Restoration Ecology

RESEARCH ARTICLE

Release method evaluation for swift fox reintroduction at Bad River Ranches in South Dakota

Indrani Sasmal[1,2], Kevin Honness[3,4], Kristy Bly[5], Magnus McCaffery[3], Kyran Kunkel[6], Jonathan A. Jenks[1], Mike Phillips[3]

Reintroductions have increasingly become effective at restoring populations of imperiled native wildlife. How animals are reintroduced into unfamiliar environments may have pronounced impacts on behavior, survival, and reproduction. We evaluated the influence of four release methods on survival rates of translocated swift foxes at Bad River Ranches (BRR) in western South Dakota: (1) hard-release, (2) short-soft-release, (3) long-soft-release, and (4) captive born. A total of 179 foxes captured in Wyoming during 2002–2007 and in Colorado during 2006–2007 were released into BRR and the surrounding area. In addition, 43 pups born to foxes in the long-soft-release category were also released. All release methods incorporated a 14- to 21-day quarantine period. Hard-release foxes were released directly from a transport kennel, whereas short-soft-release foxes were released from soft-release pens by opening the door and allowing the foxes to leave voluntarily. Long-soft-release foxes were held for more than 250 days on-site in soft-release pens through the winter and released in the following year in early summer. During 2002–2007, survival of reintroduced foxes differed significantly ($p < 0.05$) by age (adult vs. juvenile), release year, and release method. The short-soft-release method had the highest 60-day post-release survival probability compared with the other release methods. We did not detect any differences in mortality hazards between wild-born and short-soft-release foxes. Reintroduction programs based on short-soft-releases are useful for restoring or augmenting populations to advance the conservation of the swift fox.

Key words: **Cox proportional hazard model, hard release, Kaplan–Meier estimator, soft release, survival rate, swift fox, translocation, *Vulpes velox***

Implications for Practice

- Conservation practitioners should use a short-soft-release method over hard-release, long-soft-release, and captive-born release methods for swift fox translocations.
- Short-soft-releases ameliorated some stresses associated with the sudden release of individuals into unfamiliar environments.
- Short-soft-releases were both economical and feasible because they did not involve captive husbandry of individuals of the species for a lengthy period of time (almost a year) as was required for the long-soft-releases and releases of captive-born individuals.

Introduction

Swift foxes (*Vulpes velox*) were once abundant throughout the short-grass and mixed-grass prairies of the Great Plains of North America (Egoscue 1979). Since settlement of the Great Plains, swift fox have disappeared from 60 to 90% of their historical range (Kahn 1997). Much of this decline has been attributed to conversion of native prairie to agriculture and associated decline in prey species, unregulated hunting and trapping, and predator control programs focused on larger carnivores (Kilgore 1969; Egoscue 1979; Carbyn et al. 1994; Allardyce & Sovada 2003). The present distribution of the species is characterized by disjunct populations from southern Wyoming through eastern Colorado, western Kansas, eastern New Mexico, the Oklahoma panhandle, northern Texas, western South Dakota, western Nebraska, northern Montana, and southern Canada (Carbyn 1998; Schmitt & Oakleaf 2000; Zimmerman et al. 2003; Fig. 1).

Reintroduction (or translocation) of species to areas from which they have become extirpated has increasingly been used in attempts to restore populations of endangered, threatened, or imperiled native wildlife (Sarrazin & Barbault 1996; Ostermann et al. 2001; Seddon et al. 2007). Reintroductions

Author contributions: KH, KK, JAJ, MP conceived and designed the research; KH, KB collected the data; IS, JAJ analyzed the data; IS, KB, MM, KK, JAJ, MK wrote and edited the manuscript.

