D.E. Roddy, M.A. Wild, and J.G. Powers. 2007. Effects of sarcoptic mange on coyotes at Wind Cave National Park. Journal of Wildlife Management in press.

Gese, E.M., O.J. Rongstad, and W.R. Mytton. 1988. Home-range and habitat use of coyotes in southeastern Colorado. Journal of Wildlife Management 52:640-646.

Grigione, M.M., P. Beier, R.A. Hopkins, D. Neal, W.D. Padley, C.M. Schonewald, and M.L. Johnson. 2002. Ecological and allometric determinants of home-range size for mountain lions (*Puma concolor*). Animal Conservation 5: 317-324.

Harrison, D. J., D. A. Bissonette, and J. A. Sherburne. 1989. Spatial relationships between coyotes and red foxes in eastern Maine. Journal of Wildlife Management 53:181-185.

Hemson, G., P. Johnson, A. South, R. Kenward, R. Ripley, and D. Macdonald. 2005. Are kernels the mustard? Data from Global positioning system collars suggests problems for home-range analyses with least-squares cross-validation. Journal of Animal Ecology 74:455-463.

Holzman, S., M.J. Conroy, and J. Pickering. 1992. Home range, movements, and habitat use of coyotes in southcentral Georgia. Journal of Wildlife Management 56: 139-146.

Kamler, J.F., W.B. Ballard, R.L. Gilliland, and K. Mote. 2003. Spatial relationships between swift foxes and coyotes in northwestern Texas. Canadian Journal of Zoology 81:168-172.

Kie, J.G., and A.A. Ager. 2007. On the importance of choosing a bandwidth in kernel home-range analyses. Ecology: In review.

Kitchen, A. M. 1999. Resource partitioning between coyotes and swift foxes: space, time, and diet. Thesis. Utah State University, Logan, Utah, USA.

Kitchen, A.M., E.M. Gese, and E.R. Schauster. 2000. Changes in coyote activity patterns due to reduced exposure to human persecution Canadian Journal of Zoology 78:853-857.

Kreeger, T.J. 1999. Handbook of wildlife chemical immobilization. Wildlife Pharmaceuticals, Inc. Ft. Collins, CO. 342 pp.

Laundre, J.W., and B.L. Keller. 1984. Home-range size of coyotes: a critical review. Journal of Wildlife Management 48:127-139.

Litvaitis, J.A., and J.H. Shaw. 1980. Coyote movements, habitat use, and food habits in southwestern Oklahoma. Journal of Wildlife Management 44: 62-68.

Major, J.T., and J.A. Sherburne. 1987. Interspecific relationships of coyotes, red foxes, and bobcats in western Maine. Journal of Wildlife Management 51:606-616.

Olson, T. L., and F. G. Lindzey. 2002. Swift fox survival and production in southeastern Wyoming. Journal of Mammalogy 83:199-206.

Rodgers, A.R., A. P. Carr, L. Smith, and J.G. Kie 2005. HRT: Home-range tools for ArcGIS. Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada.

Sargeant, A. B., S. H. Allen, and J. O. Hastings. 1987. Spatial relations between sympatric coyotes and red foxes in North Dakota. Journal of Wildlife Management 51:285-293.

Servin, J., V. Sanchez-Cordero, and S. Gallina. 2003. Distances traveled daily by coyotes in a pine-oak forest in Durango, Mexico. Journal of Mammalogy 84: 547-552.

Smith, G.J., J.R. Cary, and O.J. Rongstad. 1981. Sampling strategies for radio-tracking coyotes. Wildlife Society Bulletin 9:88-93.

Sovada, M. A., C. C. Roy, J. B. Bright, and J. R. Gillis. 1998. Causes and rates of mortality of swift foxes in western Kansas. Journal of Wildlife Management 62:1300-1306.

Sovada, M.A., and G.M. Schroeder. 2006. Experimental reintroduction of swift foxes in Badlands National Park, Final Report. Northern Prairie Wildlife Research Center, U.S. Geological Servey. Final Report submitted to the USGS-BRD Central Regional Office.

Sovada, M. A., C. C. Slivinski, R. O. Woodward, and M. L. Phillips. 2003. Home range, habitat use, litter size, and pup dispersal of swift foxes in two distinct landscapes of western Kansas. Pages 149-160 *in* M. A. Sovada and L. Carbyn, editors. The swift fox: ecology and conservation of swift foxes in a changing world. Canadian Plains Research Center, Regina, Saskatchewan, Canada.

Swift Fox Conservation Team Annual Report. 2000. C. G. Schmitt and B. Oakleaf, editors. 2001. New Mexico Department of Game and Fish, Albuquerque, New Mexico, USA.

Tremblay, J., M. Crete, and J. Huot. 1998. Summer foraging behavior of eastern coyotes in rural versus forest landscape: a possible mechanism of source-sink dynamics. Ecoscience 5: 172-182.

Wilkinson, L. 1990. SYSTAT: the system for statistics. SYSTAT, Inc., Evanston, Illinois, USA.

Worton, G. J. 1989. Kernel methods for estimation the utilization distribution in home-range studies. Ecology 70:164-168.

Young, J.K., W.F. Andelt, P.A. Terletzky, and J.A. Shivik. 2006. A comparison of coyote ecology after 25 years: 1978 versus 2003. Canadian Journal of Zoology 84: 573-582.

