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RESEARCH ARTICLE

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The San Joaquin Desert of California: Ecologically Misunderstood and Overlooked

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ABSTRACT: The vegetation community of the San Joaquin Valley of California has been formally classified as a perennial grassland based largely on assumptions of past climax state. However, historical records suggest that the region might be more accurately classified as a desert. The distinction is important in determining the appropriate management strategies for this ecosystem, particularly for the many rare and endemic taxa that reside there. Abiotic and biotic factors–including low precipitation, arid soils, and desert-adapted plants and vertebrate–are consistent with conditions typical of desert areas. We examined the distributions of these factors to define the extent of the San Joaquin Desert. We conclude that the San Joaquin Desert historically encompassed 28,493 km2 including the western and southern two thirds of the San Joaquin Valley, and the Carrizo Plain and Cuyama Valley to the southwest. However, this ecosystem has been reduced by up to 59% from agricultural, industrial, and urban activities. The conservation of the unique biodiversity of this region is dependent upon this ecosystem being appropriately managed as a desert and not as a perennial or annual grassland.

Index terms: biogeography, desert distribution, endemism, grassland, LoCoH analysis

INTRODUCTION

Deserts are defined in many ways, but mainly they are regions with low precipitation and high evapotranspiration (Meigs 1953; Jaeger 1957; Budyko 1974; Mabbutt 1977; Daubenmire 1978). In the Whittaker (1970) classification of biomes, desert areas usually receive less than 250 mm of precipitation annually, whereas temperate grasslands that are in the same temperature regime generally receive greater than 635 mm. Low precipitation and vegetation biomass lead to characteristic soils that are alkaline, calcareous, low in organic matter, and weakly zonal or stratified (Dregne 1984). This climatic regime also generally limits perennial vegetation to low shrubs, cacti, succulents, and a few grasses and forbs (Jaeger 1957; Mabbutt 1977; Daubenmire 1978). However, some desert areas receive so little precipitation that no plants grow, while others receive enough precipitation to support small trees and tall columnar cacti, such as the Sonoran Desert in North America (Shreve 1942; Turner and Brown 1982). Depending on the rainfall regime, deserts periodically can also produce dramatic blooms of native annual plants (Minnich 2008). Because plants and animals are often adapted to deserts, they have been used to delineate boundaries of deserts (Shreve 1942; Lowe 1955; Morafka 1977; MacMahon 1979). Indeed, MacMahon and Wagner (1985) believe that climate factors alone are too variable to define the limits of deserts in North America. It also can be persuasively argued that the ecology and behavioral traits of arid-adapted plants and animals are much better at "selecting" (and thus defining) desert habitats than only climate and geology data. Thus, we have used both biotic and abiotic factors in defining the extent of the San Joaquin Desert, which we believe provides much of the most important information that will be needed to effectively manage and protect these dwindling natural areas from the increasing adverse impacts of people.

Traditionally, four major deserts have been recognized in North America, with all located in the southwestern part of the continent (Shreve 1942; Jaeger 1957; MacMahon 1979; MacMahon and Wagner 1985; Hafner and Riddle 1997). The Great Basin Desert (149,000 km^2) is the most northerly and is located mostly in Nevada and western Utah. The Mojave Desert (140,000 km^2) is just south of the Great Basin Desert and is mostly in southeastern California. The Sonoran Desert (275,000 km^2) extends southeasterly from the Mojave Desert into southern Arizona and northwestern Mexico. The Chihuahua Desert (453,000 km^2) covers southern New Mexico, southwestern Texas, and north central Mexico (Shreve 1942; Jaeger 1957; MacMahon 1979; MacMahon and Wagner 1985; Hafner and Riddle 1997). All receive less than 350 mm of precipitation per year, and although they differ considerably in elevation and seasonal temperatures, they share many of the same species of plants and vertebrates. However, each also has its own characteristic flora and fauna (MacMahon 1985; Hafner and Riddle 1997).

Much of the non-forested or non-shrubland habitat west of the Sierra Nevada in California historically has been considered native grassland (Clements 1920; Biswell 1956; Küchler 1995). This is particularly true of the San Joaquin Valley, which except for marshes, riparian habitats, and a small area of alkali sink habitat on the valley floor, has been classified as a bunchgrass prairie (Heady 1995; Küchler 1995; Baker 1978). The implication is that this region, which is currently dominated by exotic annual grasses and forbs and has large areas devoid of shrubs, was historically native perennial grassland.

Recent evidence casts doubt on the historical habitat classification of the southern San Joaquin Valley, and the adjacent Carrizo Plain and Cuyama Valley (Figure 1), as perennial grassland. Based on writings of Spanish explorers and missionaries, a convincing argument has been made that, in fact, none of the pre-European herbaceous cover in the San Joaquin Valley (D'Antonio et al. 2007; Schiffman 2007; Minnich 2008) was ever dominated by perennial or annual grassland. Rather, annual wildflowers of numerous species were the dominant cover (Minnich 2008) for a short time during the spring. Because of the extreme aridity of much of the San Joaquin Valley, the herbaceous layer of vegetation would have dried and disintegrated by May, leaving barren ground dotted with bushes throughout the summer (Minnich 2008). Thus, without the exotic species, the physical and biotic characteristics of most of the San Joaquin Valley are consistent with conditions typical of a desert, albeit one that is under a Mediterranean climate regime (Dallman 1998), which receives no meaningful summer rainfall.