[1]Department of Natural Resource Management, South Dakota State University, Brookings, SD 57007, U.S.A.
[2]Address correspondence to I. Sasmal, email bulirchithi@gmail.com
[3]Turner Endangered Species Fund, 1123 Research Drive, Bozeman, MT 59718, U.S.A.
[4]Deceased
[5]World Wildlife Fund, Northern Great Plains Program, 320 Meadow Lake Drive, Columbia Falls, MT 59912, U.S.A.
[6]University of Montana, 1875 Gateway South Drive, Gallatin Gateway, MT 59730, U.S.A.

doi: 10.1111/rec.12211
Supporting information at:
http://onlinelibrary.wiley.com/doi/10.1111/rec.12211/suppinfo

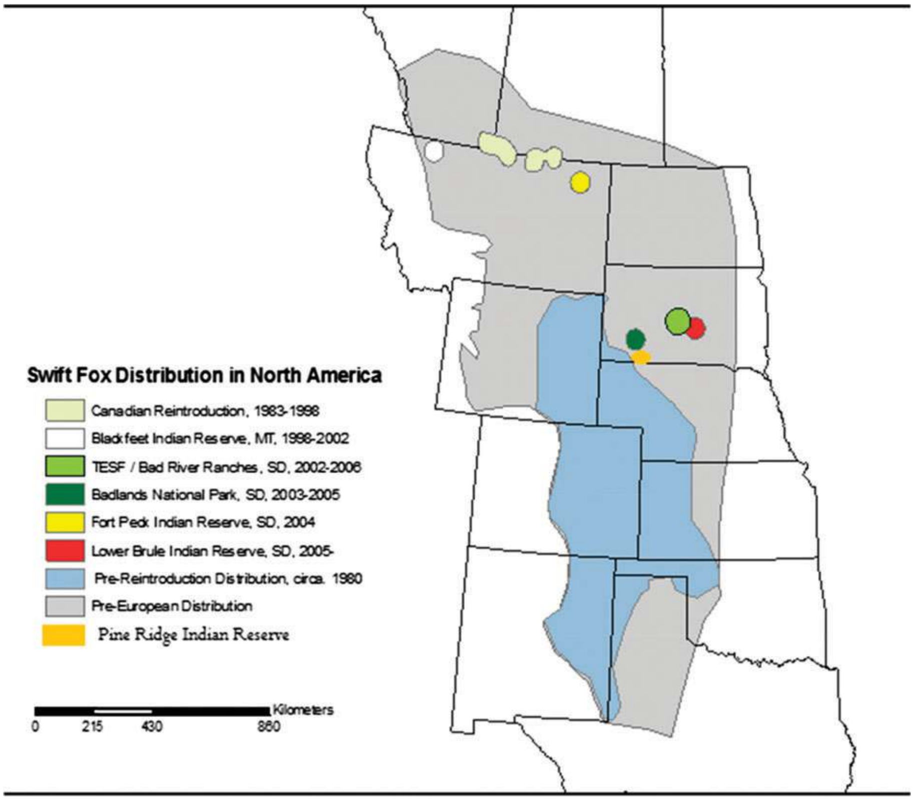

Figure 1. Swift fox distribution map.

to suitable habitat that are now depauperate of the species may offer a viable approach for maintaining, re-establishing, or facilitating range-expansion of imperiled wildlife populations (Wilcox & Murphy 1985; Wolf et al. 1996) by helping mitigate effects of habitat loss, habitat fragmentation, and extirpations. The first successful reintroduction program for swift foxes was initiated in 1983 by the Canadian Wildlife Service, with the effort focused largely on public land along with some private lands in Alberta and Saskatchewan, Canada (Carbyn et al. 1994). The success of this program was evident from the increasing population size, high survival rate of the reintroduced population, and about 98.6% of captured pups during the 2000–2001 census were identified as wild-born individuals (Moehrenschlager & Moehrenschlager 2001). Since then, several reintroductions have attempted to restore swift fox populations to unoccupied, yet suitable, habitat within their historical range. These efforts include reintroduction at Bad River Ranches [BRR; Turner Endangered Species Fund (TESF)] and environs in South Dakota from 2002 to 2007.

