SPACE USE AND MOVEMENTS BY KIT FOX FAMILY MEMBERS

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ABSTRACT: We investigated home range and movement patterns by members of San Joaquin kit fox (*Vulpes macrotis mutica*) family groups at the Naval Petroleum Reserves in California in 1994 by monitoring radio-collared foxes. Our objective was to gain insights on kit fox social ecology. Home range and core area size was similar between adult males and females, but larger for adults compared to pups. Adult males exhibited higher movement rates than adult females, and adult rates were higher than pup rates. Kit fox family members moved around their common home ranges independently; family members were located within 150 m of each other <12% of the time. Low affiliative behavior is common among canids that use small prey, possibly because cooperative hunting strategies are not required.

Key words: San Joaquin kit fox, *Vulpes macrotis mutica*, home range, core area, movements, social ecology, California, endangered species

2001 TRANSACTIONS OF THE WESTERN SECTION OF THE WILDLIFE SOCIETY 37:84-87

Although various aspects of endangered San Joaquin kit fox (*Vulpes macrotis mutica*) ecology have been investigated, the social ecology of this taxon is not well understood. In particular, little information is available on relative space use by members of kit fox social groups. Investigating patterns of relative space use by family members can provide insights into intrafamilial resource partitioning and how young achieve independence and gain experience. Information on social ecology can contribute to understanding population dynamics and space requirements which subsequently can be used to develop effective conservation strategies.

We investigated home range and movement patterns by members of San Joaquin kit fox family groups at the Naval Petroleum Reserves in California (NPRC). Specifically, we compared home range size, core area size, and movement rates between adults and their pups, and also examined the relative proximity of family members during nightly movements.

STUDY AREA

The 313-km^2 NPRC is located in the southwestern portion of the San Joaquin Valley of California about 42 km southwest of Bakersfield. The NPRC encompasses the Elk Hills and Buena Vista Hills and surrounding alluvial plains and valleys. Elevations range from 88 m to 473 m. Primary land use on the NPRC is oil and gas production, but large portions of the study area remain largely undisturbed (Warrick and Cypher 1998). Sheep are grazed intermittently on some portions of the study area.

Regional weather patterns consist of hot, dry summers and cool, damp winters (National Oceanic and Atmospheric Administration 1995). Mean daily maximum and minimum temperatures were 37°C and 20°C, respectively, in July, and 14°C and 3°C, respectively, in January. Precipitation averaged about 15 cm annually and primarily occurred between October and April. The vegetation community within NPRC was classified formerly as Lower Sonoran Grassland (Twisselmann 1967) or Valley Grassland (Heady 1977), and more recently as Allscale Series (Sawyer and Keeler-Wolf 1995). Desert saltbush (*Atriplex polycarpa*) was the dominant shrub, and other shrubs present included spiny saltbush (*A. spinifera*), cheesebush (*Hymenoclea salsola*), bladderpod (*Isomeris arborea*), and matchweed (*Gutierrezia californica*). Herbaceous vegetation was dominated by red brome (*Bromus madritensis*) and red-stemmed filaree (*Erodium cicutarium*).

METHODS

We examined space use by kit foxes at 5 sites within NPRC (see Koopman et al. 2001). These locations were chosen based on the presence of radio-collared kit foxes that were being monitored as part of an on-going demographic study of kit foxes at NPRC (Cypher et al. 2000).

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We monitored nocturnal kit fox movements using portable null-peak telemetry stations. Each station consisted of two 3-element Yagi antennas set 2 m apart on a crossbar mounted on a 6-m mast. One station was mounted on a truck and the other was freestanding. Bearings were determined using a compass rosette and pointer attached to the mast. Prior to monitoring sessions, the stations were placed at locations whose coordinates had been determined using a global positioning system (GPS) unit. The compass rosettes were oriented using transmitter beacons placed in known locations. Bearings were taken hourly on beacons to measure location error. Mean (± SE) location error was 0.96° ± 0.07°.

We monitored foxes during 4-5 hr sessions beginning at sunset. Kit foxes exhibit increased activity during this period (Morrell 1972, Zoellick 1990). During each monitoring session, we collected bearings at 15-minute intervals on all foxes in a given area. To reduce error due to movement of foxes, locations based on compass bearings taken >3 min apart were excluded from analyses. The average time interval (± SE) between bearings from the 2 stations was 21 ± 2.4 seconds. We calculated coordinates for fox locations from paired bearings using the program Locate II (Pacer, Truro, Nova Scotia, Canada). This program automatically removed paired bearings that intersected at angles <20° or >160°. Fox locations with 95% error ellipses (10 ha also were removed from the data set.

We included kit foxes with more than 75 locations in home range analyses. We estimated 100% minimum convex polygons and 75% harmonic mean isopleths (Dixon and Chapman 1980) using the program CALHOME (Kie et al. 1996). The 75% harmonic mean isopleths were considered estimates of core areas within home ranges (Dixon and Chapman 1980). Locations gathered at 15-min intervals frequently are autocorrelated (Swihart and Slade 1985*a*), and autocorrelation was detected in our data. However, Gese et al. (1990) found that coyote (*Canis latrans*) home ranges estimated from sequential locations were not significantly different from those estimated from point locations, even when the sequential locations were autocorrelated. Also, non-statistical home range estimators, such as the minimum convex polygon method, may be less sensitive to the effects of autocorrelation (Swihart and Slade 1985*b*). Therefore, we used the sequential locations to estimate home range size, which also facilitated comparison to previous home range estimates for kit foxes at NPRC (Zoellick et al. in press).

