San Joaquin Kit Fox Conservation in a Satellite Habitat Area

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EXECUTIVE SUMMARY

San Joaquin kit foxes (*Vulpes macrotis mutica*) once were widely distributed in the San Joaquin Valley of California. However, their range has been significantly reduced due to profound habitat loss and they now persist in a metapopulation consisting of 3 main "core" populations and probably less than a dozen "satellite" populations. A number of demographic and ecological studies have been conducted on kit foxes in core areas, but virtually no such studies have been conducted in satellite areas. The availability of information on the demographic and ecological attributes of a given population provides the opportunity to design more specific conservation and management strategies that have a greater probability of success. We used radio-telemetry, scat analysis, and automated camera stations to examine kit fox survival, sources of mortality, reproduction, space use, den use, food habits, and competitor abundance in a satellite population on the Northern Semitropic Ridge Ecological Reserve (NSRER) in Kern County, California. The goal of this project was to collect information on a significant satellite population of endangered San Joaquin kit foxes, and to use this information to develop effective site-specific as well as regional conservation strategies.

During 2012, we captured 21 kit foxes; 8 were fitted with GPS collars and 5 were fitted with VHF collars. Five foxes were found dead during the study; 4 were suspected to have been killed by predators and 1 died of unknown causes. Mortality rates for kit foxes at NSRER were higher than rates from core areas, and also were higher than most rates from other satellite population areas. The relative small size of protected habitat, high local habitat fragmentation, and high edge effect may have contributed to this high mortality rate. Although we were unable to observe pups with any of our 3 collared adult females, all showed evidence of reproduction (e.g., enlarged mammae) and we also captured 8 young-of-the-year during trapping. So, successful reproduction was documented. We only were able to locate 9 dens and multiple collared foxes were found in a den on 3 occasions. Mean 100% MCP, 95% MCP, and 50% MCP home range sizes were 3.7 ± 0.4 km^2, 2.4 ± 0.2 km^2, and 0.9 ± 0.2 km^2, respectively. Home ranges were considerably smaller than those in core or other satellite areas. Home ranges also overlapped extensively and tended to be centered on a low-lying "ridge" where flooding was less likely and kangaroo rats were more abundant. Concomitantly, kangaroo rats were the primary item consumed by kit foxes, and invertebrates (e.g., crickets, grasshoppers, and beetles) also were frequently consumed. Competitors detected on the study area included coyotes, bobcats, domestic dogs, badgers, and striped skunks.

Based on this 1-year study, the demographic and ecological attributes observed for kit foxes at NSRER are consistent with a population at high density in habitat that is highly suitable but also limited in size and fragmented. Conservation recommendations include (1) increased protections for conserved lands, (2) expanding the amount of conserved habitat, (3) disease surveillance, (4) a vaccination program if disease is detected, and (5) annual kit fox population and prey base monitoring.

INTRODUCTION

San Joaquin kit foxes (*Vulpes macrotis mutica*) once were widely distributed in the San Joaquin Valley of California. However, their range has been significantly reduced due to profound habitat loss and consequently they are listed as Federally Endangered and California Threatened (U.S. Fish and Wildlife Service 1998, U.S. Fish and Wildlife Service 2010, Cypher et al. 2013). The San Joaquin kit fox now persists in a metapopulation consisting of 3 main "core" populations and probably less than a dozen "satellite" populations. Core areas are characterized by large blocks of high quality habitat and support relatively large kit fox populations that are persistent and self-sustaining. Satellite areas are characterized by more fragmented or lower quality habitat with kit fox populations that are small or even intermittently present. A number of demographic and ecological studies have been conducted on kit foxes in core areas, but virtually no such studies have been conducted in satellite areas.

Habitat conditions and ecological stressors can vary among locations due to local environmental and anthropogenic influences. Consequently, demographic and ecological attributes of populations also may vary among locations. Such attributes include survival rates, mortality sources, reproductive rates, dispersal rates, habitat selection, space use and movement patterns, food item availability and selection, and presence of competitors. These attributes affect population dynamics and ecological interactions, and ultimately the long-term viability of a given population. Thus, the availability of information on the demographic and ecological attributes of a given population provides the opportunity to design more specific conservation and management strategies that have a greater probability of success.

A kit fox satellite population occurs in the Semitropic Ridge area in northern Kern County. No demographic or ecological data were available on this population. Casual observations of kit foxes, their sign, and roadkilled animals in this area suggested that this may be a persistent, and therefore, important satellite population. Also, the presence of federal, state, and private conservation lands in this area not only likely facilitates this persistence, but also provided access to this population for study. The goal of this project was to collect information on a significant satellite population of endangered San Joaquin kit foxes, and to use this information to develop effective site-specific as well as regional conservation strategies. Specific objectives were to (1) quantify kit fox survival, mortality sources, reproduction, den use, home range use, movements, diet, and competitor presence in the Semitropic Ridge area, and (2) to use this information to develop recommendations for conservation strategies for this kit fox population.

STUDY AREA

The study was conducted on the Northern Semitropic Ridge Ecological Reserve (NSRER) and adjacent lands in northern Kern County, CA (Figure 1). The site is located approximately 20 km northwest of the city of Wasco and 10 km northeast of the town of Lost Hills. The NSRER is owned and managed by the California Department of Fish and Wildlife (CDFW), and consists of multiple parcels totaling 6,222 ha. Land ownership in this area is a mosaic that includes federal (U.S. Fish and Wildlife Service, U.S. Bureau of Land Management [BLM]), state (CDFW), conservation (Center for Natural Lands Management [CNLM]), and private lands. Habitat in this area is highly fragmented and occurs within a matrix of agricultural lands consisting primarily of tree nuts. Other regional conservation lands include the Allensworth Ecological Reserve, Kern and Pixley National Wildlife Refuges, BLM's Atwell Island Demonstration Project, and CNLM preserve lands. The main area where most work was conducted was bounded by Corcoran Road on the east, Goose Lake Canal on the west, private lands and the Kern National Wildlife Refuge on the north, and private agricultural lands on the south.

