THE SAN JOAQUIN KIT FOX IN NORTH-CENTRAL CALIFORNIA: A REVIEW

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Abstract: There is a significant need to determine the current status of the San Joaquin kit fox in the northern extent of its range. The last peer-reviewed account of this question was addressed in 1993. Here we report our findings of an extensive literature review of the San Joaquin kit fox in the northern range and status conclusions extrapolated from these reviews. Possible reasons for lack of a robust kit fox population in the northern range may include lack of the preferred Heteromyid prey item, higher predatory pressures, and lack of new immigrant foxes from southern core populations. Various characteristics lead to this prediction; namely, the fox occurs at a high trophic level, exhibits a low population density, has a relatively slow life history, and utilizes a small geographic range isolated from larger populations. Other risk factors can be accounted for by anthropogenic activities that have an effect on the fox irrespective of the fox's ecology, charactering the northern range as a sink population for the San Joaquin kit fox and susceptible to localized extirpation.

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The San Joaquin kit fox (*Vulpes macrotis mutica*) was first described and named by C. H. Merriam from a specimen collected near Tracy, San Joaquin County (Merriam 1902). There are few records of kit foxes in the northern portion of the range from the early 1900s and by 1937, Grinnell et al. (1937) reported that kit foxes were probably extirpated from this area. Historically, the San Joaquin kit fox occupied valley and foothill grasslands, arid shrub habitats, and oak savanna communities in the greater San Joaquin and Salinas valleys in California (USFWS 1998). The northern San Joaquin Valley was most likely once a vast riparian forest and tule marsh (USFWS 1998); kit foxes normally would not inhabit such a habitat type since they are a desert-adapted species and probably only occurred within the grasslands along the western foothills. From 1900 to the 1940s, conversion of tule marsh and riparian forest to agriculture occurred in the northern San Joaquin Valley, and the kit fox probably did not occupy these agricultural fields in significant numbers, if at all (Kelly et al. 2005). The San Joaquin kit fox was designated as endangered and protected under the federal Endangered Species Act in 1967 and as threatened by the State of California in 1971.

Kit foxes use areas with sparse ground cover and loose-textured soils (Morrell 1972). However, more than 95% of the potential habitat for kit foxes on the San Joaquin Valley floor has been converted to irrigated agriculture or has been urbanized, displacing the kit fox to marginal habitat where densities were historically low (USFWS 1998). Agricultural, industrial, and urban developments, including the development of water and transportation infrastructures, have resulted in habitat loss, fragmentation, and degradation (USFWS 1998). A direct result of the development of native habitat is the fragmentation of the landscape, which limits dispersal, recruitment, and genetic flow between populations (Schwartz et al. 2005).

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As of 2006, the majority of the kit fox population occurred in the southern San Joaquin Valley. However, satellite populations and individuals also occur on the western edge of the San Joaquin Valley extending nearly to Antioch, Contra Costa County, California (Bell 1994). The status of the kit fox in the northernmost extent of its range has remained relatively unknown; however, several sightings have occurred which indicate that kit foxes have either recolonized the area or were present throughout the period, but the population had dropped below detectible numbers. The northernmost extent of San Joaquin kit fox range is defined within this paper as points north of Santa Nella, Merced County, California, between the western edge of the San Joaquin Valley floor, and the eastern edge of the coast range foothills. The northernmost point is the Black Diamond Mines Regional Preserve, Contra Costa County (37° 57' N, 121° 51' W; East Bay Regional Park District).

Herein we summarize existing information concerning the status and distribution of the San Joaquin kit fox in the northern San Joaquin Valley, California. We describe northern range kit fox distribution, habitat, prey base, restrictions to kit fox movements, and competition with other carnivores and raptors. We examine each of these ecological components in an attempt to explain why the San Joaquin kit fox is having difficulty surviving within the northern range landscape, and recommend future research objectives.

