Arnold Schwarzenegger
Governor

CORRIDOR EFFECTS ON THE ENDANGERED PLANT KERN MALLOW AND ITS HABITAT

PIER FINAL PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
California State University, Stanislaus
Endangered Species Recovery Program

May 2005
CEC-500-2005-063

Prepared By:
California State University, Stanislaus
Endangered Species Recovery Program
Fresno, California
Ellen A. Cypher, Project Manager

Contract No. 500-02-004
Work Authorization MR-03-16

Prepared For:
California Energy Commission
Public Interest Energy Research (PIER) Program

Gina Barkalow,
Contract Manager

Kelly Birkinshaw,
Program Area Team Lead

Ron Kukulka,
Acting Deputy Director
ENERGY RESEARCH AND DEVELOPMENT DIVISION

Robert L. Therkelsen
Executive Director

Acknowledgements

The primary author expresses appreciation to the following individuals for their contributions to this study:

- Upekala Wijayratne and Emily Orling for their hard work in the field and for remaining cheerful throughout the field season.
- Alexander Brown, Stephen Harrison, and Jessica Huddleston for assistance in the field and the laboratory.
- Patrick Kelly, Daniela Giovannetti, and Ann Roussow for contract administration.
- Brian Cypher for his assistance with conception and design of the project.
- The staff of the California Energy Commission and the California Institute for Energy and Environment for funding the project and providing guidance throughout the contract period.

Please cite this report as follows:

Cypher, Ellen. 2005. *Corridor Effects on the Endangered Plant Kern Mallow and Its Habitat.* California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2005-063.

Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies

What follows is the final report for the Effect of Transmission Line Corridors on the Demography of the Endangered Plant Kern Mallow and on Plant Species Composition in the Lokern Area project, contract number 500-02-004, work authorization MR-03-16, conducted by the California State University, Stanislaus, Endangered Species Recovery Program. The report is entitled *Corridor Effects on the Endangered Plant Kern Mallow and Its Habitat.* This project contributes to the Energy-Related Environmental Research program.

For more information on the PIER Program, please visit the Energy Commission's Web site at www.energy.ca.gov/pier or contact the Energy Commission at (916) 654-4628.

Table of Contents

List of Figures

List of Tables

Abstract

This project studied whether transmission lines are contributing to the decline of endangered species in the Lokern area of Kern County, California. We compared the demography of the endangered plant Kern mallow (*Eremalche kernensis*) in transmission line/road corridors and control (undisturbed) areas, quantified the abundance of nonnative plants relative to distance from roads, and collected data regarding Kern mallow population stability.

Kern mallow survival was significantly lower in corridors than in controls, but flower production and seed-to-ovule ratios were not. Kern mallow abundance was not correlated with distance from roads. Survival and reproductive rates of Kern mallow were lower in burned areas, and Kern mallow plants in burned areas were less tolerant of disturbance from corridors or livestock grazing than those in unburned areas. Soil type, burn history, and grazing history seem to have a greater influence on plant species composition in the Lokern area than do corridors. The relative cover of nonnative species did not differ between corridors and controls and was not correlated with distance from roads.

Our preliminary conclusion is that road corridors, with or without transmission lines, are reducing the overall survival rate of Kern mallow but are not affecting the dominance of nonnative plants in the Lokern area. Restricting access to existing roads is not necessary, but creation of new access roads should be avoided. Better management of livestock and wildfires is recommended. Kern mallow population trends cannot be predicted until additional data are collected.

Keywords: Kern mallow, *Eremalche kernensis*, endangered species, nonnative plants, transmission lines, corridors

Executive Summary

Introduction

The Lokern area of western Kern County, California, is a key area for the survival and recovery of several endangered species, including the plant Kern mallow (*Eremalche kernensis*), blunt-nosed leopard lizards (*Gambelia sila*), giant kangaroo rats (*Dipodomys ingens*), and San Joaquin kit foxes (*Vulpes macrotis mutica*). Kern mallow does not grow anywhere else, so maintaining the health of the Lokern population is vital to the species' existence.

The Lokern area is also important to California's energy supply because numerous electrical transmission lines traverse the area en route to the Midway electrical substation near the town of Buttonwillow. Each transmission line corridor includes an access road for installation and maintenance. Utility companies are required to minimize the amount of area they disturb and to buy comparable land for nature reserves, but the transmission line corridors nonetheless cause fragmentation of the endangered species habitat in the Lokern area.

Conservation biologists are concerned about the effect of roads on endangered species and natural lands because research elsewhere has shown that roads alter the physical and chemical conditions of the habitat, potentially making it unsuitable for native species, and roads often create conditions favorable for growth of nonnative plants. Nonnative plants compete with native plants for water and nutrients and change the structure of the habitat, impeding movements of small animals such as lizards and kangaroo rats. Endangered species may not be able to persist when nonnative plants invade their habitat.

Purpose

The primary purpose of this research was to determine whether transmission lines and their associated road network in the Lokern area are contributing to the decline of Kern mallow. A secondary goal was to determine whether the roads associated with transmission lines favor nonnative plants and therefore degrade habitat for the suite of endangered species in the Lokern area. The ultimate goal was to identify appropriate measures to alleviate any effects of transmission line corridors that may be contributing to the decline of Kern mallow or the degradation of the larger Lokern ecosystem.

Project Objectives

The project had four specific objectives:

- Determine whether Kern mallow plants growing in transmission line corridors have reduced survival or reproduction compared to plants growing in the midst of undisturbed (control) areas
- Determine whether nonnative plants are more abundant in transmission line corridors than in undisturbed (control) portions of the Lokern area
- Collect data that will help determine whether the Kern mallow population is stable or declining overall

- Provide recommendations on the siting of new transmission lines and the management of existing transmission lines for the benefit of rare and endangered species in the Lokern area

Project Outcomes

Our findings were as follows:

- Survival rates of Kern mallow were significantly lower in corridors than in control areas, but reproductive rates were not.
- Kern mallow distribution and cover were not affected by the proximity of roads.
- Survival and reproductive rates of Kern mallow were lowest in areas that had burned in a 1997 wildfire and have since been disturbed by livestock or use of corridors.
- Overall, 81.5% of the Kern mallow seedlings present in February 2004 survived to the flowering stage, but only 45.1% survived long enough to produce seeds.
- The number of seeds produced per Kern mallow plant was lower than would be expected based on their reproductive potential.
- Nonnative plants were no more abundant in corridors than they were elsewhere in the Lokern area, but they were more diverse near roads.

Conclusions

Our preliminary conclusions, based on a small number of plots and one growing season with below-average rainfall, include the following:

- Road corridors reduce the overall survival rate of Kern mallow, regardless of whether or not the corridors contain transmission lines.
- Restricting access to roads is not likely to improve Kern mallow survival because reduced survival rates were found along even the most lightly traveled roads.
- Kern mallow plants in burned areas are less tolerant of disturbance from corridors or livestock grazing than those in unburned areas.
- Nonnative plants are widespread in the Lokern area, even in a dry year, but roads do not contribute to their dominance.
- Soil type, burn history, and grazing history appear to have a greater influence on plant species composition in the Lokern area than do corridors.
- Stability of the Kern mallow population cannot be determined yet because additional data are needed.

Recommendations

Our research has led to the following recommendations:

- Creation of new access roads in Kern mallow habitat should be avoided. New transmission lines, wells, or other facilities could be installed along existing roads, or stretches of transmission lines and pipelines that cross Kern mallow habitat could be designated as "no vehicular access" areas. In this way, very little additional Kern mallow habitat would be lost and the amount of corridor area, which is subject to reduced Kern mallow survival, would not increase.
- Vehicles should stay within the defined road margins in Lokern during the growing season (October through May) to avoid killing Kern mallow plants that grow immediately adjacent to roads.
- Unavoidable construction in the Lokern area should occur during the dormant season for Kern mallow (June through September) to avoid killing growing plants. The topsoil should be salvaged and respread as soon as possible because it will likely contain viable Kern mallow seeds at that time of year.
- Wildfires in the Lokern area should be controlled as quickly as possible to prevent detrimental effects to any more of the Kern mallow population. Management options (including controlled burns) should be considered to reduce the incidence of wildfires.
- Sheep should not be trailed, penned, bedded, or otherwise concentrated in portions of the Lokern area that have burned because intensive grazing severely reduces Kern mallow survival and reproduction in burned areas. The burned areas can be easily identified by the lack of mature shrubs.
- Follow-up research on the effects of corridors, burning, and livestock grazing should be designed to increase sample sizes for statistical analysis.
- Future research should be considered to identify the specific factors that are limiting Kern mallow in the burned areas, followed by implementation of appropriate restoration techniques.
- Although nonnative plants are found throughout the Lokern area, the use of locally occurring native plants is encouraged for revegetation projects to increase the proportion of native plant cover.

Benefits to California

This project helps resolve a potential conflict between California's electricity grid and its endangered species. By identifying the environmental and habitat impacts of transmission lines and recommending appropriate management of existing corridors, this work helps protect rare and endangered species in the Lokern area—specifically, the endangered plant Kern mallow.

If transmission infrastructure expansion becomes necessary in the Lokern area, planners and decision makers will be able to use the results of this study to minimize impacts on resident species. The methodology and the recommendations may also be helpful in other parts of California where transmission lines and roads could conflict with endangered species.

Californians may continue to rest assured that our natural heritage is being protected without impeding delivery of our electrical power supply.

1.0 Introduction

1.1 Background and Overview

California has about 64,000 kilometers (40,000 miles) of electricity transmission lines crisscrossing its varied landscapes (California Energy Commission, in press). These lines constitute the high-voltage portion of the state's electricity grid, connecting electricity-generating plants to substations, which lower the voltage and allow power to be delivered to our doorsteps. California also has the most extensive and diverse population of native animals and plants of any state in the country, comprising almost 1,000 native vertebrate species and approximately 5,000 native plant species (Schoenherr 1992). The health of each of these two valuable resources—California's electricity transmission infrastructure and its wealth of plant and animal species—is essential for maintaining the quality of life in the state.