Translocated animals endure stress related to being captured, handled, and released into unfamiliar environments. Typically, reintroduced animals are released using one of two fundamental strategies: "hard" or "soft" release. Fritts et al. (2001) defined hard-release as an immediate and direct release of animals into a new environment and soft-release as a delayed release from a temporary enclosure. The degree of stimulation by humans at the time of release is the variable that best characterizes the two approaches (Fritts et al. 2001). Hard-releases are generally less costly and labor consumptive than soft-releases because they do not require release infrastructure. Soft-releases involve construction of acclimation pens and temporary husbandry, which increases cost and labor intensity. Soft-releases have been used successfully in reintroductions of northern Rocky Mountain gray wolf (*Canis lupus occidentalis*, Fritts et al. 2001), red wolf (*Canis rufus*, Phillips et al. 2003), Mexican wolves (*Canis lupus baileyi*, Parsons 1998), and gopher tortoise (*Gopherus polyphemus*; Tuberville et al. 2005). In Canada, Carbyn et al. (1994) found that soft-release, captive-born swift foxes had higher annual survival rates than hard-release, captive-born individuals. These soft-releases were eventually replaced by hard-releases due to fiscal constraints. Schroeder (2007) documented that survival of released swift foxes at Badlands National Park in South Dakota was mostly influenced by post-release distance traveled, which again was influenced by release method (i.e. hard-release foxes traveled longer distances).

The objective of this study was to evaluate the influence of four release methods: hard-release, short-soft-release, long-soft-release, and captive-born, on the survival of swift foxes released on the BRR. We hypothesized that soft-releases (short-soft and long-soft) would positively influence site and mate fidelity, which would in turn lead to higher rates of survival. We also hypothesized that age and sex of released foxes would influence the survival of translocated swift foxes at BRR.

Methods

The Swift Fox Restoration Area (SFRA) was approximately 10,000 km^2 in west-central South Dakota encompassing portions of Haakon, Jackson, Jones, Lyman, and Stanley counties (Fig. 2), and was situated within the Pierre Hills physiographic region (Johnson et al. 1995). Soils are primarily clays derived from Cretaceous Pierre Shale, and the topography consists of flats cut by intermittent drainages, including the Bad River, and gently rolling hills. Elevation ranges from approximately 590 to 797 m. Climate is temperate, with average temperatures ranging from −4°C in winter to 23°C in summer. Mean annual precipitation is 46.0 cm/year with most rainfall occurring in March and June. Kuchler (1975) characterized the dominant cool season grasses as a western wheatgrass (*Agropyron smithii*)–green needlegrass (*Stipa viridula*) community within the typical mixed-grass prairie community region. Buffalo grass (*Buchloe dactyloides*) is the dominant warm season grass. Deciduous woodlands dominated by plains cottonwood (*Populus deltoides*) follow the Bad River Valley floodplain and its northern tributaries. BRR constituted the core of the SFRA and included approximately 570 km^2 of mixed-grass prairie that was managed for bison (*Bison bison*) production and conservation of biodiversity. Swift fox releases were conducted on the SFRA (Fig. 2) under the authority of the South Dakota Department of Game, Fish and Parks (SDGFP) and with permission of cooperating private landowners. The TESF partnered with Fort Pierre National Grasslands (FPNG) and the Lower Brule Sioux Tribe (LBST).