SUMMARY OF NORTHERN RANGE KIT FOX RESEARCH

Distribution

Much of the past research on kit foxes in the northern range had focused mainly on occurrences of kit foxes in order to determine its distribution and the limits of its range Over the past several decades the range of the San Joaquin kit fox has been shifted and adjusted as more information is gathered. New sightings led to a northward range expansion. Laughrin (1970a, b) initially reported that the northernmost range limit was west of Los Baños, Merced County. He was the first to hypothesize that populations may be building in the foothill areas and in some of the drier Coast Range valleys adjacent to the San Joaquin Valley due to the conversion of kit fox habitat to cropland; however, there is no evidence to support this claim (USFWS 1998). Later research cataloged several kit fox sightings during the 1970s in Contra Costa County, although local residents recalled seeing kit foxes during the 1950s (Jensen 1972). Kit foxes were observed on the Bonde Ranch, south of Byron, in 1969 and 1970 (Jensen 1972). In 1969, a kit fox was detected on Corral Hollow Road, and a road killed kit fox was found at the intersection of Corral Hollow Road and Interstate 580 in 1971 (Jensen 1972).

Further research by Swick (1973) also reported sightings of kit foxes in Contra Costa County between 1967 and 1973. He concluded that the range of the kit fox in Contra Costa County was limited to the southeastern portion, extending approximately 3.0 km north and 6.5 km west of Byron. Sharp habitat differences in Contra Costa, Alameda, and San Joaquin counties, including coastal mountains to the west, the San Joaquin delta and intensive agriculture to the north, and the California Aqueduct and Delta-Mendota Canal to the east all serve to restrict the range of the kit fox. At the time, it was not known if the populations in Contra Costa County and Merced County were connected by means of a corridor (Jensen 1972), though Swick concluded that kit fox populations in this extended area appeared to be dependent on a narrow strip of grassland habitat between the coastal mountains and the California Aqueduct and Delta-Mendota Canal. Approximately 600 kit foxes were estimated to occur in three northern counties (Alameda, Contra Costa, and San Joaquin), but this figure may have been overestimated (Swick 1973). Comparatively, in 1970, the range-wide population was estimated at 1000-3000 foxes (Laughrin 1970a) and by 1975, the population was estimated at 10,000 to nearly 15,000 adult animals (Morrell 1975).

Only two investigations by the California Department of Fish and Game (CDFG) in 1983 have focused on kit foxes in the northern range since Swick (1973). The Los Vaqueros Reservoir project and the Bethany Reservoir Wind Turbine project both focused on the same group of kit foxes in the same general area. Orloff et al. (1986) summarized the data collected during these studies. The Los Vaqueros and Bethany study sites were located in eastern Contra Costa and Alameda counties and, at the time, were considered the northern extreme of the accepted range for the San Joaquin kit fox. The presence of kit fox was confirmed in Alameda County when 8 kit foxes were captured and radio-collared near the Bethany Reservoir (Orloff et al. 1986). However, the Los Vaqueros and Bethany Reservoir studies, as well as 15 other surveys for proposed wind farm developments, were unsuccessful in determining the presence of kit fox in Contra Costa County, although kit foxes were sighted in Contra Costa County up to 1973 (Swick 1973). Orloff et al. (1986) hypothesized that the kit fox population in Contra Costa County was extirpated locally due to the California ground squirrel (*Spermophilus beecheyi*) eradication program. Kit foxes were sighted near the Midway Substation and at the Carnegie New Town on the San Joaquin and Alameda County border, though Orloff et al. (1986) were uncertain if the Bethany population and the Midway Substation/Carnegie New Town population were connected by means of a travel corridor.

Since 1983, no kit foxes have been detected in northern Alameda County. Weslar (1992) confirmed the presence of the same population of 8 kit foxes at the Bethany Reservoir (Orloff et al. 1986) in northeastern Alameda County, although 6 of the 8 kit foxes experienced mortality by the end of the study in 1983. In studies conducted in 1987, Weslar (1992) detected 21 kit foxes in the proposed Carnegie New Town project, but found no evidence of kit fox from the Alameda County line to 5 km into the corridor connecting Stanislaus County in the south to Alameda County in the north, suggesting that the corridor is becoming narrower. These surveys were also unable to detect kit foxes in the areas around Byron, Camp Parks Training Area, and the San Ramon Valley. Weslar concluded that in the northern range, kit foxes were restricted to a narrow corridor through 9 counties (from Kings to Contra Costa County), and surveys suggested that the distribution of kit fox in these 9 counties were most likely shrinking. In 1986, the northernmost extent of this species was believed to be northeastern Alameda County (Orloff et al. 1986).

