Species Status Assessment Report
for the
San Joaquin kit fox
(*Vulpes macrotis mutica*)

Photo by Tim Ludwick

Version 1.0

August 2020

Acknowledgements

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EXECUTIVE SUMMARY

The San Joaquin kit fox was listed as endangered under the Endangered Species Preservation Act in 1967, because of increasing threats of habitat loss. The San Joaquin kit fox (*Vulpes macrotis mutica*) is the largest subspecies of kit fox (*Vulpes macrotis*). The San Joaquin kit fox's range is restricted to the San Joaquin Valley in south-central California, as well as the Carrizo Plain, Panoche Valley, and adjacent smaller valleys in the Coast Range. The preferred habitat of the San Joaquin kit fox is native, sloping annual grassland with sparse vegetation (Cypher 2006, pp. 1–2).

This report summarizes the results of a species status assessment (SSA) that the U.S. Fish and Wildlife Service (USFWS) completed for the San Joaquin kit fox. To assess the species' viability, we used the three conservation biology principles of resiliency, redundancy, and representation (together, the 3 R's). These principles rely on assessing the species at an individual, population and species level in order to determine whether the species can maintain its persistence into the future and avoid extinction by having multiple resilient populations distributed widely across its range. The species occurs across much of its historical range which corresponds to the areas identified in recovery criteria for the San Joaquin kit fox in the 1998 Upland Species Recovery Plan (USFWS 1998), although kit fox have not been documented in portions of the range in over 10 years. There are 16 geographic units where the species can be found, representing the breadth of the historical range of the species. These regions are based on the units from the 1998 Upland Species Recovery Plan (USFWS 1998, p. 132–134) and 2010 5-year Review (USFWS 2010b, p. 12). For this SSA, resiliency of the San Joaquin kit fox was assessed at the geographic unit as a surrogate for the population level. Data on long-term occupancy of these known sites suggest that San Joaquin kit foxes still have relatively high resiliency in much of the southern and western portion of the San Joaquin Valley, despite frequent and sometimes extreme population fluctuations. For the San Joaquin kit fox, resiliency was assessed using information on occupancy, population trend, connectivity, prey availability, terrain slope, and native habitat.

Our analysis of the past, current, and future influences on San Joaquin kit fox needs for long-term viability revealed that there are several factors that contribute to the current condition and pose a risk to the future viability of the species. These risks, or stressors as we call them in this document, include habitat modification or destruction, climatic variability, rodenticide use, predation, and disease. Under current conditions, we determine the San Joaquin kit fox has 3 geographic analysis units in high condition, 5 units in moderate condition, and 3 units in in low condition. Five of the analysis units were in very low condition. The condition of a unit characterizes the probability that San Joaquin kit foxes will continue to persist. High condition equates to a high likelihood of continued persistence, while low condition equates to an increased risk of extirpation.

The influences to viability described above play a large role in the future resiliency, redundancy, and representation of the San Joaquin kit fox. If geographic units lose resiliency, they are more vulnerable to extirpation, which results in losses of representation and redundancy for the species ultimately reducing viability. The rates at which future stressors might act on specific regions and the long-term efficacy of the current conservation actions are unknown. Therefore, we forecasted how possible future conditions could impact the resiliency, redundancy, and representation and overall condition of the San Joaquin kit fox. In order to assess future condition, we have developed three future, plausible scenarios. The following is a description of these future scenarios, the status of the San Joaquin kit fox when analyzed under each scenario, and a summary of the assumptions we made under each scenario:

Scenario 1 assumes that there will be warm and wet conditions (CNRM-CM5, RCP 4.5). We assume under this emission and global circulation scenario that increased precipitation and frequency of extreme weather events will lower habitat suitability for the species. Under a warm and wet scenario we expect an increase in herbaceous vegetation that may reduce overall habitat availability. However, we assumed that populations on protected lands with habitat management plans will have grazing or other management activities that will counteract the increases in vegetation in some cases. In addition to changes in habitat suitability, we expect an increase in drought years. Drought years are associated with decreased reproduction, presumably because of decreases in prey availability or other factors. Development and land conversion continues in this scenario at current rates, which continues to negatively impact San Joaquin kit fox populations on unprotected lands by decreasing the size and connectivity of suitable habitat.

Under the conditions described in this scenario, we projected that the species would have zero populations in high condition, 7 populations in moderate condition, 3 populations in low condition, and 6 populations in very low condition. Management on protected lands is particularly important on the edges of the species range where populations are small and climate effects compound existing threats. As population resiliency is lowered across the species range, redundancy and representation are also reduced for the species. In particular, the prediction that all populations outside of the Carrizo Plain and Western Kern core areas are in low or very low condition and that connectivity will continue to decline results in a decrease in representation across the species.

Scenario 2 assumes that there will be hot and dry conditions (MIROC-ESM, RCP 8.5). We assume under this emission and global circulation scenario that decreased precipitation and increased extreme weather events will influence habitat for the species. We again assumed that increased drought years will limit reproduction for the species, however this may be offset by increases on overall habitat suitability and prey abundance. Although we expect an increase in fallowed agriculture lands, this has uncertain conservation value for the species and we do not expect this to contribute to habitat for the kit fox without specific recovery actions. Although a drier climate tends to point toward an increase in suitable habitat for the species, it is unlikely that the species will expand into any new areas without restoration and/or other recovery actions. Instead, we project in this scenario that development continues at its current rate, reducing habitat size and connectivity for populations in unprotected areas.

Under the conditions described in this scenario, we projected that the species would have 3 populations in high condition, 4 in moderate condition, 4 in low condition, and 5 populations in very low condition. Under this scenario decreases in habitat due to development are somewhat offset by increasing habitat suitability and, thus, representation and redundancy remain similar to the current condition.

Scenario 3 makes the same climate assumptions as in Scenario 2: hot and dry conditions and increased droughts. However, in this scenario we assume that there will be aggressive restoration of fallowed agricultural lands, particularly in the central portion of the species range. We assume that development will continue in the San Joaquin Valley, reducing habitat size and connectivity for some populations, but that restoration will increase the condition for these two factors in some locations.

Under the conditions described in this scenario, we projected that the species would have 6 populations in high condition, 5 in moderate condition, 1 in low condition, and 4 in very low condition. This is the most optimistic of our future scenarios.

The projected conditions under all scenarios rely on continuation of management activities in protected lands. The importance of habitat management is especially important under the warm and wet climate projection, but we emphasize that management is important under all potential climate projections. The main difference between outcomes of the scenarios depends on the implementation of strategic restoration of fallowed agricultural lands. The current emphasis on strategic land restoration and recovery for upland species in the San Joaquin Valley increases the likelihood of implementation of the restoration projections associated with Scenario 3.

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Chapter 1. Introduction

This report summarizes the results of a Species Status Assessment (SSA) conducted by the U.S. Fish and Wildlife Service (Service) for the San Joaquin kit fox (*Vulpes macrotis mutica*). The San Joaquin kit fox is a small canid endemic to the San Joaquin Valley and adjacent valleys of California.

We used the SSA framework to conduct an in-depth review of the species' biology and the stressors that impact it, to evaluate its current biological status, and to predict the future status of resources and conditions as a means of assessing the San Joaquin kit fox's viability. This SSA report summarizes the results of our analysis using this framework. As new information becomes available, we intend to update this SSA report as needed so that it can support all functions of the Endangered Species program.

The purpose of this SSA report is to provide the biological and scientific foundation of the current 5-year review and ongoing recovery implementation. Importantly, this SSA report does not result in a decision document, but instead provides the biological information and scientific analysis needed to support future decisions made by the USFWS under the Act. Decisions for changing the status of the San Joaquin kit fox will be made by the USFWS after reviewing the SSA report and all relevant laws, regulations, and policies, and the USFWS will announce the policy decision independently in the Federal Register.

1.1 Petition History and Previous Federal Actions

The San Joaquin kit fox was listed as endangered under the Endangered Species Preservation Act in 1967, at which time it was not subject to the current listing processes. The species recovery strategy is described in the Recovery Plan for Upland Species of the San Joaquin Valley, California, along with 33 additional species of plants and animals that occur in the region (USFWS 1998, entire). A 90-day finding on a petition to delist the San Joaquin kit fox was published in 57 FR 28167 on June 24, 1992 (USFWS 1992, entire). The Service's finding was that the petition did not present substantial scientific information indicating that delisting the kit fox was warranted. The petition was based on taxonomic considerations. The Service concluded that the status of kit fox and swift fox (*Vulpes velox*) taxonomy remained a subject of ongoing scientific debate, but found that, regardless of the outcome of the continuing debate, the San Joaquin kit fox was a distinct population segment subject to protection under the ESA (USFWS 1992, entire). The Service published the last 5-year Review on February 16, 2010 (USFWS 2010b, entire). The Service published a notice announcing initiation of the 5-year review of this taxon and the opening of a 60-day period to receive information from the public in the Federal Register on July 2, 2019 (USFWS 2019, entire).

Recovery Plan Summary

The San Joaquin Valley Upland Species Recovery Plan (USFWS 1998) outlined specific de-listing and downlisting criteria for the San Joaquin kit fox (Table 1).

Table 1. Recovery Criteria for the San Joaquin kit fox.

Recovery Step	Secure and protect specified recovery areas from incompatible uses	Management Plan approved and implemented for recovery areas that include survival of the species as an objective	Population monitoring in specified recovery areas shows:
Downlist to threatened	The three core populations, Carrizo Natural Area, western Kern County, and Ciervo-	For all protected areas identified as important to continued survival	Stable or increasing populations in the three core areas through one precipitation cycle; population

	Panoche Area; three satellite populations		interchange between one or more core populations and the three satellite populations
Delist	Several additional satellite populations (number dependent on results of research) encompassing as much as possible of the environmental and geographic variation of the historic geographic range	For all protected areas identified as important to continued survival	Stable or increasing populations in the three core areas and three or more of the satellite areas during one precipitation cycle

The plan also outlined site-specific protection requirement that are required to meet delisting criteria. In the Ciervo-Panoche area and western Kern County the plan specifies that 90% of existing potential habitat needs to be protected. In the Carrizo Plain, 100% of existing potential habitat should be protected. Outside of the 3 core areas above the plan specifies that 80% of existing habitat should be protected in greater than or equal to 9 satellite populations.

1.2 The Species Status Assessment Framework

This SSA report summarizes the results of our in-depth review of the San Joaquin kit fox's biology and stressors, an evaluation of the species' biological status, and an assessment of the resources and conditions needed to maintain long-term viability. For the purposes of this assessment, we define viability as the ability of the species to sustain populations in the wild into the future in a biologically meaningful timeframe, which is 60 years for our analyses (explanation for our timeframes given in Chapter 4. Future Condition).

Using the SSA Framework (Figure 1), we considered what the San Joaquin kit fox needs to be viable into the future by characterizing the current and future condition of the species using the concepts of resiliency, redundancy, and representation (the "3Rs") from conservation biology (Shaffer and Stein 2000, pp. 308–311; USFWS 2016, p.12).

- **Resiliency** is the ability of populations to tolerate natural, annual variation in their environment and to recover from periodic or random disturbances, known as stochastic events. Resiliency can be measured using metrics like vital rates, such as annual births and deaths, and population size. In general, populations with high abundance and stable or increasing population trends are more resilient than those with limited resources or declining populations. Populations with high resiliency can better withstand stochastic changes in demography or their environment due to natural or anthropogenic disturbances.

- **Redundancy** is the ability of a species to withstand catastrophic events, such as a rare, destructive natural event that affects multiple populations. Redundancy is measured by the duplication and distribution of

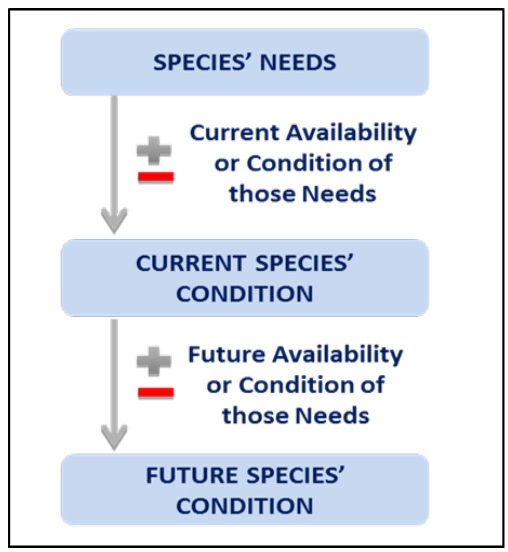


Figure 1. The three phases (blue boxes) of the SSA Framework used to guide this analysis.

To assess the viability of the San Joaquin kit fox, we evaluated the species' needs, the current availability and condition of those needs, and the species' current condition. We then predicted the species' future condition based on the future availability and condition of the species' needs.

populations across the range of the species. The more redundant a species, or the greater number of populations a species has distributed over a larger landscape, the better able it is to recover from catastrophic events. Redundancy helps "spread the risk" and ensures all populations are not extirpated at once due to a catastrophic event.

- **Representation** is the ability of a species to adapt to changing physical (climate, habitat) and biological (diseases, predators) conditions. Representation can be measured by looking at the genetic, morphological, behavioral, and ecological diversity within and between populations across a species' range. The more representation, or diversity, a species has, the more likely it is to adapt to and persist with natural or human-caused changes to its environment.

For the purpose of this SSA, viability is defined as the ability of a species to sustain populations in the wild over time. Viability is not a single state; rather, there are degrees of viability. In other words, we do not conclude that a species is or is not viable upon completion of an SSA. Instead, we characterize the resiliency, redundancy, and representation a species currently presents and predict how these characteristics may change into the future. Species with higher resiliency, redundancy, and representation are more protected from the vagaries of the environment, can better tolerate stressors and adapt to changing conditions, and are thus more viable than species with low levels of the 3Rs.

To assess the viability of the San Joaquin kit fox, we analyzed the species' ecology, historic and current conditions, and projected the viability of the species under several future scenarios, all in the context of the 3Rs and using the best scientific data available. Chapter 2 of this SSA report summarizes the biology, ecology, and needs of the San Joaquin kit fox at the individual, population, and species levels. Chapter 3 examines the stressors which impact the resiliency of San Joaquin kit fox populations and analyzes the historical and current conditions of the species. Chapter 4 predicts the future condition of the species under three potential scenarios. In Chapter 5, we summarize all the information presented in this SSA and analyze the viability of the San Joaquin kit fox.

1.3 Summary of New Information

Since the completion of the 5-year review for the San Joaquin kit fox in 2010, we evaluated new peer-reviewed literature and solicited data and new information from partner agencies within the state of California, including, but not limited to, state wildlife management agencies, universities, private contractors, and the Bureau of Land Management (BLM). Specifically, we requested new information (after 2010) on:

- The species' distribution, population sizes, population trends, and any updates to the species range or mapped colonies;
- The magnitude and severity of ongoing habitat loss;
- Other threats to the species including energy development, wildfire and rodenticide use;
- Updates to laws, regulations, or policies that might apply to the species; and
- Any ongoing conservation for the species and its habitats.

Our literature review and data solicitation resulted in new information on the impacts of solar facilities, genetic structure, habitat extent, and sarcoptic mange impacts. We incorporated these data, which include spatial data, peer-reviewed literature, reports, and personal communications, into various parts of the SSA, including the analysis of the current distribution of the San Joaquin kit fox and the severity of stressor and related conservation actions. If we lacked specific data for some aspect of our analysis, we used information from the desert kit fox (*Vulpus macrotis macrotis*).

1.4 Uncertainties and Assumptions

This report incorporates the best available information through reports, peer-reviewed literature, and communication with species experts. When information is not available at the species level, we sometimes use surrogate species, but are always careful to make this clear throughout the report.

Because the species' historical range covers a broad area throughout the San Joaquin Valley, and because current surveys and research tends to be restricted to discrete plots within land management units (*e.g.*, survey grids within National Wildlife Refuges, Ecological Reserves, etc.), we generally assume that these findings carryover more broadly into other areas of contiguous habitat.

Additional uncertainties and assumptions are highlighted in Chapter 4 (Historical and Current Condition) and Chapter 5 (Future Condition).

Chapter 2. Species Ecology and Needs

In this chapter, we provide basic biological information about the San Joaquin kit fox, including its taxonomic history and relationships, morphological description, physical environment, and reproductive and other life history traits. We then outline the needs of the San Joaquin kit fox at the individual, population and species levels. This is not an exhaustive review of the species' natural history; rather, it provides the ecological basis for the SSA analyses conducted in this report.

2.1 Taxonomy and Genetics

The San Joaquin kit fox is one of two currently recognized subspecies of kit fox (*Vulpes macrotis*) and was first described by Merriam (1902, p. 74) from a locality near Tracy in San Joaquin County, California. The taxonomic treatment of the smaller *Vulpes* foxes has varied over time, but genetic work supports the recognition of *V. m. mutica* as a valid subspecies (Mercure *et al.* 1993, p. 1323). The taxonomy of small, North American foxes has been revised several times, and several different taxonomies for these species have been proposed (Rohwer and Kilgore 1973, entire; Waithman and Roest 1977, entire). More recently, Dragoo *et al.* (1990, pp. 927–328) proposed that all small, arid-land foxes belonged to the swift fox (*V. velox*) and proposed that the kit fox be synonymized under *V. velox macrotis*. Genetic work concluded that while there was evidence of limited hybridization between the swift fox and kit fox, it was over a limited geographic area and the two should be considered separate species and that the San Joaquin Valley population of the kit fox was the most distinct and should be considered a valid subspecies (Mercure *et al.* 1993, pp. 1323, 1325–1326). Mercure *et al.* (1993) also concluded that (Mercure *et al.* 1993, p. 1323). Recent genetic work focusing on the San Joaquin kit fox provided evidence for 3 population clusters centered on Bakersfield, the Lokern Valley-Carrizo Plain-Camp Roberts area, and the Ciervo-Panoche region (Wilbert 2005, p 74).

2.2 Species Description

The San Joaquin kit fox is the larger of the two subspecies of kit fox, which is the smallest canid species in North America. Grinnell *et al.* (1937, p. 399) found a difference in body size between males and females: males averaged 31.7 inches (80.5 centimeters) in total length, and 11 .6 inches (29.5 centimeters) in tail length; females averaged 30.3 inches (76.9 centimeters) in total length, and 11.2 inches (28.4 centimeters) in tail length. Kit foxes have long slender legs and are about 12 inches

(30 centimeters) high am the shoulder. The average weight of adult males is 5 pounds (2.3 kilograms), and of adult females is 4.6 pounds (2.1 kilograms) (Morrell 1972, p. 21). General physical characteristics of kit foxes include a small, slim body, relatively large ears set close together, narrow nose, and a long, bushy tail tapering slightly toward the tip (Figure 2). The tail is typically carried low and straight. Color and texture of the fur coat of kit foxes varies geographically and seasonally. The most commonly described colorations are buff, tan, grizzled, or yellowish-gray dorsal coats (McGrew 1979, p. 1). Two distinctive coats develop each year: a tan summer coat and a silver-gray winter coat (Morrell 1972, p. 19). The undersides vary' from light buff to white, with the shoulders, lower sides, flanks and chest varying from buff to a rust color. The ear pinna (external ear flap) is dark on the back side, with a thick border of white hairs on the forward-inner edge and inner base (Grinnell *et al*. 1937, p. 399). The tail is distinctly black tipped (Figure 2). The foot pads of kit foxes are small by comparison with other canids. A sample of 21 tracks from throughout the San Joaquin Valley had an average length of 1.2 inches (3.1 centimeters) and an average width of 1 inch (2.6 centimeters) (Orloff *et al*. 1993, p. 50). Other characteristics such as the degree to which the feet are furred and the size, shape, and configuration of the pads distinguish kit fox tracks from those of co-occurring canids and domestic cats (Orloff *et al*. 1993, p. 50). Because all three fox species that occur in the San Joaquin Valley are primarily nocturnal, identification of free-living, and often fast-moving, animals can be a challenge. The black-tipped tail and coat color differences usually distinguish kit foxes from red foxes (*V. vulpes*). At 8 to 11 pounds (4 to 5 kilograms), the red fox also is much heavier than the kit fox. Gray foxes (*Urocvon cinereoargenteus*) are sometimes misidentified as kit foxes, especially in winter when the kit fox coat is thicker and has more gray. Both species have a black tail tip but gray foxes also have a distinctive black stripe running along the top of the tail. Gray foxes are more robust than kit foxes; they are heavier with an average body weight of about 8 pounds (3.6 kilograms) (Grinnell *et al*. 1937, p. 402). However, San Joaquin kit foxes have longer ears, averaging 3.4 inches (8.6 centimeters) compared with 3 inches (7.8 centimeters) for gray foxes (Grinnell *et al*. 1937, p. 399).

Figure 2. San Joaquin kit fox. Photo taken while conducting spotlight surveys (Tim Ludwick/USFWS).

2.3 Range of the San Joaquin Kit Fox

Historically, the San Joaquin kit fox occupied an area of the San Joaquin Valley from Kern County north to Tracy on the western side and the Merced River on the eastern side as well as the Carrizo Plain, Panoche Valley, and adjacent smaller valleys in the Coast Range (Grinnell *et al.* 1937, p. 403) (Figure 3).