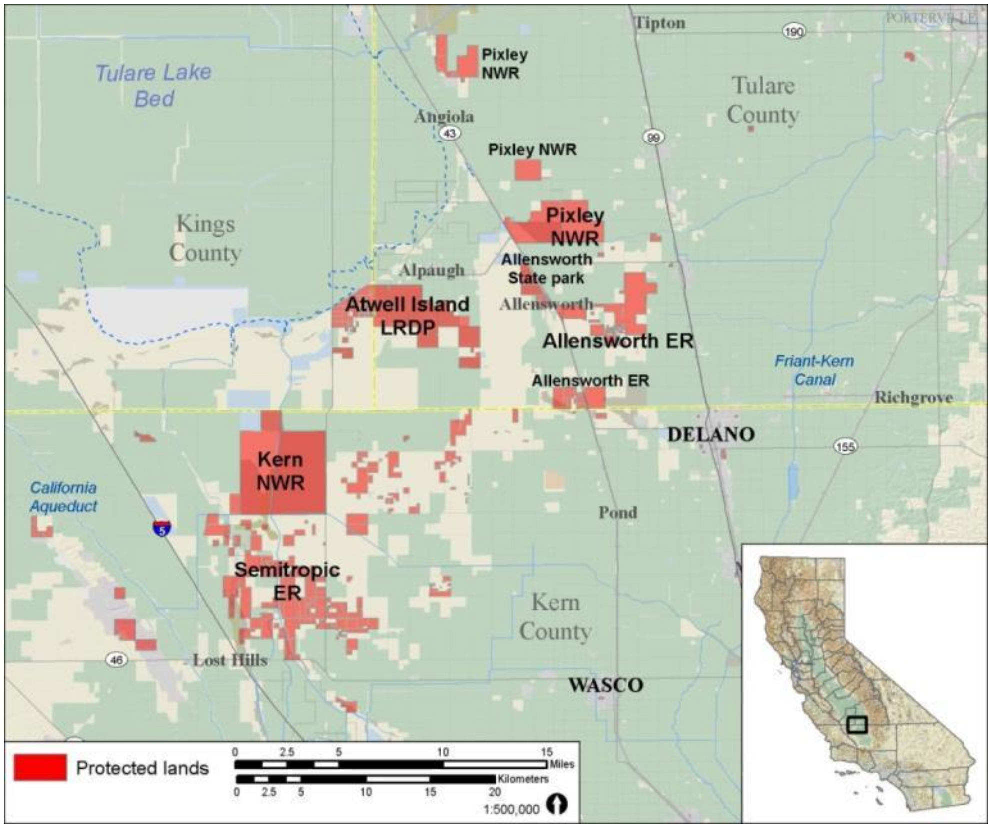

Figure 1. Location of the Northern Semitropic Ridge Ecological Reserve and nearby conservation lands including the Kern National Wildlife Refuge, Allensworth Ecological Reserve, Allensworth State Park, Pixley National Wildlife Refuge, and Atwell Island Land Retirement Demonstration Project.

Geographically, the SNRER is located on the floor of the San Joaquin Valley. Elevations in the area generally are less than 100 m. The terrain on the study area was primarily flat with a slightly elevated (ca. 2-4 m) north-south "ridge" traversing the site. The regional climate was Mediterranean in nature and was characterized by hot, dry summers, and cool, wet winters with frequent fog (ESA 2008). Annual precipitation averaged ca. 15 cm and occurred primarily as rain falling between October and April (National Oceanic and Atmospheric Administration 1996).

The vegetation communities in and around the NSRER consist primarily of alkali sink scrub and non-native grasslands. Common plants in the area include saltbush (Atriplex *polycarpa* and *A. spinifera*), seepweed (*Suaeda moquinii*), iodine bush (*Allenrolfea occidentalis*), alkali heath (*Frankenia salina*), saltgrass (*Distichlis spicata*), red brome (*Bromus madritensis*), Arabian grass (*Schismus arabicus*), and red-stemmed filaree (*Erodium cicutarium*).

METHODS

KIT FOX CAPTURE AND RADIO-COLLARING

Kit foxes were captured using wire-mesh live-traps (38 x 38 x 107 cm) baited with a meat product and covered with tarps to provide protection from inclement weather and sun. Traps were set adjacent to unpaved roads throughout the study area in pairs, with one trap each on opposite sides of the road. We set traps in late afternoon or early evening and then checked them beginning around sunrise. We coaxed captured kit foxes from the trap into a denim bag and handled them without chemical restraint. Data collected for each fox included date, location, sex, age (adult or juvenile), mass, and dental condition, and we placed a uniquely numbered tag in one ear.

During the initial trapping in winter, all foxes were fitted with collars equipped with a GPS tracking unit and a VHF transmitter with a mortality sensor (Quantum 4000E Micro Mini Collar; Telemetry Solutions, Concord, CA). The GPS units were programmed to collect 3 locations per night: early evening, around midnight, and early morning before sunrise. Each unit also included a UHF download function to remotely download location data from the units. The entire telemetry package weighed 60-65 g and were less than 3% of body mass. During later trapping in summer, 35-g VHF collars with mortality sensors (model M1930; Advanced Telemetry Systems, Isanti, MN) were placed on juveniles that were too small to wear GPS collars. The mortality sensors on both types of collars activated a doubled pulse rate if an animal remained motionless for 8 hours.