Studies since Orloff et al. (1986) have re-confirmed kit fox presence in Contra Costa County, specifically north of Bethany Reservoir in eastern Contra Costa County, east of the Altamont Hills. Sproul and Flett (1993) reviewed existing literature up to 1993 and other published and unpublished data on the kit fox in the area, including 14 kit fox surveys west of the Altamont Hills crest and north of I-580 in Alameda and Contra Costa counties conducted to comply with environmental regulations. Three surveys resulted in confirmation of kit fox in the area; kit fox sightings and sign (dens and tracks) led Sproul and Flett (1993) to conclude that a small population of San Joaquin kit fox existed in the crest area and western slope of the Altamont Hills. Sproul and Flett (1993) wrote that kit foxes may be moving through the area, but did not appear to be able to maintain a stable residence west of the Altamont Hills in Contra Costa and Alameda counties.

Surveys conducted by Bell (1994) using spotlights, camera stations, and track plates showed evidence of kit fox in Contra Costa, Alameda, and San Joaquin counties. The use spotlights, track plates and camera stations confirmed the presence of kit fox in the Corral Hollow area in 1991. Further surveys by Bell in 1992 resulted in few kit fox sightings: a kit fox was observed within the Kellogg Creek Watershed, 2 adult kit foxes were observed in the Round Valley Regional Park, and a kit fox was observed on the Lougher Trail at the western boundary of the Black Diamond Mines Regional Preserve. The kit fox sightings at the Black Diamond Regional Preserve represent the northern-most sighting to date (Bell 1994).

Later, H. T. Harvey & Associates (1997) summarized sighting records of the San Joaquin kit fox and the results of surveys in Alameda, Contra Costa, and San Joaquin counties. These records were used to delineate the range limit of the San Joaquin kit fox in these counties, which represented little change from that of Swick (1973). The kit fox range appeared to be restricted to the Altamont Hills and the western edge of the San Joaquin Valley.

More recent sightings prompted further research to determine the current distribution of the San Joaquin kit fox in the northern range. These sightings included observations of kit foxes on the Black Diamond Mines Regional Preserve in 1996, 1997, and 1999; 3 kit foxes at Bethany Reservoir in 1998; kit foxes at Vasco Caves (East Bay Regional Parks) in 2001 and 2002; 2 kit foxes at Brushy Peak (East Bay Regional Parks) in 2002; and 2 kit foxes at Carnegie State Recreation Area (CDFG 2007).

Clark et al. (2002a, b) concluded that the current status of the kit fox in the northern range is unknown and that continued development in the northern range would reduce habitat availability for kit foxes. These factors could negatively affect the probability of maintaining a viable kit fox population in the northern range. Smith et al. (2006) suggested that the northern range may possibly be a *sink* for the San Joaquin kit fox and future resources should be directed in conserving kit foxes in the 3 core populations described in the Recovery Plan (USFWS 1998).

Habitat

The San Joaquin kit fox commonly occupies grasslands, alkali scrub, or oak savanna, and may also use vernal pool areas. Although the kit fox is rather adaptable, the grassland habitats of the northern range may lack some components, and this may prevent it from optimizing its ability to survive. The northern section of the kit fox range in Alameda, Contra Costa, and San Joaquin counties is varied in land use and topography. The interface between Alameda and Contra Costa counties is characterized by low rolling hills covered with annual grassland ranging in elevation from 73 m to 244 m (Swick 1973, Orloff et al. 1986). Swick (1973) concluded that kit fox populations in this extended area are sparse and although there is some suitable grassland habitat in the North Livermore Valley, Dublin, and areas west of Vasco Road, kit foxes have not expanded into these areas. If the kit foxes in the northern extreme of their range are constrained to the marginal habitats of their historic range, then certain biotic and abiotic factors may act singularly or in concert to restrict further expansion of the kit fox (H.T. Harvey & Associates 1997).