Chapter 3

Survival and Movement of Translocated Swift Foxes

INTRODUCTION

The swift fox (*Vulpes velox*) is a key species native to the short grass and mixed-grass prairies of the Great Plains of North America. Historically, this small fox (~2 kg) occurred in all or portions of North Dakota, South Dakota, Montana, Nebraska, Wyoming, Colorado, Kansas, Oklahoma, New Mexico, and Texas, and the southern prairie region of Alberta, Manitoba, and Saskatchewan (Hall 1981, Scott-Brown et al. 1987, Sovada and Scheick 1999, Allardyce and Sovada 2003). With European settlement of the plains, swift fox populations declined dramatically by the late 1800s (Zumbaugh and Choate 1985, Allardyce and Sovada 2003). Swift fox declines were greatest in their northern range, being extirpated from Canada and North Dakota (Soper 1964, Sovada and Scheick 1999, Allardyce and Sovada 2003) and remaining in scattered, remnant populations in South Dakota, Nebraska, and Montana (Allardyce and Sovada 2003).

The present contiguous range of the swift fox extends from Wyoming south through eastern Colorado, western Kansas, eastern New Mexico, Oklahoma panhandle and extreme northern Texas. Small, fragmented populations exist in South Dakota and Nebraska (Allardyce and Sovada 2003). An isolated, but expanding, population exists in southern Canada and northern Montana as a result of the Canadian Wildlife Service's swift fox reintroduction program (Giddings 1998). The only significant expansion of the swift fox distribution in the northern part of their historic range has occurred because of reintroduction programs (Carbyn 1998).

The first successful swift fox reintroduction program began in 1983. The Canadian Wildlife Service and cooperators began a swift fox reintroduction, focusing their efforts largely on private lands in Alberta and Saskatchewan, Canada (Carbyn et al. 1994). The success of the Canadian swift fox relocation program has sparked a surge in efforts to restore swift fox populations into unoccupied, yet suitable habitat within their historic range. These efforts include a reintroduction (i.e., release of captive reared foxes, see Kleiman 1989 for definitions) on the Blackfeet Reservation in Montana from 1999-2002 (Ausband and Foresman 2007) and four translocations (i.e., capture and transfer of free-ranging foxes from one part of historic range to another) currently in progress. Three translocations are in South Dakota, one on the Bad River Ranches (Turner Endangered Species Fund) and one on Lower Brule Sioux Tribal Land (Lower Brule Sioux Tribe Department of Wildlife, Fish and Recreation and the Maka Foundation) and the one herein, at Badlands National Park. One additional translocation is in Montana, at Fort Peck.

Several strategies are being applied to these restoration efforts. For example, on the Blackfeet Reservation in Montana, captive reared foxes were released (Ausband and Foresman 2007), whereas at other sites wild foxes are being translocated from one part of their historic range to another (e.g., Bad River Ranches, South Dakota; Honness et al. 2005). The Canadian program used both captive reared and translocated foxes. Evaluating and understanding the successes and failure of the different approaches to reintroduction are essential for improving reintroduction strategies and for conserving the species (Wolf et al. 1998, Fischer and Lindenmayer 2000).

Coyotes (*Canis latrans*) have been identified as the principal cause of swift fox mortality (Carbyn et al. 1994, Sovada et al. 1998, Kitchen 1999, Olsen and Lindzey

2002). Swift foxes tend to set up home ranges outside of coyote core areas (50% use area) (Kamler et al. 2003). Furthermore, red foxes (*Vulpes vulpes*; a species with similar relationships to coyotes) living sympatrically with coyotes maintain home ranges on the periphery of coyote territories and do not venture into the core areas used by coyotes (Sargeant et al. 1987, Harrison et al. 1989). Territorial boundaries tend to have less coyote activity than core areas of use (Sargeant et al. 1987); thus, encounters between the species should be fewer than in high-use areas. The objective of this study was to determine if survival differed for swift foxes released outside of coyote core areas versus those released at random locations. I hypothesize that placement of swift fox release sites outside of coyote core areas would increase their survival.

METHODS

Capture and Handling of Swift Foxes

In late summer (2003-2006), coinciding with the start of the dispersal period (Sovada et al. 1998), we captured approximately 15 male and 15 female swift foxes from stable populations in Wyoming and Colorado for translocation to the BNP study area. We worked in coordination with the Colorado Division of Wildlife and Wyoming Game and Fish Department to ensure that removal of animals for translocation did not impact donor populations. To maximize diversity of foxes and to reduce impact on local populations, no more than two foxes were removed from one location (equivalent to an estimated home range size). Modified wire boxtraps (Sovada et al. 1998) were set in the evening and checked in the morning. Foxes were removed from traps and manually restrained. Age, weight, gender, and general body condition were recorded for each captured fox. Samples of ectoparasites were saved and blood was collected (NPWRC General Management Procedure 15) to test for plague and distemper. We attached a VHF radio collar (<40g; Advanced Telemetry systems, Isanti, Minnesota, USA) on foxes selected for translocation.

To minimize risk of disease transference, we selected individual foxes for translocation based on recommendations of Miller et al. (2000) and Pybus and Williams (2003). Blood from each captured fox was tested for sylvatic plague (*Yersinia pestis*) and canine distemper. If a fox tested positive for plague, had high titers for distemper, or showed outward signs of rabies, it was returned to the capture site and released. All foxes were vaccinated for rabies, distemper, infectious hepatitis, leptospirosis, parainfluenza, parvovirus, and corona virus. Parasites were treated with sustained-released Ivermectin (Apsen Veterinary Resources, ® Ltd. Kansas City, Missouri, USA**)** and dusting with carbaryl powder (Wellmark International, Schaumburg, Illinois, USA). Foxes suitable for release were transported to the study site within 48 hours. Foxes were placed in kennels, provided water and dog food (Del Monte Pet Products, San Francisco, California, USA), and transported by vehicle directly to BNP where they were held in facilities for a 14-day quarantine period. Foxes that were captured as pairs were caged together during quarantine and later released together. Single foxes were held in pens adjacent to potential release mates. Release pairs were selected by choosing foxes that were captured as distant as possible from one another; thus, reducing the chance of a fox being paired with a related fox.