Processing of captured animals was completed within about 20 minutes, and we released all foxes at the capture site. All fox trapping, handling, and collaring was consistent with guidelines for the use of wild animals in research established by the American Society of Mammalogists (Sikes et al. 2011), and was conducted in accordance with conditions and protocols established in a research permit (TE825573-2) from the USFWS and a Memorandum of Understanding from the California Department of Fish and Game.

DEMOGRAPHIC AND ECOLOGICAL ATTRIBUTES

Approximately biweekly, 2 biologists in a vehicle equipped with 3-m tall roof-mounted yagi antenna searched for telemetry signals from collared foxes. Searches were conducted after dark when foxes had emerged from their dens and were more easily detected. If a mortality signal was detected, then the biologists returned the next day to track the signal on foot and recover the carcass. We recovered dead foxes as soon as possible and preserved them by freezing until we conducted a post-mortem examination. We attempted to determine cause of death based upon physical evidence at the recovery site and on the carcass (e.g., tooth puncture wounds, location of bone breaks).

When a signal was heard from animals with GPS units, we attempted to get close enough (usually within ca. 200 m) to download data remotely. Downloads were conducted using a UHF antenna mounted along with the yagi antenna and connected to a laptop computer.

Telemetry sessions also were conducted during daylight hours when possible in an attempt to locate signals, download data from GPS units, and track foxes to their daytime dens. Coordinates were recorded for all new den locations and a uniquely numbered wooden stake was placed near the den.

We created 100%, 95% and 50% minimum convex polygons (MCPs) for each fox using Biotas (Version 2.0, Ecological Software Solutions LLC, Hegymagas, Hungary). The 100% MCPs reflected total space use, the 95% MCPs represented home range use, and the 50% MCPs represented core area use (White and Garrott 1990). Mean home range size was compared between males and females using *t*-tests. We also examined home range and core area use relative to the "ridge" traversing the study site.

We determined the diet of kit foxes through analysis of fecal samples. We collected scats opportunistically from along dirt roads and den site and also from traps in which foxes had been captured. We air-dried scats in paper bags and then oven-dried them at 60° C for ≥24 hr to kill any parasite eggs and cysts. We then placed samples in individual nylon bags and washed them to remove soluble materials, and then dried them in a tumble dryer. We then identified food items from the remaining undigested material. We identified mammalian remains (e.g., hair, teeth, bones) using macroscopic (e.g., length, texture, color, banding patterns) and microscopic (e.g., cuticular scale patterns) characteristics of hairs (Moore et al. 1974) and by comparing teeth and bones to reference guides (Glass 1981, Roest 1986) and specimens. We identified other vertebrates to class and invertebrates to order, based on exoskeleton characteristics and comparison to reference specimens. We determined total and seasonal food item use with seasons defined as winter (January-March), spring (April-June), summer (July-September), and fall (October-December).

We identified potential competitors of kit foxes using automated digital field cameras (Cuddeback Digital Attack IR, Model 1156, Non Typical Inc., Green Bay, WI). The cameras were secured to 1.2-m U-posts with zip ties and duct tape. The cameras were positioned ca. 0.5 m above the ground. A can of cat food was staked to the ground approximately 2 m in front of each camera using 30-cm nails. To further attract carnivores, several drops of a scent lure (Carman's Canine Call Lure, Russ Carman, New Milford, PA) were place on the cat food can and on some vegetation near the camera. Camera stations were deployed throughout the study area and generally were separated by at least 0.5 km. The cameras were deployed for about 40 days in May-June 2012.

RESULTS

Trapping for foxes was conducted in January 2012 to deploy GPS collars. Additional trapping was conducted in July 2012 to deploy additional GPS collars on adult foxes as well as VHF collars on young of the year. A final trapping session was conducted in November-December 2012 to remove collars from foxes. A total of 21 foxes (10 males, 11 females) were captured during the project (Appendix A). Eight foxes (5 males, 3 females) were fitted with GPS collars, 5 foxes (2 males, 3 females) were fitted with VHF collars, and 8 foxes (3 males, 5 females) were eartagged but not collared.

The average minimum number of days that foxes were known to be alive following collaring was 140 (range 5-336; Appendix A). Of the 11 collared adult foxes, 5 were eventually recaptured and their collars were removed. Signals for 2 other foxes were not heard after a certain period of time and the foxes were not recaptured, and so their fate is unknown. For the 4 remaining foxes, their collars emitted a mortality signal. One of these was found dead (Figure 2), but the carcass was too desiccated to determine the cause of death. For the other 3, just the collar was found. For 1 of the 2 collared juvenile foxes, the collar was found with the anterior portion of a fox mandible nearby (Figure 2). The mandible was fresh and was presumed to be from the collared fox. The evidence indicated that this fox was killed and consumed by a predator. The other juvenile was recaptured and its collar was removed.

Figure 2. Body of kit fox male 6588 found dead 19 July 2012 (left), and portion of mandible of male 6600 found on 14 November 2012 (right) at the Northern Semitropic Ridge Ecological Reserve, Kern County, CA.

We were unable to locate dens of adult female foxes, and therefore were not able to determine whether any of the collared females successfully reproduced based on the presence of pups. However, all 3 adult females that were captured and collared in January were recaptured in July, and all exhibited enlarge mammae, which indicated that they had nursed young. Whether the pups survived to emergence from their natal dens (typical metric for successful reproduction) is unknown. However, during trapping in summer and fall, we captured 8 foxes (3 males, 5 female) that were apparent young of the year. Thus, although we were not able to estimate success rates among collared foxes, there was evidence of successful reproduction on the study site.