Suitable habitat in the northernmost portion of the kit fox range appears to be limited. The understanding of the geographic range and specific habitat characteristics of the San Joaquin kit fox in the northernmost portion of its range is lacking when compared to the information available for the southern range, and Bell (1994) cautioned that it might not be appropriate to base kit fox habitat use patterns in the northern range on use patterns in the southern range. Kit fox presence has been reported in habitats that include some grassland, clay soils, and a history of kit fox sightings with 1.5 km; though these characteristics do not conclusively indicate the presence of kit fox in an area, they do increase the probability of identifying potential kit fox habitat in the northern range (Bell 1994).

Orloff et al. (1986) reported on the habitat requirements of the San Joaquin kit fox in the northern limit of its range based on 2 sites. The habitat of the 2 study sites (Los Vaqueros and Bethany Reservoir) consisted of low rolling hills with annual grasslands. These sites had steeper slopes and denser soils characteristic of hard-packed clays or clay loams when compared to most of the San Joaquin kit fox range. Orloff et al. (1986) found 51 kit fox dens, including one natal den, used by the 8 radio-collared kit foxes, on slopes ranging from 2% to 14% and lacking the classic ramp often found with dens in the southern kit fox range. The maximum number of dens used by a single individual was 23. No evidence was apparent that kit foxes on the 2 sites constructed their own dens; most appeared to be enlarged California ground squirrel burrows, and was assumed that the hard soils prevent kit foxes from digging their own dens. Therefore, many portions of the northern range may be unsuitable for kit fox if ground squirrels are not present (Orloff et al. 1986).

Prey base

The San Joaquin kit fox primarily preys upon rodents and lagomorphs (McGrew 1979). In the southern range, kit foxes generally feed on kangaroo rats (genus *Dipodomys*), though it appears that kit foxes in the northern range have shifted their diet to primarily take the California ground squirrel due to the lack of kangaroo rats (Orloff et al. 1986). This leads to an anomaly that cannot be readily explained; kit foxes are a nocturnal species, yet in the northern range, they forage for a diurnal prey species. The dependence of the kit fox on ground squirrels as a prey item may be an important factor in kit fox ecology in the northern range. However, kit foxes in some southern range locations also rely on ground squirrels (e.g., parts of Bakersfield, eastern Kern County, and Camp Roberts). Based on observations in Bakersfield, kit foxes catch ground squirrels early in the morning when the squirrels are first emerging, so the foxes are not really appreciably altering their activity periods (B. Cypher, pers. comm.). Kit foxes have sufficient ecological and behavioral plasticity that they are able to prey on ground squirrels when necessary (Cypher et al. 2000). Kit foxes primarily prey on ground squirrels when their preferred prey, i.e., kangaroo rats, are not present. Grinnell et al. (1937), Morrell (1972), and others have posited the strong link between kit foxes and kangaroo rats. In natural areas where kit foxes exhibit large, dense populations and long-term persistence, their primary prey is kangaroo rats (see Cypher et al. 2000). The northern range may be more marginal in quality for kit foxes if for no other reason than that kangaroo rats are not sufficiently abundant to support foxes.

Orloff et al. (1986) wrote that the effects of rodent control programs on kit fox are difficult to determine. Contra Costa County mounted a California squirrel eradication program from 1955 to 1978, which may have reduced the numbers of kit foxes in Contra Costa County, or led to extirpation in the area (Orloff et al. 1986, Weslar 1992). H. T. Harvey & Associates (1997) also concluded that California ground squirrel eradication programs might have influenced kit fox density in the area.

