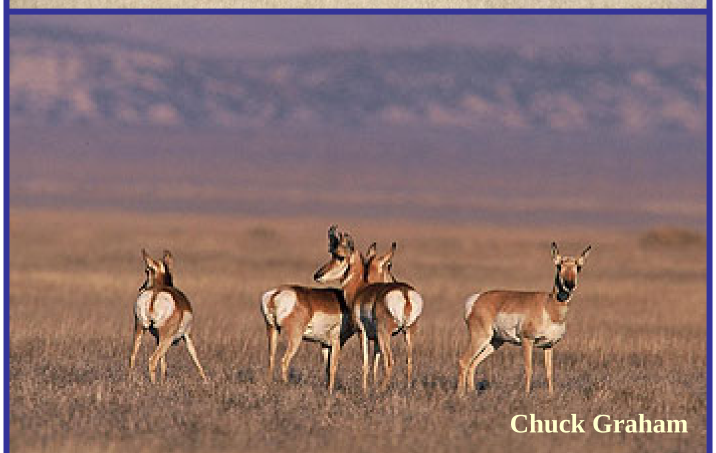
Habitat Connectivity Planning for Selected Focal Species in the Carrizo Plain



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Habitat Connectivity Planning for Selected Focal Species in the Carrizo Plain

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The Carrizo Plain is located on the southwestern edge of the greater Central Valley ecoregion and boasts one of the largest remaining remnants of the San Joaquin Valley grassland ecosystem (Rosier et al. 2005). Extensive conservation investments, such as the Carrizo Plain National Monument, have been made in the region to protect the unique flora and fauna that occur there. The high potential for solar energy production in the Carrizo Plain has resulted in several applications for development of this resource in the central portion of the plain, including proposals submitted for construction of Topaz Solar Farm and SunPower – California Valley Solar Ranch. The extensive footprints and traffic that would be generated by the proposed energy facilities has the potential to negatively impact biological resources within the region. This study is intended to provide insight into the existing baseline conditions of the landscape, and how that landscape provides habitat and movement opportunities for wildlife. The results of the baseline conditions analyses will be used by the County of San Luis Obispo to analyze potential impacts of the proposed solar projects, both in isolation and cumulatively, on the focal species and evaluate proposed mitigation options and strategies that were not expressly addressed by this study.

Carrizo Plain is home to a number of sensitive species that could be detrimentally affected by loss and fragmentation of their habitat and their ability to move through the region. Three species of special management concern: tule elk (*Cervus elaphus nannodes*), pronghorn antelope (*Antilocapra americana*), and San Joaquin kit fox (*Vulpes macrotis mutica*) were selected as focal species. Habitat suitability models were developed for each of the species using variables, valuations, and weighting selected in consultation with biologists with expert knowledge of the species. Variables included vegetation (type and density), road density, slope, and terrain ruggedness. Potential cores and patches of habitat were identified for each species by selecting contiguous areas with higher suitability scores that could sustain at least 50 individuals (core) or less than 50 but at least one breeding pair (patch).

We used least-cost corridor analysis to measure landscape permeability for the focal species. Variables for this analysis varied by species and included: vegetation (type and density), road density, topography, and terrain roughness. Least-cost corridors were then identified between either core areas or 95% minimum convex polygons inscribing occurrence records for that species. These analyses coupled with the habitat suitability analyses suggest both areas that are important to populations of the focal species and areas that best allow for movement between populations.

The results of the analyses indicate that the focal species utilize different component areas of Carrizo Plain leading to substantial use of much of the study area by these species. Relatively little of the study area was found to lie outside areas of high importance for at least one of the focal species. The footprints associated with the two proposed projects nearly bisect Carrizo Plain into a north and south section and will likely lead to impacts to both habitat (e.g. foraging and reproduction) and connectivity (e.g. seasonal movement and dispersal) of the three focal species.

Section 2
Introduction

2.1. Background and Project Need

The Carrizo Plain of San Luis Obispo County is a semi-arid landscape with high solar energy potential as well as high biological resource values. Over the past few years, three proposals were submitted to develop large-scale solar energy production facilities on the Carrizo Plain. This habitat connectivity study was undertaken to assist California Energy Commission, County of San Luis Obispo, California Department of Fish and Game (CDFG) and U.S. Fish and Wildlife Service (FWS) in assessing baseline conditions, potential impacts and mitigation options for the previously proposed Carrizo Energy Solar Farm, a 177-MW solar thermal power plant sited off of SR-58 in the northern portion of the Carrizo Plain. The study was also intended to assist with assessing cumulative impacts of Carrizo Energy Solar Farm with two proposed photovoltaic power plants in the Carrizo Plain, the Topaz Solar Farm and the California Valley Solar Ranch, which are not under the California Energy Commission's jurisdiction but the County of San Luis Obispo's jurisdiction. The Carrizo Energy Solar Farm is no longer being proposed, but that project site has been acquired to expand the Topaz Solar Farm. This study is intended to provide insight into the existing baseline conditions of the landscape, and how that landscape provides habitat and movement opportunities for wildlife. The results of the baseline conditions analyses will be used by the County of San Luis Obispo to analyze potential impacts of the proposed solar projects, both in isolation and cumulatively, on the focal species and evaluate proposed mitigation options and strategies that were not expressly addressed by this study.

The large extent of the proposed projects has the potential to impact the biological resources of the region. Carrizo Plain is home to a number of sensitive species that could be detrimentally affected by loss and fragmentation of their habitat and their ability to move through the region. Three species of special management concern: tule elk (*Cervus elaphus nannodes*), pronghorn antelope (*Antilocapra americana*), and San Joaquin kit fox (*Vulpes macrotis mutica*) were selected as focal species. It is assumed that maintaining habitat connectivity for these species will not only sustain their long-term population viability, but will also help to maintain healthy populations of other native species, as well as provide resilience to native ecosystems, and the ecological processes that they support, in the face of climate change. The three focal species use portions of the proposed project areas for foraging, reproduction, and/or movement between other areas to varying degrees. The objective of this study was to model baseline conditions to estimate habitat suitability and permeability to species movements within the study area.

3.1. Study Area

3.1.1. Location. Carrizo Plain is located in the southeastern portion of San Luis Obispo County. It lies on a northwest-southeast trend, and is approximately 70 km long and 10 km wide. It is generally considered to be the far southwest portion of the Central Valley ecoregion (Hickman 1993), although it is separated from the Central Valley proper by low ranges, especially the Temblor Range.

3.1.2. Physical features. Carrizo Plain is bounded by several mountain ranges: the Temblor Range on the northeast and the Caliente and La Panza Ranges on the southwest. These ranges rise up to 1000 m above the valley floor. Drainage from these ranges collects in Soda Lake, a shallow, alkali terminal lake in the center of the valley floor. The semi-arid nature of Carrizo Plain (average rainfall of 15 cm; Rosier and Ronan 2006) results in the lake being ephemeral in nature. Carrizo Plain is well known for tectonic activity associated with the San Andreas Fault (Grant and Sieh 1994, Argus and Gordon 2001), which runs along the northeast side of the valley floor.

3.1.3. Biological features. The valley floor supports mostly annual grassland and alkali sink vegetation (in the vicinity of Soda Lake; White and Ralls 1993). Alkali sink vegetation includes dominant species such as saltbush (*Atriplex* spp.) and iodine bush (*Allenrolfea occidentalis*). Also found on the valley floor are dryland grain crops, fallow grain fields, one-time areas of wheat cultivation, and to a lesser extent orchards and vineyards (White and Ralls 1993). Vegetation types on mountain slopes include several types of chaparral, with oak woodlands at higher elevations.

A number of important regulatory or management species are found in Carrizo Plain, including two wide-ranging ungulate species that were once abundant throughout central California but are now restricted to a handful of locations: tule elk and pronghorn antelope. See Section 4 for more details on these species. Another important species from a management perspective is the San Joaquin kit fox, a small canid that is federally listed as endangered. Other species of regulatory concern include blunt-nosed leopard lizard (*Gambelia sila*), giant kangaroo rat (*Dipodomys ingens*), longhorn fairy shrimp (*Branchinecta longiantenna*), Nelson's antelope squirrel (*Ammospermophilus nelsoni*), and burrowing owl (*Athene cunicularia*) (CDFG 2009).

3.1.4. Human features. Much of the Carrizo Plain region remains in natural condition. However, there have been some human impacts in the area. Portions of the valley floor have been converted to agricultural fields, and livestock grazing occurs over much of the region. Vegetation found in seasonally fallow agricultural fields are often used by both tule elk and pronghorn for forage.

Just north of Soda Lake lies California Valley, a small rural community of several hundred residents (Atascadero Chamber of Commerce 2010). Originally a 25,000 acre ranch, this area was subdivided into thousands of lots on which a handful of houses were built. There are currently many dirt roads dissecting the area, but relatively few structures and little associated human activity.

Two paved state highways cross the study area. State Route 58 runs east-west through the center of the Carrizo Plain, while State Route 46 (also east-west) is found in the northern end of the region. While these are relatively lightly traveled routes, they could serve as barriers to movement for some species as well as potential sources of mortality for individuals crossing them. In addition to the highways, several locally important roads run longitudinally on the valley floor. Bitterwater Road (the southern portion of which is paved) runs north from SR-58, and Soda Lake Road runs south from an intersection with Bitterwater Road to its terminus with State Route 166, just south of the study area. These roads may also serve as movement barriers or mortality risks for species that are sensitive or vulnerable to vehicular traffic.

In 2001, an approximately 250,000 acre portion of the study area was declared a National Monument (administered by the Bureau of Land Management, California Department of Fish and Game, and The Nature Conservancy). The National Monument includes both the valley floor and the Caliente Range, from Soda Lake in the north to the southern end of Carrizo Plain in the south. The designation was made in order to acknowledge and provide additional protection to the area’s wildlife, archeological features, and geology. Private land holdings remain within the Monument boundary and are used for agricultural purposes.

3.2. The Proposed Energy Projects

3.2.1. Topaz Solar Farm. Topaz Solar Farm is a proposed solar photovoltaic (PV) facility proposed for the central-west portion of Carrizo Plain (Althouse and Meade, Inc. 2009). The overall project footprint encompasses approximately 4,054 ha (10,019 ac). Project infrastructure components include PV arrays, inverters and transformers, buried lines, an operations and maintenance facility, and staging areas for use during the 3-year construction phase (Topaz Solar Farms 2008).

3.2.2. SunPower – California Valley Solar Ranch. SunPower – California Valley Solar Ranch (“SunPower”) is a PV facility proposed to be built adjacent to the California Valley subdivision and straddling SR-58. The overall project footprint encompasses roughly 2,117 ha (5,230 ac). Infrastructure would include eight solar PV arrays and such associated components as a transmission line, substation, and switchyard (SunPower Corporation 2009). Other project infrastructure would include a visitor’s center, operations and maintenance building, and water tank. The transmission line would run 2.5 miles and connect the project to the existing PG&E Morro Bay-Midway transmission line. The proposed transmission line would be the only project component located north of SR-58; the remainder of the project would be located between SR-58 and California Valley.

4.1 Pronghorn antelope

Distribution and Status: Pronghorn antelope (*Antilocapra americana*) are widely distributed in the western United States, Canada, and Mexico. In 1997, it was estimated that there were nearly one million pronghorn distributed among 15 U.S. states and two Canadian provinces (Byers 1997). Historically, pronghorn were common in southern, central, and northeastern California (Yoakum 2004a), and grasslands of the San Joaquin Valley once supported exceptional numbers (Newberry 1855, cited in Yoakum 2004b). Brown et al. (2006) reported that pronghorn were once widely-distributed in plains and valleys on both sides of the Coastal and Peninsular ranges, from Monterey south as far as the Magdalena Plain in Mexico. According to ranchers, pronghorn herds once numbered in the hundreds at the north end of Carrizo Plain (Koch and Yoakum 2002).

However, pronghorn disappeared from many parts of California, including the Carrizo Plain, by the 1940s due to over-hunting and the conversion of native grasslands to croplands (Yoakum 2004b). CDFG has since reintroduced pronghorn throughout portions of their historic range, including the Carrizo Plain. In 1987, 1988, and 1990, a total of over 200 pronghorn were translocated from the shrub-steppes of northeastern California to the Carrizo Plain and surrounding rangelands (Koch and Yoakum 2002, Yoakum 2004b, Longshore and Lowrey 2008). Koch and Yoakum (2002) estimated population size to fluctuate around 50 animals during 1999-2003. In 2008, the population was estimated at approximately 100 animals (R. Stafford, CDFG, unpublished data). The herd objective for Carrizo National Monument is 250 animals and the greater herd goal (including the solar project areas) is 500 (R. Stafford, CDFG, personal communication).

Whereas pronghorn of the Sonoran Desert (*A. a. sonoriensis*) are Federally listed as endangered, pronghorn in some portions of California are a game species subject to regulated hunting. Limited (bucks only) pronghorn hunting occurred on Carrizo Plain during 1996-2001 (Koch and Yoakum 2002) but the season was discontinued in 2002 due to low numbers of animals.

Habitat Associations: Pronghorn avoid predators by visual detection and speed, and therefore prefer open grasslands and shrub communities with good horizontal visibility, gentle slopes, and few movement obstacles. They inhabit a variety of low-growing vegetation communities, including sagebrush, bitterbrush, grassland, open pinyon-juniper, and alkali desert scrub. Although they typically occupy open, gentle terrain (<10% slope; Ockenfels et al. 1994), pronghorn require some rolling topography or shrubs for cover from inclement weather and concealment of young (Barrett 1981, Ryder and Irwin 1987, Yoakum 2004a). In general, preferred vegetation height averages 38-61 cm, and shrublands with vegetation >88 cm are used less frequently than areas with shorter vegetation (Yoakum 2004a). Based on a literature review, Longshore and Lowrey (2008) suggested that high quality habitat is characterized by slopes ≤ 5%, medium quality habitat typically includes slopes between 5% and 20%, and areas with slopes >20% are low quality. Pronghorn have been documented at elevations from below sea level to 3,353 meters (Yoakum 2004a).

Pronghorn are opportunistic feeders that select forage based on nutritional value, availability, and palatability (Yoakum 2004d). In grasslands, they generally prefer forbs and shrubs over grasses (Yoakum 2004d). Pronghorn dietary patterns can shift dramatically depending on forage availability and quality. Mitchell (1980) suggested that high grass and shrub consumption in pronghorn diets indicate scarcity of the preferred forb species. Dirschl (1963) identified a positive correlation between plant protein content and the degree of consumption by pronghorn, suggesting that plants with protein contents above 10% were the most preferred. A study of feeding ecology of pronghorn in the Cholame area of southern California (Jones 1991) suggested that pronghorn in that area were "receiving suboptimal amounts of protein, energy and phosphorous in the summer. Summer and early fall conditions in the Cholame area will determine the carrying capacity for antelope [sic] in these ranges". This result may also be valid for other existing southern pronghorn herds in California.

Forbs are of paramount nutritional importance to pronghorn (Buechner 1950), especially during spring, when fetal growth is greatest during the third trimester, and during peak lactation in early summer. Forbs contain large amounts of protein, are highly digestible and provide preformed water (Ellis 1970, Smith and Beale 1980, Hervert et al. 2000). Numerous studies of pronghorn feeding habits throughout their range confirm that nutritious forbs are the most selected forage items for pronghorn when available (Beale and Smith 1970, Yoakum 2004b). Hansen et al. (2001) reported pronghorn consumed large quantities of perennial forbs during a mild winter with little snow covering small herbaceous plants.

Optimal habitat has been described as approximately 40-60% grass, 10-30% forbs, and 5-20% shrubs (Sundstrom et al. 1973, Autenrieth 1978, Yoakum 1978). Pronghorn have been documented to feed on alfalfa and other cultivated plants in California (Hopkins, No date). Use of agricultural fields appears to depend on their proximity to natural lands (Sexton et al. 1981). Pronghorn in Montana were observed to use grain fields within 0.8 km (0.5 mi) of natural rangelands more frequently than grain fields farther from natural rangelands (Cole and Wilkins 1958). CDFG biologists also observed pronghorn to restrict use of irrigated agricultural fields in the Salinas Valley and other areas in the northern part of the range to areas within about 0.8 km (0.5 mi) of suitable natural habitat (R. Stafford, CDFG, personal communication).

Pronghorn water requirements are not well understood, and it is likely that needs are related to forage quality and moisture content (Yoakum 2004a). Yoakum (2004a) stated that rangelands with year-round surface water every 1.6 – 3.2 km will support higher densities than areas with fewer water sources.

Pronghorn rarely jump fences, but rather crawl underneath. Fences can impede movements, reduce habitat quality, and cause mortalities, depending on fence design, because pronghorn do not readily jump fences (Byers 1997, Yoakum 2004c). Pronghorn movement in Arizona was not impacted by unfenced, paved two-lane roads, but fenced rights-of-way including two- and four-lane roads and railroads acted as barriers and influenced shapes of pronghorn home ranges (Ockenfels et al. 1997). In the Carrizo Plain, types of fences vary but fence breaks are frequent enough to make barrier quality difficult to define with certainty. Typically, pronghorn find openings or locations where the bottom fence wire is high enough off the ground to allow passage underneath. This is why pronghorn are observed moving between parcels surrounded by four- and five-strand fences. These fences do inhibit movements, but they are not complete barriers (D. Hacker and R. Stafford, CDFG, personal communication).

Spatial Patterns: Pronghorn are gregarious animals found in a wide range of group sizes, depending on such factors as forage quality and quantity, population density, season, and predation risk. On the Carrizo Plain, pronghorn tend to be most gregarious during winter, and are observed in smaller groups during the remainder of the year (R. Stafford, CDFG, unpublished data). The degree of territoriality among males varies among populations, and may be influenced by habitat quality, density, and home range size. Maher (1994) found males on the Carrizo Plain to be less territorial than those in a second research population in Nevada, possibly because the Carrizo Plain population was small, widely dispersed, and recently introduced.

Home range size varies considerably with habitat quality. Annual home range estimates of eight male pronghorn monitored in the rolling plains of Texas ranged from 600 to 1,800 ha (Aiken 2005), whereas another study in semi-desert shrub/grassland habitat in western Texas reported average 3-year home range sizes of 2,509 ha and 4,238 ha for 8 males and 28 females, respectively (Canon 1993). In grassland and juniper habitat in northern Arizona, home ranges of 20 radio-collared animals averaged 8,200 ha for 5 males and 12,400 ha for 15 females (Ockenfels et al. 1997). Although home range estimates are not available for individual pronghorn on the Carrizo Plain, herd range size was estimated at 13,000 ha, based on flight surveys conducted during 1999-2008 (R. Stafford, CDFG, unpublished data). In some populations, territorial males use smaller home ranges than females, and female ranges may overlap multiple male home ranges. For example, in semi-desert shrub/grassland habitat in western Texas, Canon (1993) observed significantly larger home ranges among females than males. In other areas, no gender-based home range differences were detected (O'Gara 2004).

Dispersal distances are not available for individual pronghorn on the Carrizo Plain, but translocated animals in other populations have been documented to travel 50 km and swim across a river to return to their natal ranges (Byers 2003). Movements of up to 93 mi (150 km) have been reported for pronghorn in California (California Department of Fish and Game 2009).

Most pronghorn herds exhibit seasonal movements (Einarsen 1948, Yoakum 1978) between summer and winter ranges and have been reported to move up to 258 km between seasonal ranges (Sawyer et al. 2005). Generally, changes in climatic and vegetative conditions trigger the onset and length of seasonal movements. During dry seasons, southern pronghorn may move great distances in search of forage and water (Buechner 1950, Hailey 1979). Yoakum (1978) reported daily movements of 0.06-0.5 mi (0.1-0.8 km) in spring and summer, and 1.9-5.8 mi (3.2-9.7 km) in autumn and winter.

4.2 Tule elk

Distribution and Status: The tule elk (*Cervus elaphus nannodes*) is the smallest of all elk subspecies in North America. Although the species as a whole is widespread throughout north temperate zones of the world, tule elk are endemic to valleys and foothills of coastal and central California, including the Carrizo Plain. In the early 1800s, tule elk were found in large numbers in the Sacramento Valley as far north as Red Bluff (Maloney 1945, cited in McCullough 1969) and in large valleys to the west of the Sacramento Valley (McCullough 1969). Along the coast, they were documented in the San Francisco Bay region and in the southern Coast Range, with abundant records in the Monterey Bay area. Historically, elk also occurred in large numbers in the San Joaquin Valley, in particular in the Sacramento-San Joaquin Delta. Tule elk occurred as far south as the Tehachapi Mountains, which apparently form the southern boundary of their distribution, and east to the foothills of the Sierra Nevada (McCullough 1969).

Historically, tule elk were reported to be the predominant herbivore of California's grasslands, sharing the range with deer (*Odocoileus hemionus*), pronghorn antelope, and domestic cattle. Herds of 2000 animals were reported, and it was estimated that 500,000 tule elk may have inhabited the State (McCullough 1969). However, a combination of competition from domestic livestock, market hunting, and land conversion to agriculture caused their numbers to decline precipitously. By 1870, tule elk were nearly extinct, with only one small population remaining in the Buena Vista Lake area in the San Joaquin Valley (McCullough 1969). Subsequent translocations were able to save this subspecies from extinction, and by 1969 three small populations existed in California. By 1996, additional translocations had resulted in 22 populations, distributed primarily across the coastal regions of central California, with one population in Owens Valley to the east (McCullough et al. 1996). In 2007 the state-wide estimate was 3,800 animals (Greco et al. 2009). Tule elk have become a popular game animal in the State, and hunting is allowed at a number of locations, including Carrizo Plain National Monument.

Habitat Associations: In terms of habitat use, tule elk are a specialized subspecies because they inhabit open habitat in semi-arid environments, whereas the species as a whole typically inhabits temperate climates and uses areas of heavy vegetation at least seasonally (McCullough 1969). Typical habitat of tule elk includes large grassland areas, which range from grasslands interspersed with marshy habitats in floodplains to relatively xeric rolling grasslands interspersed with trees and brush stands (McCullough 1969). Tule elk use brush and chaparral habitats if they are in proximity to grasslands (McCullough 1969). Historical records described elk habitat as consisting of "open lands," including extensive plains with rich alluvial soil, interspersed with limited numbers of oaks, sycamores, and ash, and with grasses sometimes knee- or breast-height (McCullough 1969). McCullough (1969) further noted that this subspecies is typically found in areas subject to periodic drought.