At the time the Recovery Plan was developed the range was likely similar to the historical range, research projects and incidental sightings indicated that kit foxes inhabited some areas of suitable habitat on the San Joaquin Valley floor and in the surrounding foothills of the coastal ranges and Sierra Nevada; Tehachapi Mountains, from southern Kern County north to Contra Costa, Alameda, and San Joaquin Counties on the west; near La Grange, Stanislaus County, and across some of the larger scattered islands of natural land on the Valley' floor in Kern, Tulare, Kings, Fresno, Madera and Merced Counties (Grinnell *et al.* 1937, pp. 403–404). Kit foxes also occurred westward into the interior coastal ranges in Monterey, San Benito, and Santa Clara Counties, including the Pajaro River watershed, the Salinas River watershed, and in the upper Cuyama Valley (Cypher *et al.* 2003, p. 126). Kit foxes inhabit several urban areas in the San Joaquin Valley including the cities of Taft, Coalinga, and Bakersfield (Harrison *et al.* 2011, p. 304).

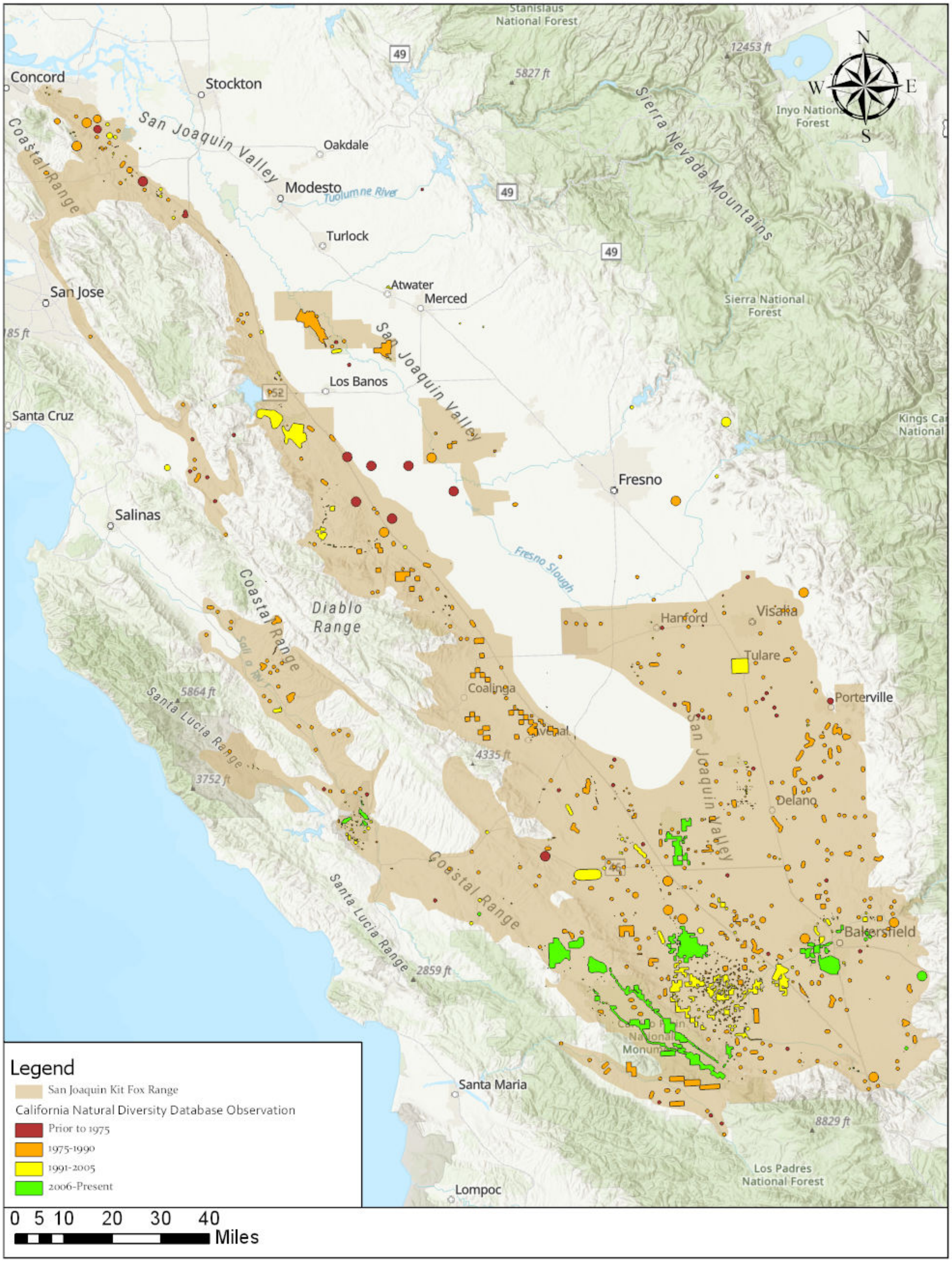


Figure 3. Historical range of the San Joaquin kit fox. Observations from the California Natural Diversity Database (CDFW 2020).

2.4 Species Ecology

2.4.1 Habitat

The Central Valley of California is characterized by a Mediterranean climate (O'Farrell *et al.* 2016 p. 4). Winters within the range of the San Joaquin kit fox are cool and daytime temperatures rarely fall below 50.0˚F (10˚C); overnight temperatures do not often drop below freezing (Williams 1992, p. 302). On the other hand, summers are long and hot with midday temperatures that regularly exceed 100.4˚F (38˚C) (Williams 1992, p. 302; O'Farrell *et al.* 2016 p. 4). The San Joaquin Valley receives < 5.9 in (15 cm) of rain annually (Williams and Kilburn 1991, p. 6). Most rain that does fall, occurs during the winter months - between November and April (Williams and Kilburn. 1991, p. 2). Due to limited annual rainfall and high summer temperatures, the southwestern portion of the San Joaquin Valley is characterized as a climatic desert (Germano *et al.* 2011, pp. 139–145). Even so, the cool wet winters allow rich grasslands to form on the western slopes of the valley, which support a wide diversity of endemic plants and animals (Williams 1992, pp. 302–303).

Historically, the San Joaquin Valley floor was a mosaic of uplands, wetlands, and riparian corridors. The wetlands were fed by runoff from the nearby Sierra Nevada Mountains that flowed into seasonal wetlands that surrounded shallow lakes (Griggs *et al.* 1992, pp. 111–118). Much of the southwestern San Joaquin Valley was desert-scrub with alkali-sink habitats (Germano *et al.* 2011, p. 139). San Joaquin kit fox were historically found throughout upland habitats within the San Joaquin, Salinas, Cuyama, Panoche Valleys along with adjacent smaller adjacent valleys. San Joaquin kit fox are uniquely adapted to desert climates and reach their highest densities in landscapes with low stature vegetation, gentle slopes, and abundant small mammal prey.

The kit fox is primarily found in association with Valley Sink Scrub, interior Coast Range Saltbush Scrub, Upper Sonoran Subshrub Scrub, Annual Grassland, and other grassland vegetation communities. Within these communities, optimal habitat for the San Joaquin kit fox is sparsely vegetated communities on gentle slopes (McGrew 1979, p. 123; Cypher *et al.* 2013, p. 26) (Figure 4). Plant communities such Northern Hardpan Vernal Pool, Northern Claypan Vernal Pool, Alkali Meadow, and Alkali Playa are often smaller and more widely scattered; and in general, do not provide good denning habitat for kit foxes because all have moist or waterlogged clay or clay-like soils. However, where they are interspersed with more suitable kit fox habitats they provide food and cover. Kit fox can also be found in human altered habitats such as grazed grasslands, petroleum fields (Morrell 1972, p. 4; O'Farrell 1984, p. 208), urban areas, and survive adjacent to tilled or fallow fields (Warrick *et al.* 2007, p. 275). In the northern portion of their range, kit foxes commonly are associated with annual grassland (Orloff *et al.* 1986, p. 62).

Figure 4. An example of San Joaquin kit fox habitat within the Carrizo Plain National Monument.

Kit fox dens are primarily found in loose texture soils (Morrell 1972, p. 10). However, kit foxes will occupy soils with a high clay content where they modify burrows dug by other animals (Orloff *et al.* 1986, p. 63).

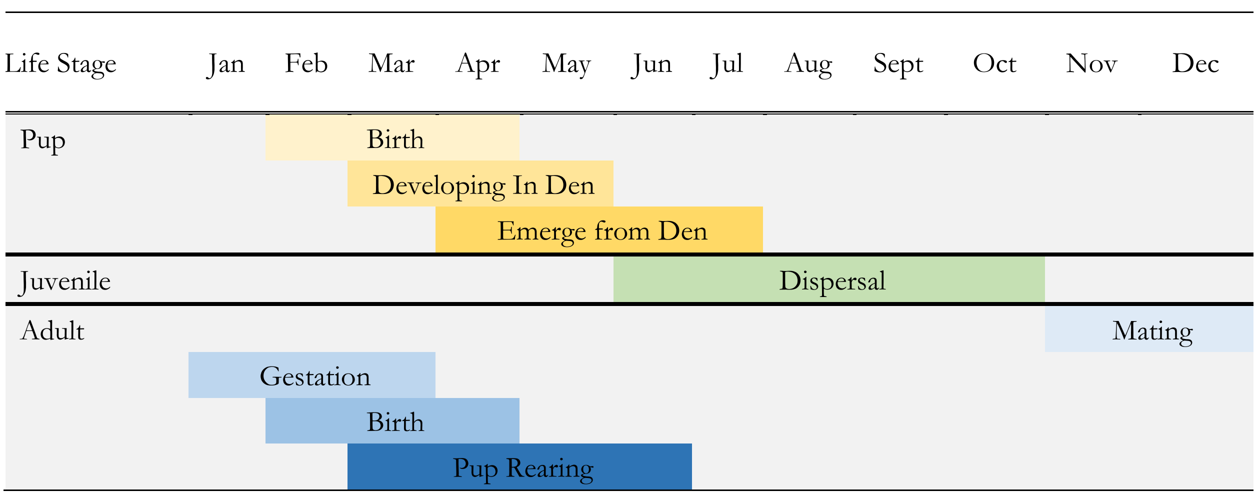
2.4.2 Diet

Although the kit fox diet can vary seasonally and in response to available prey, kangaroo rat remains comprised 80 to 90 percent of fecal material at most collecting sites throughout the range of the kit fox (Laughrin 1970, p. 11). Data suggests that kangaroo rats might be the preferred prey species, even in areas where other prey, such as leporids, are present (Koopman *et al.* 2001, p. 82). Kit fox in the Elk Hills showed a slight preference for kangaroo rats, although when leporid populations were high, those species were increasingly incorporated into their diet (Cypher *et al.* 2000, p. 20). Kit foxes are also known to consume other small mammal species, including leporids (rabbits and hares: *Lepus* and *Sylvilagus* spp.), ground squirrels (*Ammospermophilus* and *Spermophilus* spp.), and insects (Archon 1992, p. 43, Cypher and Brown 2006. pp. 9–10, Table 4); however, consumption of these species appears to be secondary to consumption of kangaroo rats in non-urban populations (Cypher *et al.* 2000, p. 20). In the southern San Joaquin Valley, kangaroo rats were found to be the primary small mammal present at undeveloped and moderately developed sites, while smaller rodents (California pocket mice [*Chaetodipus californicus*], San Joaquin pocket mice [*Perognathus inornatus*], deer mice [*Peromyscus maniculatus*], and house mice [(*Mus musculus*]) were found most frequently at an intensively developed site (Spiegel *et al.* 1996, pp. 43–46, Table 2). At Bethany Reservoir in Alameda County, California ground squirrels were found to be the most common prey and no kangaroo rats (*Dipodomys* sp.) were detected at this site (Orloff *et al.* 1986, p. 63). In some instances, ground squirrels have also been found to be an important food item where kangaroo rats appeared to be abundant (Balestreri 1981, pp. 14 19–20, Table 4). In the Bakersfield vicinity, urban kit foxes have access to anthropogenic food resources to supplement available natural prey so, in general, food is abundant. (Newsome *et al.* 2010, p. 1317)

2.4.3 Reproduction and Lifecycle

Kit foxes can breed when 1 year old but may not breed their first year of adulthood (Morrell 1972, p. 20). Adult pairs remain together all year, sharing the home range but not necessarily the same den. During September and October, adult females begin to clean and enlarge natal or pupping dens which often have multiple openings (Morrell 1972, p. 10). Mating and conception take place between late December and March (Morrell 1972, p. 19; Spencer *et al.* 1992, p. 9) (Table 2). The median gestation period is estimated to range from 48 to 52 days. Litters of from two to six pups are born sometime between February and late March (Morrell 1972, p. 19; Spencer *et al.* 1992, p. 9). The female is rarely seen hunting during the time she is lactating. During this period the male provides most of the food for her and the pups. The pups emerge above ground at slightly more than 1 month of age. After 4 to 5 months, usually in August or September, the family bonds begin to dissolve and the young begin dispersing. Occasionally juveniles will remain with the family group beyond the first summer (Koopman *et al.* 2000, p. 220). During a 6-year study at the Elk Hills Naval Petroleum Reserves in California, pups dispersed an average distance of approximately 5 miles (8 kilometers) from the natal den (Scrivner *et al.* 1987, p. 20). Adult and juvenile kit foxes radio-collared at the Elk Hills Naval Petroleum Reserves in California dispersed through disturbed habitats, including agricultural fields, oil fields, rangelands, and across highways and aqueducts. One pup crossed the Temblor Range into the Carrizo Plain (Scrivner *et al.* 1987, p. 27). Reproductive success of kit foxes appears to be closely correlated with abundance of their prey (Egoscue 1975, p. 126). Recent studies have supported early observations that kit fox appear to be strongly linked ecologically to kangaroo rats (White and Ralls 1993, pp. 863, 865–866).

Table 2. Timeline showing one year in the lifecycle of a San Joaquin kit fox.



2.4.4 Survivorship

Kit foxes are generally short-lived and have a low juvenile survival rate. Desert kit foxes in a Utah population had an average age of 2 years (Egoscue 1975, p. 124) and in a population at the Elk Hills Naval Petroleum Reserve-1, animals less than 1 year old outnumbered older foxes by 2.8:1 (Berry *et* *al.* 1987a, pp. 18, 23). Despite this, individual kit foxes can have a relatively long lifespan. Kit foxes on Naval Petroleum Reserve-1 (NPR-1) were found to live as long as 8 years (Berry *et al.* 1987a, p. 18, Table 4) but such longevity appears to be rare. Annual survival rates of juvenile foxes have ranged from 0.26 on Naval Petroleum Reserve-1 in California (Berry *et al.* 1987a, pp. 19, 24, 25, Table 6) to 0.21 to 0.41 on the Carrizo Plain (Ralls and White 1995, p. 726, Table 1). An annual adult mortality rate of approximately 50 percent has been reported (Morrell 1972, p. 22; Berry *et al.* 1987a, pp. 19, 24; Ralls and White 1995, p. 726, Table 1; Standley *et al.* 1992, p. 17).

Predation by larger carnivores (e.g., coyotes) is high and presumed to be a major factor in regulating kit fox populations (White and Garrott 1997, p. 1983). The effects of disease, parasites and accidental death are largely unknown, but were thought to account for only a small portion of mortality (Berry *et al.* 1987a, pp. 22–23, 27). More recent data from Camp Roberts and Bakersfield is challenging this assumption (section 3.3.5). Drought plays a role in low reproductive success (i.e., pups are born but do not survive to weaning). Adults can maintain weight and body condition and females can give birth, but pairs apparently cannot catch enough prey to support pups (White and Ralls 1993, p. 866). Success decreases when the density of prey species drops because of drought, too much rainfall, or other circumstances (White and Ralls 1993, p. 864).

Starvation, especially of pups, was noted to be a likely limiting factor for kit fox populations (Morrell 1972, p. 22). Consumption of small rodent species and leporids occurred concurrently with population increases in those species, suggesting to the authors that the ability to exploit a variety of resources on an opportunistic basis would enable kit foxes to persist in altered environments, and in areas subject to drought-related fluctuations in prey. Cypher *et al.* (2000, p. 31) suggested that kit fox preferentially forage on kangaroo rats and that declines in kangaroo rat densities negatively affect kit fox survival. Data from this study suggested that the relative rate of population growth was positively correlated with kangaroo rat presence and negatively correlated with the presence of other prey items. The decline in local kit fox populations has also been linked to the loss of kangaroo rat populations within that same area (Bean and White 2000, p. 7). Precipitation-mediated changes in prey availability are most often related to changes in vegetation. Low precipitation levels characteristic of droughts result in reduced seed production in the natural habitats of the San Joaquin Valley (Williams *et al.* 1993, pp. 36–37, 39, Figure 4; Germano and Williams 2005, p. 12). During several years of drought, seed resources for granivorous rodents, such as kangaroo rats, become scarce, resulting in declining abundance of these kit fox prey species (Williams *et al.* 1993, p. 94, 95; Cypher *et al.* 2000, pp. 32–33; Germano and Williams 2005, p. 12). In many locations, kit fox population abundance responds to lower prey abundance by declining, although there generally is a lag-time of one or more years before kit fox declines occur (Cypher *et al.* 2000, p. 31). High rainfall events also are known to reduce prey abundance dramatically (Germano 2010, p. 86). In eastern Contra Costa County, kit foxes were believed to have been extirpated in the county primarily due to an intensive California ground-squirrel control program (Orloff *et al.* 1986, p. 68). To date, no studies have addressed the energetic relationships for the kit fox associated with capture effort and food value of different prey species.

2.4.5 Den Use and Home Range

San Joaquin kit foxes use dens for temperature regulation, shelter from adverse environmental conditions, reproduction, and escape from predators. Den characteristics and use vary by location and season. Dens may be constructed by the animal itself (Berry *et al.* 1987b, p. 26; USFWS 1983, p. 12), modified from those constructed by other animals (Morrell 1972, p. 10), or they may use anthropogenic structures such as culverts, pipes, or other underground structures (Berry *et al.* 1987b, p. 22). Natal and pupping dens are generally larger than typical kit fox dens and nearly always have multiple entrances (Morrell 1972, p. 11; Berry *et al.* 1987b, p. 12, Table 1). Suitable den sites are an essential component of kit fox habitat as they provide shelter from extreme conditions, escape cover from predators, and provide a secure place to rear the young. In general, kit fox dens are found in flat or gently rolling terrain with slopes of less than 10 degrees and most dens (89%) are found on slopes of less than 30 percent (Archon 1992, p. 15, 30). Natal and pupping dens are generally found on flatter ground with slopes of about 6 degrees (O'Farrell and McCue 1981, p. 30; O'Farrell *et al.* 1980, pp. 44–45). Foxes change dens four or five times during the summer months and change natal dens one or two times per month (Morrell 1972, p. 15). Foxes on the Carrizo Plain Natural Area maintain numerous dens within their home range (White *et al.* 1994, p. 1833). Radio-telemetry studies indicate that foxes use individual dens for a median of 2 days (mean of 3.5 days) before moving to a different den. Den changes have been attributed to depletion of prey in the vicinity of the den, increases in external parasites such as fleas (Egoscue 1956, p. 353), and predator avoidance (White *et al.* 1994, p. 1833).

Kit fox home range in an area impacted by oil development in western Kern County found home ranges that averaged between 1.8 mi^2 (4.6 km^2) (Zoellick *et al.* 2002, p. 155) and 2.4 mi^2 (6.13 km^2) (Spiegel and Bradbury 1992, p. 85). Kit foxes on the Carrizo Plain had an average home range size of 4.5 mi^2 (11.6 km^2) (White and Ralls 1993, p. 864). A study conducted in conjunction with solar development on the northern end of the Carrizo Plain found an average home range size of 3.6 mi^2 (9.4 km^2) on the solar development site and 2.0 mi^2 (5.1 km^2) on the undeveloped reference site (Cypher *et al.* 2019, p. 23). In a fragmented landscape impacted by irrigated agriculture and with limited natural community availability home range sized averaged 1.3 mi^2 (3.4 km^2) (Cypher *et al.* 2014, p. 5). Occasionally foxes use home ranges much larger than reported by averages. Cypher *et al.* (2019, p. 23) reported home range sizes as small as 0.2 mi^2 (0.5km^2) up to 9.3 mi^2 (24.1 km^2).

Variations in home range appear to be related primarily to overall prey density. White and Ralls (1993, p. 866) found that home range sizes appeared to be associated with low prey availability on the Carrizo Plain where nocturnal rodents (primarily *Dipodomys* sp.) were the primary prey species. The also documented that prey densities were less than 20% of that at oil field sites in western Kern County (White and Ralls 1993, p. 866) where average home ranges were approximately 50% smaller (Spiegel and Bradbury 1992, p. 85; Zoellick *et al.* 2002, p. 155). Cypher *et al.* (2019, p. 56) also hypothesized that this inverse relationship between prey availability and home range size might explain some of the differences they observed between the developed solar site and reference site. Home range size in Bakersfield, where food is relatively abundant, averaged 0.7 mi^2 (1.7 km^2) (Frost 2005, p. 23). The maintenance of large and relatively non-overlapping home ranges, as noted on the Carrizo Plain, may be an adaptation to drought-induced periods of prey scarcity that are episodic and temporary on the Carrizo Plain (White and Ralls 1993, p. 866).

