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TRANSLOCATION OF THE ENDANGERED SAN JOAQUIN KIT FOX, *VULPES MACROTIS MUTICA:* A RETROSPECTIVE ASSESSMENT

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ABSTRACT.—In 1988, a study of federally endangered San Joaquin kit foxes (*Vulpes macrotis mutica*) was initiated to develop techniques for translocating kit foxes onto Naval Petroleum Reserve No. 1 (NPR-1) in California. Our objective is to review the translocation program and provide recommendations for future efforts. There were no problems trapping, translocating, and maintaining foxes in captivity. We released 12 foxes onto NPR-1 in 1989 and 28 foxes in 1990. Of the 12 foxes released in 1989, 10 died within 1 year. Of 28 foxes released in 1990, 1 was still alive, 24 were dead, and the fate of 3 was undetermined when the study was terminated on 30 April 1992. Annual survivorship of translocated foxes was 0.03, which was less than survivorship of free-ranging foxes (0.35). Survivorship was not influenced by year of release, sex or age of translocated animals, or terrain in which foxes were released. Predation was the main cause of death. Six foxes survived through 1 breeding season, and 3 of these 6 foxes survived through 2 breeding seasons. Four of the 6 foxes bred with free-ranging foxes. Excluding 1 fox that moved 124 km before being killed by a vehicle, the distance between the release site and the location of death averaged 9.9 km (SE 1.9) for 11 foxes released in 1989 and 4.4 km (SE 1.1) for 24 adults released in 1990. The distance between the release site and the location of death was less for foxes released from pens in hilly terrain (3.1 km, SE 1.7) than for foxes released in level terrain (5.6 km, SE 1.5). Declining prey availability may have negatively influenced survivorship. Survivorship also may have been low because foxes were not familiar with their environment, including food and cover locations. Installing artificial dens or other forms of escape cover may improve survival of translocated foxes. If mortality factors can be mitigated, we believe the likelihood that foxes can be successfully translocated is good. To increase survivorship and to reduce the length of time between the release date and pair-formation we recommend that foxes be released in fall.

RESUMEN.—En 1998, se inició un estudio sobre los zorros kit de San Joaquín (*Vulpes macrotis mutica*), que se encuentran en peligro de extinción, para desarrollar técnicas para translocarlos en la Reserva Naval Petrolera N°1 (NPR-1, por sus siglas en inglés), en California. Nuestro objetivo es analizar el programa de translocación y hacer recomendaciones para esfuerzos futuros. No se presentaron problemas en cuanto a atrapar, transferir y mantener a los zorros en cautiverio. Liberamos 12 zorros en NPR-1 en 1989 y 28 en 1990. De los 12 zorros liberados en 1989, 10 murieron ese mismo año. De los 28 zorros liberados en 1990, solo uno sobrevivió, 24 murieron y el paradero de 3 de ellos fue indeterminado al momento de concluir el estudio, el 30 de abril de 1992. La supervivencia anual de los zorros translocados fue de 0.03, menor a la de zorros silvestres (0.35). La supervivencia no estuvo influida por el año de su liberación, el sexo o la edad de los animales, ni por el terreno en el que los zorros fueron liberados. La depredación fue la causa principal de muerte. Seis zorros sobrevivieron durante una época reproductiva, de los cuales solo tres sobrevivieron durante dos temporadas reproductivas. Cuatro de los seis zorros fueron criados por zorros silvestres. A excepción de un zorro que se trasladó 124 km antes de ser atropellado por un vehículo, la distancia entre el sitio de liberación y el sitio de la muerte tuvo un promedio de 9.9 km (SE 1.9) en el caso de 11 zorros que fueron liberados en 1989 y 4.4 (SE 1.1) en el caso de 24 adultos liberados en 1990. La distancia entre el sitio de liberación y el sitio de muerte fue menor en zorros que fueron liberados de sus jaulas en terrenos montañosos (3.1 km, SE 1.7) que en aquellos liberados en terrenos llanos (5.6 km, SE 1.5). La disminución de la disponibilidad de presas podría haber influido negativamente en la supervivencia. Además, la supervivencia pudo haber sido baja porque los zorros no estaban familiarizados con el ambiente, la comida y los refugios. Instalar guaridas artificiales u otras formas de refugios podría aumentar la supervivencia de los zorros translocados. Si los factores de mortalidad pudiesen ser mitigados, creemos que la probabilidad de que los zorros puedan ser translocados con éxito sería mayor. Recomendamos que los zorros sean liberados durante el otoño con el propósito de aumentar la tasa de supervivencia y de reducir la duración del tiempo entre la fecha de liberación y la formación de parejas.

