San Joaquin Kit Foxes and Solar Farms

San Joaquin Kit Foxes and Solar Farms:

Coexistence of an Endangered Species and Renewable Energy

Edited by

Brian Cypher and Erica Kelly

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This book is dedicated to the many individuals, including biologists, solar farm owners and managers, solar farm construction workers, regulatory agency personnel, environmental organization members, interested members of the public, and others, who have worked so hard to increase the compatibility between solar farms and San Joaquin kit foxes.

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PREFACE

Numerous photovoltaic electricity generating facilities, referred to as "solar farms", have been constructed within the habitat of the San Joaquin kit fox, potentially further imperiling this endangered species. Furthermore, a number of additional facilities are under construction or planned. To date, several investigations have been conducted assessing the effect of solar farms on San Joaquin kit foxes. The results have been somewhat unexpected, but in a positive way. Based on the results of these studies, kit foxes continued using the lands upon which solar farms are constructed. Furthermore, in all of the studies assessing the response of kit foxes to solar farms, the demographic and ecological attributes of foxes using solar farms were similar to those of foxes in nearby natural land sites. In some cases, the attributes were even better for foxes using the solar farms.

We and other colleagues studying kit foxes on solar farms have been surprised (pleasantly) by these results. Given the rapidly growing number of solar farms in San Joaquin kit fox habitat, these findings are significant with immense conservation implications. Thus, we felt that it was important to summarize this information and make it available. We also felt that it was imperative to emphasize the crucial caveat that these positive findings were largely attributable to the implementation of appropriate mitigation measures during and after construction of the facilities. We felt that it would be most impactful and that accessibility would be enhanced if the information was presented in a single organized package. Hence our decision to prepare an edited volume.

It is our sincere hope that this book will be useful to all involved in the construction of solar farms within kit fox habitat including designers, planners, builders, and operators as well as those involved in issuing environmental permits and those responsible for developing and implementing mitigation strategies. We are convinced that solar farms can be designed and constructed in a manner that is compatible with continued use of the landscape by kit foxes. This book provides details and considerations on strategies for achieving this. Our ultimate goal with this work is to contribute to efforts to conserve San Joaquin kit foxes in the hopes that one day they might no longer require formal legislative protections.

Brian Cypher and Erica Kelly

CHAPTER 1

SAN JOAQUIN KIT FOXES AND SOLAR FARMS: WHY IS THIS TOPIC IMPORTANT?

BRIAN L. CYPHER AND ERICA C. KELLY

On a warm day in the San Joaquin Desert region of central California, a small fox rests in the shade of a photovoltaic solar panel (Fig. 1-1). The scene is tranquil, but also unusual. The location is within an extensive solar array consisting of thousands of panels covering hundreds of acres. The array is part of a massive facility that generates hundreds of mega-watts of electricity. Dozens of workers ply the site each day operating and maintaining the facility. By no stretch of the imagination does this constitute natural habitat for the fox. Indeed, the construction of the electricity generating facility resulted in the loss of some of the fox's habitat. Also, the fox is an endangered San Joaquin kit fox (*Vulpes macrotis mutica*), a species whose populations have declined significantly due to habitat loss. So why is this fox here? Does it have nowhere else to live? Can it survive at this location or will it eventually leave the facility or perish?

The use of solar energy to generate electricity is rapidly increasing worldwide, and associated with this increase has been an accelerated rate of construction of utility-scale solar powered generation facilities (REN21 2016). The increase in facility construction has been particularly acute in California (Solar Energy Industries Association 2016) where optimal conditions (e.g., flat terrain, high insolation rates) are abundant (Lovich and Ennen 2011, Cameron et al. 2012, Stoms et al. 2013, Sengupta et al. 2018). Also, the California state legislature passed a bill in 2015 that required all power-supplying utilities to obtain at least 50% of their electricity from renewable energy sources by 2030 (de León 2015). A subsequent bill required that the 50% target be achieved by 2026 and 60% be achieved by 2030, and that renewable and zero-carbon energy sources supply 100% of retail sales of electricity by 2045 (de León 2018). These requirements further encourage the construction of solar facilities in California.

Figure 1-1. San Joaquin kit fox resting in the shade of a photovoltaic panel at the Topaz Solar Farms, San Luis Obispo County, California. Photo by C. Van Horn Job.