Release Site Selection

Location data retrieved from GPS collars was used to estimate coyote home ranges and core-use areas (50% adaptive kernel estimate) (see Chapter 2). This information was used in concert with habitat data to determine locations for release of swift foxes. Our intent was to release foxes in peripheral areas of coyote territories. Territorial boundaries tend to have less coyote activity than core areas of use (Sargeant et al. 1987); thus, encounters between the species should be fewer than in high-use areas. Each year approximately one half of the captured swift foxes were released at sites with suitable habitat and outside the core-use areas of coyotes; remaining foxes were released at random sites within areas of suitable habitat.

Release Method

Swift foxes were released using three methods: hard, semi-hard, or short-term soft release (hereafter soft release). During the Canadian Wildlife Service's swift fox restoration project, swift foxes were released using hard (no enclosure, food, or water provided) and soft (held in enclosures and given food and water) release techniques (Herrero et al. 1991). Hard released foxes were brought to the release site in portable kennels and released at dusk. Foxes were released with semi-hard release methods during daylight hours by placing the foxes in underground dens (holes no longer used by other mammals) that were located at release sites. The soft release technique involved placing temporary pens (1- x 4-m chicken wire enclosure) around potential dens that were located at selected release sites. Foxes were held in soft release pens and provided with ample food and water. Within 3-5 days, the temporary pens were removed during daylight hours.

Swift fox location data

To monitor swift foxes, we used a null-peak vehicle-mounted antennae system equipped with an electronic digital compass and GPS unit (Brinkman et al. 2002). Telemetry systems were calibrated using methods described by Cox et al. (2002); transmitters were placed in specified locations within areas suitable for swift fox habitation. Swift fox locations were estimated from 2 or 3 bearings taken in rapid succession (<10 minutes) from different locations by one observer (Sovada et al. 2003, Kitchen et al. 2005). To reduce error, acceptable fixes included only bearings with an angle of intersection that was > 20° and < 160° (Gese et al. 1988, Chu et al. 1989). Locational error was estimated with LOAS 3 (Ecological Software Solutions 2004); ellipses were calculated with a maximum likelihood estimator and a standard deviation of 2. One or 2 locations per fox were collected each week of monitoring.

Movement and Survival

Daily movement of translocated and resident swift foxes did not differ after 50 days post release for the Canadian release project (Moehrenschlager and Macdonald 2003**)**. Therefore, the effect of release site selection and release method on survival and movement distance of swift foxes should be negligible after 50 days. Straight-line distance between swift fox release location and location at 50 days post-release was calculated with Home Range Tools (Rodgers et al. 2005). Mortality locations were used if foxes did not survive 50 days. For movement analysis, all swift foxes that left the study were given a movement distance equal to 50.0 km (the greatest movement detected in 50 days of foxes that remained in the study area was at 49.7 km). Swift foxes released in 2006 were not included in movement analyses because only presence/absence in the study area was determined at 50 days post-release.

Survival at 50 days was used to compare release variables: gender, age, release site, release method, and release year. All swift foxes that left the study area were classified as dead to the release population one day after the last detection.

Data Analysis

Survival rates of swift foxes were calculated with SYSTAT 11.0 (Wilkinson 1990). For release years 2003-2006, Kaplain-Meier survival rates were calculated and compared by gender, age, release site, release method, and release year.

Swift fox survival was estimated with Cox Regression for release years 2003-2005. Variables included in the model were gender, age, release site, release method, and distance from release site. Model variables were removed using log-rank backward elimination with $\alpha = 0.05$. The model was stratified by release year. Distances swift foxes moved from release sites were compared by gender, age, release site, and release method. An analysis of variance (ANOVA) was used to compare movement of swift foxes by release variables. A hierarchical approach was used in these analyses due to sample size considerations for some combinations of variables.

RESULTS

A total of 114 swift foxes (51 males, 63 females) was released from 2003-2006. Number of swift foxes released by year was 30 in 2003, 28 in 2004, 30 in 2005, and 26 in

2006. For 2003-2006, ages of released swift foxes were 59 juvenile, 35 subadults, and 20 adults. Relative to release sites, 53 swift foxes were released outside of coyote core use areas and 61 swift foxes were released at random sites. As for release method, 35 swift foxes were hard released, 47 swift foxes were semi-hard released, and 32 swift foxes were soft released.

Thirty swift foxes died or were classified as dead during the 50-day post-release period. Cause specific mortality was 13 from coyotes, 2 from vehicle collisions, 4 unknown, and 11 were classified dead because they dispersed out of the study area.

Table 2. Cause specific mortality of swift foxes. Badlands National Park Swift Fox Restoration Project, South Dakota (2003-2006)

Year	Coyote	Vehicle	Unknown	Dispersed
2003	3	1	0	5
2004	3	0	0	0
2005	6	0	2	4
2006	1	1	2	2
Total	13	2	4	11

Survival (2003-2005)

For 2003-2005, swift fox survival rates at 50 days post-release differed by release year (χ^2 = 6.8, df = 2, $P \leq 0.03$; Table 3). Therefore, the Cox regression was stratified by release year. Backward elimination in the Survival Cox Regression demonstrated that release site (t-ratio = 0.14, df = 1, P = 0.89), release method (t-ratio = 0.87, df = 2, P = 0.38), age (t-ratio = -0.11, df = 2, P = 0.91) and gender (t-ratio = 1.20, df = 1, P = 0.23) did not predict swift fox survival, while mean distance moved from release sites (t-ratio = 3.4, df = 1, P = 0.001) was the only variable that contributed to the final model (χ^2 = 10.7, df = 1, $P < 0.001$).

