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Movements and home ranges of San Joaquin kit foxes (*Vulpes macrotis mutica*) relative to oil-field development

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MOVEMENTS AND HOME RANGES OF SAN JOAQUIN KIT FOXES
(*VULPES MACROTIS MUTICA*)
RELATIVE TO OIL-FIELD DEVELOPMENT

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ABSTRACT.—We examined the effect of oil-field development on movements and patterns of spatial use of San Joaquin kit foxes (*Vulpes macrotis mutica*) on the Naval Petroleum Reserves in California (NPRC) in the San Joaquin Valley. To do this, we compared movements and home ranges of kit foxes from June 1984 to September 1985 in areas developed for petroleum production (30% of native habitat lost to production facilities) and areas with little development (3%). Distances traveled nightly by kit foxes did not differ between levels of petroleum development or between sexes ($P > 0.2$). Mean length of nightly movements during breeding (14.6 km) was longer than during pup-rearing (10.7 km) and pup-dispersal (9.4 km) periods ($P = 0.01$). Mean size of home ranges was 4.6 ± 0.4 ($s_{\bar{x}}$) km² ($n = 21$) and did not differ between levels of petroleum development and sexes ($P > 0.2$). Overlap of home ranges of foxes from the same social group ($78 \pm 4.3\%$) was greater than that of same-sex foxes ($35 \pm 7.8\%$) and males and females of different social groups ($32 \pm 8.0\%$, $P < 0.01$). Overlap of home ranges did not differ between kit foxes inhabiting developed and undeveloped areas ($P > 0.4$). Despite extensive overlap of home ranges, kit foxes on NPRC maintained relatively exclusive core areas, particularly adjacent foxes of the same sex. Future studies should examine which levels of habitat conversion impact spatial use of kit foxes.

Key words: San Joaquin kit fox, *Vulpes macrotis mutica*, home range, movements, spatial organization, oil-field development, San Joaquin Valley.

San Joaquin kit foxes (*Vulpes macrotis mutica*) inhabit the Naval Petroleum Reserves of California (NPRC), an area of intensive petroleum exploration and production in the San Joaquin Valley. Since 1979 the effects of oil-field development on kit foxes have been investigated to identify and minimize adverse impacts to kit foxes and to ensure their continued existence on the NPRC. Oil-field development may affect patterns of space use of kit foxes, including overlap and size of home ranges and use of habitats.

Size of home ranges is influenced by body size and resulting energetic needs (McNab 1963, Harestad and Bunnell 1979, Gittleman and Harvey 1982), but home-range size can be affected by food availability (Harestad and Bunnell 1979). Other studies indicate that size of home ranges of kit foxes (White and Ralls 1993) and red foxes (*Vulpes vulpes*; Macdonald 1981) is not influenced by temporary changes

in prey availability but may be controlled by long-term levels of prey biomass.

Spacing patterns of home ranges, however, may be influenced by short-term changes in prey abundance (White and Ralls 1993). Harris (1986) determined that oil-field development did not affect prey abundance on NPRC, but development altered local distribution of prey. In addition to replacing native habitat with production facilities, development on NPRC affected habitat composition and likely prey availability by increasing shrub cover along roads and pipelines (Warrick and Cypher 1998).

The purpose of this study was to examine kit fox movements, home range size, and spatial patterns of home ranges in developed and undeveloped portions of NPRC. Specific objectives were to (1) determine if the length of nightly movements of kit foxes differed between areas of petroleum development and undeveloped areas; (2) examine the length of

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movements during breeding, pup-rearing, and pup-dispersal periods; and (3) examine the effect of oil-field development on the size and spatial organization of home ranges of kit foxes.

STUDY AREA

Located approximately 42 km southwest of Bakersfield, California, the Naval Petroleum Reserves encompass the moderately steep slopes of Elk Hills and Buena Vista Hills, which are low foothills of the Temblor Range that extend southeast into the San Joaquin Valley (Fig. 1). The 2 foothills are separated by Buena Vista Valley. Elevations range from 88 to 473 m above sea level. We studied kit foxes on 2 areas of NPRC: an area extensively altered by oil-field development located on the southwestern slopes of the Buena Vista Hills and adjacent valley lands (Fig. 1), and an area primarily unaltered by oil-field development located in Buena Vista Valley and portions of the southwestern slopes of Elk Hills (Fig. 1).