When new or increased electricity demand requires transmission lines to cross sensitive habitat, those responsible for siting new transmission lines need information on the potential impacts of those lines on threatened or endangered species. Hundreds of animal and plant species in California are listed as threatened or endangered (California Department of Fish and Game 2004); therefore, it is crucial that planners and decision makers receive sound scientific information regarding the potential impacts of new line construction on these species.

The need for scientific information is especially urgent now, because the state needs to expand its transmission lines. A recent study of transmission research and development in California concluded that "expansion of the California transmission system has not kept pace with demand over the last 20 years… [resulting in] congestion, reliability problems, and higher costs" (California Energy Commission 2003). Moreover, the new renewable energy units that will be brought online in response to the state's Renewable Portfolio Standard will need new transmission lines to tie them to the electricity grid.

The primary goal of this research was to determine whether transmission lines and their associated road network in the Lokern area of Kern County, California, are contributing to the decline of the endangered plant Kern mallow (*Eremalche kernensis*). A secondary objective of this research project was to determine whether the roads associated with transmission lines are contributing to dominance by nonnative plants and therefore degrading habitat for the suite of endangered and threatened species in the Lokern area.

Kern mallow, an annual plant in the mallow family (Malvaceae), is found only in the Lokern area of western Kern County (U.S. Fish and Wildlife Service 1998). By definition, an annual plant lives less than one year; its entire life cycle from seed germination to seed production is completed in a single growing season. Kern mallow flowers have five petals (see photo in Appendix A); they are usually white but are occasionally pale lavender. The seeds are similar in size and shape to a poppy seed and are arranged in a circular, wheel-like pattern. As with many desert annuals, the size and flowering season of Kern mallow vary greatly depending on precipitation. In dry years, Kern mallow plants may be only a few centimeters tall with one or two flowers, whereas in wet years the plants may be 50 cm (20 inches) tall with hundreds of flowers. Kern mallow typically flowers in March and early April, although flowers may be present in late February or into May if weather conditions are favorable (E. Cypher unpublished data).

Kern mallow was federally listed as endangered in 1990, primarily on account of habitat loss from oil and gas development and cultivation of crops (U.S. Fish and Wildlife Service 1990). The current range of Kern mallow is approximately 2,000 hectares (~5,000 acres), which represents only about 10% of the remaining natural land in the Lokern area. The reasons why Kern mallow does not occupy the other 90% are not fully understood but appear to be related to soil factors and previous habitat disturbance (Andreasen et al. 2002). The currently occupied Kern mallow habitat is subject to ongoing disturbances from oil and gas development, cultivation, transmission line construction and maintenance, and inappropriate grazing regimes. Other ongoing threats to this species are competition from nonnative plants and potential loss of pollinating insects (U.S. Fish and Wildlife Service 1990, 1998).

Recovery[1] actions for Kern mallow include preventing further habitat loss and managing the remaining habitat appropriately. A stable or increasing population size is critical to the long-term survival of Kern mallow (U.S. Fish and Wildlife Service 1998). Any declines would have to be addressed before the population dropped below a critical threshold, and any incompatible activities would have to be curtailed to ensure the continued existence of the species. However, the population trend is unknown at this time, and the effects of ongoing activities on Kern mallow have not been investigated.

In addition to Kern mallow, the Lokern area provides habitat for a number of endangered or threatened animals, including blunt-nosed leopard lizards (*Gambelia sila*), giant kangaroo rats (*Dipodomys ingens*), San Joaquin kangaroo rats (*Dipodomys nitratoides*), San Joaquin antelope squirrels (*Ammospermophilus nelsoni*), and San Joaquin kit foxes (*Vulpes macrotis mutica*). As with Kern mallow, habitat loss is the primary reason that these animals have been listed as endangered or threatened. The Lokern area is key for recovery of these species as well as Kern mallow. Appropriate habitat management for the animals may differ from that for Kern mallow, but habitat loss and degradation contribute to declining populations of both endangered animals and plants (U.S. Fish and Wildlife Service 1998).

Numerous electricity transmission lines traverse the Lokern area en route to the Midway electrical substation east of Buttonwillow. Among these are transmission lines originating at the Diablo Canyon, La Paloma, Midway-Sunset, Morro Bay, and Sunrise power plants, as well as additional smaller power lines that bisect the Lokern area. Most of these have been present for a decade or more; however, the La Paloma and Sunrise lines were constructed since 2000 (Curt Uptain, California State University, Stanislaus, Endangered Species Recovery Program, personal communication 2004). Additional construction is likely given the increasing demand for energy in California. Although recently constructed transmission lines have been run parallel to existing lines, some habitat has been disturbed during each project. Mitigations required for new disturbances include minimizing the amount of area affected and

---

1 *Recovery* is the process by which listed species and their ecosystems are restored and their future is safeguarded to the point that protections under the Endangered Species Act are no longer needed. When an endangered or threatened species meets the criteria identified in an official recovery plan, it is considered to be recovered and can be removed from the list of endangered or threatened species.

compensating by acquiring additional reserve land, but the overall effect is still a net loss of habitat and degradation of the remaining habitat in the Lokern area.

Based on the length and width of transmission line corridors in the range of Kern mallow, more than 44 hectares (109 acres) of occupied Kern mallow habitat are estimated to have been destroyed or degraded by transmission line construction to date. After transmission lines are installed in similar natural communities in the Mojave Desert, vegetation typically takes 20 to 33 years to return to pre-disturbance cover and density. Species composition continues to be affected for even longer periods (Vasek et al. 1975a; Lathrop and Archbold 1980). Complete recovery from the roads and towers associated with transmission lines may take 100 years or more in the Mojave Desert (Lathrop and Archbold 1980). Given the similarity of the study area to the Mojave Desert, similar recovery times would be expected in the Lokern area, even if the roads were abandoned after transmission line installation.

Kern mallow habitat disturbance due to transmission lines occurs primarily during road construction and placement of power-line towers. Typically, shrubs are cleared from the desired road path or tower site by a front-end loader, which also churns up the soil surface. A grader then smooths the road surfaces for use by heavy equipment. Road fill is rarely if ever used in the Lokern area, and surfaces are not often compacted mechanically. Little vegetation grows on the road surfaces because vehicles use them regularly and because they are graded periodically to smooth out erosion gullies. Ongoing vegetation management is not necessary under transmission lines in the Lokern area because the vegetation is short and does not contact the wires (Randi McCormick, McCormick Biological Consulting, personal communication 2004). For placement of power-line towers, holes are drilled into the soil for each leg, then filled with concrete to create support structures. Soil that is removed from the holes may be spread along the corridor or transported off the site (Curt Uptain, California State University, Stanislaus, Endangered Species Recovery Program, personal communication 2004).

Dirt roads created for transmission line construction in the Lokern area typically remain open indefinitely. These roads are widely traveled by persons other than those repairing and maintaining the lines, including livestock operators, oil company employees and contractors, researchers, beekeepers, and recreational users. The dirt roads along transmission lines in the study area are lightly traveled, averaging perhaps one vehicle trip per day. Another road in the study area that was formerly paved but has not been maintained is used less than the dirt roads, averaging perhaps 10 vehicle trips per month. Roads are of concern for native species because they alter the physical and chemical conditions of the habitat, create openings available for colonization by nonnative plants, and act as dispersal corridors for seeds transported by vehicles or animals (Trombulak and Frissell 2000).

Vegetation in the Lokern area is a mosaic of arid shrublands and annual grasslands. The most widespread natural community in the area is Valley Saltbush Scrub, as defined by Holland (1986). The understory in the scrub areas consists of annual plants typical of Nonnative Grassland (Holland 1986). At least 80 plant species have been recorded in the Valley Saltbush Scrub and Nonnative Grassland communities of the Lokern area (E. Cypher, unpublished data). Among them, 50 (62.5%) are native, including the dominant shrubs common saltbush (*Atriplex polycarpa*) and spiny saltbush (*A. spinifera*). Despite the large percentage of native species present, nonnative species dominate the grasslands, including red brome (*Bromus madritensis* ssp. *rubens*), red-stemmed filaree (*Erodium cicutarium*), and foxtail barley (*Hordeum murinum*).

Repeated wildfires have killed many shrubs and thus converted much of the former shrubland in the Lokern area to Nonnative Grassland. Shrubs are gradually returning to the burned area, but their distribution is patchy. Rainfall in the Lokern area averages approximately 15 cm (5.9 inches) per year (Western Regional Climate Center 2004), with extreme variations in rainfall from year to year (Major 1977; Chang 1988).

All types of disturbance favor nonnative plants (Hobbs and Huenneke 1992; Prieur-Richard and Lavorel 2000; Randall and Hoshovsky 2000). The effect of nonnative plants on California ecosystems includes alterations in nutrient, hydrological, and fire cycles as well as competition and hybridization with native plants (Randall and Hoshovsky 2000). Dense stands of nonnative grasses also create unfavorable conditions for native wildlife (Goldingay et al. 1997; Randall and Hoshovsky 2000), including the rare animals found in the Lokern area (U.S. Fish and Wildlife Service 1998; Germano et al. 2001). Nonnative annual grasses are more of a problem than broad-leaved herbs in arid areas such as the Mojave Desert (Brooks 1999 and 2000a; Lovich and Bainbridge 1999) and the southern San Joaquin Valley (U.S. Fish and Wildlife Service 1998). In California grasslands, nonnative annual grasses have displaced native plants on a huge scale and are so pervasive that eradication is impossible (Heady 1977). However, the spread of newly introduced species can be curtailed if they are eradicated quickly, and widespread infestations can be managed to minimize their effects (Bossard et al. 2000).[2]

One way that roads favor nonnative plants is by deposition of nitrogen from vehicle exhaust. The higher nitrogen availability promotes growth of nonnative grasses, especially on nutrient-poor soils (Weiss 1999). Either paved or dirt roads can favor nonnative plants, but the effect is more pronounced when roads have improved surfaces (Greenberg et al. 1997; Lovich and Bainbridge 1999; Gelbard and Belnap 2003). On the Colorado Plateau, improved roads favored the growth of both native and nonnative plants immediately adjacent to the road edge, but 50 meters away from the road nonnative plants benefited much more than native plants (Gelbard and Belnap 2003). The overall "disturbance effect" of roads and other linear corridors extends far beyond their margins. For primary roads, the "effect zone" ranges from 305 to 810 meters (0.2 to 0.5 mile), whereas that for secondary roads is approximately 200 meters (0.1 mile) in width (Forman 2000).