Straight-line distance from release site to fox locations 50 days post-release differed (t = 2.7, df = 27, P = 0.01) for swift foxes that died (22.6 ± 4.2 km) versus swift foxes that survived (10.5 ± 1.2 km; Table 3). Among surviving foxes, distance from release site at 50 days did not differ by gender ($F_{1, 61}$ = 2.67, P = 0.12), age ($F_{2, 60}$ = 1.26, P = 0.29), release year ($F_{2, 60}$ = 2.34, P = 0.11), release site ($F_{1, 61}$ = 0.77, P = 0.39), or release method ($F_{2, 60}$ = 2.67, P = 0.08).

Table 3. Mean straight-line distance between release site and (1) mortality site for swift foxes that died < 50 days post release and (2) swift fox location 50 days post-release for swift foxes that survived ≥ 50 days. Badlands National Park Swift Fox Restoration Project, South Dakota (2003-2005)

		Mortalities			**Survivors**		
		Distance (km)	SE	N	Distance (km)	SE	N
Gender	M	19.6	6.1	12	8.4	1.8	28
	F	25.7	6.1	12	12.3	1.6	35
Age	Juvenile	16.0	5.6	13	8.3	1.9	26
	Subadult	31.1	8.3	6	11.5	2.0	23
	Adult	29.8	9.1	5	13.0	2.6	14
Release Site	Coyote	23.5	6.7	10	9.4	1.8	30
	Random	22.0	5.7	14	11.6	1.7	33
Release Method	Hard	26.3	6.1	12	12.3	2.0	22
	Semi-hard	21.6	8.7	6	13.6	2.4	15
	Soft	16.5	8.7	6	7.3	1.9	26
Year	2003	33.9	6.5	9	13.1	2.1	20
	2004	12.6	11.3	3	11.3	1.9	25
	2005	16.7	5.6	12	6.6	2.2	18
Overall		22.6	4.2	24	10.5	1.2	63

Straight-line distance from release site to fox locations 50 days post-release was compared by age (Figure 6) and release method (Figure 7). Distance was not affected by two way interactions between age and release method ($F_{4, 54} = 1.94$, $P = 0.12$; Figure 8). Distance was affected by release method ($F_{2, 54} = 5.79$, $P < 0.01$) and age ($F_{2, 54} = 2.81$, $P = 0.07$).

Straight-line distance from release site to fox locations 50 days post-release was compared by age and gender. Distance was not affected by two way interactions between age and gender ($F_{2, 57} = 0.87$, $P = 0.43$). Distance was not affected by age ($F_{2, 57} = 1.68$, $P = 0.19$) or gender ($F_{1, 57} = 2.67$, $P = 0.11$). Straight-line distance from release site to fox locations 50 days post-release was compared by release method and gender. Distance was not affected by two way interactions between release method and gender ($F_{2, 57}$ = 0.16, P = 0.86). Distance was not affected by release method ($F_{2, 57}$ = 2.42, P = 0.10) or gender ($F_{1, 57}$ = 2.11, P = 0.15). Straight-line distance from release site to fox locations 50 days post-release was compared by release method and release site. Distance was not affected by two way interactions between release method and release site ($F_{2, 57}$ = 0.04, P = 0.96). Distance was not affected by release method ($F_{2, 57}$ = 2.09, P = 0.13) or release site ($F_{1, 57}$ = 0.26, P = 0.61). Straight-line distance from release site to fox locations 50 days post-release was compared by release site and gender. Distance was not affected by two way interactions between release site and gender ($F_{1, 59}$ = 0.20, P = 0.65). Distance was not affected by release site ($F_{1, 59}$ = 0.92, P = 0.34) or gender ($F_{1, 59}$ = 2.68, P = 0.11). Straight-line distance from release site to fox locations 50 days post-release was compared by release site and age. Distance was not affected by two way interactions between release site and age ($F_{2, 57}$ = 2.21, P = 0.12). Distance was not affected by release site ($F_{1, 57}$ = 1.54, P = 0.22) or age ($F_{2, 57}$ = 0.82, P = 0.45).