During the study, we tracked foxes to dens on 14 occasions. Eight foxes were found using 9 different dens. One fox used 4 different dens, 2 foxes each used 2 different dens, and the other 5 foxes each used 1 den. Three different collared foxes were found in one den on one occasion, and 2 foxes were found in 1 den on 2 occasions.

Home range estimates were calculated for 8 foxes (5 male, 3 female; Table 1). Mean ± SE 100% MCP, 95% MCP, and 50% MCP sizes were 4.9 ± 1.3 km^2, 3.4 ± 1.0 km^2, and 1.2 ± 0.3 km^2, respectively. The home range of male 6587 was disproportionately larger than the other home ranges (Table 1). When this fox was excluded, the mean 100% MCP, 95% MCP, and 50% MCP sizes were 3.7 ± 0.4 km^2, 2.4 ± 0.2 km^2, and 0.9 ± 0.2 km^2, respectively. With male 6587 excluded, mean 100% MCP, 95% MCP, and 50% MCP size did not differ between male and female foxes (t = - 1.03, 5 df, p = 0.35; t = - 0.97, 5 df, p = 0.38; t = - 0.75, 5 df, p = 0.49; respectively).

Table 1. Space use (minimum convex polygon size and ridge use) by San Joaquin kit foxes at the Northern Semitropic Ridge Ecological Reserve, Kern County, CA in 2012.

		Area (km^2)			
Fox	**Sex**	**100% MCP**	**95% MCP**	**50% MCP**	**Ridge use**
6686	F	2.3	2.1	0.9	Mostly on
6590	M	2.9	1.5	0.4	Mostly on
6589	F	3.5	1.7	0.4	Mostly on
6599	M	2.9	2.8	1.7	Partially on
6685	F	3.7	2.6	1.0	Partially on
6598	M	5.1	2.8	0.7	Partially on
6588	M	5.5	3.3	1.3	Partially on
6587	M	13.6	10.5	3.4	Off

Kit foxes exhibited focused use of the “ridge” at NSRER. Most foxes were captured on or near the ridge. Also, most of the home ranges (95% MCPs) were centered on the ridge (Figure 3) and the ridge encompassed most of the area within 6 of the 8 core areas (50% MCPs; Figure 4). There also was a trend for home range size to increase with use of non-ridge areas (Table 1). Home ranges overlapped extensively on the ridge (Figure 3).

A total of 238 kit fox scat samples were analyzed: 62 from winter, 7 from spring, 89 from summer, and 80 from fall. Items found in the scats (Table 2) included kangaroo rats (*Dipodomys heermanni* and *D. nitratoides*), pocket mice (*Perognathus inornatus*), ground squirrel (*Spermophilus beechyi* or *Ammospermophilus nelsoni*), deer mouse (*Permomyscus maniculatus*), harvest mouse (*Reithrodontomys megalotus*), rabbit (*Lepus californicus* or *Sylvilagus audubonii*), unidentified birds, unidentified snakes and lizards, beetles (Coleoptera), Jerusalem crickets (*Stenopelmatus spp.*), other crickets and grasshoppers (Orthoptera), earwigs (*Forficula auricularia*), scorpions (Scorpiones), sun scorpions (Solifugae), moths (Lepidoptera), sheep (*Ovis aries*), and miscellaneous materials such as chew toy material (from the traps) and vegetation (incidentally ingested with prey). Kangaroo rats and Orthopterans (crickets and grasshoppers) were the most frequently occurring items in the scats (Table 1). When grouped into broader item categories (Figure 5), rodents and invertebrates were consumed extensively whereas rabbits, birds, reptiles, vegetation, and anthropogenic items were consumed occasionally. Seasonally, rodents were by far the primary food item in winter followed by birds and invertebrates (Figure 6). Invertebrates and rodents were the primary items consumed during the other seasons.