---

[2] One opportunity for management of nonnative grasses is to prevent their recolonization after periods of low abundance. Declines in the abundance of nonnative grasses have been demonstrated in the Lokern area following several years of drought (E. Cypher, unpublished data). This is because the most common nonnative grass species do not have a long-lived seed bank. The seeds germinate but during droughts the grasses do not survive long enough to produce more seeds (Brooks 2000b). Anecdotal evidence indicates that red brome and other nonnative grasses in Lokern and nearby areas return to their former abundance after two or three years of normal or higher rainfall. The same pattern has been observed after fire (E. Cypher, unpublished data). It is possible that if disturbance is curtailed, nonnative grasses will not regain dominance after periods of low abundance. However, if patches of nonnative grasses remain through drought cycles, they are likely to recolonize rapidly after several successive seasons of above-average rainfall. Targeted removal of small nonnative grass patches and minimization of surface disturbance possibly could prevent widespread recolonization if the nonnative grasses were sufficiently localized.

The specific effects of transmission lines and roads on Kern mallow are unknown. Kern mallow grows in several of the transmission line corridors in Lokern, but it is found infrequently on the surface of the dirt roads (Olson and Magney 1987; E. Cypher, unpublished data). The effect of nonnative grasses on Kern mallow has been studied to some extent but has not been quantified with respect to population trends. One preliminary study on Kern mallow indicated that the survival rate of seedlings was reduced in dense stands of nonnative grasses compared to sparsely vegetated sites (Cypher 1994). Similarly, removal of competitors increased flower production significantly (E. Cypher, unpublished data).

Although the roads in the transmission line corridors may favor nonnative plants, the roads could have some favorable effects on Kern mallow or other native plants. In general, sparse vegetation on road surfaces and shoulders allows native plants to escape the competition present in dense nonnative annual grasslands. Increased moisture on the road margin from runoff may allow natives to grow larger than those receiving only ambient rainfall (Johnson et al. 1975; Vasek et al. 1975b). Native species also may benefit from seed dispersal by animals or vehicles traveling along roads. These positive effects may be more pronounced along improved roads than along dirt roads, as was observed on the Colorado Plateau (Gelbard and Belnap 2003).

1.2 Project Objectives

This project addressed the following objectives:

1. Determine whether Kern mallow plants growing in transmission line corridors have reduced survival or reproduction compared to plants growing in the midst of undisturbed (control) areas. Compare survival and reproductive rates of marked plants between corridors and control areas using statistical tests.

2. Determine whether nonnative plants are more abundant in transmission line corridors than in undisturbed (control) portions of the Lokern area. Compare relative cover of nonnative species on sampling plots in corridors to those in control areas using statistical tests.

3. Collect data that will help determine whether the Kern mallow population is stable or declining overall. This determination requires at least two years of data on survivorship, seed bank density, and seed-to-ovule ratio. The 2004 field season represents the first year of data. The observed values for the relevant factors will be reported herein.

4. Provide recommendations on the siting of new transmission lines and the management of existing transmission lines for the benefit of rare and endangered species in the Lokern area. These recommendations will be based on the patterns observed during the 2004 field season. Evaluating the effectiveness of the recommendations in protecting endangered species habitat is beyond the scope of this study because it could not take place until the measures had been implemented and it would require additional monitoring.

1.3 Report Organization

The methods and results are reported separately for each of the first three objectives identified in Section 1.2. The fourth objective was to provide recommendations; these are presented in the Conclusions and Recommendations section following Project Outcomes because they are based on the results of all the research tasks combined. The relevance of the findings also is discussed in the Conclusions and Recommendations section, in the same order as the objectives. Photographs of Kern mallow and the study area are included in Appendix A.

2.0 Project Approach

For the purposes of this report, "corridor" refers to the combined area under a transmission line and its associated access road, including 10 meters (33 feet) beyond the discernable road margin (outer edge of pavement, dirt shoulder, or vehicle track). Where transmission lines occurred on both sides of a dirt road, the corridor was defined from the outermost cable of one line to the outermost cable of the other. One corridor was not associated with a transmission line; it was defined as 10 meters beyond the road margin on each side of the road. Control plots were at least 500 meters (1640 feet or 0.3 mile) away from the nearest corridor and were paired with at least one corridor plot in terms of plant community, soil type, fire history, and grazing status. For the analysis of plant species composition only (relative cover and richness[3]), all quadrats[4] 100 meters (328 feet) or more from a corridor were considered to be control areas. Plot names were assigned based on the Cadastral section number followed by the type of corridor or control (e.g., 15 road, 21 wooden, 22 control).

2.1 Objective 1: Survival and Reproduction

Objective 1: *Determine whether Kern mallow plants growing in transmission line corridors have reduced survival or reproduction compared to plants growing in the midst of undisturbed (control) areas.*

To determine whether Kern mallow plants growing in corridors differed in survival or reproduction from plants growing in control areas, individual plants were marked in the seedling stage and tracked throughout their life cycle. Approximately 150 plants were marked in each of 10 subpopulations in the Lokern area, including 6 corridor plots and 4 control plots. At maturity, 2 of the 10 subpopulations (one corridor and one control plot) proved to be desert mallow (*Eremalche exilis*) rather than Kern mallow and were therefore omitted from the study.[5] Kern mallow plants were selected at random within each square meter of the plot, marked with a small metal frame, and labeled individually. Plots varied in size depending on Kern mallow density and road straightness. Corridor plots typically were 100 to 150 meters long and 5 meters wide (328 to 492 feet long by 16 feet wide). Fifty plants were marked each in the 0–1 meter, 2–3 meter, and 4–5 meter bands parallel to the corridor (0–3.3 feet, 6.6–9.8 feet, and 13.1–16.4 feet bands); gaps between the bands allowed researchers to access marked plants without disturbing them. Control plots were typically longer and wider because Kern mallow densities were lower; thus a larger area was needed to obtain 150 plants separated by at least a meter. One modification to the proposed methods was that marking of Kern mallow plants continued

---

[3] *Richness* is the number of species present.

[4] A *quadrat* is a rectangular sampling unit.

[5] Desert mallow is a closely related species that looks very similar to Kern mallow and can be distinguished by close examination of the flower parts. However, the seedlings of the two species are indistinguishable.

into the first week in March because random selection and marking of plants was more time-consuming than anticipated.

Among the five corridor plots, two were along dirt roads under a metal-tower transmission line, two were along dirt roads under a wooden-pole transmission line, and one was along a road but not under a transmission line (Figure 1, Table 1). The “metal” corridor included two separate transmission lines: one north and one south of a single dirt access road. The towers on the two lines were different in design, but each carried six cables, and the four metal supports for each tower were set into concrete bases. The total width of the “metal” corridor, including both transmission lines and the intervening access road, was approximately 50 meters (164 feet). The “wooden” corridor included a single set of wooden telephone-type poles with three cables; the line crossed the dirt access road periodically. The “wooden” corridor was approximately 25 meters (82 feet) wide from the outermost cable to the far side of the access road. Although two study plots were located in the same “metal” corridor and two were in the same “wooden” corridor, they were independent because other aspects of site history differed (Table 1). In the case of the fifth corridor plot, the road had been paved decades ago; it has not been maintained and the road surface was therefore a mosaic of pavement and dirt. It was approximately 10 meters (33 feet) wide.