Greco et al. (2009) modified existing elk habitat suitability ratings presented in the California Wildlife Habitat Relationships System (CDFG 2009) to specifically address tule elk habitat needs. They identified annual grasslands, freshwater emergent wetlands, and valley foothill riparian habitats as having the highest suitability for tule elk. Other important habitat types included irrigated hayfields, grain crops, row and field crops, and pastures—used primarily for feeding—as well as eucalyptus groves—used primarily for cover. CDFG biologists observed tule elk using irrigated agricultural fields in the Salinas Valley and other areas in the northern part of the range within about 0.8 km (0.5 mi) of suitable natural habitat (R. Stafford, CDFG, personal communication).

Tule elk feed on a wide variety of plant species, including annual forbs and grasses, perennial forbs, grasses, and grass-like plants, browse, and even acorns (McCullough 1969). Annual forbs are an important diet item in the spring and early summer, and grasses and sedges are eaten throughout the year (McCullough 1969). Tule elk also eat aquatic vegetation when available. Water requirements likely vary with season, temperature, and moisture content of vegetation.

The impact of fences on tule elk distribution is not well understood. Elk can cross over or go under fences, depending on fence design; however, elk have been known to run into and damage fences when alarmed (McCullough 1969, Ferrier and Roberts 1973). On the Carrizo Plain, as in other tule elk habitat in California, paved roads appear to hinder elk movement, with the result that they often delimit herd ranges (R. Stafford, CDFG, personal communication). Only 13 out of more than 30,000 point locations gathered using standard telemetry showed that elk had crossed paved roads, and nearly all observed road crossings occurred immediately after translocated elk were released (R. Stafford, personal communication).

Spatial Patterns: Home range size depends on habitat quality, gender, and annual precipitation (McCullough 1969, Peek 2003). O'Connor (1988) reported mean home range of nine tule elk females in Cache Creek to range from 2,309 to 4,141 ha depending on analysis method used. In comparison, tule elk herds in Contra Costa County (central California) and at Point Reyes National Seashore were reported to use areas of 869 ha and 359 ha, respectively (Pomeroy 1986, Gogan 1986, cited in O'Connor 1986). On the Carrizo Plain, home ranges of radio-collared females ranged from 3,618 ha to 12,640 ha based on 95% minimum convex polygons (R. Stafford, CDFG, unpublished data).

Tule elk are highly social, and may be found in large groups that are dynamic in terms of size and composition (McCullough 1969). Group size depends on season, sex, population, and vegetation density, with the largest groups often observed in open habitats (Knight 1970). Tule elk exhibit pronounced periods of sexual segregation, with males segregated from females for most of the year outside of the autumn breeding period (Peek and Lovaas 1968). Females may be found in large groups with calves and young animals for most of the year, but disperse into smaller groups of 2-10 animals during the spring parturition season (McCullough 1969).

Tule elk do not exhibit the extensive seasonal ranges shifts observed in some other elk subspecies, and are thus not typically considered to be migratory (McCullough 1969). However, herds may exhibit seasonal shifts in response to local forage conditions and annual patterns of plant productivity (McCullough 1969).

Tule elk are capable of moving great distances in short time periods. McCullough (1969) reported that bull elk introduced near the center of the Owens Valley in the 1930s were observed at the north and south ends of the valley, approximately 230 km apart, within one year of release, indicating dispersal of approximately 115 km. On the Carrizo Plain, elk in established herds were observed to move 20 km during a 2-year period, whereas some animals were observed to move 40 km after their initial release (D. Hacker, CDFG, personal communication).

4.3 San Joaquin kit fox

Distribution & Status: Historically, San Joaquin kit foxes were distributed throughout the San Joaquin Valley and adjacent low foothills, from the vicinity of Byron in Contra Costa County to the foothills of the Tehachapi Mountains (Grinnell et al. 1937). By 1930, their range had been reduced by more than half due to habitat conversion to agriculture and other uses, with the largest areas of occupied habitat remaining in the southern and western portions of their original range (Grinnell et al. 1937). By 1975 the pre-1930 estimate of population size (about 8,700 to 12,100) was reduced by 20-43% (USFWS 1983). San Joaquin kit foxes were Federally-listed as endangered in 1967 and State-listed as threatened in 1971, and the population is believed to have declined even more since the 1970s (USFWS 1998). Currently, kit foxes have a very limited range, mostly in foothill areas and arid valleys of the coastal ranges, in foothills and arid valleys below about 914 m in the western Sierra Nevada, and the Tehachapi Mountains foothills (USFWS 1998, Koopman et al. 1998, Thelander et al. 1994). The largest extant populations are in western Kern County in the vicinity of the Elk Hills and Buena Vista Valley, and in the Carrizo Plains area of San Luis Obispo County (USFWS 1998). The Carrizo Plain population is one of three populations designated a high priority for enhancement and protection by the U.S. Fish and Wildlife Service (USFWS 1998).

Habitat Associations: Kit fox distribution is strongly influenced by topography, vegetative cover, prey availability, and predator densities (Grinnell et al. 1937, Egoscue 1962, Daneke et al. 1984, cited in Warrick and Cypher 1998; Haight et al. 2002, Zoellick et al. 1989). Kit foxes primarily inhabit annual grasslands and sparsely vegetated scrub habitats such as alkali sink scrub, saltbush scrub, and chenopod scrub. Other habitats such as open oak savannah, vernal pools, perennial grasslands, alkali meadows and playas are also used (USFWS 1998, B. Cypher, California State University, Stanislaus, personal communication). Kit foxes prefer areas with abundant rodent populations and open environments where they can detect and evade coyotes and other predators (Warrick and Cypher 1998). High kit fox capture rates have been documented in recently burned areas, which were attributed to the openness of the habitat and its affect on predator evasion (Zoellick et al. 1989). Kit foxes can also persist in and adjacent to agricultural areas, such as row crops, irrigated pastures, orchards, and vineyards, as well as vacant lands or open spaces (e.g., parks, golf courses, and flood control areas) within urban areas (USFWS 1998, Cypher and Frost 1999). Warrick et al. (2007) documented use of agricultural lands for foraging up to 1 kilometer from adjacent suitable natural habitats. Among grasslands, kit foxes prefer more open, low-growing, and sparsely vegetated areas, such as *Bromus*-dominated grasslands in drier regions, and tend to avoid taller, denser grasslands such as *Avena*-dominated communities in moister areas (B. Cypher, personal communication).

Kit foxes use dens year-round to escape predators, bear young, and as daytime resting places. Kit foxes may be found on a wide variety of soils, but they prefer loose-textured soils (USFWS 1998) which facilitate burrow construction and tend to support more rodents that are kit fox prey.

San Joaquin kit foxes are typically associated with low elevations on valley floors. Grinnell et al. (1937) placed the upper elevation limit at about 1,200 feet (366 m), but Laughrin (1970) observed kit foxes at 2,400-ft (732 m) elevations during spotlighting surveys, and estimated that kit foxes in the southwestern portion of their range, south of Highway 46, range up to about 2,500 feet (762 m). They are mainly associated with gently sloping and flat terrain. The literature suggests that slopes of 0-5% are ideal, slopes of 5-15% provide fair habitat, and areas with slopes >15% are largely unsuitable (B. Cypher, personal communication). Warrick and Cypher (1998) found a negative relationship between topographic ruggedness and capture rates of kit foxes in Elk Hills and Buena Vista Hills of the Temblor Range.

Spatial Patterns: Kit fox pairs remain together all year and share a home range (USFWS 1998). Home range estimates vary from less than 260 ha to approximately 3,100 ha (Morrell 1972, Knapp 1978, cited in USFWS 1998, Zoellick et al. 1987, Spiegel and Bradbury 1992, White and Ralls 1993). Home range sizes at the Naval Petroleum Reserve averaged 460 ha (Zoellick et al. 2002), whereas home range size of 21 animals on the Carrizo Plain averaged 1,160 ha (White and Ralls 1993). Home range size is largely dependent on prey availability, which can vary annually in relation to precipitation (Haight et al. 2002). The sexes typically do not differ in home range size (White and Ralls 1993, Zoellick et al. 2002). Haight et al (2002) assumed two kit foxes per home range, which they estimated to average 390 ha in good habitat and 780 ha in fair habitat. In optimal habitat, each kit fox family requires approximately 486 ha, with larger space requirements in suboptimal habitats (Cypher et al. 2007).

Dispersal distances vary widely, with male foxes known to travel over 40 km (Haight et al. 2002) and juvenile dispersal from natal dens documented to range from 8 to 96 km (Thelander et al. 1994). Mean dispersal distance of 48 kit foxes at the Naval Petroleum Reserves was 7.8 $\pm$ 1.1 km, with no sex-based differences observed (Scrivner et al. 1987 cited in Koopman et al. 2000). Koopman et al. (2000) found that 33% of animals dispersed from their natal territory, and significantly more males (49%) dispersed than females (24%). Average nightly distance moved during the breeding period (14.6 $\pm$ 1.1 km) was greater than during the pup-rearing (10.7 $\pm$ 1.0 km), and pup dispersal periods (9.4 $\pm$ 1.1 km; Zoellick et al. 2002).

Adult and juvenile kit foxes are known to move through disturbed habitat, including agricultural fields, oil fields, and rangelands, and across highways and aqueducts (Haight et al. 2002). However, major highways and heavily traveled road are obstacles to movement (Cypher et al. 2000). Vehicles are the greatest source of mortality in urban areas, whereas predation, primarily by coyotes, is the primary cause of mortality in most other areas (Cypher et al. 2000, B. Cypher, personal communication). Cypher et al. (2005) examined the effects of 2-lane highways on kit foxes in the Lokern Natural Area, and found no significant negative effects on fox demography or ecology. However, the authors cautioned that increased road density could have a negative impact, citing studies that reported increased swift fox (*Vulpes velox*) mortality with increasing road density (Cypher et al. 2005), selection by bobcats of habitat with lower road density (Lovallo and Anderson 1996), and declining gray wolf habitat suitability with increased road density (Thiel 1985, Jensen et al. 1986).

5.1 Modeling baseline conditions of habitat suitability and connectivity for each focal species

5.1.1 Compilation and refinement of digital data layers

We compiled GIS data layers for the study area, including the following (see Appendix A for details concerning the source, type, scale, and date of each data layer):

- recent high-resolution aerial photos,
- digital elevation models,
- roads,
- vegetation (including crop and agriculture data from San Luis Obispo and Kern counties),
- protected lands,
- species occurrence data from wildlife agencies, Endangered Species Recovery Program, and California Natural Diversity Database, and
- project boundary data from project proponents.

We manually updated the road and vegetation layers within the study area to be as up-to-date and accurate as possible. For the refined vegetation layer (Figure 1), we compiled vegetation data available from the County of San Luis Obispo website, crop data from San Luis Obispo and Kern counties, and regional vegetation data compiled by the state (CalVeg). We evaluated this compiled vegetation layer in relation to recent high-resolution aerial imagery and made changes where necessary to reflect the most recent land use status. Particular emphasis was placed on agricultural and urban land cover types. For example, we corrected the vegetation classification of some lands that had recently been converted to agriculture or urban but were still shown as natural vegetation in the compiled vegetation data layer. Conversely, areas shown as agriculture or urban within the compiled vegetation layer that had not actually been converted to either land use were changed back to the vegetation type in either the CalVeg or County Vegetation data layer.

Further refinements were made to the vegetation layer based on input received during the January 27, 2009 comment period on the input data layers:

- Polygons identified as “undefined agriculture” were assigned specific categories, such as dryland grain crops, irrigated row and field crops, vineyards, and orchards based on aerial imagery and review by CDFG biologists familiar with the area.
- Polygons defined as pasture were examined using imagery to determine if they were irrigated or non-irrigated. All non-irrigated pasture polygons were changed to annual grassland; all irrigated pasture polygons remained as pasture.
- Based on input from field biologists familiar with vegetation in the study area, (B. Cypher, personal communication) we differentiated *Avena*- and *Bromus*-dominated grasslands using precipitation data. Cypher and colleagues (personal communication) had found the 9-inch annual precipitation isocline to be a good threshold for

Figure 1.
Vegetation
in the Study Area

Vegetation
Name

- Alkali Desert Scrub
- Annual Grassland - Avena
- Annual Grassland - Bromus
- Barren
- Blue Oak Woodland
- Blue Oak-Foothill Pine
- Chamise-Redshank Chaparral
- Closed-Cone Pine-Cypress
- Coastal Oak Woodland
- Coastal Scrub
- Desert Riparian
- Desert Wash
- Dryland Grain Crops
- Eucalyptus
- Freshwater Emergent Wetland
- Irrigated Row and Field Crops
- Juniper
- Lacustrine
- Mixed Chaparral
- Montane Chaparral
- Montane Hardwood
- Montane Hardwood-Conifer
- Orchard and Vineyard
- Pasture
- Perennial Grassland
- Pinyon-Juniper
- Sagebrush
- Sierran Mixed Conifer
- Urban
- Valley Foothill Riparian
- Valley Oak Woodland
- Vineyard
- Wet Meadow
- Highways
- Rivers & Streams
- Hydrography
- County Boundaries

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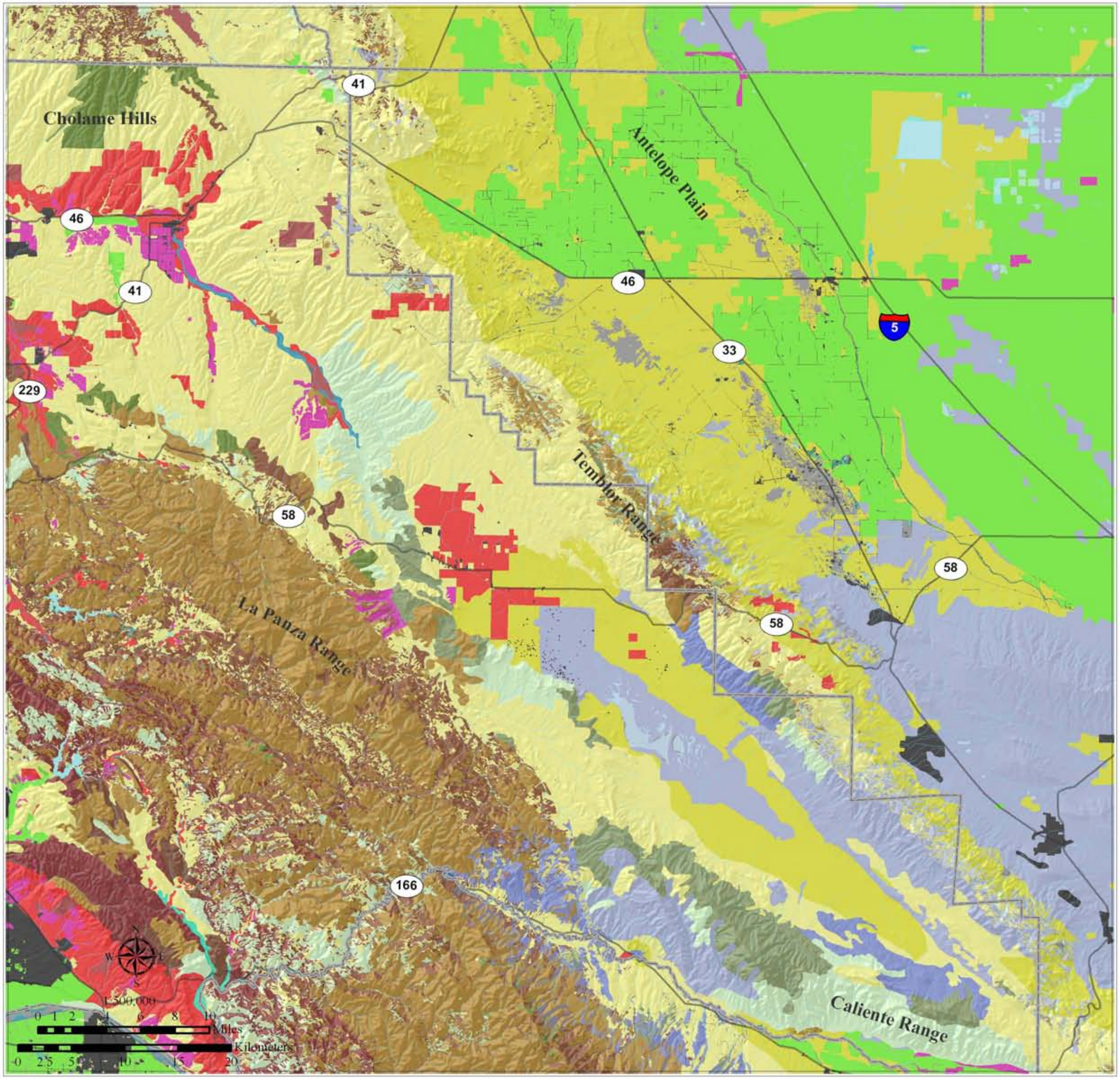


differentiating denser, taller grasses, usually dominated by *Avena*, and generally considered less than optimum for kit fox, from sparser, shorter grasslands, typically dominated by *Bromus*, and generally favored by kit foxes. We therefore downloaded and processed PRISM precipitation data (gridded 30 arc-second [800m] annual normals) for 1971-2000 and classed annual grassland vegetation as *Bromus*-dominated ($<$ 9 inches precipitation) or *Avena*-dominated ($\geq$ 9 inches precipitation).

Additional updates to the vegetation layer were made in response to comments received on the April 2009 draft report of baseline conditions. These updates include information from California Department of Fish and Game who recently did a flyover of the study area to ground truth the vegetation layer and comments received from Carrisa Alliance for Responsible Energy. Still further updates to the vegetation layer were made in response to comments received on the June 2009 draft report of baseline conditions. These changes incorporate vegetation layers received from Topaz Solar Farm and SunPower within their project footprints as well as further refinements to delineate grassland type (i.e., *Bromus* vs. *Avena* dominated).

To create and update the road layer, we first downloaded 2007 Tiger Line road data and evaluated them using recent high-resolution aerial imagery, adding dirt roads not captured by the 2007 Tiger Line data. To delineate paved roads, we used Caltrans highway data and input from CDFG biologists. We then re-evaluated the study area using recent high resolution aerial imagery to identify other paved roads not captured in the Caltrans data. All other roads in the 2007 Tiger Line Data were delineated as dirt roads (Figure 2).

5.1.2 Modeling habitat suitability

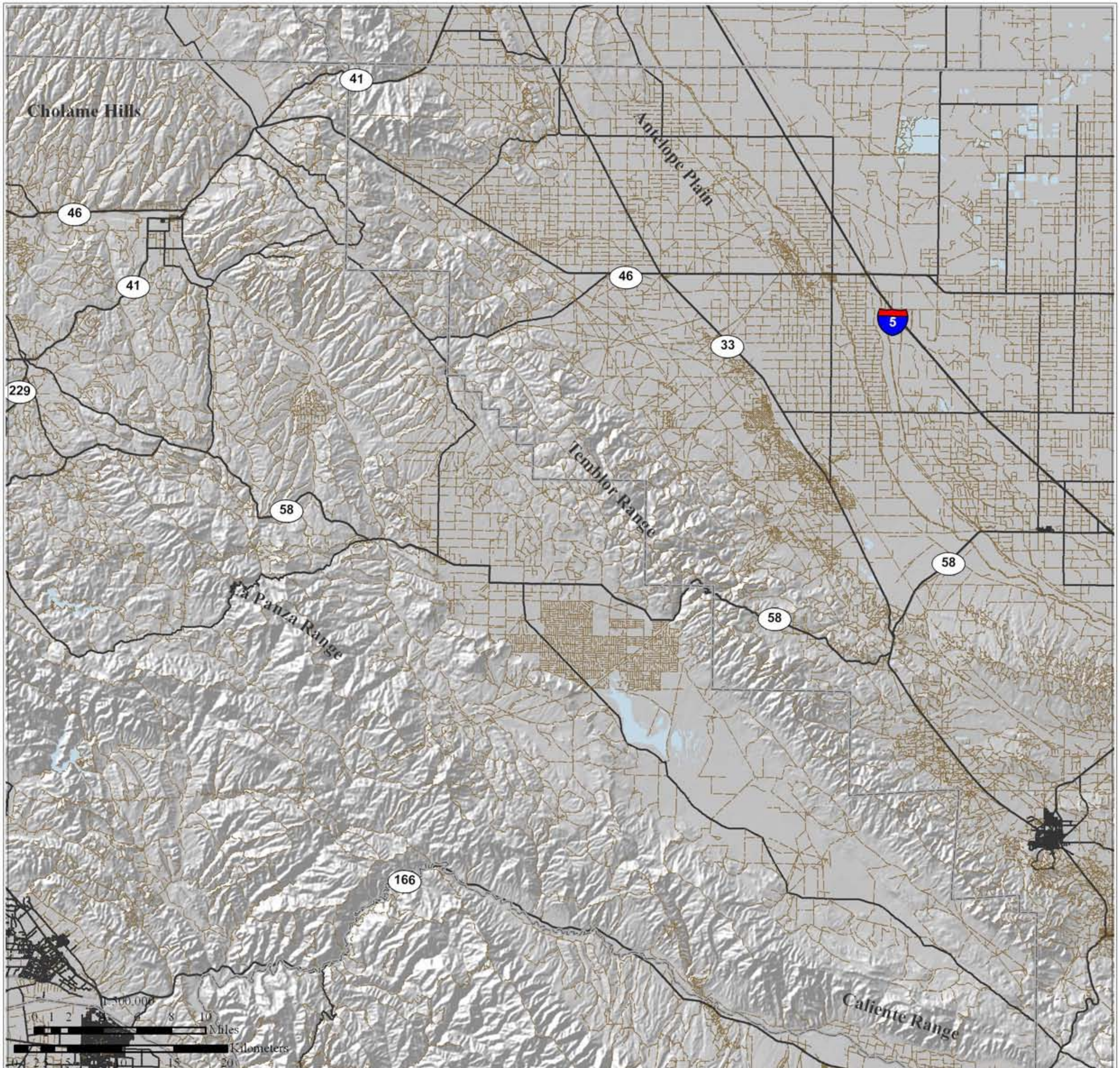
We created habitat suitability models for each species by estimating how the species responded to different habitat factors that were mapped at a 30 x 30-m cell resolution. The actual spatial data layers used in each habitat suitability model depended on the species. For example, factors incorporated into the pronghorn antelope model were vegetation type, slope, and road density. (Details of the species-specific models are described in Section 5.1.4.) Within each factor, suitability scores were assigned to each category (e.g., each vegetation type) on a scale of 0 (unsuitable) to 1 (most suitable). Habitat suitability was calculated for each 30-m^2 pixel using a Weighted Geometric (Multiplicative) Mean:

$$\text{Suitability} = (S_A^{WA}) * (S_B^{WB}) * (S_C^{WC})$$

where S_A, S_B, and S_C are suitability ratings for factors A, B, and C, respectively, and WA, WB, and WC are the factor weightings.