Although the expansion of solar energy is positive in many regards (e.g., reducing emissions of greenhouse gases), a significant concern has been environmental impacts associated with solar energy facilities, many of which cover hundreds or even thousands of hectares. These impacts include habitat loss, habitat fragmentation and disruption of movement corridors, direct and indirect animal and plant mortality, alteration of ecosystem processes, and other impacts (Tsoutsos et al. 2005, Lovich and Ennen 2011, Stoms et al. 2013, Hernandez et al. 2014, Grippo et al. 2015, Moore and Pavlik 2016, Moore-O'Leary et al. 2017). These issues are enhanced when species of conservation concern are potentially impacted (Leitner 2009, Lovich and Ennen 2011, Moore-O'Leary et al. 2017, Boroski 2019, Phillips and Cypher 2019). Some of the rare species affected by recent solar projects in California include the Agassiz's desert tortoise (*Gopherus agassizii*; Federal Threatened, California Threatened), Mohave ground squirrel (*Xerospermophilus mojavensis*; California Threatened), giant kangaroo rat

(*Dipodomys ingens*; Federal Endangered, California Endangered), and San Joaquin kit fox (Leitner 2009, Moore-O'Leary et al. 2017, Boroski 2019, Phillips and Cypher 2019).

San Joaquin kit foxes are endemic to a region known as the San Joaquin Desert in central California (U.S. Fish and Wildlife Service [USFWS] 1998, Germano et al. 2011). They are geographically and genetically isolated from other subspecies of kit foxes by the Sierra Nevada and Tehachapi Mountain ranges (Mercure et al. 1993, USFWS 1998). San Joaquin kit foxes once were widely distributed in arid shrubland and grassland habitats throughout this region. However, their distribution and abundance has been significantly reduced due to profound habitat loss associated with agricultural, urban, and industrial developments throughout their range (Cypher et al. 2013). Consequently, they were listed as Federally Endangered in 1967 and California Threatened in 1971 (USFWS 1998). Remaining numbers are estimated at 3-5,000 (Cypher et al. 2013). San Joaquin kit foxes now persist in a metapopulation consisting of three larger "core" populations and less than a dozen smaller "satellite" populations, most with limited interconnectivity. To reduce extinction probability and enhance long-term population viability, it is imperative to conserve ecologically functional landscapes for kit foxes and maintain or enhance connectivity between remaining populations (USFWS 1998, 2010; Cypher et al. 2013).

Facilities that use photovoltaic panels to generate electricity are commonly known as "solar farms". Many of the utility-scale solar farms occupy hundreds or even thousands of hectares. When constructed in natural lands, this results in the loss of considerable habitat and the fragmentation of remaining habitat. This potentially constitutes a threat to San Joaquin kit foxes as well as other at-risk species. Consequently, when some of the initial utility-scale facilities were constructed within the San Joaquin Desert region, the environmental compliance permits for these projects included a requirement to assess the impacts of the facilities on San Joaquin kit foxes. The results of these studies were surprising and quite unexpected. Kit foxes continued using the lands upon which the facilities were constructed. Also, the demographic (e.g., survival, reproduction) and ecological (e.g., space use, den use, food habits) attributes of foxes using solar farms were similar to those of foxes using nearby natural lands. In some cases, the attributes were even better (e.g., higher survival) for foxes using the solar farms. Furthermore, there were indications that the solar farms may even provide some benefits to foxes such as reduced predation risk. An extremely important caveat is that the results above likely were achieved due to the implementation of numerous mitigation measures during construction of the solar farms and their subsequent operation and maintenance. Another very significant mitigation measure was that for each facility, a considerable quantity of habitat was permanently conserved and endowments were provided for the protection and management of these lands. This will immensely benefit kit foxes as well as co-occurring species.