Fox Capture and Translocation

We obtained all permits required to capture and translocate swift foxes from Wyoming (2002–2006) and Colorado (2006–2007) to South Dakota. In each year, trap sites were located ≥9 km from the trap sites used in the previous year. Trapping was carried out during fall (August–October) of each year. To maximize genetic diversity and reduce local impacts, we removed ≤3 foxes from any localized area (one family unit home range, approximately 5 km^2; L. Carbyn, Canadian Wildlife Service, personal communication). We set traps in the evening, checked them at dawn, and left the traps closed during the day. When captured, we examined the foxes' physical condition, measured body weight, attached an ear tag, implanted a microchip, and attached a radio collar (ATS and Telonics collars weighing 42–50 g) to foxes. We also dusted foxes with carbaryl powder (SEVIN) to kill fleas and followed recommendations of Miller et al. (2000) and Pybus and Williams (2003) to minimize disease risks during translocation (handling and disease risk assessment details are provided in Appendix S1, Supporting Information). Foxes free of any overt signs of disease were quarantined at TESF's Van Metre Field Station (Field Station) in Jones County, South Dakota, for a minimum of 14 days prior to release. We used kennels to transport foxes from Colorado and Wyoming to the quarantine pens at the Field Station; the quarantine pens also served as the acclimation and holding pens (detailed description of pens are attached in Appendix S1). We fed and watered foxes daily and monitored their health. Wild-born pups at the Bad River study area were also captured at their natal dens following the same procedures as adults. To ensure humane treatment of foxes, all capture and handling procedures followed recommendations of the American Society of Mammalogists (Sikes & Gannon 2011) and internal guidelines that we developed in collaboration with biologists from Wyoming, Colorado, and South Dakota.

Release Site Selection

We selected quarantine/acclimation pen sites based on swift fox habitat preferences (Kunkel 2003), home range sizes (Kamler et al. 2003), and accessibility that minimized disturbance to foxes. We distributed 11 pens over BRR in areas where we could monitor post-release movements. Release sites were selected using similar criteria as for selecting pens sites. Releases were evenly divided between hard and soft-release types (Fig. 2).

Release Methods

Hard and Short-Soft-Releases. Following the 14- to 21-day quarantine period, swift foxes in the hard-release treatment group were placed in shipping kennels and taken to predetermined release sites where the kennel door was left open for foxes to exit. Releases took place in the late afternoon/evening as soon as possible after the quarantine period. We staggered the release of individuals in each release cohort by several days to better manage post-release monitoring. We defined hard-releases as those in which foxes were held in quarantine pens at the field station, moved to the release sites, and immediately released. Short-soft-release foxes were in "acclimation" pens on sites throughout the BBR study area and released from "acclimation" pens by opening the door and allowing the foxes to leave voluntarily. Thus, cover (i.e. pen) was available to short-soft-release foxes, whereas it was absent for hard-release foxes. Both hard and short-soft-releases occurred during the fall of respective years from August to October.

Long-Soft-Releases. Foxes in this treatment group were held for more than 250 days on-site in soft-release pens through the winter and released the following year in early summer (captive husbandry details are provided in Appendix S1). Pups born to fox pairs in the long-soft-release category formed the "captive-born" release cohort. Foxes released from long-soft-release pens were released in mid-July when pups, if any, were old enough to travel short distances but were still dependent on adults for food.

We designed both short and long-soft-releases to acclimate foxes to the release area and to attenuate the magnitude of post-releases to minimize encounters with coyotes (*Canis latrans*) (Carbyn et al. 1994; Moehrenschlager 2000; Fritts et al. 2001). We selected soft-release pairs based on trapping locations to minimize pairing of related individuals. Prior to the long-soft-release, we weighed all foxes, replaced radio collars on adult foxes, fitted pups with collars once they weighed greater than 1.5 kg, and vaccinated pups with treatments

Figure 2. TESF SFRA along with release sites by release type for foxes released during 2007 at SFRA in South Dakota, U.S.A.

provided to adults when initially captured (Appendix S1). We released foxes from the long-soft-release group by opening pen doors in mid-July. Doors were left open so that foxes could return at will to pens. We continued to provide food at the pens as long as foxes were in the area.

