FINAL REPORT

DEMOGRAPHIC AND ECOLOGICAL PATTERNS OF ENDANGERED SAN JOAQUIN KIT FOXES IN THE CARRIZO PLAIN NATIONAL MONUMENT

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INTRODUCTION

San Joaquin kit foxes (*Vulpes macrotis mutica*) are listed as Federally Endangered and California Threatened, primarily due to profound habitat loss throughout their range (U.S. Fish and Wildlife Service 1998). Kit foxes once were widely distributed in the San Joaquin Valley of California, but their range has been significantly reduced. The San Joaquin kit fox now persists in a metapopulation consisting of three main “core” populations and about a dozen “satellite” populations (U.S. Fish and Wildlife Service 1998, Cypher et al. 2013). 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.

Robust demographic and ecological data for San Joaquin kit foxes have been conducted in one of the core areas (western Kern County). However, this area is subject to substantial anthropogenic impacts which might alter kit fox demographic and ecological patterns. The CPNM encompasses the majority of remaining habitat within the largest remaining core area. Among the three remaining core areas, the habitat within the CPNM is the least degraded and fragmented, and is the most intact with regard to ecological function. Thus, the population in this core area can in essence serve as a standard against which to assess attributes for populations in the other core as well as satellite areas. This will facilitate the identification of potential conservation measures for these areas.

From 2014 to 2019, we assessed demographic and ecological patterns of endangered San Joaquin kit foxes relative to resource and competitor abundance in the Carrizo Plain National Monument (CPNM). Specific objectives were to (1) assess survival and sources of mortality, (2) assess reproductive success and litter size, and (3) examine space use patterns, (4) determine food habits of both kit foxes and coyotes (*Canis latrans*), which are the main competitors of kit foxes, (5) assess the relative abundance and distribution of kit foxes and coyotes, and (6) assess variation in the demographic and ecological attributes above relative to variation in the abundance of rodents and rabbits, which are the main prey for kit foxes and coyotes.

In addition to providing critical information on the demographic and ecological attributes for a kit fox population in an important core area, this project also will facilitate monitoring and conservation objectives outlined in the CPNM Resource Management Plan (U.S. Bureau of Land Management 2010). In particular, this project will contribute to the following management actions listed in the Plan:

- Action BIO-10(I): Monitor populations to determine trends and further define minimum population threshold values to identify when to take management actions. If populations approach target minimums, initiate management actions depending on species’ characteristics and specific factors influencing population trends as identified in the Conservation Target Table (Attachment 5). (p.II-21)

- Action BIO-11(S): Support research that identifies and defines factors that influence population trends of target species. Support research on the biology/ecology of target species. (p.II-21)

• Action BIO-16(S): Support research and education on special status, declining, or unique species. Focus efforts on topics useful in formulating management actions and to promote conservation. (p.II-25)

The proposed project also will contribute to fulfilling the following recovery tasks identified for San Joaquin kit foxes in a multi-species recovery plan for upland species in the San Joaquin Valley (U.S. Fish and Wildlife Service 1998) and reiterated in recent status reviews for San Joaquin kit foxes (U.S. Fish and Wildlife Service 2020a,b):

• Task 4.5: Assess SJKF reproduction and demography on the Carrizo Plain area.

• Task 4.57: Assess kit fox-red fox-coyote interactions.

• Task 4.80: Generate data for a spatially-explicit metapopulation viability analysis for the SJKF.

In 2014, we initiated an investigation of kit fox food use and interactions with competitors within the CPNM. Data were collected on kit fox and coyote food habits, relative abundance, and availability of small rodents and rabbits, which constitute the primary prey for kit foxes and coyotes in this region. In 2015 and 2017, funding became available to expand this project and to live-trap and collar kit foxes to examine survival, sources of mortality, reproduction, and home range use. Due to limited funding, the telemetry efforts were conducted for one year each.

In this report, we provide summaries of data collected and offer conclusions and recommendations based on those summaries.

STUDY DESIGN

Study area

This project was conducted in the portion of the CPNM within San Luis Obispo County, California (Fig. 1). In an effort to capture ecological variation in areas with kit foxes, research activities were primarily conducted along the southern half of the Soda Lake Road, southern half of the Elkhorn Road, and the northern portion of Simmler Road (aka San Diego Creek Road).

Kit fox live-trapping and radio-collaring

Live-trapping was conducted in late fall in 2015 and 2017 to capture and radio-collar kit foxes. 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. Trapping was conducted in the fall and early winter, and traps were set in late afternoon or early evening and then checked beginning around sunrise the next morning. Captured kit foxes were coaxed from the trap into a denim bag and handled without chemical restraint. Data collected for each fox included date, location, sex, age (adult or juvenile), mass, and dental condition, and a uniquely numbered tag was placed in one ear.

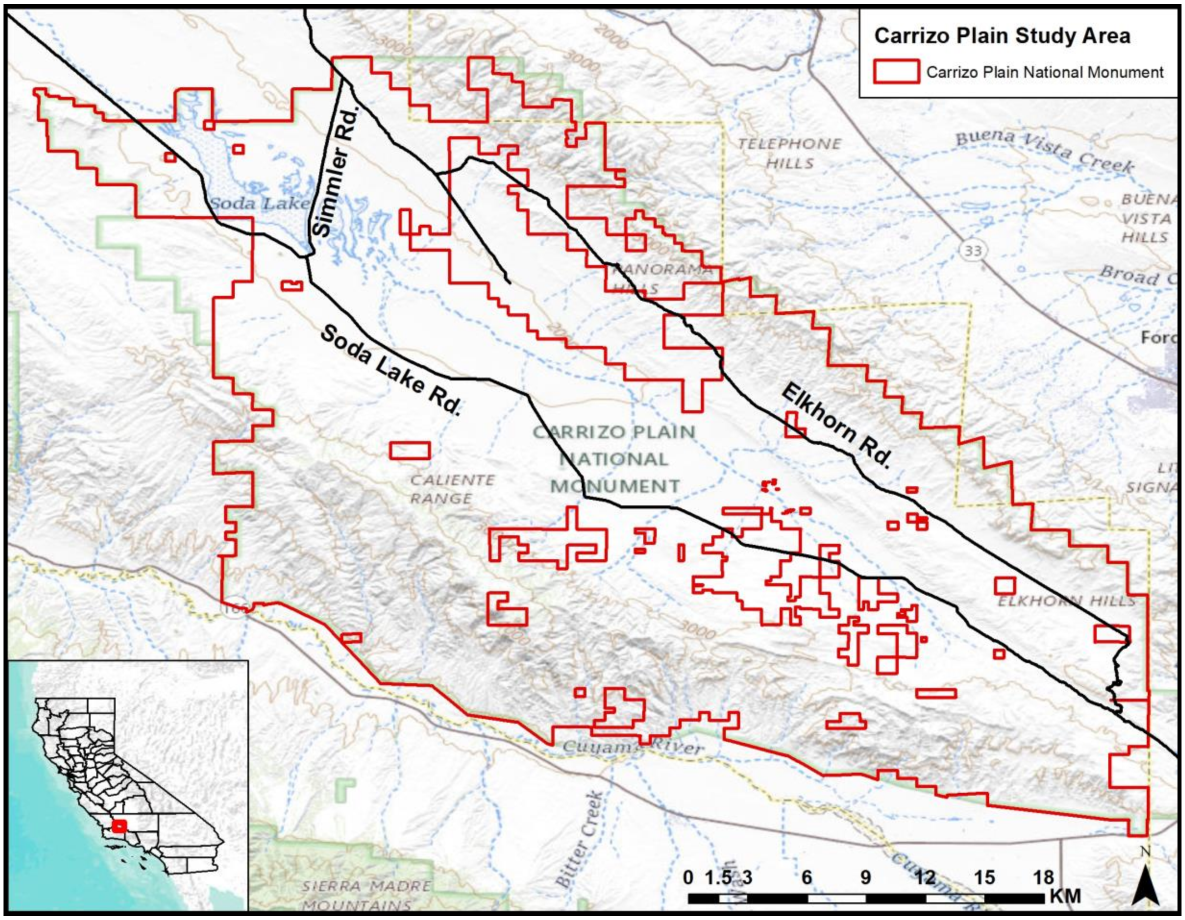

Figure 1. General study area in the Carrizo Plain National Monument, California.

Foxes were fitted with collars (Quantum 4000E Micro Mini Collars, Telemetry Solutions, Concord, CA) equipped with a GPS tracking unit and a VHF transmitter with a mortality sensor. The GPS units were programmed to collect 1 location per night with the time of night varied. Each unit included a UHF download function so that data could be downloaded remotely. A collar with only a VHF transmitter (Advanced Telemetry Systems, Isanti, MN) was placed on young-of-year foxes that were too small for the GPS collars. All foxes were released at the capture site. Collared foxes were tracked approximately weekly to assess survival, den use, and (in the spring) reproduction.

All fox trapping, handling, and collaring were consistent with guidelines for the use of wild animals in research established by the American Society of Mammalogists (Sikes et al. 2011), and conducted in accordance with conditions and protocols established in the research permit (TE825573-6) held by California State University at Stanislaus-Endangered Species Recovery Program from the U.S. Fish and Wildlife Service and a Memorandum of Understanding from the California Department of Fish and Wildlife.

Survival and reproduction

If a mortality signal was detected from a collared fox, the signal was tracked on foot and the carcass recovered. Cause of death was determined based upon physical evidence at the recovery site (e.g., tracks of larger predators, carcass caching, occurrence on or near a road) and on the carcass (e.g., evidence of mass trauma, tooth puncture wounds, location of bone breaks).

To assess survival, we calculated the number of days that a fox was known to be alive based on radiotelemetry monitoring. The fate of each fox monitored was categorized as: survived, died, or fate unknown. Fate was considered unknown in situations where telemetry transmitters expired and contact was lost with an animal, the fox dispersed out of the study area, or a radiocollar was removed. Data from unknown fate foxes were treated as truncated or "right-censored" for survival analyses.