In this book, researchers who have been working extensively with kit foxes on solar farms attempt to summarize study results, relevant observations and experiences, and technical details. Chapter 2 describes the overlap in suitability of lands as habitat for kit foxes and as optimal sites for solar farms, thus defining the potential conflict between the two. Chapters 3-6 constitute the real core of the book. In these chapters, the results of multi-year studies conducted at four solar farms (Fig. 1-2) are presented with three of these detailing robust quantitative comparisons of demographic and ecological attributes between kit foxes using solar farms and kit foxes using nearby natural lands. Chapter 7 describes the responses of kit foxes during the construction of solar farms. In Chapters 8 and 9, the mitigation measures implemented during solar farm construction and operation are detailed, and the habitat conservation measures associated with the construction of solar farms are described in Chapter 10. Chapter 11 describes some of the other wildlife species that have been detected using solar farms in the San Joaquin Desert region. Finally, Chapter 12 provides some concluding observations including recommendations for future solar farm construction and operation in the San Joaquin Desert region as well as other regions.

The overarching goal of this book is to summarize relevant information gathered to date on the interactions between San Joaquin kit foxes and solar farms. The data gathered and the lessons learned should provide invaluable guidance for the continued construction of solar farms in the San Joaquin Desert region. Much of the information presented also could, and should, be applied in other regions as well such as the Mojave Desert where a number of at-risk species are present and numerous solar farms have been or will be constructed. Based on the available information, San Joaquin kit foxes and solar farms can coexist with facilitation by the implementation of appropriate mitigation and conservation measures. This book makes that case and provides abundant supporting evidence.

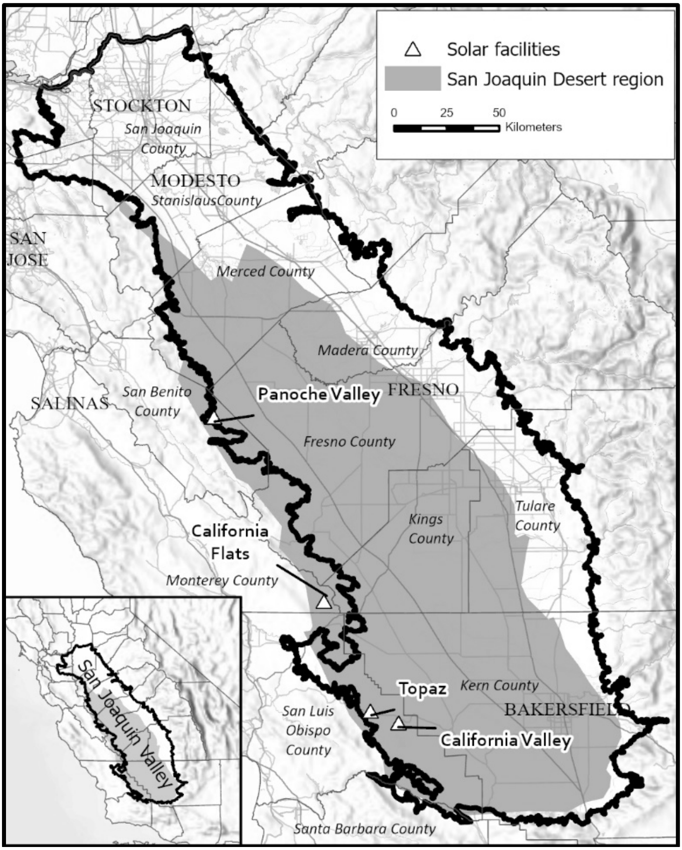

Figure 1-2. Locations of four solar farms in the San Joaquin Desert of California where multi-year studies of the effects of solar farms on San Joaquin kit foxes were conducted.

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CHAPTER 2

COMPETITION FOR SPACE: OVERLAP OF SUITABLE LANDS FOR SOLAR FARMS AND RARE SPECIES IN THE SAN JOAQUIN VALLEY, CALIFORNIA

SCOTT E. PHILLIPS AND BRIAN L. CYPHER

Note: This chapter is largely a reprint, with some minor modifications, of an article previously published in the journal *Western Wildlife* (Phillips, S. E., and B. L. Cypher. 2019. Solar energy development and endangered species in the San Joaquin Valley, California: Identification of conflict zones. Western Wildlife 6:29-44.). It is reprinted here with permission from *Western Wildlife*.