Thirty percent of the developed study area is altered by petroleum development (well pads, sumps, roads, pipelines, pipe storage yards, and other facilities). The town of Taft covers approximately 5.1 km² adjacent to the developed study area. An average of 3% of undeveloped study area is altered by oil-field development (pipelines and roads). Exceptions are 2 sections (2.6 km² each) located on the northeastern edge of the area, of which 37% and 21% are altered by oil-field facilities (primarily pipe storage yards and well pads). Warwick and Cypher (1998) provide a detailed description of oil-field development on NPRC.

Vegetation of the study areas is dominated by red brome (*Bromus madritensis*) and red-stemmed filaree (*Erodium cicutarium*), characteristic of the Valley Grassland vegetation type (Heady 1977). Desert saltbush (*Atriplex polycarpa*) is the most common shrub and grows in dense stands along washes and in disturbed areas. Other common shrubs include spiny saltbush (*Atriplex spinifera*), cheesebush (*Hymenoclea salsola*), matchweed (*Gutierrezia bracteata*), and bladderpod (*Isomeris arborea*).

Annual weather patterns consist of hot, dry summers and mild, damp winters. Mean maximum temperatures 42 km east of NPRC in

Bakersfield, California, are 37°C in July and 14°C in January (National Oceanic and Atmospheric Administration 1995). Mean minimum temperatures are 20°C in July and 3°C in January. Mean annual precipitation is 12.5 cm, most (90%) occurring between October and April.

METHODS

We trapped San Joaquin kit foxes in wire-mesh live-traps (38 × 38 × 107 cm) baited with canned mackerel. Most foxes were trapped during semiannual trapping sessions in July 1984 and December 1984, conducted to estimate size of the kit fox population on NPRC (Harris et al. 1987). Additional foxes were trapped at dens during April–June 1984 and 1985, when we attempted to radio-collar foxes from all social groups on the study areas. We weighed, sexed, ear-tagged, and radio-collared each fox.

Radiotelemetry

We monitored kit foxes from July 1984 to September 1985. By taking simultaneous bearings from 1 of 4 pairs of fixed-tower receiving stations (Fig. 1), we triangulated the location of foxes at night, using the null-signal method. The receiving stations were located on hilltops and consisted of two 3-element directional antennas mounted 2 m apart on a 7.6-m-tall mast and connected to a null junction box and radio receiver. We located foxes every 15 minutes during night-long (sunset to sunrise) monitoring sessions. We monitored 10–15 foxes during a session. Foxes in undeveloped habitat were monitored 4–5 nights (generally 1 night/week) per month from June to September 1984 and December 1984 to May 1985. Foxes in developed habitat were monitored 4–5 nights per month from December 1984 to September 1985 (exceptions were 2 foxes in developed habitat that were monitored during June–September 1984 and December 1984–January 1985).

We also located foxes at dens during the day 1–3 times per week, using hand-held antennas. We considered foxes to be paired or belong to the same social group if they frequently shared dens. Foxes that were radio-collared and occupied adjacent areas, but never shared dens, were considered to belong to different social groups.