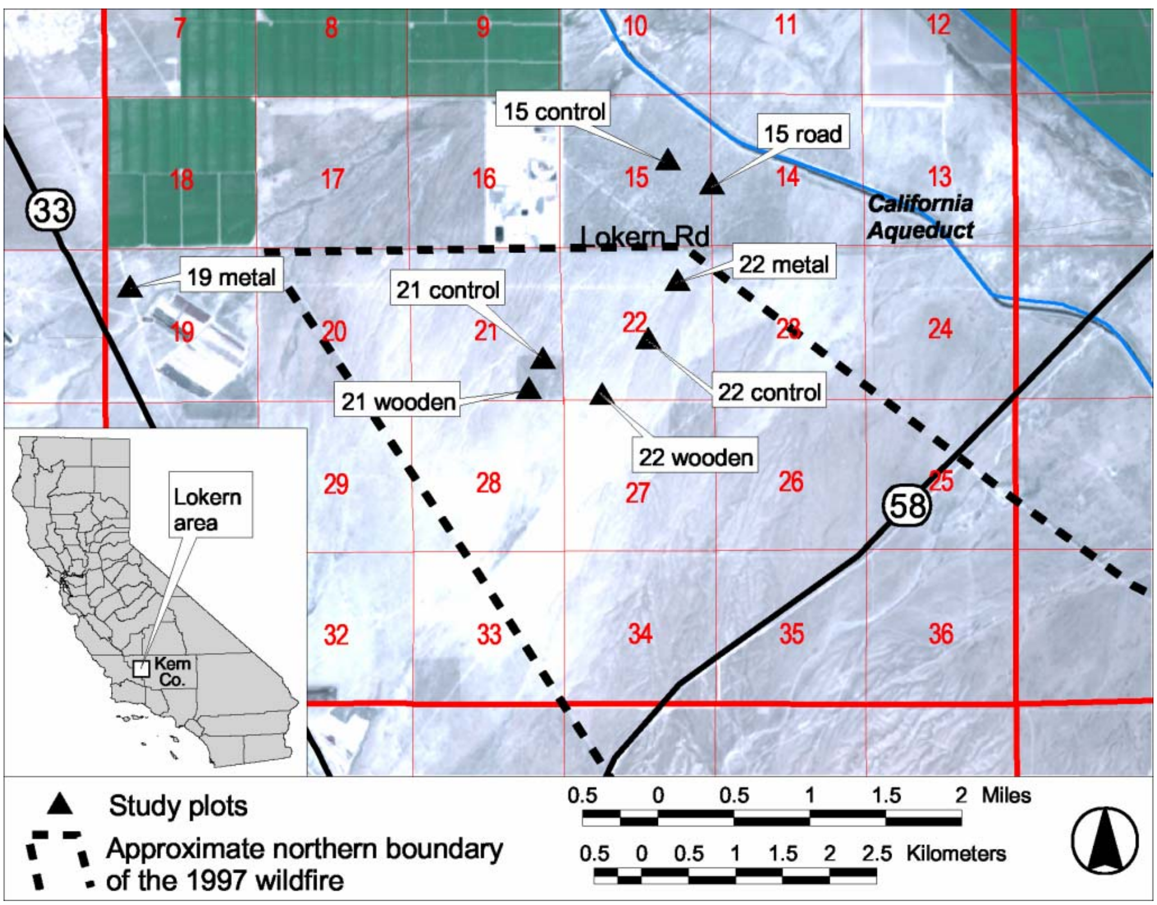

Figure 1. Location of the study plots in the Lokern area, Kern County, California

The set of eight plots represented a diverse combination of burning history and grazing status, hereinafter referred to as “site history” (Table 1). Five plots were in areas that had burned in a wildfire on May 19, 1997. The fire originated along Lokern Road just south of the hazardous waste facility and carried rapidly to the southeast, crossing State Highway 58 and continuing on into Elk Hills (Figure 1). High winds, dry grass, and low relative humidity contributed to a very high-temperature fire that incinerated the shrubs in its path. Sheep grazed two of the burned plots and all three unburned plots in March 2004. Sheep grazing patterns differed throughout the study area, however. Herders kept the sheep confined in the metal-tower transmission corridor for many days in March 2004, leading to intensive grazing in those areas. In contrast, sheep were allowed to wander in other grazed parts of the study area, resulting in a more dispersed grazing pattern. No unburned, ungrazed populations of Kern mallow were found and thus they were not included in the study design. Cattle have not grazed in the Lokern area since 2001 due to insufficient forage. However, between 1998 and 2001 three of the plot areas had been subject to dispersed cattle grazing (Table 1). Plot pairs tested in subsequent analyses were 15 control/15 road, 15 control/19 metal (because the planned control plot for section 19 had only desert mallow), 21 control/21 wooden, 22 control/22 metal, and 22 control/22 wooden.

Table 1. Site history of the eight Kern mallow demographic monitoring plots in Lokern, 2004
(See text for additional information on timing of various events)

Plot Name	Corridor	Burned in 1997	Sheep Grazing 2004	Cattle 1998-2001
15 control	No	No	Dispersed	No
15 road	Yes	No	Dispersed	No
19 metal	Yes	No	Concentrated	No
21 control	No	Yes	None	No
21 wooden	Yes	Yes	None	No
22 control	No	Yes	Dispersed	Yes
22 metal	Yes	Yes	Concentrated	Yes
22 wooden	Yes	Yes	None	Yes

2.1.1 Survival

As annuals, Kern mallow plants are expected to die at the end of each growing season. Therefore, the marked plants were considered to have survived if they remained alive through the flowering stage (i.e., remained alive long enough to reproduce). Collection of final survival and reproductive data began in late March rather than April because hot, dry conditions led to early dieback of the Kern mallow. To test the null hypothesis[6] that survival rates were at least as great in corridors as in control plots, plot pairs were tested via the Wilcoxon signed ranks test.[7] The acceptable Type I error rate[8] was 5%, and the test was one-tailed.[9] The paired T test[10] was not applicable to this data set because the differences were not normally distributed.[11]

To determine whether site history had an effect, we also tested the null hypothesis that survival rates among all sampling plots were equal. Survival frequencies were compared via contingency table analysis[12] with multiple comparisons[13] (Zar 1984, page 401). The acceptable Type I error rate was 5%, and the test was two-tailed.[14] An analysis of variance[15] was not

---

[6] The *null hypothesis* assumes there is no difference between the variables being compared. If the observed difference is sufficiently large that it is unlikely to have been obtained by chance, one rejects the null hypothesis and concludes that there is a difference.

[7] The *Wilcoxon signed ranks test* considers whether the difference between paired values is consistently negative or positive.

[8] A *Type I error* occurs when one rejects a null hypothesis that is actually true. With a Type I error rate of 5%, the probability that we would reject a true null hypothesis is only 5%, i.e., we would reject a true null hypothesis only 5 times out of 100 trials.

[9] A *one-tailed test* considers whether one value is greater than or equal to another. In this case, we used a one-tailed test because we were asking whether corridors reduced the survival of Kern mallow. See also footnote 10.

[10] The *paired T test* is similar to the Wilcoxon test, but the paired T test considers the magnitude of the differences between values, not just whether the differences are negative or positive.

[11] The *normal distribution* is a characteristic pattern of many data sets that is a prerequisite for using most standard statistical techniques. In general, the alternative techniques for use with data that are not normally distributed are less likely to detect a false null hypothesis.

[12] A *contingency table analysis* compares the observed frequency of occurrence of individuals in two or more categories to the expected (theoretical) frequency of occurrence. Here, the “survival” variable has two categories (survived, died) and the “plot” variable has eight categories. The contingency table is appropriate for proportional data, although the actual counts are analyzed rather than the proportions.

[13] *Multiple comparison* is a technique for determining which categories among the set are significantly different.

[14] A *two-tailed test* considers whether one value is greater than or less than another. In this case, we used a two-tailed test because we were interested in whether plot history either improved or reduced the survival of Kern mallow. The decision on whether to use a one-tailed or two-tailed test is made before data collection begins.

[15] An *analysis of variance* simultaneously compares the effect of two or more factors and the interactions among those factors. At a minimum, one data point (i.e., sample) representing each possible combination of factors is needed to conduct the analysis, and additional requirements must also be met.

possible because it would have required at least 24 samples (one for each possible combination of factor levels) and we had only eight plots.

2.1.2 Reproduction

Reproductive success was evaluated at least twice for each plant between March 14 and April 8, 2004. The maximum number of flowers and fruits[16] observed at one time was considered to represent reproductive success per plant. Although fruit production alone would have been more indicative of the reproductive contribution to the next generation, circumstances were not favorable for that determination. When reproductive status was evaluated in mid-March, the number of flowers per plant was not recorded separately from the number of fruits. By late March, when fruit production was counted, some plants had been lost to sheep grazing. It is likely that some flowers matured into fruits before the plants were grazed, and the pre-grazing reproduction was considered to be more representative of the effects of corridors independent of sheep.

The reproductive success of corridor plots versus their paired control plots was compared via the paired-sample T test, using the median reproduction for each plot. The use of means was not appropriate because the data were not normally distributed and could not be normalized despite transformation,[17] but the paired T was acceptable because the set of differences was normally distributed. The null hypothesis was that reproductive rates were at least as great in corridors as in control plots, the acceptable Type I error rate was 5%, and the test was one-tailed. In addition, the null hypothesis that reproduction was equal among all sampling plots was tested to evaluate the effect of site history. The Kruskal-Wallis test[18] with multiple comparisons (Zar 1984, page 199) was used to evaluate the latter null hypothesis; the acceptable Type I error rate was 5%, and the test was two-tailed.

2.2 Objective 2: Abundance of Nonnative Plants

Objective 2: Determine whether nonnative plants are more abundant in transmission line corridors than in undisturbed (control) portions of the Lokern area.

To determine whether nonnative plants were more abundant in corridors than in control areas of Lokern, vegetation cover was estimated by species in quadrats measuring 0.7 by 0.35 meters (2.3 by 1.1 feet). Quadrats were placed at intervals along a transect beginning at a road edge. The intervals were every 1 meter (3 feet) for the first 10 meters (33 feet), then every 10 meters up

---

[16] In botanical terms, a *fruit* is any structure that contains seeds. In this case, a "wheel" of seeds constitutes a fruit.

[17] *Transformation* is a mathematical manipulation that can sometimes convert data that are not normally distributed to a normal distribution.

[18] The *Kruskal-Wallis test* analyzes differences among groups based on their ranks (lowest rank =1, next rank = 2, etc.). It is appropriate for data that are not normally distributed and do not represent proportions.

to 100 meters (328 feet) from the road, then every 100 meters, with a maximum distance of 500 meters (1640 feet) from the road edge. Although our proposal indicated that the sampling intervals would be every 10 meters from the 10-meter point out to the center of the block, intervals were increased so a larger number of sites overall could be sampled. The vegetation-sampling sites included all of the areas where demographic data had been collected, plus other blocks with varying levels of disturbance, regardless of whether they supported Kern mallow. Within the quadrats, the cover of each plant species was estimated to the nearest 1%.

Detrended correspondence analysis[19] and principal components analysis[20] were used to analyze the species data obtained from quadrats. Species patterns were then interpreted with respect to the following environmental variables: distance from the road edge, type of road (paved versus dirt), soil type, grazing status, and burn history. The relationship of species abundance and distance from road edge to a given axis were analyzed via the Kendall correlation coefficient.[21] The other environmental variables were not quantitative[22] and therefore could not be correlated with the axes. Instead, their interpretation was based on inspecting the distribution of plots relative to various environmental variables on the axes.