Abstract: *A number of animal and plant species in the San Joaquin Valley (SJV) of California are rare due to profound habitat loss and degradation. A significant portion of the remaining habitat for these species also has high potential for solar energy generation. We conducted a spatially explicit GIS analysis of lands in the SJV to identify areas of potential conflict between rare species and solar energy development and also to identify areas where such conflict would be minimized. We modeled solar energy generation potential and also modeled habitat suitability for five federally listed animal species whose ranges encompass those of additional rare species. We then layered the model results to identify areas of greater or lesser conflict. Approximately 4,145 km*^{2} *have moderate to high potential for solar energy development and also have moderate to high quality habitat for listed species. The potential for environmental conflicts is high on these lands. Approximately 8,436 km*^{2} *have moderate to high potential for solar energy development but no or low-quality habitat for rare species. These lands are the optimal sites for solar energy generation projects. Furthermore, siting projects on lands with no or marginal habitat value could enhance the value*

of these lands for rare species and create linkages between occupied areas. Our approach can be applied in other locations to identify general areas and even specific locations where siting solar facilities would result in minimal or no impacts to sensitive resources and possibly even enhance regional conservation efforts.

Introduction

Numerous utility-scale solar facilities have been constructed or proposed for the San Joaquin Valley (SJV) region of California. In addition to high insolation rates and an abundance of flat terrain, relatively low land prices and proximity to transmission corridors enhance the attractiveness of this region for such facilities (Pearce et al. 2016); however, a large number of rare species also occurs in this region due to geographic isolation and high levels of endemism coupled with profound habitat loss (U.S. Fish and Wildlife Service [USFWS] 1998). By 2004, approximately 70% of the over 3.9 million ha of historical habitat in the SJV had been replaced by irrigated agriculture and urban development (Kelly et al. 2005). Thus, developments in the remaining natural lands further enhance the risk of extinction for multiple animal and plant species.

We conducted a spatially explicit analysis using a GIS-based model to assess location-specific potential for conflicts between listed species and solar energy development in the SJV. Our objectives were to identify areas more conducive to solar energy facilities due to high solar energy potential and low impacts to rare species, and identify areas where solar projects should be avoided based on the presence of high-value habitat and the potential for the occurrence of multiple rare species.

Methods

Study area

The SJV in central California (see Fig. 2-1) extends about 415 km from north to south, and encompasses approximately 3.44 million ha below the 152-m (500-ft) contour (USFWS 1998). The SJV is bounded on the east by the Sierra Nevada, on the west by the Coast Ranges, on the south by the Transverse Ranges, and on the north by the extensive delta of the Sacramento and San Joaquin Rivers. The SJV is an arid region characterized by hot, dry summers and cool, rainy winters. Historical habitat types included arid grasslands, arid shrublands, woodland savannahs, and lakes and marshes on the valley floor connected by rivers and sloughs (USFWS

1998, Germano et al. 2011). The savannahs, lakes, and wetlands have been all but eliminated by agricultural and urban development, and the grasslands and shrublands have been significantly reduced to a fraction of their former acreage (USFWS 1998, Kelly et al. 2005). Urban regions in the SJV are growing rapidly and major population centers include Stockton, Modesto, Merced, Fresno, Visalia, and Bakersfield. Most constructed and planned solar energy plants are located in the more arid western and southern SJV described by Germano et al. (2011) as the San Joaquin Desert.

To examine conflicts between listed species and energy development in the SJV, we developed a GIS-based model (see Appendix A in Phillips and Cypher 2019 for model schematic) to determine how those areas best-suited for solar development compare with the suitability of remaining habitat for five federally or state listed animal species typically associated with the San Joaquin Desert. The five species were the Federally Endangered and California Endangered blunt-nosed leopard lizard (*Gambelia sila*), Federal Endangered and California Threatened San Joaquin kit fox (*Vulpes macrotis mutica*), Federal Species of Concern and California Threatened San Joaquin antelope squirrel (*Ammospermophilus nelson*), Federal Endangered and California Endangered giant kangaroo rat (*Dipodomys ingens*), and San Joaquin kangaroo rat (*D. nitratoides*), which consists of three subspecies: Federal Endangered and California Endangered Tipton kangaroo rat (*D. n. nitratoides*), Federal Endangered and California Endangered Fresno kangaroo rat (*D. n. exilis*), and Federal Species of Concern and California Species of Special Concern short-nosed kangaroo rat (*D. n. brevinasus*). We selected these species because of their relatively wide distributions, which encompass those of most other rare species occurring in the San Joaquin Desert. GIS models have been used elsewhere to identify areas of conflict between solar energy development and conservation goals (Cameron et al. 2012, Stoms et al. 2013). Our analysis did not explicitly include other regionally important components of conservation concern, in particular wetland habitats and associated species, and listed or rare plants.