Predation and competition

Historically, the coyote (*Canis latrans*) and kit fox co-evolved, with the kit fox optimizing its survival with various ecological partitioning strategies. Examples include year-around den use, food item partitioning, and use of slightly different habitats (Nelson 2005, Nelson et al. 2007). In addition, the increasing presence of the non-native red fox (*V. vulpes*) compounds the predation pressures on the kit fox in the northern range.

Orloff et al. (1986) wrote that one of the major factors limiting the distribution of the kit fox in the northern portion of their range is competitive exclusion and predation by other canids (e.g., coyotes). Competition with coyotes and red foxes may influence kit fox density (H. T. Harvey & Associates 1997), although Bell (1994) suggested that the presence of red foxes or coyotes in a given area should not necessarily eliminate the possible use of a site by kit foxes. Although the influence of red foxes on the current distribution and abundance of kit foxes is unknown, increasing red fox abundance may be reducing the suitability of the remaining habitat for kit fox occupation (Clark et al. 2005).

Recent surveys for kit foxes (Clark et al. 2003, Smith et al. 2006) confirmed the presence of red fox at the Haera Conservation Bank and at Bethany Reservoir by genetic analysis of scats found by the detection dogs, in addition to an observation of a live red fox at Bethany Reservoir. The presence of red foxes is potentially detrimental to kit foxes. Red foxes have been known to kill kit foxes (Clark 2001, Clark et al. 2005, Ralls and White 1995), displace kit foxes from their dens and habitat, compete for food resources, and may transmit diseases to kit foxes (Cypher et al. 2001). The presence of red foxes may also increase competitive pressure on kit foxes, which concomitantly could reduce the kit fox's ability to persist.

Grinnell et al. (1937) documented Golden Eagle (*Aquila chrysaetos*) predation on San Joaquin kit foxes, similar to the Golden Eagle and island gray fox (*Urocyon littoralis*) dynamic occurring on the Channel Islands (Roemer et al. 2001, 2002; Coonan et al. 2005). The Golden Eagle is found in mountainous areas, canyons, shrub-land, and grassland. The northern range of the kit fox is comprised of this type of habitat (Kochert et al. 2002), and contains the highest density of Golden Eagles in the world (Franklin et al. 1998, Hunt et al. 1998). One bird can carry up to 3.5 kg in flight (USFWS 1998), and Golden Eagles have been known to kill ungulates, including mountain sheep (Bleich et al. 2004), and take coyote pups (Ingles 1965). Mollhagen et al. (1972) and Olendorff (1976) also noted that kit foxes, which weigh on average 2.3 kg as adults, were taken as prey by Golden Eagles.

Recovery Strategy for the San Joaquin Kit Fox

In 1998, the *Recovery Plan for Upland Species of the San Joaquin Valley, California* was published (USFWS 1998). Within this Recovery Plan, a community-level approach was used to address and facilitate the recovery of threatened and endangered species, as separate conservation strategies for each species in the Recovery Plan would be inefficient and impractical (e.g., USFWS 1983). Thus, use of the endangered San Joaquin kit fox as an "umbrella" species in conservation and recovery efforts was presented due to the relatively large tracts of land required to support viable populations of kit fox. Conservation efforts, particularly habitat conservation, on behalf of the kit fox will benefit other species that require recovery from extinction (USFWS 1998).

The Recovery Plan (USFWS 1998) proposed a series of linkages and connective areas for the San Joaquin kit fox from the core kit fox populations in the southern San Joaquin Valley to satellite populations through a linkage that extends along the western portion of the San Joaquin Valley stretching from Kern County to San Joaquin County. Corridors are important for the recovery of small isolated populations, such as the San Joaquin kit fox in the north-central California. In association with this linkage, the Recovery Plan also identified areas along the Valley's edge within which a contiguous band of natural lands and wildlife-compatible farmlands should be maintained. These areas extend from Kern County to Contra Costa County and are primarily west of the Interstate 5 where the foothills meet the San Joaquin Valley floor (USFWS 1998).