Most of the southern San Joaquin Valley was desert scrub habitat on the upland sites and alkali sink habitats on the valley floor. There were riparian corridors along rivers that carried runoff from the Sierra Nevada into seasonal wetlands that surrounded shallow lakes (Figure 1; Griggs et al. 1992).

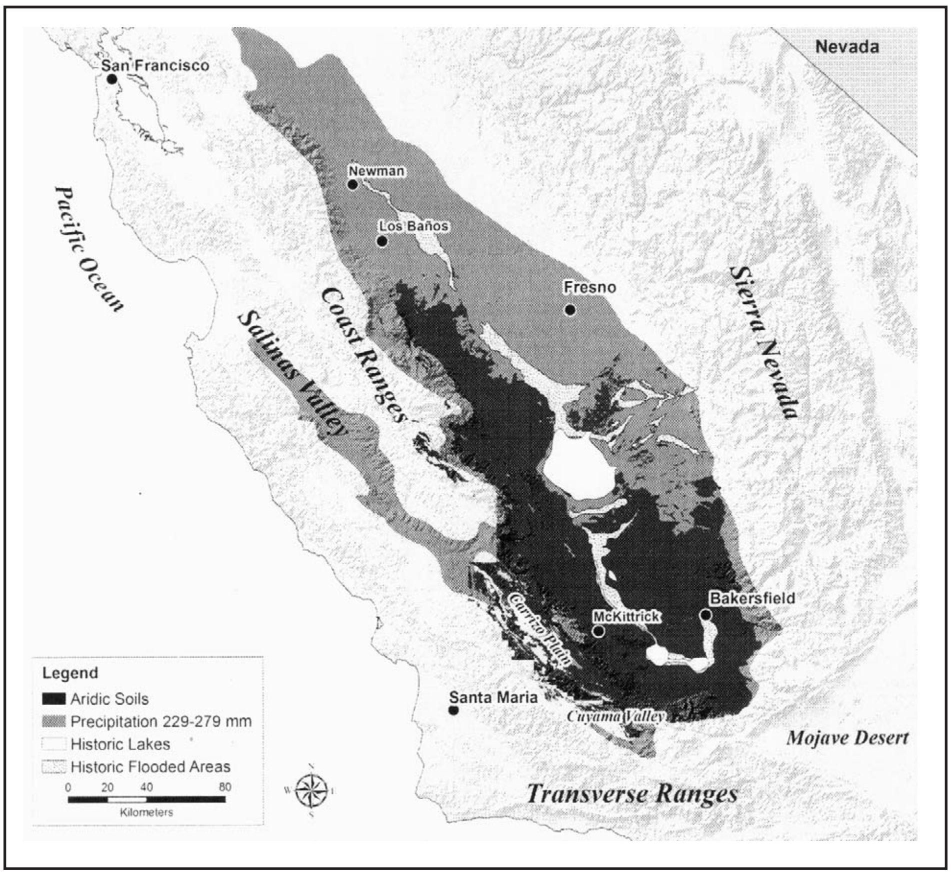

Figure 1. The area receiving an average of 229–279 mm (9–11 in) of precipitation per year, and the occurrence of aridic soils, in the San Joaquin Valley and surrounding central California. The precipitation polygon completely overlays the aridic soil distribution.

The scrub habitats likely were dominated by saltbush (*Atriplex spinifera* and *A. polycarpa*) with a few other low-stature shrubs (Griggs et al. 1992). According to Vasek and Barbour (1995) and Axelrod (1995), saltbush scrub is typical in basins and valleys of the Mojave Desert and occurs at the western edge of the San Joaquin Valley from Panoche southward. Also shared by both the Mojave Desert and the southern San Joaquin Valley is halophytic alkali sink scrub that occurs on playas, sinks, and near seeps (Vasek and Barbour 1995). Several vertebrates typical of the Mojave Desert also occur in the San Joaquin Valley. Before the widespread invasion of exotic annual plants and the conversion of vast areas to human use, the desert in the San Joaquin Valley would have been a unique North American habitat, with extreme arid areas infused with three large but shallow lakes with associated rivers and wetlands, which supported a remarkable abundance of waterfowl (Griggs 1992). The area would have been reminiscent of the desert of southern Iraq that supports a vast marshland.

Identifying the southern and western San Joaquin Valley as a true desert is not novel. Based on the plant and animal species of this area, Hawbecker (1953) considered this part of the Valley as a desert. In his book on birds of California, Small (1975) has a section on the "San Joaquin Valley Desert" and maps its boundary. Hafner and Riddle (1997) also treated this area as a desert, equal in status to other North American deserts, and were the first authors to name this area the "San Joaquin Desert." Axelrod (1995) notes species such as the San Joaquin kit fox (*Vulpes macrotis mutica*) and the blunt-nosed leopard lizard (*Gambelia sila*) that "inhabit saline *Kern Desert* [italics ours] in Kern and southern Kings Cos." Commenting on the amount of moisture necessary to recharge soil capacity in various parts of California, Major (1995) said, "In general, in cismontane California winter precipitation is sufficient to fully recharge soil water. Where it is not, the area can properly be termed a desert. South of Fresno with a rather dry, but otherwise typical Californian Mediterranean climate, the southern San Joaquin Valley is such a desert, as at Bakersfield, and so is its west side as far north as Los Baños to Newman."