San Joaquin kit foxes (*Vulpes macrotis mutica*) have a distribution restricted largely to the Central Valley of California (Grinnell et al. 1937). They occur in arid scrub and grassland habitats, but these habitats have been significantly reduced by conversion to agricultural, urban, and industrial uses (USFWS 1998). Due primarily to this profound habitat loss,

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fragmentation, and degradation, San Joaquin kit foxes were listed as endangered under the Endangered Species Protection Act in 1967, and the current Endangered Species Act in 1973. In 1971 they were listed as state threatened under the California Endangered Species Act. Despite foxes being listed since 1967, habitat loss has continued, and San Joaquin kit foxes are still declining (USFWS 2010, Cypher et al. 2013).

Consequently, aggressive conservation actions are warranted, and one such strategy is translocation of animals to enhance existing populations or establish new ones (Kleiman et al. 1994). This strategy has been an important component of conservation strategies for other imperiled canids including swift foxes (*Vulpes velox;* Carbyn et al. 1994, Smeeton and Weagle 2000), gray wolves (*Canis lupus;* Bangs and Fritts 1996), Mexican wolves (*Canis lupus baileyi;* Parsons 1998, Romo et al. 2013), and red wolves (*Canis rufus;* Sefscik 2002, Phillips et al. 2003, Bartel and Rabon 2013).

Translocation of animals is notoriously challenging (Kleiman 1989, 1996, Chivers 1991, Stanley Price 1991, Yalden 1993, Kleiman et al. 1994, Reading and Clark 1996, Fischer and Lindenmayer 2000, Breitenmoser et al. 2001). Common problems include stress associated with capture and transport, lack of familiarity of translocated individuals with critical resources such as food and cover at release sites, failure to mitigate factors responsible for the species being absent at recipient sites, dispersal of translocated individuals from release sites, and failure to translocate a sufficient number of individuals to successfully establish a self-sustaining population (Chivers 1991, Kleiman et al. 1994, Breitenmoser et al. 2001). Consequently, many translocation efforts fail to achieve desired objectives (e.g., enhancing existing populations or establishing new ones). Even when such efforts are not successful, they offer an opportunity to gain information that hopefully will inform and improve future efforts. Such learning opportunities are particularly critical when dealing with rare species where limited availability of "surplus" individuals for translocation may limit attempts.

A population of San Joaquin kit foxes on the U.S. Department of Energy's (DOE) Naval Petroleum Reserve No. 1 (NPR-1) in the Elk Hills of western Kern County, California, was monitored beginning in 1979. This population declined during the 1980s (Cypher et al. 2000). The 1987 Biological Opinion issued by the USFWS (USDI 1987) specified that "DOE examine alternative means to offset kit fox habitat loss . . ." In 1988, it appeared that the number of foxes on NPR-1 was below carrying capacity; there were portions of the reserve that no longer supported populations of kit foxes, even though the density of dens and the relative abundance of prey appeared to be comparable to areas where foxes still existed. In 1989 and 1990, kit foxes were translocated to and released at Elk Hills in an effort to supplement and increase the population.

"Soft" translocations were used, which involved holding foxes in pens to accustom them to the release site and then releasing foxes in spring and summer when prey were presumably most abundant. Soft translocations were thought to be more likely to be successful than "hard" translocations, which is releasing animals immediately after translocation. The soft release technique was similar to translocation techniques used by the Canadian government to reestablish swift foxes in portions of Alberta (Scott-Brown et al. 1986, Carbyn 1989, Canadian Wildlife Service 1990).

Some aspects of this translocation program were successful, but overall it did not appear to achieve the desired goal. Our objective is to describe this kit fox translocation effort, analyze the results relative to project objectives, discuss known and potential reasons for the observed results, and offer recommendations for any future kit fox translocation attempts.

Although applied retroactively, the design and execution of this study fulfilled all of the IUCN Guidelines and Annexes to Guidelines for translocation efforts involving vulnerable species, especially Annex 3.2 that calls for assessing extinction causes and threats when deciding when translocation is an acceptable option (IUCN/SSC 2013).