Kit fox survival was quantitatively assessed using Micromort and Cox proportional hazards regression analysis. Survival analyses were only conducted for foxes greater than 9 months of age as foxes younger than this were not radiocollared. Program Micromort (Heisey and Fuller 1985) produces a maximum likelihood estimate of the probability of surviving ($\hat{S}_i$) for a specified interval of time based on the number of days collared foxes survived. Use of number of days as the metric for survival allowed staggered entry of individuals (Pollock et al. 1989). The interval of time used was 365 days, and survival probabilities were calculated for foxes for each of the two periods (2015-16 and 2017-18) that foxes were monitored. Survival probabilities were compared between periods using a two-tailed *z* test (Heisey and Fuller 1985):

$$z = \frac{\hat{S}_1 - \hat{S}_2}{\sqrt{var\ \hat{S}_1 + var\ \hat{S}_2}}$$

where $var\ \hat{S}_i$ is the variance for survival probability *i* and is calculated by Micromort.

Survival curves were calculated for kit foxes for each period using Cox proportional hazard regression analysis (Cox and Oakes 1984). The analyses were conducted using the Cox Regression function in the SPSS Statistics package. A Wald test is calculated to determine whether levels of a variable differ significantly in the "hazard" or the probability of surviving.

Finally, we calculated a simple index of mortality that is easily compared among studies with disparate monitoring methodologies. We divided the number of mortalities of collared adult foxes by the total number of days that collared foxes were monitored and multiplied that number by 1,000. Thus, the index produced is the rate of mortalities per 1,000 days of monitoring.

To assess reproductive success, the dens of collared adult foxes were monitored in the spring. Dens were examined for signs of pups (e.g., small scats and tracks, prey remains). Automated camera stations were set at dens to determine whether pups were present. If pups were present, then data from the cameras were used to estimate litter size. The proportion of female kit foxes successfully producing litters was compared between years (2016 and 2018) using a two-tailed Fisher's exact probability test. Mean litter size was compared between years using a two-tailed *t*-test.

Home range use and den use

Space use by foxes was assessed using nocturnal telemetry locations from the GPS collars. We calculated 95% and 50% minimum convex polygons (MCPs) for each fox using ArcGIS. The 95% MCPs represent home range use, and the 50% MCPs represent core area use (White and Garrott 1990). Mean home range size and mean core area size were compared between 2015-16 and 2017-18 with a two-tailed *t*-test.

Food habits

Food item use by kit foxes as well as coyotes was assessed through analysis of scats (fecal samples). Scats were collected opportunistically from along roads, den sites, camera stations, and also traps in which foxes had been captured. Scats were placed in paper bags labeled with the date and coordinates for the location. Scats were oven-dried at 60° C for ≥24 h to kill any parasite eggs and cysts. The scats then were placed in individual nylon bags, washed to remove soluble materials, and then dried in a tumble dryer. Remaining undigested material was examined to identify food items. Mammalian remains (e.g., hair, teeth, bones) were identified 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. Other vertebrates were identified to class and invertebrates to order, based on feathers, scales, and exoskeleton characteristics and comparison to reference specimens. Annual frequency of occurrence of items in scats was determined for kit foxes and coyotes. Items also were grouped into one of six broader categories: rabbit, rodent, bird, reptile, invertebrate, and other. The proportional occurrence of these categories was determined for each year for both kit foxes and coyotes.

Prey availability

Prey availability for kit foxes and coyotes was assessed along 60 0.5-km transects (Fig. 2). Two transects were established in the vicinity of each camera station. Along each transect, active rodent burrows and fresh rabbit pellets were counted in a 2-m wide belt. Rodent burrows were further classified as "large" (e.g., squirrel or kangaroo rat) or "small" (e.g., pocket mouse, deer mouse, lizard). Large burrows had an entrance greater than or equal to 3 cm in diameter while small burrows had an entrance less than 3 cm in diameter. Also, active (e.g., fresh digging, fresh fecal droppings, vegetation clipping) giant kangaroo rat precincts (i.e., burrow systems) intersected by the belt transect were tallied. The transect surveys were conducted in the spring.

Mean counts of burrows, precincts, and pellets were graphically compared among years relative to annual precipitation. Annual mean counts of small burrows were compared to the annual occurrence of pocket mice in kit fox and coyote diets. Annual mean counts of small burrows were compared to the annual occurrence of pocket mice in kit fox and coyote diets. Annual mean counts of large burrows and giant kangaroo rat precincts were compared to the annual occurrence of kangaroo rats and all rodents in kit fox and coyote diets. Annual mean counts of rabbit pellets were compared to the annual occurrence of rabbit in kit fox and coyote diets.

Kit fox and competitor abundance and distribution

Relative abundance of kit foxes and competitor species was determined by establishing automated camera stations throughout the study area. Stations were established 50-100 m off of established roads and stations were separated by at least 0.8 km. During 2014-17, 30 stations were deployed annually and 10 additional stations were added in 2018 and 2019 (Fig. 2). To attract predators, a perforated can of cat food and several drops of a commercial scent lure were placed approximately 2 m in front of each camera. The camera stations were operated for approximately 30 nights annually. Images captured on camera were examined to determine the identity and frequency of detections of all species visiting the stations.

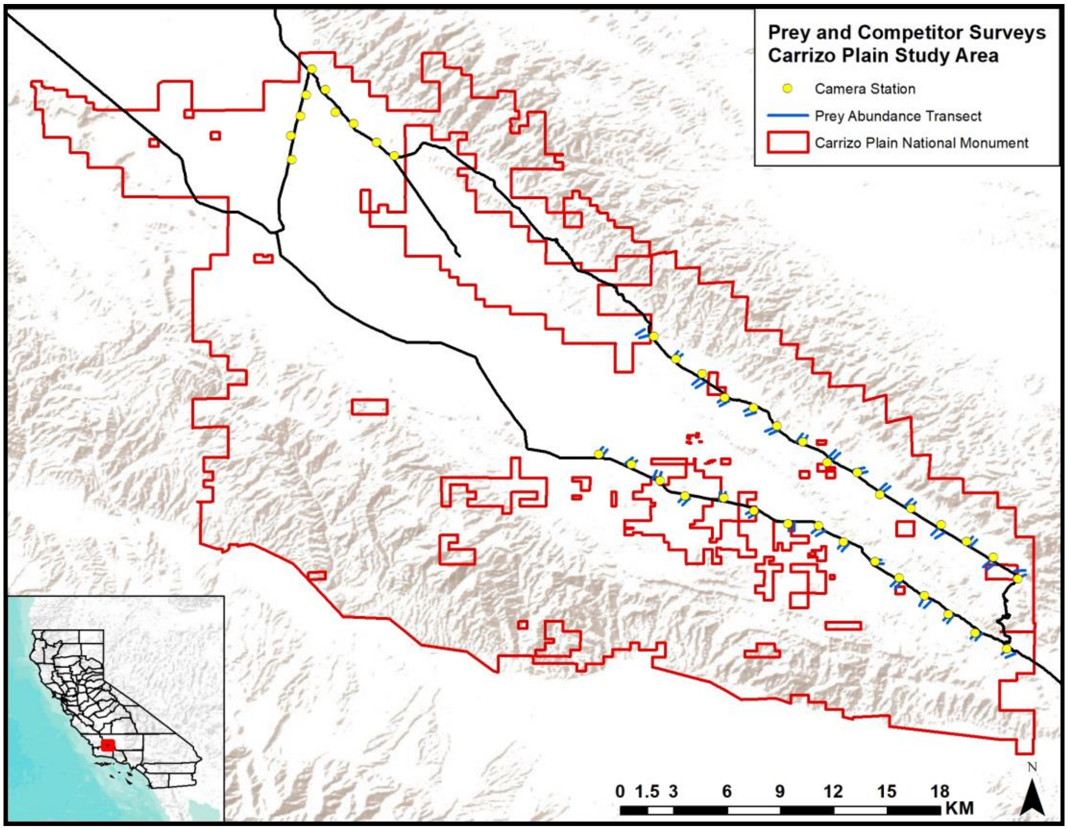

Figure 2. Locations of prey availability transects and camera stations during 2014-19 in the Carrizo Plain National Monument, California.

A visitation rate was calculated for each species by station. The rate was the number of nights a species was detected at each station divided by the number of nights the station was operational x 100. The mean rate for a given species across all stations was calculated for each year. This rate serves as an index of abundance. In particular, rates were calculated for kit foxes, coyotes, kangaroo rats, and black-tailed jackrabbits. Finally, the proportion of stations visited each year by kit foxes that were also visited by coyotes was determined for each year.

RESULTS

Live-trapping was conducted during December 2015-January 2016 and also during December 2017-January 2018 to deploy radio collars on kit foxes. During the 2015-2016 trapping session, 32 foxes were captured and fitted with radio collars. Twenty-nine adult foxes received GPS collars and 3 juvenile foxes received VHF collars. During the 2017-2018 trapping session, 24 foxes were captured and fitted with radio collars (Table 1). Twenty-nine adult foxes received GPS collars and 3 juvenile foxes received VHF collars. Fourteen adult foxes received GPS collars and 10 juvenile foxes received VHF collars.

Seven collared foxes died during the study with five dying during the 2015-2016 period and two dying during the 2017-2018 period (Table 1). For one fox, a mortality signal was heard but then ceased before the signal could be tracked to the source. For three foxes, only the collar was recovered. For two foxes, a collar and limited remains (e.g., clumps of fur, desiccated parts) were found. For one fox, a half-buried carcass was recovered. Based on the locations (Fig. 3) of the collars or remains and the evidence at the locations, we suspect that all seven foxes likely were killed by predators.

Table 1. San Joaquin kit foxes found dead during 2015-16 and 2017-18 on the Carrizo Plain National Monument, California.

Fox	Sex	Age	Collared	Last live signal	Notes
320	F	A	7/29/2015	1/15/2016	Collar collected on 1/25/16.
879	F	A	8/14/2015	3/21/2016	Half-buried carcass collected on 4/14/16
276	F	A	7/28/2015	4/6/2016	Remains collected on 4/14/16; just fur clumps and collar.
6869	M	A	12/16/2015	5/26/2016	Heard briefly from a hill near Travers Ranch. Never heard again and carcass not recovered.
6870	F	A	12/17/2015	6/11/2016	GPS points indicate she died on 06/11/16; carcass was not found until 06/30/16 outside a coyote den.
7184	F	J	12/13/2017	4/18/2018	Only the collar was recovered.
7158	F	A	12/12/2017	5/20/2018	Only the collar was recovered.