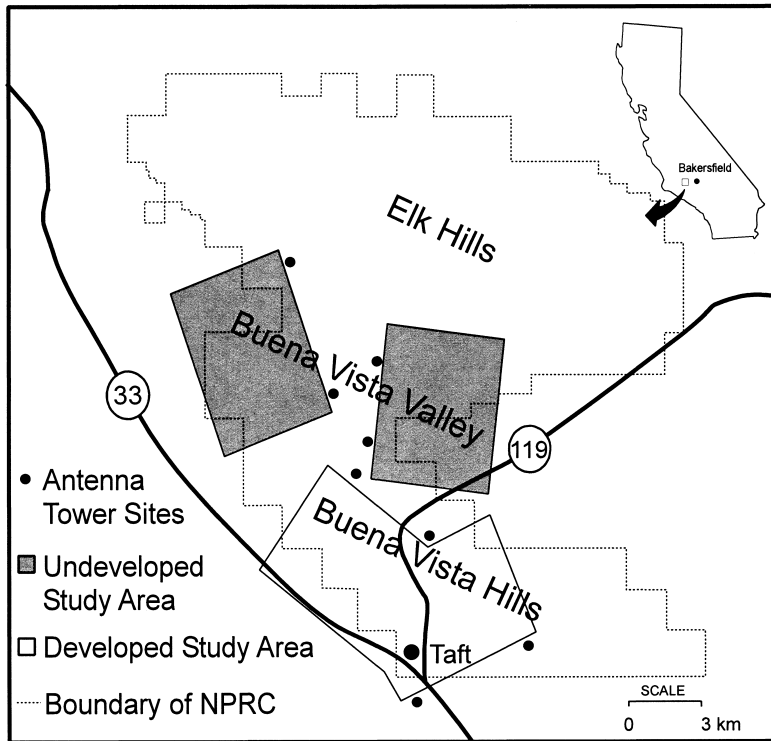


Fig. 1. Location of study areas on Naval Petroleum Reserves in California (NPRC) and area map of the location of NPRC.

To reduce error, triangulated locations composed of bearings intersecting at angles $<30^\circ$ or $>150^\circ$ were eliminated from all analyses. We also discarded all outlier locations (those >2 km from the previous location) identified from visual inspection of locations obtained every 15 minutes during night-long monitoring sessions. Using methods of Lee et al. (1985), we evaluated the accuracy of the radio-tracking system. Bearings taken from towers to surveyed points had standard deviations of 1.0° – 1.7° . We calculated average 95% confidence ellipse areas for fox locations using an average standard deviation of 1.5° and the size of the study areas monitored from each pair of receiving stations (White 1985). Locations of foxes in the undeveloped study area had average 95% confidence ellipse areas ranging from 0.3 to 0.4 km² (accurate within 330–358 m). Locations of foxes on the developed study area had average 95% confidence ellipse areas ranging from 0.2–0.3 km² (accurate within 269–329 m).

Movements

We calculated the distance that a fox moved during a night by summing straight-line lengths between successive locations taken every 15 minutes from sunset to sunrise. When the length of time a fox was monitored was 1–2 hours less than the length of night (because of gaps in the collection of successive 15-minute relocations), we estimated the distance the fox moved during the night by dividing the length moved (km) by the time monitored (hr) and then multiplying by the number of hours from sunset to sunrise. When the length of night was >2 hours longer than duration of the monitoring period (due to logistic, weather, or equipment problems), we combined movements (of the same fox) from 2 different sample periods, obtained within a 2-week period, to estimate the length of nightly movement. Mean lengths of nightly movements estimated from combined samples ($n = 14$) did not differ from means estimated from single-night samples ($n = 17$) for either males or females during

the pup-dispersal period (t tests, $P > 0.10$). Lengths of 3 nightly movements were estimated using distances moved by a fox during portions of 3 different sample periods.

We determined the length of nightly movements during 3 biological periods: breeding (December–mid-February), pup-rearing (mid-February–May), and pup-dispersal (June–September; Zoellick et al. 1987). We examined the length of nightly movements of foxes relative to level of development for pup-dispersal periods of 1984 and 1985. We compared average length of nightly movements between level of development, sex, and the interaction between level of development and sex using analysis of variance (ANOVA). In addition, for foxes inhabiting developed areas, we compared length of nightly movements among biological periods, between sexes, and the interaction between biological period and sex using ANOVA. To avoid pseudoreplication, lengths of nightly movements were treated as subsamples. Average distances traveled nightly by individual foxes (for a given biological period and level of development) were used in ANOVAs examining the length of nightly movements. Repeated-measures ANOVA was not used to compare length of movements among biological periods because most (8 of 10) foxes were present during only 1 or 2 of the 3 periods sampled. The Tukey-Kramer HSD test was used to examine differences in pairs of means.