Post-Release Monitoring and Data Analysis

Our monitoring strategy included aerial- and ground-based telemetry and visual observations at den sites in early summer. Aerial reconnaissance was most effective during the evening hours, especially when combined with coordinated ground crews who were able to pinpoint the location of dispersing or dead foxes. For the first 70 days following a release (for all treatment groups), we attempted to locate all foxes daily. Tracking occurred primarily by triangulation using mobile three-element null-peak systems mounted in 4 × 4 vehicles where roads and landscape characteristics allowed. Aerial telemetry was used once weekly as weather permitted to locate dispersing foxes. Foxes were monitored during all times of the day. We investigated mortalities following standard protocols (Disney & Spiegel 1992; Kunkel 1997). Field staff conducted mortality site analysis and a veterinarian conducted laboratory necropsies on dead foxes.

Because survival of translocated swift foxes has been related to the distance moved from their release site (Schroeder 2007) and there has been no reported difference in the daily movements of translocated and resident foxes after about 50 days post-release (Moehrenschlager & MacDonald 2003), we estimated the 60-day post-release survival rate to assess the effect of release type on swift fox survival. We calculated Kaplan–Meier survival rates using SYSTAT 13 (Wilkinson 1990), and compared them using chi-square statistical tests by sex, age, release method, and release year for the release years 2002–2007 (the p value of age and release method interaction model was 0.2, release year and release type interaction model p value was 0.3 and age, release year and release type interaction model p value was 0.3). We used SAS 9.2 (SAS Inc., Cary, NC, USA) to estimate a Cox proportional hazard regression model for assessing the influence of the covariates age, sex, release year, and release type on released swift fox survival for release years 2002–2007. We also tested the linear hypothesis that the coefficient for hard-release and long-soft-release types were similar using SAS 9.2 (SAS Inc.) in a Cox proportional hazard regression model. We used the following four categories, hard-release, short-soft-release, long-soft-release, and captive-born, in analyses. We also evaluated the survival rate of wild-born foxes for comparison by release type.

Results

A total of 179 foxes (85 males and 94 females; 91 adults and 88 sub-adults) were translocated and released onto the SFRA (Fig. 2, Table 1). In addition, we released 43 pups (26 males, 17 females) born in long-soft-release pens (Table 1). We documented 90 pups born in the wild to released foxes (33 males, 29 females, 28 unknown; Table 1). Over the 6-year study period, we documented a total of 160 mortalities of released foxes (82 females, 77 males) attributed to coyotes (43%), vehicles (14%), human (8%), bobcats (*Lynx rufus*, 4%), raptors (4%), swift fox (1%), miscellaneous (1%), and unknown (25%) causes.

The 60-day post-release survival of foxes differed significantly based on release age (p value = 0.001), release year (p value = 0.032), and release type (p value < 0.0001); there was no difference in survival based on sex (p value = 0.497). The 60-day post-release survival probability of sub-adult foxes (0.808, SE = 0.03) was greater than that of adult released foxes (0.628, SE = 0.05; Fig. 3). The survival rate was not significantly higher (p value = 0.113) between sub-adults (0.714, SE = 0.041) and adults (0.628, SE = 0.052) after removing the wild-born cohort from the analysis. During the study, the 60-day post-release survival of foxes was highest (0.947, SE = 0.05) in 2002, and lowest (0.605, SE = 0.08) in 2003 (Fig. 4). The 60-day post-release survival probability of foxes was again higher in 2004 (0.811, SE = 0.06) than in 2005 (0.745, SE = 0.061), 2006 (0.776, SE = 0.055), and 2007 (0.727, SE = 0.06; Fig. 4). The short-soft-release method resulted in the highest 60-day post-release survival probability (0.757, SE = 0.04) in comparison with hard-release (0.609, SE = 0.1), long-soft-release (0.659, SE = 0.07), and captive-born (0.484, SE = 0.09) release methods (Fig. 5). The short-soft-release method also resulted in the highest survival probability (0.818, SE = 0.052) among sub-adult foxes for years 2003–2007 in comparison with long-soft-release (0.667, SE = 0.136), and captive-born (0.484, SE = 0.09) release methods. We documented similar 60-day post-release survival probabilities for male (0.771, SE = 0.037) and female (0.727, SE = 0.039) foxes at BRR and the surrounding area. All the wild-born foxes survived to 60 days.