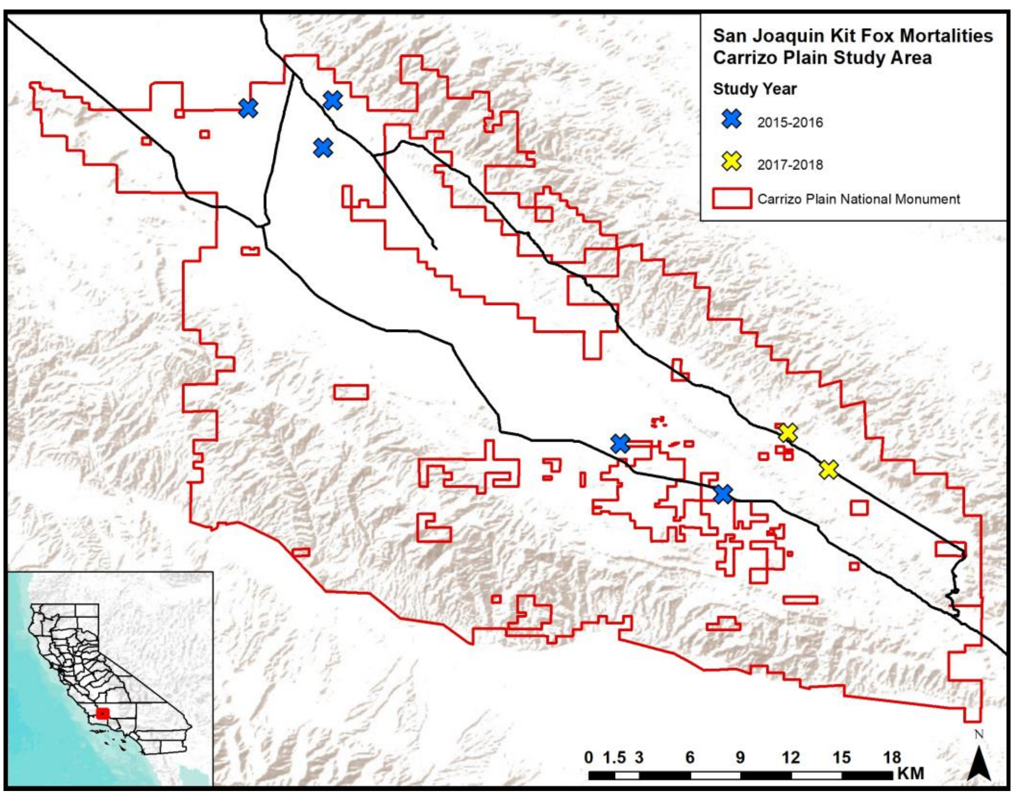

Figure 3. Locations of San Joaquin kit fox mortality sites on the Carrizo Plain National Monument, California in 2015-16 and 2017-18.

The probability of surviving for 365 days was 0.69 (95% CI = 0.50-0.96) for kit foxes during 2015-16 and 0.87 (95% CI = 0.70-1.00) during 2017-18. However, these values were not statistically different (z = -1.211, p = 0.226). Based on the Cox proportional hazards analysis, foxes were 2.74 times more likely to not survive during 2015-16 (Cox statistics for the variable "Year": β = 1.006, SE = 0.848, Wald = 1.409, 1 df, p = 0.235, exp(β) = 2.735, 95% CI for exp(β) = 0.519-14.401; Fig. 4). Fox deaths per 1,000 monitoring days was 1.01 for 2015-16 and 0.42 for 2017-18.

Nine female kit foxes were assessed in spring 2016 and 4 (44.4%) of these were confirmed to have produced litters of pups. Eleven females were assessed in spring 2018 and 8 (72.7%) were confirmed to have produced litters of pups. However, the proportions of females successfully reproducing was not statistically different based on a Fisher's exact probability test (p = 0.713). Litter sizes ranged from 3-5 in 2016 and 2-7 in 2018. Mean litter size (± SE) was 4.0 (± 0.58) in 2016 and 4.4 (± 0.65) in 2018, and was not different between years (t_{10} = -2.22, p = 0.721).

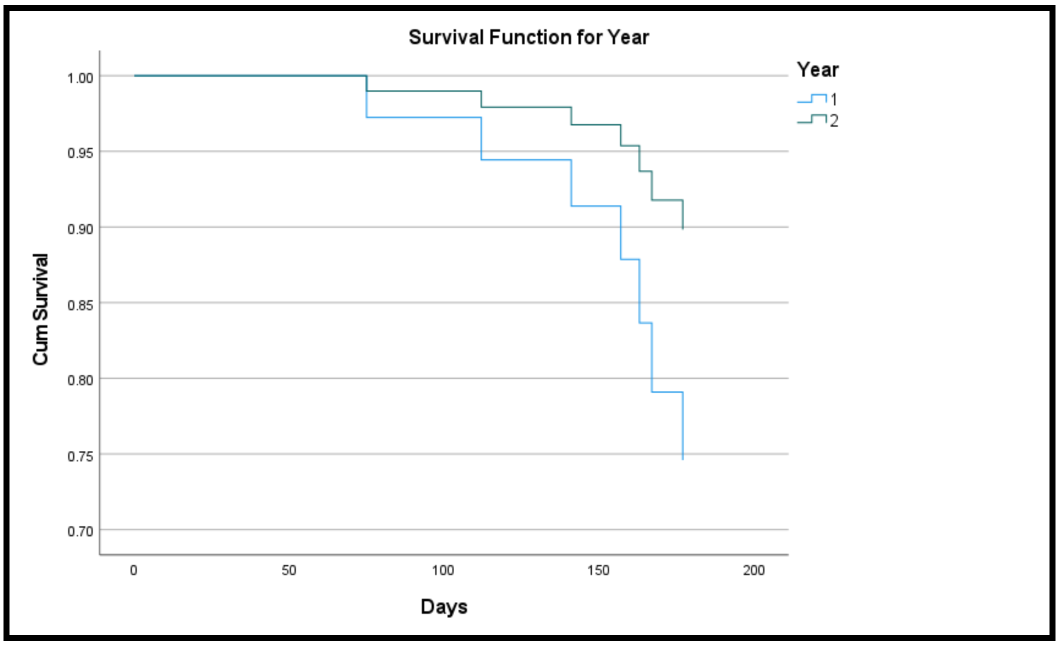

Figure 4. Survival probability curves for San Joaquin kit foxes on the Carrizo Plain National Monument, California during 2015-16 (Year 1) and 2017-18 (Year 2).

Home ranges (95% minimum convex polygons) were calculated for 22 kit foxes monitored in 2015-16 and 12 foxes monitored in 2017-18 (Table 2, Figs. 5 and 6). The number of locations obtained per fox ranged from 63-468 in 2015-16, and from 74-792 in 2017-18. Home range size ranged from 0.9-15.8 km^2 in 2015-16, and from 0.7-2.2 km^2 in 2017-18. Mean (± SE) home range size was 4.3 (± 0.7) km^2 in 2015-16 and 1.3 (± 0.1) km^2 in 2017-18, and differed significantly between years (t_{32} = 3.081, p = 0.004). Core area size ranged from 0.3-2.7 km^2 in 2015-16, and from 0.2-0.7 km^2 in 2017-18. Mean (± SE) core area size was 1.1 (± 0.1) km^2 in 2015-16 and 0.4 (± 0.1) km^2 in 2017-18, and differed significantly between years (t_{32} = 3.52, p = 0.001).

Table 3. Home ranges (95% MCP) and core areas (50% MCP) for San Joaquin kit foxes on the Carrizo Plain National Monument, California during 2015-16 and 2017-18.

Year	Fox	Sex	No. Points	95% MCP (km^2)	50% MCP (km^2)
2015-16	040	F	151	2.44	0.64
2015-16	276	F	63	1.24	0.35
2015-16	314	F	91	3.53	0.81
2015-16	364	F	108	1.80	0.56
2015-16	517	F	156	3.60	1.56
2015-16	604	F	63	3.29	1.02
2015-16	607	F	131	0.98	0.35
2015-16	879	F	89	2.70	0.42
2015-16	012	M	64	0.91	0.34
2015-16	093	M	66	15.82	2.09
2015-16	262	M	152	6.24	2.79
2015-16	303	M	123	3.04	0.87
2015-16	313	M	193	5.64	1.04
2015-16	343	M	150	3.65	1.37
2015-16	6622	M	147	10.31	1.07
2015-16	6865	F	158	2.29	0.65
2015-16	6866	F	114	3.55	1.51
2015-16	6867	M	147	6.06	1.90
2015-16	6870	F	316	4.99	1.63
2015-16	6871	M	138	3.00	1.01
2015-16	6876	F	289	4.05	1.19
2015-16	6875	M	468	5.18	1.06
2017-18	6884	F	518	0.81	0.27
2017-18	7144	M	613	1.73	0.95
2017-18	7150	M	792	1.81	0.72
2017-18	7158	F	335	0.96	0.20
2017-18	7159	M	771	2.24	0.41
2017-18	7163	F	569	1.33	0.47
2017-18	7166	M	543	1.09	0.41
2017-18	7183	F	586	1.03	0.26
2017-18	7185	F	471	1.60	0.42
2017-18	7186	M	543	1.17	0.44
2017-18	7187	M	74	0.72	0.29
2017-18	7188	M	495	0.95	0.45