METHODS

Kit foxes were translocated to NPR-1 in western Kern County, California (Fig. 1). At the time, this site was owned and administered by DOE for oil and gas production. In 1998 it was sold to Occidental Petroleum Corporation. NPR-1 encompassed approximately

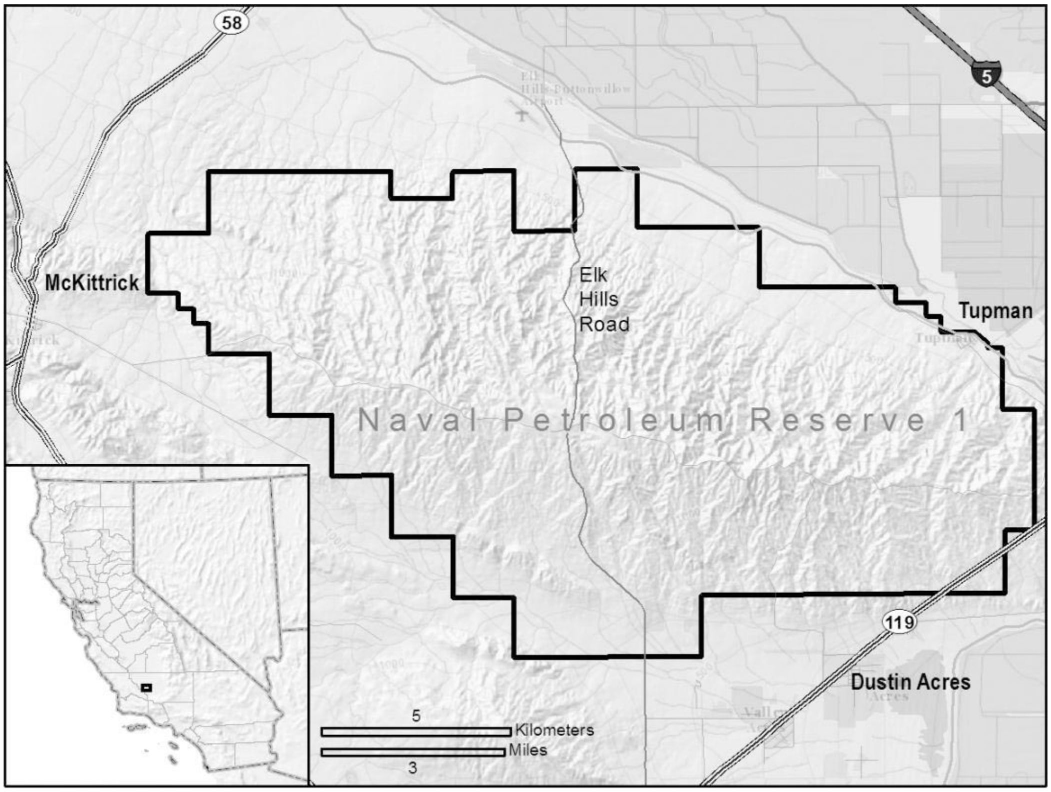

Fig. 1. Location of U.S. Department of Energy's Naval Petroleum Reserve No. 1, Kern County, California.

19,120 ha and included most of the Elk Hills, which is a long narrow ridge projecting eastward from the Temblor Range of the Coast Ranges mountains (O'Farrell et al. 1986). Elevations are 88–473 m above sea level. Higher elevations consist of deep, steeply sloped drainages. Gently rolling hills and flat valley land occur along the perimeter of NPR-1.

In 1988 we built 6 pens (6.1 × 6.1 × 1.8 m) in hilly terrain; and in 1989 we built 8 pens (6.1 × 3.1 × 1.8 m)—1 in hilly terrain and 7 in level valleys. Thus, by 1989 we had 7 pens in hilly terrain and 7 pens in level-valley terrain, allowing us to test whether terrain had an effect on translocation success. We constructed each pen using chain-link panels. We placed pens in areas of NPR-1 where past trapping results indicated foxes once were resident. When possible, we placed pens on small hills with a view of the surrounding terrain. We anticipated that the unobstructed view of the surrounding terrain could provide visual orientation. Also, we placed most pens at least 45–90 m from the nearest well, road, power line, or other anthropogenic feature.