Suitability for solar development

We evaluated suitability for solar development using methods similar to those used by Butterfield et al. (2013) to evaluate site-suitability for large-scale (e.g., photovoltaic sites > 20 MW) solar facilities. Our criteria included land use, terrain, protected land status, and insolation rates (Table 2-1). These criteria are not comprehensive and other factors, such as proximity to transmission corridors and land values, also can affect site selection for solar farms; however, as noted by Pearce et al. (2016), these other factors can change rapidly and so we did not consider them in this analysis. We assumed that utility-scale solar facilities sites would need to be larger than 80 ha (200 acres) in area based on a high estimate (75th percentile) of acres/MW for photovoltaic solar sites larger than 20 MW estimated by the National Renewable Energy Laboratory (NREL 2013), and screened out areas smaller than that minimum size. Because we did not include all possible factors, some areas identified as suitable may be impractical to develop because of other limiting factors.

Table 2-1. Criteria used to evaluate suitability for large-scale solar development in the San Joaquin Valley, California. Slope was averaged over a 128-ha (320-ac) neighborhood.

	Potential for solar development		
Criteria	None to low	Moderate	Highest
Land use	Developed (urban areas, industrial, extractive), permanent crops (orchards or vineyards), open water, forests, or wetlands.	Irrigated farmland excluding permanent crops (e.g., row crops)	Rangeland, fallow/idle farmland, or dryland-farmed areas (e.g., winter wheat)
Slope	> 15°	< 15°	< 15°
Protected lands	Protected lands (public lands, private conservation lands, or conservation easements)	Other private land	Other private land
Insolation	N/A	5.68 - 6 kWh/m^2/day (or row crops with > 6 kWh/m^2/day)	6.00–6.42 kWh/m^2/dday

We developed a GIS layer of current land use classes based on a combination of the National Agricultural Statistics Service (NASS) 2014 cropland data layer (U.S. Department of Agriculture NASS 2015) and the California Department of Conservation (CDOC) Farmland Mapping and Monitoring Program (FMMP) important farmland layer (CDOC 2015). We combined land use classes from both layers to create a simplified classification (Table 2-2) that we used to evaluate both solar site potential and habitat availability. The two source layers (FMMP, NASS) are created using different methods and for different purposes and so differ in thematic accuracy (correct classification) and thematic resolution (number of mapped land use classes). The FMMP layer is created using direct interpretation from aerial photography and field observations (CDOC 2004), whereas NASS uses semi-automatic classification of satellite imagery. Based on a comparison of NASS classifications to observed classifications in reconnaissance surveys (Endangered Species Recovery Program, unpubl. data), we found that semi-automatic classification techniques are less reliable for land uses that have similar vegetation and ground cover such as rangeland and idle farmland (two important categories for our analysis). We also found that the FMMP included a more accurate depiction of the extent of rangeland but lacked the thematic resolution (detailed land use categories) of NASS (e.g., orchards, vineyards, wetlands, and forest). Because it takes less time to produce, NASS is updated on a yearly cycle, and is usually more current than what is available from FMMP at any given time. To take advantage of both the thematic accuracy of FMMP and thematic resolution of NASS, we used a GIS overlay analysis to combine information data from both sources using the following classification rules: Where FMMP land use was classified as agricultural land or unknown, we used the more-detailed categories from the NASS. Otherwise, we used the FMMP land use categories that we found to be more thematically accurate for non-agricultural areas, urban areas, and water. For the non-agricultural area (e.g., rangeland), we added supplemental information where the more detailed NASS data had identified areas of forest or wetlands (classes included in the NASS but not included in the FMMP).

Table 2-2. Land use classification used to evaluate solar and habitat potential in the San Joaquin Valley, California. FMMP = Farmland Mapping and Monitoring Program 2012 important farmland layer from the California Department of Conservation. NASS = National Agricultural Statistics Service 2014 cropland data layer.