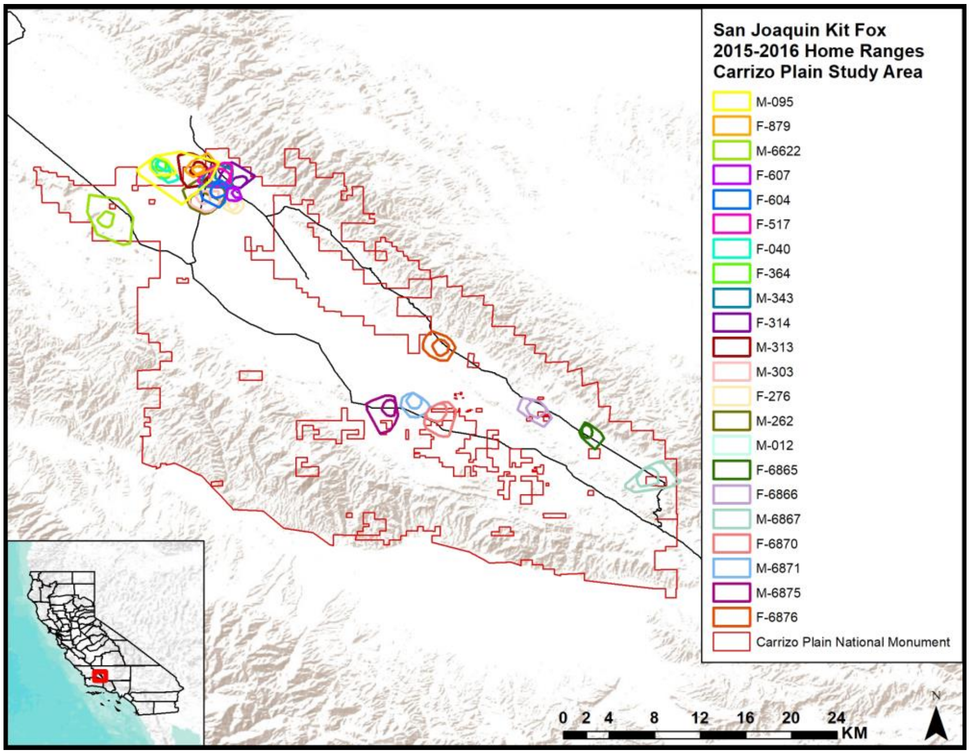

Figure 5. Home ranges and core areas for San Joaquin kit foxes on the Carrizo Plain National Monument, California during 2015-16.

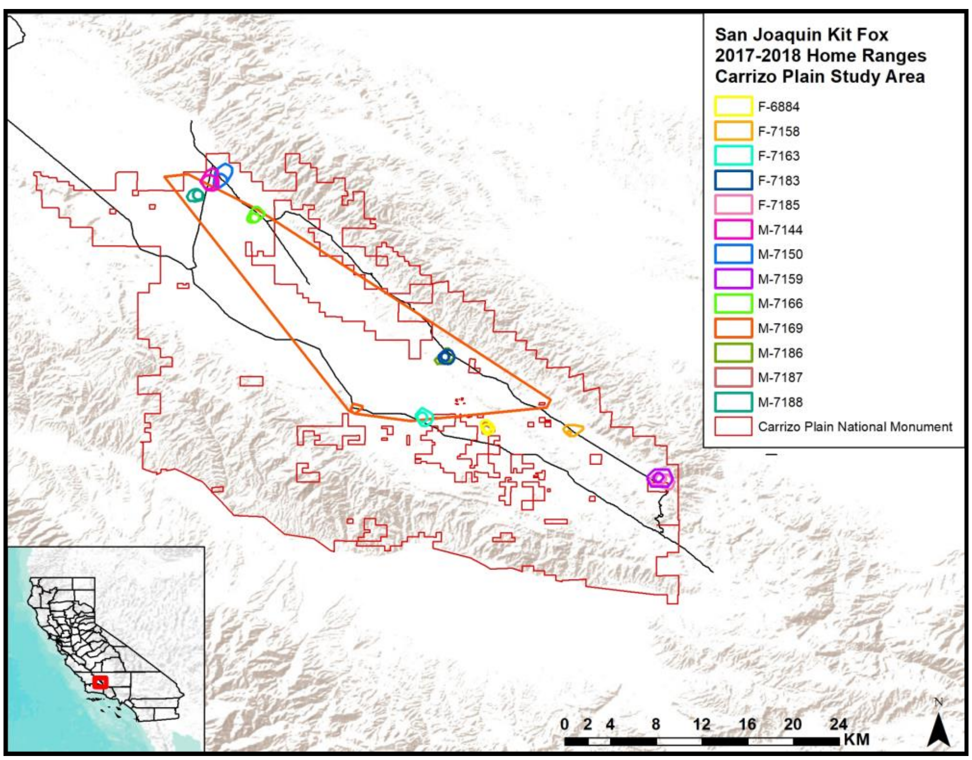

Figure 6. Home ranges and core areas for San Joaquin kit foxes on the Carrizo Plain National Monument, California during 2017-18.

To examine food use by kit foxes and coyotes, we analyzed 1,433 kit fox scats and 574 coyote scats (Tables 4 and 5). Annual sample size ranged from 105-462 for kit foxes and 52-159 for coyotes. Kit foxes consumed at least 21 different items while coyotes consumed at least 31 items. When grouped into broader categories, rodents and invertebrates clearly were the primary items consumed by kit foxes in all years (Fig. 7). The rodents most frequently consumed were kangaroo rats. The invertebrates primarily consumed were Jerusalem crickets, beetles, and beetle larvae. Coyote diets were much more diverse as evidenced by the greater number of items consumed compared to kit foxes and the more equitable distribution of items among the broader food categories (Fig. 8). For coyotes, all of the item categories exceeded 10% frequency of occurrence in scats in at least 3 of the 6 years with rabbits, rodents, and invertebrates exceeding 10% frequency of occurrence in all years. The specific items most frequently consumed included kangaroo rats, pocket mice, birds, snakes, Jerusalem crickets, beetles, and juniper berries.

Table 4. Frequency of occurrence of food items found in San Joaquin kit fox scats collected on the Carrizo Plain National Monument, California during 2014-19. Major food categories are shown in bold type.

	Frequency of occurrence (%)					
Items	2014 n = 202	2015 n = 114	2016 n = 462	2017 n = 105	2018 n = 391	2019 n = 159
Rabbit	**5.5**	**4.4**	**2.2**	**1.0**	**0.8**	**1.3**
Rodent	**55.0**	**63.2**	**94.2**	**95.2**	**95.7**	**93.7**
Kangaroo Rat	32.2	29.8	52.0	64.8	57.3	45.3
Pocket Mouse	2.0	6.1	11.0	-	3.3	-
Deer Mouse	0.5	1.8	7.1	3.8	-	-
Woodrat	-	-	0.2	-	2.6	-
Gopher	3.5	2.6	0.2	-	-	-
Squirrel	1.5	2.6	1.1	-	0.5	0.6
Unk Rodent	16.3	21.1	31.6	29.5	35.8	47.8
Bird	**5.9**	**10.5**	**0.9**	**1.9**	**3.3**	**1.3**
Unk bird	5.9	9.6	0.9	1.9	3.3	1.3
Bird Egg	-	1.8	-	-	-	-
Reptile	**7.9**	**8.8**	**5.2**	**0**	**4.9**	**1.3**
Snake	7.3	7.0	4.1	-	3.1	1.3
Lizard	0.5	8.8	0.9	-	1.3	-
Unk Reptile	-	8.8	0.2	-	0.5	-
Invertebrate	**86.1**	**75.4**	**20.4**	**20.0**	**31.5**	**63.5**
Jerusalem Cricket	21.3	54.4	0.9	9.5	-	44.7
Camel Cricket	2.5	1.8	-	-	0.8	-
Field Cricket	12.4	8.8	-	-	1.5	12.6
Grasshopper	8.9	4.4	1.7	1.0	1.8	6.3
Unk Orthopteran	5.9	8.8	1.1	1.0	2.1	1.9
Darkling Beetle	0.5	8.8	-	-	-	-
May Beetle	0.5	1.8	-	-	-	-
Unk Coleoptera	27.2	9.6	1.1	7.0	3.6	1.3
Larva	11.9	24.6	0.9	-	3.6	-
Unk Insect	42.6	14.9	8.4	10.5	8.4	8.2
Scorpion	18.3	3.5	0.9	-	0.8	-
Solpugid	3.5	2.6	0.4	-	1.0	1.3
Centipede	0.5	-	-	-	-	-
Other	**2.5**	**0**	**0**	**0**	**0.3**	**0**
Juniper	0.5	-	-	-	0.3	-
Anthropogenic	0.5	-	-	-	-	-
Walnut	1.5	-	-	-	-	-

Table 5. Frequency of occurrence of food items found in coyote scats collected on the Carrizo Plain National Monument, California during 2014-19. Major food categories are shown in bold type.

	Frequency of occurrence (%)					
Items	2014 n = 57	2015 n = 76	2016 n = 159	2017 n = 52	2018 n = 148	2019 n = 82
Rabbit	**29.8**	**17.1**	**39.6**	**44.2**	**23.0**	**35.4**
Rodent	**36.4**	**22.4**	**71.7**	**80.8**	**43.2**	**68.3**
Kangaroo Rat	14.1	11.8	41.5	65.4	35.8	47.6
Pocket Mouse	1.8	4.0	21.4	15.4	5.4	-
Deer Mouse	1.8	1.3	17.6	3.8	-	-
Woodrat	-	-	-	1.9	-	1.2
Gopher	10.5	6.6	-	1.9	2.7	7.3
Squirrel	1.8	-	6.3	7.7	1.4	6.1
Vole	1.8	-	-	-	-	-
Unk Rodent	10.5	4.0	9.4	7.7	3.4	15.9
Bird	**19.3**	**13.2**	**3.1**	**7.7**	**13.5**	**-**
Unk bird	19.3	9.2	3.1	7.7	13.5	-
Bird Egg	-	4.0	-	-	-	-
Reptile	**26.3**	**42.1**	**23.9**	**15.4**	**14.2**	**8.5**
Snake	21.1	30.3	21.4	11.5	10.1	6.1
Lizard	5.3	13.2	2.5	1.9	3.4	1.2
Unk Reptile	-	1.3	0.6	1.9	1.4	1.2
Invertebrate	**54.4**	**88.2**	**39.0**	**34.6**	**31.1**	**52.4**
Jerusalem Cricket	29.8	50.0	14.5	21.2	18.9	41.5
Sand Cricket	-	2.6	-	-	-	-
Field Cricket	-	5.3	0.6	-	-	2.4
Grasshopper	1.8	6.6	3.8	-	2.7	6.1
Unk Orthopteran	8.8	-	0.6	-	-	-
Darkling Beetle	8.8	6.6	1.9	-	-	2.4
June Beetle	-	-	-	-	5.4	-
Ground Beetle	-	2.6	-	-	-	-
Blister Beetle	-	-	-	-	-	1.2
Unk Coleoptera	26.3	44.7	12.6	3.8	4.1	1.2
Larva	-	27.6	1.3	1.9	1.4	-
Earwig	-	1.3	-	-	-	-
Unk Insect	7.0	1.3	13.2	11.5	6.1	6.1
Scorpion	8.8	1.3	3.1	-	-	-
Snail	-	1.3	-	-	-	-
Other	**38.6**	**14.4**	**7.7**	**7.7**	**39.3**	**9.7**
Juniper	10.5	-	-	-	37.2	2.4
Grape	15.8	-	0.6	-	0.7	-
Coyote Melon	7.0	-	3.4	-	-	6.1
Domestic animal	5.3	5.2	1.2	7.7	-	-
Bobcat	-	1.3	-	-	-	-
Anthropogenic	-	1.3	-	-	0.7	1.2
Walnut	1.8	6.6	2.5	-	0.7	-