Home Ranges

We used program HOME RANGE (Ackerman et al. 1990) to estimate size of home ranges using the 100% minimum convex polygon (MCP) method (Hayne 1949), and to estimate size of core home range areas using the harmonic mean method (Dixon and Chapman 1980). Core areas were defined as the area within the 50% isopleth of the harmonic mean (Spencer and Barrett 1984, White and Ralls 1993). For harmonic mean calculations, we used a scale of 609.6 and a grid size of 72×32 (Gallerani Lawson and Rodgers 1997). We also estimated size of home ranges using the grid-cell method (Rongstad and Tester 1969, Voight and Tinline 1980, Laundre and Keller 1981) from the number of 0.04-km^2 ($200 \times 200\text{-m}$) grid cells (Zoellick and Smith 1992) entered by a fox. We calculated grid-cell home ranges to examine whether convex polygons overestimate home-range size by including substantial

areas of non-use. We determined the number of nightly sample periods or locations needed to adequately sample home range with area observation curves (Odum and Kuenzler 1955). We examined the percent change in the size of MCP home ranges that occurred with the addition of locations collected during full-night sample periods. By the 5th nightly sample, area observation curves increased $<5\%$. Therefore, we assumed that sequential locations from 4 to 5 nightly samples (172–215 locations) were sufficient to estimate size of home ranges.

Home ranges were calculated using all locations collected within a 1-year period (generally November 1984–September 1985 for foxes in developed areas and June 1984–May 1985 for foxes in undeveloped areas). Estimates of home range sizes were based on a mean of 409 locations/fox ($n = 9$, range = 271–820) in undeveloped areas and 550 locations/fox ($n = 12$, range = 165–1109) in developed areas.

Using 2-way ANOVA, we compared sizes of home ranges and core areas between foxes inhabiting undeveloped and developed areas and between sexes. Percent overlap of core areas and home ranges was calculated for foxes of the same social group and for foxes of different, but adjacent, social groups using the method of Macdonald et al. (1980). Percent overlap of home ranges and core areas was arcsine transformed. We used t tests to examine differences in overlap of core areas and home ranges of foxes inhabiting undeveloped and developed areas.

Oil-field Development

We estimated the percentage of land area affected by oil-field development (e.g., well pads, sumps, roads, pipelines, pipe storage yards, production facilities) for each quarter section (65 ha) of NPRC by overlaying transparent dot grids (Mosby 1980) on 1:10,000 scale aerial photographs taken in 1983. We considered kit foxes to occupy developed habitat if their home ranges had $>15\%$ land alteration from oil-field development.

RESULTS

Between June 1984 and May 1985, we studied 13 adult kit foxes (2 pairs, 2 females cooperatively rearing pups, and 7 foxes from

different social groups) on the undeveloped study area. Nine kit foxes (4 males, 5 females) were monitored from June to September 1984, while 4 kit foxes (3 males, 1 female) were monitored from June 1984 to May 1985. Two kit foxes (1 male, 1 female) were assigned to developed habitat because their home ranges included areas of oil-field development in the northeastern corner of the study area. During December 1984 to September 1985, we studied 10 adult kit foxes (3 males, 7 females; all from different social groups) on the developed study area. Additional adult kit foxes were radio-collared on the study areas (4 on the undeveloped and 12 on the developed area), but they were located too infrequently to estimate home ranges or length of movements.

Movements

We determined the length of 52 nightly movements of 11 kit foxes (6 males, 5 females) inhabiting undeveloped areas, and of 73 nightly movements of 10 foxes (4 males, 6 females) in developed areas (Table 1). Lengths of nightly movements of kit foxes were sampled primarily during pup-dispersal, particularly for foxes inhabiting undeveloped areas (Table 1). Lengths of nightly movements did not differ between undeveloped and developed areas ($F_{1,12} = 1.52, P = 0.24$) or between male and female foxes ($F_{1,12} = 1.7, P = 0.3$), and interaction between development and sex was not significant ($F_{1,12} = 1.41, P = 0.26$).

Lengths of nightly movements of foxes in developed areas (Table 1) differed among biological periods ($F_{2,14} = 6.39, P = 0.01$), but not between sexes ($F_{1,14} = 0.36, P = 0.56$). The interaction between sex and biological period was not significant ($F_{2,14} = 0.66, P = 0.53$). Average length of nightly movements

during the breeding period ($14.6 \pm 1.1 [s_{\bar{x}}]$ km, $n = 6$) was greater than during pup-rearing (10.7 ± 1.0 km, $n = 7$) and pup-dispersal periods (9.4 ± 1.1 km, $n = 6$; $P < 0.05$). Lengths of nightly movements did not differ between pup-rearing and pup-dispersal ($P = 0.66$).