Restrictions within the San Joaquin kit fox corridor

Spatial narrowing of corridors can be detrimental to wildlife movements (Fahrig and Merriam 1985, Harrison 1992). The nearest kit fox source population for the northern range is the Ciervo-Panoche Natural Area of western Fresno and eastern San Benito counties. Historically, kit foxes occurred in western Fresno County in healthy numbers. Grinell et al. (1937) noted that "…in 1919, Arthur Oliver [a trapper] caught 100 [kit] foxes in one week in an area 20 miles long and 2 miles wide, on the plains on the west side of the San Joaquin Valley, Fresno County [15 miles southwest of Firebaugh near the base of the Ciervo-Panoche Hills]" (Kelly et al. 2005). Today, Oliver's "plains" have been converted to farmland that is considered some of the most productive in the world (Kelly et al. 2005). Kit foxes were most likely resident within the several coastal range valleys, including Ciervo-Panoche, San Luis, Romero, and Simon Newman, but may have been locally extirpated from the Tracy area by 1937.

There are several linkage areas along the westside kit fox corridor that are being eroded due to development. The most discussed pinch point, however, is the Santa Nella area, located in Western Merced County. The Santa Nella area was developed during the 1960s with water delivery projects and several highway systems, making it difficult for kit foxes to move through the area. Smaller populations and family groups persevered in valleys just south of San Luis Reservoir (Archon 1992, Briden et al. 1992) and in smaller valleys north of Santa Nella, primarily Romero Ranch and Simon Newman Ranch (H. Clark, unpub. data). The many movement barriers in the Santa Nella area (i.e., forebay, highways, canals, and other developments) may significantly reduce the recruitment of individual kit foxes into the northern range. Other carnivores that compete with and kill kit foxes, such as coyotes and non-native red foxes, also use the corridor. The lack of recruitment into the northern range may lead to inbreeding depression over time (Frankham and Ralls 1998, O'Grady et al. 2006). Potentially, dispersing juvenile kit foxes from the Ciervo-Panoche Natural Area could provide recruitment opportunities to the small populations and family groups in the valleys north and south of the Santa Nella area, and in turn, these valley groups could provide dispersing individuals into the northern range. However, mortality rates of dispersing juvenile foxes are rather high. Out of 209 juvenile kit foxes monitored in the southern kit fox range during 1980-1996, only 33% dispersed from their natal areas (Koopman et al. 2000).

Estimates of the mean annual probability of survival for juvenile kit foxes ranges from 0.14 to 0.21 (Ralls and White 1995, Cypher et al. 2000). Spiegel and Disney (1996) reported that 85% of juvenile foxes died by the end of their second year. During the dispersal season, juveniles can move up to 9.4 km in one night (Zoellick et al. 2002). A lack of escape dens in juvenile dispersing routes further hinders their survival, as they are unable to successfully escape predators. The lack of escape dens in the northern range may be a limiting factor to kit fox survival in the region.

CONCLUSIONS

The status of the San Joaquin kit fox in the northern range is uncertain. Kit foxes have been observed with some regularity since the 1950s, albeit in small numbers. Often, kit foxes in the northern range have been referred to as a *population*, though it appears the kit foxes in the area exist as small family groups in isolated patches of habitat. Researchers have stated that, at times, kit foxes in the northern range have either experienced extirpation or fallen below detectable numbers (Grinell et al. 1937, Orloff et al. 1986, Weslar 1992).

Kit foxes in the northern range may differ behaviorally from their southern range counterparts. The main prey item is the California ground squirrel, which means a shift may have occurred in their activity pattern: from being nearly a generally nocturnal animal to both a nocturnal and more crepuscular one. If they pursue California ground squirrels after sunrise, there may be the potential to increase the chance of predation by a whole new suite of predators, such as raptors. The lack of Heteromyid populations in the northern range may be the most significant factor in the lack of robust kit fox presence in the region. The strong link between kit foxes and kangaroo rats has been well documented, and with few options for prey-switching during drought years, may lead to unrecoverable kit fox population levels (Koopman et al. 2001, White et al. 1993, 1996).