Although deserts of the world are usually identified and named when they cover relatively large areas, smaller areas that have climatic and biotic characteristics of deserts should also be formally identified and named so that the general public and resource managers correctly recognize the landscapes in which they reside and work, and which they impact and manage. For example, a recently published popular review of the deserts of California (Pavlik 2008) makes no mention of the suite of unique plants, animals, and habitats found in the southern San Joaquin Valley, thus providing the public and land managers no insights into the importance of this arid area of great biodiversity and endemism.

Although portions of the San Joaquin Valley (and adjacent valleys to the southwest) have been recognized by some as desert in general terms as outlined above, the extent of the desert has not been quantified and the desert is still not widely acknowledged. In this paper, we propose boundaries of the San Joaquin Desert using the distribution of several factors typical of deserts, including precipitation, soils, plants, and vertebrates (MacMahon and Wagner 1985). We then assess the current status of this desert in terms of anthropogenic changes to habitats and the implication of these changes to the conservation of this unique ecosystem.

METHODS

To define the approximate boundary of the San Joaquin Desert, we examined the distribution of precipitation, soils, plants, and vertebrates typical of desert environments. We obtained rainfall data from the Fire and Resource Assessment Program, California Department of Forestry and Fire Protection. The precipitation isohyets we used (polygon shape files available online at http://frap.cdf. ca.gov) are based on a 60-year (1900–1960) annual average from approximately 800 stations maintained by the U.S. Geological Survey, the California Department of Water Resources, and the California Division of Mines. We used the 229-279 mm isohyets to define desert areas because this encompasses the typical highest amount of rainfall that deserts receive.

The soils data we used were obtained from the U.S. Department of Agriculture's Natural Resources Conservation Service (available online at http://websoilsurvey. nrcs.usda. gov/app/HomePage.htm) for Madera County, Fresno County (western part), Kings County, Tulare County (central and western parts), Kern County (northwestern and southwestern parts), Carrizo Plain, and Santa Barbara County (northern part). For the analysis, we selected "Aridic Soil Moist" and "Xeric Soil Moist" subclass units. These moisture regimes refer to the presence or absence of water held at a tension of < 1500 kPa in the soil or in specific horizons during periods of the year. These aridic soils in normal years are dry in all parts for more than half of the cumulative days per year when the soil temperature at a depth of 50 cm from the soil surface is above 5 °C and are moist in some or all parts for less than 90 consecutive days when the soil temperature at a depth of 50 cm is above 8 °C.

We selected plants that occur in the San Joaquin Valley and are characteristic of the following desert communities: Mojave Creosote Bush Scrub, Mojave Mixed Woody Scrub, Mojave Mixed Steppe, Mojave Wash Scrub, Desert Saltbush Scrub, or Desert Sink Scrub (Holland 1986). We then further restricted the list (Table 1) by excluding those plants that also occurred in non-desert mountainous or coastal areas of the region (e.g., *Allenrolfea occidentalis*, *Eriogonum fasciculatum* var. *polifolium*, *Frankenia salina*, and *Isomeris arborea*) because these plants would unreasonably exaggerate the boundaries of the desert. We also included several San Joaquin Valley endemics with close relatives in the Mojave Desert (e.g., Bakersfield cactus, *Opuntia basilaris* var. *treleasei*). Location coordinates were obtained from data provided by the Consortium of California Herbaria (2008). Those locations without coordinates, but with adequately detailed descriptions, were georeferenced using Google Earth (2008).

We used vertebrates endemic to the San Joaquin Valley, plus some that occur in the other North American deserts but that are also found in the Valley. However, we excluded vertebrates with desert affinities that occur in the Valley if they also are found in adjacent non-desert montane or coastal habitats (e.g., coast horned lizard, *Phrynosoma coronatum*; black-tailed jackrabbit, *Lepus californicus*; greater roadrunner, *Geococcyx californicus*) because, similar to plant species, we did not want to have habitat generalists distort our analyses. Location information for all mammals, the blunt-nosed leopard lizard, and the Le Conte's thrasher (*Toxostoma lecontei*) were assembled by the Endangered Species Recovery Program, Fresno, California (U.S. Fish and Wildlife Service 1998). Location data for reptiles were provided to us by Robert Hansen (Editor, *Herpetological Review*), which we supplemented with museum records from the Museum of Vertebrate Zoology and the California Academy of Sciences.