2.4.6 Metapopulation Dynamics

San Joaquin kit foxes persist across the landscape in scattered pockets of habitat of varying quality. These populations are challenging to identify due to annual population fluctuations and the overall low density of many of the populations. Across the range of the species, kit fox populations experience marked instability driven by density-independent variations in reproductive rates (White and Garrott 1999, p. 491). Some habitat patches support populations with growth rates which encourage emigration, while other habitat patches are less favorable. Additionally, ongoing habitat alteration as well as normal climatic variation can lead to rapid changes in the suitability of any habitat patch, further impacting growth rates and emigration. These source-sink dynamics are characteristic of a metapopulation, which often have a finite lifetime, and are prone to local extinction (Hanski 1991, p. 4).

2.5 San Joaquin Kit Fox Needs

A species can only be viable if its basic ecological needs are met. In this section, we translate our knowledge of the San Joaquin kit fox's biology and ecology into its needs at the individual, population, and species levels. For individual San Joaquin kit fox, we describe the habitat resources or conditions that adults, pups, and juveniles need to complete each stage of their life cycle. We then describe the habitat and demographic conditions that San Joaquin kit fox populations need for resiliency. Finally, we describe what the species needs in order to be viable, in terms of resiliency, redundancy, and representation (Figure 5).

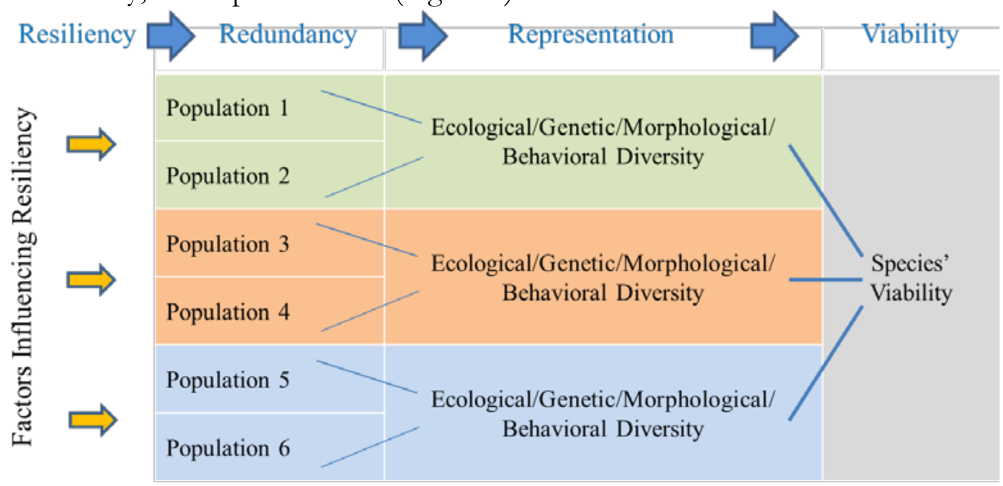


Figure 5. General overview illustration of how resiliency, redundancy, and representation influence what a species needs for viability.

2.5.1 Individual Needs

Individual needs for San Joaquin kit foxes vary somewhat by life stage but are all centered on the availability of suitable dens for breeding and sheltering (Figure 6). Kit fox pups are born underground between February and March and spend the first month of their life underground. In order to survive this life stage, the pups need burrows that are deep enough to provide shelter from the environment and potential predators. Adequate prey is needed for the female to produce enough milk for the young to grow large enough to leave the den. While the pups are underground, the female rarely leaves the den and the male gathers food for the pair. Often the pair will move the young at least once prior to the young emerging from the den and so multiple suitable den locations within the territory are needed. Once the young emerge from the burrow, they continue to be fed by the adults for several months. The pups typically emerge from the burrow after about 1 month (generally April) and gradually become more independent from April through June. During this period the female needs adequate prey to continue to provide milk and the pups need adequate prey as they are weaned and begin to forage for themselves. The pups gradually disperse from the natal site and generally move far enough to find unoccupied territory with suitable den sites and prey. However, it is likely that most individuals remain near their natal territories within their lifetime. Because of this, habitat connectivity is essential for San Joaquin kit fox viability.

San Joaquin kit foxes are most often limited to arid habitat with sparse or low vegetation, gentle slopes (less than 15%) with sandy-loam soils where den excavation or modification is relatively easy. Although individual kit foxes have been found moving through or denning on steeper slopes, natal dens appear to be restricted to slopes of 10% or less. In all life stages, kit foxes rely on suitable dens for shelter and escape from predators.

San Joaquin kit foxes primarily feed on small mammals, mostly kangaroo rats and adult kit foxes need abundant small mammal prey in order to survive and raise pups. Adult kit foxes also prey on a wide variety of other animals including insects, birds, and lizards, but successful breeding appears closely related to the abundance of small mammal prey. Home ranges of San Joaquin kit foxes appear to vary in response to prey availability and habitat quality, but average 1.7 mi^2 (4.5 km^2). As such, adult and juvenile kit foxes require large enough or connected habitat patches in order to find enough prey.

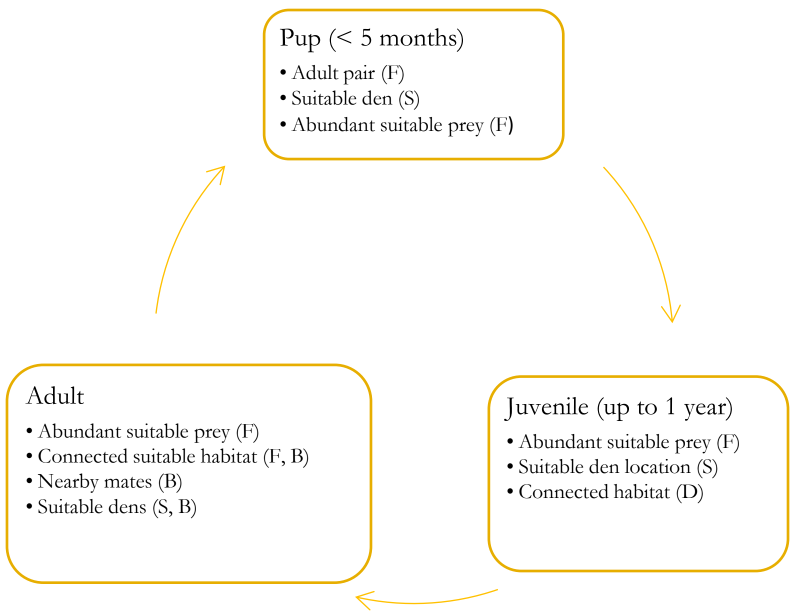


Figure 6. San Joaquin kit fox lifecycle diagram. Letters in parentheses denote whether the need is essential for feeding (F), sheltering (S), breeding (B), or dispersal (D).

2.5.2 Population Needs

San Joaquin kit fox populations for the most part need the same habitat features as individuals, although in larger quantities. We describe habitat and demographic needs of San Joaquin kit foxes in relation to population resiliency.

Resiliency

Resiliency describes the ability of the species to withstand stochastic disturbance events, an ability that is associated with habitat quality and demographic characteristics of the populations.
The San Joaquin kit fox does not appear to have easily distinguishable populations that can be defined by discrete ranges or genetic differences. For the purposes of this SSA, we broadly define a population of San Joaquin kit fox as a group of animals in the same general space and with the

potential to breed. For convenience, we refer to populations using the core and satellite units identified in the 2010 5-year review (USFWS 2010b, p. 12). We modified the boundaries of the "core" and "satellite" areas based on updated information on kit fox distribution and included the Salinas Valley, which had not been included in the prior 5-year review (USFWS 2010b, p. 12). These core and satellite areas are used as our geographical analysis units throughout the remainder of the document. Much of the historic habitat of the San Joaquin kit fox has been converted to agriculture, fragmenting the historical range and isolating suitable habitat patches. Highly connected habitats still have the largest, most robust populations of San Joaquin kit foxes, suggesting that contiguous habitats are needed for long-term species' survival. Populations likely need habitat patches of an appropriate size in order to sustain over time.

Demographic indicators that might suggest population resiliency are related to effective population size, fecundity, survival, and connectivity. Briefly, effective population size is calculated using an equation that incorporates heterozygosity, a measure of genetic diversity. Effective population size in wildlife is often much lower than census population size (Frankham 1995, entire). The ratio between effective population size and census population size varies based on factors such as unequal sex ratios, variance in family size, and population fluctuations. Of these factors, population fluctuations based on limited reproduction in drought years could be a contributing factor for San Joaquin kit foxes. Populations need sufficient numbers of juveniles and adults to be able to withstand drought conditions that limit reproduction. Because the species is relatively short-lived (Egoscue 1975, p. 124; Berry *et al.* 1987a, pp. 18, 23) and exhibits moderately high annual adult mortality (Morrell 1972, p. 22; Berry *et al.* 1987a, pp. 19, 24; Ralls and White 1995, p. 726, Table 1; Standley *et al.* 1992, p. 17), evidence of breeding is important.

Connectivity within and between populations is important to maintain (or in some cases, reestablish) gene flow. Although San Joaquin kit foxes probably occurred in connected populations throughout the historical range, anthropogenic habitat fragmentation has greatly reduced the potential for gene flow between populations in the current landscape. In isolated populations or genetic clusters, maintaining sufficient numbers of adults in a population to guard against loss of alleles (*e.g.*, from demographic bottlenecks) is important. Attempting to reestablish connectivity between fragmented areas, when possible, will also add to population resilience.

Figure 7 presents a core conceptual model showing the needs for, and threats to, San Joaquin kit fox population resiliency. To remain ecologically functional, geographic analysis units need high levels of fecundity and juvenile survival as well as connectivity between habitat patches both within the unit and between adjacent geographic analysis units. High levels of fecundity and juvenile survival can drive population growth and allow smaller populations to recover from stochastic disasters, such as extreme weather events.

Given the relatively short longevity of adults, annual recruitment of juveniles is imperative to replace the loss of reproductive individuals every year. Connectivity between habitat patches encourages dispersal of individuals and maintains gene flow, which prevents extirpation due to low genetic diversity and accelerated genetic drift.

The best physical predictors of suitable habitat for the kit fox are land cover/land use, terrain ruggedness, and vegetation density (White *et al.* 1995, p. 344; USFWS 1998, p. 129, Warrick and Cypher 1998, p. 716; Cypher *et al.* 2013, p. 26). Highly suitable habitat for the kit fox is characterized by low slopes (< 5%) (Warrick and Cypher 1998, p. 716), arid land vegetation communities with short stature (McGrew 1979, p. 3), and areas free of anthropogenic disturbance (Warrick *et al.* 2007, p. 276; Cypher *et al.* 2013, p. 26). This suggests a specific set of climatic and habitat conditions that are needed to maintain resiliency within the species range. Changes to vegetation and land cover, particularly during the breeding season could hinder the species' long-term viability.

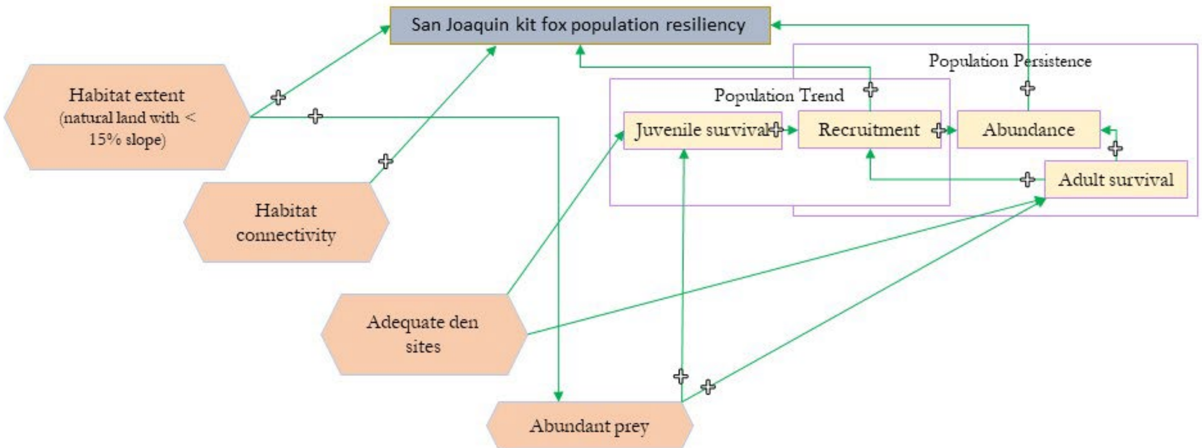


Figure 7. Core Conceptual Model showing the needs for San Joaquin kit fox population resiliency.

2.5.3 Species Needs

In order to adapt to changing environmental conditions, the species needs to maintain its ecological and genetic diversity (representation) in resilient populations distributed throughout the species range (redundancy).

Redundancy

Redundancy contributes to the ability of a species to withstand catastrophic events by spreading risk among multiple populations and/or across a large area. Thus, redundancy is related to the number, distribution, and resilience of populations. When evaluating redundancy, it is important to identify potential natural or anthropogenic catastrophic events that could occur within the range of the species and that could lead to population extirpations. For the San Joaquin kit fox, potential catastrophic events include a prolonged drought or large-scale disease outbreak. San Joaquin kit foxes are currently found in a band of habitat along the western San Joaquin Valley, the Carrizo Plain, and the Panoche Valley and as highly fragmented populations across the center, south, and eastern portions of the San Joaquin Valley. Because individual San Joaquin kit fox populations can often vary widely from year to year with changing environmental conditions, having multiple resilient populations is necessary for the species to weather potential catastrophic events.

Representation

Representation describes the ability of a species to adapt to changing environmental conditions, which is related to the breadth of genetic and ecological diversity within and among populations. As a species, the San Joaquin kit fox needs multiple, resilient, connected populations that display a breadth of ecological and genetic diversity across its range. Schwartz *et al.* (2005, p. 34) found evidence consistent with a high gene flow across the range of the species and suggested that ongoing gene flow (at least in the southern portion of the range) is occurring. They suggest that the data indicate that migration is likely in important factor in the partitioning of genetic variation (Schwartz *et al*. 2005, p. 34). Maintaining this diversity is important for the species to persist in the future in response to changing climatic variables or stochastic events. Well-connected geographic units with San Joaquin kit foxes that display high levels of immigration and emigration across the landscape ensure gene flow and allow for recolonization following droughts or other events that may depress a population.

San Joaquin kit fox habitat, although once widespread and abundant, has decreased dramatically since the early 1900s due in part to agricultural development. Today, the San Joaquin kit fox exists in a highly fragmented landscape and there is diminishing opportunity for gene flow across the range of the species. Connected habitats of appropriate composition are essential to the species survival; habitat fragmentation and decreased habitat connectivity can be detrimental to the long-term survival of the San Joaquin kit fox species. In order to adapt to changing physical and biological conditions, the species needs to maintain its genetic and ecological diversity (representation) and a certain number and distribution of resilient populations across its range (redundancy).

2.5.4 Summary of Species Needs in Terms of the 3Rs

When individual kit foxes have access to ample food, suitable den sites, and habitat, reproductive rates and populations increase. These conditions create large, resilient populations that can withstand periodic natural disturbances, such as drought or disease outbreaks (resiliency). At the population level, juvenile survival drives population growth and connectivity maintains dispersal and gene flow between occupied areas. The distribution of kit fox territories across the landscape, as well as high connectivity between areas of suitable habitat, create populations that can recover from catastrophic events (redundancy). At the species level, connectivity facilitates a network of multiple (redundant), self-sustaining (resilient) populations distributed across the San Joaquin kit fox's range that display a breadth of genetic and ecological diversity (representation). This increases the ability of the species to adapt to changing physical and biological conditions (representation). Having sufficient resiliency, representation, and redundancy supports maintenance of the species in the wild over time (viability).

Chapter 3. Historical and Current Condition

In this chapter, we summarize the historical and current conditions of the San Joaquin kit fox at the population and species levels. To do this, we introduce the stressors that have and continue to influence the species' condition as well as current conservation efforts which buffer against these stressors. We then detail how kit fox abundance has changed over time.

Finally, we put the species' historical and current conditions in the context of the 3Rs to assess the species' current viability. At the species level, the San Joaquin kit fox needs multiple, connected, resilient populations across the breadth of ecological settings in its range to be viable (Chapter 2).

For the purposes of this SSA we compiled spatial data from the California Natural Diversity Database (California Department of Fish and Wildlife 2020), California Conservation Easement Database (2019), California Protected Areas Database (2019) and data provided by researchers.

We used ESRI ArcGIS Pro for the spatial analyses conducted within this chapter. The data sources for these analyses are cited throughout this section.

3.1 Historical Distribution and Abundance

The historical range of the San Joaquin kit fox was first defined by Grinnell *et al.* (1937, p. 403). Prior to 1930, kit foxes likely inhabited most of the San Joaquin Valley from southern Kern County north to Tracy (San Joaquin County), on the western side of the Valley, and near La Grange (Stanislaus County), on the eastern side. These authors believed that by 1930 the kit fox range had been reduced by more than half, with the largest portion of the range remaining in the southern and western parts of the Valley (Grinnell *et al.* 1937, p. 403). The range of the kit fox was refined and better defined in 1975 using prior range mapping efforts, sightings, den locations, and road killed records (Morrell 1975, p. 6, 10). Orloff *et al.* (1986, p. 62, 68) concluded that kit foxes were likely rare in Alameda County and may have been recently extirpated in Contra Costa County. A summary of that status of the kit fox in the northwestern portion of the range was uncertain, and, if present, consisted of small family groups in isolated habitat patches (Clark *et al.* 2007, p. 32).

In 1969, Laughrin (1970, p. 14) estimated that range-wide kit fox densities were 0.52 to 1.04 per square mile (0.2 to 0.4 per square kilometer). The population of kit fox in 1975 was estimated to be between 5,066 and 14,800 (Morrell 1975, p. 18). The estimated mean density of trappable adult kit foxes was from 2 to 2.8 per square mile (0.8 to 1.1 per square kilometer) between 1980 and 1982 on the Naval Petroleum Reserves in California (O'Farrell 1984, p. 208). In the 1983 recovery plan (USFWS 1983, p. 10), it was estimated that the population range-wide of adult kit foxes prior to 1930 may have been between 8,667 and 12,134 assuming an occupied range of 8,667 square miles (22,447 square kilometers) and densities of 1.04 to 1.55 per square mile (0.4 to 0.6 per square kilometer). The kit fox population in San Luis Obispo, Santa Barbara, Kings, Tulare and Kern Counties was estimated to be about 11,000 animals in the early 1970s based on limited aerial surveys of pupping dens and amount of historic habitat, but without correction for cultivated and urbanized lands (Waithman 1974, p. 4). Laughrin (1970, p. 15) reported an estimated total population size of 1,000 to 3,000 foxes in 1969. In the 1983 recovery plan (USFWS 1983, p. 8), Morrell's data was adjusted and a corrected estimate of 6,961 foxes in 1975 was obtained. When compared to the pre-1930 estimate, this represents a possible population decline of 20 to 43 percent. Approximately 85 percent of the fox population in 1975 was found in only six counties (Kern, Tulare, Kings, San Luis Obispo, Fresno, and Monterey), and over half the population occurred in two of those counties: Kern (41 percent) and San Luis Obispo (10 percent) (Morrell 1975, p. 19, Table X).

3.2 Distribution and Abundance

Although there are no current rangewide survey data available, a patchwork of survey results and data from the California Natural Diversity Database (CNDDB) indicate that kit foxes were likely distributed throughout most of their historical range through the early 2000's. The CNDDB is the most up-to-date resource for current sighting information. Data submission to CNDDB is voluntary and the database is a presence only record. However, it does provide a snapshot of distributional changes over time and can show where the most robust kit fox populations are found.

Data from four of the northern units seem to show an absence from those areas recently (California Department of Fish and Wildlife 2020), but recent survey efforts have been opportunistic and do not likely cover all of the available habitat. Extensive surveys using scent dogs in 2001-2003 (Smith *et al.* 2006, p. 214) did not detect any kit fox sign in the survey areas in Contra Costa and Alameda counties. Over a period of 30 months from 2005-2007 surveys (camera trap, track station, and spotlighting) were conducted throughout the Santa Nella area (Constable *et al.* 2009, pp. 15–18, Table 2). In that period, only 2 observations (1 track, 1 scat) were documented north of Highway

152 (Constable *et al.* 2009, pp. 16–17, 18, Table 2). The authors conducted a least-cost path analysis through the Santa Nella area and concluded that these 2 observations were most likely indicative of a dispersing kit fox and not a resident individual (Constable *et al.* 2009, p. 36). Scent dog surveys conducted in 2018 at Lawrence Livermore National Laboratory Site 300 did not detect any kit fox sign across approximately 33 km of transects (Woollet 2019, p. 8). Although there is habitat remaining in the Salinas Valley, there is no current documented evidence of kit foxes in this area and the species is no longer found at Fort Hunter-Liggett or Camp Roberts. Over the last decade, data in CNDDB shows a pattern of kit fox occurrence concentrated in the southwest San Joaquin Valley (mainly Kern and Kings Counties), the Carrizo Plain (San Luis Obispo County), and urban Bakersfield (Kern County). A continuous pattern of occurrences is also reported from the Semitropic area (Kern County), Ciervo-Panoche Valley (San Benito County), Coalinga area (Fresno County) and western Merced County. Additional reporting has documented kit foxes in the Cuyama Valley (Ueda 2020) and Cholame Valley (Purnell 2020, entire).