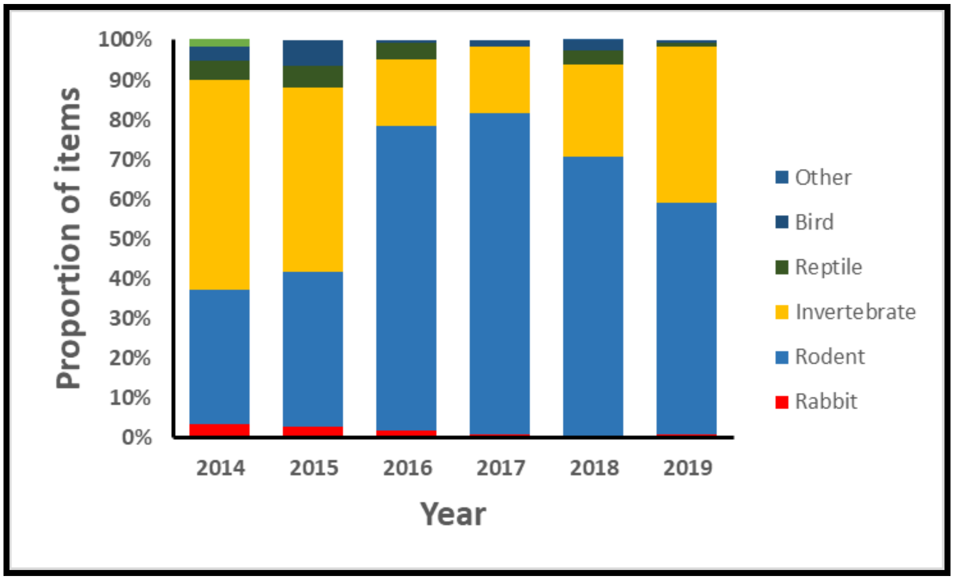

Figure 7. Use of food categories by San Joaquin kit foxes on the Carrizo Plain National Monument, California during 2014-2019.

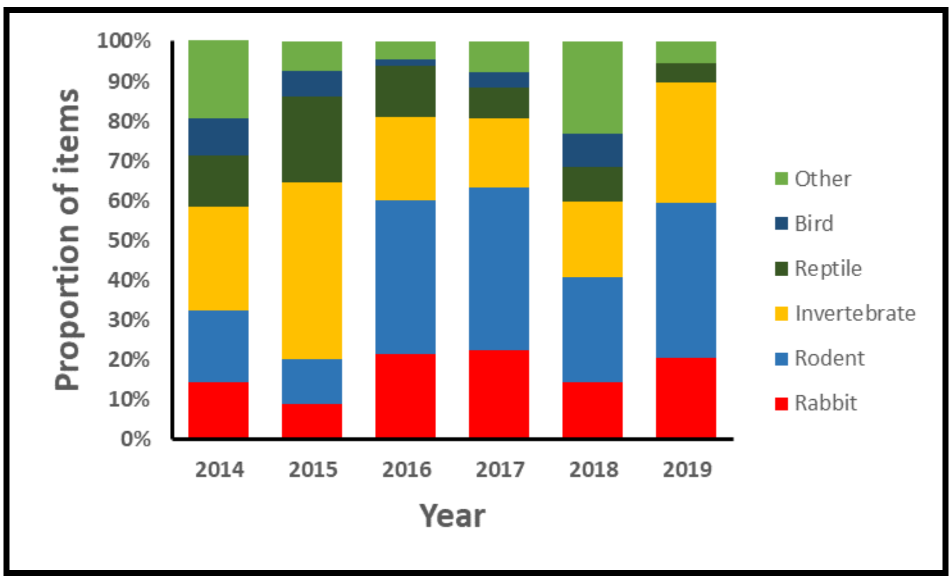

Figure 8. Use of food categories by coyotes on the Carrizo Plain National Monument, California during 2014-2019.

The abundance of small burrows was consistently low with a small increase in 2016 (Fig. 9). Large burrow abundance also was consistent with an increase in 2019. The number of active giant kangaroo rat precincts and the number of rabbit pellets were low during 2015-2017 but increased markedly in 2018 and 2019, probably in response to two consecutive years of higher precipitation.

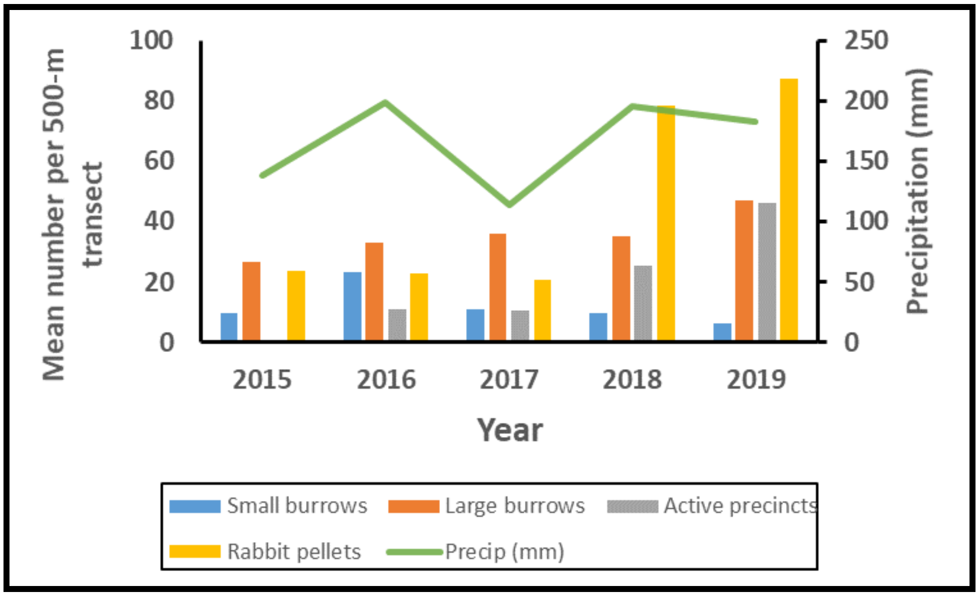

Figure 9. Abundance of small burrows, large burrows, active giant kangaroo rat precincts, rabbit pellets, and precipitation during 2015-19 on the Carrizo Plain National Monument, California.

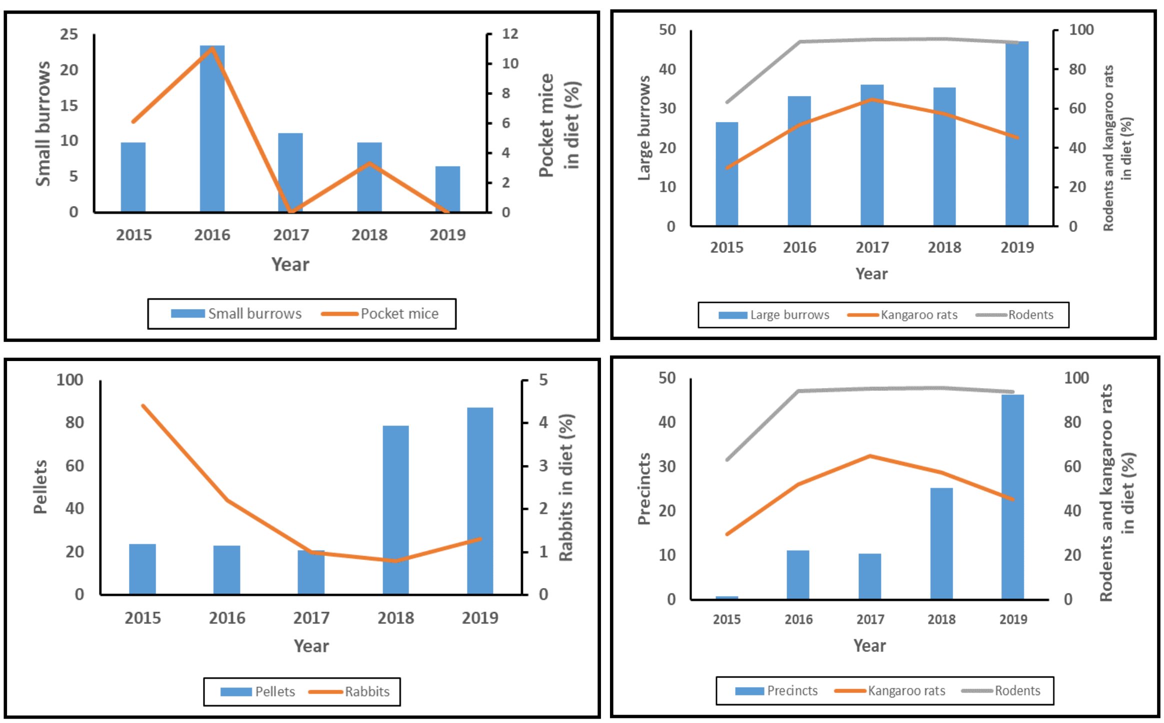

Figure 10. Abundance of small burrows, large burrows, active giant kangaroo rat precincts, rabbit pellets relative to occurrence of pocket mice, kangaroo rats, rodents, and rabbits in the diets of San Joaquin kit foxes during 2015-19 on the Carrizo Plain National Monument, California.