Home Ranges

HOME-RANGE SIZE.—MCP home range size of kit foxes averaged 4.6 ± 0.4 km² ($n = 21$) and did not differ between developed (4.8 ± 0.7 km², $n = 12$) and undeveloped areas (4.3 ± 0.5 km², $n = 9$; $F_{1,17} = 0.84, P = 0.37$) or between sexes ($F_{1,17} = 1.61, P = 0.22$). Size of MCP home ranges averaged 5.2 ± 0.9 km² ($n = 9$) for males and 4.2 ± 0.4 km² ($n = 12$) for females. Home ranges calculated with the grid-cell method averaged 4.3 ± 0.3 km² ($n = 21$) in size and did not differ from MCP estimates ($F_{1,40} = 0.34, P = 0.56$). Size of grid-cell home ranges averaged 4.7 ± 0.6 km² ($n = 9$) for males and 4.0 ± 0.3 km² for females ($n = 12$).

Size of core areas averaged 1.2 ± 0.1 km² ($n = 21$) and did not differ between foxes inhabiting developed (1.2 ± 0.2 km², $n = 12$) and undeveloped areas (1.2 ± 0.2 km², $n = 9$; $F_{1,17} = 0.02, P = 0.9$) or between sexes ($F_{1,17} = 0.49, P = 0.49$). Size of core areas averaged 1.3 ± 0.1 km² ($n = 9$) for males and 1.1 ± 0.1 km² for females ($n = 12$).

SPATIAL ORGANIZATION.—Overlap of home ranges calculated with the MCP method for male and female foxes of different social groups averaged $37.9 \pm 5.2\%$ ($n = 30$) and did not differ between developed areas ($40.2 \pm 6.6\%$, $n = 22$) and undeveloped areas ($31.6 \pm 8.0\%$, $n = 8$; $t_{28} = 0.9, P = 0.4$). Home ranges of same-sex foxes from different social groups overlapped an average of $33.4 \pm 3.9\%$ ($n = 26$) and did not differ between developed ($32.9 \pm$

TABLE 1. Length of nightly movements (km) of San Joaquin kit foxes in undeveloped and developed areas of the Naval Petroleum Reserves in California during pup-dispersal, breeding, and pup-rearing periods; number of foxes (n_f); and number of nightly movements sampled (n_n), 1984–85.

Period ^a	Developed areas								Undeveloped areas							
	Males				Females				Males				Females			
	\bar{x}	$s_{\bar{x}}$	n_f^b	n_n	\bar{x}	$s_{\bar{x}}$	n_f	n_n	\bar{x}	$s_{\bar{x}}$	n_f	n_n	\bar{x}	$s_{\bar{x}}$	n_f	n_n
Pup-dispersal	8.0	1.7	2	12	10.7	1.1	5	22	10.9	1.3	4	27	10.8	1.1	5	20
Breeding	14.6	1.5	3	6	14.6	1.5	3	5	15.5	2.6	2	2				
Pup-rearing	10.9	1.5	3	12	10.5	1.3	4	16	13.6	0.9	2	3				

^aPup-dispersal = June–September, breeding = December–mid-February, pup-rearing = mid-February–May.

^bAverage distance traveled nightly by an individual fox (for a given biological period and level of development) was the sample unit used for statistical analyses.

4.6%, $n = 20$) and undeveloped areas ($35.0 \pm 7.8\%$, $n = 6$; $t_{24} = 0.2$, $P = 0.8$). Overlap of home ranges of males and females and same-sex foxes from different social groups, calculated with the MCP method, averaged $35.8 \pm 3.3\%$ ($n = 56$). Home ranges calculated with the grid-cell method for those foxes overlapped an average of $32.7 \pm 2.8\%$. No kit foxes belonging to the same social group were adequately monitored in developed areas to calculate overlap of their home ranges.

Overlap of home ranges of kit foxes in undeveloped areas calculated with the MCP method differed among foxes belonging to the same social group, same-sex foxes, and males and females from different social groups ($F_{2,17} = 11.89$, $P = 0.001$). Average overlap of home ranges was greater ($P < 0.01$) for foxes belonging to the same social group ($77.7 \pm 4.3\%$, $n = 6$) than between same-sex foxes from different social groups ($35.0 \pm 7.8\%$, $n = 6$) and males and females from different social groups ($31.6 \pm 8.0\%$, $n = 8$). Overlap did not differ between same-sex foxes and males and females from different social groups ($P = 0.9$). Overlap data for foxes belonging to the same social group included 2 females who cooperatively raised a litter of pups in 1984 and 2 known mated pairs.