Relative cover was used to determine the abundance of nonnative plants relative to natives by summing the cover of all nonnative plants in a given quadrat and dividing by the sum of cover values for all species. In addition, richness (number of species) of both native and nonnative species was tallied for each quadrat. Empty plots (those with 0% cover) were omitted.

The null hypotheses that relative cover and richness of nonnative species were no greater in corridors than in control areas were tested via the Mann-Whitney test;[23] the acceptable Type I error rate was 5%, and tests were one-tailed. In addition, the relative cover of nonnative species

---

[19] *Detrended correspondence analysis* is a technique that summarizes patterns of plant species composition. It combines the information from many variables into just two or three factors, which are expressed as axes (similar to the X axis and Y axis in a scatter diagram). The amount of variability (variance) in the data set that is incorporated into each axis can be calculated. Similar species and similar samples will group close together when the combined scores are plotted on these axes. The grouping patterns are then compared to environmental characteristics to aid interpretation.

[20] *Principal components analysis* is a statistical technique similar in concept to detrended correspondence analysis, but it uses different mathematical formulas to create groupings.

[21] The *Kendall correlation coefficient* estimates the relationship between two variables using the ranks of the values. It is less commonly used than the similar Spearman correlation coefficient (see footnote 24) but happens to be the correlation coefficient generated by the detrended correspondence analysis program we used.

[22] *Quantitative variables*, such as distance, can be measured. Designations such as "soil type" or "burned" are *categorical variables*, which may be designated by numbers but are not measurements. Only quantitative variables can be used to calculate correlation coefficients.

[23] The *Mann-Whitney test* compares two samples by using the ranks of the values.

and richness of nonnative species were correlated separately with distance from the corridor using the Spearman correlation coefficient.[24] The null hypotheses were that cover and richness of nonnative plants did not decrease with distance from the road edge; the acceptable Type I error rate was 5%, and tests were one-tailed. Although determining the relative abundance of native species was not a specific objective of this study, the richness of native plants was tested for comparison. The null hypothesis that the richness of native species was equal in corridors and control areas was tested via the Mann-Whitney test; the acceptable Type I error rate was 5%, and tests were two-tailed.

Two hypotheses regarding abundance of Kern mallow in relation to roads also were tested using the quadrat data. The frequency of Kern mallow in quadrats and the median absolute cover of Kern mallow in quadrats were correlated separately with distance from the corridor using the Spearman correlation coefficient. The null hypotheses were that Kern mallow frequency and cover were not related to distance from the road edge; the acceptable Type I error rate was 5%, and tests were two-tailed.

2.3 Objective 3: Population Stability

Objective 3: *Collect data that will help determine whether the Kern mallow population is stable or declining overall.*

An intensive approach known as *demographic monitoring* (Pavlik 1994) was employed to provide information on the population trend of Kern mallow. Demographic monitoring can predict the trend of a plant population in as little as two to five years, compared to fifteen or more years for typical monitoring. Important elements of demographic monitoring for annual plants are determination of survivorship, seed production, seed-to-ovule ratio, and seed bank density. These factors contribute to an understanding of the population trend because they provide an early indication of whether individuals in the population can replace themselves, if not every year, then at least in favorable years. If few plants survive to reproduction, then few seeds are produced. Even if the majority of the plants survive to reproductive age, if they do not produce a sufficient amount of seeds, the population will decline.

Seed production can be observed directly by counting seeds, but it indicates only how much seed was produced, not whether there are problems with the seed set. The seed-to-ovule ratio indicates both the potential (ovules) and the actual seed production. When few ovules mature into seeds, problems with pollination or incompatibility among plants within a population are suspected; these conditions would cause a population to decline. Seed-to-ovule ratios in rare plants are typically compared to those of a common relative (Pavlik 1994). The soil seed bank (i.e., the presence of viable seeds in the soil for long periods) is important for long-term survival because it provides a buffer against poor seed production in any given year, allows for growth of larger numbers of plants in especially favorable years, and can include a greater genetic

---

[24] The *Spearman correlation coefficient* estimates the relationship between two variables using the ranks of the values. It uses a different formula for calculation than the Kendall correlation coefficient (see footnote 21).

diversity than the population of growing plants (McCue and Holtsford 1998). Stable populations have a much higher density of seeds in the soil than the density of growing plants, and the density of viable seeds in the soil does not change radically even when the number of growing plants fluctuates (Pavlik 1994).

2.3.1 Seed-to-ovule ratios

Survivorship and reproduction of Kern mallow were determined as described under Objective 1. The number of seeds per fruit was determined in the course of evaluating seed-to-ovule ratios. Fruits were collected from randomly located plants on March 31 and April 1 to determine seed-to-ovule ratios. Although we had collected ovaries earlier and planned to collect only fruits late in the season, we found that undeveloped ovules remained easily identifiable within fruits even after the seeds matured. By counting both fertilized and unfertilized ovules from the same fruit, we were able to avoid discrepancies arising from variation in ovule numbers between flowers on the same plant.

Study plots 19 metal, 22 metal, and 22 control were omitted from this analysis because sheep grazing had removed most fruits by the time we made collections for determining seed-to-ovule ratios. For this test, data from another area were substituted for 22 control. The site that substituted for 22 control was in a non-corridor area of Section 29 that was burned in 1997, non-sheep-grazed in 2004, and historically cattle-grazed. Thus, only three data pairs were analyzed for this test: 15 control/15 road, 21 control/21 road, and 22 wooden/29 substitute.

Two null hypotheses were tested relative to seed-to-ovule ratios. The observed seed-to-ovule ratio was compared to the desirable value of 0.85 for stable populations (Wiens 1984; Pavlik 1994) via the one-sample T test.[25] The null hypothesis was that the population seed-to-ovule ratio in Lokern (over both sexes) was at least 0.85, the acceptable Type I error rate was 5%, and the test was one-tailed. The null hypothesis that seed-to-ovule ratios in corridors were at least as high as those in control plots was tested via the paired T test, with the mean value for each section/treatment combination representing a data point. The acceptable Type I error rate for this test was 5%, and the test was one-tailed. Although ratio values are typically transformed prior to statistical analysis, the data set met the assumptions of normality and therefore transformation was not necessary.

2.3.2 Seed bank density

Soil for determining seed bank density was collected at five sites per plot between March 14 and 19, 2004, which was after Kern mallow seed germination but prior to seed-set. Sampling sites were located in stratified random fashion within the sampling plots; in corridors, each meter-wide band outward from the road edge was a separate stratum. A similar strategy was used in control plots, with a baseline used in place of the road edge. The number of Kern mallow plants was counted within a 1-meter (3.3-foot) square frame, then two soil samples were collected from opposite corners of the frame and combined. Soil samples were collected with a commercially

---

[25] The *one-sample T test* compares the mean of observed values to a theoretical value.

available bulb planter 5.5 cm (2.2 inches) in diameter inserted 5 cm deep into the soil. The combined samples represented a ground surface area of 47.52 cm^2 (0.00475 m^2 or 7.4 in^2) within each square meter sampled. The soil samples were placed in bags, air-dried, and then dry-sieved to remove particles larger and smaller than Kern mallow seeds. The appropriately sized fraction of each soil sample was then examined under a dissecting microscope for the presence of Kern mallow seeds. The null hypothesis for this aspect of the study was that the number of seeds per square meter of soil was greater than the number of growing plants per square meter. A paired T test (one-tailed) was planned, with an acceptable Type I error rate of 5%, but data were insufficient to conduct the statistical test (see Outcomes for Objective 3).

3.0 Project Outcomes

3.1 Objective 1: Survival and Reproduction

Objective 1: *Determine whether Kern mallow plants growing in transmission line corridors have reduced survival or reproduction compared to plants growing in the midst of undisturbed (control) areas.*

Outcome 1A: *Survival rates of Kern mallow were significantly lower in corridors than in control areas.*

The overall survival rate of marked Kern mallow plants in corridors was 76.7%, versus a survival rate of 88.9% in control plots. The Wilcoxon signed ranks test verified that the pattern of lower survival in corridors was statistically significant ($Z = -2.023$, $df = 4$, $P = 0.022$). Among the five plot pairs, four had significantly higher survival in controls than corridors, as determined through the multiple-comparison test (see Outcome 1B). The plot pairs in which survival in the control significantly exceeded that in the corridor were 15 control/15 road, 15 control/19 metal, 21 control/21 wooden, and 22 control/22 metal (Figure 2). Survival rates in 22 wooden did not differ significantly from 22 control, but the observed survival was approximately 4% higher in the control plot.