We used point data for eight plants, four reptiles, one bird, and five mammals (Table 1) to construct utilization polygons representing their distributions (Fortin et al. 2005). The utilization polygons were constructed by the localized convex hull (LoCoH) method of Getz and Wilmers (2004) and Getz et. al. (2007) using ESRI ArcMap 9.2 GIS software with a downloaded map template (Lyons et al. 2009) for LoCoH analyses. We subjectively chose the most representative polygon, rejecting those with obviously unreasonably fragmented distributions, for each species after applying several different K factors (number of nearest neighbors) to each data set. The complexity of the resulting polygons was dictated by the distribution of occurrence points available for each species (Table 1). Precipitation and soil data already existed as polygons, as indicated above. To determine the extent of the San Joaquin Desert, we overlaid (unioned) all 20 polygons. This resulted in 1653 polygons from which we determined the number of coincident (overlapping) distributions and the area contributed by each overlap (Figure 2). Even though 20 distribution polygons were used, there was only a maximum of 16 coincident polygons. We looked for

Table 1. Plant and animal species used to define the San Joaquin Desert (see text for criteria for choosing taxa). The number of locations refers to the number of georeferenced locations used to determine the distribution polygon. The K value for the LoCoH analysis is the variable used to determine the size of the hulls that the software uses to construct distribution polygons (see Getz and Wilmers 2004). An asterisk denotes species listed by either the California Department of Fish and Game or the U.S. Fish and Wildlife Service, or both, as threatened or endangered.

Common Name	Scientific Name	General Distribution	Number of Locations	K Value for LoCoH	Area in San Joaquin Valley, km^2
Shrubby Alkali Aster	*Arida carnosa*	North American deserts	7	10	2,189
Arrowscale	*Atriplex phyllostegia*	North American deserts	22	8	10,517
Allscale Saltbush	*Atriplex polycarpa*	North American deserts	32	15	16,209
Spinescale Saltbush	*Atriplex spinifera*	Mojave & San Joaquin deserts	36	10	8,203
Jackass Clover	*Wislizenia refracta*	North American deserts	25	10	17,330
San Joaquin Wooly-threads*	*Monolopia congdonii*	San Joaquin endemic	87	15	8,250
Kern Mallow*	*Eremalche parryi* ssp. *kernensis*	San Joaquin endemic	21	15	1,282
Bakersfield Cactus*	*Opuntia basilaris* var. *treleasei*	San Joaquin endemic	38	15	1,481
Blunt-nosed Leopard Lizard*	*Gambelia sila*	San Joaquin endemic	548	35	21,106
Desert Spiny Lizard	*Sceloporus magister*	North American deserts	22	10	5,602
San Joaquin Coachwhip	*Masticophis flagellum ruddocki*	San Joaquin endemic	71	12	31,319
Glossy Snake	*Arizona elegans*	North American deserts	53	12	26,586
Le Conte's Thrasher	*Toxostoma lecontei*	Mojave & San Joaquin deserts	48	10	2,390
San Joaquin Antelope Squirrel*	*Ammospermophilus nelsoni*	San Joaquin endemic	349	20	13,580
Tulare Grasshopper Mouse	*Onychomys torridus tularensis*	San Joaquin endemic	40	15	12,338
Giant Kangaroo Rat*	*Dipodomys ingens*	San Joaquin endemic	366	25	8,155
San Joaquin Kangaroo Rat*	*Dipodomys nitratoides*	San Joaquin endemic	578	20	19,698
San Joaquin Kit Fox*	*Vulpes macrotis mutica*	San Joaquin endemic	2604	50	20,904