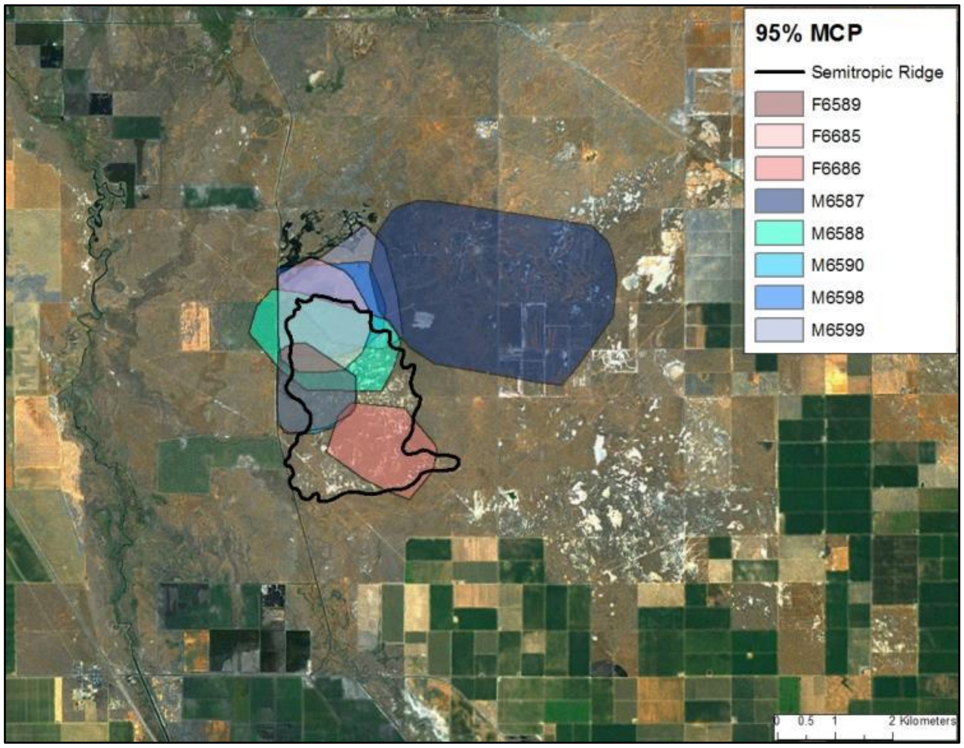

Figure 3. San Joaquin kit fox home ranges (95% MCPs) on the Northern Semitropic Ridge Ecological Reserve, Kern County, CA in 2012.

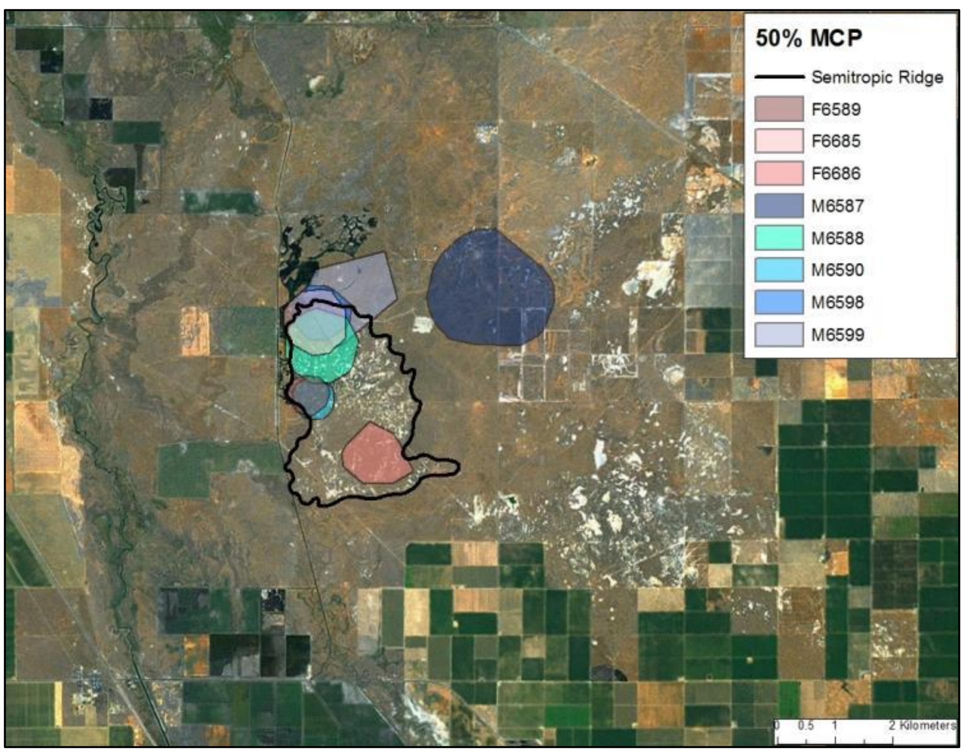

Figure 4. San Joaquin kit fox core areas (50% MCPs) on the Northern Semitropic Ridge Ecological Reserve, Kern County, CA in 2012.

Table 2. Frequency of occurrence of items in 238 kit fox scats collected at the Northern Semitropic Ridge Ecological Reserve, Kern County, CA in 2012.

Item	Total occurrences	Percent
Kangaroo rat	104	43.7%
Orthoptera	102	42.9%
Unknown insect	43	18.1%
Unknown rodent	40	16.8%
Chew toy	27	11.3%
Coleoptera	25	10.5%
Scorpion	24	10.1%
Rabbit	20	8.4%
Bird	20	8.4%
Pocket mouse	15	6.3%
Ground squirrel	10	4.2%
Vegetation	8	3.4%
Earwig	6	2.5%
Snake	5	2.1%
Sheep	5	2.1%
Jerusalem cricket	3	1.3%
Deer mouse	2	0.8%
Harvest mouse	2	0.8%
Sun scorpion	2	0.8%
Moth	1	0.4%
Larvae	1	0.4%
Lizard	1	0.4%
Man-made material	1	0.4%
Eggshell	1	0.4%