Cypher *et al.* (2013, entire) analyzed the remaining habitat within the range of San Joaquin kit fox quantified as "high" and "moderate" suitable habitat and the home range needed by a kit fox. They calculated that a population of 3,616 foxes might currently remain within the species range. While this estimate makes several assumptions, it is considered a valid model of the potential size of the kit fox population (Cypher, 2020 pers. comm). Given that no persistent kit fox populations are present in "moderate" suitable habitat, this number may over-estimate the effective population size (Cypher *et al.* 2013, p. 29). San Joaquin kit foxes can exhibit significant population size variability. Most of the populations in natural areas fluctuate regularly depending on environmental conditions, particularly extremes of rainfall that have effects on prey species. Because of this, measuring changes in occupied areas through surveys has been a more effective way of assessing long-term populations viability rather than population numbers.

Although no range-wide distribution surveys have been conducted, data indicate that the kit fox have a moderate to high likelihood of occurrence in 11 of the 16 geographic analysis units (Figure 8). Populations have persisted throughout the western portion of the San Joaquin Valley south of San Luis Reservoir to the Buena Vista Valley, in the Panoche and Cuyama Valleys, and Carrizo Plain. Populations also continue to persist in the central portion of the Valley around Kern NWR and Semitropic Ecological Reserve, in Bakersfield, and in the southeastern portion of the Valley north to Porterville. Based on available survey data detailed below, we evaluated the certainty of occurrence across its range. We categorized this certainty into "low", "moderate", and "high". Low certainty of occurrence corresponded to those areas where either focused surveys (such as those at Camp Roberts) have documented a disappearance of the species or where broader surveys have not documented the species in over 15 years. Areas where we are moderately certain that the species persists are characterized by either more recent sightings or habitat connection to nearby areas with documented extant populations. Finally, those areas that correspond to high certainty are those areas where kit foxes are routinely documented. Currently, the only areas with high certainty of kit fox occupancy are found in the southern half of the San Joaquin Valley (Figure 8). Prior to the sarcoptic mange epidemic, the Bakersfield population has appeared stable or expanding with a population of 200–400 animals (Cypher and Van Horn Job 2012, p. 347), making it one of the largest remaining populations. Currently, this population is undergoing a severe decline which is discussed in detail in Section 3.2.5.

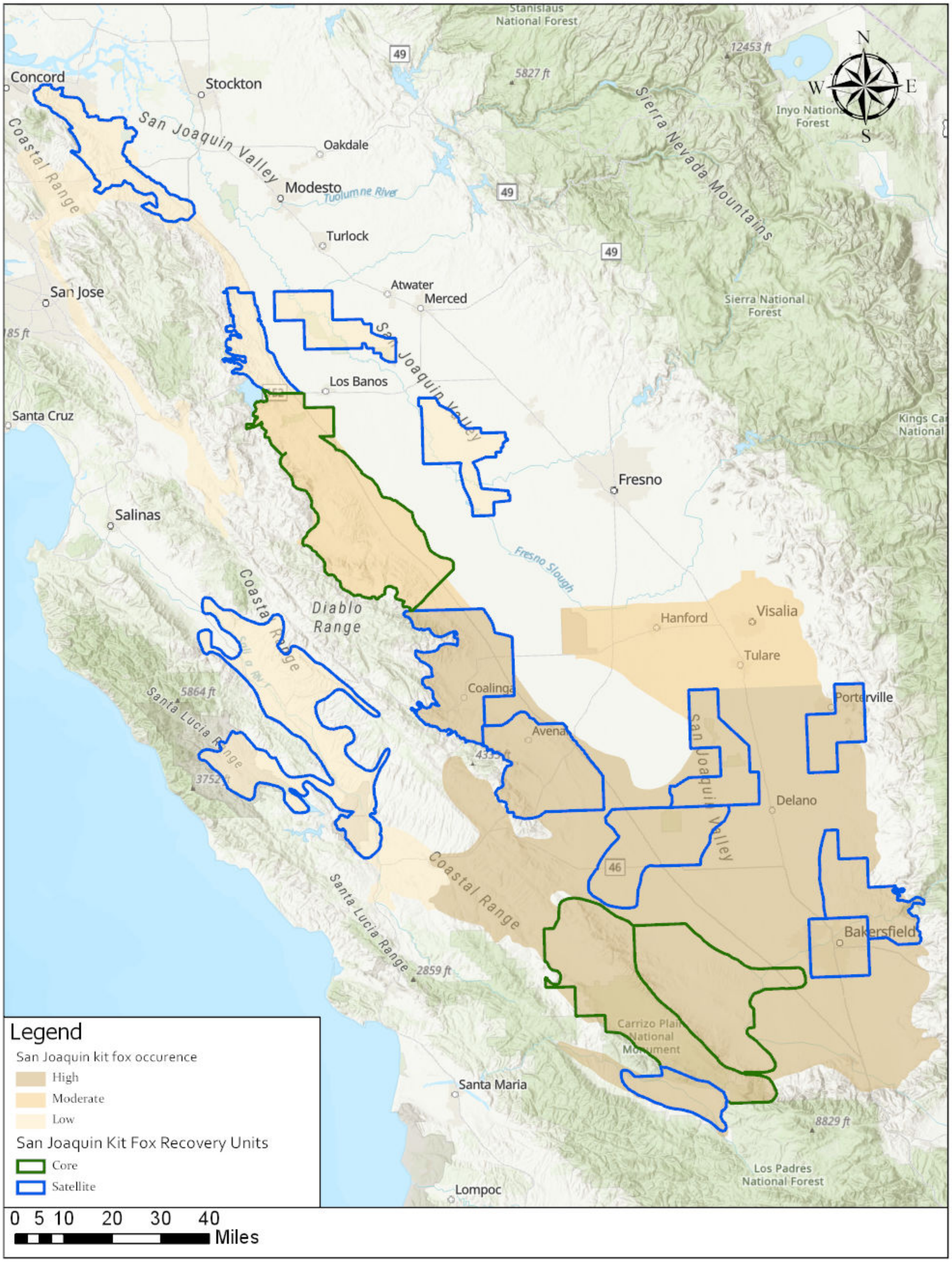


Figure 8. San Joaquin kit fox occurrence map. The kit fox range is divided into areas of "high", "moderate", and "low" certainty of occurrence based on California Natural Diversity Database information, researcher input, and other records.

3.2.1 Analysis Units

To assess the current condition across the range of the species, we used the geographic analysis units described in Section 2.5.2. These units generally center around historical kit fox sightings and, with a few exceptions, are bounded by topographical or man-made land use barriers that constrain kit fox movement. Although foxes do occur outside of these units (e.g. Cholame Valley), the analysis units represent the majority of the occupied habitat in a particular geographic area. However, these areas may provide important connectivity between geographic analysis units for dispersing kit foxes.

Throughout the historical range of the San Joaquin kit fox, sixteen distinct geographic units supporting kit fox populations have been identified (Figure 9). Within these units, individuals are scattered in pockets of optimal habitat in populations that are difficult to identify due to annual population fluctuations and lack of historic data. For a full description of these units see the recovery plan (USFWS 1998, p. 132-134).

3.3 Stressors Affecting the Species' Condition

In this section, we discuss how the long-term viability of the San Joaquin kit fox is affected by the 3R's. We discuss the external factors (stressors) that might influence the 3R's, and thus the viability of the San Joaquin kit fox. Previous documents which address the status of the species (USFWS 1998, pp. 122–136, USFWS 2010b, entire) describe some of these threats. We will use the term 'stressor' to include previously identified threats, as well as other factors which might affect the overall viability of the species.

Through review of the available literature, we chose to evaluate stressors for which there is broad consensus of the potential to impact the species. These stressors include habitat modification and destruction, energy development, drought, disease or pathogens, rodenticides, and predation. There are other possible stressors identified as potential threats in other documents, which were considered in the course of our analysis, such as off road vehicle use, mining, and overgrazing (USFWS 1998, pp. 130–131; USFWS 2010b, pp. 25–70) but these stressors are most often associated with negative effects to individual animals rather than entire populations. Therefore, these stressors are excluded from further analysis in our SSA report. For the stressors which are included, we provide a description of the magnitude of the stressor, and an influence diagram modelling the potential impacts of the stressor on population resiliency (Figure 12), and a summary of ongoing and potential conservation that might lessen these impacts.

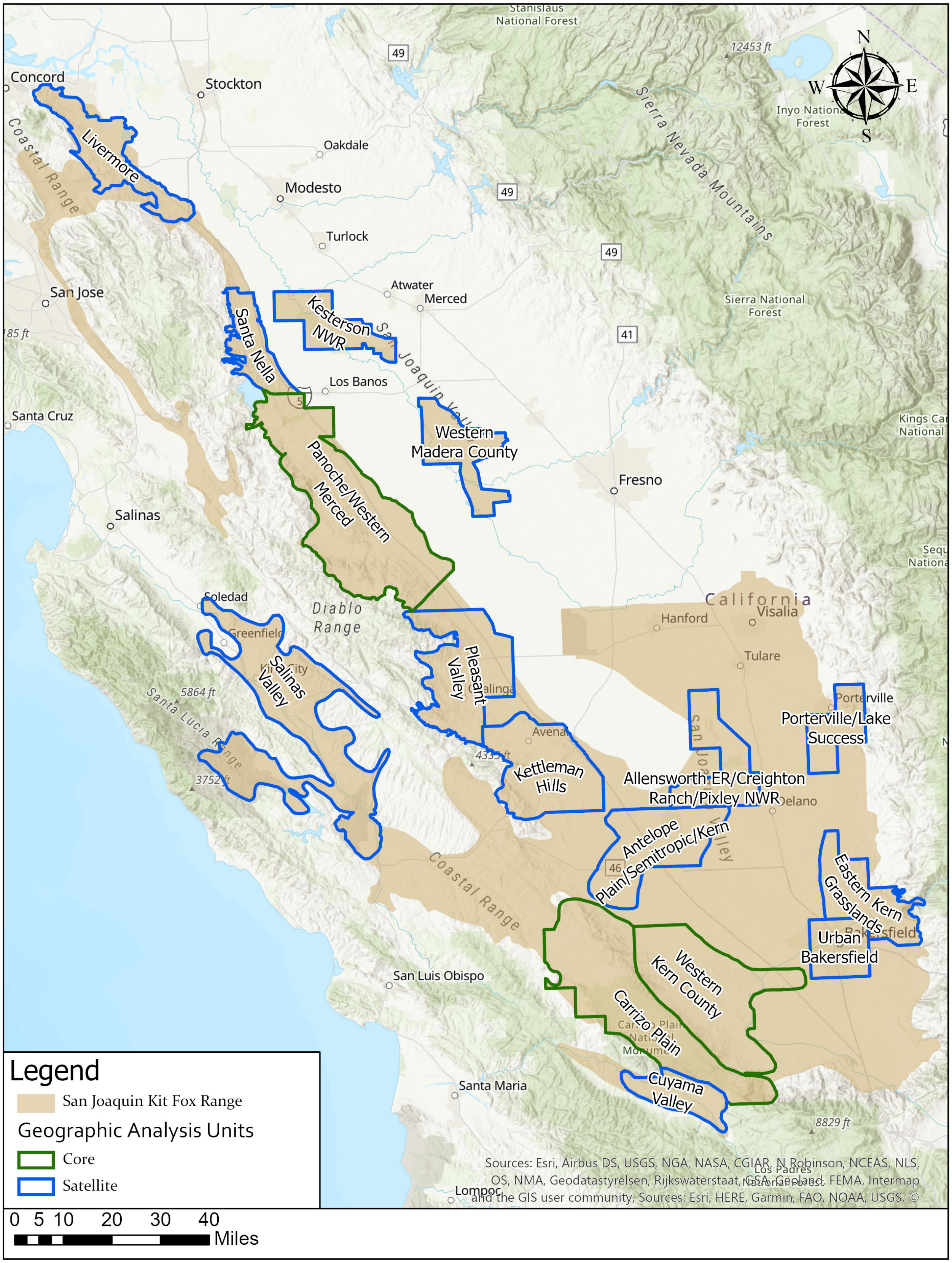


Figure 9. Geographic Analysis Units across the historic range of the San Joaquin kit fox.

3.3.1 Land Development

The loss and modification of habitat due to agricultural conversion, infrastructure construction, and urban development is the largest threat to the kit fox. Oil extraction and mining activities, solar energy development, changes in wildfire prevalence, and changes to vegetation structure due to non-native species and altered grazing regimes also result in habitat losses on a smaller scale.

At the time of listing, the USFWS identified land conversion to agriculture as the main stressor leading to the decline of the San Joaquin kit fox. Land conversion due to agriculture, mining, road construction, and urban and residential development were all identified as threats (i.e., Stressors) in the latest 5-year Review (USFWS 2010b, p. 25 –64). As habitat loss increases, so does habitat fragmentation, leading to a decrease in habitat patch size and an increase in non-habitat, or matrix habitat, between patches; both the loss of habitat and the isolation of habitat patches can reduce population sizes to such low levels that species become locally extinct (Gaines *et al.* 1997, p. 294). Several attempts have been made at quantifying the habitat loss in the San Joaquin Valley. Each estimate used different methodology to quantify habitat. However, they all paint a picture of significant habitat loss in the San Joaquin Valley to agricultural and urban development. The 1998 recovery plan estimated that less than 5 percent (approximately 150,000 acres or 60,700 hectares) of habitat on the San Joaquin Valley floor remained in native habitat at that time (USFWS 1998, p. 1). More recently, Germano *et al.* (2011, pp. 140–145) estimated that at least 59% of habitat in the San Joaquin Valley has been converted to agriculture and or urban areas. Cypher *et al.* (2013, entire) developed a model of habitat suitability for the kit fox and estimated that according to their criteria there was approximately 1,647 mi^2 (4,267 km^2) of highly suitable and 2,150 mi^2 (5,569 km^2) of moderately suitable habitat remaining within the range of the species (Figure 10).

Today, land conversion due to transportation, energy development, agriculture, and urbanization continues to stress the San Joaquin kit fox and its habitat while also presenting an obstacle to recovery efforts. Habitat patches, primarily on private land, continue to be altered for agricultural use. However, conservation practices and land acquisitions since the time of listing have increased the amount of protected land. Although conservation efforts have helped the species in recent years, habitat loss in general remains the greatest factor negatively affecting the viability of the San Joaquin kit fox (USFWS 2010a, p. 69).

3.3.1.1 Agricultural Land Conversion

Agricultural activities have occurred in the San Joaquin Valley since the 19th century when the region was first settled. The Central Valley Project (CVP) was completed in 1951 and accelerated the conversion of native lands to agriculture so that by 1979, 1979 less than 2 percent of the valley remained uncultivated (USDI 2005, p. 1). Land conversion contributes to declines in kit fox abundance through both direct (mortality, injury, displacement) and indirect (reduction in carrying capacity, changes in kit fox predator and competitor density) effects. Although kit fox can use dry land farmed areas (Jensen 1972, p. 6), irrigated agricultural is generally avoided by kit foxes when foraging and not used for denning (Warrick *et al.* 2007, p. 275). Conversion of native habitats to agricultural land, particularly orchards and irrigated crops, likely places increased pressure on local populations and can present dispersal barriers to the kit fox. Although the pace of native habitat loss has likely slowed from earlier in the 20th century, land conversion to agriculture continues to occur. Additionally, crop conversion is ongoing. Today, agricultural conversion from native habitat has slowed substantially, because most tillable land has already been cultivated due to lack of water or

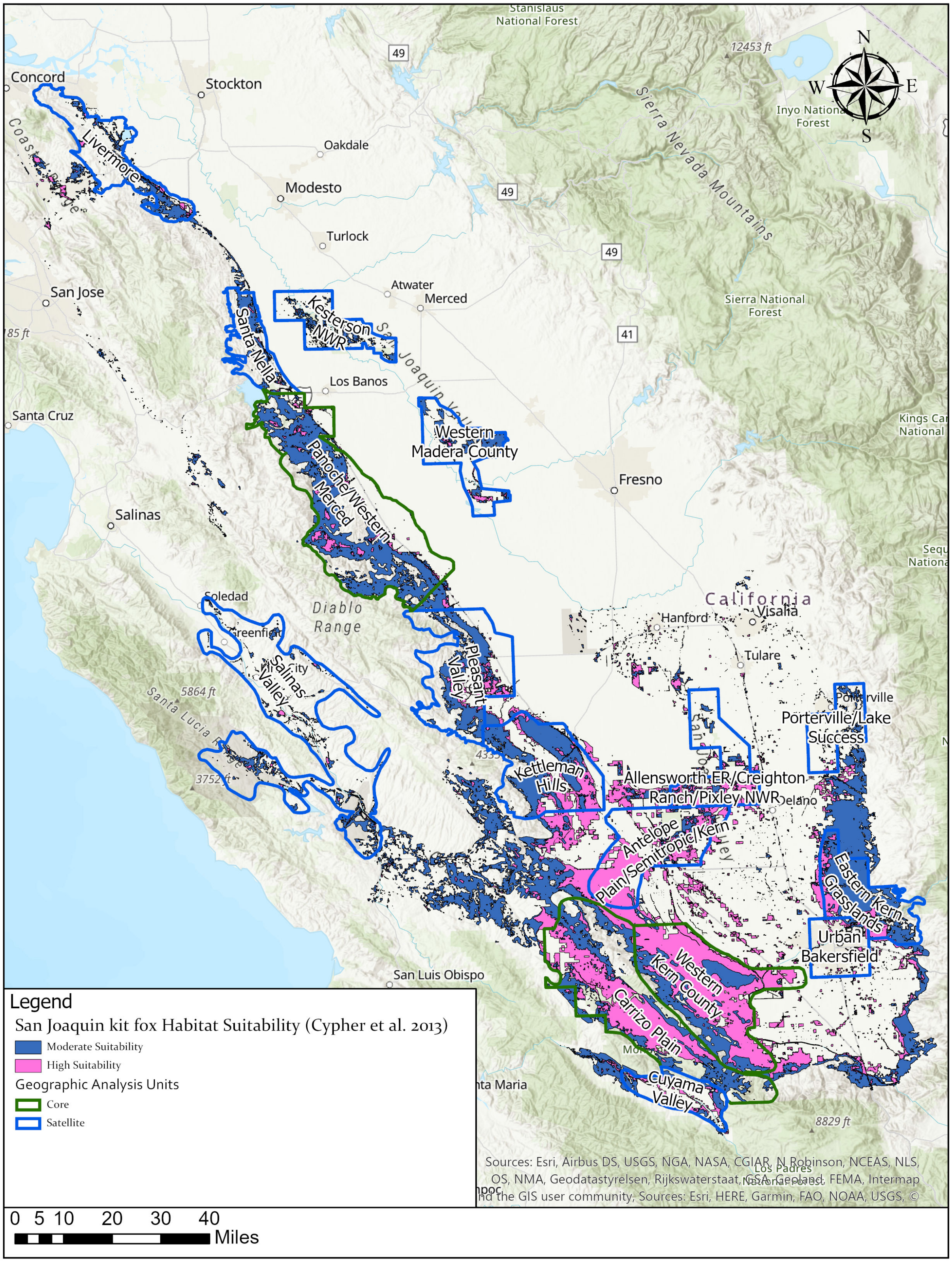


Figure 10. Modeled suitable habitat for the San Joaquin kit fox.

irrigation, and the remaining land is ill suited to agricultural development (USFWS 1998, p. 92).

In addition to the direct loss of habitat for denning and foraging by kit fox, some trapping studies have shown a difference in the small mammal communities between lands in irrigated agriculture and adjacent undeveloped land (Warrick *et al*. 2007, p. 274). Pesticide application associated with agricultural development reduce prey availability and may indirectly harm kit foxes (Hosea 2000, p. 242; Nogeire *et al*. 2015, p. 7). Throughout the San Joaquin Valley, farmlands often border and are interspersed with remaining parcels of natural habitat, fragmenting remaining habitat. The structure of some annual crops, such as cotton which forms a dense thicket up to 3 feet tall, may impede kit fox movement between parcels of native land (Warrick *et al*. 2007, p.275).

The conversion of natural lands to agriculture continues to be a threat, as blocks of suitable habitat continue to be converted to irrigated agriculture (Kelly *et al*. 2005, p. 65, Figure 2). Although analyzed at a broader scale, one study estimated a 37% loss of remaining grassland habitat across the Central Valley by 2100 (Byrd *et al*. 2015, p. 748).

3.3.1.2 Urbanization

The increasing human population of California, with the concomitant high demand for limited supplies of land, water, and other resources, contributes to many other stressors that impact natural communities (Gonzales and Hoshi 2015). A report by Fresno County in 2012 estimated that the valley-wide population may increase from 3,970,000 in 2010 to 6,740,000 by 2050 (The Planning Center 2012, p. 19). Within the counties that make up the core of the kit fox range (Kern, Kings, Tulare, Fresno, and Merced) the population is projected to nearly double by 2050 (Table 3).

Table 3. Projected population growth in the southern San Joaquin Valley (The Planning Center 2012 p. 18, Table 5).

County	Year	
	2010	**2050**
Kern	840,000	1,540,000
Kings	153,000	266,000
Tulare	442,000	710,000
Merced	256,000	461,000
Fresno	930,000	1,521,000
TOTAL	2,621,000	4,498,000

This continued increase in the human population has resulted in increased urban development throughout the San Joaquin Valley. Urbanization occurs throughout much of the range of the San Joaquin kit fox, but is particularly concentrated around existing urban development.