To determine movement rates of kit foxes, we plotted sequential locations for each fox. The straight-line distance between successive locations was measured and divided by the elapsed time between the locations to estimate the rate of movement (m/min). To examine relative movements by members of a particular family group, we measured the distance between locations obtained for members at a given point in time.

We compared home range size between adults and pups (age <1 year) and between sexes for adults using Mann-Whitney *U*-tests. We used Student's *t*-tests to compare mean movement rates between sexes for both adults and pups.

RESULTS

From June to September 1994, home range and core area sizes were determined for 11 kit foxes: 8 adults and 3 pups. Family groups monitored consisted of a mated pair of adults and their pup, one set of sibling pups, and an adult female and her 2 pups. Mean home range size (± SE) of adults (433.7 ± 142.5 ha) was significantly larger (U = 24, 1 df, P <0.01) than that of pups (131.7 ● 25.0 ha). Mean core area size (± SE) of adults (134.0 ± 37.6 ha) also was significantly larger (U = 23, 1 df, P = 0.03) than that of pups (47.0 ± 10.0 ha). Mean home range and core area size did not differ between adult males and females (home range: U = 5, 1 df, P =0.46; core area: U = 6, 1 df, P = 0.66).

Mean (± SE) movement rates for adult and pup foxes were 23 ± 1 m/min and 15 ± 1 m/min, respectively. The mean rate for 3 adult males (26 ± 1 m/min) was significantly higher (t = 3.69, 702 df, P <0.01) than the rate for 5 adult females (21 ± 1 m/min). The mean rate for 1 female pup was 19 ± 2 m/min while the rate for 2 male pups was 13 ± 1 m/min.

In general, movements by related foxes appeared to be relatively independent. Pups were located within 150 m of their mothers on 11.1% of occasions, and within 150 m of their fathers on 4.3% of occasions. Sibling pups were located within 150 m of each other on 10.8% of occasions. Members of a mated pair were located within 150 m of each other on only 3.1% of occasions.

DISCUSSION

Although our data set was limited in the number of foxes and study duration, it provided insights into space use patterns within kit fox family groups. Kit fox pups used smaller home ranges and core areas than adults. This was not a function of pups remaining at den sites while adults foraged because during the period of study, pups would have been 4-7 mo old and would have been foraging for themselves (Morrell 1972, O'Neal et al. 1987). The discrepancy in home range and core area size between adults and pups also was not a function of energetics. At age 4-7 mo, pups would have achieved 70-80% of adult mass (Warrick and Cypher 1999), yet on average were only using an area about 30% the size of that used by adults. Possibly, the larger area used by adults was related to home range maintenance activities. Adults may have been traversing and marking an area of sufficient size to meet annual resource needs. At 4-7 mo of age, pups may not engage in such behavior and may limit activities to an area sufficient to satisfy daily foraging requirements. O'Neal et al. (1987) reported smaller home ranges for pups compared to adults in Nevada during July-November. Spiegel et al. (1996) reported that adult and pup home ranges were similar in size, but they monitored pups to a much older age (1 yr).

Based on home range and core area size for adult male and female kit foxes, space use patterns of both sexes were similar. Space use was found to be similar between adult males and females in other studies (O'Neal et al. 1987, White and Ralls 1993, Zoellick et al. in press). This is consistent with predictions for a species with a monogamous mating system and strong pair bonds (e.g., Bowen 1982).

The higher movement rates for adult males compared with adult females observed at NPRC also were observed among kit foxes in Arizona (Zoellick et al. 1989). The reason for this is unclear. In the Arizona study, greater movements by males were attributed to increased activity by males during the breeding season (Zoellick et al. 1989). However, our study period did not overlap with the kit fox breeding season (late fall - early winter). Movement rates among males could be higher simply because they are structurally larger than females (Grinnell et al. 1937, O'Neal et al. 1987). The higher rates among males also might indicate that they visit a greater proportion of the home range on a given night, perhaps engaging in home range maintenance activities. Similarly, the reasons for the higher rates among adults compared to pups also are unclear. Again, this could be a function of the size differences between adults and pups, or the larger home range used by adults.

Kit fox social groups exhibited relatively low rates of affiliative behavior during nightly activities. This is an interesting contrast to the communal denning frequently observed during the day by mated pairs, parents and young, and siblings (Koopman et al. 1998). Our results indicate that although kit fox family members share space, concurrent use is infrequent. Instead, family members appear to move about their common home range independently, as has also been reported by O'Neal et al. (1987) and White et al. (2000). Small canids typically forage for relatively small prey and therefore do not exhibit cooperative hunting strategies (Moehlman 1986). Consistent with this generalization, the kit foxes in our study consumed primarily kangaroo rats (*Dipodomys* spp.) supplemented by leporids, insects, and reptiles (Koopman et al. submitted). Also, pups apparently only accompany their parents for a short time when learning to hunt. O'Neal et al. (1987) observed that kit fox pups in Nevada hunted with their parents for 1 week, after which they hunted on their own.

ACKNOWLEDGEMENTS

Funding and other support were provided by the Wildlife Graduate Student Fund and the A. Starker Leopold Endowed Chair at the University of California at Berkeley, the U.S. Department of Energy, Chevron U.S.A., Bechtel Petroleum Operations, Inc., EG&G Energy Measurements, Inc., Enterprise Advisory Services, Inc., and Critique, Inc. C. Liang and H. McQuillan provided field assistance. M. Scott provided GIS assistance. R. Barrett and S. Haddock provided valuable input on study design. We thank L. Chow and 2 anonymous reviewers for helpful comments on the manuscript.

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