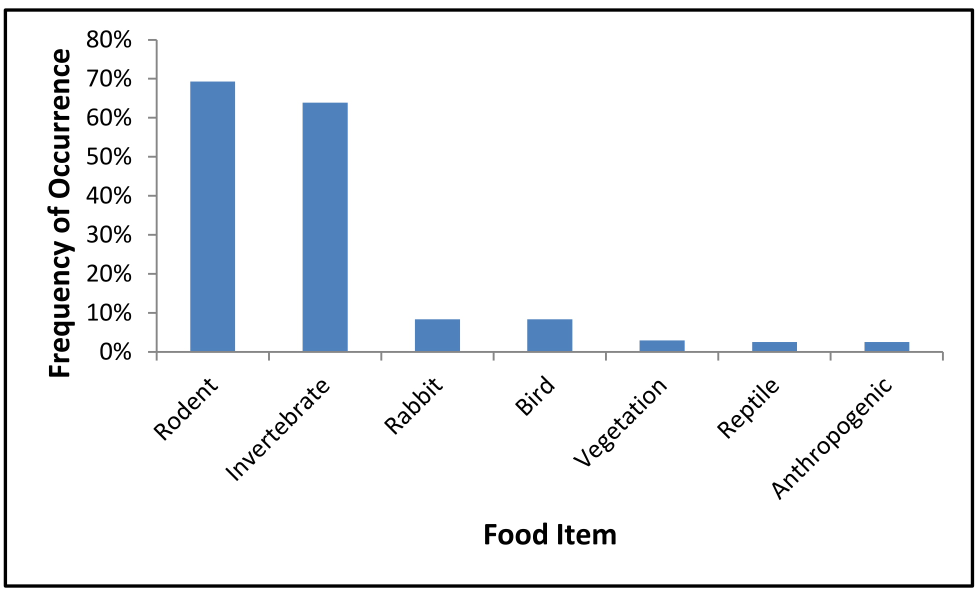

Figure 5. Occurrence of items by category in kit fox scats at the Northern Semitropic Ridge Ecological Reserve, Kern County, CA in 2012.

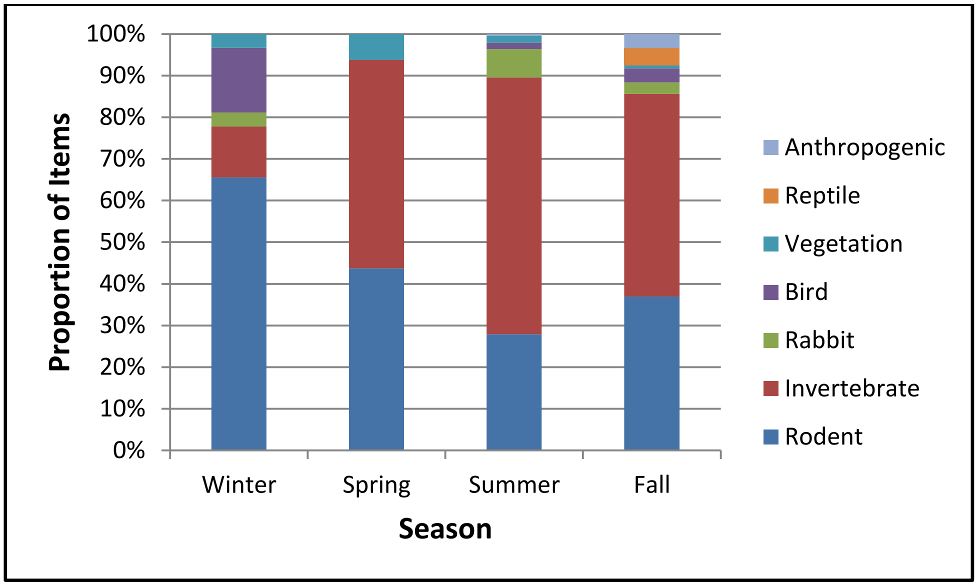

Figure 6. Proportional occurrence of items in kit fox by season at the Northern Semitropic Ridge Ecological Reserve, Kern County, CA in 2012.

Seven camera stations were deployed throughout the study area during May-June 2012. Six cameras were deployed for 40 nights and one was deployed for 34 nights. Carnivores detected (Table 3) included coyote (*Canis latrans*), badger (*Taxidea taxus*), and striped skunk (*Mephitis mephitis*). Other species detected included jackrabbit, cottontail, antelope squirrel, California ground squirrel, kangaroo rat, roadrunner (*Geococcyx californianus*), and raven (*Corvus corax*). Additionally, other carnivore species observed while conducting field activities included bobcats (*Lynx rufus*) and domestic dogs (*Canis familiaris*).

Table 3. Species detected on camera stations during 274 camera-nights at the Northern Semitropic Ridge Ecological Reserve, Kern County, CA in 2012.

Species	Nights detected
Kit fox	104
Coyote	9
Badger	1
Skunk	1
Jackrabbit	73
Cottontail	41
Antelope squirrel	1
California ground squirrel	1
Kangaroo rat	5
Roadrunner	7
Raven	7

DISCUSSION

The data gathered during this project were insufficient to conduct an in-depth assessment of kit fox survival. Such assessments generally require larger numbers of foxes monitored over multiple years. The sample of foxes in this study was relatively small, and the duration of monitoring was limited by funding and the battery life of the collars, which was approximately 6-8 months. The limitations on both the sample size and battery life were a function of using GPS collars for the project. These units are expensive compared to conventional VHF collars. Thus, only a certain number of units could be purchased with the available funding. Also, because the units included both a GPS receiver and VHF transmitter, the drain rate on the battery is higher compared to smaller, simpler VHF-only units. However, we felt that the GPS collars were the best approach for this study because of the superior data they provided on space use by the foxes.

Despite the caveats above, the survival data obtained still was informative. The proportion of radiocollared adults that died during the study period (36%) seemed consistent with mortality rates from other studies. During one study in the western Kern County core area, the mean annual proportion of adult foxes that died also was 36% and ranged from 9% to 56% (Cypher et al. 2000). To further compare survival at NSRER with that in other areas, we divided the number of mortalities of collared adult foxes at a given site by the total number of days that the foxes were monitored (Table 4). This was the one metric for which comparison was possible among multiple sites where different methodologies had been employed. The value for the NSRER was higher than the values from 3 sites in core areas, and also higher than values from 2 other satellite areas. Values were similar between NSRER and a satellite area in Merced County (Briden et al. 1992) that also is relatively small and fragmented by unfavorable terrain for kit foxes (Cypher at al. 2013). This indicated that the mortality rate among adult foxes at the NSRER may be relatively high. One caveat to emphasize is that the data for NSRER are only for one year and so it is unknown whether this mortality rate is representative of long-term trends.