Bakersfield is currently the largest city within the range of the kit fox with a population of 380,000. The urban and suburban Bakersfield area has expanded to comprise approximately 70 percent of the Metropolitan Bakersfield satellite area for the kit fox.

3.3.1.3 Energy Development

At the time that the San Joaquin kit fox was federally listed, extraction of petroleum products (including crude oil, propane, natural gas, etc.) was not considered to be a threat to the kit fox, as most of the petroleum-producing land was still relatively undisturbed (Jensen 1972, p.7). Since that time, oil and gas extraction has expanded throughout the southern and western portion of the kit fox range; primarily in western Kern, Kings, and Fresno Counties.

Oilfields in the southwestern portion of the San Joaquin Valley include the Midway-Sunset Oilfield which is the highest-producing BLM lease in the United States (BLM 2008) and the 74 mi^2 Elk Hills Oilfield (the 7th largest in the United States). Oil and gas development is made up of both privately owned and federal (BLM) mineral estate. Most oil and gas leasing and development activities on public lands occur in the San Joaquin Valley on lands managed by the BLM's Bakersfield Field Office.

Development of oil fields likely impacts the prey species for the kit fox both through direct loss of the species as well as alteration of the small mammal community. A study of an oil spill found a decrease in abundance of Heermann's kangaroo rat (*Dipodomys heermanni*) between spill areas and control areas (Warrick *et al.* 1997, p. 22). High density oil field disturbances in western Kern County have been found to shift the composition of the small mammal community toward more generalist species (Fiehler *et al.* 2017, p. 139). Specialist species such as Nelson's antelope squirrel (*Ammospermophilus nelsoni*) and short-nosed kangaroo rat (*Dipodomys nitratoides*) were not found in high density oil fields (Fiehler *et al.* 2017, p. 139). Although, kit fox have a varied diet, (Cypher *et al.* 2000, p. 21; White *et al.* 1996, p. 364), during drought conditions, they did not appear to significantly shift their diet away from preferred species during periods of prey scarcity (White *et al.* 1996, p. 374). Instead, the kit foxes showed a pattern of decreased reproduction and may have contributed to poorer nutritional condition of the foxes (White *et al.* 1996, p. 375). Small mammal populations at NPRC showed strong responses to precipitation (Cypher *et al.* 2000, p. 31) and did not significantly differ between developed and undeveloped sites (Zoellick *et al.* 2002, p. 156). Impacts to prey species and small mammal communities within oil and gas development may be less important than year-to-year precipitation variation and direct loss of habitat. San Joaquin kit foxes appear to be tolerant of human disturbance as evidenced by their occupation of active oil and gas fields, solar facilities, and urban areas such as Bakersfield. In oil and gas fields they can be found denning in manmade structures such as pipes and culverts (Berry *et al.* 1987b, p. 12, Table 1). Oil and gas development impacts may impact kit fox through habitat loss and an associated reduction in overall carrying capacity (Cypher *et al.* 2000, p. 37). However, this relationship may not be linear and kit foxes continue to persist in areas of oil development (Cypher *et al.* 2000, p. 37).

Permanent modification to habitat due to oil and gas activities can reduce the species' ability to disperse and find new habitat. As more land is affected by extraction of natural resources, there could be population level responses associated with habitat degradation and habitat modification. The full extent of the effect to the San Joaquin kit fox from current or future oil and gas development is not fully understood at this time.

As of 2015, there were 48 utility-scale (> 20 MW) solar development projects planned, under construction, or operating within the range of the San Joaquin kit fox (Hernandez *et al.* 2015, p. 5). The largest of these are found in the Carrizo Plain where two solar firms have installed panels on approximately on 5,250 acres on the northern end of the Carrizo Plain in San Luis Obispo County (Cypher *et al.* 2019, p. 1). Another utility-scale solar facility covering 1,688 acres has been installed in the Cholame Valley in Monterey County. The most recently installed solar farm is a 2,154-acre facility in the Panoche Valley in San Benito County. Although these facilities have likely had impacts to San Joaquin kit foxes and their habitat, monitoring has shown that that solar development is not incompatible with kit fox presence (Cypher *et al.* 2019, entire). In addition, development of the solar facilities resulted in thousands of acres of land set aside under permanent conservation as mitigation. The Service expects that additional solar projects will be proposed on lands important to the kit fox at the southern extent of its range.

3.3.1.4 Land Protection

Central Valley Project Conservation Program (CVPCP) and Habitat Restoration Program (HRP)

The Central Valley Project (CVP) is a large multi-purpose water conveyance network designed to supply water and provide flood protection throughout a 400 mile (644 km) section of central California (Interior Region 10 2019). The Conservation Program (CVPCP) and CVP Improvement Act Habitat Restoration Program (HRP) are dual projects designed to protect and restore habitats impacted by the CVP. The San Joaquin kit fox is listed as a high priority species for these projects, with emphasis on efforts to: determine habitat management and compatible land uses, conduct presence/absence surveys, and protect key habitat areas (Bureau of Reclamation 2017, p. 2). Notable projects under the two programs include land acquisition and habitat restoration. The history of the CVPCP and HRP is discussed in detail in the blunt-nosed leopard lizard 2010 5-year Review (USFWS 2010a, pp. 24–33), including discussion of the Land Retirement Program and a list of lands acquired through the Bureau of Reclamation. Much of this land is mapped in the California Protected Areas Database (CPAD) and California Conservation Easement Database (CCED) (see next section).

Other Protected Land

Other entities including Federal and State agencies, non-governmental organizations (NGOs), Counties, and others protect land within the range of the kit fox. This land is subject to a wide variety of uses and land management, including areas with no mandate for wildlife protection. However, areas without a specific management plan in place can provide suitable habitat for the kit fox under certain conditions and are candidates for actions that could enhance their value for the species. Habitat Conservation Plans (HCP) developed under section 10 of the ESA are a critical component of land protection for the kit fox. To date, HCPs covering the San Joaquin kit fox have committed to protecting over 90,000 acres. While not all this acreage is comprised of kit fox habitat, a significant proportion of the land acquisition for these HCPs protects annual grassland and shrubland habitats. Large plans such as the East Contra Costa County HCP/NCCP and Metro Bakersfield HCP have been instrumental at preserving relatively large parcels of land under permanent easement for the benefit of the kit fox. We compared land protection within species historical range and within the identified analysis units to assess the proportion of land within the range of the species that may provide some long-term protections from land conversion. We note that some of these areas do not currently (or may never) provide habitat for the kit fox due to land management, public access issues, or generally unsuitable terrain or landcover. For example, Mendota Wildlife Area is 11,800 acres but is mostly floodplain or flatlands, with limited alkali scrub (CDFW 2020).

The CPAD and CCED map existing land protections in California, and are a useful visual tools to assess contiguous blocks of land that support San Joaquin kit fox populations, as well as potential land acquisitions that could help promote corridors between populations. We mapped CPAD and CCED relative to the San Joaquin kit fox historic range and analysis units (Figure 11). Because large blocks of contiguous land are important for the resilience of San Joaquin kit fox populations, conserving connected parcels of land is important for the health of the species.

Summary of impacts to the 3Rs

Reduction in habitat quality and quantity due to human induced land use change can alter the local habitat composition of an area making populations of San Joaquin kit fox less resilient and more vulnerable to stochastic events. Habitat fragmentation can also reduce connectivity and prevent gene flow among populations, leading to a reduction in population resiliency and species redundancy. In some areas, land protections have been put in place to prevent further alterations to native habitat. In other areas, mitigation and restoration is being done to restore lands that were once habitat back to their native state. Protected lands may help offset effects to the 3R's that arise from land use changes.

3.3.2 Climate Variability

Drought is defined as a deficiency in precipitation over an extended period, which reduces water supply, water quality, and range productivity, and impacts social and economic activities. Although drought is a relatively normal process throughout southern California, under climate change scenarios natural, historical stressors (i.e., drought, wildfires, flooding, etc.) have the potential to become exacerbated and extreme, due to anthropogenic factors. Small, fragmented populations of San Joaquin kit fox are at a higher risk of local extinction during extreme climatic events than are large populations on contiguous habitat. Drought specifically impacts the San Joaquin kit fox through alteration to the prey species. Giant kangaroo rat populations are greatly affected by changes in precipitation and herbaceous plant growth (Germano and Saslaw 2017, p. 1616). An extreme drought in California which lasted approximately from 2013 – 2016 saw precipitous declines in giant kangaroo rat numbers (Prugh *et al.* 2018, p. 2). Data suggest that kit foxes show decreases in reproduction and overall population decline in response to alterations in prey resulting from a drought period (Cypher *et al.* 2000, p. 33).

San Joaquin kit foxes are well adapted to annual cycles of drought and rainfall that are characteristic of the San Joaquin Valley. However, under current climate change scenarios climatic variability in the San Joaquin Valley is likely to increase. The Valley will likely see prolonged periods of drought (5 years or longer) punctuated by uncharacteristically heavy rainfall events. Individual San Joaquin kit fox will need to move throughout the environment to find enough mates and resources to survive and reproduce during times of drought and increased temperatures. Therefore, large areas of contiguous habitat are needed to ensure the species can survive harsh conditions (Figure 7). Data from the Carrizo Plain and Elk Hills show significant population changes in response to drought. In the Carrizo Plain, this variation appears to correspond to change in availability of the main prey species, the giant kangaroo rat (*Dipodomys ingens*).

Under current reasonable climate change scenarios, the San Joaquin Valley is likely to see changes in current ecosystem processes (Stewart *et al.* 2019, p. 6). Currently, the western slopes of the San Joaquin Valley are a climatic desert with low annual rainfall (Germano *et al.* 2011, p. 6). Precipitation typically occurs in the winter months, primarily between October and April. Historically there has always been inter-annual variation in precipitation and temperature; to which native species have adapted. These historical processes are projected to change and become more variable under predicted future climate scenarios, and extreme droughts punctuated by heavy, episodic rainfall are both reasonable climate predictions. San Joaquin kit foxes are well adapted to variable climate conditions. However, drought has been linked to population declines in kit foxes and increasing frequency and severity of drought conditions may have an effect. Increasing variability in inter-annual precipitation (Single *et al.* 1996, pp. 36, 38–39) is already affecting portions of southern California, including the San Joaquin Valley. Weather patterns altered from historical norms are likely to affect annual rainfall; variation in annual rainfall can affect food availability for San Joaquin kit fox, causing population level responses.

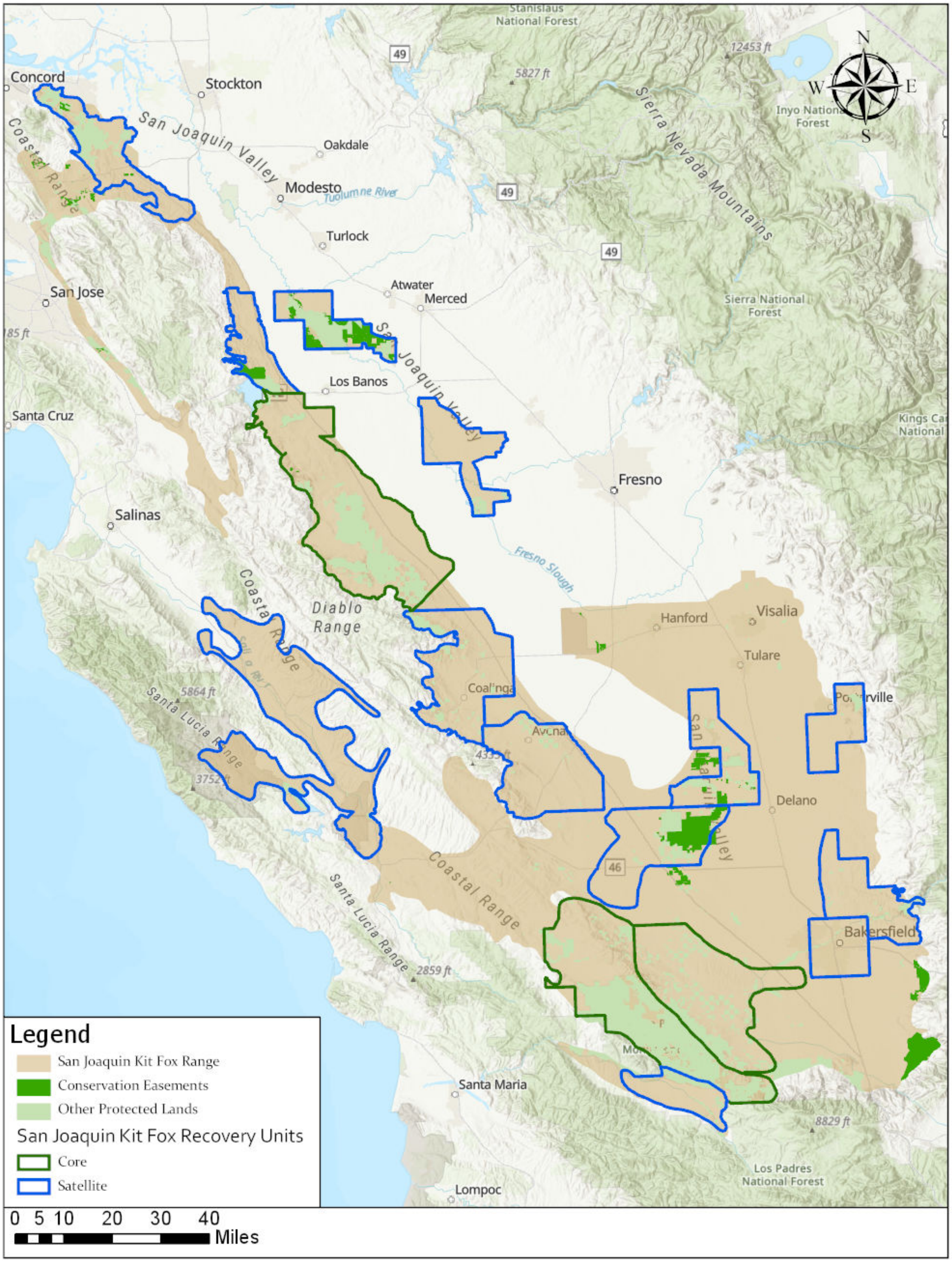


Figure 11. Land protection across the historic range of the San Joaquin kit fox.

Summary of Impacts to the 3Rs

Kit fox populations affected by drought exhibit lower abundance, reproduction, and survival due to the impacts of drought on prey availability. This makes kit fox populations less resilient and more vulnerable to other stochastic events. San Joaquin kit foxes are well-adapted to xeric habitats (Morrell 1972, p. 4); however, if drought-induced decreases in population size could limit immigration and gene flow. This could lead to the loss of populations across the range and decrease the redundancy of the species, making it more susceptible to a wide scale, catastrophic event. The effects of drought may be amplified if it occurs in concert with other stressors.

3.3.3 Pesticide Use

Pesticides, and specifically rodenticides, pose a threat to kit foxes through direct or secondary poisoning. For example, kit foxes may be killed if they ingest rodenticide in a bait application, or if they consume rodents that have consumed bait (Orloff *et al.* 1986, p. 66; Berry *et al.* 1992, p. 11; Huffman and Murphy 1992, p. 378; Standley *et al.* 1992, p.16; Hosea 2000, p. 242). From the 1960s into the early 1980s rodenticides were often broadcast over large areas by airplane (USFWS 1998, p. 92). It is difficult to assess the magnitude of current impacts from rodenticides to San Joaquin kit fox populations. The state of California no longer broadcasts rodenticides over large areas of habitat (USFWS 2010a, p. 33). However, anticoagulant rodenticides are still used in agriculture to prevent damage to plants by wild rodent species (Franklin *et al.* 2018, p. 1). Anticoagulant rodenticide exposure and poisoning has emerged as a conservation concern for non-target wildlife on public lands (Gabriel *et al.* 2012. p. 1). Kit foxes may also be threatened by loss of prey if rodent prey populations decline due to rodent control programs. This is surmised as a cause for declines in the kit fox population in Contra Costa County (Orloff *et al.* 1986, p. 66).

Rodenticides are also used in urban, suburban, and rural areas to control a variety of rodents, including house mice, voles, pocket gophers, ground squirrels, and Norway rats (USEPA 2008, p. 2), animals that may comprise prey for the kit fox to varying degrees, depending on the prey community available in each locality. Predatory mammals (particularly the kit fox) from the urban-suburban environment surrounding Bakersfield experience high levels of exposure to anticoagulant rodenticides (McMillin *et al* 2008, p. 165). Use of these rodenticides by the untrained public is thought to be the likely source of exposure for these animals. Schitoskey (1975, p. 417) found that captive kit foxes consistently preferred dead kangaroo rats over anthropogenic food sources indicating that if dead rodents were present on the landscape, they would likely be consumed by the kit fox. Exposure modelling estimated that 36% of kit foxes were exposed to rodenticides and that 70% of this exposure resulted from low-density development (Nogiere *et al.* 2015, p. 7). A study in Bakersfield found that 73.5% of sample foxes showed evidence of rodenticide residue and 42.6% showed evidence of more than one rodenticide (Cypher *et al.* 2014, p. 7). Mortalities from rodenticides have been documented by Hosea (2000, p. 239, Table 2), Standley *et al.* (1992, p. 16), and McMillin *et al.* (2008, p. 165).

While regulations and procedures have been implemented to reduce non-target exposure, the effectiveness of these new regulations is not clear at this time. Kit foxes continue to be exposed to products used legally and illegally, or even to products whose use has been discontinued but have ongoing residual effect. However, given the potential for secondary exposure of kit foxes throughout its range, particularly in agricultural areas, along canals, and in urban areas, the Service expects rodenticide exposure could have effects to some kit fox populations, particularly where these populations are small or where they rely on target species, such as ground squirrels and murid rodents, for prey.

Summary of Impacts to the 3Rs

Kit fox populations affected by pesticide use may exhibit lower abundance, reproduction, and survival. Although precise effects of non-target exposure are unknown, studies of kit fox and other non-target wildlife have shown effects ranging from a reduction in fecundity to mortality. Exposure across the range of the species may depress reproduction and lower survival rates for juvenile kit foxes. This in turn, reduces population sizes and may make exposed populations less resilient and more vulnerable to other stochastic events. The effects of pesticide exposure are likely amplified by the effects from other stressors such as drought or habitat fragmentation.

3.3.4 Predation

Predation has been identified as a leading cause of kit fox mortality (Ralls and White 1995, p. 727). Most predator-related deaths are attributable to coyotes (Ralls and White 1995, p. 727; Cypher *et al.* 2000, p. 27), but bobcats also may contribute to much of the predator-caused mortality (Spiegel and Disney 1996, pp. 75 –76, Table 2; Cypher *et al.* 2000, p. 27). In addition to mortality caused by wild canids, kit foxes have also been killed by badgers, golden eagles, and free-ranging dogs (Briden *et al.* 1992, p. 87; Standley *et al.* 1992, p. 15; Ralls and White 1995, p. 727; Spiegel and Disney 1996, pp. 81, 85; Clark *et al.* 2005, p. 158). The lack of available dens for shelter in altered landscapes may increase the predation risk to kit fox from canids in these areas (Cypher *et al.* 2005, p. 10). Mortality due to interactions with predators, primarily coyotes, has ranged between 57 percent and 89 percent in the southern San Joaquin Valley (Standley *et al.* 1992, p. 15; Ralls and White 1995, p. 727; Spiegel and Disney 1996, p. 75; Cypher *et al.* 2000, p. 16, Tables 4 and 5). An experimental coyote-control program at the Elk Hills Naval Petroleum Reserves in California did not result in an increase in survival rate for kit foxes, nor did coyote-induced mortality decrease (Cypher and Scrivner 1992, p. 45). Often canid predators do not consume the kit foxes they kill indicating that canid predators do not always consume their prey, so kit fox mortality from coyotes may be due to interference competition (Cypher and Spencer 1998, p. 211; Cypher *et al.* 2000, p. 34; Nelson *et al.* 2007, p. 1473). Interference competition occurs when individuals of one species behave in a manner that suppresses individuals of another species, effectively reducing the second species' use of shared resources. Although this is generally not defined as predation, for the purposes of this discussion we lumped this type of mortality under the umbrella of "predation".

Other canids such as gray foxes and red foxes may compete with kit fox, though the degree of competition is unknown. The need for similar den sites and prey species probably place nonnative red foxes in direct competition with the much smaller kit fox. Nonnative red foxes are expanding their geographic range in central California (Orloff *et al.* 1986, p. 67; Lewis *et al.* 1993, p. 14), and competition with or predation on kit foxes may be a factor in the apparent decline of kit foxes in the Santa Clara Valley, and perhaps elsewhere in the northwestern segment of their range. Coyotes aggressively dominate encounters with red foxes and will pursue and kill both red and gray foxes (Sargeant and Allen 1989, entire), as well as kit foxes. Coyotes may reduce the negative impacts of red foxes on kit foxes by limiting red fox abundance and distribution, but details of interactions between the two species and the extent to which coyotes might slow or prevent the invasion of red foxes into kit fox habitats are unknown (White *et al.* 1994, p. 1835; Ralls and White 1995, pp. 727–728).