The occurrence of pocket mice in kit fox diets roughly tracked the abundance of small burrows (Fig. 10). Likewise, the occurrence of kangaroo rats and all rodents roughly tracked the abundance of large burrows and giant kangaroo rat precincts, although use of kangaroo rats did appear to decline somewhat in 2018 and 2019. The occurrence of rabbits in the diet was roughly inversely related to the abundance of rabbit pellets and also to the occurrence of kangaroo rats.

Similar to kit foxes, the occurrence of pocket mice in coyote diets roughly tracked the abundance of small burrows (Fig. 11). Likewise, the occurrence of kangaroo rats and all rodents roughly tracked the abundance of large burrows but less so with giant kangaroo rat precincts. and giant kangaroo rat precincts, although use of kangaroo rats did appear to decline somewhat in 2018 and 2019. The occurrence of rabbits in the diet generally was high in all years except 2014. The occurrence of both rabbits and rodents was lower in 2018 when the occurrence of juniper berries was markedly higher.

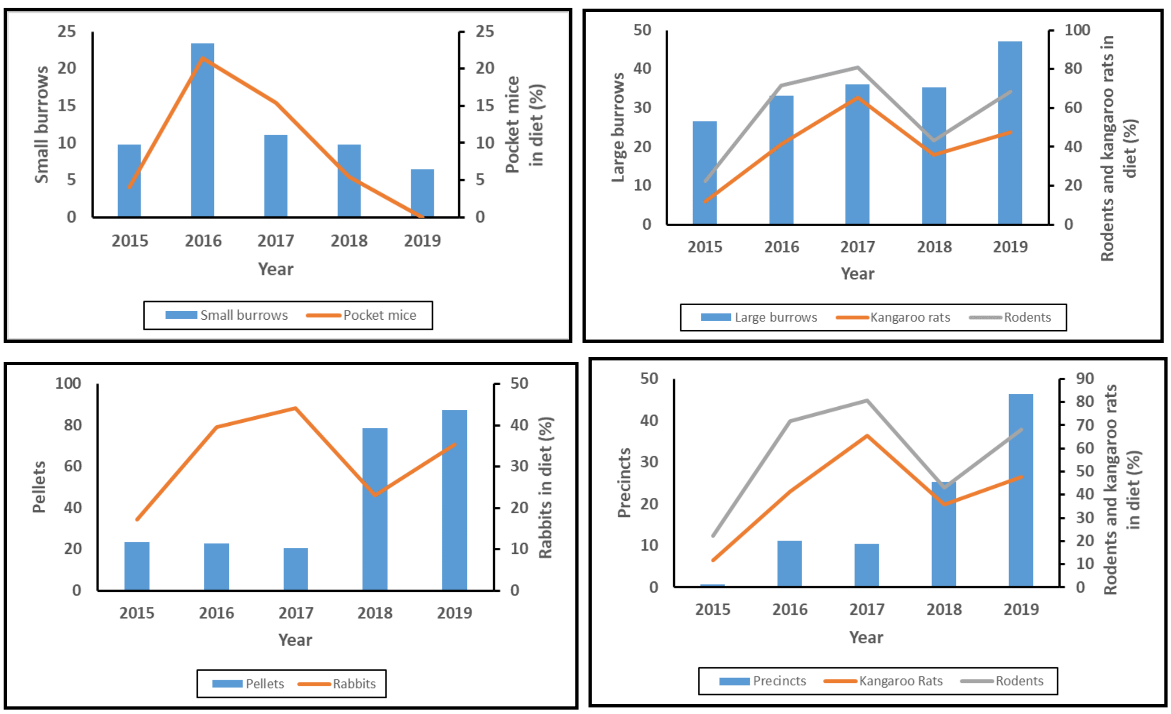

Figure 11. Abundance of small burrows, large burrows, active giant kangaroo rat precincts, rabbit pellets relative to occurrence of pocket mice, kangaroo rats, rodents, and rabbits in the diets of coyotes during 2015-19 on the Carrizo Plain National Monument, California.

Camera station surveys were conducted each year during 2014-19. Visitation indices indicated that both kit fox and coyote abundance generally increased from 2014 to 2019 although abundance for both species declined somewhat in 2018 (Table 6, Fig. 12). Rabbit abundance based on detections exhibited a similar trend. Kangaroo rat abundance increased from 2014 to 2017, but then declined in 2018 and 2019 (Table 6, Fig. 12). The decline in kit fox and coyote abundance in 2018 coincided with the decline in prey species, although both canids then increased again in 2019. As abundance of both kit foxes and coyotes increased, the proportion of stations visited by kit foxes that was also visited by coyotes increased as well (Fig. 13). A variety of other species were incidentally detected at the camera stations as well (Table 7).

Table 6. Mean visitation rates (no. of nights camera stations were visited/no. camera station nights x 100) for San Joaquin kit foxes, coyotes, kangaroo rats, and rabbits during 2014-2019 on the Carrizo Plain National Monument, California.

	Mean visitation rate					
Species	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
San Joaquin kit fox	7.4%	11.8%	33.9%	48.6%	35.9%	60.7%
Coyote	5.5%	1.5%	10.0%	12.6%	9.5%	14.4%
Kangaroo rats	0.1%	2.7%	7.6%	49.3%	29.1%	10.1%
Black-tailed jackrabbit	3.7%	6.2%	11.2%	18.2%	8.2%	15.1%
Camera station nights	990	990	812	829	1352	1155

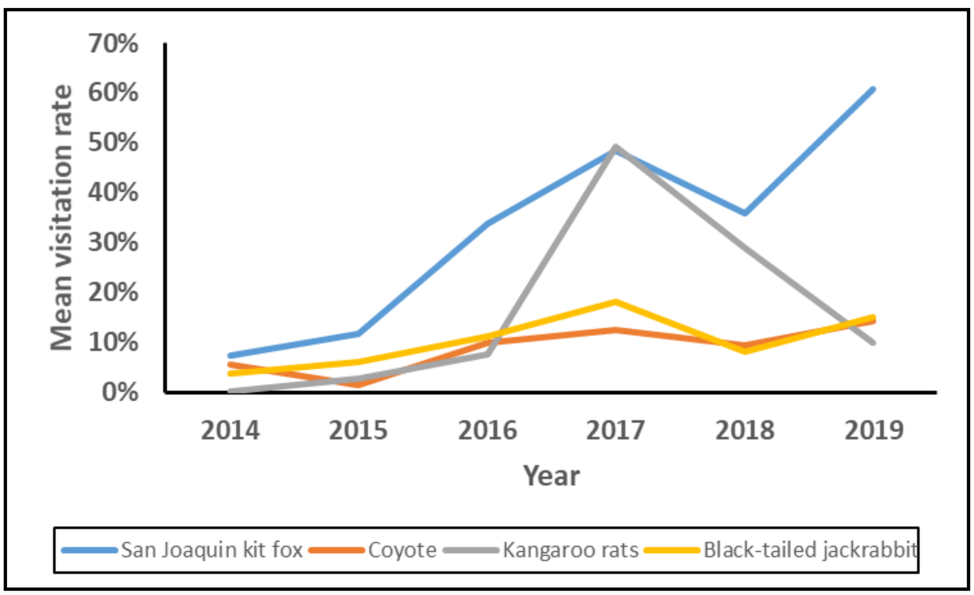

Figure 12. Mean visitation rates (no. of nights camera stations were visited/no. camera station nights x 100) for San Joaquin kit foxes, coyotes, kangaroo rats, and rabbits during 2014-2019 on the Carrizo Plain National Monument, California.

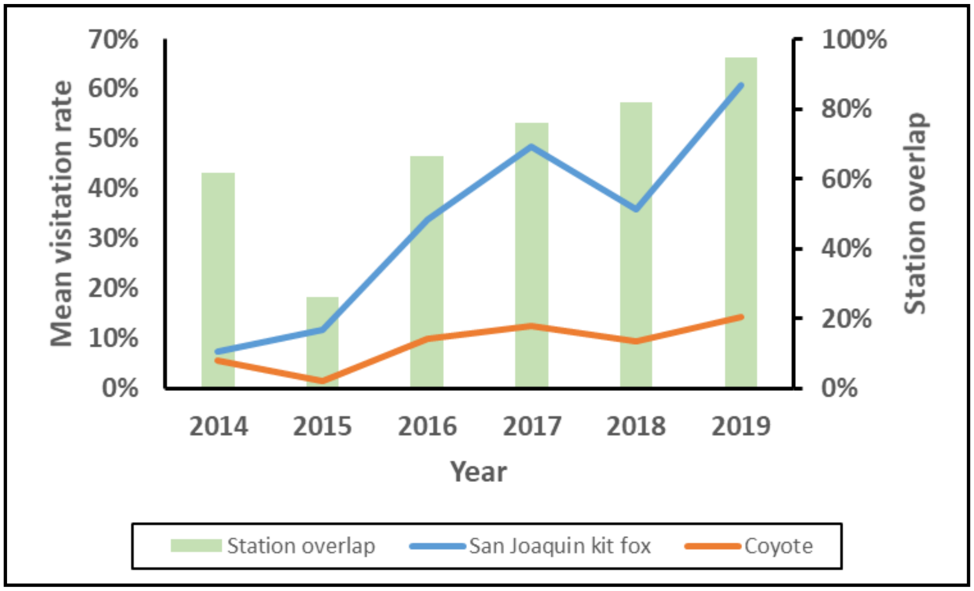

Figure 13. Mean visitation rates (no. of nights camera stations were visited/no. camera station nights x 100) for San Joaquin kit foxes and coyotes, and the proportion of stations (visited by kit foxes that were also visited by coyotes during 2014-2019 on the Carrizo Plain National Monument, California.