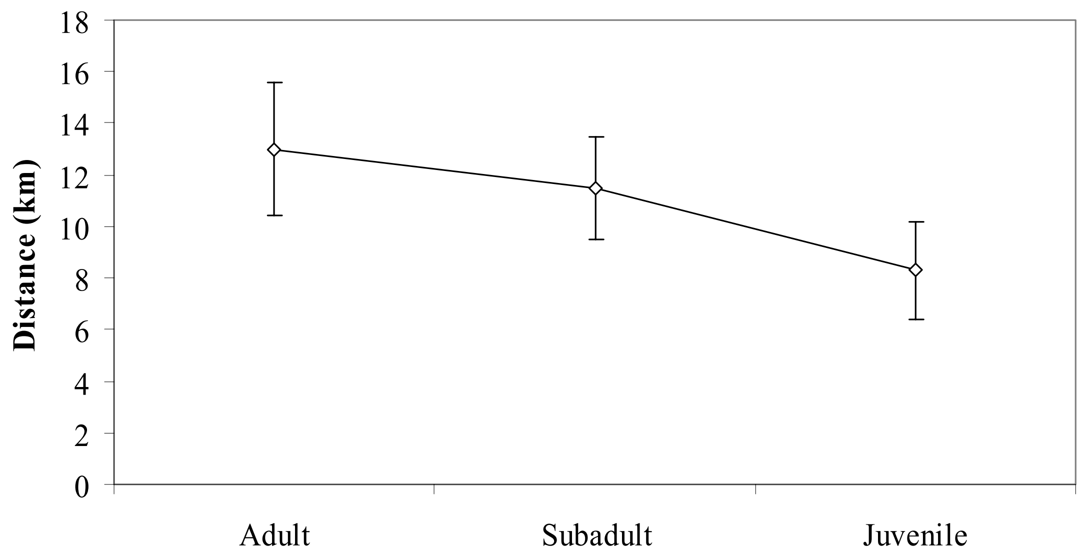

Figure 6. Mean straight-line distance (km) from release site to location 50 days post-release by age class for Badlands National Park Swift Fox Restoration Project, South Dakota (2003-2005)

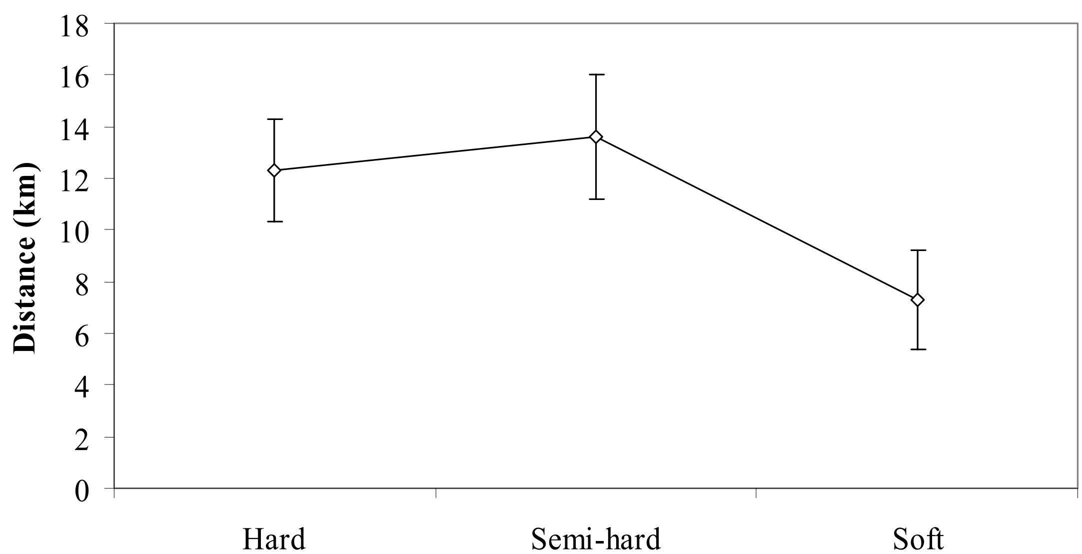

Figure 7. Mean straight-line distance (km) from release site to location 50 days post-release by release method for Badlands National Park Swift Fox Restoration Project, South Dakota (2003-2005)

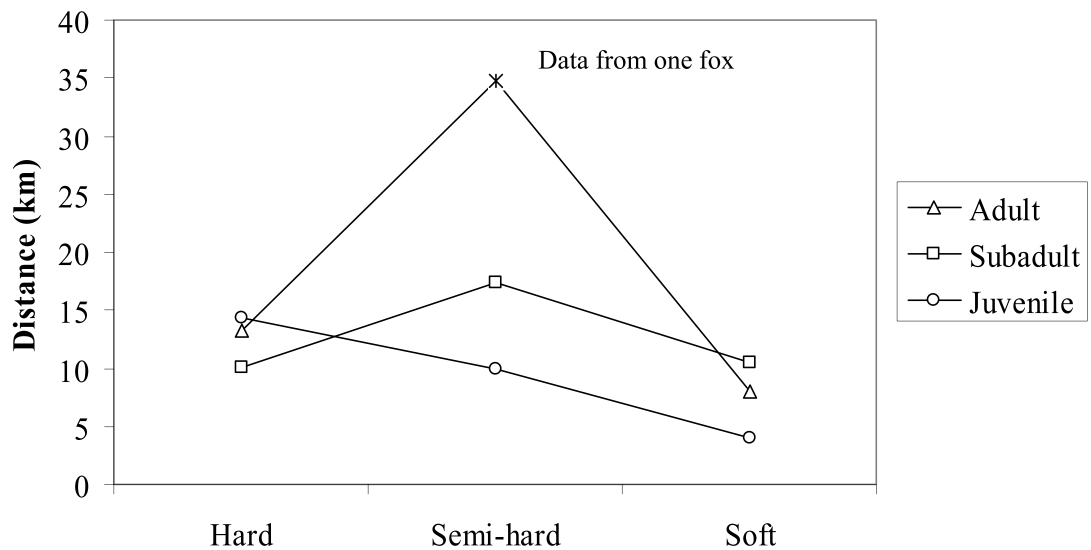

Figure 8. Mean straight-line distance (km) from release site to location 50 days post-release by release method and age for Badlands National Park Swift Fox Restoration Project, South Dakota (2003-2005)

Survival (2003-2006)

Swift fox survival rates differed by release year (χ^2 = 7.70, df =3, P = 0.05) (Table 3). However, in 2005, survival rates did not differ by gender (χ^2 = 0.01, df =1, P = 0.91), age (χ^2 = 1.88, df =2, P = 0.39), release site (χ^2 = 0.01, df =1, P = 0.95), or release method (χ^2 = 2.14, df =2, P = 0.34). Therefore, data from 2005 was pooled with 2003, 2004, and 2006 for analyses. For 2003-2006, swift fox survival rates did not differ by gender (χ^2 = 0.04, df = 1, P = 0.84), age (χ^2 = 0.05, df = 2, P = 0.98), release site (χ^2 = 0.47, df = 1, P = 0.50), or release method (χ^2 = 2.26, df = 2, P = 0.32; Table 4).