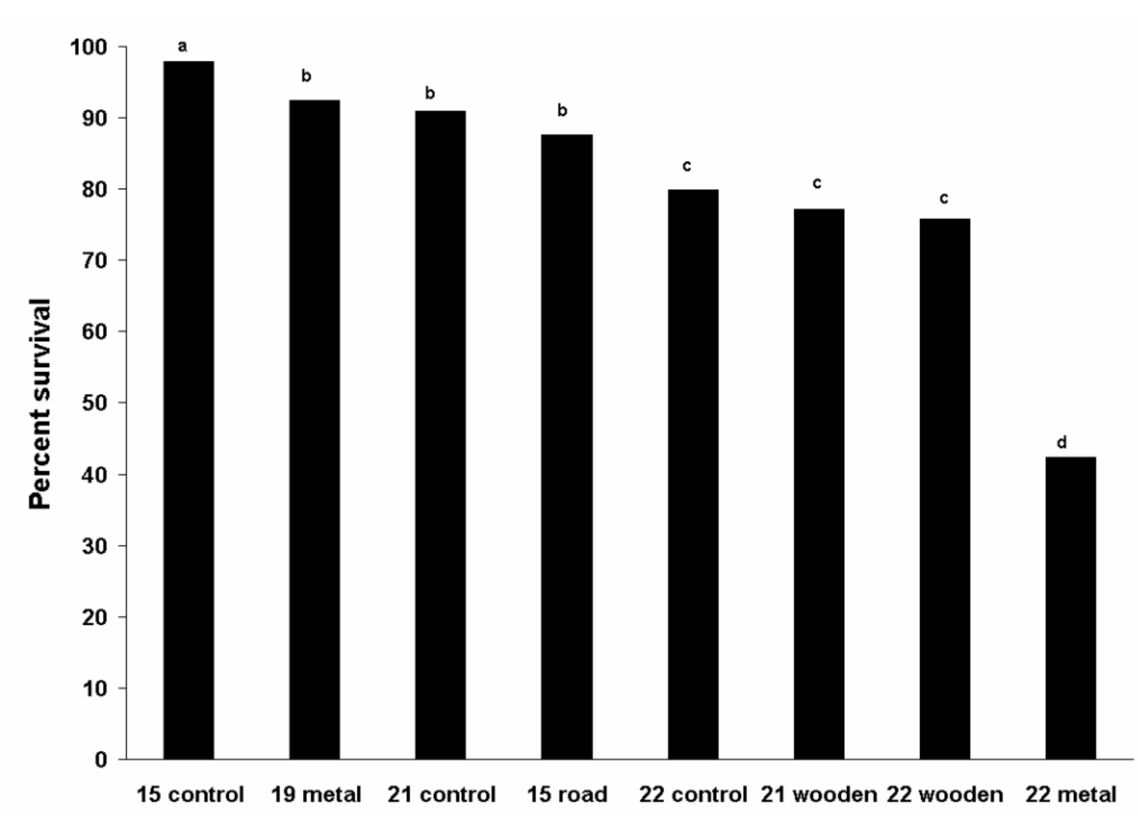

Figure 2. Kern mallow survival rates among plots in Lokern. Plots are designated by section number and corridor type or control. Groups that differ statistically are represented by different letters; bars with the same letter are not significantly different.

We did not collect data on mortality factors for each marked plant in this study, but the two biggest sources of mortality appeared to be (1) dehydration (i.e., insufficient moisture) and (2) sheep grazing. Dehydration affected plants throughout the Lokern area. Grazing was particularly intensive along the metal-tower transmission corridor paralleling Lokern Road; sheepherders confined the flocks along the roadside in that corridor and restricted them to short stretches of the road (less than 0.5 kilometer or 0.3 mile) for several days in a row. This intensive grazing impacted our 19 metal and 22 metal plots. Sheep grazed in a more dispersed fashion north of Lokern Road, where the 15 control and 15 road plots were located, and south of the metal-tower transmission line, where 22 control was located. Sheep did not enter our 21 control, 21 wooden, or 22 wooden plots. Thus, although concentrated sheep grazing contributed to the higher mortality rates in 19 metal and 22 metal compared to their respective controls, grazing was not responsible for the higher mortality rates in the other corridor plots. Minor sources of mortality observed in corridors but not in controls were inundation from puddles in the roads (particularly in 21 wooden and 22 wooden), burial by wind-eroded soil (21 wooden), and vehicle strikes (particularly in 19 metal and 22 metal). Other factors such as dust, physical or chemical changes in soils, or exhaust emissions also may have contributed to mortality of Kern mallow in corridors but they were not observable.

Outcome 1B: Survival rates of Kern mallow differed significantly among study plots that differed in site history. Plots that had burned in the 1997 wildfire and have since been disturbed by livestock or use of corridors exhibited the poorest survival rates.

Kern mallow survival rates ranged from 42.3% to 97.9%, and the difference among plots was highly significant ($X^2 = 167.28$, df = 7, $P < 0.001$). Among the eight study plots, survival rates fell into four groups (Figure 2) based on multiple comparison tests of statistical significance. The group differences cannot be conclusively attributed to specific factors because the small number of samples precluded a statistical analysis of variance. However, inspection of group attributes revealed some common factors within the observed groupings. The highest survival rate of 97.9% was in 15 control (group a in Figure 2), which was not in a corridor, had never been burned or grazed by cattle, and had experienced only dispersed sheep grazing. Relatively high survival rates of 87.6% to 92.4% were observed in three plots (group b) that represented both corridors and controls, both sheep-grazed (19 metal, 15 road) and no-sheep areas (21 control), and both burned (21 control) and unburned (19 metal, 15 road) areas; none of these plots had ever been subject to cattle grazing. The third group (c), with moderate survival ranging from 75.8% to 79.9%, consisted of three plots that had been burned in the 1997 wildfire. Group c included both corridors and controls, both sheep-grazed (22 control) and no-sheep areas (21 wooden and 22 wooden), and both cattle-grazed (22 control and 22 wooden) and no-cattle areas (21 wooden). The fourth group (d) consisted of a single plot, 22 metal, with a survival rate of 42.3%. The 22 metal plot was in a corridor, had been burned in the 1997 wildfire, was sheep-grazed in 2004, and was cattle-grazed until 2001. Thus, by far the lowest Kern mallow survival rate was in an area that had been subject to the full range of disturbances: wildfire, corridor use, intensive sheep grazing, and cattle grazing.

Outcome 1C: Reproductive rates of Kern mallow in corridors were at least as high as those in controls.

The overall reproductive rate of marked Kern mallow plants in corridors was 6.44 flowers per plant, which was not significantly lower than the 6.83 flowers per plant in control plots ($t = -1.481$, $df = 4$, $P = 0.107$).

Outcome 1D: Reproductive rates of Kern mallow differed significantly among study plots that differed in site history. Plots that burned in the 1997 wildfire had poorer reproductive rates than those that did not burn. The greater the number and severity of disturbances, the lower the reproduction.

Median reproduction of Kern mallow by plot ranged from 0.7 to 15.9 flowers per plant, and the difference among plots was highly significant ($X^2 = 277.95$, $df = 7$, $P < 0.001$). Among the eight study plots, reproductive rates fell into three groups (Figure 3) based on multiple comparison tests of statistical significance. As discussed under Outcome 1B above, the individual factors responsible for the group differences were not tested statistically due to inadequate sample sizes. Therefore, potential reasons for differences among the plots were based solely on interpretation of observed patterns. High reproductive rates of 14.0 to 15.9 flowers per plant (i.e., group a in Figure 3) were observed in both corridors (15 road and 19 metal) and controls (15 control) in sheep-grazed, unburned areas that have not been cattle-grazed. Moderate reproductive rates (group b) ranging from 4.4 to 5.4 flowers per plant were observed in both corridors and controls; both sheep-grazed (22 control) and non-sheep areas (21 control, 21 wooden, and 22 wooden); and both cattle-grazed (21 wooden, 22 control, and 22 wooden) and non-cattle areas (21 control). All four of these plots had been burned in the 1997 wildfire. The lowest reproductive rate was observed in 22 metal (group c), with only 0.7 flowers per plant. The 22 metal plot was in a corridor, was sheep-grazed in 2004, was cattle-grazed prior to 2002, and had been burned in the 1997 wildfire.

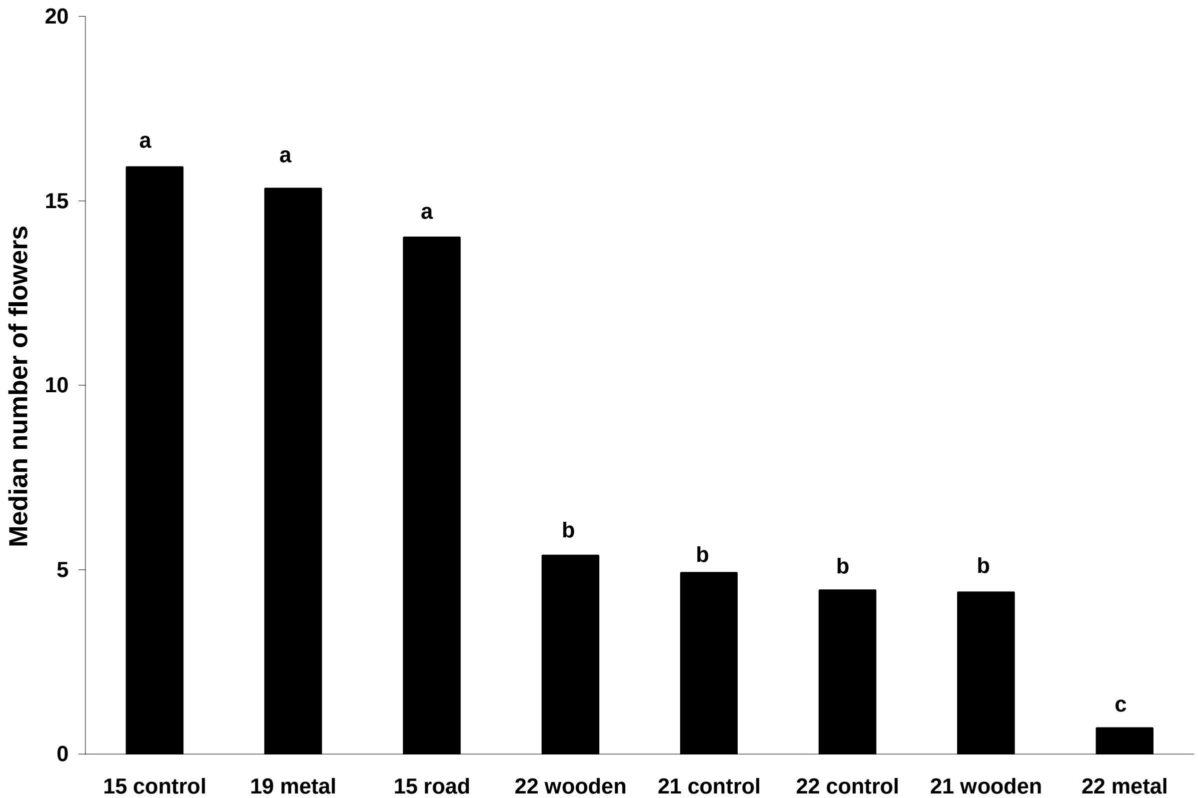

Figure 3. Median Kern mallow flower production among plots in Lokern. Plots are designated by section number and corridor type or control. Groups that differ statistically are represented by different letters; bars with the same letter are not significantly different.