Summary of Impacts to the 3Rs

Kit fox populations affected by increased predation may exhibit lower abundance and survival, particularly of juvenile foxes. This would have a long-term effect of reducing the size of the population which may make populations less resilient and more vulnerable to other stochastic events. Because increased predation may occur in areas where human development, both urban and agriculture, is occurring the effects of increased predation are likely increased by concurrent effects from land conversion.

3.3.5 Disease

Wildlife diseases (rabies, canine parvovirus, canine distemper virus, etc.) could cause substantial mortality or contribute to reduced fertility in female kit foxes (White *et al.* 2000, p. 205; Miller *et al.* 2000, p. 802). Diseases may threaten long-term viability of small populations of wildlife (Thorne and Williams 1988, pp. 67–69). Overall, disease was thought not to be a leading cause of mortality in kit foxes (McCue and O'Farrell 1988, pp. 278–279; Standley and McCue 1992, p. 12). However, two recent incidents at Camp Roberts and in Bakersfield have demonstrated that in certain instances, disease outbreaks may have population-level effects. Rabies has been implicated in the loss of a population at Camp Roberts (White *et al.* 2000, p. 209) and currently an outbreak of sarcoptic mange (*Sarcoptes scabei*) is causing steep population declines in the Bakersfield kit fox population (Deatherage 2020, p. 70). The mange epidemic in Bakersfield was first observed in 2013, and, although mortality from this outbreak is high (70% overall and 100% without veterinary intervention), thus far it appears to be largely limited to Bakersfield (Cypher *et al.* 2017, pp. 48–49, 51, Table 1). A few kit foxes with sarcoptic mange have been documented from Taft, but the outbreak does not appear to have spread into natural lands (Cypher pers. comm. 2020). Disease and predation may have both contributed to the catastrophic decline in the isolated population of San Joaquin kit fox at Camp Roberts, in San Luis Obispo County. Kit fox captures decreased from 103 in 1988 to 20 in 1991, and further to only 3 in 1997 (White *et al.* 2000, p. 207, 209, Table 1). During this same period, captures of striped skunks (*Mephitis mephitis*) also decreased, but the proportion of skunks that were found to be rabid increased. This correlation led biologists to propose that rabies was a factor in the kit fox decline (White *et al.* 2000, pp. 208, 209, Table 3).

3.3.6 Road Mortality

Vehicle strikes are a consistent, but small source of kit fox mortality on natural lands (Cypher *et al.* 2000, pp. 14–16, Tables 4 and 5; Bjurlin and Cypher 2003, p. 398, Table 1), with vehicle strikes accounting for <10 percent of mortality at the NPRC (Cypher *et al.* 2000, p. 27). On natural lands, kit foxes are sometimes killed by vehicle strikes, but impacts of roads on kit fox ecology are generally thought to be low (Cypher *et al.* 2005, p. 16). Although vehicle strikes may not have population-level effects in natural lands where traffic volume is low, vehicle strikes appear to be a more substantial source of mortality in human-altered landscapes, including urban environments (Bjurlin *et al.* 2005, p. 20; Cypher *et al.* 2003, as cited in Cypher and Brown 2006, p. 10). In urban settings such as Bakersfield, vehicle strikes can be the largest source of kit fox mortality and may impact urban kit fox populations (Bjurlin *et al.* 2005, p. 20).

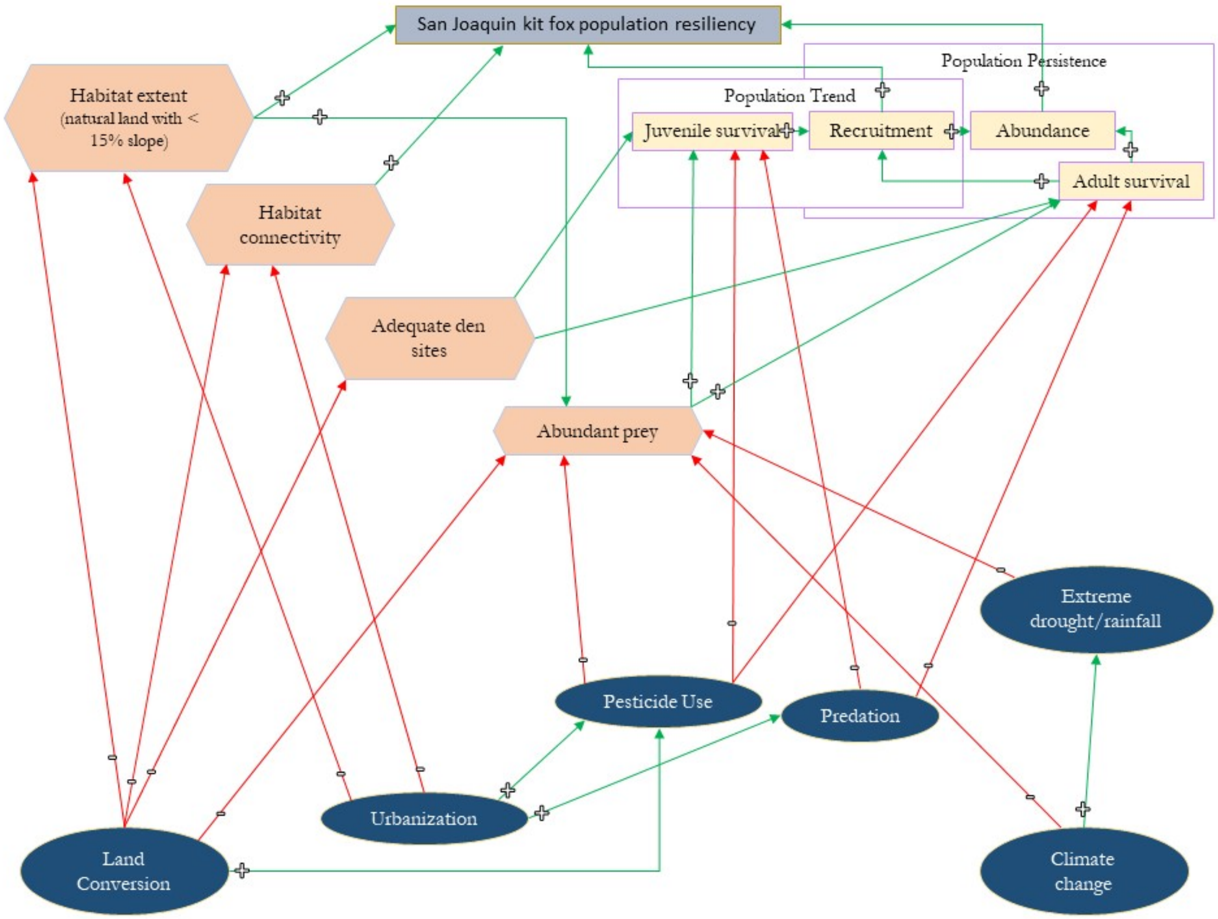


Figure 12. Core conceptual model showing the stressors and needs for the San Joaquin kit fox.

Based on survey data at Camp Roberts, the population of San Joaquin kit fox in the Salinas Valley appears to have significantly dwindled and may no longer be present. Similarly, the population at Fort Hunter-Liggett has not been documented in several decades. Continuing records in the Paso Robles area suggest that kit foxes may still be present, but at low densities in this area (Dave Hacker pers com). Currently the only verified extant population in Monterey County occurs in the Cholame Valley. Finally, there are no current verified records within the last 10 years of kit fox north of Porterville on the east side of the San Joaquin Valley.

Although kit foxes have been documented in this area on occasion, historic data suggest that the fox has always been rare in this area (California Department of Fish and Wildlife 2020). In particular, large portions of the landscape north of Fresno are designated critical habitat for a wide variety of vernal pool species and the landscape is dominated by more mesic species. The characteristics that provide a premier vernal pool landscape such as clay soils and significant ponding likely reduce the suitability of the habitat for the kit fox by restricting the available areas for denning (Cypher *et al.* 2013, p. 29).

Throughout much of the kit fox range, individual populations are fragmented into smaller islands of suitable habitat that are isolated by topographic and manmade barriers. Currently the largest, most robust populations exist on the western periphery of the southern San Joaquin Valley and in the

Carrizo Plain. Habitats in this area are primarily comprised of sparse annual grassland and shrubland, and in some areas, there are large blocks of intact habitat. This area was mapped as having the most "high" habitat suitability by Cypher *et al.* (2013, p. 27). North of Santa Nella, habitats are primarily comprised of *Aveena* sp. grassland and the topography is generally steeper. Cypher *et al.* (2013, p. 27) modeled this as "moderate" habitat suitability.

Genetic studies have supported division into three distinct genetic clusters: Ciervo-Panoche, Bakersfield, and western Kern County/Carrizo Plain/Camp Roberts (Wilbert 2013, p. 80). In particular, Wilbert (2013, p. 85) indicated that the population in Bakersfield shows a unique genetic signature that is rarely found in the other genetic clusters. Both landscape level genetic studies indicate that gene flow is continuing through the sampled kit fox populations (Schwartz *et al.* 2005, p. 33; Wilbert 2013, p. 83) and that none of the sample populations were showing evidence of robust levels of genetic diversity and heterozygosity (Wilbert 2013, p. 80).

3.3.7 Existing Regulation

3.3.7.1 California Endangered Species Act (CESA)

The CESA (California Fish and Game Code, section 2080 et seq.) prohibits the unauthorized take of State-listed threatened or endangered species, The CESA requires State agencies to consult with the California Department of Fish and Wildlife that might affect a State-listed species and mitigate for any adverse impacts to the species or its habitat. Pursuant to CESA, it is unlawful to import or export, take, possess, purchase or sell any species or part or product of any species listed as endangered or threatened. The State may authorize permits for scientific, educational, or management purposes, and to allow take that is incidental to otherwise lawful activities.

3.3.7.2 Endangered Species Act (ESA)

The Endangered Species Act of 1973, as amended (ESA), is the primary Federal law providing protection for the San Joaquin kit fox. The Service has responsibility for administering the Act, including sections 7, 9, and 10 that address take. Section 9 prohibits the taking of any federally listed endangered or threatened species. Take is defined in section 3 as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harass is defined by Service regulations at 50 CFR 17.3 as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. Harm is defined by the same regulations as an act which actually kills or injures wildlife. Harm is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering. The ESA provides for civil and criminal penalties for the unlawful taking of listed species.

Since listing, the Service has analyzed the potential effects of Federal projects under section 7(a)(2), which requires Federal agencies to consult with the Service prior to authorizing, funding, or carrying out activities that may affect listed species. For projects without a Federal nexus that would likely result in incidental take of listed species, the Service may issue incidental take permits to non-Federal applicants pursuant to section 10(a)(1)(B). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity (50 CFR 402.02). To qualify for an incidental take permit, applicants must develop, fund, and implement a Service-approved Habitat

Conservation Plan that details measures to minimize and mitigate the project's adverse impacts to listed species. Many of these Habitat Conservation Plans are coordinated with the State of California's related Natural Community Conservation Planning program.

The status of the kit fox as a species listed under the ESA can reduce the severity of the effects of habitat loss due to urban and energy development, and, in some case, agricultural development. Development projects that are subject to section 7 consultation or result in the issuance of an incidental take permit under section 10 typically include habitat compensation, which can reduce the severity of overall habitat loss typically associated with these projects. Habitat compensation can occur via a variety of mechanisms, including the purchase of credits at approved conservation banks, through permittee responsible mitigation, and through the development of habitat conservation plans (HCPs). In addition to reducing the amount of overall habitat loss for the species, section 10(a)(1)(A) of the ESA allows for permits to be issued for recovery activities that result in take. Recovery activities are those activities that are specifically implemented for scientific purposes or to enhance the propagation or survival of the affected species, including interstate commerce activities.

Conservation Banks

A conservation bank is a site, or suite of sites (i.e., umbrella bank), that is conserved and managed in perpetuity, and provides ecological functions and services for specified listed species or resources. Conservation banks function to offset adverse impacts to these species that occurred elsewhere; therefore, the Service approves a specified number of credits that the bank owner may sell to developers or other project proponents for use as compensation for adverse impacts their projects have on those species. The bank owner then uses the money from the credit purchases to permanently protect and manage the land for those species and resources. More information about conservation banks within the Sacramento Fish and Wildlife Office's Service area can be found at: https://www.fws.gov/sacramento/es/Conservation-Banking/Banks/In-Area/.

Currently, there are 16 banks covering 23,681 acres that conserve habitat for the kit fox. Conservation banks are found throughout the range of the species. Four banks totaling 9,953 acres have sold out of credits. The remaining 12 banks are currently active. Not all the land within each bank provides suitable habitat for the species. However, conservation banks provide permanent protection that can secure suitable habitat and link movement corridors.

Permittee Responsible Mitigation

Permittee-responsible mitigation includes activities or projects undertaken by a permittee (or authorized agent) to provide compensatory mitigation for which the permittee retains full responsibility. Permittee-responsible mitigation projects are typically not established in advance of the impacts they are offsetting and they do not have credits that can be used at a later time to offset different impacts, like conservation banks.

Habitat compensation through permittee responsible mitigation for the San Joaquin kit fox occurs throughout the species range for a number of projects. The primary agencies implementing permittee responsible mitigation for the San Joaquin kit fox include the Bureau of Reclamation, Caltrans, oil and gas companies, and several solar facilities.

HCPs

Habitat Conservation Plans (HCPs) are planning documents required as part of an application for an incidental take permit. They describe the anticipated effects of the proposed taking; how those impacts will be minimized, or mitigated; and how the HCP is to be funded. HCPs can apply to both listed and non-listed species, including those that are candidates or have been proposed for listing. Regional HCPs develop large-scale conservation strategies within a specific region that are designed to conserve functional ecological systems and the covered species that depend on them. Such HCPs aim to avoid a fragmented conservation landscape by working with local land use authorities and a designated implementing entity to conserve, enhance, and manage a preserve system. Project-level HCPs are designed to fully offset the impacts associated with the permitted activity by contributing to a larger conservation design.

Being included as a covered species under an HCP can result in habitat being set aside and managed for the species as mitigation for impacts associated with covered activities, such as planned urban development, within the HCP permit area. In addition to mitigation, avoidance, minimization, and other conservation measures (e.g. monitoring, seasonal work windows, habitat management, etc.) are implemented. HCPs can also utilize banks, in-lieu fee programs, or other mechanisms to preserve habitat in perpetuity and contribute to a regional conservation strategy.

There are 27 HCPs that include the San Joaquin kit fox as a covered species. The majority (10) of HCPs are in or cover portions of Kern County. More information about HCPs that include the San Joaquin kit fox as a covered species can be found at: https://ecos.fws.gov/ecp0/profile/speciesProfile?spcode=A006.

Recovery Permits

Recovery permits, also referred to as 10(a)1(A) permits, allow scientists to take listed species to ultimately contribute to the recovery of the listed species. The data acquired from some actions covered under recovery permits (e.g., occurrence, abundance, distribution, etc.) allow the Service to make informed decisions for the species that will enhance their survival and recovery. Recovery permits can be issued for activities that directly aid the recovery of a species, such as captive breeding, reintroductions, habitat restoration, removal or reduction of threats, and educational programs. The Service's recovery permitting program aids in the conservation of listed species by ensuring permittees have adequate field experience and qualifications for conducting activities with the target listed species and, for most species, ensures that permittees are following standardized protocols while surveying. The recovery permitting application process ensures that scientific proposals are crafted using the recommended actions laid out in the Recovery Plan for the target species. There is currently no protocol survey guidance for the San Joaquin kit fox; however, there are minimum qualifications to obtain a recovery permit for the species. Minimum qualifications and species specific protocols can be found at: https://www.fws.gov/sacramento/es/Permits/

Safe Harbor Agreements

Safe Harbor Agreements are also permitted under the Service's recovery permitting program. The Safe Harbor Policy provides incentives for property owners to restore, enhance and maintain habitats for listed species. Because many endangered and threatened species occur exclusively, or to a large extent, on non-Federally owned property, the involvement of non-Federal property owners in the conservation and recovery of listed species is critical to the eventual success of these efforts. Under the policy, the Service will provide participating property owners with technical assistance to develop Safe Harbor Agreements that manage habitat for listed species, and provide assurances that additional land, water, and/or natural resource use restrictions will not be imposed as a result of their voluntary conservation actions to benefit covered species. When the property owner meets all the terms of the Agreement, the Service will authorize incidental take of the covered species at a level that enables the property owner to return the enrolled property back to an agreed upon baseline condition. There has been one Safe Harbor Agreement covering the San Joaquin kit fox for a project to install escape dens. The permit was issued in April 2003.

3.4 Analysis of Current Condition

In this section, we analyze the current conditions of the geographic analysis units of the San Joaquin kit fox as a way of assessing population resiliency. We then use our resiliency results to assess the redundancy and representation across the species. Assessing current condition as part of the SSA analysis is associated with, but independent from, assessing habitat suitability. Habitat suitability analyses use a suite of habitat predictor variables known or hypothesized to be important to the ecology and distribution of the species to create models that assess habitat and classify it according to suitability. Thus, different habitat sites that are modeled as "suitable" may be based on varying combinations of predictor variables. Models can be tested using historical or current occurrence data, but habitat modeled as suitable may or may not actually be occupied by, or accessible to, the species. Therefore, while habitat suitability can be an important component of understanding population resiliency and can inform future conservation efforts, habitat suitability alone may not accurately reflect the current condition of a specific population or of the species. When assessing population condition in the SSA framework, we identify specific habitat and demographic variables thought to be the main drivers of viability of the species.

Table 4. Stressors used to analyze the current and future condition of the San Joaquin kit fox.

Stressor	Effect to Individuals or populations is known	Negative Response has been Quantified	Species or Population Level Response	Stressor Carried Forward in Analysis
Habitat Modification or Destruction	Yes	Yes	Yes	Yes
Stochastic Precipitation Patterns	Yes	Yes	Yes	Yes
Drought	Yes	Yes	Yes	Yes
Rodenticides	Yes	Yes	Unknown	No
Disease	Yes	Yes	Yes	Yes
Predation	Yes	Yes	No	No

In doing so, we address the individual and population needs of the species, as well as the main factors influencing viability (Table 4). We use quantitative or qualitative assessments to classify these categories into high, moderate, and low conditions in a Condition Category Table (CCT) and analyze the overall condition of each analysis unit across all the categories. Using the same table to assess the current and future condition of our analysis units allows for comparison between how the species is doing now and, in the future, (described in Chapter 4 of this document). We refer to "suitable habitat" when analyzing current and future condition of the populations, using modeled or otherwise projected habitat suitability in relation to current and future habitat factors and threats.

We analyzed the current condition of San Joaquin kit fox within the sixteen, geographic analysis units, as described above (Figure 9). These areas continue to encompass the known extant locations for San Joaquin kit fox thought to be important for the viability and recovery of the species. After consulting with experts and taking into account the data available to us, we identified average slope within the unit, natural land extent, connectivity, land protection, prey occurrence, population trends, and frequency of occupancy as the most important variables to include in our resiliency analysis for the reasons described below.

Average slope was included in our analysis because studies show San Joaquin kit fox tend to avoid areas of steep terrain. High slope areas may be used for foraging and dispersal, but steep habitat is not used routinely by breeding foxes. Therefore, in our analysis it was assumed that areas of high slope within the geographic units restricted the movement of the species and kit foxes were not likely to occupy these high slope areas in a significant way.

Because it is not possible to attain range-wide habitat quality data, we used available landcover data to assess the available potential habitat for the San Joaquin kit fox. Although certain habitat types are preferred by kit foxes, we presume much of the undeveloped land in the San Joaquin Valley may be used by the kit fox. The suitability of individual parcels may vary widely from year to year based on precipitation and land management factors (fire and grazing), but overall kit foxes are likely able to use most of the natural land within their range.

There is agreement among experts that habitat loss and fragmentation are the main stressors to the San Joaquin kit fox. We assess the connectivity across and between each analysis unit to capture the ability of an individual to move across the landscape. In order to measure connectivity, we qualitatively assessed the average natural land parcel size within the analysis unit, and fragmentation of natural lands and barriers such as incompatible land uses (urban and agricultural development), infrastructure, and topography both within and surrounding the analysis unit.

At the species and population level, San Joaquin kit fox need space and suitable habitat in order for populations to be viable over time. Land protection is important to ensure the long-term viability of the species. The percentage of land within each unit was assessed to determine how much protected land was available to the species. This analysis is consistent with the down- and delisting criteria outlined in the Recovery plan for the species (USFWS 1998, p. 186).

The availability of prey impacts adult survival and recruitment. Although we do not have range-wide data on prey availability, we assumed that where natural land extent was higher, there was likely more abundant natural prey. Kit fox will take a wide variety of prey items. However, for our analysis we focused on small mammals and considered areas where kangaroo rats were most prevalent to be in the highest condition for the species.

The demographic needs of the species are presented in two categories in our analysis of current condition: population trend and population persistence. Survival is not directly assessed in the table but is strongly correlated with the habitat components described above. Fecundity is captured through the assessment of persistence over time. It is assumed that analysis units that show a pattern of long-term occupancy also have relatively high fecundity. Because San Joaquin kit fox reproductive rates and population sizes can vary widely from year to year, long-term trends are likely a more accurate indicator of the health of a population. We used a timeframe of 30 years as our indicator for long-term persistence.

The criteria are defined in Table 5 and the analysis is presented in Table 6. We separated our overall metrics into demographic and habitat characteristics to avoid overweighting any one factor in either category.