Land use class	Primary source	Secondary source
Urban/Industrial/Other developed	FMMP	NASS
Permanent crops	NASS[1]	-
Row crops	NASS[1]	-
Fallow or dryland farmed	NASS[1]	-
Rangeland	FMMP	NASS
Barren	NASS[1]	-
Forests or wetlands	NASS[1]	-
Water	FMMP	NASS

[1] No equivalent category in FMMP.

We calculated slope (in degrees) from digital elevation models available from the U.S. Geological Survey (USGS) National Elevation Program (USGS 2014). To screen out small patches of flat slope in otherwise steep terrain, we used a spatial averaging function (Focal Statistics in ArcGIS). Specifically, we calculated each cell as the mean value of cells within a 640-m-radius circular area (approximately 320 ac or 128 ha).

We screened out areas identified as protected fee or easement lands (GreenInfo Network 2015). While fee and easement lands have varying levels of protection from development such as large-scale utility solar facilities, we considered them all as having generally higher protection against solar development and focused our analysis on private lands. We also estimated insolation using solar resource data available from the NREL (NREL 2012). Solar resource data were derived from NREL estimates for photovoltaic energy (tilt = latitude collector) available as 10-km grids. To match the resolution of our other data sources, we converted the grids to a higher-resolution surface using a spatial interpolation function using an Inverse Distance Weighting function in ArcGIS (Power = 2; Search Radius = 12 neighboring cells). We combined map layers for the four criteria using a series of GIS Map Algebra steps statements to create a composite map of potential suitability for solar development consisting of three categories: Low, Moderate, and High (Fig. 2-1).

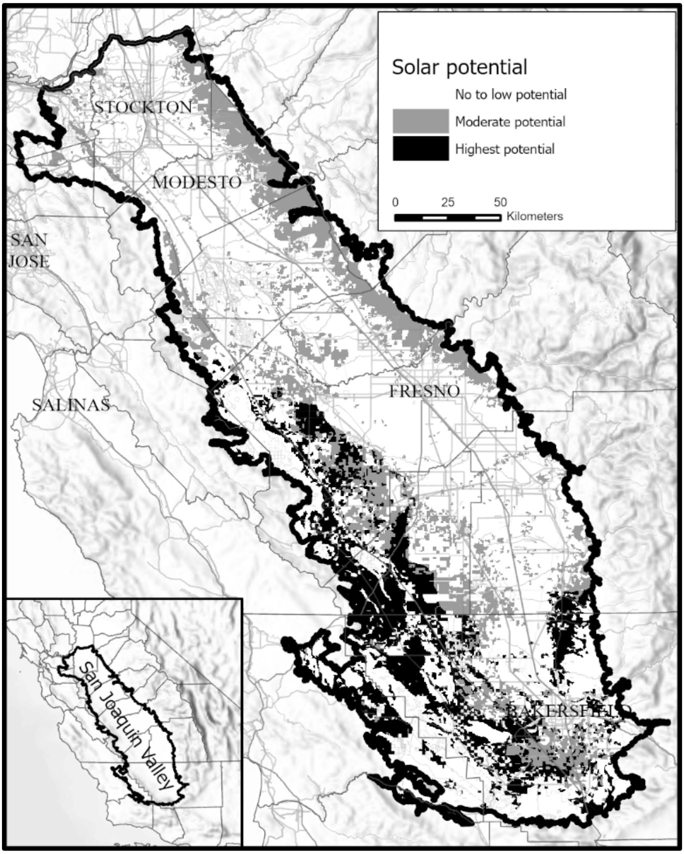

Figure 2-1. Estimated solar potential based on land use, protected land status, slope, and insolation in the San Joaquin Valley, California.

Suitability for listed species

We evaluated habitat quality for the listed species using an approach similar to Germano et al. (2011) who used the distribution of multiple species along with ancillary information to identify a general region (i.e., San Joaquin Desert) important to multiple arid-adapted species of the SJV. Our approach was to develop a relatively detailed (approximately 1:125,000) GIS layer of historical land cover. To do this, we digitized map units from a set of soil surveys of the San Joaquin Valley that pre-date most of the conversion of rangelands to irrigated agriculture (Nelson et al. 1918,