The Weighted Geometric Mean is strongly influenced by low suitability ratings, such that if a score for any class is 0, then suitability of the pixel remains 0 regardless of factor weight or scores for other factors. We divided the resulting suitability values into five classes (low, low to medium, medium, medium to high, and high) using natural breaks for pronghorn and tule elk, and quantile classification for kit fox. Additional details concerning habitat suitability analyses are in Section 5.1.4 and Appendix B.

**Figure 2.
Roads in the
Study Area**



Roads

- Highway
- Other Paved Roads
- Dirt Roads
- County Boundaries
- Hydrography

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Lands rated in the top two suitability classes (i.e., medium-high, high) for pronghorn antelope and tule elk and in the top three suitability classes (i.e., medium, medium-high, high) for kit fox were used to identify species-specific habitat *patches* and habitat *cores* based on contiguous area. *Potential core areas* were defined as the amount of contiguous suitable habitat necessary to sustain at least 50 individuals (Beier et al. 2006). Potential cores are probably capable of supporting the species for several generations. A *patch* was defined as the area of contiguous suitable habitat needed to support at least one male and one female, but less than the potential core area. Patches can support at least one breeding pair of animals (perhaps more if home ranges overlap greatly) and are probably useful to the species if the patch can be linked via dispersal to other patches and core areas.

To determine whether the distribution of suitable habitat allows species to disperse among patches and core areas, we conducted a configuration analysis to identify which patches and core areas were functionally isolated by distances too great for the focal species to traverse. Because the majority of methods used to document dispersal distance underestimate the true value (LaHaye et al. 2001, Beier et al. 2006), we assumed each species can disperse twice as far as the longest documented dispersal distance.

5.1.3 Modeling landscape permeability

Landscape permeability analysis is a GIS technique that models the relative cost for a species to move between target areas based on how each species is affected by habitat characteristics, such as topography, elevation, vegetation composition, and road density. This analysis identifies a least-cost corridor, or the best potential route for each species between targeted areas (Craighead et al. 2001, Singleton et al. 2002). The purpose of the analysis is to identify land areas which would best allow the focal species to live in or move through the linkage (Beier et al. 2006).

For each species, the relative cost of travel was calculated using habitat factors considered most influential on that species' movements (selected from among the factors vegetation type, vegetation density, road density, elevation, topographic position, and terrain ruggedness). The factors, class rankings, and weighting values may therefore differ from those used for each species in determining habitat suitability. We derived four topographic classes from elevation and slope models: canyon bottoms, ridgelines, flats, and slopes. Terrain ruggedness was measured as the variance in elevation between each grid cell and its neighboring cells. For tule elk and kit fox, road density was measured as kilometers of paved road per square kilometer (averaged over a 1-km^2 moving window), whereas for pronghorn, road density was measured using both paved and dirt roads. Vegetation density was based on reflectance data derived from satellite imagery (see Section 5.1.4.3 for additional details on this index).

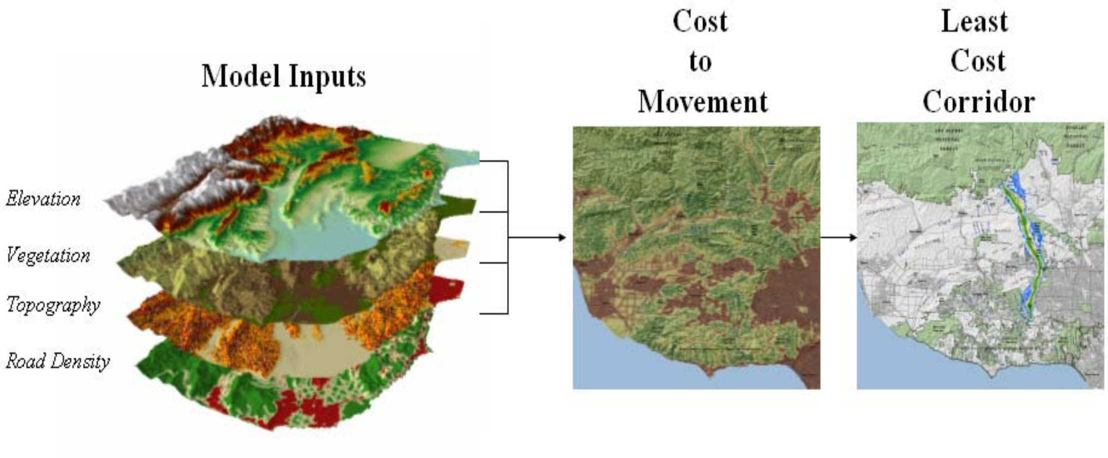


Figure 3. Example permeability model inputs: elevation, vegetation, topography, and road density. Landscape permeability analysis models the relative cost for a species to move between target areas based on how each species is affected by various habitat characteristics.

Within each factor, experts assigned each category (e.g., various vegetation categories or categories of road density) a rating between 1 (preferred) and 10 (avoided) based on each species ability to move through areas with these characteristics, as determined from available literature and expert opinion. Cost to movement was then calculated as the Weighted Geometric Mean for each species (where cost of movement can be thought of as the inverse of permeability). A unique resistance surface (cost raster) was thus developed for each species. The least-cost corridor analysis then maps the relative degree of permeability for a species based on the cumulative travel cost calculated using the cost raster and distance between targeted core areas. We then used a “slice” (or cost contour) of the resulting cost surface based on expert opinion to delineate a least cost corridor that is biologically meaningful for the species.

Performing permeability analyses requires identifying the endpoints (or targets) to be connected. For pronghorn and tule elk, Target Zones were identified at the southern and northern extent of the study area and target endpoints for the analysis were selected as medium-high and high suitable habitat within each Target Zone. For kit fox, three Target Zones were identified at the northern extent of the study area (i.e., Salinas River Watershed, Palo Prieto-Cholame Valley, and Western Kern County in the vicinity of the Antelope Plain) to better reflect the goals outlined in the recovery plan for this species (USFWS 1998). Within these three Target Zones, target endpoints were selected as medium- to high-suitability kit fox habitat. In the southern Target Zone, target endpoints were selected as habitat of medium to high suitability on the Carrizo Plain side of the Temblor Range.

Appendix B and Section 5.1.4 describe species-specific model input data and additional details concerning the habitat suitability and landscape permeability analyses.

5.1.4 Species-specific model input data and conceptual basis for model development

5.1.4.1 Pronghorn antelope

Habitat Suitability: We developed a Weighted Geometric (Multiplicative) Mean GIS habitat suitability model using vegetation type, slope, and road density as primary variables, based on information summarized in Section 4.1 and discussions with species experts. The model reflects that pronghorn prefer open terrain, short vegetation, few barriers, and gentle slopes. Because pronghorn use a wider range of elevations (0 to 3,353 meters) than occurs in the study area, elevation was not an input factor.

Habitat suitability ratings (from 0 to 1, with 1 being most suitable and 0 being unsuitable) for individual vegetation, road density, and slope classes were provided by CDFG biologists most familiar with this species on the Carrizo Plain (R. Stafford and D. Hacker; Appendix B). Suitability ratings shown in Appendix B were further refined as follows:

- Within the factor "Slope" categories were based on recommendations by Longshore and Lowrey (2008): slopes > 5% and ≤ 20% were rated as medium suitability (rating = 0.6) and slopes > 20% were rated as low suitability (rating = 0.3). "Flats," ≤ 5% slope by definition, were rated as high suitability (rating = 1.0).
- Irrigated row and field crops within 0.8 km (0.5 mi) of suitable natural habitat areas (suitability ≥ 0.5) were rated as shown in Appendix B; but irrigated row and field crops more than this distance from suitable natural habitat were rated as unsuitable (rating = 0), based on observations that pronghorn only use such fields in proximity to suitable natural habitats (Cole and Wilkins 1958, R. Stafford, CDFG, personal communication).

Habitat use by pronghorn on the Carrizo Plain may not be directly affected by roads, per se, but habitat use may be adversely affected by fences (Ockenfels et al. 1997). Because many roads in the study area, both paved and unpaved, are accompanied by fences, and because a comprehensive fence data layer was not available, the pronghorn habitat suitability model considered areas with a high road density to be less suitable than less-roaded areas, and this factor did not differentiate between paved and unpaved roads.

Although distance to water may influence pronghorn habitat suitability, especially during summer (Yoakum 2004a; Section 4.1), a complete map of water sources (including both natural and artificial water sources) was not available for this study area and we thus did not include water in our model.

Appendix B lists the category scores and factor weights for each factor, provided based on expert opinion by R. Stafford and D. Hacker (CDFG, personal communication). Each factor was weighted from 0% to 100%, such that all weights must sum to 100%. Habitat suitability was calculated for each 30-m^2 pixel in the study area as the weighted geometric mean of scores for that pixel:

$$(\text{Vegetation Score}^{0.35}) * (\text{Road Density Score}^{0.10}) * (\text{Topography Score}^{0.55}) = \text{Habitat Suitability.}$$

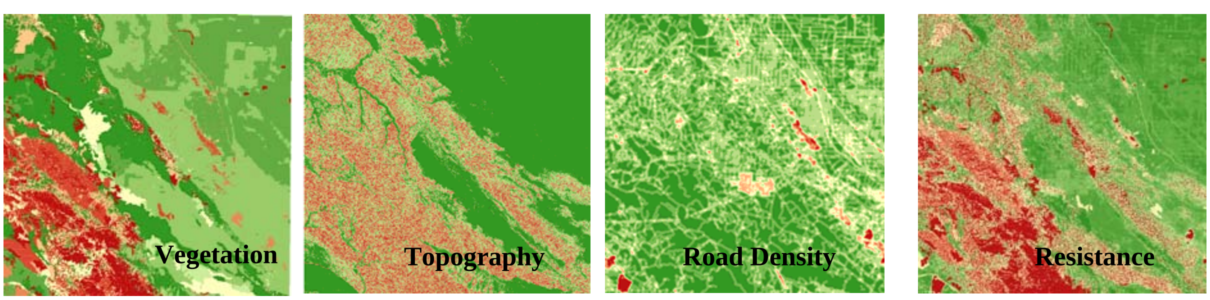
Habitat Patches and Cores: Potential Habitat Patches and Cores were identified as contiguous polygons of medium-high and high suitability habitat meeting the following size criteria.

Minimum patch size (defined as the area of suitable habitat capable of supporting at least two individuals) was estimated as 13,000 ha based on estimated herd range size on the Carrizo Plain as determined from flight data gathered between 1999 and 2008 (R. Stafford, CDFG, unpublished data). Core areas (defined as areas potentially supporting 50 or more individuals) were estimated to be ≥ 65,000 ha (herd range x 5) based on expert opinion (R. Stafford and D. Hacker). Thus, patch size was defined as ≥ 13,000 ha but < 65,000, and core areas were defined as ≥ 65,000 ha. Any suitable habitat < 13,000 ha was defined as less than a patch. These areas may serve as stepping stones between potential patches and core areas. Dispersal distance was defined as 100 km for the patch configuration analysis for pronghorn.

Landscape Permeability: For permeability analysis, we identified areas to be connected as habitat of medium-high and high suitability within two Target Zones: one in the southeastern portion of the study area as defined by a 95% minimum convex polygon inscribing the occurrence data for points south of Soda Lake and one in the northwestern portion of the study area defined by a 95% minimum convex polygon inscribing the occurrence data north of State Route 46 in the Cholame Valley. These Target Zones were selected to represent known herd ranges that include important habitat for the species and that should remain connected to assure long-term population viability. The Target Zone in the southeast on Carrizo Plain National Monument (CPNM) is known to support a population of pronghorn, and current pronghorn distribution is known to extend from this area northwest beyond the State Route 46-State Route 41 intersection. Although the Target Zone in the northwestern portion of the study area is not currently protected, it represents an intact landscape that connects to intact lands beyond the northwest extent of our study area. As such, maintenance of connectivity from CPNM to the northwestern zone is assumed to provide pronghorn with important connectivity to areas beyond this zone.

Permeability ratings were provided by CDFG biologists most familiar with pronghorn on the Carrizo Plain (R. Stafford and D. Hacker; Appendix B). They were combined using the following Weighted Geometric Mean equation, which represents cost of movement (the inverse of permeability):

$$-(\text{Vegetation Score}^{0.35}) * (\text{Topography Score}^{0.55}) * (\text{Road Density Score}^{0.10}) = \text{Resistance}.$$



Pronghorn antelope model inputs and resulting resistance surface.

The equation reflects that pronghorn are most likely to move through open terrain, with short vegetation, few barriers, and gentle slopes. Because pronghorn use a wider range of elevations (0 to 3353 meters) than occur in the study area, elevation was not an input factor into the permeability model.

5.1.4.2 Tule elk

Habitat Suitability: We developed a Weighted Geometric (Multiplicative) Mean GIS habitat suitability model using vegetation type and road density as primary variables, based on information summarized in Section 4.2 and discussions with species experts. The model reflects that tule elk prefer large grassland areas, freshwater emergent wetlands, and valley foothill riparian habitat, but that they also use a wide variety of other habitats including agricultural lands, open brush habitats, and dispersed stands of oaks, sycamore, eucalyptus and other trees. The presence of paved roads influences tule elk movement and appears to delimit some herd ranges on the Carrizo Plain (Section 4.2); thus the model includes density of paved roads as an input. The habitat suitability model considered areas with a high road density to be less suitable than less-roaded areas.

Habitat suitability ratings (from 0 to 1, with 1 being most suitable and 0 being unsuitable) for individual vegetation and road density classes were provided by CDFG biologists most familiar with this species on the Carrizo Plain (R. Stafford and D. Hacker; Appendix B). Suitability ratings shown in Appendix B were further refined as follows:

- Irrigated row and field crops within 0.8 km (0.5 mi) of suitable natural habitat areas (suitability ≥ 0.3) were rated as shown in Appendix B; but irrigated row and field crops more than this distance from suitable natural habitat were rated as unsuitable (rating = 0), based on observations that tule elk only use such fields in proximity to suitable natural lands (R. Stafford, CDFG, personal communication).

Tule elk use a variety of topographic land forms and a wide range of elevations relative to areas available within our study area, so topographic position and elevation were not included in the model. Because the impact of fences on tule elk habitat suitability is not well understood, and a comprehensive fence data layer was not available for the study area, we did not include fences as an input to our model. Similarly, because water needs of tule elk are not well understood, and a complete map of water sources (including both natural and artificial water sources) was not available for this study area, we did not include water in our model.

Appendix B lists the category scores and factor weights for each factor, provided based on expert opinion by R. Stafford and D. Hacker (CDFG, personal communication). Each factor was weighted from 0% to 100%, such that all weights must sum to 100%. Habitat suitability was calculated for each 30-m^2 pixel in the study area as the weighted geometric mean of scores for that pixel:

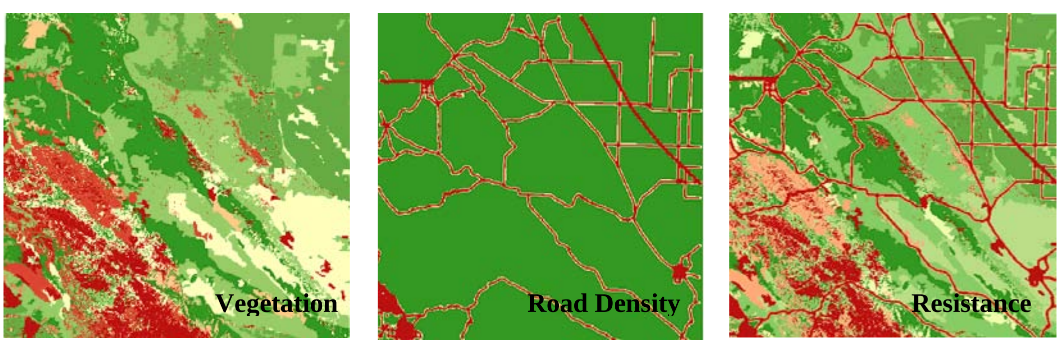
$$(\text{Vegetation Score}^{0.50}) * (\text{Road Density Score}^{0.50}) = \text{Habitat Suitability}$$

Habitat Patches and Cores: Habitat Patches and Cores were identified as contiguous polygons of medium-high and high suitability habitat meeting the following size criteria. Minimum patch size (defined as the area of suitable habitat capable of supporting at least two individuals) was estimated as 3,600 ha based on the minimum home range size observed for female elk on the Carrizo Plain (R. Stafford, CDFG, unpublished data). Because elk are gregarious, and home range estimates come from animals living in natural groups, we assumed that one home range could support at least two individuals. Core areas (defined as areas potentially supporting 50 or more individuals) were estimated to be ≥ 63,000 ha (the largest home range observed on the Carrizo Plain x 5) based on expert opinion (R. Stafford and D. Hacker). Thus, patch size was defined as ≥ 3,600 ha but < 63,000, and core areas were defined as ≥ 63,000 ha. Any suitable habitat < 3,600 ha was defined as less than a patch; these areas may serve as stepping stones between potential patches and core areas. Dispersal distance was defined as 80 km for the patch configuration analysis for tule elk.

Landscape Permeability: For permeability analysis, we identified areas to be connected as habitat of medium-high and high suitability within three Target Zones that were delineated using 95% minimum convex polygons (MCP) inscribing tule elk occurrence data of five subherds: the Cholame Valley MCP (north of the westernmost extent of State Route 46), California Valley/Carneros Rocks MCP in the central Carrizo Plain and portions of the Temblor Range, and the American/South Chimineas MCP in Carrizo Plain National Monument. These Target Zones were selected to represent known herd ranges in the study area that should remain connected to assure long-term population viability. Permeability was assessed between the Cholame Valley MCP and the California Valley/Carneros Rocks MCP and between the California Valley/Carneros Rocks MCP and American/South Chimineas MCP. Permeability between the Cholame Valley herd and American/South Chimineas hers was not analyzed, as the California Valley herd is located between the other two, potentially serving as a "stepping stone" location between the herds on either side. All Target Zones are known to be used by tule elk, and elk distribution extends northwest beyond the Cholame Valley MCP. Although not all Target Zones are currently protected, they represent intact landscapes that connect to intact lands beyond the northwest extent of our study area. As such, maintenance of connectivity from CPNM to the northwestern zone is assumed to provide tule elk with important connectivity to areas beyond this zone.

Permeability ratings were provided by CDFG biologists most familiar with tule elk on the Carrizo Plain (R. Stafford and D. Hacker; Appendix B) and combined using the following Weighted Geometric Mean equation, which represents cost of movement (the inverse of permeability):

$(\text{Vegetation Score}^{0.50}) * (\text{Road Density Score}^{0.50}) = \text{Resistance}.$



Tule elk model inputs and the resulting resistance surface.

The equation reflects that elk movement will mostly be influenced by vegetation and density of paved roads and that the influence of these two factors should be relatively equal. Because tule elk use a wide range of elevation and topographical terrain types, relative to what is available in our study area, elevation and topographical position were not used as input factors into the permeability model.

5.1.4.3 San Joaquin Kit fox

Habitat Suitability: We determined habitat suitability for San Joaquin kit fox using methods similar to those developed by Cypher et al. (2007). This habitat suitability model was found to have good predictive power when compared to field data on fox distribution (B. Cypher, personal communication). The model, which was based on the Weighted Geometric Mean of vegetation type, topographic ruggedness, and vegetation density, reflects that kit foxes use gentle open terrain, primarily within grasslands and open scrub habitats, and that they select sparse versus dense grasslands (Section 4.3).

Habitat suitability ratings (from 0 to 1, with 1 being most suitable and 0 being unsuitable) for individual vegetation classes in the study area were provided by kit fox expert, B. Cypher (personal communication; Appendix B). Suitability ratings shown in Appendix B were further refined as follows:

- Dryland grain crops within 1 km (0.62 mi) of suitable natural habitat areas (suitability $\geq$ 0.5) were rated as 0.4; but dryland grain crops more than this distance from suitable natural habitat were rated as shown in Appendix B, based on observations that kit fox will occasionally forage in such fields in proximity to suitable natural lands (Warrick et al. 2007, B. Cypher, personal communication).
- Irrigated row and field crops within 1 km (0.62 mi) of suitable natural habitat areas (suitability $\geq$ 0.5) were rated as 0.3; but irrigated row and field crops more than this distance from suitable natural habitat were rated as shown in Appendix B, based on observations that kit fox will occasionally forage in such fields in proximity to suitable natural lands (Warrick et al. 2007, B. Cypher, personal communication).

In addition to vegetation community classes, the model weighted suitability of natural lands by terrain ruggedness (Valentine et. al. 2004, Cypher et al. 2007). Research on kit foxes at Naval Petroleum Reserves in California has shown terrain ruggedness as a “consistent factor that affected capture rates of kit foxes,” with foxes most abundant in areas of low topographic ruggedness (Warrick and Cypher 1998). Terrain ruggedness was classified using a 30-m digital elevation model and classifying areas as rugged according to elevation differences between each grid cell and its neighboring cells. The resulting values were then reclassed into four classes with values of 0 to 1 with high values (lowest ruggedness) being the most suitable.

The model used reflectance data based on satellite imagery in the form of a Normalized Difference Vegetation Index [NDVI] as an index of vegetation density. The NDVI was derived from remote sensing imagery that compares visible and near infrared radiation to estimate “greenness” or vegetation density relative to bare ground. Each cell was assigned a value based on a composite dataset of mean values from 2001-2006. NDVI values were then reclassed to suitability values ranging from 0 to 1 with high values being most suitable, using known locations of kit fox to guide classification (Cypher et al. 2007, S. Phillips, California State University, Stanislaus, personal communication).

Although San Joaquin kit fox distribution may be influenced by elevation, we assumed that inclusion of vegetation type and terrain ruggedness in the suitability model would likely account for elevational influences.