Table 4. Mortality rates calculated for adult kit foxes at the NSRER and 6 other locations.

Site	Years	Number collared foxes	Number mortalities	Total days monitored	Mortalities per 1,000 monitoring days	Source
NSRER (satellite)	2012	11	4	1,592	2.51	This study
Carrizo solar mitigation lands (satellite)	2013	10	2	1,649	1.21	Cypher et al., unpublished data
Camp Roberts (satellite)	1988-1991	67	35	20,366	1.72	Standley et al. 1992
Merced County (satellite)	1985-1987	14	7	2775	2.52	Briden et al. 1992
Elk Hills (core)	1980-1995	341	225	94,521	2.38	Cypher et al. 2000
Lokern (core)	2001-2004	47	4	5,857	0.68	Cypher et al. 2009
Carrizo Plain (core)	1989-1991	24	10	13,339	0.75	Ralls and White 1995

If the rate of kit fox mortality at NSRER is indeed typically high, it could be a function of the fact that the available habitat in this area is highly fragmented. Such fragmentation creates considerable "edge" and this could expose the population to more threats due to increased accessibility. For example, people were observed in the area on numerous occasions and were engaged in a variety of activities including hunting (some with dogs), sheep grazing, and accessing adjacent agricultural lands. Also, free-ranging dogs (both domestic and feral) were observed in the area on several occasions and likely originated from residences on the private lands interdigitated with conserved lands. Dogs were a significant source of mortality of kit foxes in a study conducted in the Lokern area (Spiegel and Disney 1996). Edge has been shown to increase the probability of extinction for carnivore populations (Woodruffe and Ginsberg 1998).

Unfortunately, cause of death could not be definitely determined for any of the fox mortalities. The one carcass recovered was too decomposed to conduct a thorough post-mortem examination. In the other 4 cases, just collars were recovered. The fresh kit fox jaw next to one of the collars indicated that this fox likely was killed and consumed by a predator. Our presumption is that this also was the fate of the other 3 foxes for which just the collar was found. The collars were fitted in a manner that essentially precluded passage over the head of the fox. Thus, it is unlikely that the foxes simply "slipped" their collars and were still alive. Coyotes and bobcats are common in the area and are known predators of kit foxes (Standley et al. 1992, Ralls and White 1995, Spiegel and Disney 1996, Cypher et al. 2000, Nelson et al. 2007). The killing of kit foxes by coyotes typically is a function of interference competition, and therefore the carcasses generally are not consumed (Spiegel and Disney 1996, Cypher and Spencer 1998). However, bobcats do prey upon and consume kit foxes and may have been the cause of death in the 4 instances where carcasses were missing.

We were not able to establish rates of reproductive success by female kit foxes at NSRER. However, we were able at least to confirm that successful reproduction did occur on the site, based on the presence of young of the year foxes captured in summer.

Reproductive success may be largely driven by resource availability in a given year (Spiegel and Tom 1996, White and Garrott 1999, Cypher et al. 2000).

Space use by kit foxes at NSRER was considerably lower than that reported for kit foxes in other locations (Table 5). Total space use (100% MCP), home range size (95% MCP), and core area size (50% MCP) all were generally smaller than comparable space use metrics reported for other sites, particularly when the data for male 6587 were excluded. Also, home range overlap among foxes was extensive (Figure 3). As with the higher fox mortality rate we observed, small home range size may be a function of the relatively limited available habitat in this satellite area. This may have forced foxes to share available space resulting in the observed overlap. Also, again because of limited regional habitat availability, dispersal potential may have been limited resulting in higher fox densities. This, too, might force animals to share space. Furthermore, increased intra-specific competition associated with higher densities can result in smaller home range size. Decreased home range size and increased spatial overlap associated with higher densities also has been observed in red foxes (*Vulpes vulpes*; Trewhella et al. 1988, Frey and Conover 2007) and island foxes (*Urocyon littoralis*; Roemer 1999, Roemer et al. 2001, Drake et al. submitted). Similarly, small home range sizes and extensive spatial overlap were observed among San Joaquin kit foxes inhabiting an urban environment where available habitat was limited and fox density was high (Frost 2005, Cypher 2010).

Table 5. Space use by adult kit foxes at the NSRER and 6 other locations.

	Size (km^2)			
Site	**100% MCP**	**95% MCP**	**Core area**	**Source**
NSRER (satellite)	4.9	3.4	1.2 (50% MCP)	This study
NSRER w/o 6587 (satellite)	3.7	2.4	0.9 (50% MCP)	This study
Carrizo solar mitigation lands (satellite)	10.0	6.4	2.0 (50% MCP)	Cypher et al., unpublished data
Elk Hills (core)	4.3	-	1.3 (75% HM*)	Koopman 1995
Elk Hills (core)	4.6	-	1.2 (50% HM*)	Zoellick et al. 2002
Lokern (core)	-	6.1	1.3 (50% HM*)	Spiegel and Bradbury 1992
Lokern (core)	-	5.9 (95% kernel)	-	Nelson 2005

* HM = harmonic mean method

Kit foxes exhibited concentrated use of the ridge feature at NSRER. The ridge is slightly higher than the surrounding lands and therefore may be less prone to flooding. Consistent with this, most of the kit fox dens we located were on the ridge area. Also, kangaroo rats are more abundant on the ridge compared to surrounding lands (G. Warrick, Center for Natural Lands Management, unpublished data; CDFW, unpublished data). This potentially is a function of the lower flood potential and the greater sand composition of the soils on the ridge relative to soils in the surrounding area (ESA 2008). As food habit analyses revealed, kangaroo rats were a primary item in kit fox diets at

NSRER. Consequently, habitat quality probably was higher on the ridge. As further evidence of this, fox home ranges that encompassed a greater proportion of ridge habitat were smaller in size. Smaller home range size in areas with higher quality habitat also has been demonstrated among kit foxes elsewhere (O'Neal et al. 1987, Koopman et al. 2001) and island foxes (Roemer 1999, Sanchez 2012).