Table 7. Number of camera stations visited by various species on the Soda Lake study area on the Carrizo Plain National Monument, California.

Common Name	Scientific Name	2014 (n = 30)	2015 (n = 30)	2016 (n = 29)	2017 (n = 30)	2018 (n = 40)	2019 (n = 40)
San Joaquin kit fox	*Vulpes macrotis mutica*	21	19	27	29	39	39
Coyote	*Canis latrans*	19	10	20	22	32	38
American badger	*Taxidea taxus*	4	7	4	6	11	16
Bobcat	*Lynx rufus*	1	4	1	2	2	-
Domestic cat	*Felis catus*	-	-	-	-	-	1
Mule deer	*Odocoileus hemionus*	-	1	-	-	1	1
Pronghorn	*Antilocapra americana*	-	1	-	-	-	-
Black-tailed jackrabbit	*Lepus californicus*	7	21	24	28	31	29
Desert cottontail	*Sylvilagus audubonii*	2	2	1	2	1	-
San Joaquin antelope squirrel	*Ammospermophilus nelsoni*	3	8	7	20	26	7
Kangaroo rat species	*Dipodomys* sp.	1	6	12	24	33	18
Pocket mouse	*Heteromyidae*	-	-	-	-	1	-
Woodrat	*Neotoma* sp.	-	-	-	1	-	-
Golden eagle	*Aquila chrysaetos*	-	-	-	1	2	1
Prairie falcon	*Falco mexicanus*	-	-	-	-	3	
Red-tailed hawk	*Buteo jamaicensis*	-	-	1	2	1	1
Red-shouldered hawk	*Toxostoma redivivum*	-	-	-	-	1	-
Killdeer	*Charadrius vociferus*	-	1	-	-	-	-
Mourning dove	*Zenaida macroura*	1	-	-	-	-	-
California quail	*Callipepla californica*	-	-	-	1	1	-
Greater roadrunner	*Geococcyx californianus*	1	-	2	3	3	1
Great horned owl	*Bubo virginianus*	-	-	1	-	-	1
Short-eared owl	*Asio flammeus*	-	-	-	-	2	-
Burrowing owl	*Athene cunicularia*	-	-	1	-	-	-
Loggerhead shrike	*Lanius ludovicianus*	-	1	1	4	6	1

Common raven	*Corvus corax*	-	2	1	1	14	15
Rock wren	*Salpinctes obsoletus*	-	-	2	1	1	-
Say’s Phoebe	*Sayornis saya*	-	-	-	2	3	2
California thrasher	*Toxostoma redivivum*	-	-	1	-	-	-
LeConte's thrasher	*Toxostoma lecontei*	-	2	1	5	2	-
Horned lark	*Eremophila alpestris*	-	-	-	1	-	-
Sage thrasher	*Oreoscoptes montanus*	-	1	1	-	-	-
House finch	*Haemorhous mexicanus*	-	-	-	-	-	1
Lark sparrow	*Chondestes grammacus*	-	1	-	-	-	-
Sparrow sp.	*Emberizidae*	-	1	-	-	1	-
Western meadowlark	*Sturnella neglecta*	-	-	1	1	5	-
Unknown bird species	-	2	-	1	3	1	-

DISCUSSION

This investigation provided valuable insights into ecological processes that drive San Joaquin kit fox population dynamics on the CPNM and indeed throughout the range of the species. Kit fox populations exhibit immense temporal fluctuations (Cypher et al. 2000, CDFW unpublished data). Understanding the source of these fluctuations is important in determining what is "natural" and what is cause for concern, particularly because the San Joaquin kit fox is an at-risk species. Also, understanding these dynamics may help identify management strategies that might reduce the magnitude of the fluctuations, particularly the depth of the population low points, and this could contribute to population stability and reduce extinction risk for San Joaquin kit foxes.

Information from both the prey transects and the camera stations indicated marked variation in the availability of important prey species during 2014-2019. The annual abundance of most of the natural food items consumed by kit foxes and coyotes varies with annual primary productivity, which in turn varies with annual precipitation levels, particularly that falling during October to March (Cypher et al. 2000, Cypher 2001, Germano et al. 2012, Germano and Saslaw 2017). These relationships can be complex and are influenced by factors such as the timing of the precipitation, cumulative effects, lag effects, and species interactions. Thus, the relationships are difficult to precisely predict, but the annual trends are generally positively related.

Relatively low precipitation levels during 2011 to 2014 resulted in low prey availability for kit foxes and coyotes at the beginning of the study. Concomitantly, kit fox and coyote abundances were low as well. Higher precipitation levels in 2015, 2016, 2018, and 2019 led to increasing prey populations, and consequently, increasing kit fox and coyote abundance. There were some interesting exceptions to these general trends. Pocket mice appear to have initially increased and then decreased, based on the abundance of small burrows and occurrence of pocket mice in the diets of the canids. This trend has been commonly observed among pocket mice as they quickly respond to improved conditions following dry periods but then decline within a year or two as they are competitively excluded by more slowly responding but larger kangaroo rats (Bowers 1986, Otten and Holmstead 1996). Prey species and consequently the canids appeared to experience a small decline in abundance in 2018, which may have been a result of lower precipitation in 2017. Also, a "mortality event" of unknown cause among giant kangaroo rats was reported to have occurred in 2018 (B. Boroski, H.T. Harvey and Associates, personal communication; W. Bean, Cal Poly-San Luis Obispo, personal communication) and this may have reduced the abundance of this species resulting in the decline in consumption by kit foxes and coyotes.

These general trends among prey populations facilitate interpretation of the ecological and demographic trends observed among kit foxes and coyotes during the study. Kit foxes are specialized foragers on nocturnal rodents, particularly kangaroo rats (Grinnell et al. 1937, Spiegel et al. 1996, Cypher et al. 2000, Koopman et al. 2001). Thus, their annual dietary composition on the CPNM largely reflects the trends in kangaroo rat abundance detailed above. Kit foxes also consumed considerable quantities of invertebrates, as has been observed in other locations (Spiegel et al. 1996, Cypher et al. 2000, Nelson et al. 2007).

When other foods, particularly kangaroo rats, are less abundant, kit foxes seem to maintain good body condition and health on a diet consisting largely of invertebrates, although reproductive success generally is lower (Cypher 2003, Cypher et al. 2014).

Coyotes are more generalists and consume a wider variety of food items compared to kit foxes (Voigt and Berg 1987, Bekoff and Gese 2003). This was reflected in the greater number of different food items consumed by coyotes on the CPNM and the more equitable distribution of items among the food categories, particularly in the later years when food availability in general was higher. One interesting example of this generalized foraging behavior is the opportunistic consumption of what appears to have been a “bumper” juniper berry crop in 2018. Over one-third of all coyote scats collected that year contained juniper berry seeds. Rabbits constituted a consistent staple in coyote diets, as has been observed elsewhere (Ferrel et al. 1953, Clark 1972, MacCracken and Hansen 1987, Cypher et al. 1994), and coyote abundance trends closely tracked those of rabbits.

Many food items were commonly found in both kit fox and coyote diets. This overlap in item use creates the potential of exploitative competition between kit foxes and coyotes. Essentially, use of a particular resource by one species could result in a lower availability of that resource for another species. On the CPNM, coyote diets appeared to become more diverse as food resources increased in response to higher precipitation levels. This diversification may have reduced resource competition between kit foxes and coyotes as kit foxes continued to exploit primarily kangaroo rats and invertebrates.

Kit fox home ranges were significantly influenced by the prey availability patterns. Mean kit fox home range size was over three times larger in 2015-16 when prey availability was lower. The smaller home ranges in 2017-18 likely were a function a greater prey density resulting in kit foxes having to travel shorter distances to secure food. In investigations conducted on the California Valley Solar Ranch and the Topaz Solar Farm just north of the CPNM, mean home range size for San Joaquin kit foxes also decreased significantly as prey availability increased (Cypher et al. 2019, H.T. Harvey and Associates 2019).

A demographic consequence of smaller home range sizes is that survival was noticeably higher for kit foxes in 2017-18. The more time a fox needs to spend foraging and the greater the distance it needs to travel to find food, the higher the potential for encountering a larger predator. Thus, greater food availability and smaller home ranges could reduce predation rates leading to higher survival. Less time and distance required for foraging results in less exposure to predators. The somewhat higher reproductive success in 2017-18 also likely was a consequence of higher prey availability. More prey results in more nutrition to support gestation and lactation, more food for growing pups post-weaning, and more time spent by the adults in tending and guarding pups.

Greater prey availability likely enhanced kit fox survival and reproductive success, and consequently kit fox abundance also increased. The increase in abundance was based on visitation rates to camera stations. Increasing kit fox abundance during 2014-2019 also was evident on the CPNM based on spotlight surveys conducted by the California Department of Fish and Wildlife (Fig. 14; CDFW unpublished data). Thus, as food availability on the CPNM increased, kit fox abundance also increased and kit foxes exhibited more robust demographic attributes.