We translocated foxes from private lands in Bakersfield, California (ca. 50 km east of NPR-1), that were scheduled for development or from Naval Petroleum Reserve No. 2 (NPR-2), which is adjacent to NPR-1. We trapped foxes following procedures described by O'Farrell (1987). We estimated the ages of foxes based on tooth wear and classified foxes as juveniles (≤10 months) or adults (>10 months). The foxes were then transported to NPR-1 and radio-collared; and a male and female were placed in each translocation pen. Prior to release, we trapped each fox 2–8 times to determine mass and to check general condition. Foxes placed in pens as juveniles were released as adults. For more information regarding pen construction and care of foxes see Scrivner et al. (1993).

Foxes released in 1989 were translocated in August and December 1988 and January 1989. Foxes released in 1990 were translocated during late June through early October 1989. To increase the likelihood they would reproduce in captivity, foxes released in 1990 were translocated earlier in the year than those released in 1989. We reasoned that releasing adults with pups would increase the likelihood that the adults would remain in the vicinity of the release site.

In spring, a few days prior to release, we trapped the foxes to conduct a final examination. At this time, we placed new radio collars on each animal. After foxes were released, we used radiotelemetry to monitor fox movements and survivorship 4–5 days per week. Free-ranging foxes from a population adjacent to the translocation area also were radiocollared and monitored so that survivorship of translocated and free-ranging foxes could be compared. Since translocated foxes were released from pens that were scattered throughout NPR-1, the distance between translocated foxes and free-ranging foxes varied. Plant composition, plant density, and other features of the habitat in which free-ranging foxes were monitored were similar to the translocation area. When we monitored the free-ranging population, we recorded the location, day, and time foxes were found. We also tracked foxes during the night if their radio signals could not be heard during the day because they were denning in metal pipes or similar structures that attenuated the radio signals. If radio signals were not detected during the day or night at ground level, then attempts were made to locate foxes using aircraft. We left supplemental food consisting of canned cat food in the pens of translocated foxes for 1 month after their release.

Necropsies were performed in our field office lab to determine cause of death. When we observed tooth-puncture wounds, wounds to skin and bones, and hemorrhage around tooth marks, we concluded that death was caused by predation. We used the distance between canine tooth punctures to infer probable identity of the predator. If a carcass was found on or near a road and had evidence of massive trauma, we classified the cause of death as roadkill. If we could not determine the cause of death because the carcass was decomposed, desiccated, or scavenged, we classified the cause of death as unknown.

We used a paired-sample t test to assess whether mass changed while foxes were in captivity. We used a 2-way ANOVA to test whether the terrain where pens were placed (hilly or level valley) or the presence of pups influenced the distance foxes released in 1990 moved from the pen. We used 3-way ANOVA to test whether year of release, sex, or age influenced the distance foxes moved from the release site; whether year of release, sex, or age influenced the number of days foxes survived; and whether terrain where pens were located, sex, and age influenced the number of days foxes released in 1990 survived. Data not normally distributed were log-transformed for analysis. When log-transformed data were not normally distributed, we used a Kruskal–Wallis test. We used correlation analysis to examine the relationship between the length of time foxes were in captivity and survivorship of foxes after their release, and the length of time foxes were in captivity and the distance foxes moved from the release site.

We calculated survival rates using a procedure described by Heisey and Fuller (1985). Survival rates were compared using a modified Z test (New Features of Micromort 1.3, Todd Fuller, Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, MA). All means are reported with 1 standard error (SE). We considered all analyses statistically significant when $P < 0.05$.

RESULTS

Translocation of Foxes

We translocated 12 foxes in 1989 (Table 1) and 28 in 1990 (Table 2). Foxes released in 1990 were in captivity longer (307 d, SE 7, range 222–354) than foxes released in 1989 (131 d, SE 21, range 32–225). Based on our observations of mass gain, most foxes adjusted well to captivity. The mean mass of 9 nonpregnant adults increased 0.23 kg (SE 0.05, range 0.05–0.45; $t_1 = 4.5$, $P < 0.01$) whereas juveniles increased 0.36 kg (SE 0.05, range −0.05 to 0.75; $t_1 = 8.3$, $P < 0.01$). Mean mass of released males was 2.39 kg (SE 0.05, range 2.15–3.15) and that of females was 2.12 kg (SE 0.05, range 1.65–2.45).

In 1989, 1 pup was reared in captivity and released with its parents. In 1990, 12 of 14 pairs whelped at least 25 pups in captivity. Although a high percentage of females whelped (86%) in 1990, only 10 pups from 4

TABLE 1. San Joaquin kit foxes (*Vulpes macrotis mutica*) translocated to Naval Petroleum Reserve No. 1, Kern County, California, and released in 1989.