Habitat suitability was calculated for each 30-m^2 pixel in the study area using the following weighting equation, based on expert opinion (B. Cypher, personal communication):

(Vegetation Score $^{.50}$) * (Terrain Ruggedness Score $^{.25}$) * (Vegetation Density Score $^{.25}$) = Habitat Suitability.

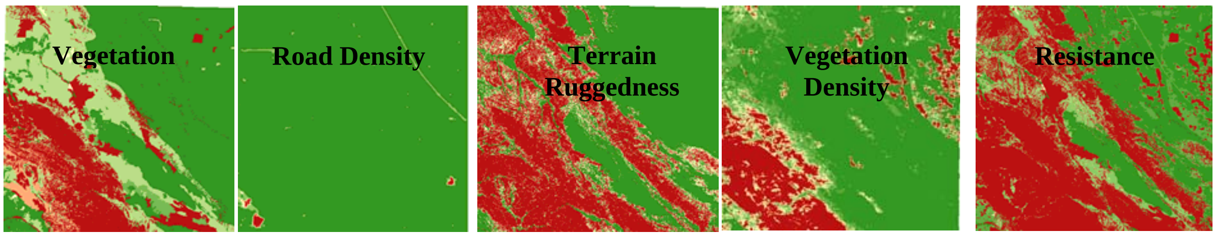
We divided the resulting suitability values into five classes (low, low to medium, medium, medium to high, and high) using quantile classification, to better reflect the nuances in the intensity of land uses in the study area than would be possible with fewer classes.

Habitat Patches and Cores: Potential Habitat Patches and Core Areas were identified as contiguous polygons of medium to high suitability habitat meeting the following size criteria. Minimum patch size (defined as the area of suitable habitat capable of supporting at least two individuals) was estimated as 486 ha, based on the estimate that this area could support one kit fox family in optimal habitat (Cypher et al. 2007). Core areas (defined as areas potentially supporting 50 or more individuals) were estimated to be ≥ 12,150 ha (family area x 25). Thus, patch size was defined as ≥ 486 ha but < 12,150, and core areas were defined as ≥ 12,150 ha. Any suitable habitat < 486 ha was defined as less than a patch; these areas may serve as stepping stones between potential patches and core areas. Dispersal distance was defined as 192 km for the patch configuration analysis for kit fox.

Landscape Permeability: For the landscape permeability analysis, we identified areas to be connected as habitat of medium to high suitability on the Carrizo Plain side of the Temblor Range within the Target Zone in the southeastern portion of the study area (CPNM, Carrizo Plain Ecological Reserve, Bureau of Land Management parcels contiguous with the National Monument and Ecological Reserve, and small portion of the Bittercreek National Wildlife Refuge), and medium to high suitability habitat within the three Target Zones in the northwestern portion of the study area, generally north of the westernmost extent of State Route 46 and west of State Route 33. These Target Zones were selected to represent large intact landscapes that included important habitat for kit fox (i.e., Salinas River Watershed, Palo Prieto-Cholame Valley, and Western Kern County in the vicinity of the Antelope Plain) and that should remain connected to the Carrizo Plain Natural Area to assure long-term population viability. The Target Zone in the southeast is known to support kit foxes, and their distribution is known to extend from this area northwest beyond the State Route 46-State Route 41 intersection. Although the Target Zones in the northwestern portion of the study area are not currently protected (with the exception of the Palo Prieto Conservation Bank), they represent large intact landscapes that connect to intact lands beyond the study area. As such, maintenance of connectivity from CPNM to the northern zones is assumed to provide kit foxes with important connectivity to areas beyond this zone.

Permeability ratings were provided by kit fox expert, B. Cypher (personal communication; Appendix B) and combined using the following Weighted Geometric Mean equation, which represents cost of movement (the inverse of permeability):

(Vegetation Score $^{.40}$) * (Road Density Score $^{.05}$) * (Terrain Ruggedness Score $^{.50}$) * (Vegetation Density Score $^{.05}$) = Resistance.



Kit fox model inputs and resulting resistance surface.

This equation reflects that kit foxes use areas of gentle terrain in open vegetation associations, and that they tend to avoid densely vegetated areas. This model also reflects that increased road density may reduce permeability, but that terrain ruggedness and vegetation are probably more influential than roads on kit fox movements.

Three analyses were run from the southern Target Zone to each of the three northern Target Zones. The results of each analysis were then overlaid to create a union of the three least-cost corridors for kit fox.

6.1 Baseline conditions of habitat suitability and connectivity for each focal species

6.1.1 Habitat Suitability

6.1.1.1 Pronghorn antelope

Suitable habitat for pronghorn antelope in the study area is largely restricted to open, forb-rich vegetation communities on gentle terrain. The model identified abundant medium to high suitable habitat on both sides of the Temblor Range (Figure 4). The most extensive areas of highly suitable habitat are in the open grasslands and alkali desert scrub habitats on the floor of the Carrizo Plain and San Joaquin Valley and Antelope Plain. Modeled high-value habitat corresponds well with the distribution of sightings in the Carrizo Plain, Cholame Valley, and Navajo and San Juan Creeks with 94% of the recorded occurrences in medium-high and high suitability classes. Some agricultural lands were also identified as medium to high suitability. Highly roaded portions in the community of California Valley which would otherwise be modeled as high-value habitat, appear as medium-high. Habitat for pronghorn antelope generally becomes unsuitable southwest of the La Panza Range in the southwestern portion of the study area and unsuitable in the dense agriculture lands on the San Joaquin Valley floor and in the Santa Maria Valley in the southwestern portion of the study area.

Pronghorn antelope recorded occurrences by habitat suitability class within study area.

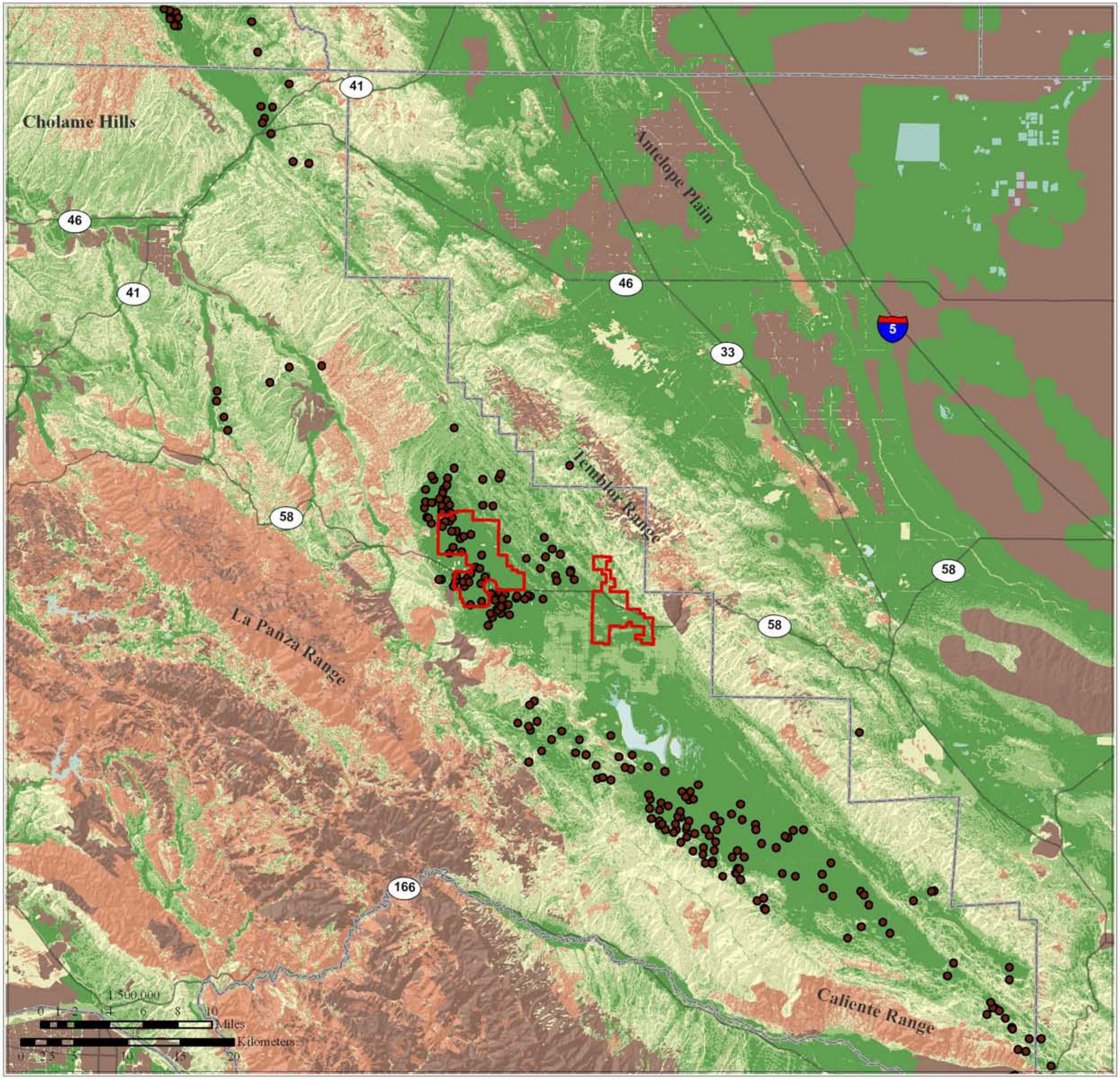
Suitability Class	*Recorded Occurrences*
Low suitability	3
Low-Medium suitability	2
Medium suitability	11
Medium-High suitability	65
High suitability	195
Total Occurrences in Study Area	276

The patch size analysis delineated core areas of medium-high and high-suitability habitat in the Carrizo Plain proper; in the Cholame Valley and Navajo and San Juan Creeks drainages; and in the San Joaquin Valley and Antelope Plain. The core area for pronghorn in the Carrizo Plain proper ranges from about 10 to 20 km wide for roughly 77 km in length. One patch was delineated in the Cuyama Valley along the base of the Caliente Range, while several stepping stones of habitat (i.e., <Patch) were delineated throughout the study area (Figure 5). All potential core areas and habitat patches are within the species' dispersal distance (figure not shown), although barriers to movement may exist between areas of suitable habitat.

6.1.1.2 Tule elk

Suitable habitat for tule elk is widespread in the study area in grassland, meadow, scrub, brush, woodland, and riparian communities as well as some agricultural types, such as dryland grain crops and irrigated row and field crops. The most highly suitable habitat primarily follows the

Figure 4.
Habitat Suitability
for
Pronghorn antelope



Degree of Suitability
- High
- Med-High
- Med
- Low-Med
- Low
- Pronghorn Sightings
- Highways
- County Boundaries
- Hydrography
- Outer Project Boundaries

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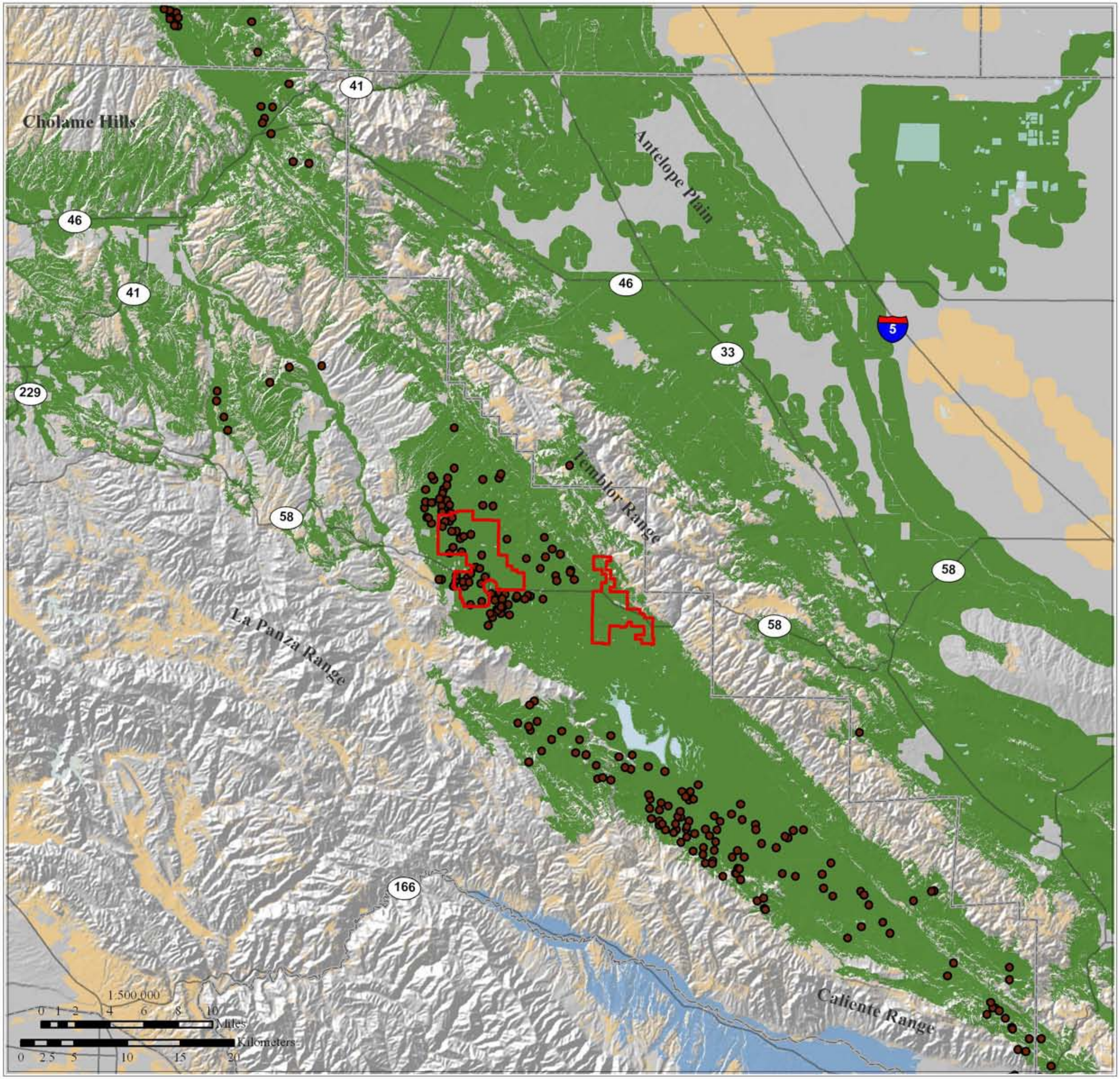
Figure 5.
Potential Cores & Patches for Pronghorn antelope



- Core
- Patch
- < Patch
- Pronghorn Sightings
- Highways
- County Boundaries
- Hydrography
- Outer Project Boundaries

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Avena-dominated annual grasslands and those irrigated row and field crops within 0.8 km of other natural habitats suitable (≥ 0.3) for tule elk (Figure 6). The majority of medium to high suitable habitat occurs between the La Panza Range and Interstate 5 and largely follows the *Bromus*-dominated grassland, coastal scrub, juniper, and dryland grain crop habitats. Other suitable habitats of note occur at the north end of the Caliente Range near Carrizo Canyon; at the base of the La Panza Range on the coastal side along the Salinas River; and along the Cuyama River, Alamo Creek, Nipomo Valley, and Canyon de los Alisos in the southwestern portion of the study area. Areas of medium-high and high suitability habitat are consistent with telemetry and flight sightings of tule elk subherds in the Cholame Valley, California Valley, Carneros Rocks, American, and to a lesser extent South Chimineas, with 77% of recorded occurrences occurring in the top two suitability classes. Chaparral, montane hardwood and conifer habitats are less suitable for tule elk, as are orchards, vineyards, and dense irrigated agriculture beyond 0.8 km of other suitable natural habitats. Paved roads and habitats in the immediate vicinity of these roads were considered unsuitable for tule elk and appear to restrict some herd ranges on the Carrizo Plain, which is evident in the road-constrained distribution of telemetry points on Figure 6. However, recently telemetry data detected one bull from the South Chimineas subherd traveling to Carneros Rocks and back, crossing SR-58 twice (CDFG, personal communication).

Tule elk recorded occurrences by habitat suitability class within study area.

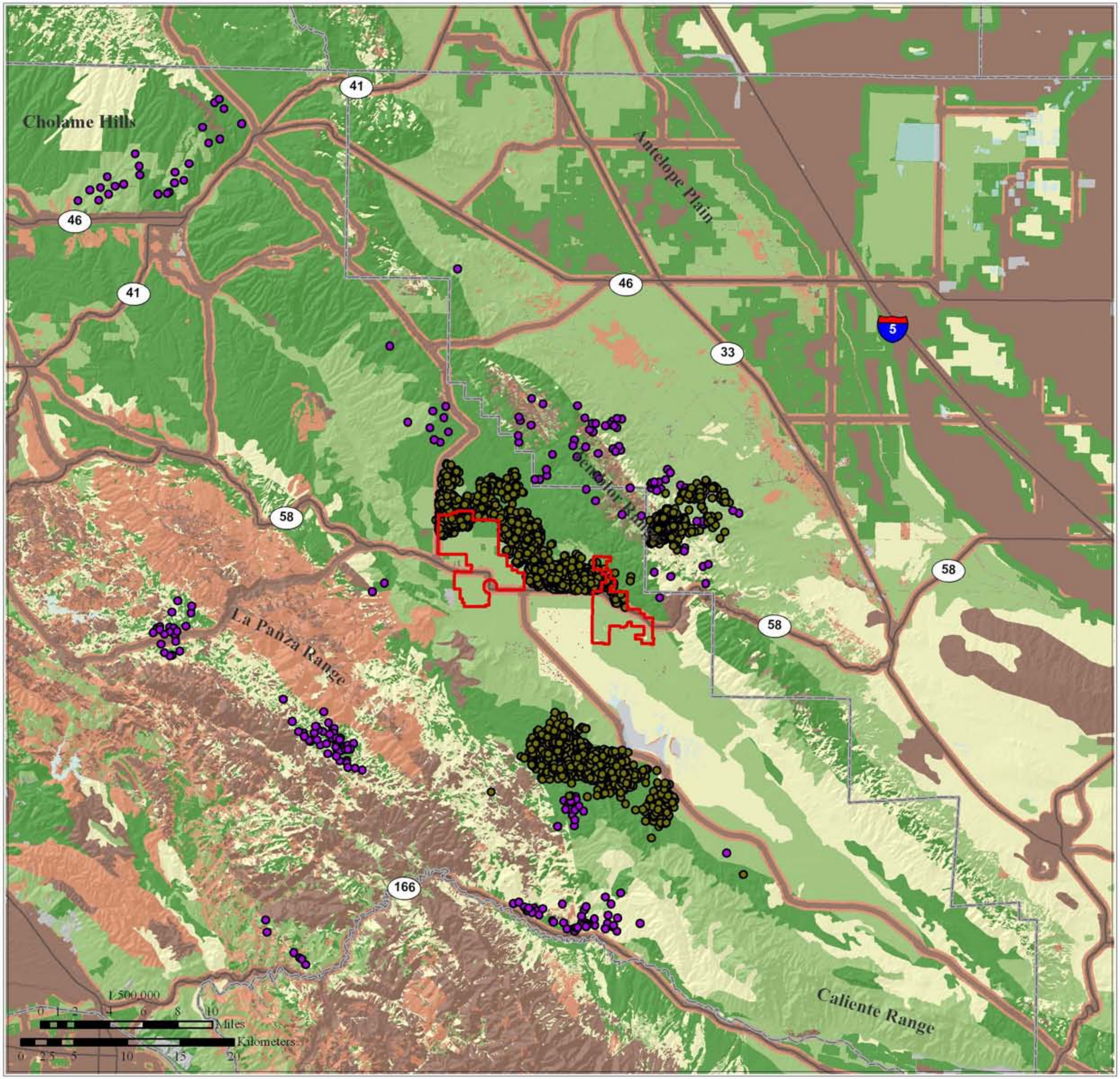
Suitability Class	*Recorded Occurrences*
Low suitability	514
Low-Medium suitability	416
Medium suitability	289
Medium-High suitability	2143
High suitability	2050
Total Occurrences in Study Area	5412

The patch size analysis identified two potential core areas separated by State Route 58 within the analysis extent. The northern core area is generally bound on the north and west by State Route 46 and Bitterwater Valley Road, on the east by State Route 33, and on the south by State Route 58; it is roughly 10 to 30 km wide and 20 to 30 km long. The southern core area is bounded on the west by the La Panza Range, on the east by Soda Lake Road, on the south by State Route 166, and on the north by State Route 58 (Figure 7); it is roughly 5 to 15 km wide and about 80 km long. Lands northwest of the State Route 46 and 41 intersection, currently identified as a patch, would also be considered a potential core area if the analysis window extended beyond the study area (R. Stafford, personal communication). Other significant patches occur between State Route 58 and Interstate 5, between State Route 58 and Soda Lake Road, and south of State Route 166, which would have been contiguous with the core areas if not for the paved roads that fragment these suitable habitat areas. Additional patches were delineated to the southwest of the La Panza Range and to the east of Interstate 5. All potential core areas and habitat patches are within the species' dispersal distance (figure not shown), although barriers to movement may exist between areas of suitable habitat.