3.2 Objective 2: Abundance of Nonnative Plants

Objective 2: *Determine whether nonnative plants are more abundant in transmission line corridors than in undisturbed (control) portions of the Lokern area.*

Outcome 2A: *Distance from roads did not influence plant species composition patterns. However, soil type, burn history, and sheep grazing did influence species composition.*

The axes obtained through detrended correspondence analysis represent combinations of variables, which are used to group similar species and samples to reveal patterns. If an axis accounts for a large percentage of the total variance (variability) in the data set, it is doing a good job of summarizing species distribution patterns. Axis 1 typically accounts for the most variance, with less captured by the subsequent axes. However, multiple axes are needed to capture the maximum amount of variance in the data set. When an *environmental* variable is highly correlated with an axis, it is very influential in determining patterns of plant species composition. When a *species* is highly correlated with an axis, it is responding to the environmental variables that influence that axis.

The detrended correspondence analysis accounted for 68.8% of the variance in the data set, with Axis 1, Axis 2, and Axis 3 explaining 55.6%, 7.2%, and 5.9% of the variance, respectively. Distance of plots from the road margin was not correlated with any of the axes ($\tau = 0.000$ for Axis 1, 2, and 3) and therefore did not influence species distribution patterns. Type of road surface (paved versus dirt) did not show any apparent influence on any of the axes. Soil type influenced all three axes. On Axis 1, plots on Panoche clay loam on 2%–5% slopes and Kimberlina fine sandy loam on 0%–2% slopes achieved the greatest separation. Axis 2 primarily separated Kimberlina sandy loam on 2%–5% slopes from Kimberlina fine sandy loam on 0%–2% slopes, and Axis 3 separated Panoche clay loam on 0%–2% slopes from Kimberlina sandy loam on 2%–5 % slopes. Burning history and sheep grazing both clearly influenced Axis 2, but cattle grazing history did not show any clear relationship to any of the axes.

The two plant species most highly correlated with Axis 1 were the native forb[26] fiddleneck (*Amsinckia menziesii* var. *intermedia*, $\tau = 0.449$) and the nonnative Mediterranean grass (*Schismus arabicus*, $\tau = -0.569$). Although fiddleneck is a native plant, it is more tolerant of disturbance than many other natives; for example, it often dominates fallow agricultural fields. The two species most highly correlated with Axis 2 were the nonnative grasses red brome ($\tau = 0.327$) and Mediterranean grass ($\tau = -0.367$). Axis 3 was most highly correlated with three native forbs: Kern mallow ($\tau = -0.399$), peppergrass (*Lepidium dictyotum*, $\tau = 0.324$), and white Sierran layia (*Layia pentachaeta* ssp. *albida*, $\tau = -0.311$). The position of Kern mallow on Axis 3 indicates that it reached its greatest abundance on Kimberlina fine sandy loam on 0%–2% slopes.

Principal components analysis did not reveal additional patterns. Axis 1 of the principal components analysis accounted for only 9.6% of the variance in the data set, and nine axes were needed to account for 50% of the variation. Therefore, correlations with environmental factors and species were not explored.

Outcome 2B: Relative cover of nonnative species was not significantly higher in corridors than in controls.

The median relative cover of nonnative plants in corridors was 90.9%, which did not differ significantly from the 86.1% relative cover of nonnatives in control plots ($Z = -0.116$, $df = 137$, $P = 0.454$).

Outcome 2C: Richness of nonnative and native plants did not differ between corridors and controls.

The median richness of nonnative plants in corridors was 2.5, which was not significantly greater than the 2.3 richness in control plots ($Z = -1.220$, $df = 138$, $P = 0.111$). Median native plant richness in corridors was 1.2, which did not differ significantly from the 1.4 richness in control plots $Z = -0.313$, $df = 138$, $P = 0.755$).

[26] A forb is an herb with broad leaves, as opposed to grasses and their relatives, which have narrow leaves. Most common wildflowers are forbs.

Outcome 2D: Relative cover of nonnative plants was not correlated with distance from roads.

The Spearman correlation coefficient between relative cover of nonnative plants and distance from road margin was not significant ($r_s = -0.005$, df = 224, P = 0.472). The relative cover of nonnative plants in individual quadrats ranged from 8.3% to 100%, but when all quadrats at a given distance from roads were considered collectively, the median cover of nonnatives ranged from 75.7% to 100% (Figure 4). The shaded portions of the bars in Figure 4 show the high proportion of nonnative plant cover at all distances from roads, and the white portions of the bars show that the proportion of native cover is no greater 100 meters (328 feet) or more from a road than it is within a few meters of a road.

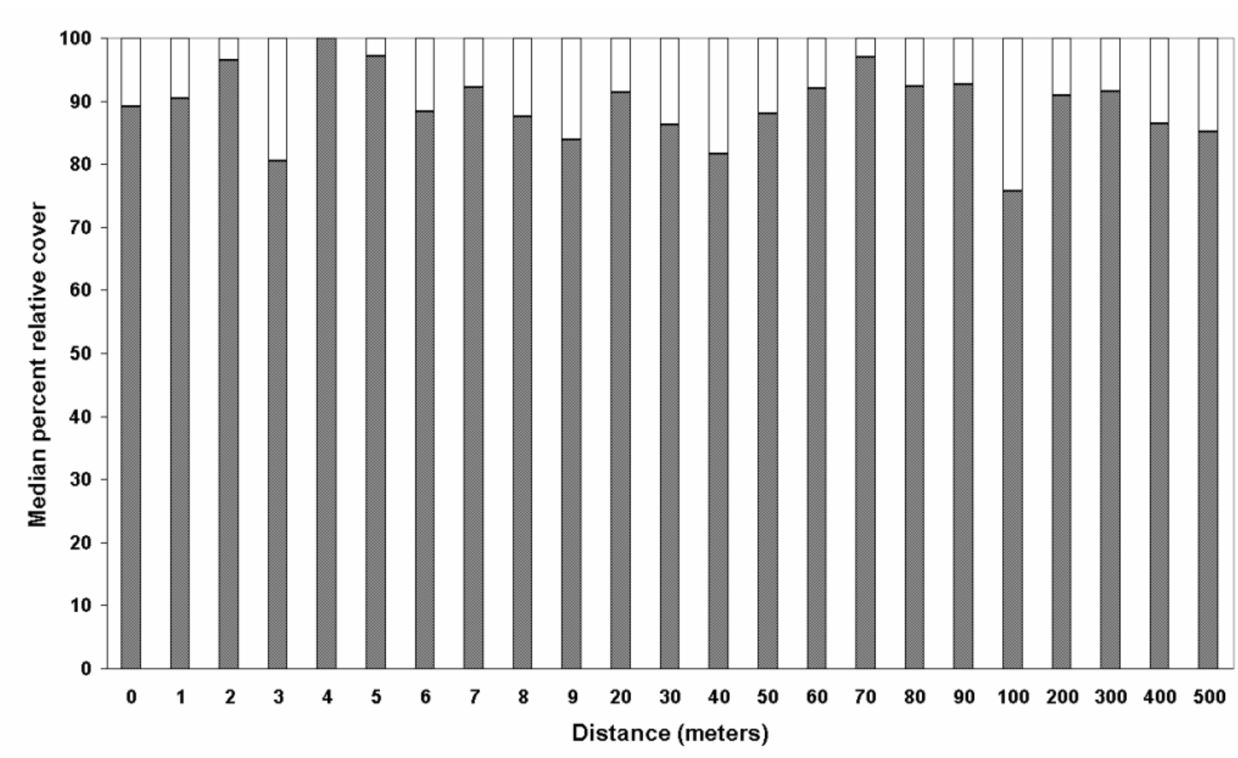

Figure 4. Relative cover of native and nonnative plants relative to distance from roads. White portions of bars represent native plants and shaded portions of bars represent nonnative plants. The relative cover of natives and nonnatives at each distance sums to 100.

Nonnative plants were more likely than natives to dominate quadrats at any distance from roads (Figure 5). Among the 223 quadrats sampled, native plants dominated only 21 (9.4%), and those were distributed more or less evenly relative to distance from roads; native plants co-dominated with nonnatives on 3 quadrats (1.3%). The shaded bars in Figure 5 show that nonnative plants dominated the majority of plots at all distances, and the lack of white bars at 0, 7, 9, 70, 200, 400, and 500 meters (0, 23, 30, 230, 656, 1312, and 1640 feet) shows that native plants did not dominate any quadrats at those distances.