Fox ID	Sex	Age when translocated	Pen terrain	Survival (days)	Distance from release site to death site (km)	Cause of death
3741	Female	Juvenile	Hilly	539	3.4	Unknown
3924	Male	Juvenile	Hilly	13	16.2	Predation
3782	Female	Juvenile	Hilly	41	7.1	Predation
3925	Male	Adult	Hilly	4	3.2	Predation
3930	Female	Adult	Hilly	21	8.8	Roadkill
3976	Male	Adult	Hilly	102	4.0	Predation
3800	Female	Adult	Hilly	17	23.7	Predation
3990	Male	Adult	Hilly	38	10.9	Predation
3957	Female	Adult	Hilly	39	14.0	Predation
3958	Male	Adult	Hilly	918	12.4	Trap-related
3923	Female	Juvenile	Hilly	38	124.0	Roadkill
3795	Male	Juvenile	Hilly	16	5.2	Predation

TABLE 2. San Joaquin kit foxes (*Vulpes macrotis mutica*) translocated to Naval Petroleum Reserve No. 1, Kern County, California, and released in 1990.

Fox ID	Sex	Age when translocated	Pen terrain	Survival (days)	Distance from release site to death site (km)	Cause of death
4052	Female	Adult	Hilly	2	1.0	Unknown
4056	Male	Adult	Hilly	69	7.1	Unknown
3986	Female	Juvenile	Hilly	1	0.3	Predation
4057	Male	Juvenile	Hilly	(Missing)	—	—
4030	Female	Juvenile	Hilly	5	1.4	Unknown
4051	Male	Juvenile	Hilly	5	0.8	Predation
4053	Female	Juvenile	Hilly	1	0.2	Predation
4036	Male	Juvenile	Hilly	64	1.8	Unknown
4058	Female	Adult	Hilly	31	1.3	Predation
4050	Male	Adult	Hilly	30	20.6	Unknown
4061	Female	Juvenile	Hilly	32	1.8	Unknown
4096	Male	Juvenile	Hilly	(Alive)	—	—
4029	Female	Juvenile	Hilly	83	0.6	Unknown
4302	Male	Juvenile	Hilly	7	0.6	Predation
4076	Female	Juvenile	Level	3	2.3	Predation
4048	Male	Juvenile	Level	44	5.0	Unknown
3987	Female	Juvenile	Level	58	2.7	Unknown
4363	Male	Juvenile	Level	90	10.9	Unknown
4023	Female	Juvenile	Level	8	1.0	Predation
4044	Male	Juvenile	Level	505	2.7	Predation
4034	Female	Juvenile	Level	42	14.5	Predation
4049	Male	Juvenile	Level	3	4.5	Predation
4059	Female	Juvenile	Level	(Missing)	—	—
4037	Male	Juvenile	Level	41	2.7	Predation
4046	Female	Juvenile	Level	(Missing)	—	—
4019	Male	Juvenile	Level	7	16.3	Unknown
4054	Female	Adult	Level	588	2.4	Predation
4062	Male	Adult	Level	36	2.3	Unknown

litters were reared successfully by their parents. The remaining 15 pups died before foxes were released: 3 appeared to have been killed by their parents, 1 died of a neural disorder, and the cause of death was unknown for 11 pups.

Survivorship of Released Foxes

Of the 12 adult foxes we released in 1989, 10 died within 1 year; 1 within 1.5 years, and 1 within 2.5 years (Table 1). Eight foxes were killed by predators, 2 were hit by vehicles, the cause of death was undetermined for 1 fox, and there was 1 trap-related mortality (Table 1). Of the 28 foxes released in 1990, 1 (3%) was still alive, 24 (86%) were dead, and the fates of 3 (11%) were undetermined when the study was completed in 1992 (Table 2). We lost radio contact with the 3 missing foxes at 3, 196, and 498 d after release. Of the 24 foxes recovered dead, 12 were killed by predators, and the cause of death could not be determined for 12 foxes (Table 2). Coyotes (*Canis latrans*) were the dominant predator of kit foxes on NPR-1.

Mean annual survivorship rates for adult foxes released in 1989 (n = 12) and 1990 (n = 27) did not differ ($Z = 0.04$, $P = 0.97$). For the combined data, annual survivorship was 0.03 (95% CI 0.01–0.11). One of the 28 foxes released in 1990 was excluded from the analysis because radio contact was lost 3 days after its release.