6.1.1.3 San Joaquin kit fox

Suitable habitat for kit fox in the study area is somewhat limited, being primarily restricted to grassland and scrub habitats in gentle terrain on valley floors. The most highly suitable habitat largely follows the drier, *Bromus*-dominated annual grassland and alkali desert scrub habitats in

Figure 6.
Habitat Suitability
for
Tule elk



Degree of Suitability
- High
- Med-High
- Med
- Low-Med
- Low
- Collared Sightings
- Flight Sightings
- Highways
- County Boundaries
- Hydrography
- Outer Project Boundaries

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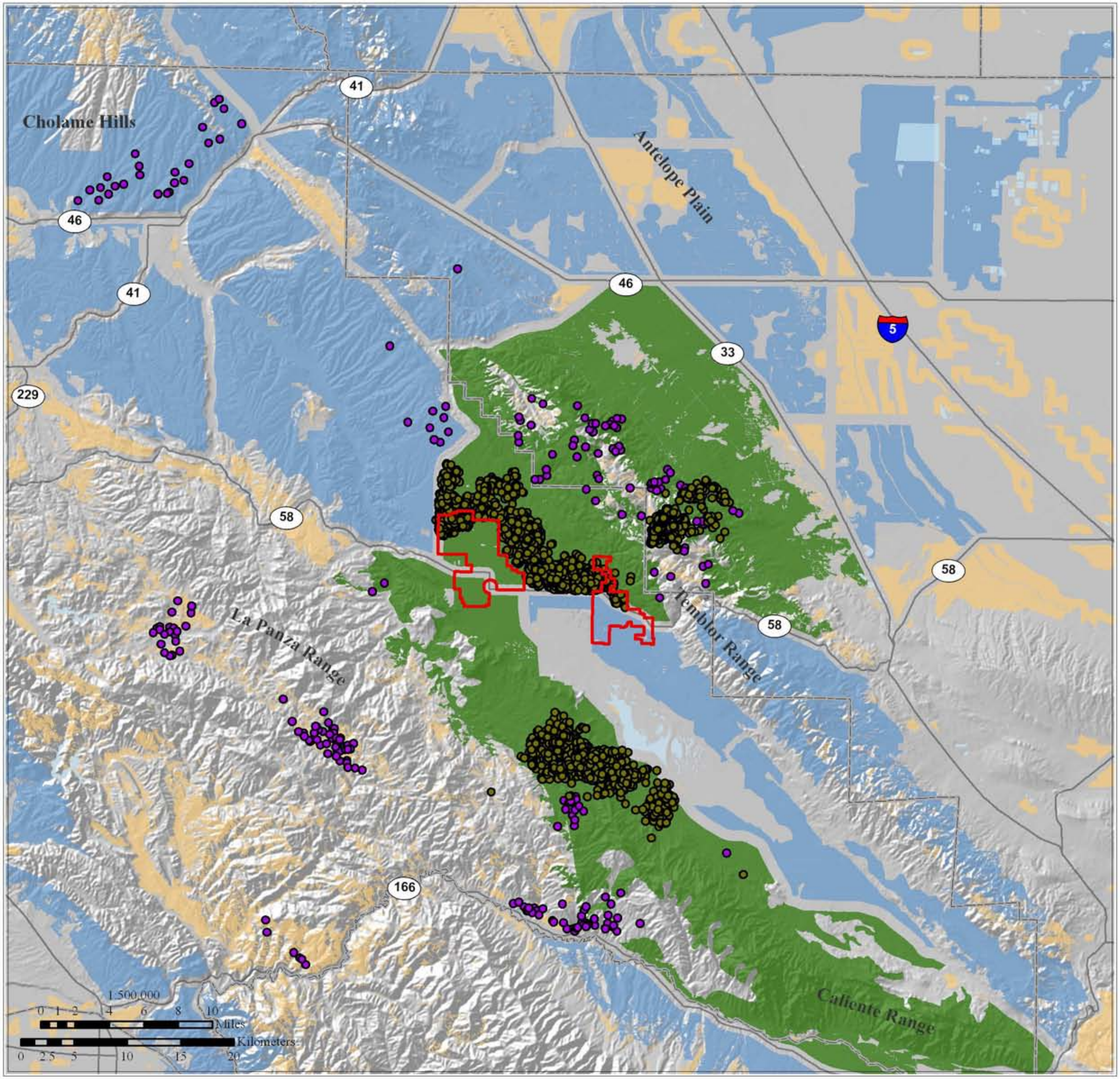
Figure 7.
Potential Cores & Patches
for
Tule elk

Core
Patch
< Patch
Collared Sightings
Flight Sightings
Highways
County Boundaries
Hydrography
Outer Project Boundaries



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the Carrizo Plain and on the San Joaquin Valley side of the Temblor Range (Figure 8). Areas identified as medium to high suitability for kit fox are primarily *Avena*-dominated grassland and alkali desert scrub habitats with low topographic ruggedness. These habitats generally occur on the lower slopes and at the base of Temblor Range, around the base of the Caliente Range, straddling State Route 58 in the Carrizo Plain, in the Cholame Valley, and in scattered patches on gentle terrain between State Routes 58 and 46. Kit fox occurrences had a high correspondence with these habitats, with 91% found in areas of medium-high and high habitat classes. Areas identified as medium suitability for kit fox are largely restricted to dryland grain crops and irrigated row and field crops within a kilometer of contiguous suitable natural habitat areas (suitability ≥ 0.5). These areas occur in Shandon, Camatta Canyon, San Juan Valley, straddling SR-58 primarily west of Simmler Bitterwater Road, Cuyama Valley, and in the northeastern part of the study area generally north of SR-46 and east of SR-33. These areas are used for foraging by kit fox, with specific patterns determined by annual variation in crop phenology as well as tilling and fallowing activities (Brian Cypher, personal communication). If fields are tilled every year, they are typically not used for denning, but if left fallow for a year or two then dens can more easily become established. All other portions of the study area were considered largely unsuitable for kit fox.

San Joaquin kit fox recorded occurrences by habitat suitability class within study area.

Suitability Class	*Recorded Occurrences*
Low suitability	144
Low -Medium suitability	188
Medium suitability	129
Medium-High Suitability	1754
High Suitability	2939
Total Occurrences in Study Area	5154

The majority of medium- to high-suitability habitat is in large enough continuous areas to serve as potential core areas for kit fox (Figure 9). These areas correspond well to recorded kit fox observations. The two largest contiguous core areas are in the Carrizo Plain and the Central Valley, separated by the Temblor Range. The core area in the Carrizo Plain ranges from 10 to 15 km wide for roughly 70 km. In the Central Valley, contiguous core habitat extends all along the base of the Temblor Range, from the Antelope Plain area to south of Lokern. Some significant patches of suitable habitat were also delineated in the Cuyama Valley. All potential core areas and habitat patches are within the species' dispersal distance (figure not shown), although barriers to movement may exist between areas of suitable habitat.

6.1.2 Habitat Permeability

6.1.2.1 Pronghorn antelope

The least-cost corridor for pronghorn antelope between the northern and southern Target Zones is roughly 70 km long and from 5 to 20 km wide using the most permeable 3% portion of the landscape (Figure 10). The least-cost corridor is much broader in the southern half of the corridor, where areas of high permeability span the width of the Carrizo Plain, than in northern half, which is more restricted by topography (Figure 10 inset). The most permeable path extends through highly suitable habitat (mostly *Avena*-dominated annual grassland and dryland grain

Figure 8.
Habitat Suitability
for
San Joaquin kit fox

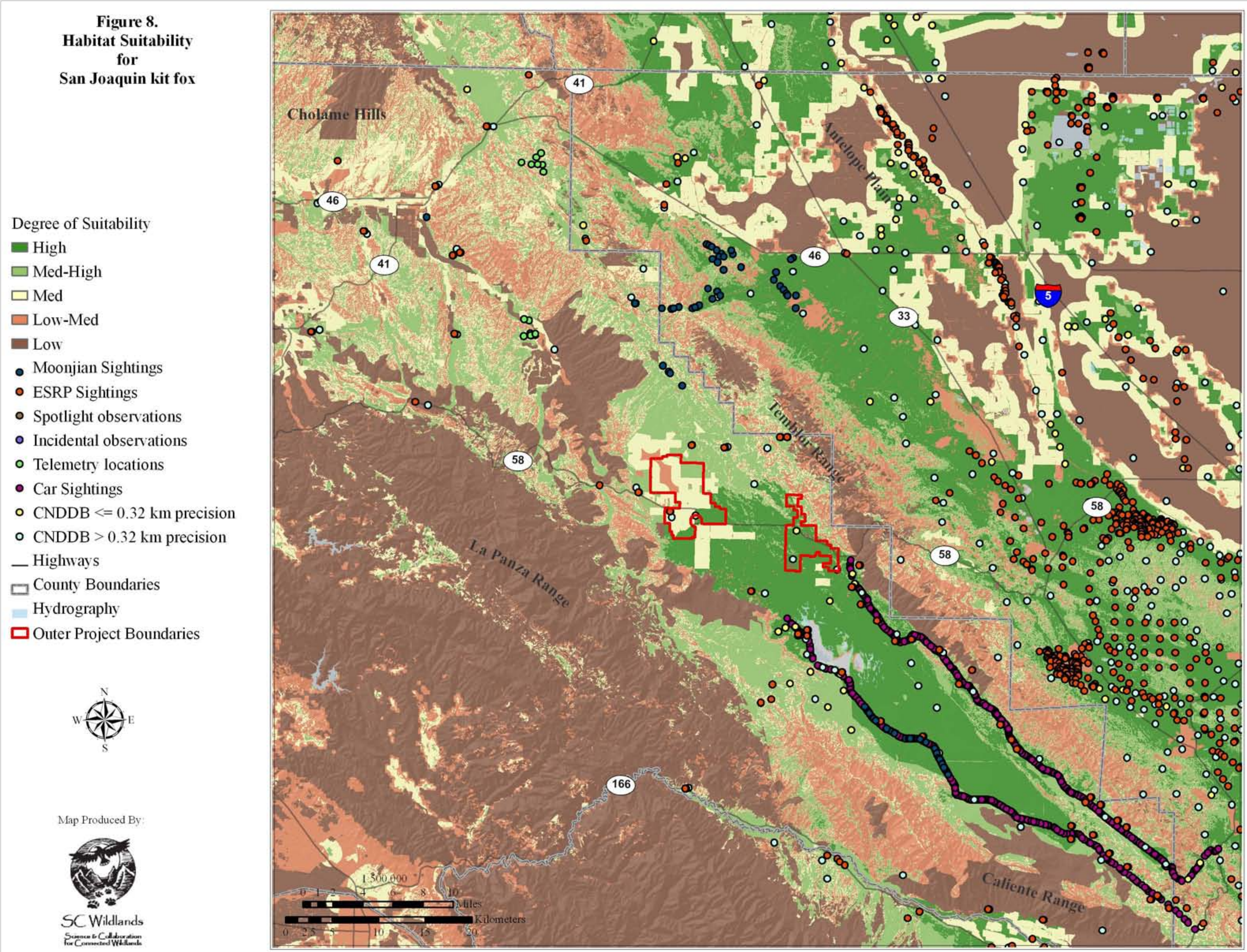
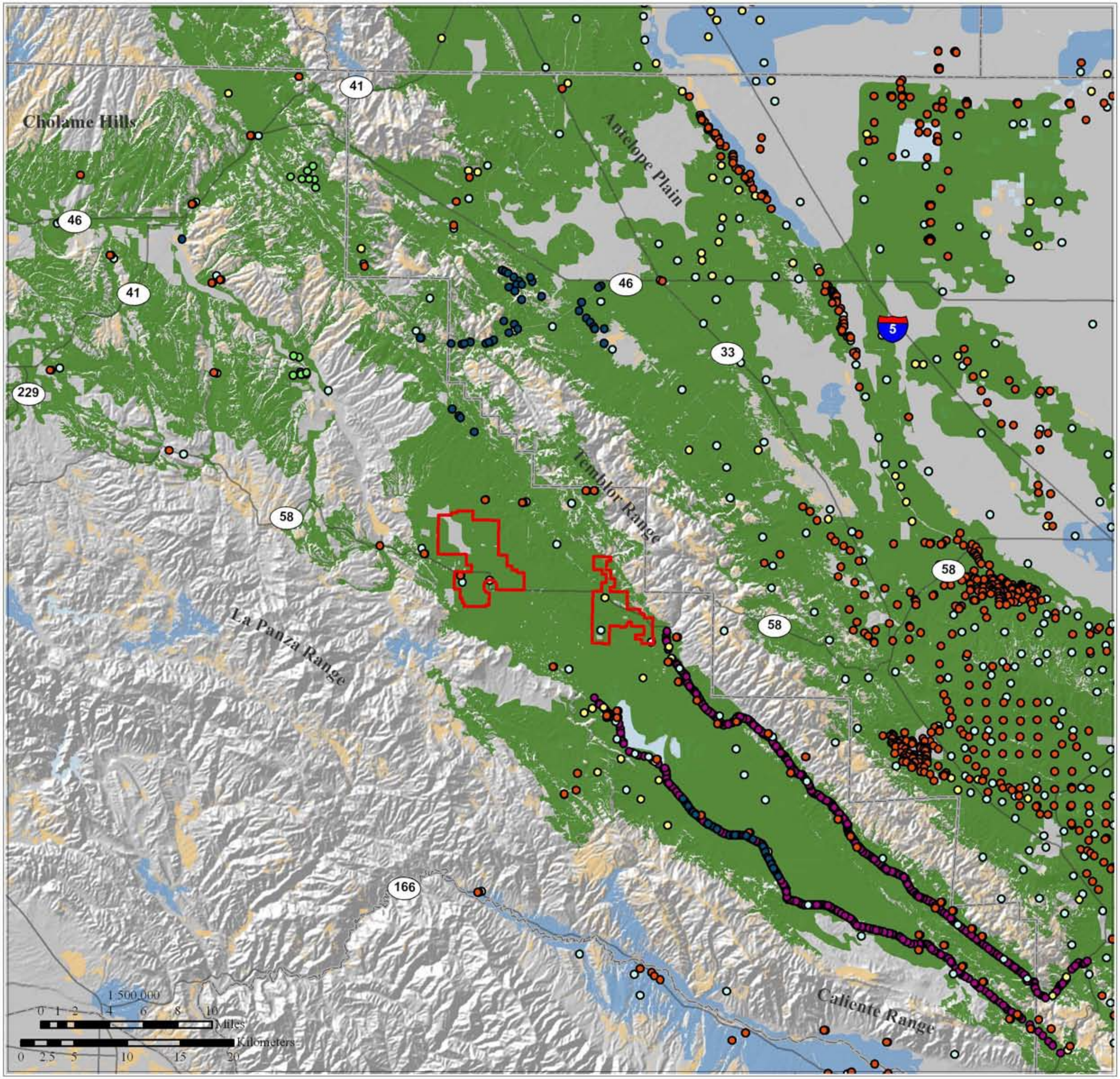


Figure 9.
Potential Cores & Patches
for
San Joaquin kit fox



- Core
- Patch
- < Patch
- Moonjian Sightings
- ESRP Sightings
- Spotlight observations
- Incidental observations
- Telemetry locations
- Car Sightings
- CNDDB <= 0.32 km precision
- CNDDB > 0.32 km precision
- Highways
- County Boundaries
- Hydrography
- Outer Project Boundaries

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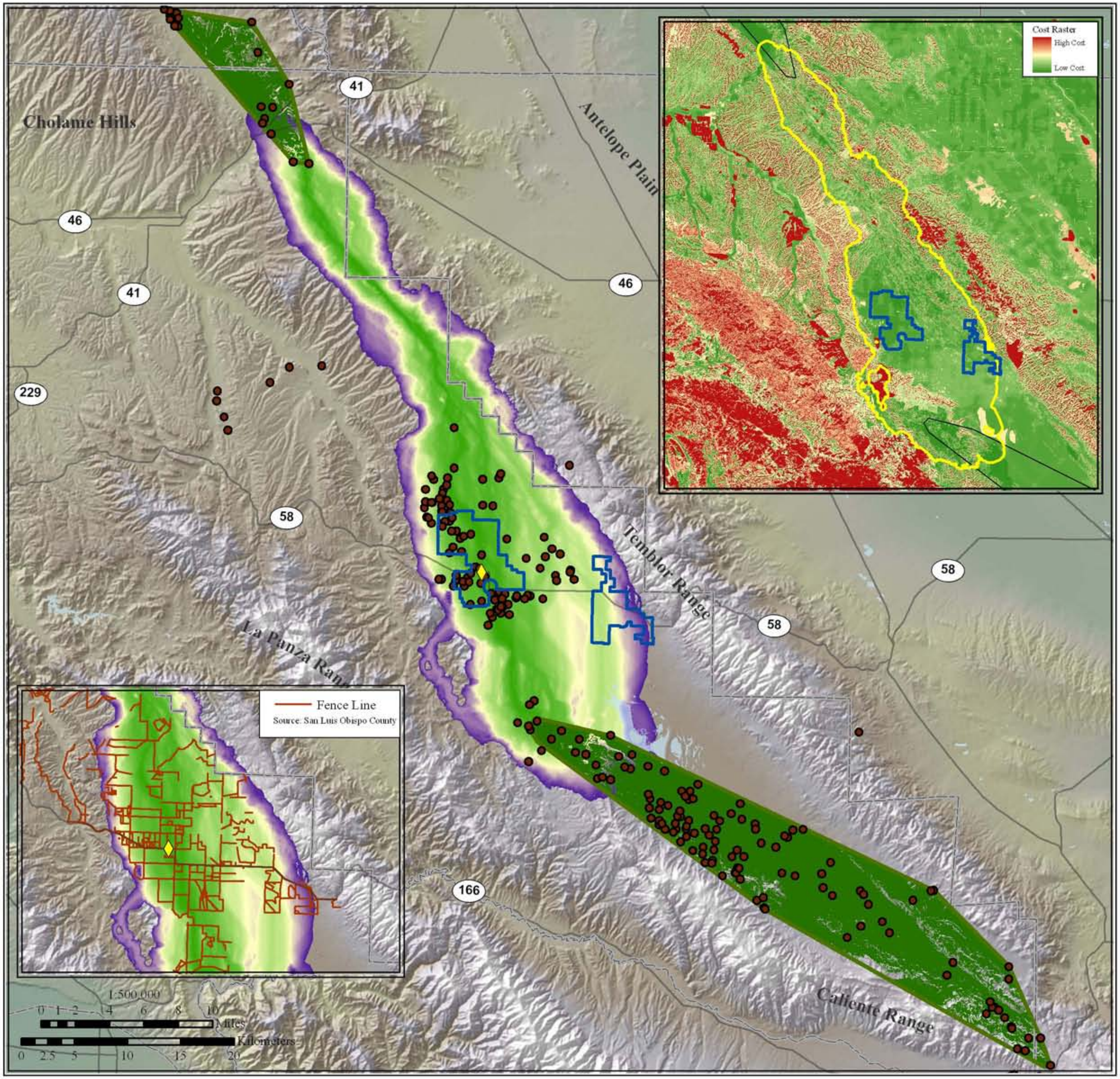
Figure 10. Landscape Permeability for Pronghorn antelope



Least-Cost Corridor* (3%)
Less Cost
More Cost
Target Zone
Suitable Habitat**
Pronghorn Sightings
Pronghorn Crossing
Highways
County Boundaries
Hydrography
Outer Project Boundaries

* Cumulative cost to movement

** This analysis was run from Medium-High to High Suitable Habitat within each Target Zone.

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crops on gentle terrain) between the southern and northern Target Zones. The most permeable path also corresponds to an observed herd crossing across SR-58, despite the fact that there are many fences through this area (Figure 10 inset). In the Carrizo Plain, fence types vary, but fence breaks are frequent enough to make barrier quality difficult to define with certainty. It is possible that pronghorn may be able to negotiate many of these fences, but without more details about their design (height, wire spacing, etc) it is difficult to draw firm conclusions. Ongoing efforts, such as those by CDFG and volunteers to make fences more "pronghorn-friendly" (by raising the bottom wires) and to remove old field fencing, should be continued and expanded.

6.1.2.2 Tule elk

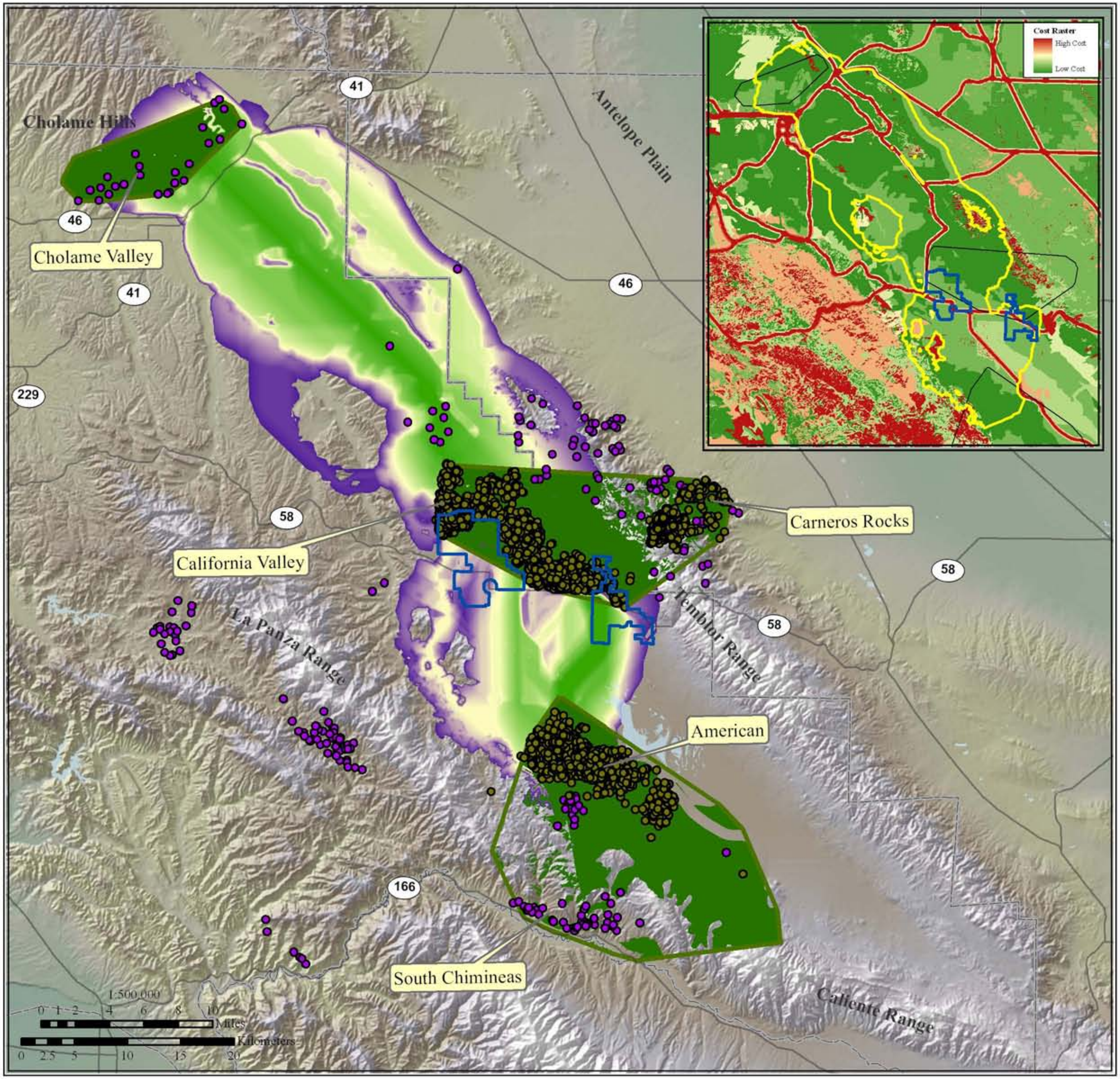
Using the 3% permeability threshold, the least-cost corridors for tule elk between the three Target Zones are roughly 20 km in wide, narrowing to approximately 15 km just north of the American subherd and northwest of the California Valley subherd (Figure 11). The least-cost corridor between the southern and central herds runs generally north-south, with the most permeable portions diverging to the west and east of Soda Lake Road to cross Highway 58. The least-cost corridor between the central and northern herds runs northwest-southeast with the most permeable swath west of Simmler Bitterwater Road, Annette Road, and Palo Prieta Cholame Road. The cost raster (Figure 11 insert) shows that the two least-cost corridors and the California Valley/Carneros Rocks MCP take in the majority of low-cost pixels between the La Panza and Temblor ranges, though there is roughly 3 to 5 km of additional low-cost pixels to the west of the least-cost corridor along State Route 58. A secondary route of moderate permeability follows highly suitable habitat to the east of Simmler Bitterwater Road at the north end of the Temblor Range. There are narrow (2-3 km), less permeable branches associated with each of the least-cost corridors on the west side of the major corridors. Another short, narrow swath of lesser permeability extends northwest from the Carneros Rocks subherd on the east side of the Temblor Range.