Table 4. Fifty-day post-release survival rates of swift foxes. Badlands National Park Swift Fox Restoration Project, South Dakota (2003-2006)

		Survival Rate	SE	Number Released
Gender	Male	0.73	0.06	51
	Female	0.75	0.06	63
Age	Juvenile	0.73	0.06	59
	Subadult	0.74	0.07	35
	Adult	0.75	0.10	20
Release Site	Coyote	0.77	0.06	53
	Random	0.71	0.06	61
Release Method	Hard	0.66	0.08	35
	Semi-hard	0.75	0.06	47
	Soft	0.81	0.07	32
Year	2003	0.70	0.08	30
	2004	0.89	0.06	28
	2005	0.60	0.09	30
	2006	0.77	0.08	26
Overall		0.74	0.04	114

Release Site

We did not detect differences in survival at $\alpha < 0.05$ for swift foxes released outside of coyote core-use areas or at random sites by gender ($P = 0.60$), age ($P = 0.16$), year ($P = 0.27$), or release method ($P = 0.76$) (Table 5).

Table 5. Fifty-day survival rates of swift foxes released outside of coyotes core-use areas (Coyote) and at random sites (Random). Badlands National Park Swift Fox Restoration Project, South Dakota (2003-2006)

		Release Site	Survival Rate	SE	Number Released
Sex	Males	Coyote	0.71	0.09	24
		Random	0.74	0.08	27
	Females	Coyote	0.83	0.07	29
		Random	0.68	0.08	34
Age	Juveniles	Coyote	0.77	0.08	31
		Random	0.68	0.09	28
	Subadults	Coyote	0.92	0.07	13
		Random	0.64	0.10	22
	Adults	Coyote	0.56	0.17	9
		Random	0.91	0.09	11
Year	2003	Coyote	0.79	0.11	14
		Random	0.63	0.12	16
	2004	Coyote	0.87	0.09	15
		Random	0.92	0.07	13
	2005	Coyote	0.58	0.14	12
		Random	0.61	0.12	18
	2006	Coyote	0.83	0.11	12
		Random	0.71	0.12	14
Release Method	Hard	Coyote	0.71	0.11	17
		Random	0.61	0.12	18
	Semi-hard	Coyote	0.78	0.10	18
		Random	0.72	0.08	29
	Soft	Coyote	0.83	0.09	18
		Random	0.79	0.11	14
	Total	Coyote	0.77	0.06	53
		Random	0.71	0.06	61

Release Method

We did not detect differences in survival at α < 0.05 for hard, semi-hard, or soft released foxes by gender ($P = 0.71$), age ($P = 0.84$), or release site ($P = 0.76$) (Table 6).

Table 6. Fifty day survival rates of swift foxes by release method (hard, semi-hard and soft) for Badlands National Park Swift Fox Restoration Project, South Dakota (2003-2006)

		Release Method	Survival Rate	SE	Number Released
Gender	Males	Hard	0.67	0.11	18
		Semi-hard	0.74	0.11	17
		Soft	0.74	0.11	16
	Females	Hard	0.64	0.12	17
		Semi-hard	0.72	0.08	30
		Soft	0.87	0.08	16
Age	Juveniles	Hard	0.63	0.17	8
		Semi-hard	0.75	0.07	36
		Soft	0.73	0.11	15
	Subadults	Hard	0.69	0.13	13
		Semi-hard	0.70	0.15	10
		Soft	0.83	0.11	12
	Adults	Hard	0.64	0.13	14
		Semi-hard	1.00		1
		Soft	1.00		5
Release Site	Coyote	Hard	0.71	0.11	17
		Semi-hard	0.78	0.10	18
		Soft	0.83	0.09	18
	Random	Hard	0.61	0.12	18
		Semi-hard	0.72	0.08	29
		Soft	0.79	0.11	14
Total		Hard	0.66	0.08	35
		Semi-hard	0.75	0.06	47
		Soft	0.81	0.07	32

DISCUSSION

Survival at 50 days for translocated swift foxes was effected by distance from release site. My results were similar to Moehrenschlager and Macdonald (2003), with one exception. While movement distance and gender were variables that contributed significantly to their final model, gender did not contribute to our final survival model. Based on their model results, Moehrenschlager and Macdonald (2003) recommended future swift fox translocations be biased toward releasing more females. In 2003, I released an equal sex ratio of foxes; but in 2004 and 2005 our release cohorts were skewed toward females. Survival was similar by gender for my releases at 50 days post-release and slightly greater for females by the pair formation/breeding season (Badlands National Park, unpublished data). In spring 2004, 2005, and 2006, more females than males were present in the population. Swift foxes are primarily monogamous; thus, future swift fox translocation cohorts should have balanced sex ratios.