Keen diurnal predators such as raptors, combined with competitive and predatory pressures of the coyote, red fox, and bobcat (*Lynx rufus*) make kit fox survivability all the more challenging (Benedict and Forbes 1979, Clark et al. 2005, Ralls and White 1995). Areas with thick vegetative cover further place kit foxes at risk of predation by ambush predators, such as bobcats, as they are unable to see and escape approaching predators (Nelson 2005, Nelson et al. 2007).

Dens are critical to the survival of kit foxes. They ensure a safe means for kit foxes to escape from larger and faster predators such as coyotes, and serve as a means of temperature regulation and raising young. The Contra Costa County California ground squirrel eradication program resulted in fewer burrows that kit foxes could expand for their use (Schitoskey 1975, see also Hosea 2000). Additionally, the hard clay soils in the northern range are unlike the loose-textured, well-drained soils with which kit foxes may have evolved. A stable escape den system is lacking in the northern range due to the kit foxes inability to create the several dens they require within their home range. These factors may be reducing the ability of kit foxes to persist in the northern range.

Smith et al. (2006) proposed that the northern range may possibly be a *sink*, meaning it is not self-sustaining and must receive immigrants from other areas in order to persist over time, and may be at risk of local extinction. Schwartz et al. (2005) concluded that with the continuing habitat degradation in the San Joaquin Valley, isolation of some kit fox populations is highly probable. Some of these populations, such as kit foxes in the Los Baños and Camp Roberts areas, are at extreme risk of isolation and are either extinct, or on the verge of extinction (White et al. 2000, Schwartz et al. 2005).

There are several research questions that need to be answered in order to better address the status of the kit fox in the northern range. The geographic range of the kit fox in the northern part of the range must first to be accurately delineated and a clearer definition of “range” needs to be better communicated, i.e., anywhere a species is located versus areas which provide for all of a species’ needs to support its population. This task requires intense Geographic Information System mapping and an influx of current survey data. The maps should draw from scientific definitions of species ranges, which may not be consistent with where the animals have been seen.

The factors potentially limiting the northern edge of the kit fox geographic range need to be further explored and defined. The kit fox range should be mapped against the soil types to ascertain suitability of soils for den excavation and potential prey base patterns. Golden Eagle densities and biomass of nocturnal small mammal prey should be mapped against the kit fox range to see how well the range boundary correlates with these potential limiting factors. Golden Eagles nests should be inventoried to determine the rate of kit fox take.

Landscape-level vegetation mapping should be executed to determine if certain species of grasses are incompatible with kit fox use. The term “grassland” is oftentimes synonymous with “kit fox habitat,” but within the northern extent of the kit fox range, this may be untrue.

What is the size of the northern range population? Is it still declining? General methods for estimating the kit fox population should be explored. Estimating the population size would be useful for many conservation questions (Abbitt and Scott 2001).

Do population models show the northern range population as a sink? A "sink" population can only persist in the long run with immigration. Under certain circumstances, sink habitat can still be beneficial to the overall persistence of a population.

The northern range population is dependent upon immigration through the corridor near Santa Nella; therefore, how much immigration is needed and is the size of the corridor sufficient? A population model is needed to conclusively answer these questions, as well as determine an estimate of population size, population variability, and reproduction and mortality rates.

It appears from our review that the northern range of the San Joaquin kit fox was most likely marginal habitat historically and has further degraded due to development pressures, habitat loss, and fragmentation. The lack of functional travel corridors from southern core populations have allowed for the continued isolation of the northern kit fox populations. Local extinction is likely unless restoration of the historic corridor system that once funneled kit foxes into the northern region can be implemented, which will allow the necessary immigration and genetic fluidity necessary for kit fox survival. An alternative solution would be to consider a future reintroduction program of kit foxes in to the northern range, by relocating foxes from the 3 southern core populations. Reintroduction programs for swift foxes (*V. velox*) have been successful (Ausband and Foresman 2007) and if the kit fox is expected to persevere in the northern extent of its range, drastic conservation measures will need to take place.

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