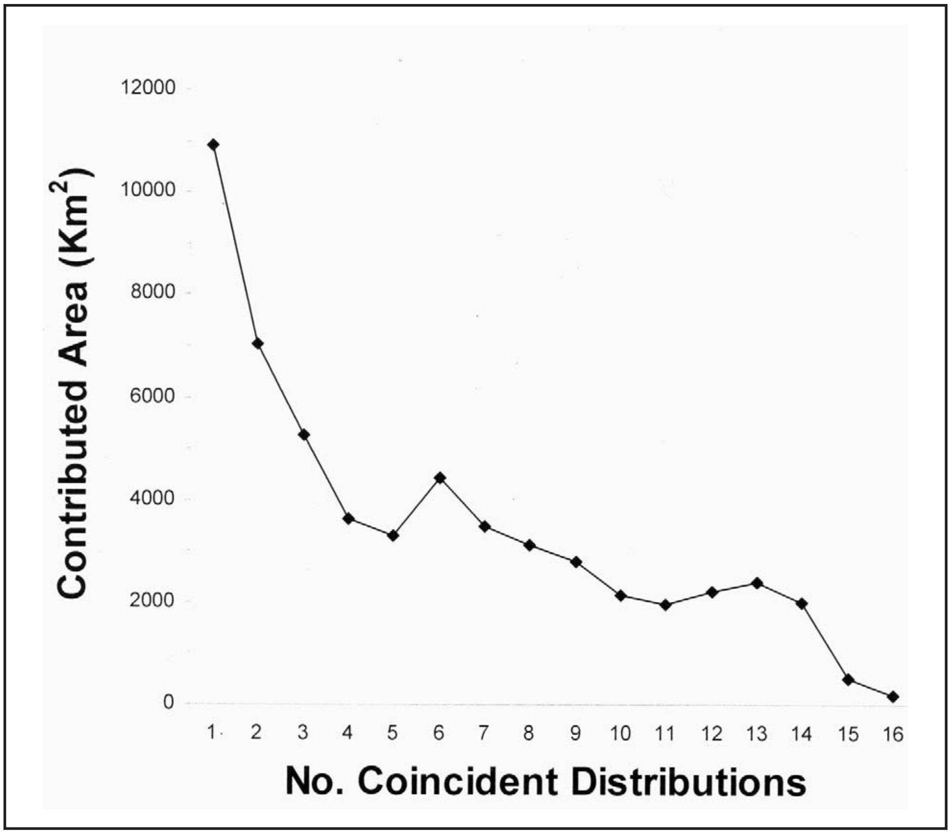

Figure 2. The relationship between the contributed area and number of coincident distributions of soil, rainfall, plants, reptiles, birds, and mammals in California. There is a natural break in contributed area at about 5 to 12 coincident distributions.

natural breaks in the graph comparing the number of coincident distributions with the area each coincident distribution contributed (Figure 2); and using the coincident distribution polygons, we merged data into ranges of 1 to 4, 5 to 12, and 13 to 16 coincident distributions.

RESULTS

The polygon representing the 229-279 mm mean annual rainfall isopleth covers the southern two thirds of the San Joaquin Valley and extends up the Salinas Valley on the west side of the inner coast range of mountains nearly to Monterey Bay, and to the south includes the Cuyama Valley and Carrizo Plain (Figure 1). The arid soils polygon is largely coincident with the rainfall isopleth (Figure 1), but is more restricted to the southern end of the San Joaquin Valley, where it is tightly bound by the Sierra Nevada, Transverse Range, and Inner Coastal Mountains, similar to the rainfall. Arid soils are also found in the Cuyama Valley and the Carrizo Plain (Figure 1).

Desert plant distributions are almost all in the San Joaquin Valley, Carrizo Plain, and Cuyama Valley, similar to the rainfall and soils distributions. Similarly, the distributions of reptiles, mammals, and the Le Conte's thrasher are confined mostly to the southern and western areas of the San Joaquin Valley, the Cuyama Valley, and the Carrizo Plain (Figure 3). That these distributions are so well defined in the southern San Joaquin Valley is not surprising given that 10 of the 19 taxa are endemic (Table 1). Jackass clover (*Wislizenia refracta*) and the San Joaquin coachwhip (*Masticophis flagellum ruddocki*) have occurrences on the edge of the Salinas Valley, which considerably expands the distributions of these species to include vast areas with no likely occurrences. The San Joaquin kit fox has an extensive range that encompasses many mountainous areas on the west side of the San Joaquin Valley, although, like all the other plants and vertebrates, it is tightly bound by the Sierra Nevada to the east and Transverse Range to the south.

The map of coincident distributions shows a core area of high overlap in the southern end and western side of the San Joaquin Valley, which includes the Carrizo Plain and Cuyama Valley (Figure 4). With each category of less coincidence the area increases, especially to the north, but also creeps into mountainous habitats. The areas of high, medium, and low coincidence are, from the core outward: 5061; 28,493; and 55,360 km^2; respectively. The area encompassed by just the precipitation isopleth is 37,620 km^2 and that of the arid soil polygon is 16,174 km^2.

Most desert areas of the world experience relatively little human disturbance, but the San Joaquin Desert supports vast areas of intensively irrigated agriculture, oil extraction, and urban development (Figure 5). The area (km^2) of relatively undisturbed habitat that remains within each of the three polygon categories of coincidence, from high to low coincidence, is: 2910; 12,458; and 29,752 km^2. Based on these data and the total area for each of the coincidence polygons, 43.3%, 59%, and 35.5%, respectively, of the desert habitat in the San Joaquin Valley has been modified beyond recognition (Table 2).

DISCUSSION

Precipitation and temperature regimes in the San Joaquin Valley are largely dependent on the direction and timing of winter (November-March) storms out of the northern Pacific, resulting in a Mediterranean climate with hot, dry summers and cool, moist winters (Biswell 1956; Twisselmann 1967; Griggs et al. 1992; Major 1995). These regimes result in two decreasing moisture gradients in the Valley: north to south and east to west. The inner coastal mountain range forms the western boundary of the valley and creates a rain shadow (Major 1995), while rainfall on the eastern side increases because of the orographic effect of the Sierra Nevada. Thus, on the west side, yearly average precipitation decreases from Panoche (230 mm) in the north to Taft (117 mm) in the