While not significant, survival did increase from hard to semi-hard to soft releases (0.66, 0.75, and 0.81, respectively). Moehrenschlager and Macdonald (2003) recommended releasing swift foxes using soft release techniques. Yet, they hard released translocated swift foxes for logistical purposes. A major difference exists in the definition of the term “soft release” between the Canadian reintroduction program and my reintroduction program. Canadian foxes were held for 3-8 months in soft release pens whereas our foxes were held for 3-5 days. The Canadian soft release technique requires extensive time and money (i.e., feeding and caring for foxes for 3-8 months). Our semi-hard release method (placing the swift fox in a potential den without artificial protection) had not been previously attempted. These semi-hard and soft releases were employed to reduce the "flight" response of swift foxes trying to distance themselves from their human releasers, without requiring the additional time and expense of long-term soft releases. For translocated hard released foxes, survival of foxes (0.66 ± 0.08) was similar to results from Canadian releases for 1987-1992 (0.61) and 1994-1996 (0.80 ± 0.09; Carbyn et al. 1994, Moehrenschlager and Macdonald 2003).

Distance from release site was the most important variable effecting survival. Age and release method had significant effects on movement for swift foxes that survived. Movement distances were less for soft released foxes compared to hard or semi-hard releases and movement distances decreased from adult to subadult to juvenile swift foxes. Moehrenschlager and Macdonald (2003) recommended releasing juvenile swift foxes over adults because they survived as well, but moved less. Our results support the recommendation of Moehrenschlager and Macdonald (2003).

Swift fox survival only differed by release year, with lowest survival occurring during 2005. Survival did not differ by gender, age, release site, or release method within that year and thus, some other factor affected survival. Vegetation height is correlated with precipitation (Rogler and Haas 1947) and April – August precipitation in 2005 was above the 45 year average (Figure 3). Rainfall in 2003, 2004, and 2006 was below the long-term average. Russell (2006) measured vegetation height in the Badlands National Park study area in 2004 and 2005. Vegetation was higher in 2005 (42 cm) than in 2004 (15 cm). Eye-level height of swift foxes is about 30 cm. Therefore, swift foxes likely had reduced ability to detect coyotes in 2005 and as a result suffered higher mortality.

Coyotes were the principal cause of swift fox mortality in 2005 (Table 2). Mean movement distance of swift foxes that survived in 2005 was lower than foxes in 2003 and 2004 (Table 3). Furthermore, in 2004 mean movement distance of swift foxes was similar for those that survived or died. We also documented mortality of 10 of 48 swift fox pups as a result of vehicle collisions before radio collaring began in August 2005. In contrast, only 1 of 55 pups died as a result of vehicle collisions before radio collaring in August 2006. Consequently, swift fox pups that used roads as travel corridors suffered higher mortality because of the higher vegetation in 2005.

Swift fox survival did not differ for foxes released outside coyote core use area compared to foxes released at random locations (Table 5). Swift foxes preferred habitat close to roads (Russell 2006). These variables were not considered when selecting release sites based on coyote core-use areas. Coyote home ranges often follow natural landscape features, including roads (Young et al. 2003). Thus, coyote core-use areas may be important in selecting swift fox release sites if paired with distance to roads.

Literature Cited

Allardyce, D., and M.A. Sovada. 2003. A review of the ecology, distribution, and status of swift foxes in the United States. Pages 3-18 *In* M.A. Sovada and L.N. Carbyn, editors. The swift fox: ecology and conservation of swift foxes in a changing world. Canadian Plains Research Center, University of Regina, Saskatchewan, Canada.

Ausband, D.E. and K.R. Foresman. 2007. Dispersal, survival and reproduction of wild-born, yearling swift foxes in a reintroduced population. Canadian Journal of Zoology 85: 185-189.

Brinkman, T. J., C. S. DePerno, J. A. Jenks, J. D. Erb, and B. S. Haroldson. 2002. A vehicle-mounted radiotelemetry antenna system design. Wildlife Society Bulletin 30:256-258.

Carbyn, L., H. J. Armbuster, and C. Mamo. 1994. The swift fox reintroduction program in Canada from 1983 to 1992. *In* M.L. Bowles and C.J. Whelan. Restoration of endangered species: conceptual issues, planning and implementation. Cambridge University Press.

Chu, D. S., B. A. Hoover, M. R. Fuller, and P. H. Geissler. 1989. Telemetry location error in forested habitat. Pages 188-194 in C. J. Amlaner, ed. Biotelemetry X. Univ. Arkansas Press, Fayetteville.

Cox, R. R., Jr., J. D. Scalf, B. E. Jamison, and R. S. Lutz. 2002. Using an electronic compass to determine telemetry azimuths. Wildlife Society Bulletin 30:10391043.

Ecological Software Solutions. 2004. LOAS. Version 3.x. Urnäsch, Switzerland.

Fischer, J., and D.B. Lindenmayer. 2000. An assessment of the published results of animal relocations. Biological Conservation. 96: 1-11.

Gese, E. M., O. J. Rongstad, and W. R. Mytton. 1988. Home-range and habitat use of coyotes in southeastern Colorado. Journal of Wildlife Management 52:640-646.

Giddings, B. 1998. Swift fox management activities in Montana. Pages 18-22 in C. Roy, editor. Annual report of the Swift fox Conservation Team 1998. Kansas Department of Wildlife and Parks, Emporia, Kansas, USA.

Hall, E.R. 1981. The mammals of North America. Volume 2, pages 601-1181-90. John Wiley and Sons, Inc. New York, New York, USA.

Harrison, D. J., D. A. Bissonette, and J. A. Sherburne. 1989. Spatial relationships between coyotes and red foxes in eastern Maine. Journal of Wildlife Management 53:181-185.