We monitored 10 free-ranging (i.e., nontranslocated) adult foxes in 1989 for a total of 1716 monitoring days. Four of the 10 foxes died within 1 year and annual survivorship was 0.43 (95% CI 0.18–0.98). In 1990, we monitored 16 free-ranging adult foxes for 2836 monitoring days. Nine of the 16 foxes died within 1 year and annual survivorship was 0.31 (95% CI 0.15–0.67). Survivorship values of free-ranging foxes monitored in 1989 and 1990 were not different ($Z = 0.52$, $P = 0.60$), and for the combined data survivorship was 0.35 (95% CI 0.20–0.62), which was greater than for translocated foxes ($Z = 3.09$, $P < 0.01$).

For the translocated foxes that died within 1 year of their release, the number of days between the release date and the date foxes were recovered dead averaged 31.0 (SE 4.9, range 1–102) and did not differ between 1989 (n = 10) and 1990 (n = 22) (Kruskal–Wallis $\chi^2_1 = 0.03$, $P = 0.85$), between males (n = 16) and females (n = 16) (Kruskal–Wallis χ^2_1 = 1.64, df = 1, $P = 0.20$), or between foxes that were translocated as juveniles (n = 21) or as adults (n = 11) (Kruskal–Wallis $\chi^2_1 = 0.03$, P = 0.87). For foxes that died within 1 year of release, there was no correlation between the number of days foxes were in captivity and the number of days that foxes survived after their release ($r_{1,30} = -0.18$, $P = 0.32$).

For 24 foxes released in 1990 and recovered dead, there was no difference in the log of the number of days between the release date and the date foxes were found dead for 12 foxes released from hilly terrain and 12 foxes released from pens in level terrain ($F_{1,16}$ = 3.57, $P = 0.08$), for 12 males and 12 females ($F_{1,16} = 0.05$, $P = 0.83$), and for 6 foxes translocated as adults and 18 foxes translocated as juveniles ($F_{1,16} = 2.12$, $P = 0.16$). For the 24 foxes released in 1990, foxes survived an average of 73.1 days (SE 30.4, median = 31.5, range 1–588).

The single pup released with the adults in 1989 died 17 d after release. The cause of death was predation, probably by coyotes. The 10 pups released in 1990 survived 6.3 d (SE 1.5, range 1–17). Two pups were killed by predators, 1 pup drowned in a man-made pool of oil, and the cause of death could not be determined for 7 pups.

Reproduction of Released Foxes

In 1989, 1 male and 1 female survived through a breeding season. Our trapping data indicated both foxes reproduced the year after release. Only the male survived through a second breeding season, but locating the dens used by him and his mate was difficult; hence, their reproductive status was not determined.

In 1990, 2 released females and 2 males survived through a breeding season. No pups were ever observed or trapped at the dens used by the males. The reproductive status of the females was not determined because locating these foxes was difficult. Of the foxes released in 1990, 1 female and 1 male survived through a second breeding season, and both foxes reproduced. The female whelped ≥6 pups and the nonstudy female paired with the translocated male whelped ≥3 pups.

Fox Movements

The distance moved by foxes after release varied. In 1989, one traveled 124 km before being killed by a vehicle. When we excluded this fox, the mean distance between the release site and location of death was less for 24 adults released in 1990 (4.4 ± 1.1 km, range 0.2–20.6, median = 2.3) than for 11 adults released in 1989 (9.9 ± 1.9 km, range 3.2–23.7, median = 8.8; log-transformed data: $F_{1,27} = 8.3$, $P < 0.01$). The mean log distance moved by foxes did not differ between sexes ($F_{1,27} = 2.0$, $P = 0.17$) or age classes ($F_{1,27} = 1.1$, $P = 0.31$).

Of the 24 foxes released in 1990 and recovered dead, 12 were from pens in hilly terrain and 12 were from pens in level terrain. Eight were released with pups and 16 were released without pups. There was no evidence that terrain at the pen or presence of pups influenced the distance foxes released in 1990 moved from their pens (two-way ANOVA: $F_{3,20}$ = 2.5, P = 0.09). However, the effect of terrain was significant when evaluated with a one-way ANOVA ($F_{1,22}$ = 6.6, P = 0.02). The mean log distance between the release site and location of death was 3.1 km (SE 1.7, median = 1.1, n = 12) for foxes released from pens in hilly terrain and 5.6 km (SE 1.5, median = 2.7, n = 12) for foxes released from pens in level terrain. The mean log distance between the release site and the location of death for foxes released with pups (2.1 km, SE 0.8, median = 1.6, n = 8) and without pups (5.5 km, SE 1.6, median = 2.6, n = 16) did not differ ($F_{1,20}$ = 1.1, P = 0.31).