Core areas were relatively exclusive for kit foxes of the same sex (Fig. 2). Core areas of male and female foxes from different social groups often overlapped, with overlaps averaging $14.4 \pm 4.3\%$ ($n = 30$). Overlap of core areas did not differ between foxes inhabiting developed ($12.8 \pm 5.4\%$, $n = 22$) and undeveloped areas ($19.0 \pm 6.4\%$, $n = 8$; $t_{28} = 1.284$, $P = 0.26$).

DISCUSSION

Movements

The lengths of nightly movements of kit foxes from this study (11.5 ± 0.5 km for all biological periods, $n = 38$) were 18% shorter than those of kit foxes in western Arizona (Zoellick et al. 1989). Available prey biomass was substantially lower in Arizona than in the San Joaquin Valley (Zoellick and Smith 1992), which likely contributed to the difference in length of movements between the 2 areas. Length of nightly movements of kit foxes from this study was longer during the breeding period, similar to that of male kit foxes in western Arizona

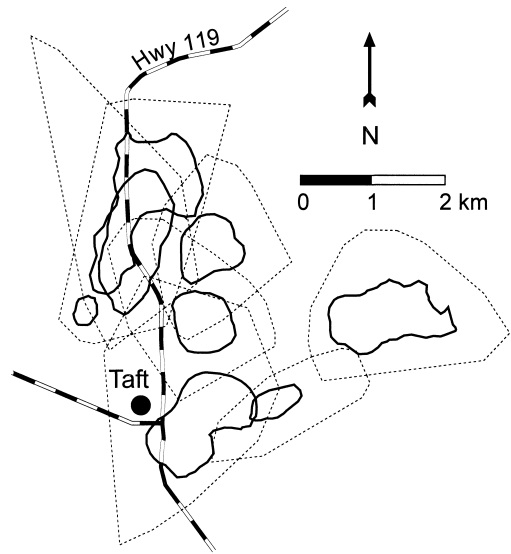


Fig. 2. Spatial arrangement of the home ranges (dashed lines) and core areas (solid lines) of 7 female kit foxes in developed areas of the Naval Petroleum Reserves in California, 1984–85. Home ranges were plotted using the minimum convex polygon method, and core areas were plotted using the 50% isopleth of the harmonic mean method.

(Zoellick et al. 1989). Visits by males to dens of other pairs of kit foxes increased the length of nightly movements during the breeding period of kit foxes in western Arizona (Zoellick et al. 1989). Kit foxes on NPRC were primarily nocturnal (Morrell 1972). The longer night length during the breeding period (December to February) also probably contributed to the increase in length of movements by allowing kit foxes to be active for a longer period of time.

Length of movements did not differ between kit foxes inhabiting developed and undeveloped areas of NPRC likely because oil-field development did not impact the abundance of prey species. Lagomorphs were the primary prey of kit foxes on NPRC during 1984–85 (Cypher et al. 2000). Densities of lagomorphs did not differ between developed and undeveloped study areas, averaging 103/km² during 1984–85 (O'Farrell et al. 1987).

Kangaroo rats (*Dipodomys* spp.) were also frequent prey of kit foxes during 1984–85 (ca 20% occurrence in diet; Cypher et al. 2000). Small mammals were common on both the developed and undeveloped study area in

1984 (capture probabilities of 25–35%; O'Farrell et al. 1987, Scrivner et al. 1987), but they may have been less abundant in 1985 because precipitation was lower in 1984 (13.4 cm) than in 1983 (25.3 cm). Cypher et al. (2000) reported small mammal abundance on NPRC was related to the previous year's precipitation between 1985 and 1995. Any year differences in small mammal abundance would have been additive to the effect of oil-field development; most data from kit foxes in developed areas were collected in 1985 when small mammals likely were less abundant. Yet, no differences in movements and home range use were observed between levels of oil-field development, similar to the findings of Spiegel and Bradbury (1992) for an oil field near NPRC.