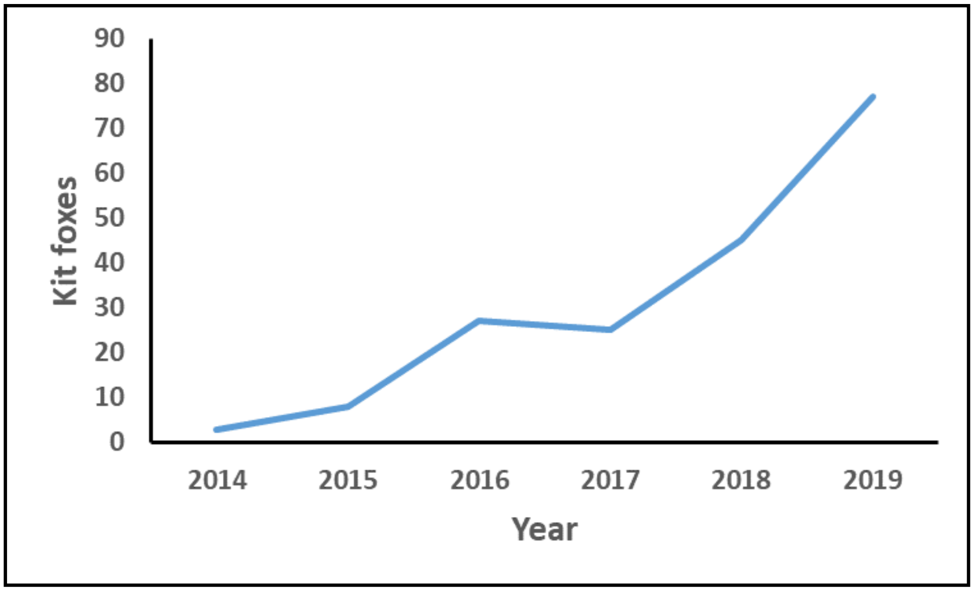

Figure 14. Number of San Joaquin kit foxes observed during spotlight surveys conducted by the California Department of Fish and Wildlife during 2014-2019 on the Carrizo Plain National Monument, California.

Coyote abundance also increased during the study. Also, local-scale spatial overlap may have increased as indicated by the greater proportion of camera stations visited by kit foxes that also were visited by coyotes. Consequently, the potential for encounters between the two species likely was greater (Fig. 13). Coyotes are a primary cause of mortality for San Joaquin kit foxes. Thus, increased coyote abundance and higher encounter rates could lead to increased interference competition that potentially could limit kit fox survival and abundance. However, as noted above, kit fox survival trended higher and kit fox abundance increased despite the increase in coyote abundance and possible increase in spatial overlap.

Figure 13. San Joaquin kit fox behind a coyote at a camera station on the Carrizo Plain National Monument, California in 2019.

Based on the results of this investigation, the data strongly indicate that the San Joaquin kit fox population on the CPNM is primarily influenced by food availability and not by interference or exploitative competition by a larger competitor. As food availability increased, kit fox abundance increased and survival and reproductive success trended higher. The increased abundance of kit foxes and the more robust demographic parameters occurred despite a concomitant increase in coyote abundance. Results from other locations indicate that these trends are common to San Joaquin kit foxes elsewhere (e.g., Cypher et al. 2000, Cypher et al. 2019). Consequently, kit fox populations appear to be regulated by "bottom up" processes in which trophic levels below a given level have a greater effect on that level than do trophic levels above it (e.g., Pace et al. 1999).

Determining that lower trophic levels have a greater effect on kit fox population dynamics provides critical information that can facilitate the identification of potential management strategies for kit foxes. The bottom up process suggests that any management action that benefits prey populations should also benefit the kit fox population. In particular, actions that benefit their primary prey, kangaroo rats, could be particularly beneficial. The CPNM is largely a natural system with natural processes, and therefore the options for enhancing habitat suitability for kangaroo rats is limited. One possibility is managed grazing, particularly in years of higher precipitation when dense herbaceous growth can reduce habitat suitability for kangaroo rats (and other species). Fortuitously, grazing prescriptions and guidelines for implementation already are detailed in the CPNM Resource Management Plan (U.S. Bureau of Land Management 2010).

In addition to providing important information on ecological processes affecting San Joaquin kit fox population dynamics, it also provided valuable baseline information on kit fox demography and ecology in a "core area" for the species (USFWS 1998). The CPNM is within a large relatively intact landscape with extensive suitable habitat for kit foxes (Cypher et al. 2013). Consequently and not unexpectedly, survival rate, particularly in 2017-18, was among the highest recorded and mean home range size was among the lowest recorded (CSUS ESRP unpublished data).

This report presents the main results and management/conservation implications from the investigation conducted by the CSUS Endangered Species Recovery Program. In the coming years, more detailed analyses may be conducted to further explore nuances in the extensive data that were collected, and multiple manuscripts are expected to be produced for submission to scientific journals.

LITERATURE CITED

Bekoff, M, and E. M. Gese. 2003. Coyotes. Pages 467-481 in G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild Mammals of North America: Biology, Management, and Conservation. Second edition. The Johns Hopkins University Press, Baltimore, Maryland.

Bowers, M. A. 1986. Geographic comparison of microhabitats used by three heteromyids in response to rarefaction. Journal of Mammalogy 67:46-52.

Clark, F. W. 1972. Influence of jackrabbit density on coyote population change. Journal of Wildlife Management 72:343-356.

Cox, D. R., and D. Oakes. 1984. Analysis of survival data. Chapman and Hall, London, United Kingdom.

Cypher, B. L. 2001. Spatiotemporal variation in rodent abundance in the San Joaquin Valley, California. The Southwestern Naturalist 46:66-75.

Cypher, B. L. 2003. Foxes. Pages 511-546 in G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild Mammals of North America: Biology, Management, and Conservation. Second edition. The Johns Hopkins University Press, Baltimore, Maryland.

Cypher, B. L., S. E. Phillips, and P. A. Kelly. 2013. Quantity and distribution of suitable habitat for endangered San Joaquin kit foxes: conservation implications. Canid Biology and Conservation 16:25-31.

Cypher, B. L., K. A. Spencer, and J. H. Scrivner. 1994. Food-item use by coyotes at the Naval Petroleum Reserves in California. The Southwestern Naturalist 39:91-95.

Cypher, B. L., G. D. Warrick, M. R. M. Otten, T. P. O'Farrell, W. H. Berry, C. E. Harris, T. T. Kato, P. M. McCue, J. H. Scrivner, and B. W. Zoellick. 2000. Population dynamics of San Joaquin kit foxes at the Naval Petroleum Reserves in California. Wildlife Monographs 45.

Cypher, B. L., T. L. Westall, K. A. Spencer, D. E. Meade, E. C. Kelly, J. Dart, and C. L. Van Horn Job. 2019. Response of San Joaquin kit foxes to Topaz Solar Farms: implications for conservation of kit foxes. California State University-Stanislaus, Endangered Species Recovery Program, Turlock, California.

Cypher, B. L., T. L. Westall, C. L. Van Horn Job, and E. C. Kelly. 2014. San Joaquin kit fox conservation in a satellite habitat area. California State University-Stanislaus, Endangered Species Recovery Program, Turlock, California.

Ferrel, C. M., H. R. Leach, and D. R. Tillotson. 1953. Food habits of the coyote in California. California Fish and Game 39:301-341.

Germano, D. J., G. B. Rathbun, and L. R. Saslaw. 2012. Effects of grazing and invasive grasses on desert vertebrates in California. Journal of Wildlife Management 76:670–682.

Germano, D. J., and L. R. Saslaw. 2017. Rodent community dynamics as mediated by environment and competition in the San Joaquin Desert. Journal of Mammalogy 98:1615-1626.

Glass, B. P. 1981. Key to the skulls of North American mammals. Oklahoma State University, Stillwater, Oklahoma.

Grinnell, J., D. S. Dixon, and J. M. Linsdale. 1937. Fur-bearing mammals of California. Volume 2. University of California Press, Berkeley, California.

H.T. Harvey and Associates. 2019. California Valley Solar Ranch San Joaquin kit fox monitoring study: final report. H.T. Harvey and Associates, San Luis Obispo, California.

Heisey, D. M., and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. Journal of Wildlife Management 49:668-674.

Koopman, M. E., B. L. Cypher, and D. R. McCullough. 2001. Factors influencing space and prey use by San Joaquin kit foxes. Transactions of the Western Section of the Wildlife Society 37:77-83.

MacCracken, J. G., and R. M. Hansen. 1987. Coyote feeding strategies in southeastern Idaho: optimal foraging by an opportunistic predator. Journal of Wildlife Management 51:278-285.

Moore, T. D., L. E. Spence, and C. E. Dugnolle. 1974. Identification of the dorsal hairs of some animals of Wyoming. Wyoming Game and Fish Department, Cheyenne, Wyoming.

Nelson, J. L., B. L. Cypher, C. D. Bjurlin, and S. Creel. 2007. Effects of habitat on competition between kit foxes and coyotes. Journal of Wildlife Management 71:1467-1475.

Otten, M. R. M., and G. L. Holmstead. 1996. Effect of seeding burned lands on the abundance of rodents and leporids on Naval Petroleum Reserve No. 1, Kern County, California. The Southwestern Naturalist 41:129-135.

Pace, M. L., J. J. Cole, S. R. Carpenter, and J. F. Kitchell. 1999. Trophic cascades revealed in diverse ecosystems. Trends in Ecology and Evolution 14:483–488.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53:7-15.

Roest, A. I. 1986. A key-guide to mammal skulls and lower jaws. Mad River Press, Eureka, California.

Sikes, R. S., W. L. Gannon, and the Animal Care and Use Committee of the American Society of Mammalogists. 2011. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 92:235-253.

Spiegel, L. K., B. L. Cypher, and T. C. Dao. 1996. Diet of the San Joaquin kit fox at three sites in western Kern County, California. Pages 39-52 in L. K. Spiegel, editor. Studies of the San Joaquin kit fox in undeveloped and oil-developed areas. California Energy Commission, Sacramento, California.

U.S. Bureau of Land Management. 2010. Carrizo Plain National Monument Approved Resource Management Plan and Record of Decision. U.S. Department of Interior, Bureau of Land Management, Bakersfield, California.

U. S. Fish and Wildlife Service. 1998. Recovery plan for upland species of the San Joaquin Valley, California. United States Fish and Wildlife Service, Portland, Oregon.

U.S. Fish and Wildlife Service. 2020*a*. San Joaquin kit fox 5-year review: summary and evaluation. U.S. Fish and Wildlife Service, Region 1, Portland, Oregon.

U.S. Fish and Wildlife Service. 2020*b*. Species status assessment report for the San Joaquin kit fox (*Vulpes macrotis mutica*). U.S. Fish and Wildlife Service, Sacramento, California.

Voigt, D. R., and W. E. Berg. 1987. Coyote. Pages 344-357 *in* M. Novak, J. A. Baker, M. E. Obbard and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Toronto, Ontario.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, New York, New York.