In 1989, we released all 12 adult foxes in hilly terrain. However, we recovered all but 2 foxes dead in level terrain. In 1990, 12 of 14 adults released in hilly terrain were found dead—10 in hilly terrain and 2 in level terrain. Of the 14 adults released in level terrain, we found 12 dead—7 in level terrain and 5 in hilly terrain.

When we excluded the fox that dispersed 124 km, there was a significant, but weak, negative correlation between the number of days foxes were in captivity and the distance between the release site and the location of death for 35 foxes adult foxes released in 1989 and 1990 ($r_{1,33}$ = −0.49, P < 0.01). Days in captivity accounted for about 24% of the variation in the distance traveled by foxes.

Cost of Translocation Program

The total cost of the translocation program for fiscal years 1988–1991 was $490,639 ($895,891 adjusted for inflation in 2015). Labor costs totaled $364,479 ($665,527 adj.) and cost of materials and supplies totaled $126,160 ($230,364 adj.). The most significant material and supply costs included cost of radio collars, pen materials, food for captive foxes, transportation, and charter aircraft to search for foxes.

DISCUSSION

There were no problems trapping and moving foxes to pens. The physical facilities and animal care practices appeared to be adequate. Foxes were healthy, most gained weight in captivity, and they reproduced. The low success of captive foxes in rearing pups may have been related to the age of foxes; 11 of 14 pairs were translocated as yearlings. Zoellick et al. (1987) reported that the percentage of yearling female kit foxes that raised pups was lower than that of adult females. Similarly, Schroeder (1987) found that neonatal mortality was higher among swift foxes that were first-time mothers than among females that had previously reared pups.

Low reproductive success also was observed among island foxes (*Urocyon littoralis*) in captive breeding facilities. Many females failed to produce pups, or pups died soon after birth. Conditions observed included fetal reabsorption, stillborn births, abandonment of newborn pups by females, failed milk production, and male aggression (Coonan et al. 2010).

Survivorship was lower for translocated foxes than for free-ranging foxes monitored during the release period. Cypher et al. (2000) reported that between 1980 and 1995, mean annual survival of free-ranging foxes monitored in the region was 0.44 (SE 0.05), which also was greater than survival of the translocated foxes.

Relatively few foxes survived >1 year (17% in 1989 and 11% in 1990). Carbyn et al. (1994) reported that 14 of 45 (31%) translocated swift foxes survived a minimum of 12 months for those foxes that were placed in pens in fall, held in captivity during winter, and then released the following spring, summer, or early fall.

Survivorship of translocated foxes was not influenced by sex or age. Mamo et al. (1990) reported that first-year survivorship of swift foxes released between 1983 and 1987 did not differ between sexes. Terrain in which foxes were released also had little effect on survivorship.

Prey availability may have affected the survivorship of translocated foxes. In spring 1991, the abundance of lagomorphs, a primary prey item of foxes (Cypher et al. 2000), was the lowest since monitoring began in 1983: only 7 lagomorphs were observed along forty-two 1.6-km transects (EG&G Energy Measurements, Inc. 1992). In contrast, in spring 1984, 232 lagomorphs were observed on twenty-three 1.6-km transects. A composite prey (rodents and leporids) availability index for NPR-1 exhibited a declining trend during 1989 and 1990 (Cypher et al. 2000). Adequate food supplies are important to translocation success (Carbyn 1989, Carbyn and Killaby 1989, Mamo et al. 1990, Herrero et al. 1991b, Carbyn et al. 1994). One release of 35 swift foxes was delayed because of drought, which resulted in low prey abundance (Carbyn 1989).

Survivorship of translocated foxes also may have been reduced because the foxes were unfamiliar with their environs (e.g., food and cover locations) and were more vulnerable to predation. Of those translocated foxes for which cause of death could be determined, most were killed by predators, primarily coyotes. Predation is the main cause of death of free-ranging foxes on the Naval Petroleum Reserves (Cypher et al. 2000). Carbyn et al. (1994) reported that among 89 swift foxes released from 1987 to 1991, predation, particularly by coyotes, was the greatest cause of mortality. Herrero et al. (1991b) expressed the view that the main factor limiting reestablishment of swift foxes in Canada is predation, primarily by coyotes.