6.1.2.3 San Joaquin kit fox

Three Target Zones were identified at the northern extent of the study area (Salinas River Watershed, Palo Prieto-Cholame Valley, and Western Kern County near Antelope Plain) that should remain connected to the Carrizo Plain Natural Area to assure long-term population viability and to better reflect the goals outlined in the recovery plan for this species (USFWS 1998).

The least-cost corridor for kit fox between the northern Target Zone in Western Kern County in the vicinity of the Antelope Plain and the southern Target Zone ranges in width from approximately 8 to 28 km using the most permeable 3% portion of the landscape (Figure 12). The most permeable route follows the alkali desert scrub north out of the Carrizo Plain National Monument in the southern Target Zone and then heads in a northwesterly direction through alkali desert scrub, dryland grain crops, and *Bromus* and *Avena*-dominated grassland. About 5 km north of State Route 58 it starts to head almost due north and then heads east to follow the Bitterwater Creek drainage (approximately the same route as Bitterwater Valley Road) to *Bromus*-dominated grasslands in the Shale Hills and Antelope Valley to reach the Western Kern County Target Zone. The identified route is at its narrowest while following Bitterwater Creek

Figure 11.
Landscape Permeability
for
Tule elk



Least-Cost Corridor* (3%)

- Less Cost
- More Cost
- Target Zone
- Medium-High Suitable Habitat**
- Collared Sightings
- Flight Sightings
- Highways
- County Boundaries
- Hydrography
- Outer Project Boundaries

* Cumulative cost to movement

** This analysis was run from Medium-High to High Suitable Habitat within each Target Zone.

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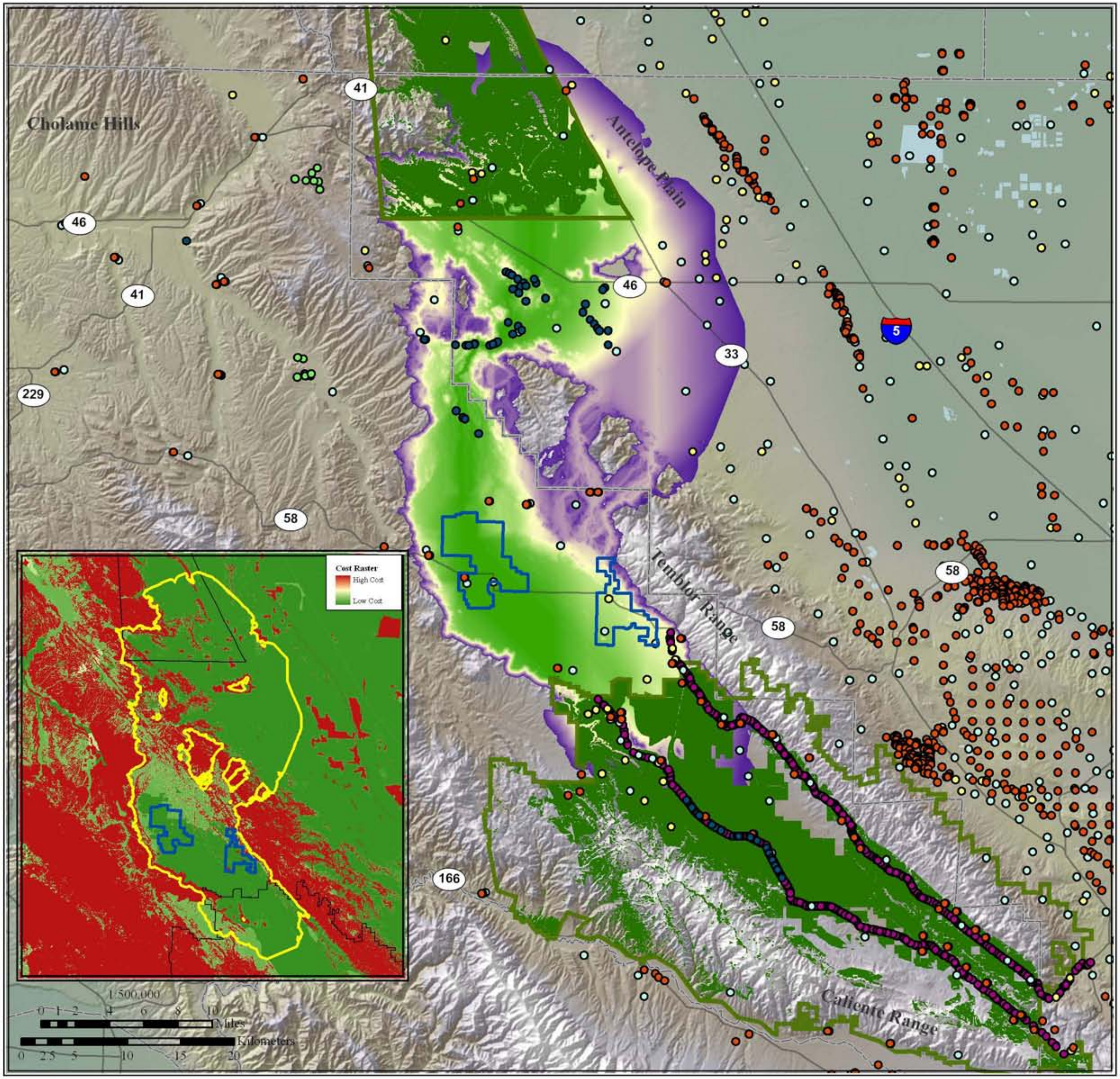
Figure 12.
Landscape Permeability for San Joaquin kit fox between the Southern Target Zone and the Northern Target Zone in Western Kern County

Least-Cost Corridor* (3%):
- Less Cost
- More Cost
- Target Zone
- Medium-High Suitable Habitat**
- Moonjian Sightings
- ESRP Sightings
- Spotlight observations
- Incidental observations
- Telemetry locations
- Car Sightings
- CNDDB <= 0.32 km precision
- CNDDB > 0.32 km precision
- Highways
- County Boundaries
- Hydrography
- Outer Project Boundaries

* Cumulative cost to movement

** This analysis was run from Medium to High Suitable Habitat within each Target Zone.



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through the Temblor Range. This route aligns closely with the kit fox experts' belief that a significant interchange between the Carrizo Plain and the San Joaquin Valley would likely occur along Bitterwater Creek and Route 46 (B. Cypher, personal communication). A slightly less permeable route over the Temblor Range is located in the Francisco Creek drainage (roughly 8 km northwest of the Bitterwater Creek route). Another less permeable route diverges from the primary route just north of Route 58, crosses the Temblor Range in the vicinity of Media Agua and Santos Creeks, and reconnects with the primary route near Route 46. Although these secondary routes are relatively low-cost, they would require foxes to negotiate some areas of extremely rugged terrain that coincide with dense shrub and woodland communities.

The least-cost corridor for kit fox between the northern Target Zone in the Palo Prieto-Cholame Valley and the southern Target Zone ranges in width from approximately 9 to 25 km using the most permeable 3% portion of the landscape (Figure 13). The most permeable route closely follows the results of the analysis to the northern Target Zone in Western Kern County, but the least-cost corridor forks with one path following Bitterwater Valley Road to *Bromus*-dominated grasslands in the Shale Hills and Antelope Valley and another highly permeable route following the Francisco Creek drainage, and another highly permeable pathway following Palo Prieto Pass through *Avena*-dominated grassland to reach the Palo Prieto-Cholame Valley Target Zone.

The least-cost corridor for kit fox between the northern Target Zone in the Salinas River Watershed and the southern Target Zone ranges in width from approximately 1.5 to 15 km using the most permeable 3% portion of the landscape (Figure 14). The most permeable route follows the alkali desert scrub habitat out of the southern Target Zone and then meanders along State Route 58 through *Avena*-dominated grassland and dryland grain crops, taking Navajo Creek up to the San Juan Valley to reach the Salinas River Watershed Target Zone. About halfway up Navajo Creek, two moderately permeable branches take in upper San Juan Creek and Camatta Canyon. A slightly less permeable route heads due north from State Route 58 and then follows Palo Prieto Pass to Cholame Creek to reach the Target Zone.

Figure 15 displays the union of the results of the least-cost corridor analyses for kit fox.

6.2 Discussion

6.2.1. Pronghorn antelope

The majority of the Carrizo Plain region was found to be highly suitable as pronghorn antelope habitat, as was Cholame Valley and portions of the San Joaquin Valley (Figure 4). These areas were delineated as core areas and all but the San Joaquin Valley are currently occupied by the species (Figure 5). Permeability was assessed between two subherds, one in Cholame Valley and the other in the southern portion of the Carrizo Plain (Figure 10). If future re-colonization of the San Joaquin Valley occurs or range expansion to this area becomes a management goal, it would be appropriate to analyze connectivity to these potential cores as well. Until such an expansion of management activity occurs, the target zones and least-cost corridor identified here overlap the three known pronghorn subherds and the vast majority of pronghorn occurrence points that have been recorded between the subherds in the Cholame Valley and the Carrizo Plain Monument.

Figure 13.
Landscape Permeability for San Joaquin kit fox between the Southern Target Zone and the Northern Target Zone in Palo Priteto-Cholame Valley

Least-Cost Corridor* (3%)
- Less Cost
- More Cost
- Target Zone
- Medium-High Suitable Habitat**
- Moonjian Sightings
- ESRP Sightings
- Spotlight observations
- Incidental observations
- Telemetry locations
- Car Sightings
- CNDDB <= 0.32 km precision
- CNDDB > 0.32 km precision
- Highways
- County Boundaries
- Hydrography
- Outer Project Boundaries

* Cumulative cost to movement

** This analysis was run from Medium to High Suitable Habitat within each Target Zone.

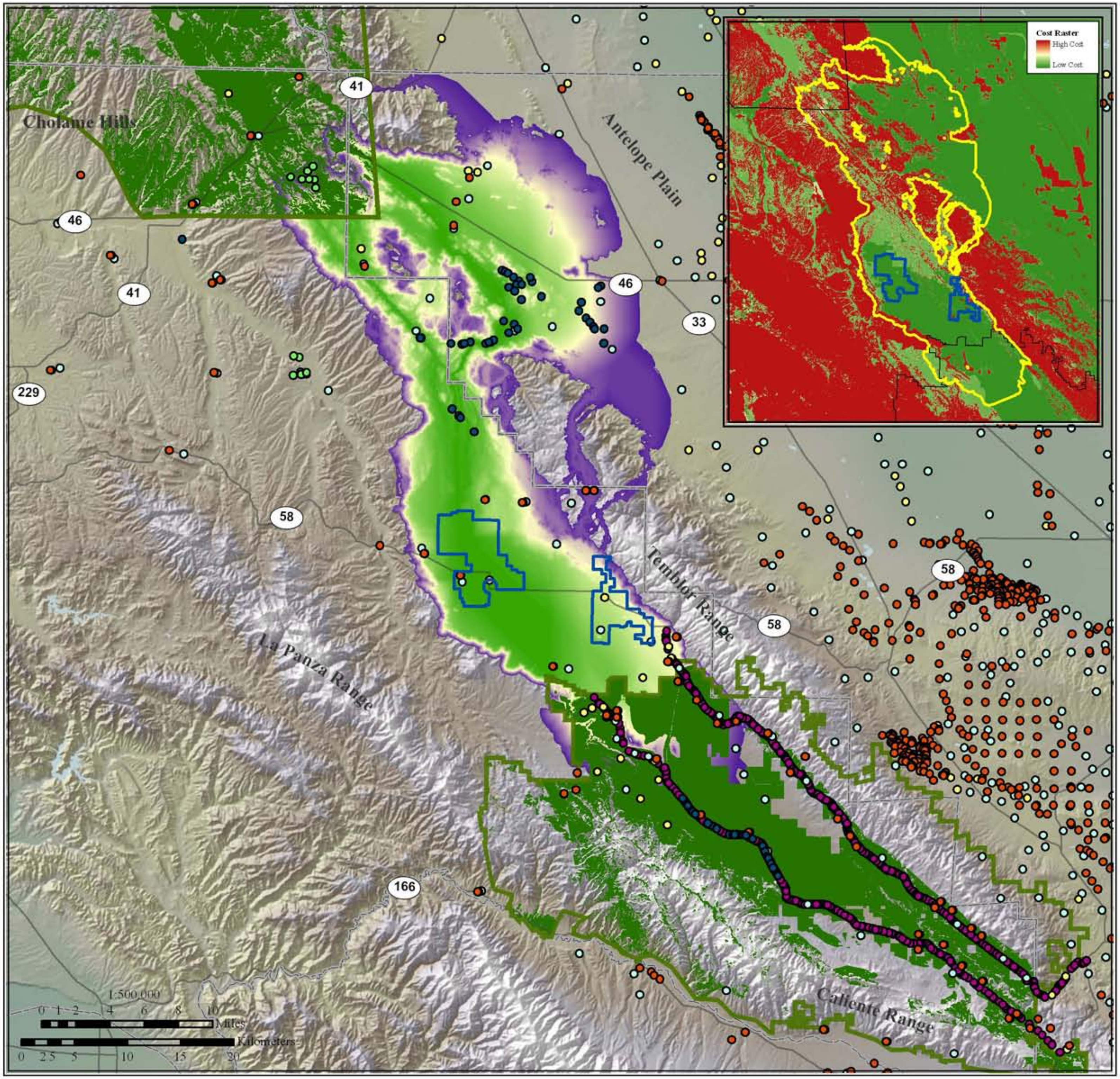

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Figure 14.
Landscape Permeability for San Joaquin kit fox between the Southern Target Zone and the Northern Target Zone in Salinas River Watershed

Least-Cost Corridor* (3%):
- Less Cost
- More Cost
- Target Zone
- Medium-High Suitable Habitat**
- Moonjian Sightings
- ESRP Sightings
- Spotlight observations
- Incidental observations
- Telemetry locations
- Car Sightings
- CNDDB <= 0.32 km precision
- CNDDB > 0.32 km precision
- Highways
- County Boundaries
- Hydrography

* Cumulative cost to movement

** This analysis was run from Medium to High Suitable Habitat within each Target Zone.

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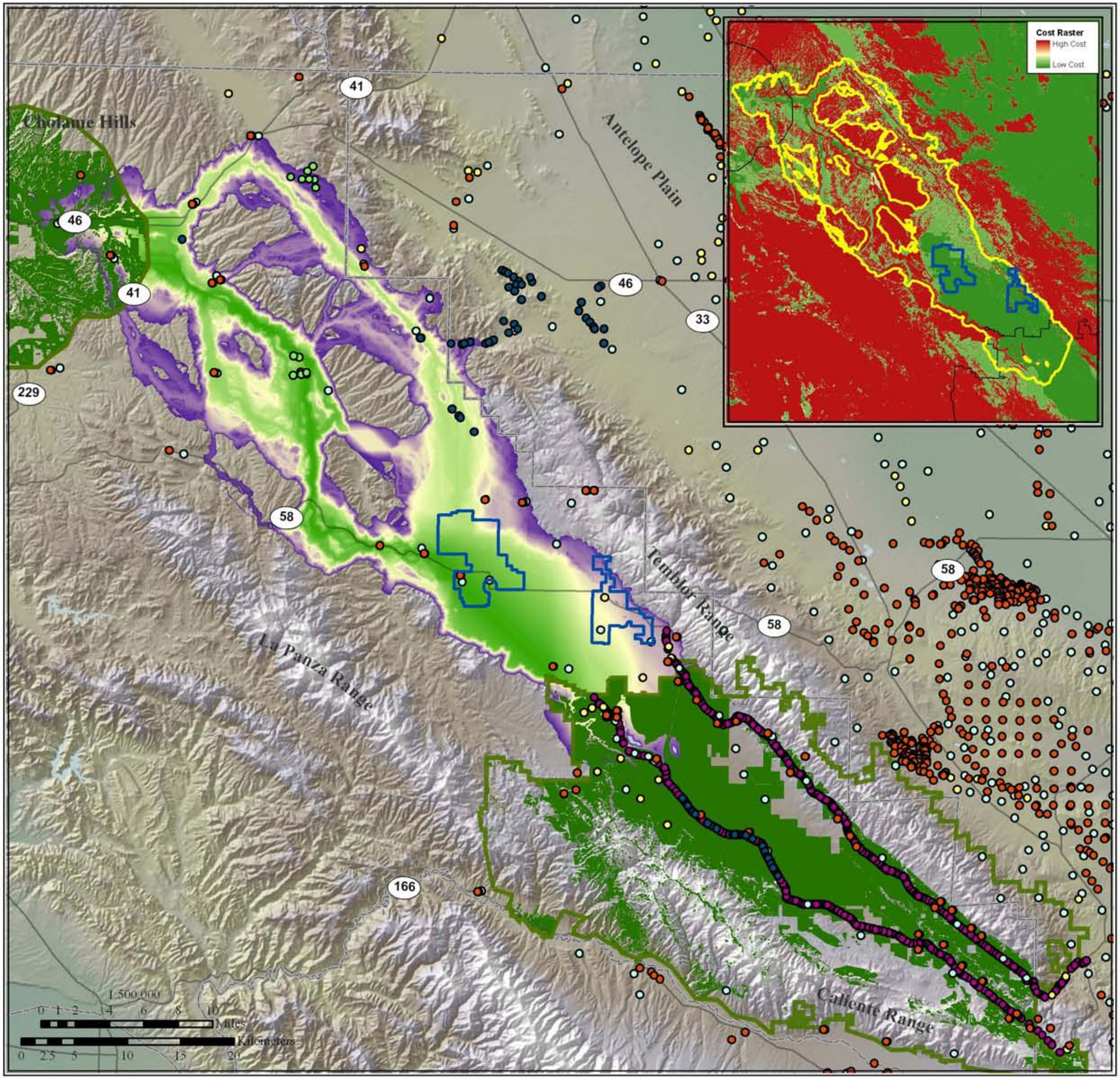
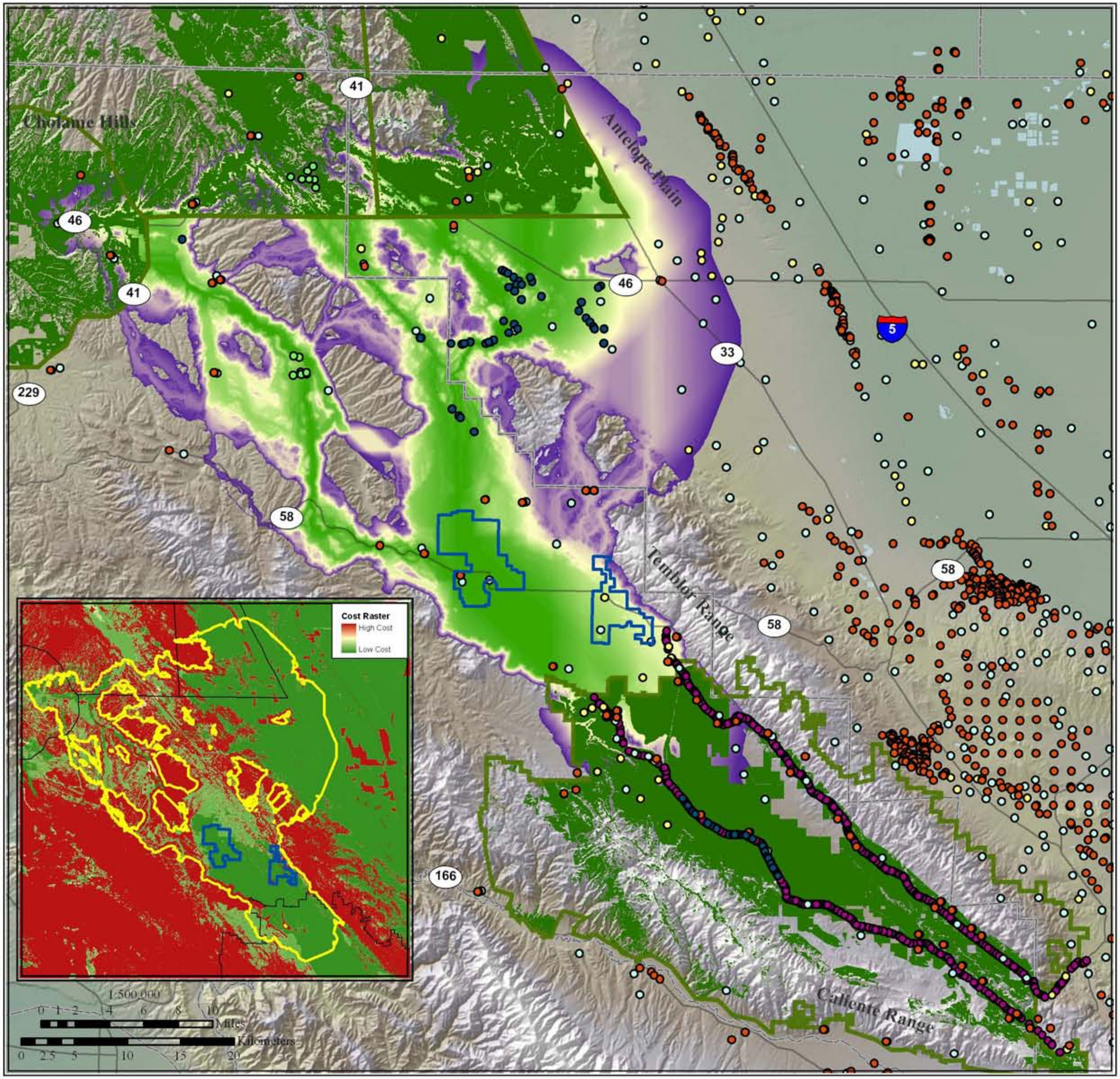


Figure 15.
Union Displaying Overlap of Three Least Cost Corridors for San Joaquin kit fox (Fig. 12, 13, & 14)



Least-Cost Corridors*
- Less Cost
- More Cost
- Target Zone
- Medium-High Suitable Habitat**
- Moonjian Sightings
- ESRP Sightings
- Spotlight observations
- Incidental observations
- Telemetry locations
- Car Sightings
- CNDDB <= 0.32 km precision
- CNDDB > 0.32 km precision
- Highways
- County Boundaries
- Hydrography
- Outer Project Boundaries

* Cumulative cost to movement

** These analyses were run from Medium to High Suitable Habitat within each Target Zone.

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The proposed solar project footprints generally overlap areas of modeled to be highly suitable habitat and highly permeable to movements of pronghorn. The Topaz project, as proposed, is centrally located within the range of a pronghorn antelope subherd, and the majority of habitat within the project footprint was identified as highly suitable core habitat (Figures 4, 5). If the Topaz Solar Farm is implemented, there will likely be a substantial reduction in available habitat for pronghorn in this portion of the Carrizo Plain and the subherd that currently utilizes the Topaz site would be displaced. The majority of the SunPower site is comprised of modeled as high and medium-high suitability core habitat, although no occurrence points fall within its boundary (Figures 4, 5).