Herrero, S., C. Mamo, L. Carbyn, and M. Scott-Brown. 1991. Swift fox reintroduction into Canada. *In* G.L. Holroyd, G Burns, and H.C. Smith eds. Proceedings of the second endangered species and prairie conservation workshop. Provincial Museum of Alberta Natural History Section, Occasional Paper No. 15, Edmonton, Alberta.

Honness, K. M., K.E. Kunkel, and M. K. Phillips. 2005. Swift fox restoration in west central South Dakota: 2004 Annual Progress Report. . Turner Endangered Species Fund Conservation Report 04-01.

Kamler, J.F., W.B. Ballard, R.L. Gilliland, and K. Mote. 2003. Spatial relationships between swift foxes and coyotes in northwestern Texas. Canadian Journal of Zoology 81:168-172.

Kitchen, A. M. 1999. Resource partitioning between coyotes and swift foxes: space, time, and diet. Thesis. Utah State University, Logan, Utah, USA.

Kitchen, A. M., E. M. Gese, S. M. Karki, and E. R. Schauster. 2005. Spatial ecology of swift fox social groups: from group formation to mate loss. Journal of Mammalogy 86:547-554.

Miller, D. S., D. F. Covell, R. G. McLean, W. J. Adrian, M. Neizgoda, J. M. Gustafson, O. J. Rongstad, R. D. Schultz, L. J. Kirk, and T. J. Quan. 2000. Serologic survey for selected infectious disease agents in swift and kit foxes from the Western United States. Journal of Wildlife Diseases 36:798-805.

Moehrenschlager, A. and D.W. Macdonald. 2003. Movement and survival parameters of translocated and resident swift foxes Animal Conservation 6:199-206.

Olson, T. L., and F. G. Lindzey. 2002. Swift fox survival and production in southeastern Wyoming. Journal of Mammalogy 83:199-206.

Pybus, M. J., and E. S. Williams. 2003. Parasites and diseases of wild swift foxes. Pages 231-236 *in* M.A. Sovada and L. N. Carbyn, editors. Ecology and conservation of swift foxes in a changing world. Canadian Plains Research Center, Regina, Saskatchewan.

Rodgers, A.R., A. P. Carr, L. Smith, and J.G. Kie 2005. HRT: Home-range tools for ArcGIS. Ontario Ministry of Natural Resources, Thunder Bay, Ontario, Canada.

Rogler, G.A. and H.J. Haas. 1947. Production as related to soil moisture and precipitation on the Northern Great Plains. Journal of the American Society of Agronomy 29: 378-389.

Russell, T.R. 2006. Habitat selection by swift foxes in Badlands National Park and the surrounding area in South Dakota. M. S. Thesis. South Dakota State University, Brookings, South Dakota, USA.

Sargeant, A. B., S. H. Allen, and J. O. Hastings. 1987. Spatial relations between sympatric coyotes and red foxes in North Dakota. Journal of Wildlife Management 51:285-293.

Scott-Brown, J.M., S Herrero, and J. Reynolds. 1987. Swift fox. Pages 432-441 in M. Novak, J.A. Baker, M.E. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Trappers Assoc., North Bay. Ontario, Canada.

Soper, J.D. 1964. The mammals of Alberta. The Hamley Press Ltd. Edmonton, Alberta, Canada.

Sovada, M. A., C. C. Roy, J. B. Bright, and J. R. Gillis. 1998. Causes and rates of mortality of swift foxes in western Kansas. Journal of Wildlife Management 62:1300-1306.

Sovada, M. A., and B. K. Scheick. 1999. Preliminary report to the swift fox conservation team: historic and recent distribution of swift foxes in North America. Pages 80-147 + appendix in C. G. Schmitt, editor. 1999 Annual report of the Swift Fox Conservation Team. New Mexico Department of Game and Fish, Albuquerque, New Mexico, USA.

Wilkinson, L. 1990. SYSTAT: the system for statistics. SYSTAT, Inc., Evanston, Illinois, USA.

Wolf, C.M., T. Garland, and B. Griffith. 1998. Predictors of avian and mammalian translocation success: reanalysis with phylogenetically independent contrasts Biological Conservation 86: 243-255.

Young, S.P. 1944. Their history, life habits, economic status, and control. Part 1. Pages 1-386 *in* The wolves of North America. The American Wildlife Institute, Washington, DC.

Zumbaugh, D. M., and J. R. Choate. 1985. Historical biogeography of foxes in Kansas. Transactions of the Kansas Academy of Science 88:1-13.

Chapter 4

Management Implications

Future swift fox reintroduction projects should continue to translocate wild swift foxes. Swift fox release cohorts should include equal sex ratios. As wild swift foxes from source populations are limited, biologists usually do not have the time or resources to translocate large numbers of foxes or to select only juveniles for release. To maximize release survival and site fidelity, short-term soft-release enclosures should be used. To reduce post-release movements and allow foxes to begin to familiarize themselves with their new habitat as soon as possible, wild swift foxes should be released after a short time in release pens,

While coyote control programs were not utilized during this study, coyote mortality did occur (7 of 41 coyotes collared). Nearly all swift foxes established home ranges in areas where coyotes could be hunted. It is unlikely that these areas had lower coyote densities, because home range size did not differ inside or outside of Badlands National Park. Swift fox survival rates were high despite no intensive coyote control measures being employed. Therefore, intensive coyote removal programs may not be necessary in all swift fox restoration programs. In areas where coyotes were exploited, they moved greater distances at night. Swift fox survival should be higher in unexploited coyote areas due to reduced movement of coyotes at night and the reduced interference competition. Further research should be conducted to determine if swift fox survival increases when coyotes are unexploited.