Kit foxes prefer arid shrublands and grasslands, as well as flat or gentle terrain (Grinnell et al. 1937, Cypher et al. 2013). Carbyn et al. (1994) reported that wild-caught swift foxes that were translocated consistently colonized open, flat, or slightly rolling prairies. Herrero et al. (1991a) suggested that high survivorship of foxes in one swift fox translocation may have been due to the relatively flat and shrubless nature of the terrain into which the animals were released, and that infrequent ravines and shrubs reduced concealment cover for coyotes. In this study, data gathered during the 1989 release suggested that animals released in hilly terrain moved into level terrain. However, the data gathered following the 1990 release were equivocal. A larger proportion of released animals were found dead within the same terrain in which they were released. All potential breeders were located in level terrain regardless of release terrain.

Excluding the kit fox that dispersed 124 km, foxes released in 1989 moved farther from the release site than foxes released in 1990. Why foxes did not move as far in 1990 is unclear, but distance moved was negatively correlated with the number of days foxes were in captivity, and foxes were in captivity longer in 1990 than in 1989. The distance moved was not influenced by sex, age, or terrain in which foxes were released. It also was not influenced by the presence of supplemental food left in the pen after foxes were released because food was left at pens in both 1989 and 1990. Carbyn et al. (1994) reported that the average distance moved by 31 swift foxes born in the wild and translocated was 19.2 km; 110 swift foxes that were born in captivity and then translocated moved an average of 12.6 km.

None of the adults released with pups in 1990 dispersed while the pups were alive. The presence of pups may increase the likelihood that adults will remain in the vicinity of the release site. However, the length of time pups survived was so short (<17 d) that the merits of rearing pups in captivity are questionable. If reproduction in captivity is not an objective, foxes could be released sooner and the cost of caring for captive animals would be reduced.

CONCLUSIONS AND RECOMMENDATIONS

Although the standards used to evaluate success of a translocation program depend on the goals of the program (Kleiman 1989, Kleiman et al. 1994), the ultimate goal of most translocation programs is to establish a self-perpetuating population of organisms (Parker 1986, Griffith et al. 1989, Phillips 1990, Kleiman et al. 1994). The survival rate of translocated foxes was lower than that for nonstudy foxes, and few survived long enough to breed. Environmental conditions during this study, particularly declining prey availability, may have influenced survivorship. Because translocated foxes were unfamiliar with the release areas, it was expected that survival rates of translocated foxes would be lower than if the foxes had not been translocated. However, many foxes were translocated from areas undergoing development in Bakersfield, where survival rates were unknown but perceived to be low. Also, providing additional escape cover in release areas may improve survival of translocated foxes. McGee et al. (2006) reported significantly higher survival of swift foxes in areas where artificial escape dens were installed.

Because few foxes survived through a breeding season, relatively few data were available to assess the reproductive success of translocated foxes. Based on available data, translocated foxes that survived long enough appeared to be as reproductively successful as free-ranging foxes. Consequently, translocated foxes did make an albeit small genetic contribution to the NPR-1 population.

We originally anticipated that the likelihood of increasing the number of foxes on NPR-1 through a translocation program would be greatest if fox pairs were released with pups. However, after captive foxes were released, none of the pups survived longer than 17 d and few adults survived long enough to breed after they were released. Based on these results a decision was made to discontinue the translocation program until the causes for the high mortality rates observed in this study were better understood and controlled. There have been no subsequent attempts to translocate San Joaquin kit foxes. Also, there have not been any assessments of predator abundance in the area of which we are aware.

If mortality factors can be mitigated, it is likely that kit foxes can be successfully translocated, especially if annual translocations are conducted for 5–10 years (see Ginsberg 1994). Similarly, endangered island fox populations recovered rapidly once the 2 primary sources of mortality, distemper disease and predation by Golden Eagles (*Aquila chrysaetos*), were mitigated (USFWS 2015).

We recommend that foxes be translocated in fall (September–October). Carbyn et al. (1994) found that survival of released swift foxes was greater in fall than in spring and that foxes did not disperse as far when released in fall compared with spring. Also, a fall release would reduce the length of time between the release date and the subsequent pair-formation and breeding season (approximately November–December) to about 1 month. Thus, the likelihood that more foxes will breed soon after they are released may by increased.

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