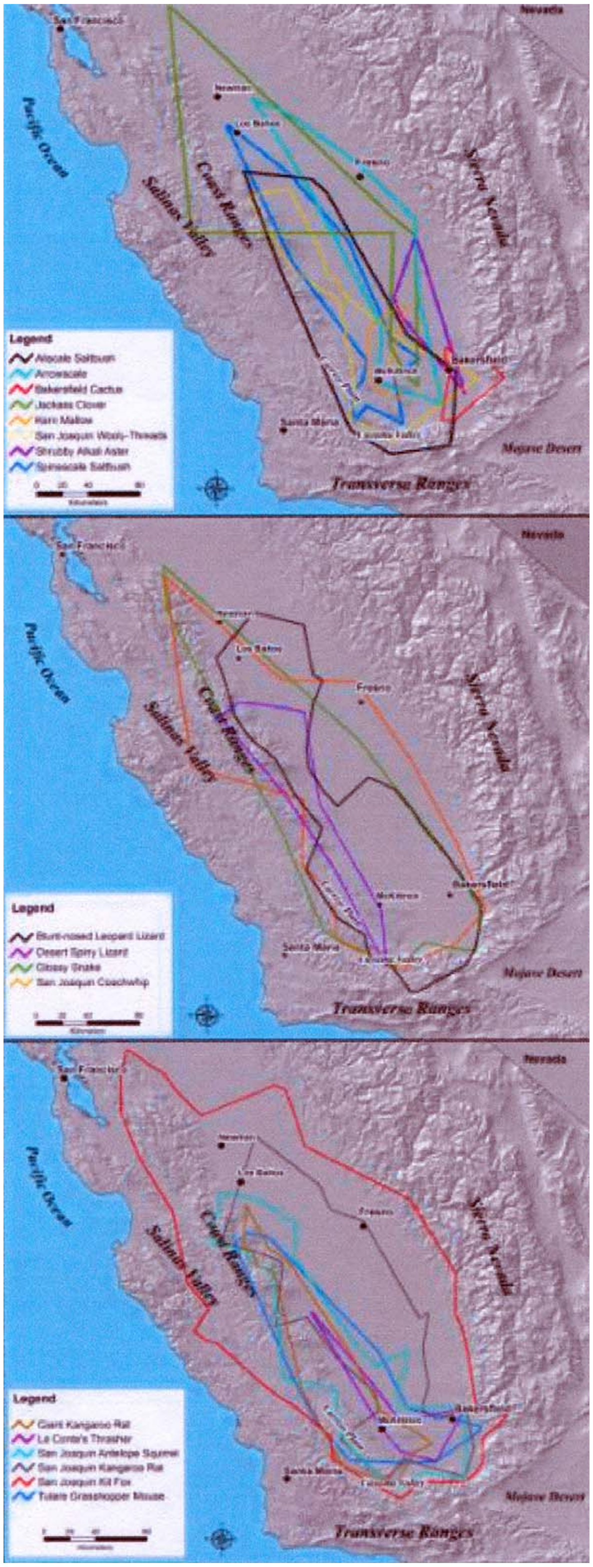

Figure 3. The distribution of desert plants (top), desert reptiles (middle), and desert mammals and LeConte's thrasher (bottom) in the San Joaquin Valley and surrounding central California.

south and increases to the east of Taft at Bakersfield (145 mm) and east of Panoche at Fresno (269 mm; Twisselmann 1967; Western Regional Climate Center 2010). These two gradients have an impact on the distributions of plants and vertebrates within the Valley, presumably resulting in those species that are tolerant of more mesic conditions having the widest distributions and conversely those most adapted to xeric conditions being restricted to the western and southern portions of the Valley (Figure 3). Interestingly, the same Mediterranean weather patterns and geological features found in the southern San Joaquin Valley are found in the long and thin Atacama and Sachura deserts of Chile and Peru, which are bound on their western and eastern sides by coastal mountains and the Andes (Dallman 1998). There is also a latitudinal aridity gradient, as in the San Joaquin Valley, but in the opposite direction.

For determining the distributions of the plants and vertebrates of the San Joaquin Valley, we have used the best available location information. These are historical data for the most part and may not reflect where the species currently occur because much of their habitat, along with the species, has been destroyed by human activities. Also, certain attributes of these data may provide inaccurate representations of species' ranges. For some species, the sample sizes are small (i.e., < 30 locations, Table 1), and some species have a few "outlier" occurrences that are geographically distant from the main areas of occurrence. These small sample sizes and outlier occurrences expand some distributions so that they include areas of likely unsuitable habitat, as we observed for the jackass clover and San Joaquin coachwhip. The low number of locations for some species also results in distribution polygons characterized by relatively long, straight lines, which may not accurately reflect a more complex distribution. On the other hand, some distributions with large numbers of occurrence points, such as the San Joaquin kit fox and San Joaquin kangaroo rat (*Dipodomys nitratoides*), also have relatively simple polygons, even though the shape of these polygons probably reflects their true distributions because of the large sample sizes and overall dispersion. The