Pronghorn habitat suitability within the overall project boundaries of the proposed solar facilities.						
	Both Projects		*Topaz*		*Sun Power*	
Suitability Class	acres	hectares	acres	hectares	acres	hectares
Low	0	0	0	0	0	0
Low-Medium	8	3	0	0	8	3
Medium	214	87	47	19	167	68
Medium-High	1550	627	197	80	1353	547
High	13476	5454	9775	3956	3702	1498
Total Area	15249	6171	10019	4054	5230	2117

Using the 3% permeability threshold, the least-cost corridor for pronghorn antelope is widest (roughly 20 km wide) in the south (Figure 10) and takes in the full width of the low cost pixels (Figure 10 insert) in this part of the Carrizo Plain where the two solar projects are proposed. The entire Topaz site is located in an area of highest permeability for the pronghorn, and the majority of recorded occurrences that occur in the most permeable areas are either within the project footprint or in clusters to the northwest and southeast of the project boundary (Figure 10). Implementation of the Topaz Solar Farm alone would reduce the width of the least-cost corridor from 20 km to approximately 9.7 km wide on the east and a 1.9 km choke-point on the west. Thus, in addition to displacing the subherd that currently utilizes habitat within the Topaz Solar Farm footprint, the project would force individuals to move around the site to the east or west and would likely reduce the potential for connectivity between subherds in the Carrizo Plain and Cholame Valley and beyond. While the great majority of the SunPower site is included in the least-cost corridor and is thus relatively permeable (Figure 10 insert) only the western half is depicted as highly permeable. Implementation of just the SunPower – California Valley Solar Ranch would reduce the width of the least-cost corridor from 20 km to roughly 13.5 km on the west, but this project would likely have less of an impact on pronghorn as they appear to use the site infrequently. Implementation of both projects would reduce the width of the least-cost corridor to 6.5 km between the two projects and a 1.9 km choke-point to the west of Topaz.

In addition to the direct habitat loss, there are indirect impacts from increased traffic, increased human presence, spread of invasive weed species, poaching, and other disturbances that could lead to pronghorn avoiding project areas (Steve Kohlmann, personal communication). An ongoing study of pronghorn (Berger et al. 2006) in the Upper Green River Basin in southwestern Wyoming reported that natural gas development (gas fields, roads and associated human infrastructure) may result in avoidance or total abandonment of heavily developed areas by pronghorn. The study documented reduced use and abandonment of habitat parcels that were less than approximately 600 acres (242 ha) in size. Areas within 100m of gas wells were also consistently avoided. Those impacts, both direct and indirect, will likely be compounded during times of drought.

6.2.2. Tule elk

The majority of the habitat east of the La Panza Range and west of SR-33 was identified as highly suitable for tule elk and incorporates known ranges of the following subherds: Cholame Valley, California Valley, Carneros Rocks, American, and South Chimineas (Figure 6). The core area delineated north of SR-58 incorporates both the California Valley and Carneros Rocks subherds, while the core area south of the 58 captures the American subherd. The Cholame Valley subherd occurs in a patch that would likely be delineated as a core if the analysis extent extended to the northwest of the study area, while the South Chimineas subherd area was mostly delineated as less than patch size (Figure 7). Permeability was assessed between three target zones representing five subherds. The three target zones and the least-cost corridors overlap the majority of sightings of these five subherds.

Both proposed projects largely occupy areas of medium-high tule elk habitat suitability, though the northernmost portions of both projects were delineated as highly suitable and overlap areas used by the California Valley subherd (Figure 6). The majority of the Topaz Solar Farm is delineated as core habitat for tule elk both north and south of the 58, while the area north of 58 in the California Valley Solar Ranch footprint is delineated as core and south of 58 is delineated as a patch (Figure 7). Both projects have the potential to displace the California Valley subherd from portions of its current range.

Tule elk habitat suitability within the overall project boundaries of the proposed solar facilities.

	Both Projects		*Topaz*		*Sun Power*	
Suitability Class	acres	hectares	acres	hectares	acres	hectares
Low	1658	671	867	351	791	320
Low-Medium	1317	533	738	299	579	234
Medium	373	151	0	0	373	151
Medium-High	10437	4224	7224	2923	3213	1300
High	1464	593	1190	482	274	111
Total Area	15249	6171	10019	4054	5230	2117

Using the 3% permeability threshold, the least-cost corridor for tule elk between the California Valley/Carneros Rocks MCP and the American/South Chimineas MCP is roughly 15 to 24 km wide and branches to either side of Soda Lake Road, with the most permeable routes taking in the western half of SunPower's California Valley Solar Ranch and the eastern portion of the Topaz Solar Farm (Figure 11). The majority of both project sites are made up of very low cost pixels with the exception of very high cost pixels along State Route 58 (Figure 11 inset). Implementation of the Topaz Solar Farm alone would essentially sever the 10-km-wide western branch of the least-cost corridor. Implementation of SunPower's California Valley Solar Ranch would reduce the most highly permeable route from approximately 10 km wide to about 2.5 km wide to the west of the project footprint. Thus if both projects are built the least-cost corridor would likely be reduced to 2.5 km wide from the southern extent of the California Valley Solar

Ranch footprint to the 58 and would likely reduce the potential for connectivity between subherds in the American/South Chimineas MCP and the California Valley/Carneros Rocks MCP.

Cumulative effects and secondary impacts on Tule elk from increased human activity, traffic, noise, weed infestations etc., will be similar to those for pronghorn by further reducing the effective width of the corridor and by reducing habitat quality in the vicinity of the proposed projects (Steve Kohlmann, personal communication). Both elk and pronghorn are active during day and night hours, and hence are more likely to be affected by human activity than strictly nocturnal species.

6.2.3. San Joaquin kit fox

The highest quality kit fox habitat was found in the southern portion of Carrizo Plain and in the San Joaquin Valley. Medium-high suitable habitat was also found in northern Carrizo Plain, Cholame Valley, Cuyama Valley, and upper portions of the Salinas River watershed. Cores were located throughout the study area, with patches scattered across the area southwest of the La Panza Range (including Cuyama Valey). The union displaying the overlap of the three least-cost corridors captures the vast majority of occurrence points between the Carrizo Plain National Monument and the three northern Target Zones. Areas of high permeability included central and northern Carrizo Plain, San Juan valley, and a large swath of western San Joaquin Valley in the Antelope Plain.

Kit fox habitat suitability within the overall project boundaries of the proposed solar facilities.

	Both Projects		*Topaz*		*Sun Power*	
Suitability Class	acres	hectares	acres	hectares	acres	hectares
Low	155	63	0	0	155	63
Low-Medium	1104	447	1045	423	59	24
Medium	6121	2477	6001	2428	121	49
Medium-High	1843	746	1195	484	648	262
High	6025	2438	1778	719	4248	1719
Total Area	15249	6171	10019	4054	5230	2117

The SunPower site is largely composed of high suitability San Joaquin kit fox habitat, while the Topaz site is a mosaic of types ranging from high to medium-low (Figure 8). Several occurrence points are located within the boundaries of both project footprints and several dens are known to occur on both sites (CDFG personal communication). Both project footprints are found in high permeability areas, though the Topaz site is located in an area of highest permeability, while the SunPower site occurs in a somewhat less permeable area (Figure 15). This is largely due to the fact that after harvest, the dryland grain crops found on the Topaz Solar Farm site are more permeable to kit fox than the *Avena*-dominated grasslands to the north of SunPower's California Valley Solar Ranch site (Brian Cypher, personal communication). Thus, the Topaz project is more likely to reduce the connectivity between Carrizo Plain populations and those found further north (Figure 15). Implementation of the SunPower project would reduce the width of the least-cost corridor from 6.5 km near the southern boundary of the project to 20 km wide at the north end of the project. Implementation of the Topaz Solar Farm would reduce the width of the low cost pixels in the least-cost corridor to the east of the project to between 2.8 km at the northern project boundary to 10 km wide at the southern boundary. On the west side of Topaz Solar Farm, the project would reduce the width of the least cost corridor to roughly 2.5 km at the southern boundary and 3.8 km wide at the northern boundary. If both projects are built out, the low cost pixels within the least-cost corridor in between the two projects would range in width from 2.8 to 6.5 km, plus the widths remaining to the west of the Topaz Solar Farm (Figure 15 inset).

6.2.4. Solar project specifics

While the solar project footprint locations can suggest potential impacts to the focal species, the details of the projects will ultimately determine the effects of development on these species. Analysis of potential impacts goes beyond the scope of this report however a few project details are presented here that should be addressed in future reporting efforts.

Topaz Solar Farm. This project would lead to loss of annual grassland and cropland habitat within the footprint (Althouse and Meade, Inc. 2009). This habitat loss could negatively affect the resident tule elk and pronghorn antelope populations that use this portion of the Carrizo Plain region for both foraging and reproduction. These habitat types are also used for foraging and denning by San Joaquin kit fox (Althouse and Meade, Inc. 2009, CDFG personal communication). Of the project's approximately 10,000 acre (4,050 ha) total footprint, 99.6% is comprised of medium-high or high pronghorn habitat, 84.0% is medium-high or high tule elk habitat, and 29.6% is medium-high or high kit fox habitat. Further, fencing of the site would prevent passage by the focal species traversing the area, although for foxes, fencing might be designed to allow passage. The construction phase of the project could also lead to temporary (3 years) impacts to the focal species. Grading, noise, and vehicle traffic have the potential to negatively affect populations of the focal species. Continuing operations (post-construction) could also have detrimental impacts on the focal species.

SunPower – California Valley Solar Ranch. The project could have negative effects on either resident species or species attempting to move through the area. On-site vehicular traffic and other noise, associated with either construction or continuing operations, could also affect wildlife, including the focal species. Tule elk, for example, are hesitant to cross roads with even relatively light vehicle use (Joe Hobbs, pers. comm.). The presence of vehicles for the lifetime of this project might render the project area less likely to be used during species' movement events. In addition to the presence of vehicles, fencing proposed for the PV array and other infrastructure (SunPower 2009) would likely prevent movement by larger species, such as tule elk and pronghorn. The proposed fence design may permit transit by San Joaquin kit fox and other smaller species. Of the project's approximately 5,200 acre (2,100 ha) total footprint, 96.7% is medium-high or high-suitability pronghorn habitat, 66.6% is medium-high or high suitability tule elk habitat, and 93.6% is medium-high or high suitability kit fox habitat.

Aiken, R. A. 2005. Determination of habitat preferences of pronghorn (*Antilocapra americana*) on the rolling plains of Texas using GIS and remote sensing. Master of Science thesis. University of North Texas. 108pp. Autenrieth, R. 1978. Guidelines for the management of pronghorn antelope. Biennial Pronghorn Antelope Workshop Proceedings 8:472-526.

Althouse and Meade, Inc. 2009. Biological Report for the Topaz Solar Farm. Althouse and Meade, Inc. Paso Robles, CA. 92 pp.

Argus, D. F., and R. G. Gordon. 2001. Present tectonic motion across the Coast Ranges and San Andreas fault system in central California. Geological Society of America Bulletin 113:1580-1592.

Atascadero Chamber of Commerce. 2010. California Valley. Atascadero Chamber of Commerce website. <http://www.atascaderochamber.org/Pages/CaliforniaValley.asp?id=a4_6_1>. Accessed 19 March, 2010.

Barrett, M. W. 1981. Environmental characteristics and functional significance of pronghorn fawn bedding sites in Alberta. Journal of Wildlife Management 45:120-131.

Beale, D.M. and Smith, A.D. 1970. Forage use, water consumption and productivity of pronghorn antelope in western Utah. *Journal of Wildlife Management*, 34(3): 570 – 582.

Beier, P.B., K.L. Penrod, C.L. Luke, W.D. Spencer, and C.R. Cabanero. 2006. South Coast Missing Linkages: restoring connectivity to wildlands in the largest metropolitan area in the United States. Pages 555-586 *in* K.R. Crooks and M.A. Sanjayan, editors. Connectivity and Conservation. Oxford University Press.

Berger, J., Berger, K.M and Beckmann, J.P. 2006. Wildlife and energy development: pronghorn of the Upper Green River Basin – year 1 summary. Wildlife Conservation Society, Bronx, NY. Http://www.wcs.org/yellowstone.

Brown, D. E., J. Cancino, K. B. Clark, M. Smith, and J. Yoakum. 2006. An annotated bibliography of references to historical distributions of pronghorn in southern and Baja California. Bulletin of the Southern California Academy of Sciences 105:1-16.

Büechner, H.K. 1950. Life history, ecology and range of the pronghorn antelope in Texas. American Midland Naturalist 43:257-354.

Byers, J. A. 1997. American Pronghorn: Social Adaptations and the Ghosts of Predators Past. The University of Chicago Press, Chicago. 300pp.

Byers, J.A. 2003. Pronghorn. Pages 998-1008 in Wild Mammals of North America: Biology, Management, and Conservation. Feldhamer, G. A., B. C. Thompson, and J.A. Chapman (eds.). The Johns Hopkins University Press, Baltimore.

California Department of Fish and Game (CDFG). 2009. California Natural Diversity Database. California Department of Fish and Game. Sacramento, CA.

California Department of Fish and Game. 2009. California Wildlife Habitat Relationships. <http://www.dfg.ca.gov/biogeodata/cwhr/>. Accessed 17 Feb 2009.

Canon, S. K. 1993. Fawn survival and bed-site characteristics of Trans-Pecos pronghorn. Ph.D. thesis, Texas Technical University. Lubbock. 133 pp.

Cole, G. F. and B. T. Wilkins. 1958. The pronghorn antelope, its range use and food habits in central Montana with special reference to wheat. Montana Fish and Game Department Technical Bulletin 2. 39pp.

Craighead, A. C., E. Roberts, F. L. Craighead. 2001. Bozeman Pass Wildlife Linkage and Highway Safety Study. Prepared for American Wildlands, http://www.wildlands.org/research.html.

Cypher, B. L., C. D. Bjurlin, and J. L. Nelson. 2005. Effects of two-lane roads on endangered San Joaquin kit foxes. Prepared for the California Department of Transportation by the California State University, Stanislaus, Endangered Species Recovery Program, Fresno. 21pp.

Cypher, B. L. and N. Frost. 1999. Condition of San Joaquin kit foxes in urban and exurban habitats. Journal of Wildlife Management 63:930-938.

Cypher, B. L., S. E. Phillips, and P. A. Kelly. 2007. Habitat suitability and potential corridors for San Joaquin kit fox in the San Luis Unit, Fresno, Kings and Merced Counties, California. Prepared for the U.S. Bureau of Reclamation South-Central California Area Office and the U.S. Fish and Wildlife Service Endangered Species Program by the California State University, Stanislaus, Endangered Species Recovery Program, Fresno. 34pp.

Cypher, B. L., G. D. Warrick, M. R. M. Otten, T. P. O'Farrell, W. H. Berry, C. E. Harris, T. T. Kato, P. M. McCue, J. H. Scrivner, and B. W. Zoellick. 2000. Population dynamics of San Joaquin kit foxes at the Naval Petroleum Reserves in California. Wildlife Monographs 145:1-43.

Daneke, D., M. Sunquist, and S. Berwick. 1984. Notes on kit fox biology in Utah. Southwestern Naturalist 29:361-362.

Di rschl, H. F. 1963. Food habits of the pronghorn in Saskatchewan. Journal of Wildlife Management 27(1):81-93.

Egoscue, H. J. 1962. Ecology and life history of the kit fox in Tooele County, Utah. Ecology 43:481-497.

Einarsen, A.S. 1948. the pronghorn antelope and its management. Monument Printing Press, Baltimore, Maryland, USA.

Ellis, J.E. 1970. A computer analysis of fawn survival in the pronghorn antelope. Dissertation, University California, Davis, Califonia, USA.

Ferrier, G. J. and E. C. Roberts, Jr. 1973. The Cache Creek tule elk range. Cal-Neva Wildlife:25-34.

Gogan, P. J. P. 1986. Ecology of the tule elk range, Point Reyes National Seashore. PhD dissertation, University of California, Berkeley. 430pp.

Grant, L. B., and K. Sieh. 1994. Paleoseismic evidence of clustered earthquakes on the San-Andreas Fault in the Carrizo Plain, California. Journal of Geophysical Research – Solid Earth 99:6819-6841.

Greco, S. E., P. R. Huber, J. Hobbs, J. Garcia, K. Stromayer, and R. Parris. 2009. Grassland Ecological Area Tule Elk Reintroduction Feasibility Study. Year 1 Final Report. Prepared for the Rocky Mountain Elk Foundation, California Department of Fish and Game, and the U.S. Fish and Wildlife Service.

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

Haight, R. G., B. Cypher, P. A. Kelly, S. Phillips, H. P. Possingham, K. Ralls, A. M. Starfield, P. J. White, and D. Williams. 2002. Optimizing habitat protection using demographic models of population viability. Conservation Biology 16:1386-1397.

Hailey, T.L. 1979. A handbook for pronghorn antelope in Texas. Federal Aid Report Series 20. Texas Parks and Wildlife Department, Austin, Texas, USA.

Hansen, M. C., J. D. Yoakum, W. H. Pyle, and R. G. Anthony. 2001. New strategies for pronghorn food habit studies. Proceedings of the Biennial Pronghorn Antelope Workshop 19:71-94.

Hervert, J.J., J.L. Bright, M.T. Brown, L.A. Priest and R.S. Henry. 2000. Sonoran pronghorn monitoring: 1994-1998. Nongame and Endangered Species Program Technical Report 16. Arizona Game and Fish Department, Phoenix, Arizona, USA.

Hickman, J. C., editor. 1993. The Jepson Manual: Higher Plants of California. University of California Press. Berkeley, CA.

Hopkins, R. A. No date. Pronghorn, *Antilocapra americana*. California Wildlife Habitat Relationship System. http://www.dfg.ca.gov/biogeodata/cwhr/ accessed on January 12, 2009.

Jensen, W. R., T. K. Fuller, and W. L. Robinson. 1986. Wolf, *Canis lupus*, distribution on the Ontario-Michigan border near Sault Ste. Marie. Canadian Field-Naturalist 100:363-366.

Jones, K.S. 1991. Feeding study of pronghorn antelope in San Luis Obispo, California. Thesis, California Polytechnic State University, San Luis Obispo, California, USA.

Knapp, D. K. 1978. Effects of agricultural development in Kern County, California, on the San Joaquin kit fox in 1977. California Department of Fish and Game, Sacramento, Nongame Wildlife Investigation, unpublished report. 57pp.

Knight, R. R. 1970. The Sun River elk herd. Wildlife Monographs 23:1-66.

Koch, A. J., and J. D. Yoakum. 2002. Reintroduction and status of pronghorn on the Carrizo Plain National Monument and surrounding areas in southern California. Proceedings of the Biennial Pronghorn Workshop 20:25-41.

Koopman, M. E., J. H. Scrivner, and T. T. Kato. 1998. Patterns of den use by San Joaquin kit foxes. Journal of Wildlife Management 62:373-379.

Koopman, M. E., B. L. Cypher, and J. H. Scrivner. 2000. Dispersal of San Joaquin kit foxes (*Vulpes macrotis mutica*). Journal of Mammalogy 81:213-222.

LaHaye, W.S., R.J. Gutierrez, and J.R. Dunk. 2001. Natal dispersal of the spotted owl in southern California: dispersal profile of an insular population. The Condor, Volume 103, pp. 691-700.

Laughrin, L. 1970. Distribution and Abundance of the San Joaquin kit fox. Cal-Neva Wildlife Transactions 1970:86-93.

Longshore, K. and C. Lowrey. 2008. Habitat suitability and food habits of pronghorn antelope in the Carrizo Plains National Monument, California. Report prepared for the Carrizo Plains National Monument, Bureau of Land Management by the Western Ecological Research Center, USGS.

Lovallo, M. J. and E. M. Anderson. 1996. Bobcat movements and home ranges relative to roads in Wisconsin. Wildlife Society Bulletin 24:71-76.

Maher, C. R. 1994. Pronghorn male spatial organizations: population differences in degree of nonterritoriality. Canadian Journal of Zoology 72(3):455-464.

Maloney, A. B. 1945. Fur brigade to the Bonaventura; John Work's California expedition, 1832-1833. for the Hudson's Bay Company, San Francisco. California Historical Society. 112 pp.

McCullough, D. R. 1969. The tule elk: its history, behavior, and ecology. University of California Publications in Zoology 88:1-207.