Table 1. Release history of swift foxes based on release type, sex, age, and release year at BRR, South Dakota, U.S.A.

Year	*HR*	*SSR*	*LSR*	*CB*	*WB*
2002					
Adult female	3	2	—	—	—
Sub-adult female	4	3	—	—	—
Adult male	1	3	—	—	—
Sub-adult male	1	3	—	—	—
Total (2002)	9	11	—	—	—
2003					
Adult female	2	2	1	—	—
Sub-adult female	4	2	4	7	1
Adult male	3	1	1	—	—
Sub-adult male	6		4	5	3
Total (2003)	15	5	10	12	4
2004					
Adult female	—	—	2	—	—
Sub-adult female	—	7	1	1	6
Adult male	—	2	2	—	—
Sub-adult male	—	9	1	2	4
Total (2004)	—	18	6	3	10
2005					
Adult female	—	9	5	—	—
Sub-adult female	—	6	2	—	6
Adult male	—	1	7	—	—
Sub-adult male	—	4	—	4	8
Total (2005)	—	20	14	4	14
2006					
Adult female	—	7	3	—	—
Sub-adult female	—	7	—	4	10
Adult male	—	6	3	—	—
Sub-adult male	—	9	—	6	7
Total (2006)	—	29	6	10	17
2007					
Adult female	—	8	5	—	—
Sub-adult female	—	5	—	5	6
Adult male	—	7	5	—	—
Sub-adult male	—	6	—	9	11
Total (2007)	—	26	10	14	17
Unknown sex (total)	—	—	—	—	28
Total number of release	24	109	46	43	90

CB, captive-born; HR, hard-release; LSR, long-soft-release; SSR, short-soft-release; WB, wild born.

The Cox proportional hazard regression model indicated that survival of foxes at 60-days post-release was influenced by release age and release type but was not influenced by sex of foxes (Table 2). We did not detect any differences between mortality hazards of wild-born and short-soft-release foxes or between long-soft-release and short-soft-release foxes

Table 2. Maximum likelihood estimates obtained from Cox proportional hazard model to assess the effect of different survival factors on 60-day post-release survival of swift fox at BRR, SD.

Survival Factor	df	*Parameter Estimate*	*SE*	*Chi-Square*	p *Value*	*Hazard Ratio*
Release age	1	−0.784	0.313	6.271	0.012	0.457
Sex	1	−0.141	0.25	0.318	0.573	0.869
Captive-born	1	1.273	0.369	11.873	0.001	3.571
Wild born	1	−15.903	882.035	0	0.986	0
Hard-release	1	0.803	0.392	4.2	0.04	2.233
Long-soft-release	1	0.215	0.334	0.414	0.52	1.24

df, Degrees of freedom; SE, standard error.

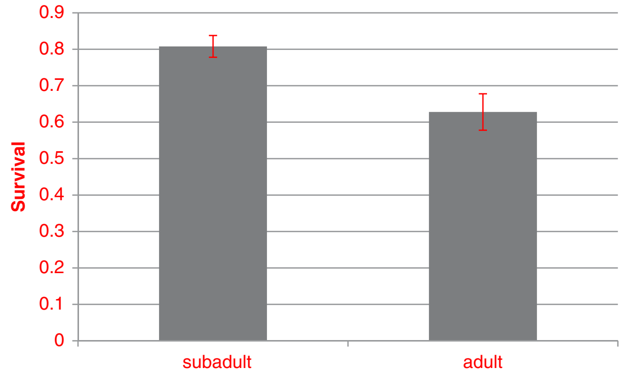

Figure 3. Sixty-day post-release survival rate along with ±SE bars of adult and sub-adult translocated swift foxes (*Vulpes velox*) from 2002 to 2007 at BRR and surrounding area in South Dakota, U.S.A.