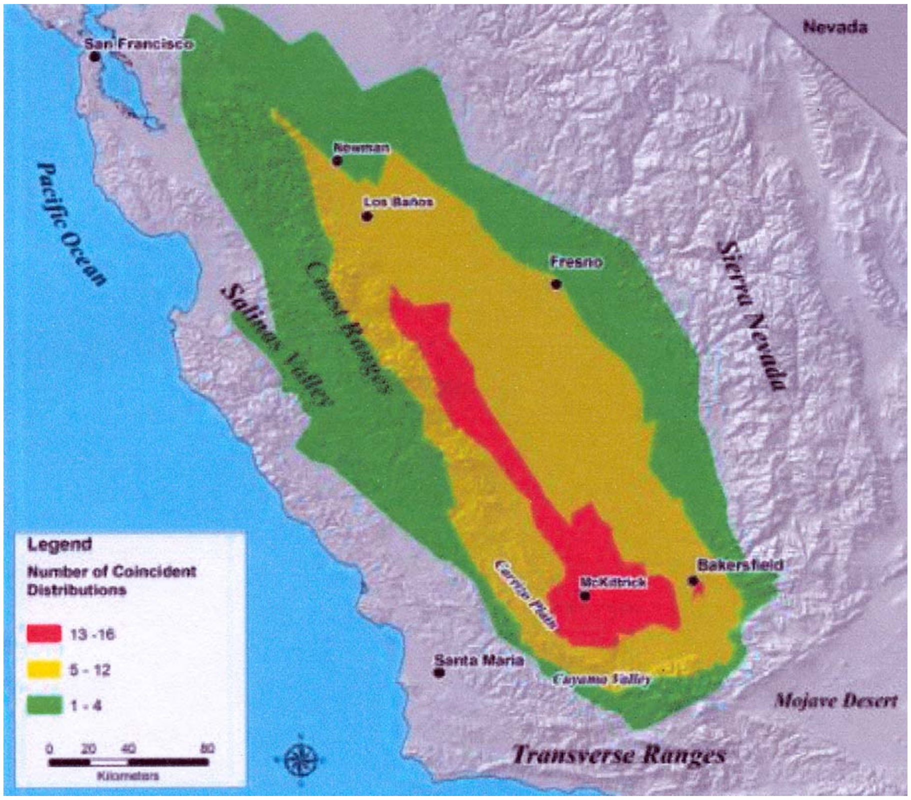

Figure 4. Areas of coincident distribution shown in Figs. 1 and 3, which we used to define the boundaries and ecotones of the San Joaquin Desert of California. We believe the 5-12 polygon area best defines the desert (see text for details).

similarity in complexity of all the species polygons probably reflects the overall relative coarseness of the distribution data, but also reflects the uniformity of the desert habitat and the highly selective nature of the arid-adapted species. In the spirit of reducing subjective interpretations, we have not altered the distributions as determined by the impartial quantitative methods described above. Despite these limitations, however, we believe that the utilization polygons are more than sufficient to define the desert with considerable accuracy, especially given that we have used 18 different species distributions with a total of 4947 locations, in addition to the soil and rainfall polygons.

The inclusion of the kit fox in our analysis may seem odd given that it has an extensive range, a good portion of which does not overlap other species. This is partly due to the ability of kit foxes to move relatively long distances (> 120 km, Schwartz et al. 2005). However, kit foxes are indeed desert-adapted (McGrew 1979); and, although not depicted on our maps, all known persistent populations of the San Joaquin kit fox occur within the 229 mm rainfall isopleth (B. Cypher, unpubl. data).

Ecotones can vary from well to poorly defined regions, and the San Joaquin Desert illustrates both extremes. If the ecotonal region of the desert is defined as that area between the outer edge of the innermost polygon and the outer edge of the outer polygon (Figure 4), it can be seen that the transition between desert habitats and foothill or mountainous habitats is quite narrow in the southern and southwestern region of the valley, but the transition between desert and woodlands and grassland to the north and east is very broad.

Despite the variation in the width of the ecotone, it is useful for the purposes of further analyses and also developing management actions to define a specific area that is mostly desert. We believe this is the area represented by the 5-12 coincident distributions polygon. Our unbiased method of boundary determination includes non-desert mountainous habitat on the western edge of the desert; but, otherwise, we think that the 5-12 polygon defines well the relatively sharp southern and western edges of the desert with a broad ecotone grading into grassland and woodland to the north and east. The boundaries we suggest are similar, although more defensible on methodological grounds, to those described by Hawbecker (1953), Small (1975), Axelrod (1995), Major (1995), and Hafner and Riddle (1997).

Species assemblages of mammals and reptiles of the southern San Joaquin Valley are composed similarly to those of the Mojave, Great Basin, and Sonoran deserts (Hafner and Riddle 1997). Of the total number of non-volant small mammal species in the San Joaquin Valley, 73.3% are considered xeric-adapted (Hafner and Riddle 1997). This is lower than in the Mojave (85%) or Sonoran deserts (76%), but higher than in either the Great Basin (63.4%) or Chihuahuan (48.3%) deserts (Hafner and Riddle 1997). Fossil remains of plants and vertebrates from the McKittrick tar pits at the southern end of the San Joaquin Valley indicate that the area has been a desert for thousands of years (Brattstrom 1953). Of special interest are Pleistocene remains of both the long-nosed leopard lizard (*Gambelia wislizenii*) and the desert tortoise (*Gopherus agassizii*), which currently are only found in the deserts to the east, including the Mojave.