Each geographic analysis unit was given a numeric score for each factor based on the condition category table (0.5 for very low condition, 1 for low condition, 2 for moderate condition, and 3 for high condition). Each geographic analysis unit's overall condition was then calculated across all the factors. Categories with unknown conditions were conservatively given a score of 0.5, or very low. Analysis of the current data indicate that demographic factors are likely more important to the overall condition of an analysis unit than the habitat factors. As such we weighted the overall demographic condition as twice as important as the overall habitat condition. We then translated the overall condition score into a current condition category of very low, low, moderate or high (Table 6; Figure 13). Low condition suggests that the population has a low probability of persistence (high extirpation risk), medium condition suggests a moderate probability of persistence, and high condition suggests high probability of persistence.

Table 5. Definitions for demographic and habitat conditions for the analysis of the San Joaquin kit fox.

	Demographic Factors		**Habitat Factors**				
Condition	**Population Trend**	**Population Persistence**	**% of sloped terrain within unit**[1]	**Undeveloped Land**[1]	**Habitat Connectivity**	**Habitat Protection**	**Prey Availability**
High	Population Stable or Increasing	Evidence of persistence over the last 30 years and multiple positive records results within the last year	Greater than 75% of the unit has a slope $\leq$ 10%	Majority of unit (>50%) is undeveloped with natural land cover or non-irrigated pasture. Natural land exists in larger contiguous blocks.	There are many large (>1,100 acres) patches of habitat within the unit that well connected both within and outside the unit	A large proportion of the natural lands are protected within unit	Abundant natural prey, mostly kangaroo rats.

Moderate	Population showing a slight decline	Evidence of persistence over the last 30 years, but less than 10 positive records within the last 5 years.	Greater than 75% of the unit has a slope ≤ 30%	Unit is comprised of < 50% natural land cover or non-irrigated pastures. Natural land exists in few or no large, contiguous blocks.	There are many large (>1,100 acres) patches of habitat within the unit, but the unit is highly fragmented both within and outside the unit by topographic and anthropogenic barriers	Some of the natural lands protected within the unit	Relatively abundant natural or anthropogenic prey, a wide variety of small mammals available.
Low	Population showing long-term consistent decline	Only sporadic records and no positive records within the last 5 years	More than 25% of the unit has a slope > 30%	Natural land cover makes up < 25% of the unit and there are no large contiguous blocks of habitat.	There are few or no large patches of habitat within the unit, and the patches and highly fragmented.	Little of the natural lands protected within the unit	Natural prey under threats and not consistently available.
Very Low[2]	No evidence of a current population	Only records are 10 years old or greater.	---	---	---	---	---

[1]These two habitat factors are included in "Habitat Extent" in the Core Conceptual Model (Figure 7).

[2]We did not categorize any habitat factors as "very low" as all the units had some measurable habitat.

Table 6. Current condition of the San Joaquin kit fox across 16 geographic analysis units.

Analysis Unit	Population Trend	Population Persistence	Overall Demography	% of sloped terrain within unit	Undeveloped Land	Habitat Connectivity	Habitat Protection	Prey Base	Habitat Overall	Total Overall
Livermore	Very Low	Very Low	Very Low	Low	High	Moderate	Moderate	Low	Moderate	Very Low
Santa Nella	Very Low	Very Low	Very Low	Moderate	High	Moderate	Low	Low	Moderate	Very Low
Kesterson NWR	Very Low	Very Low	Very Low	High	Very Low	Low	High	Low	Moderate	Very Low
Western Madera	Very Low	Very Low	Very Low	High	Low	Low	Low	Low	Low	Very Low
Pleasant Valley	Low	Moderate	Low	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Low
Porterville	Low	Moderate	Low	Moderate	Moderate	Moderate	Low	Low	Moderate	Low
Allensworth/Pixley NWR	Low	Low	Low	High	Low	Low	Moderate	Moderate	Moderate	Low
Kettleman Hills	Moderate	High	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	Moderate
Semitropic/Kern NWR	Moderate	High	Moderate	High	Moderate	Low	Moderate	Moderate	Moderate	Moderate
Eastern Kern County	Moderate	Moderate	Moderate	Moderate	High	Moderate	Low	Low	Moderate	Moderate
Carrizo Plain	High	High	High	Moderate	High	High	High	High	High	High
Bakersfield	Moderate	High	Moderate	High	Low	Moderate	Low	Moderate	Moderate	Moderate
Western Kern County	High	High	High	High	High	High	Moderate	High	High	High
Cuyama Valley	Low	Moderate	Low	High	Low	Low	Low	Moderate	Moderate	Low
Panoche/Western Merced	High	High	High	Moderate	Moderate	Moderate	Moderate	High	Moderate	High
Salinas Valley	Very Low	Very Low	Very Low	Moderate	Moderate	Moderate	Low	Low	Moderate	Very Low

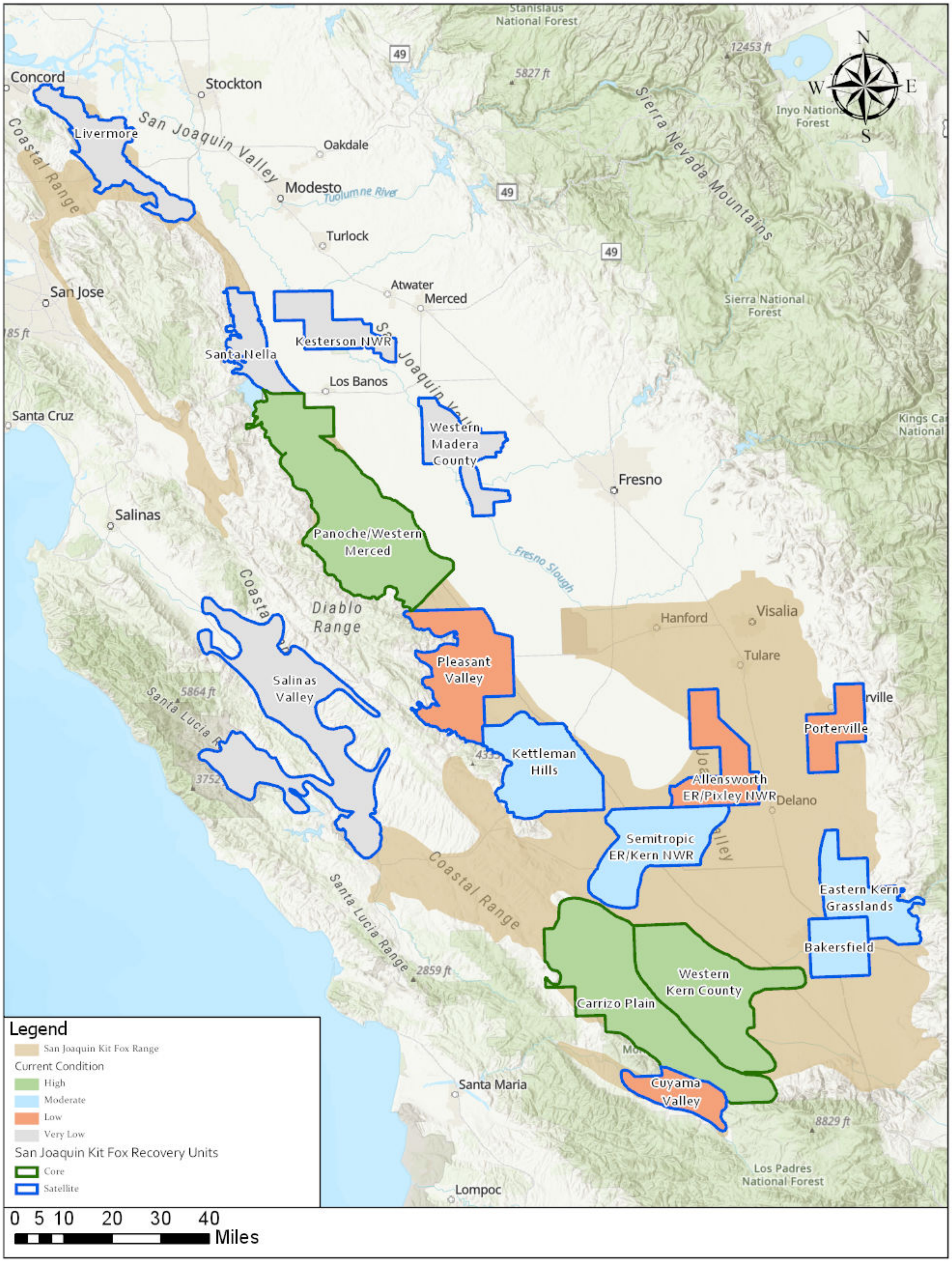


Figure 13. Current condition of the San Joaquin kit fox in 16 geographic analysis units.

3.4.1 Uncertainty of Current Condition Analysis

As discussed in our analysis of current condition, we had to make many assumptions, both in defining condition categories and in assessing the condition of each geographic analysis unit relative to these categories (Table 7). These assumptions were informed by a thorough literature review and discussions with species experts.

Table 7. Uncertainty Assumptions

Analysis Factors	Assumption
Population Trend	There are no current or past studies that examine population trends at either a range wide or analysis unit level. As such we used the frequency of observations in CNDDB to estimate trends. We assumed a pattern of continuous observation indicated a stable trend and declining observation indicated a declining trend.
Population Persistence	We used records from CNDDB over time to estimate population persistence. While not comprehensive, the long-term nature of the dataset provides information on both historical and current observations.
% of sloped terrain within unit	We assumed that habitat with lower slopes provided more habitat value for the kit fox.
Natural Land	We used the NLCD to quantify land that could be utilized by kit fox for any part of their lifecycle. We assumed that all of the identified landcover types had some value to the kit fox.
Habitat Connectivity	Connected habitat and larger patches support viable kit fox populations
Habitat Protection	We used the CCED and CPAD to estimate the habitat protection within each unit. The assumption was that lands included in these databases would not be subject to either urban or agricultural development. Although the level of protection on the land varies widely, and may not all meet recovery criteria, these lands may protect suitable habitat and linkages critical for the kit fox.
Prey Base	We assumed that the prey base was directly correlated with natural land extent. That is, the greater the amount of natural land present, the more abundant and resilient the prey base would be. Because kit fox are somewhat flexible in their diet, certain situations (e.g. Bakersfield) do not follow this assumption.

Summary of Current Condition Relative to the 3Rs

Currently, 5 of the analysis units are in very low condition and 4 are in low condition. Three of the analysis units are in high condition and 3 are in moderate condition. The high and moderate condition units are all restricted to the southern end of the San Joaquin Valley, except for the Ciervo-Panoche unit. All the units in the northern portion of the range were in very low condition, as was the disjunct Salinas Valley analysis unit.

Chapter 4. Future Condition

In this chapter, we predict the future viability of the 16 San Joaquin kit fox populations under three, plausible future scenarios. These scenarios use different combinations of climate change impacts, land-use change, and conservation measures to assess overall condition within each unit. This analysis will help predict how viability of the San Joaquin kit fox might change in the future and can help guide future conservation efforts.

4.1 Factors Influencing Future Viability

In this section, we discuss factors that might influence San Joaquin kit fox viability in the future. All of the factors that influence viability which were discussed previously are still applicable to the future condition of the species. However, they are not expanded on here, unless interactions and species responses are expected to change, which are then discussed in the context of emerging threats, or when trends or models can predict changes to these factors.

4.1.1 Climate Change

There is consensus that increases in greenhouse gas (GHG) emissions during the 20th century have resulted in global climate change characterized by: warming atmospheric and ocean temperatures, diminishing snow and ice, and rising sea levels (Intergovernmental Panel on Climate Change (IPCC) 2014, pp. 2–3). Climate change might affect San Joaquin kit fox through changes in precipitation and temperature, which can drive associated changes to vegetative communities as well alterations to prey species abundance and composition. Climate change is also associated with increased risk of catastrophic events, including floods and wildfires.

Climate models for California under different emission scenarios predict an overall warming effect somewhere between 1.7 and 5.8 degrees Celsius (3.0 to 10.4 degrees Fahrenheit) before 2100 (Cayan *et al.* 2008, p. 7). San Joaquin kit fox are adapted for arid survival and can withstand periods of high temperature. However, the thermal limits of San Joaquin kit fox survival have never been tested, and it is unclear how higher average annual temperatures might affect individuals.

Climate change is also associated with changes in precipitation cycles. Extremes in precipitation are expected to increase; current climate models predict a higher frequency of both extremely wet and extremely dry years (Swain *et al.* 2018, pp. 427–433). Some future climate projections suggest drought will be more intense; both longer, and dryer than in previous centuries (Trenberth *et al.* 2014, p. 17). San Joaquin kit fox survival and reproduction has been documented to decline during prolonged periods of drought (droughts lasting longer than two years) due to a decrease in prey availability and possibly in extremely wet years. Extremely wet years can cause over-abundance of dense, non-native grasses that may hinder the fox's ability to evade predators and successfully find prey. Stochastic flooding events could also occur, which could negatively affect populations, especially in areas with high slope and topography, such as the Panoche geographic region or in low lying areas susceptible to ponding such as the Kern NWR/Semitropic Area.

Small, isolated populations are likely at higher risk from long-term intensive drought as are populations that persist in areas with highly fragmented and small habitat patches. Decreases in prey species leading to a decline in reproduction and abundance in these areas could have irreversible consequences on the population. As such, within-patch heterogeneity, between patch connectivity, and habitat patch-size, will be important to mitigate population declines from both dry and wet years.

4.1.2 Habitat Modification and Destruction

Habitat modification and destruction caused by land use changes (e.g., agricultural development, and urbanization) are expected to continue, and most likely to affect habitat on privately held lands. San Joaquin kit foxes rarely use irrigated agriculture and have only adapted to urban environments in a few locations.

Agricultural development will be influenced by changes to the climate. Some climate models predict increases in retired croplands in response to increased aridity. Land retirement of agricultural fields across the San Joaquin Valley could result in significant changes to overall land cover; as many as 500,000 acres may be retired by 2040 to meet requirement of existing groundwater regulations, and would have the potential to be restored to natural habitat (Hanak *et al.* 2017, p. 29). Strategic restoration of retired agricultural land has the potential to aid the recovery of endangered species, including the San Joaquin kit fox. The Land Retirement Demonstration Project included a Habitat Restoration Study to investigate the efficacy of restoration techniques on vegetation and wildlife (Uptain *et al.* 2005, pp. 107–175).

Solar photovoltaic development is a key renewable energy source that is expected to contribute to California's commitment to meet half of the state's energy demand from renewable resources by 2030 (de León 2015, p. 93). Phillips and Cypher (2015, pp. 15–16) identified approximately 4,145 km^2 (1,601 mi^2) of habitat with moderate to high potential for both solar energy development and listed species, including the San Joaquin kit fox. They recommend siting solar facilities in areas with low habitat value for listed species but high potential for solar projects, identifying 8,436 km^2 (3,257 mi^2) in the southern San Joaquin Valley, especially in western Fresno County, southern Kings County, and southern Kern County. Butterfield *et al.* (2013, entire) summarizes a process for identifying least-conflict lands for solar development.

Habitat modification and destruction via housing or commercial development is expected to continue in the future. As the population in the San Joaquin Valley increases, housing/commercial development continues to threaten San Joaquin kit fox habitat, albeit at a lower level than the threat posed by other types of development. The total number of households in the San Joaquin Valley is projected to increase by just over 1 percent per year from 2010 to 2050, with the highest annual growth rates in Merced and Madera Counties (The Planning Center 2012, pp. 13–14). The population is projected to increase on average by an annual rate of 1.27 percent, increasing from approximately 4 million people in 2010 to over 6.5 million in 2050, with the highest expected increase in Merced County and the lowest increases predicted for Tulare and Fresno Counties (The Planning Center 2012, pp. 17–18). Direct or indirect impacts to the species due to energy or development projects is expected to be somewhat offset through mitigation or other measures.

4.1.3 Strategic Land Retirement and Restoration

Agricultural development will be influenced by changes to the climate, with crop conversion, continued farming, or retirement depending on water availability. Retirement of agricultural lands across the San Joaquin Valley may be as great as 500,000 acres (over 202,000 hectares) by 2040 if retirement is used as the sole strategy to meet recent groundwater regulations (i.e., the Strategic Groundwater Management Act of 2014) (Hanak *et al.* 2017, p. 29). Strategic fallowing or restoration of retired agricultural land has the potential to aid in recovery of endangered species including the San Joaquin kit fox (Lortie *et al.* 2018, entire). Fallowed agricultural land has the potential to provide habitat for the San Joaquin kit fox under some conditions, particularly if there is adjacent nearby natural land. Additionally, active restoration can enhance the suitability of fallowed agricultural land for wildlife. The Land Retirement Demonstration Project included a Habitat Restoration Study to experimentally investigate the efficacy of restoration techniques on vegetation and wildlife, which is detailed in Uptain *et al.* (2005, pp. 107–175). Importantly, for retired land to be used by the species, it must be within the dispersal distance of an extant population of San Joaquin kit fox. Parcels that are too far away from known kit fox populations may provide suitable habitat but are unlikely to be occupied. While it is unlikely that the entirety of the retired land will be available for restoration, our projection anticipates a concerted effort to use the land for conservation. Some of the retired land will likely be put to alternate economic uses that have varying utility for kit foxes. In addition, much of the land to be retired is of poor quality (e.g. drainage impaired lands) and may not have historically provided much habitat for upland species. Some experts believe that in the event these lands are retired, the poor quality of these lands may make them difficult to restore (Cypher pers. comm. 2020).

4.1.4 High Speed Rail

The high-speed rail (HSR) is a publicly funded rail system currently under construction. Currently, the HSR is projected to route between Merced and Bakersfield. The project originally included extensions to San Francisco and Los Angeles, but these were indefinitely postponed due to costs and timing. Although we include a discussion of the HSR here to highlight it as a future threat to the species, the threat is likely limited to 3 populations along the proposed alignment and could result in reduced connectivity for within these populations. The HSR is currently projected to cross areas that have extant San Joaquin kit fox populations along the eastern and central portions of the San Joaquin Valley. We note, however, that much of the area within the proposed footprint is currently highly fragmented.

4.2 Future Scenarios

For our analysis of the San Joaquin kit fox's future condition, we constructed three future scenarios focused on changes in stressors, climate change projections, and levels of conservation efforts (Table 8). While there are an infinite number of potential future scenarios we could have considered, these scenarios are meant to cover a large breadth of future conditions that could occur in the San Joaquin kit fox's range, and all scenarios might not be equally plausible. To analyze future condition under these scenarios, we projected each scenario 60 years into the future, corresponding to our climate models and projections of future development and population growth.

These scenarios are based on two general circulation models (GCMs) and two Representative Concentration Pathway greenhouse gas trajectories that were selected from among 12 considered to represent a range of future conditions for California by the end of the 21st century. In comparison to current conditions, the GCMs chosen are hotter and drier (MIROC-ESM), or warmer and wetter (CNRM-CM5). The RCPs (4.5 and 8.5) represent lower and higher levels of greenhouse gas concentrations; RCP 8.5 is in line with the current trend in greenhouse gas emissions. Taken together, the GCMs and RCPs represent a range of warming statewide from 1.99 to 4.56 degrees Celsius and between a 24.8 percent decrease in precipitation and a 22.9 percent increase, respectively. These two climate projections are both used in California Department of Fish and Wildlife (CDFW) reports on terrestrial vegetation (Thorne *et al.* 2016, p, 17-18) and mammals, including the San Joaquin kit fox (Stewart *et al.* 2019, entire). They are also used in an assessment of habitat restoration opportunities for blunt-nosed leopard lizards in the San Joaquin Desert (Stewart *et al.* 2019, entire). More information about the climate projections are available in those documents.

Table 8. Plausible future scenarios used to evaluate future condition of San Joaquin kit fox populations.

Scenario 1	Scenario 2	Scenario 3
Warm and wet (CNRM-CM5)	Hot and dry (MIROC-ESM)	Hot and dry (MIROC-ESM)
Low emissions (RCP 4.5)	High emissions (RCP 8.5)	High emissions (RCP 8.5)
Increased precipitation and resultant change to vegetation and prey base leads to range contraction	Potential northern expansion of suitable habitat	Potential northern expansion of suitable habitat
Increase in precipitation extremes increases the number of drought years	Increase in precipitation extremes increases the number of drought years	Increase in precipitation extremes increases the number of drought years
Development continues on unprotected areas, and management continues on protected lands, at current rates	Development continues on unprotected areas, and management continues on protected lands, at current rates	Restoration of fallowed croplands in the Central Valley and increased land protections in some areas, but continued development in some areas

4.2.1 Scenario 1

In Scenario 1, we assume conditions will be warm and wet (CNRM-CM5, RCP 4.5). We assume that under warm and wet conditions there will be increased annual precipitation that will result in increased amounts of herbaceous vegetation. Under this scenario, wetter portions of the kit fox's range will likely become less suitable without increasing management actions. We assume that development continues at current rates on unprotected lands, with the potential to decrease habitat size for San Joaquin kit fox populations and connectivity between them. We also assume that management and restoration continues at current levels.