Home Ranges

Home ranges of kit foxes in this study and in western Utah (3.1 km²; O'Neal et al. 1987) were significantly smaller than those of San Joaquin kit foxes on the Carrizo Plain in California (11.6 km²; White and Ralls 1993) and in western Arizona (11.2 km², $P < 0.001$; Zoellick and Smith 1992). As discussed by White and Ralls (1993) and Zoellick and Smith (1992), home-range size differs depending on prey availability. Lagomorph densities and overall prey biomass on NPRC were substantially greater than in western Arizona and on the Carrizo Plain in California (Zoellick and Smith 1992, White and Ralls 1993), and similar to those in western Utah (O'Neal et al. 1987). Home ranges of kit foxes in nearby Midway Valley in California (6.1 ± 0.45 km², $n = 26$; Spiegel and Bradbury 1992) were similar to those of kit foxes on NPRC. Midway Valley had plant communities similar to those of NPRC and presumably similar prey availability. Morrell (1972) also studied kit foxes in Buena Vista Valley and estimated size of home ranges to be 2.6–5.2 km², similar to this study.

Size of home ranges can be influenced by differences in density and social structure (Jewell 1966, Brown and Orians 1970, Schoener 1981). Kit fox density was similar between developed and undeveloped areas during the period of study. Fox density on the developed study area was estimated at 1 fox/1.0 km² during winter 1984 using a closed population model and at 1 fox/1.8 km² during summer 1985 from the minimum population size

(O'Farrell et al. 1987). Fox density in Buena Vista Valley during summer and winter 1984 was estimated to be 1 fox/1.3 km² and 1 fox/1.8 km², respectively, from closed population models (Harris et al. 1987). A minimum fox density of 1 fox/1.8 km² was estimated for summer 1985 in Buena Vista Valley (Harris et al. 1987).

Large overlaps of home ranges of kit foxes from different social groups on NPRC (averaging 36%) indicated entire home ranges were not defended from other kit foxes, either in undeveloped areas or areas of oil-field development. Morrell (1972) observed family groups hunting in the same area of Buena Vista Valley, but not at the same time. Although core areas of foxes in this study were fairly exclusive for same-sex foxes from different social groups, they overlapped an average of 14% for males and females from different social groups. Home ranges of San Joaquin kit foxes in nearby Midway Valley (Spiegel and Bradbury 1992) and on the Carrizo Plain (White and Ralls 1993) also overlapped somewhat, but both studies found that core areas were fairly exclusive for kit foxes of different social groups.

Because kit foxes on NPRC did not defend their entire home ranges from other social groups, more than 1 kit fox or pair of kit foxes could use a local food source or other resources. This may partly explain why conversion of 30% of the native habitat to oil-field facilities had little effect on movements and size of home ranges of kit foxes. Additionally, White and Ralls (1993) found that the size of home ranges of kit foxes on the Carrizo Plain in California did not change during periods of drought-induced alterations in prey abundance. Instead, overlap of home ranges of adjacent, same-sex foxes decreased. In this study overlap of home ranges did not differ between levels of oil-field development.

Overlap of home ranges of foxes from different social groups is dependent on resource availability (White and Ralls 1993). In productive, diverse habitats such as those on NPRC, kit foxes decrease the size of their home ranges and maintain less exclusive home ranges than in habitats with lower prey availability. Where prey biomass and densities of kit foxes were relatively low (1 fox per 4.1–6.5 km²; Zoellick and Smith 1992, White and Ralls 1993), overlap of home ranges of adjacent same-sex foxes

was 2–3 times less than on NPRC. Additionally, White and Ralls (1993) found increased spacing among kit foxes during a drought-related decrease in prey abundance.

The significantly smaller home ranges on NPRC, compared to the size of home ranges in other portions of the geographic range of the kit fox, indicate that NPRC lands provide some of the highest quality habitat remaining for kit foxes in the San Joaquin Valley. Conversion of 30% of the native habitat on developed portions of NPRC to petroleum-production facilities has not reached a threshold where lagomorph numbers (Harris 1986, Warrick and Cypher 1998) and movements and home ranges of kit foxes are impacted by habitat loss. Increased spacing among social groups may be the initial response of kit foxes to declines in prey abundance caused by more extensive levels of habitat conversion. Future studies should examine which levels of habitat loss due to oil-field development alter movements and use of home ranges by kit foxes.

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