Accurately defining the appropriate ecosystem classification for the southern San Joaquin Valley is not merely an academic exercise, but has important conservation implications as well. The true composition of this community is masked by anthropogenic alteration and the prevalence of non-native plants, particularly exotic grasses (Twisselmann 1967; Heady 1995; Germano et al. 2001; Minnich 2008). The erroneous classification of this region as a perennial grassland de-emphasizes its uniqueness and can lead to mismanagement, both of which could jeopardize the region's biodiversity – particularly its 10 endemic plants and vertebrates. For example, if this region

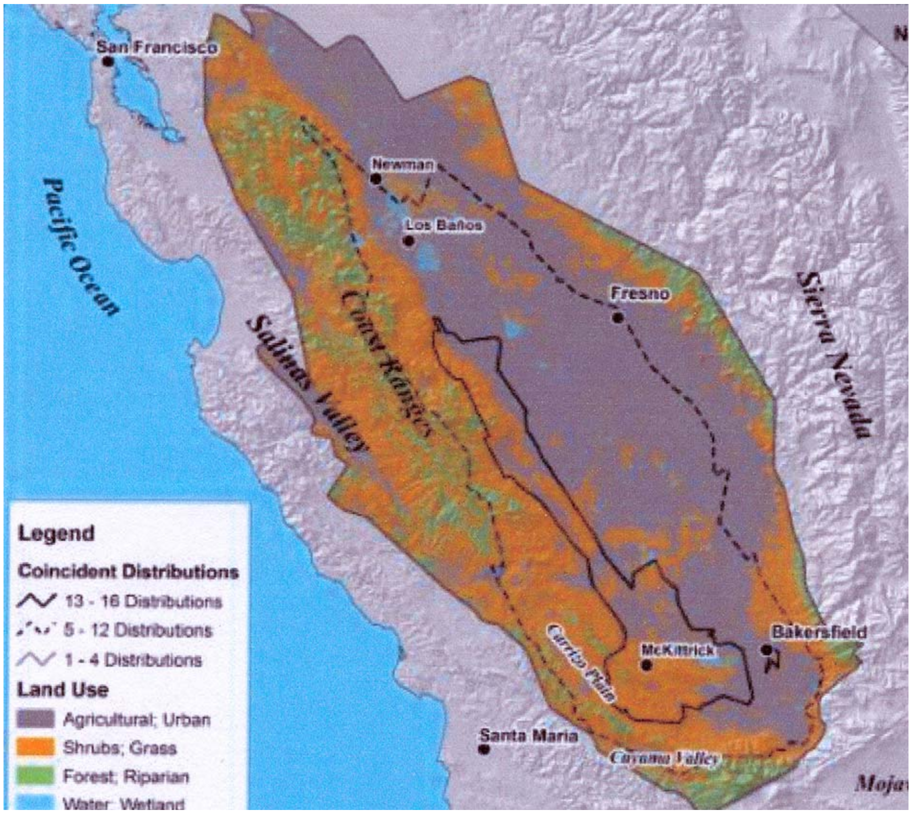

Figure 5. Current land use in the San Joaquin Desert of California. Polygon boundaries are the same areas of coincidence shown in Fig. 4.

is viewed as floristically similar to more northern grasslands, this could dilute conservation efforts, such as habitat acquisition. Conservation efforts are critical, given that at least 59% of the natural habitat in the San Joaquin Desert has already been lost to agricultural, urban, and industrial activities. This estimate is likely higher as the desert boundary that we suggest and have used includes an extensive area of non-desert mountains on the western edge that are relatively undisturbed. Fortunately, some significant actions have been taken to protect biodiversity within the San Joaquin Desert, most notably the creation of the ca. 100,000-ha Carrizo Plain National Monument.

Management of the San Joaquin Desert, including the Carrizo Plain, as a perennial grassland could result in unfavorable habitat conditions for the native plants and animals, especially those that are endemic. Management strategies that favor perennial grasses often differ from those needed to promote native annual grasses and forbs (Corbin et al. 2007; Huntsinger et al. 2007; Jackson and Bartolome 2007; Reiner 2007). Of particular importance, non-native grasses have been identified as a threat to several rare species (U.S. Fish and Wildlife Service 1998; Germano et al. 2001) including Kern mallow (*Eremalche parryi* ssp. *kernensis*), Bakersfield cactus, blunt-nosed leopard lizard, giant kangaroo rat (*Dipodomys ingens*), San Joaquin kangaroo rat, and San Joaquin antelope squirrel (*Ammospermophilus nelson*). It is imperative that management strategies strive to reduce the density of non-native plants, especially persistent non-native annual grasses, to levels suitable for desert-adapted species, which prefer a more sparse vegetation cover with areas of bare ground. Managing for a desert, rather than grassland attributes, would better meet these species' habitat requirements. Eight species inhabiting the San Joaquin Desert are already listed as endangered or threatened federally or by the state of California (U.S. Fish and Wildlife Service 1998; Table 1); and with the continuing impacts to this ecosystem, focused conservation efforts and appropriate habitat management practices are necessary to prevent the loss of species.

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Table 2. The total area, undisturbed area, and percentage of habitat disturbed of high (13-16), medium (5-12), and low (1-4) number of coincidence polygons of the San Joaquin Desert in California. Disturbance to natural habitat in the desert is to a large extent due to agricultural, industrial, and urban activities.

coincidence	total area (km^2)	undisturbed area (km^2)	% disturbed
high	5061	2910	43.3
medium	28493	12458	59.0
low	55360	29752	35.5

mammals and their habitats in Africa and the Americas.

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