4.2.2 Scenario 2

In Scenario 2, we assume conditions will be hot and dry (MIROC-ESM, RCP 8.5). In this scenario, hot and dry conditions will result in an overall decrease in precipitation, which may lead to more potentially suitable habitat in areas that are currently wetter and require more management to maintain optimal vegetation. However, because these areas may not currently be occupied by San Joaquin kit fox and are separated by significant barriers from the extant populations, without active restoration or translocation, we do not anticipate that this habitat will necessarily be occupied by the species. We assume that under hotter and drier conditions there will be an increase in fallowed croplands, especially in the Central Valley. We also assume that development continues at current rates on unprotected lands, with the potential to decrease habitat size for San Joaquin kit fox populations and connectivity between them. We assume that management and restoration continues at current levels.

4.2.3 Scenario 3

In Scenario 3, we again assume that conditions will be hot and dry, using the same climatic conditions as in the second scenario. We assume that there is strategic restoration of retired agricultural land in the central part of the species range such that habitat size and connectivity will not be reduced (in comparison to Scenarios 1 and 2) and may increase in some areas assuming that these activities are conducted within dispersal distance of extant San Joaquin kit fox populations.

In all scenarios, we assume that there will be increased precipitation extremes, meaning that drought years and years with above-average precipitation are likely to become more frequent. We also assume that the High Speed Rail will be completed according to the projected route. Although the HSR is expected to reduce connectivity between populations and will reduce habitat connectivity across the route, we do not project that it will affect the specific habitat or demographic conditions in our condition analysis.

4.3 Analysis of Future Scenarios

Future conditions were projected for each geographic unit based on the variations in precipitation, climate, extent of suitable habitat, and restoration as specified in our scenarios (Table 9). We predicted changes in two of the three habitat needs, and two demographic factors described in our current condition analysis. The habitat factor of slope was held constant under future scenarios, as it is not expected to substantially change under any scenario. We assessed changes related to habitat factors by making qualitative assumptions about habitat suitability and land protections and made changes to demographic factors in accordance with related changes in habitat in the various scenarios.

Winter precipitation is difficult to predict in future scenarios, so assumptions were made under all future conditions. In scenario 1, we expected that warm and wet conditions would increase winter rains, leading to increased primary productivity and vegetative growth. This would increase the growth of both native and non-native plant growth. An increase in vegetation growth may benefit prey species for the San Joaquin kit fox, but in increase in vegetation growth may also impact the San Joaquin kit fox negatively if the vegetation hinders the ability of the kit fox to evade predators or successfully find prey. Under this scenario, higher winter precipitation would provide a moderate benefit to the species, particularly in areas where adequate habitat management is occurring. However, this is not expected to significantly alter the overall condition of individual populations. Under scenarios 2 and 3, intense droughts are projected to increase in both duration and intensity.

This would decrease overall survival and reproduction, and the species would be assumed to respond negatively.

Summer precipitation is also difficult to predict, and similar assumptions were necessary. Under scenario 1, all summer precipitation is likely to increase, which may decrease the overall suitability of habitat during the summer largely due to negative impacts to prey species such as giant kangaroo rats or other small mammal species. This reduction in prey base may negatively affect San Joaquin kit fox survival (particularly the pups) and could depress reproduction. Under future scenarios 2 and 3, summer precipitation would decrease, meaning summers would be hotter and dryer. Because San Joaquin kit fox are already adapted for hot, dry summers, it is not likely that they would be severely, negatively impacted by these changes during the summer months. Habitat suitability models confirm, that under RCP 8.5 emission scenarios, the suitable range of the giant kangaroo rat is expected to remain similar or even expand (Widick and Bean 2019, pp. 7–9). Based on this data, it is expected that the San Joaquin kit fox may experience increased population growth under scenarios where a primary prey species does well. This positive effect of increasing suitable habitat for the fox (and its prey), may help offset the effects of more frequent or longer droughts. As a result, we predicted no overall change in demographic or prey base factors under this scenario.

Habitat connectivity among San Joaquin kit fox populations has been decreasing throughout recent history. This trend is projected to continue into the foreseeable future. Under scenarios 1 and 2, we assumed if trends stayed the same, connectivity would continue to decrease in all analysis units, for areas that are not already under protection. Under scenario 3, we assumed that aggressive land retirement under SGMA and efforts from conservation organization could increase habitat connectivity by one level. SGMA is likely to have the most affect in areas that are under extreme overdraft. This particularly will affect recovery units that are in the southern end of the San Joaquin Valley (Western Kern, Ciervo-Panoche, Semitropic/Kern NWR, and Allensworth/Pixley NWR).

Land protection was changed only for Scenario 3, where we assumed protections would increase under aggressive restoration and protection efforts.

We made changes to demographic factors in relation to expected changes to habitat factors. We assumed that under scenarios 1 and 2, frequency of occupancy would decrease across much of the range in response to continued habitat fragmentation and land conversion. These land use changes would also impact survival and reproduction by reducing the available prey base and increasing exposure to rodenticides. Conversely, under scenario 3, the long-term effects of changes in climate are likely to be offset by increasing land protection and habitat availability. In this scenario, the combined effects of increases in habitat suitability (with presumed increased prey abundance) and land protection would lead to increases in kit fox populations despite potential negative effects from increased drought frequency.

As with the current condition analysis, if the overall demographic condition was "Very Low", the condition of the geographic analysis unit could never be greater than "Very Low". This is intended to minimize the bias toward unoccupied but "suitable" suitable habitat.

Table 9. Future condition of the San Joaquin kit fox across 16 geographic analysis units under 3 different climate change, land development, and restoration scenarios.

	Scenario 1	Scenario 2	Scenario 3		Current Condition
Livermore	Very Low	Very Low	Very Low		Very Low
Santa Nella	Very Low	Very Low	Very Low		Very Low
Kesterson NWR	Very Low	Very Low	Very Low		Very Low
Western Madera	Very Low	Very Low	Low		Very Low
Pleasant Valley	Low	Low	Moderate		Low
Porterville	Low	Low	Moderate		Low
Allensworth	Very Low	Low	Moderate		Low
Kettleman Hills	Moderate	Moderate	High		Moderate
Semitropic	Moderate	Moderate	High		Moderate
E Kern	Moderate	Moderate	High		Moderate
Carrizo Plain	Moderate	High	High		High
Bakersfield	Moderate	Moderate	Moderate		Moderate
W Kern	Moderate	High	High		High
Cuyama Valley	Low	Low	Moderate		Moderate
Ciervo-Panoche	Moderate	High	High		High
Salinas Valley	Very Low	Very Low	Very Low		Very Low

4.3.1 Future Condition Uncertainty

There is a lot of uncertainty regarding climate models and the way in which San Joaquin kit fox might respond to changing climate. Models have great utility because they allow us to make predictions of how climate may change in the future, but their results should be interpreted cautiously. The models that we used in our future condition analysis are ones that are relatively much drier or wetter than most of the climate models and were chosen to present a possible range of future conditions. Models are mathematical representations of what can happen, but they do not always accurately predict future events. One key assumption in our analysis was that effects from drought would occur uniformly across the species range, and we acknowledge that drought impacts will be more nuanced than we have projected. However, based on the best available science regarding climate predictions, it seems likely that the species will face increased climate stress in the future, thus supporting the general decrease in habitat conditions in our future condition analysis. Maintenance of environmentally diverse habitats will be important towards maintaining resilient populations. There is also some uncertainty regarding the efficacy of conservation efforts in the future. There has been a big push towards preserving natural lands in the San Joaquin Valley, which is demonstrated in our future condition analysis of habitat and demographic factors related to habitat size and connectivity. Pilot studies on strategic restoration of land will be important in directing future recovery actions.

We used the best available science to forecast the future condition of San Joaquin kit fox under three plausible scenarios. Under the two most likely scenarios, conditions either remain constant or slightly decrease (Table 8). Decreases in population resiliency are expected because changes to climate are expected to put increased stress on populations, including reducing reproductive opportunities during droughts and changes to vegetation. Habitat development and agricultural conversion continue to threaten the species on unprotected lands, which can directly influence populations or restrict gene flow between them. Continued management on protected lands is essential towards maintaining resilient populations across the species range.

A handful of populations that are currently in very low condition are unlikely to positively respond to changes in habitat suitability or conservation without active efforts to restore these populations. Loss of these populations, which tend to be on the boundaries of the species range or isolated from other populations, would result in losses for species representation. These populations are not in the areas that we projected targeted restoration efforts based on models for strategic restoration in the San Joaquin Valley. Indeed, the magnitude of restoration efforts will likely be one of the biggest factors driving differences between the outcomes in our projected scenarios.

The continued presence of moderately resilient populations in the western and southwestern units across all three scenarios suggests that the species will maintain moderate levels of redundancy and representation, although both measures are likely to be lower in the future.

Chapter 5. Species Viability

We have considered what the San Joaquin kit fox needs for viability (Chapter 2) and evaluated the species' current condition in relation to those needs (Chapter 3). We also forecast how the species' condition might change in the future under three different scenarios (Chapter 4). In this chapter, we synthesize the results from our historical, current, and future analyses and discuss the potential consequences for the future viability of the San Joaquin kit fox. We assess the viability of the species by evaluating the ability of the species to maintain a sufficient number and distribution of healthy populations to withstand environmental stochasticity (resiliency), catastrophes (redundancy), and changes in its environment (representation) into the future.

5.1 Resiliency

Resiliency is the ability of populations to tolerate natural, annual variation (stochasticity) in their environment and to recovery from periodic disturbance.

Throughout the latter half of the 20th century, large portions of the San Joaquin kit fox's habitat were converted to agriculture and urban areas. Populations decreased rapidly in response to habitat loss and fragmentation. While there are few data on habitat condition and population trends prior to land conversion, evidence suggests historical populations had high resiliency, and foxes were likely widespread throughout their historical range.

Because there is no accurate, historical baseline to which we can compare, our analysis of the San Joaquin kit fox's current condition and resiliency is limited to current geographic analysis units which are fragmented, isolated, and increasingly small habitat patches throughout the range. Based on the relevant factors evaluated in our analysis, three of the current geographic analysis units are in overall high condition. These units have the highest probability of persistence. Demographically, three geographic analysis units currently are in high condition (Table 6; Panoche/Western Merced, Carrizo Plain, and Western Kern County), but none of the units are in high condition based on habitat factors. It is important to note that populations of San Joaquin kit fox on the Carrizo Plain are likely in the best current condition, being found on the largest continuous patch of habitat within the range of the species that has species-specific management. Once habitat is protected, connectivity can be increased, and populations might no longer be isolated from one another. In this case, the many of the negative effects of demographic and environmental stochasticity can be mitigated and populations are more likely to be stable. Currently, only two geographic units (the Carrizo Plain and western Kern County) are well equipped to withstand stochastic variation, leaving the remaining analysis units vulnerable to the effects of continued land conversion and climate change. This reduces the overall resiliency of the species.

Our predictions of future condition varied under our three condition scenarios. Under climate change scenarios and current land management trends, resiliency is likely to decrease in the future for two of our scenarios within all geographic units (Table 9). However, if land is converted and managed for the species, it is possible future conditions could improve for the species (Scenario 3).

5.2 Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy is measured by the duplication and distribution of populations across the range of the species.

Historically, populations of San Joaquin kit fox were distributed throughout the San Joaquin Valley. Although the current distribution of kit fox populations is like that known historically, the size of the populations has decreased. In addition, one population (Salinas Valley) may be extirpated and is in very low condition. Four additional populations in the northern portion of the range are currently in very low condition and three more populations are in low condition. Only three populations persist in high condition and two of these are adjacent to each other in the southwestern San Joaquin Valley. A catastrophic range-wide event, such as a long-term drought, has the potential to severely reduce viability of several units and lower the probability of persistence for several analysis units. In the most severe instance of a long-term drought, the three analysis units currently in high condition might be the only populations remaining.

Under two of the future scenarios, many of the geographic units could exist in low condition. Should this happen, or should populations become locally extirpated, redundant variation throughout the range might no longer be possible. Land protections and restorations can mitigate the effects to populations from climatic change, and in Scenario 3, many of the populations are in higher condition then they are currently. This means persistence of many of the populations is more likely, even under climate change scenarios with an increase in adverse stochastic events.

5.3 Representation

Representation is the ability of a species to adapt catastrophic events, or to changing physical (climate, habitat) and biological (diseases, predators) conditions.

A species' representation is measured by assessing the genetic, morphological, behavioral, and ecological diversity within and among populations across its range. The more representation, or diversity, a species has, the more likely it is to persist in changing environments. Historically, the San Joaquin kit fox was distributed throughout the southern end of the San Joaquin Valley and foothills of the Sierra Nevada and Coast Range. Within the range, San Joaquin kit fox occupied a variety of grassland, desert, scrub and upland habitats. Precipitation varies among these habitats, being more mesic in the northern, and western (coastal) portions of the range. All the northern and western portions of the range are in very low condition. This region represents a different ecological setting and possibly uniquely adapted kit foxes. The loss of these populations is a loss of representation and adaptive capacity from historic conditions. Additional loss of resiliency and extirpations forecast in the future are likely to further reduce this representation and adaptive capacity. Genetic diversity appears to remain high throughout the range of the San Joaquin kit fox. It is uncertain how much genetic diversity has already been lost, however.

Gene flow appears to continue to occur across the southern portion of the range in spite of the increase in habitat fragmentation. However, San Joaquin kit fox do not likely occur in the densities or numbers they once did, and populations continue to fluctuate throughout climatic events. However, populations still exist in a variety of habitats throughout the range, showing a moderate amount of representation. Under future scenarios, representation is likely to decrease under scenario 1 and 2, due to declining conditions across the range. As conditions decline, extirpation becomes more likely, reducing the ability of a species to withstand stochastic events. Under scenario 3, representation is likely to increase across the range, should land protection be increased.

5.4 Synopsis of Viability

Viability is the ability of a species to sustain populations over time. Species which exhibit high resiliency, redundancy, and representation are more viable than those which do not.

The San Joaquin kit fox is currently endangered. Habitat loss was the main stressors responsible for the decline of the species. Since the time of listing, populations have continued to decrease across much of the range. Abundances have fluctuated annually, and with climatic events. Currently, five of the geographic units are in “very low” condition, six are in “low” condition, and five are in “moderate” condition. Populations are still distributed throughout a variety of habitats, and show high genetic diversity and ability to rebound from climatic extremes, demonstrating redundancy and representation.

We forecast the future viability of the species by predicting the responses of our geographic unit conditions under three future scenarios 60 years into the future. Under two scenarios, most of the units are at risk of existing in “low” or “very low” condition and those in “very low” condition would be at high risk of extirpation. This would represent a significant range contraction of the species, and viability would be drastically reduced. Land protection and management in scenario 3 improves the condition of the species and increases viability.

The current persistence of the San Joaquin kit fox within the remaining habitat is evidence of the species’ resiliency and is largely due to large-scale habitat protections. Species-specific land management has been demonstrated to improve the habitat and abundance of the species locally. Habitat restoration in areas affected by agriculture or invasive grasses, could additionally help buffer the effects of climate change and historical habitat loss. This could mitigate the effect of increased drought and possible heavy precipitation.

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Personal communication

Cypher, Brian. 2020. California State University-Stanislaus, Endangered Species Recovery Program. Email with Tim Ludwick, USFWS, regarding the SSA.

Appendix 1. Tables for the three future condition scenarios

Scenario 1: Climate change results in warm and wet conditions. Development, conservation, and land use changes occur at rates similar to 2020

	Population Trend	Population Persistence	Overall Demography	% of sloped terrain within unit	Undeveloped Land	Habitat Connectivity	Habitat Protection	Prey Base	Habitat Overall	Total Overall
Livermore	Very Low	Very Low	Very Low	Low	Moderate	Low	Moderate	Very Low	Low	Very Low
Santa Nella	Very Low	Very Low	Very Low	Moderate	Moderate	Low	Low	Very Low	Low	Very Low
Kesterson NWR	Very Low	Very Low	Very Low	High	Very Low	Very Low	High	Very Low	Low	Very Low
Western Madera	Very Low	Very Low	Very Low	High	Very Low	Very Low	Low	Very Low	Low	Very Low
Pleasant Valley	Very Low	Moderate	Low	Moderate	Low	Low	Low	Low	Low	Low
Porterville	Very Low	Moderate	Low	Moderate	Low	Low	Low	Very Low	Low	Low
Allensworth/Pixley NWR	Very Low	Low	Very Low	High	Very Low	Very Low	Moderate	Low	Low	Very Low
Kettleman Hills	Low	High	Moderate	Moderate	Low	Low	Low	Low	Low	Moderate
Semitropic/Kern NWR	Low	High	Moderate	High	Low	Very Low	Moderate	Low	Low	Moderate
Eastern Kern County	Low	Moderate	Low	Moderate	Moderate	Low	Low	Very Low	Low	Moderate
Carrizo Plain	Moderate	High	Moderate	Moderate	Moderate	Moderate	High	Moderate	Moderate	Moderate
Bakersfield	Low	High	Moderate	High	Very Low	Low	Low	Low	Low	Moderate
Western Kern County	Moderate	High	Moderate	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate
Cuyama Valley	Very Low	Moderate	Low	High	Very Low	Very Low	Low	Low	Low	Low
Panoche/Western Merced	Moderate	High	Moderate	Moderate	Low	Low	Moderate	Moderate	Low	Moderate
Salinas Valley	Very Low	Very Low	Very Low	Moderate	Low	Low	Low	Very Low	Low	Very Low

Scenario 2: Climate change results in hot and dry conditions. Development, conservation, and land use changes occur at rates similar to 2020.

	Population Trend	Population Persistence	Overall Demography	% of sloped terrain within unit	Undeveloped Land	Habitat Connectivity	Habitat Protection	Prey Base	Habitat Overall	Total Overall
Livermore	Very Low	Very Low	Very Low	Low	High	Moderate	Moderate	Moderate	Moderate	Very Low
Santa Nella	Very Low	Very Low	Very Low	Moderate	High	Moderate	Low	Moderate	Moderate	Very Low
Kesterson NWR	Very Low	Very Low	Very Low	High	Low	Low	High	Moderate	Moderate	Very Low
Western Madera	Very Low	Very Low	Very Low	High	Moderate	Low	Low	Moderate	Low	Very Low
Pleasant Valley	Low	Moderate	Low	Moderate	High	Moderate	Low	High	Moderate	Low
Porterville	Low	Moderate	Low	Moderate	High	Moderate	Low	Moderate	Moderate	Low
Allensworth/Pixley NWR	Low	Low	Low	High	Moderate	Low	Moderate	High	Moderate	Low
Kettleman Hills	Moderate	High	Moderate	Moderate	High	Moderate	Low	High	Moderate	Moderate
Semitropic/Kern NWR	Moderate	High	Moderate	High	High	Low	Moderate	High	Moderate	Moderate
Eastern Kern County	Moderate	Moderate	Moderate	Moderate	High	Moderate	Low	Moderate	Moderate	Moderate
Carrizo Plain	High	High	High	Moderate	High	High	High	High	High	High
Bakersfield	Moderate	High	Moderate	High	Moderate	Moderate	Low	High	Moderate	Moderate
Western Kern County	High	High	High	High	High	High	Moderate	High	High	High
Cuyama Valley	Low	Moderate	Low	High	Moderate	Low	Low	High	Moderate	Low
Panoche/Western Merced	High	High	High	Moderate	High	Moderate	Moderate	High	Moderate	High
Salinas Valley	Very Low	Very Low	Very Low	Moderate	High	Moderate	Low	Moderate	Moderate	Very Low

Scenario 3: Climate change results in hot and dry conditions. Development and land use changes occur at rates similar to 2020, but conservation initiatives take advantage of aggressive land retirement goals to increase upland habitat.

	Population Trend	Population Persistence	Demo Overall	% of sloped terrain within unit	Undeveloped Land	Habitat Connectivity	Habitat Protection	Prey Base	Habitat Overall	Total Overall
Livermore	Very Low	Very Low	Very Low	Low	High	High	High	Moderate	Moderate	Very Low
Santa Nella	Very Low	Very Low	Very Low	Moderate	High	High	Moderate	Moderate	Moderate	Very Low
Kesterson NWR	Very Low	Very Low	Very Low	High	Low	Moderate	High	Moderate	Moderate	Very Low
Western Madera	Low	Low	Low	High	Moderate	Moderate	Moderate	Moderate	Moderate	Low
Pleasant Valley	Moderate	High	Moderate	Moderate	High	High	Moderate	High	Moderate	Moderate
Porterville	Moderate	High	Moderate	Moderate	High	High	Moderate	Moderate	Moderate	Moderate
Allensworth/Pixley NWR	Moderate	Moderate	Moderate	High	Moderate	Moderate	High	High	Moderate	Moderate
Kettleman Hills	High	High	High	Moderate	High	High	Moderate	High	Moderate	High
Semitropic/Kern NWR	High	High	High	High	High	Moderate	High	High	High	High
Eastern Kern County	High	High	High	Moderate	High	High	Moderate	Moderate	Moderate	High
Carrizo Plain	High	High	High	Moderate	High	High	High	High	High	High
Bakersfield	Moderate	High	Moderate	High	Moderate	High	Moderate	High	Moderate	Moderate
Western Kern County	High	High	High	High	High	High	High	High	High	High
Cuyama Valley	Moderate	High	Moderate	High	Moderate	Moderate	Moderate	High	Moderate	Moderate
Panoche/Western Merced	High	High	High	Moderate	High	High	High	High	High	High
Salinas Valley	Very Low	Very Low	Very Low	Moderate	High	High	Moderate	Moderate	Moderate	Very Low