McCullough, D. R., J. K. Fischer, and J. D. Ballou. 1996. From bottleneck to metapopulation: recovery of the tule elk in California. Pages 375-403 in Metapopulations and Wildlife Conservation. D. R. McCullough (ed.). Island Press, Washington D.C.

Mitchell. G.J. 1980. the pronghorn in Alberta. Alberta Department Lands and Forests, Fish and Wildlife Division and University Regina, Regina, Saskatchewan, Canada.

Morrell, S. H. 1972. Life history of the San Joaquin kit fox. California Fish and Game 58:162-174.

Newberry, J. S. 1855. Report upon the zoology of the route. Pages 70-71, No. 2., Chapter 1 *in* Reports of exploration and surveys to ascertain the most practicable and economical route for a railroad from the Mississippi River to the Pacific Ocean. Abbott, H. L. (ed.). U.S. Senate, Washington, D. C. Exec. Doc. 78, Vol. 6, in Seton 1929, 424pp.

Ockenfels, R. A., A. Alexander, C. L. D. Ticer, and W. K. Carrel. 1994. Home ranges, movement patterns, and habitat selection of pronghorn in central Arizona. Res. Branch Tech. Report 13. P-R Project W-78-R. Arizona Department of Game and Fish, Phoenix. 80pp.

Ockenfels, R. A., W. K. Carrel, and C. van Riper, III. 1997. Home ranges and movements of pronghorn in northern Arizona. Biennial Conference of Research on the Colorado Plateau 3:45-61.

O'Connor, P. M. 1988. Home range and habitat use by tule elk at Cache Creek, California. Master's thesis, Humboldt State University, Arcata, California.

O'Gara, B. W. 2004. Behavior. Pages 145-194 *in* Pronghorn: ecology and management. O'Gara, B. W. and J. D. Yoakum, (eds.). University Press of Colorado. Boulder, Colorado. 903 pp.

Peek, J. M. 2003. Wapiti (*Cervus elaphus*). Pages 877-888 in Wild Animals of North America: Biology, Management, and Conservation. Second Edition. G. A. Feldhamer, B. C. Thompson, and J. A. Chapman (eds.). The John Hopkins University Press, Baltimore, Maryland. 1216pp.

Peek, J. M. and A. L. Lovaas. 1968. Differential distribution of elk by sex and age on the Gallatin winter range, Montana. Journal of Wildlife Management 32:553-557.

Pomeroy, D. R. 1986. Spatial relationships and interspecific behavior of tule elk and cattle. M.S. thesis, University of California, Berkeley. 79pp.

Ralls, K., and P. J. White. 1995. Predation on San Joaquin kit foxes by larger canids. Journal of Mammalogy 76:723-729.

Rosier, J. R., and N. A. Ronan. 2006. Post-breeding dispersal of burrowing owls in an extensive California grassland. American Midland Naturalist 155:162-167.

Ryder, T. J. and L. L. Irwin. 1987. Winter habitat relationships of pronghorns in southcentral Wyoming. Journal of Wildlife Management 51:79-85

Sawyer, H., F. Lindzey, and D. McWhirter. 2005. Mule deer and pronghorn migration in western Wyoming. Wildlife Society Bulletin 33:1266-1273.

Scrivner, J. H., T. P. O'Farrell, and T. T. Kato. 1987. Dispersal of San Joaquin kit foxes, *Vulpes macrotis mutica*, on Naval Petroleum Reserve #1, Kern County, California. United States Department of Energy Topical Report, EGG 10282-2190.

Sexton, M. L., J. R. Choate, and R. A. Nicholson. 1981. Diet of pronghorn in western Kansas. Journal of Range Management 34:489-493.

Singleton, P.H., W.L. Gaines, and J.F. Lehmkuhl. 2002. Landscape Permeability for Large Carnivores in Washington: A Geographic Information System weighted-distance and least-cost corridor assessment. USDA Forest Service, Pacific Northwest Research Station, Research Paper PNW-RP-549.

Smith A.D., and D.M. Beale. 1980. Pronghorn antelope in Utah: Some research and observations. Publication 80-13. Utah Division Wildlife and Resources, Salt Lake City, Utah, USA.

Spiegel, L. K. and M. Bradbury. 1992. Home range characteristics of the San Joaquin kit fox in western Kern County, California. Transactions of the Western Section of the Wildlife Society 28:83-92.

Sundstrom, C., W. G. Hepworth, and K. L. Diem 1973. Abundance, distribution and food habits of the pronghorn. Wyoming Game and Fish Commission Bulletin. No. 12. 61pp.

SunPower Corporation. 2009. Conditional Use Permit Application. SunPower Corporation. San Jose, CA.

Thelander, C. G., D. C. Pearson, and G. E. Olson (eds.). 1994. Life on the Edge. BioSystems, Santa Cruz, California. 550pp.

Thiel, R. P. 1985. The relationship between road densities and wolf habitat suitability in Wisconsin. American Midland Naturalist 113:404-407.

Topaz Solar Farms. 2008. Conditional Use Permit Application. Topaz Solar Farms, LLC. Hayward, CA.

U. S. Fish and Wildlife Service. 1983. San Joaquin kit fox recovery plan. U. S. Fish and Wildlife Service, Portland, OR. 84pp.

U.S. Fish and Wildlife Service. 1998. Recovery plan for upland species of the San Joaquin Valley, California. Region 1, Portland, OR. 319pp.

Valentine, P.C., S.J. Fuller, and L.A. Scully. 2004. Terrain ruggedness analysis and distribution of boulder ridges and bedrock outcrops in the Stellwagen Bank National Marine Sanctuary region—seabed ruggedness: U.S. Geological Survey poster. URL: http://woodshole.er.usgs.gov/project-pages/stellwagen/posters/rugged.html

Warrick, G. D. and B. L. Cypher. 1998. Factors affecting the spatial distribution of San Joaquin kit foxes. Journal of Wildlife Management 62:707-717.

White, P. J. and K. Ralls. Reproduction and spacing patterns of kit foxes relative to changing prey availability. Journal of Wildlife Management 57:861-867.

Yoakum, J. D. 1978. Managing rangelands for the American pronghorn antelope. Biennial Pronghorn Antelope Workshop 8:321-336.

Yoakum, J. D. 2004a. Habitat characteristics and requirements. Pages 409-446 *in* Pronghorn: ecology and management. O'Gara, B. W. and J. D. Yoakum, (eds.). University Press of Colorado. Boulder, Colorado. 903 pp.

Yoakum, J. D. 2004b. Distribution and abundance. Pages 75-105 *in* Pronghorn: ecology and management. O'Gara, B. W. and J. D. Yoakum, (eds.). University Press of Colorado. Boulder, Colorado. 903 pp.

Yoakum, J. D. 2004c. Habitat Conservation. Pages 571-630 *in* Pronghorn: ecology and management. O'Gara, B. W. and J. D. Yoakum, (eds.). University Press of Colorado. Boulder, Colorado. 903 pp.

Yoakum, J. D. 2004d. Foraging ecology, diet studies, and nutrient values. Pages 447-502 *in* Pronghorn: ecology and management. O'Gara, B. W. and J. D. Yoakum, (eds.). University Press of Colorado. Boulder, Colorado. 903 pp.

Zoellick, B. W., C. E. Harris, B. T. Kelly, T. P. O'Farrell, T. T. Kato, and M. E. Koopman. 2002. Movements and home ranges of San Joaquin kit foxes (*Vulpes macrotis mutica*) relative to oil-field development. Western North American Naturalist 62:151-159.

Zoellick, B. W., T. P. O'Farrell, and T. T. Kato. 1987. Movements and home range of San Joaquin kit foxes on the Naval Petroleum Reserves, Kern County, California. Rep. No. EGG 10282-2184, EG&G energy Measurements, Goleta, CA. 38pp.

Zoellick, B. W., N. S. Smith, and R. S. Henry. 1989. Habitat use and movements of desert kit foxes in western Arizona. Journal of Wildlife Management 53:955-961.

Appendix A
Digital Data Sources Used

Name	Data Type	Scale	Date	Source
San Louis Obispo Vegetation	Polygon	1:100,000	1998	County of San Luis Obispo
CALVEG Vegetation	Polygon	1:24,000	1997, 2000, 2002	U.S. Forest Service
San Luis Obispo Crops	Polygon		2008	County of San Luis Obispo
Kern Crops	Polygon		2005	County of Kern
TIGER Roads	Line	1:100,000	2007	U.S. Bureau of the Census
California Highways	Line		2001	California Department of Transportation
National Elevation Dataset	Raster	10 meter	1999	U.S. Geological Survey
Conservation Lands (CPAD)	Polygon		2008	GreenInfo Network
Counties	Polygon	1:24,000	2004	California Department of Forestry and Fire Protection
Precipitation Normals	Raster	800 meters	1971-2000	PRISM Group, Oregon State University
National Hydrography Dataset	Line and Polygon	1:100,000	2007	U.S. Geological Survey
San Luis Obispo Aerial Photos			2007	San Luis Obispo County
Terrain Ruggedness	Raster	30 meter	2007	Endangered Species Recovery Program
Vegetation Density	Raster	30 meter	2001-2006	Endangered Species Recovery Program: Generated from Global Land Cover Facility MODIA Normalized Difference Vegetation Index [NDVI]

Tule Elk Model Inputs

The minimum and maximum columns indicate the specialist's uncertainty for each class.

Variable	Permeability Score	Interpretation and Assumptions	Permeability Minimum	Permeability Maximum	Suitability
Factor Weights (100%)					
Vegetation	50%		40%	80%	50%
Topography	n/a		0%	20%	n/a
Road Density	50%		30%	60%	50%
Vegetation					
Alkali Desert Scrub	6	if low density, then better	4	8	0.4
Annual Grassland (Avena)	1	assuming grass ht. >12"	1	1	0.9
Annual Grassland (Brome)	4		4	4	0.6
Barren	9		9	10	0.1
Blue Oak-Foothill Pine	7	grassy understory	6	10	0.3
Blue Oak Woodland	6	lower density and grassy understory is better, suitable when in a larger grassland	4	10	0.4
Chamise-Redshank Chaparral	9		9	10	0.1
Closed-Cone Pine-Cypress	9		9	10	0.1
Coastal Oak Woodland	9	usually too dense, limited forage in understory	8	10	0.1
Coastal Scrub	4	greater grass component increases value	3	7	0.6
Deciduous orchard	10	poorer if fenced or animals shot at	9	10	0
Desert Riparian	10		10	10	0
Desert Scrub	6	if low density, then better	4	8	0.4
Desert Wash	10		10	10	0
Dryland Grain Crops	4	poorer if tilled to bare earth when other forage unavailable	4	10	0.6
Eucalyptus	10		10	10	0
Evergreen orchard	10	poorer if fenced or animals shot at	9	10	0
Freshwater Emergent Wetland	2		2	5	0.8
Irrigated Grain Crops	2		2	5	0.8

Irrigated Hayfield	3		3	6	0.7
Irrigated Row and Field Crops	2		2	9	0.8
Juniper	4	lower density and grass between trees is better, suitable when in a larger grassland	2	6	0.6
Lacustrine	6		6	10	0.4
Mixed Chaparral	10		8	10	0
Montane Chaparral	9	very low forage potential	7	10	0.1
Montane Hardwood	10	low forage potential	10	10	0
Montane Hardwood-Conifer	10		10	10	0
Orchard-Vineyard	8		8	10	0.2
Pasture (Irrigated)	1		1	10	0.9
Perennial Grassland	1		1	4	0.9
Pinyon-Juniper	10		10	10	0
Rice	n/a		n/a	n/a	n/a
Sagebrush	7	greater grass component increases value	7	10	0.3
Sierran Mixed Conifer	10		10	10	0
Urban	10		10	10	0
Valley Foothill Riparian	5	some forage potential if grassy understory	3	8	0.5
Valley Oak Woodland	6	lower density grass understory is better, suitable when in a larger grassland (assumed analogous to blue oak woodland where telem and some aerial count data is available)	4	10	0.4
Vineyard	8	10 if surrounded by deer fencing or animals shot at	8	10	0.2
Wet Meadow	1		1	10	0.9
Road Density					
0 – 0.5 km/km^2	1	CDFG Telemetry data	1	1	0.9
0.5 – 1 km/km^2	8	CDFG Telemetry data	8	10	0.2
1 – 2 km/km^2	10		10	10	0
2 – 4 km/km^2	10		10	10	0
4 – 6 km/km^2	10		10	10	0
6 – 8 km/km^2	10		10	10	0
8 – 10 km/km^2	10		10	10	0
10 km/km^2 and above	10		10	10	0

Pronghorn Antelope Model Inputs

The minimum and maximum columns indicate the specialist's uncertainty for each class.

Variable	Permeability Score	Interpretations and Assumptions	Permeability Minimum	Permeability Maximum	Suitability
Factor Weights (100%)					
Vegetation	35%				35%
Road Density	10%				10%
Topography	55%				-
Slope	-				55%
Vegetation					
Alkali Desert Scrub	3	best with >4 species, greater bare ground (20-30%), 25-45cm veg ht (Longshore & Lowrey 2008)	2	6	0.7
Annual Grassland (Avena)	1	assume some areas >12" for fawning (O'Gara and Yoakum 2004)	1	5	0.9
Annual Grassland (Brome)	3		3	5	0.7
Barren	9	e.g. Soda Lake…could be traversible when dry	9	10	0.1
Blue Oak-Foothill Pine	7	some limited use as forage (Longshore and Lowrey 2008)	6	10	0.3
Blue Oak Woodland	7	some limited use as forage (Longshore and Lowrey 2008)	7	10	0.3
Chamise-Redshank Chaparral	9		9	10	0.1
Closed-Cone Pine-Cypress	9		9	10	0.1
Coastal Oak Woodland	9		9	10	0.1
Coastal Scrub	6		5	10	0.4
Deciduous orchard	10		10	10	0
Desert Riparian	10		10	10	0
Desert Scrub	3	best with >4 species, greater bare ground (20-30%), 25-45cm veg ht (Longshore & Lowrey 2008)	1	5	0.7
Desert Wash	10		10	10	0
Dryland Grain Crops	2	poorer if tilled to bare earth when other forage unavailable	2	10	0.8
Eucalyptus	10		10	10	0
Evergreen orchard	10		10	10	0
Freshwater Emergent Wetland	2	comprise small areas within study area, can provide forage and fawning (e.g. Cholame Vly), value would go down if too extensive and/or tall and dense	1	10	0.8
Irrigated Grain Crops	2	poorer if fenced	2	5	0.8

Irrigated Hayfield	1	poorer if it harvested or tilled when fawns are susceptible to direct mortality from equipment	1	5	0.9
Irrigated Row and Field Crops	2	poorer if fenced	2	9	0.8
Juniper	5	if relatively open (Longshore and Lowry 2008, O'Gara and Yoakum 2004, Koch and Yoakum 2002, DFG aerial count data)	3	10	0.5
Lacustrine	6		5	10	0.4
Mixed Chaparral	10	some limited use as forage on margins, if accessible (Longshore & Lowrey 2008)	8	10	0
Montane Chaparral	8		6	10	0.2
Montane Hardwood	10		10	10	0
Montane Hardwood-Conifer	10		10	10	0
Orchard-Vineyard	10		10	10	0
Pasture (Irrigated)	1	poorer if fenced	1	10	0.9
Perennial Grassland	1		1	5	0.9
Pinyon-Juniper	10		10	10	0
Rice	n/a		n/a	n/a	n/a
Sagebrush	3		1	10	0.7
Sierran Mixed Conifer	10		10	10	0
Urban	8	"urban" for Carrizo area is likely to be very low density; higher density would mean lower value	7	10	0.2
Valley Foothill Riparian	6		5	10	0.4
Valley Oak Woodland	7		6	10	0.3
Vineyard	10		10	10	0
Wet Meadow	1		1	4	0.9
Road Density					
0 – 0.5 km/km^2	1	considering dirt and paved roads for Carrizo, if associated with fences, then road density has greater effect (O'Gara and Yoakum 2004, DFG aerial count data)			0.9
0.5 – 1 km/km^2	2	O'Gara and Yoakum 2004, DFG aerial count data			0.8
1 – 2 km/km^2	2	O'Gara and Yoakum 2004, DFG aerial count data			0.8
2 – 4 km/km^2	6	O'Gara and Yoakum 2004, DFG aerial count data			0.4
4 – 6 km/km^2	7	O'Gara and Yoakum 2004, DFG aerial count data			0.3
6 – 8 km/km^2	8	O'Gara and Yoakum 2004, DFG aerial count data			0.2

8 – 10 km/km^2	9	O'Gara and Yoakum 2004, DFG aerial count data			0.1
10 km/km^2 and above	10	O'Gara and Yoakum 2004, DFG aerial count data			0
Topography					
Canyon bottoms	7	O'Gara and Yoakum 2004, Longshore and Lowrey 2008	6	10	
Ridgetops	10	for example, crest of Calientes…but a low-relief ridgetop may be more important in another setting (O'Gara and Yoakum 2004, Longshore and Lowry 2009)	6	10	
Flats	1	0-10% slope (O'Gara and Yoakum 2004, Longshore and Lowry 2010)	1	1	
Slopes	4	>10%, can be used if vegetation is suitable (O'Gara and Yoakum 2004, Longshore and Lowry 2011)	2	10	
Slope					
0-5%					0.99
5-20%					0.66
>20%					0.33

Kit Fox Model Inputs

The minimum and maximum columns indicate the specialist's uncertainty for each class.

Variable	Permeability Score	Interpretations and Assumptions	Permeability Minimum	Permeability Maximum	Suitability
Factor Weights (100%)					
Vegetation	40%				50%
Road Density	5%				-
Terrain Ruggedness	50%				25%
Vegetation Density	5%				25%
Vegetation					
Alkali Desert Scrub	1	Assuming Atriplex-dominated (i.e., saltbush) habitat	1	1	0.9
Annual Grassland (Avena)	4	not all "grasslands" are equal.	4	5	0.5
Annual Grassland (Brome)	1	not all "grasslands" are equal.	1	1	0.9
Barren	1	a fox could cross it unimpeded, although if it were a large area, the fox might be a bit leery due to lack of escape cover.	1	8	0.2
Blue Oak-Foothill Pine	10		10	10	0
Blue Oak Woodland	10		10	10	0
Chamise-Redshank Chaparral	10		10	10	0

Closed-Cone Pine-Cypress	10		10	10	0
Coastal Oak Woodland	8	This assumes that this has an "oak savannah" type structure. If this is something denser, than the rating should be a 10.	8	10	0.2
Coastal Scrub	10		10	10	0
Deciduous orchard	3	Assuming this is something like a nut orchard where the ground is relatively "sanitized". Here we need to add the caveat that permeability decrease as distance increases.	3	10	0.1
Desert Riparian	9	Dense vegetation along riparian corridors harbor coyotes and bobcats and are treacherous for foxes. However, if the corridor was sufficiently narrow, a fox might make a dash for it.	9	10	0
Desert Scrub	1		1	1	0.9
Desert Wash	1	desert washes usually are small and easily crossed, and foxes will even use them as travel corridors.	1	1	0.9
Dryland Grain Crops	1	1 if it's fallow or just harvested, 10 if it's at peak growth and the crop is over 18 inches tall -permeability decreases with distance.	1	10	0.1
Eucalyptus	10		10	10	0
Evergreen orchard	3	I'm assuming that this is something like citrus groves. And permeability decreases with distance.	3	9	0.1
Freshwater Emergent Wetland	10		10	10	0
Irrigated Grain Crops	1	1 if it's fallow or just harvested, 10 if it's at peak growth and the crop is over 18 inches tall - permeability decreases with distance.	1	10	0
Irrigated Hayfield	2	Permeability decreases with soil saturation and distance.	2	10	0
Irrigated Row and Field Crops	1	1 if it's fallow or just harvested, 10 if it's at peak growth and the crop is over 18 inches tall - permeability decreases with distance.	1	10	0

Juniper	3	4 if it's sparse and in gentle terrain, 10 if it's dense and/or in rugged terrain.	4	10	0.6
Lacustrine	10		10	10	0
Mixed Chaparral	10		10	10	0
Montane Chaparral	10		10	10	0
Montane Hardwood	10		10	10	0
Montane Hardwood-Conifer	10		10	10	0
Orchard-Vineyard	4	4 if vegetation between rows is kept low (e.g., mowed or scrapped). Permeability decreases with increasing vegetation between rows and with distance.	4	10	0
Pasture (Irrigated)	7	Assuming dryland pasture.	7	7	0.3
Perennial Grassland	1	1 if the structure is sparse and/or low (either naturally or through grazing). Permeability decreases with increasing vegetation density and height.	1	8	0.5
Pinyon-Juniper	10		10	10	0
Rice	10		10	10	0
Sagebrush	10		10	10	0
Sierran Mixed Conifer	10		10	10	0
Urban	1	Really depends upon the features in the urban landscape. We have had kit foxes disperse more than 5 miles through Bakersfield.	1	10	0.1
Valley Foothill Riparian	10		10	10	0
Valley Oak Woodland	8	This assumes that this has an "oak savannah" type structure. If this is something denser, than the rating should be a 10.	8	10	0.2
Vineyard	4	Same note as for orchard-vineyard	4	10	0
Wet Meadow	10		10	10	0
Road Density					
0 – 0.5 km/km^2	1				
0.5 – 1 km/km^2	1				
1 – 2 km/km^2	1				
2 – 4 km/km^2	3				
4 – 6 km/km^2	3				
6 – 8 km/km^2	5				
8 – 10 km/km^2	8				

10 km/km^2 and above	10				
Terrain Ruggedness					
5	10		10	10	0.05
50	10		10	10	0.5
85	3	0-5% slope seems to be really optimal for the foxes, 5-15% slope is less optimal, and foxes commonly drop out at >15% slope.	3	3	0.85
100	1	0-5% slope seems to be really optimal for the foxes, 5-15% slope is less optimal, and foxes commonly drop out at >15% slope.	1	1	1
Vegetation Density					
0-9	10				0.00-0.09
10-19	9				0.10-0.19
20-29	8				0.20-0.29
30-39	7				0.30-0.39
40-49	6				0.40-0.49
50-59	5				0.50-0.59
60-69	4				0.60-0.69
70-79	3				0.70-0.79
80-89	2				0.80-0.89
90-99	1				0.90-0.99