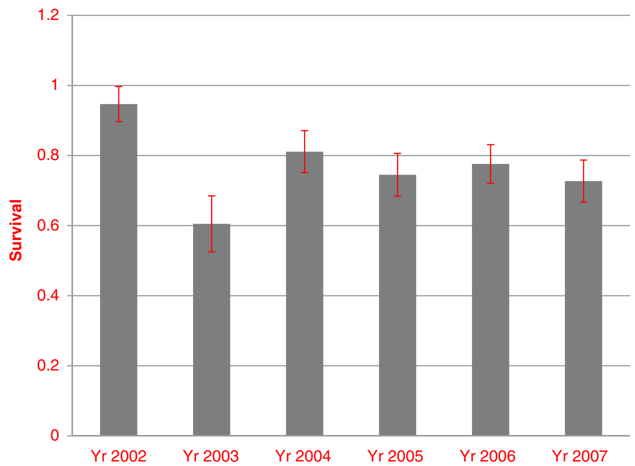

Figure 4. Sixty-day post-release survival probability along with ±SE bars of translocated swift foxes (*Vulpes velox*) in different release year from 2002 to 2007 at BRR and surrounding area in South Dakota, U.S.A.

(Table 2). We also did not detect any difference between survival rates of hard- and long-soft-release foxes after 60-days post-release using linear hypothesis testing. The mortality hazard of captive-born released swift foxes was almost four times (hazard ratio = 3.57) higher than the mortality hazard of short-soft-release foxes, whereas the mortality hazard of hard-release foxes was almost twice (hazard ratio = 2.23) that of short-soft-release foxes at BRR (Table 2).

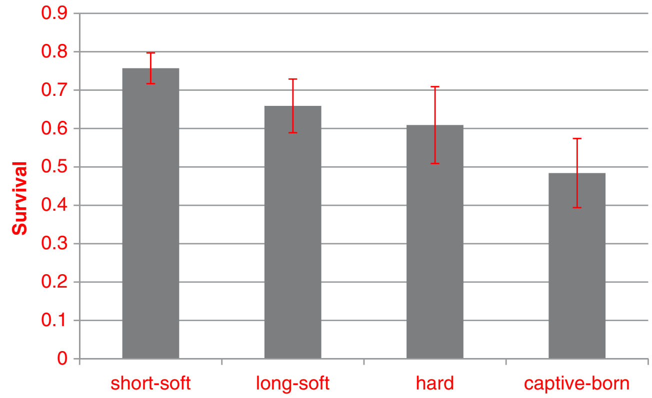

Figure 5. Sixty-day post-release survival probability along with ±SE bars of translocated swift foxes (*Vulpes velox*) based on different release methods from 2002 to 2007 at BRR and surrounding area in South Dakota, U.S.A.

Discussion

The short-soft-release method was most effective when compared to captive-born, hard-release, and long-soft-release methods. The short-soft-release method had a significantly lower mortality hazard in comparison with hard-release and captive-born foxes. Mortality hazards for wild-born and short-soft-release foxes were similar in our study area at BRR. Although the short-soft-release method involved construction of pens at suitable release sites, it did not involve captive husbandry of foxes for a lengthy period of time (almost a year) as was required for the long-soft-releases and releases of captive-born foxes. Also short-soft-releases ameliorated some stresses associated with the sudden release of foxes into unfamiliar environments as in hard-release methods and subsequently improved the survival probability of the translocated foxes in our study area. Although hard-release foxes were held in the quarantine pen for 14–21 days, similar to the short-soft-release foxes, the availability of cover (i.e. pen) relative to the short-soft-release method and not in the hard-release method did make a big difference between the two methods. The captive-born and long-soft-release individuals were released in summer, whereas hard and short-soft-releases were carried out in fall. Because fall releases were documented to be preferable over summer releases (A. Moehrenschlager, Calgary Zoological Society, unpublished data), the survival of captive-born and long-soft-release foxes might have been lower than short-soft-release foxes because of the release time of the year.