Kit foxes at NSRER primarily consumed rodents and invertebrates, which is consistent with most other studies from other locations (McGrew 1973, Cypher 2003). Use of kangaroo rats also is consistent with results from other locations. Where available, kangaroo rats usually are preferred prey (Grinnell et al. 1937, Spiegel et al. 1996, Cypher et al. 2000, Koopman et al. 2001). Extensive use of invertebrates also is consistent with results from other studies. In fact, invertebrates were the most frequently occurring items in kit fox diets in some locations, such as Merced County (Briden et al. 1992) and the northern Carrizo Plain (Cypher et al. unpublished data). Indeed, at NSRER, invertebrates collectively were the primary items consumed by foxes in 3 of 4 seasons. Only in winter, when invertebrate populations probably are lowest, did the frequency of occurrence of rodents exceed that of invertebrates.

Demographic and ecological attributes of kit foxes at NSRER are consistent with a population that occurs in a relatively small habitat patch with a high proportion of edge. Data supporting this conclusion include a high mortality rate, small home range size, and extensive home range overlap. The data collected were insufficient to estimate fox density, but we suspect that density may be relatively high on this site, based on the number of foxes captured and the overlapping space use. Although biogeographical factors (e.g., small patch size, fragmented habitat, high edge) may be at least partially responsible for the observed attributes, habitat quality might also be a factor. The extensive overlapping space use and suspected high fox density likely would only be possible if habitat quality were high. More specifically, food availability would need to be high. Based on small mammal trapping efforts in the area, rodents appear to be abundant, particularly kangaroo rats (E. Tennant, CDFW, unpublished data; G. Warrick, CNLM, unpublished data).

For relatively small meta-populations of rare species, every population matters. Although a robust meta-population viability analysis is lacking for the San Joaquin kit fox, the population at NSRER undoubtedly is critically important for the long-term persistence of this taxon. Conservation strategies will be more effective if they are tailored to a given population. Demographic and ecological data facilitate the development of such strategies. Thus, this study was valuable.

Based on the results of this study, several conservation measures likely would be beneficial. (1) Any efforts to increase protections of conserved lands might help to make this population more secure. CDFW and CNLM have installed perimeter fencing and gates in some areas. More such efforts may be warranted. Other protection measures might include feral dog removal and increased site visits and surveillance. (2) Expansion of the amount of conserved habitat would increase population security. Acquisition of additional lands in this area is on-going as opportunity allows. Such efforts will expand the protected habitat available to foxes, facilitate better management of the lands, and potentially reduce fragmentation and edge effects. (3) Disease surveillance may be prudent. Small, dense populations are particularly vulnerable to significant reduction or even extirpation from disease. Rabies, distemper, and mange are diseases of particular concern. Rabies may have contributed to the reduction and possible extirpation of a San

Joaquin kit fox satellite population in the Camp Roberts area (White et al. 2000). Distemper recently significantly reduced a desert kit fox population (D. Clifford, CDFW, unpublished data) and almost wiped out an insular population of island foxes on Santa Catalina Island (Timm et al. 2009, Coonan et al. 2010). A sarcoptic mange outbreak in a dense population of kit foxes in Bakersfield has resulted in the deaths of at least 6 animals with others suspected. (4) If disease is determined to be a significant threat to the NSRER population, then a vaccination program might be considered. (5) Annual kit fox population and prey base monitoring would be useful to track trends. CDFW and the CNLM already annually monitor small mammal populations in the area.

Finally, additional investigations similar to this one should be conducted in other satellite population areas. Possibilities include the Kern Front area north of Bakersfield, northwestern Tejon Ranch area, Cuyama Valley, Coalinga area, and southwestern Merced County in the Los Banos Grandes area. Also, a similar investigation should be conducted in the Panoche Valley core area, where little work has been conducted on kit foxes. The efficacy of conservation and recovery strategies will be improved as more demographic and ecological data are collected from more sites.

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APPENDIX A. SAN JOAQUIN KIT FOXES CAPTURED AT THE NORTHERN SEMITROPIC RIDGE ECOLOGICAL RESERVE, KERN COUNTY, CA IN 2012.

Fox	Sex	Age	Collar	GPS points	Min. days known alive	Fate
6587	M	A	GPS	898	336	Collar removed
6588	M	A	GPS	503	176	Mortality – cause unknown
6589	F	A	GPS	400	158	Unknown – lost signal, not recaptured
6590	M	A	GPS	498	247	Mortality – collar only, possible predation
6598	M	A	GPS	382	134	Collar removed
6599	M	A	GPS	15	5	Mortality – collar only, possible predation
6685	F	A	GPS	349	120	Collar removed
6686	F	A	GPS	66	118	Collar removed
6574	F	A	VHF	-	134	Collar removed
6597	F	J	VHF	-	156	Collar removed
6600	M	J	VHF	-	71	Mortality – probable predation
6609	F	A	VHF	-	76	Mortality – collar only, possible predation
6687	M	A	VHF	-	88	Unknown – lost signal, not recaptured
6570	F	J	No	-	-	
6608	M	J	No	-	-	
6569	F	A	No	-	-	
6684	M	A	No	-	-	
6688	M	J	No	-	-	
6689	F	J	No	-	-	
6690	F	J	No	-	-	
6691	F	J	No	-	-	