Translocated sub-adult foxes are generally considered the colonizers of vacant habitat (Ausband & Foresman 2007) because of their tendency to avoid other foxes and thus exhibit independence (Bekoff 1977). Other studies also documented higher survival of sub-adult translocated swift foxes (Schroeder 2007). Our results showed that though the adult and sub-adult survival of released foxes were not significantly different after removing wild-born cohorts from the analysis, it could be advantageous to release sub-adult foxes as they are better colonizers.

Survival probabilities of released foxes at BRR did not differ by sex, which was in accordance with the results of restoration efforts for swift foxes at Badlands National Park (Schroeder 2007). In contrast, Moehrenschlager and MacDonald (2003) documented higher survival probabilities of released male than released female swift foxes due to their greater experience with previous long-distance dispersal and therefore recommended female biased release in future translocations so that the translocated male foxes would possess a better chance of pairing. However, in this study, we documented the greatest dispersal distance of 263 km by a female sub-adult fox. Because swift foxes are primarily monogamous, we recommend future translocation cohorts be comprised of a balanced ratio of male and female foxes so that translocated individuals would possess a better chance of pairing.

We documented the highest survival probability (0.95) in the first year (2002) of release, and lowest survival probability (0.61) in the second year (2003) across release types, sexes, and age cohorts. In 2003, only five swift foxes were released using the short-soft-release method, whereas 12 swift foxes were released using the captive-born method. The captive-born release method was our least successful approach, and as such the survival probability of released foxes not comprising any captive-born individuals in year 2002 was highest. Being born in a controlled environment and supported by regular provisioning of food may have negatively impacted the foxes' ability to survive in the wild by diminishing their skill at hunting and locating adequate burrows. Also, precipitation in 2003 was higher than in 2002, which might have influenced vegetative growth of the study area in a manner that decreased the extent of suitable habitat by restricting the local view shed (Kamler 2003; Russell 2006; Sasmal et al. 2011).

On the BRR and surrounding environs, much of the swift fox habitat occurred on private lands; therefore, innovative approaches were needed to implement swift fox restoration activities. Through a concerted recruitment effort eventually over 100 nearby landowners supported the restoration effort. This support was of vital importance. A frequent biological cost of translocation is high mortality, in the early days or weeks after release (Moore & Smith 1990; Kleinman et al. 1991). Many authors have considered soft-release protocols useful in mammalian translocation because they reduce the stress due to novel environments and the intense activity during the first days after release (Moore & Smith 1990; Bright & Morris 1994; Biggins et al. 1999; Fischer & Lindenmayer 2000). We suggest that sub-adult swift foxes comprised of a balanced ratio of male and female foxes be released using short-soft-release methods to enhance post-release survival and hence, short-term translocation success of swift foxes.

Acknowledgments

Funding was provided by U.S. Fish and Wildlife Service, National Fish and Wildlife Foundation, South Dakota Department of Game, Fish and Parks, and Turner Endangered Species Fund. We thank the numerous private landowners in South Dakota, Wyoming, and Colorado who opened their gates and minds to the idea of swift fox restoration. We also thank BRR ranch manager T. LeFaive for his assistance with project logistics and the numerous field technicians who aided in all aspects of this project. We thank S. Datta, S. Grassel, and A. Moehrenschlager for reviewing the manuscript, and S. Olimb and R. Klaver for their suggestions on generating the study area map.

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Supporting Information

The following information may be found in the online version of this article:

Appendix S1. Fox handling and disease risk assessment.

Coordinating Editor: Eric Higgs

Received: 24 June, 2014; First decision: 16 October, 2014; Revised: 20 February, 2015; Accepted: 9 March, 2015; First published online: 28 April, 2015