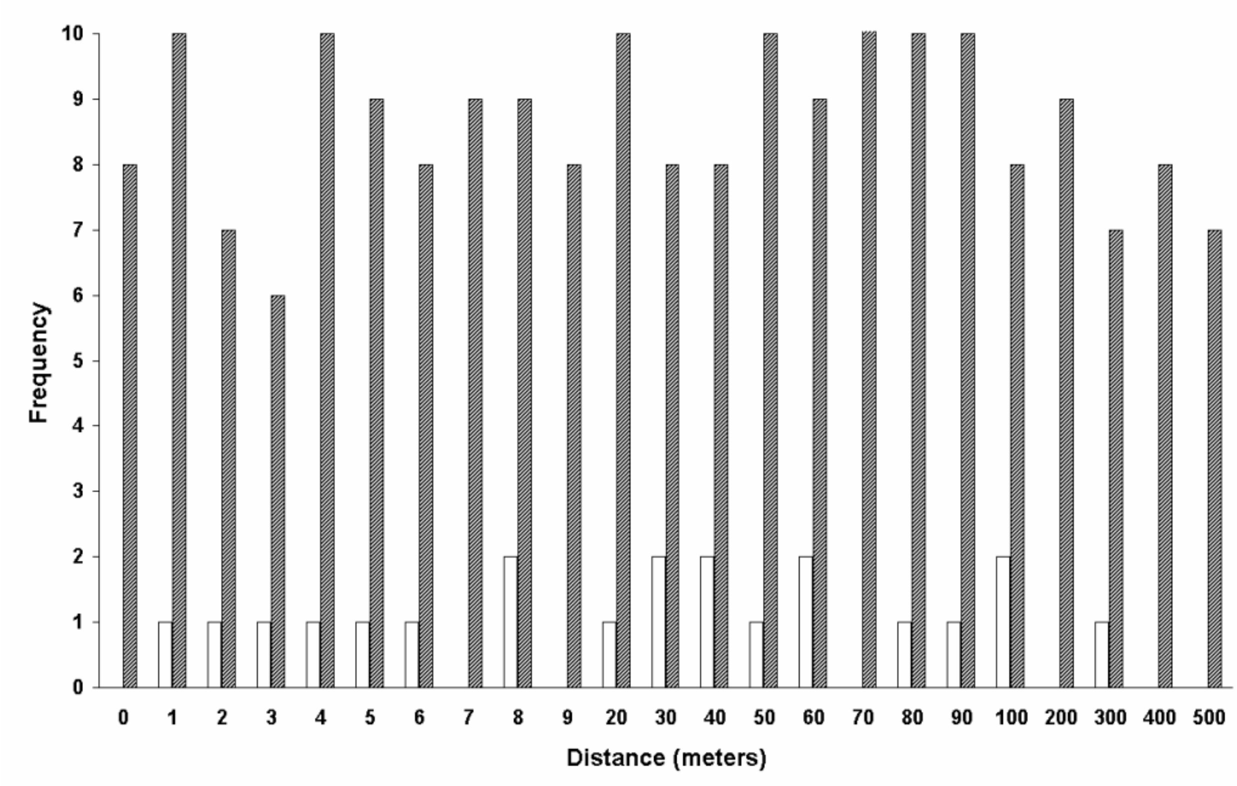

Figure 5. Number of plots dominated by native versus nonnative plants relative to distance from roads. White bars represent native plants and shaded bars represent nonnative plants.

Outcome 2E: Richness of nonnative plants decreased with distance from roads, but richness of native species did not vary with distance.

Richness of nonnative plants was negatively correlated with distance from the road margin ($r_s = -0.111$, df = 225, P = 0.049), but richness of natives was not ($r_s = -0.002$, df = 225, P = 0.978) (Figure 6). Thus, the number of nonnative plant species generally decreased with distance from roads, as shown by the height of the shaded bars decreasing from left to right in Figure 6. In contrast, the white bars in Figure 6 represent the number of native plant species, and their height does not show any identifiable pattern from left to right. Both native and nonnative plants were found from the road edge to a distance of 500 meters (0.3 mile) from the road. Overall, a median of 1.3 native plant species and 2.4 nonnative plant species were found per quadrat.

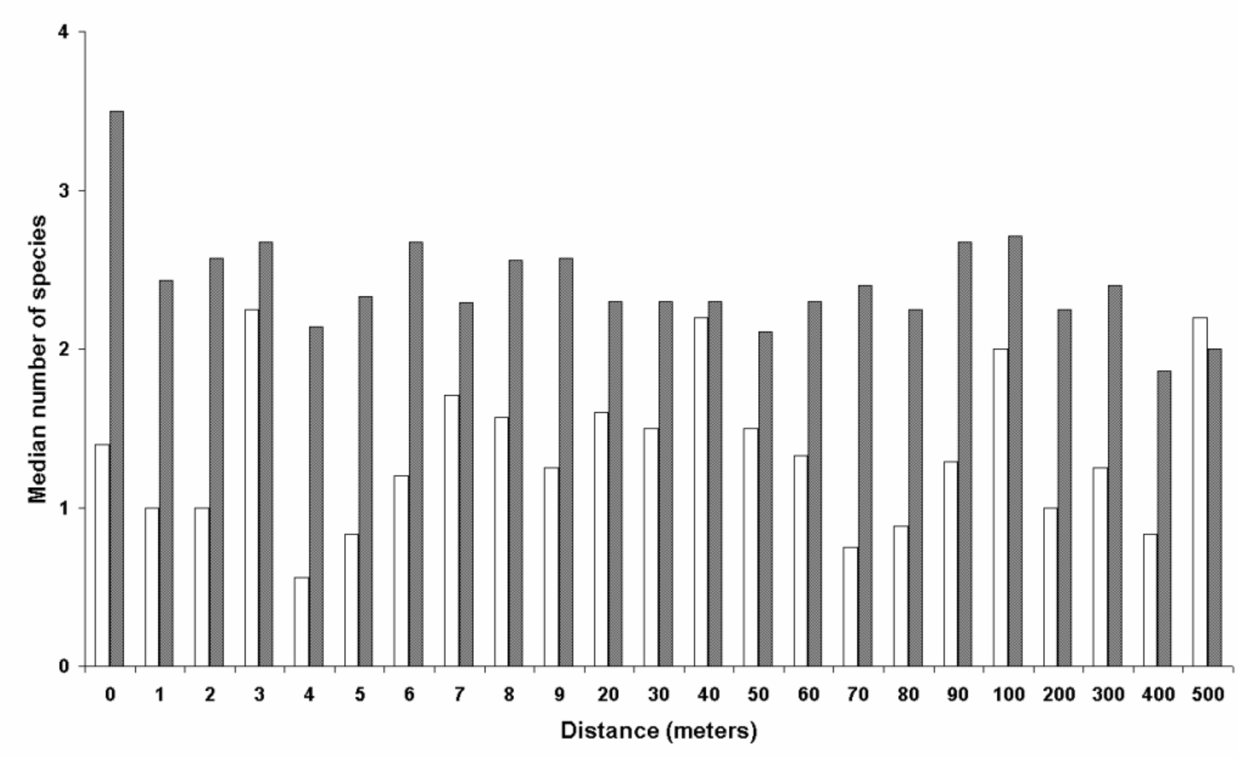

Figure 6. Richness (number of species) of native versus nonnative plants relative to distance from roads. White bars represent native plants and shaded bars represent nonnative plants.

Outcome 2F: Kern mallow frequency and cover were not correlated with distance from roads.

The Spearman correlation coefficient between frequency of occurrence of Kern mallow in quadrats and distance from road margin was not significant (r_s = 0.098, df = 22, P = 0.656). Kern mallow occurred in quadrats at all distances sampled except for 20 meters (66 feet), and no pattern of distribution was apparent (Figure 7). The lack of Kern mallow at the 20 meter distance is most likely a random event and not indicative of any particular effect. The absolute cover of Kern mallow did not follow the same pattern as the frequency of occurrence, but it did not vary in any predictable manner with distance from roads (Figure 8) and cover was not significantly correlated with distance from the road margin (r_s = 0.008, df = 224, P = 0.910).

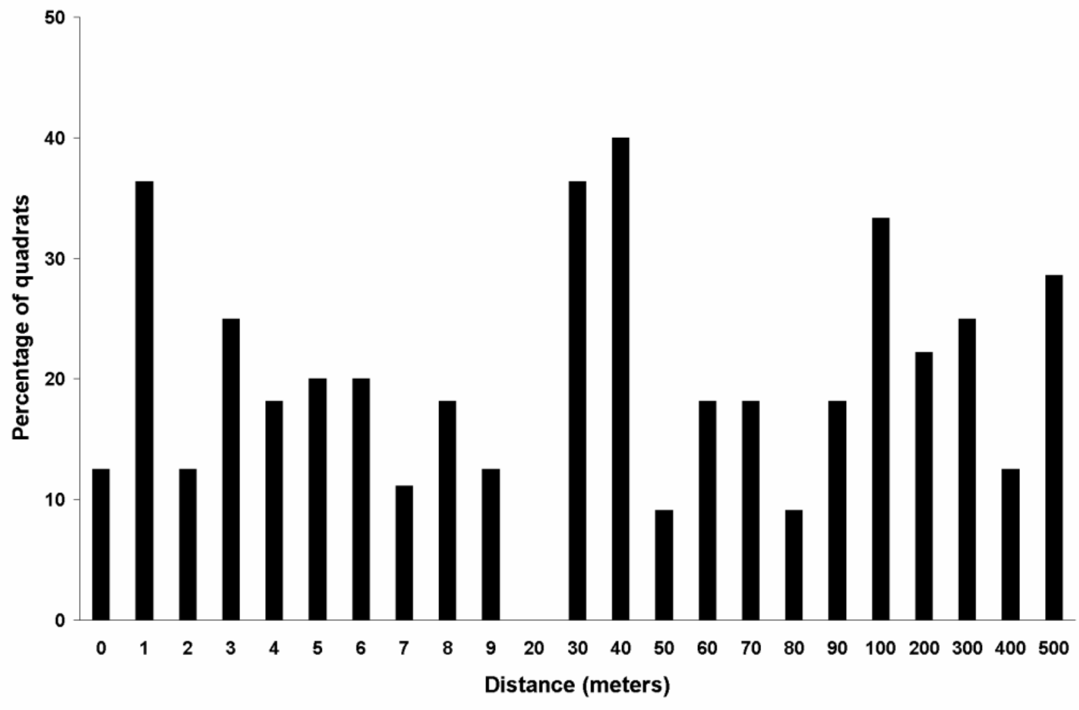

Figure 7. Frequency of Kern mallow in quadrats at various distances from roads. Kern mallow did not occur in any sampled quadrats 20 meters from the road.

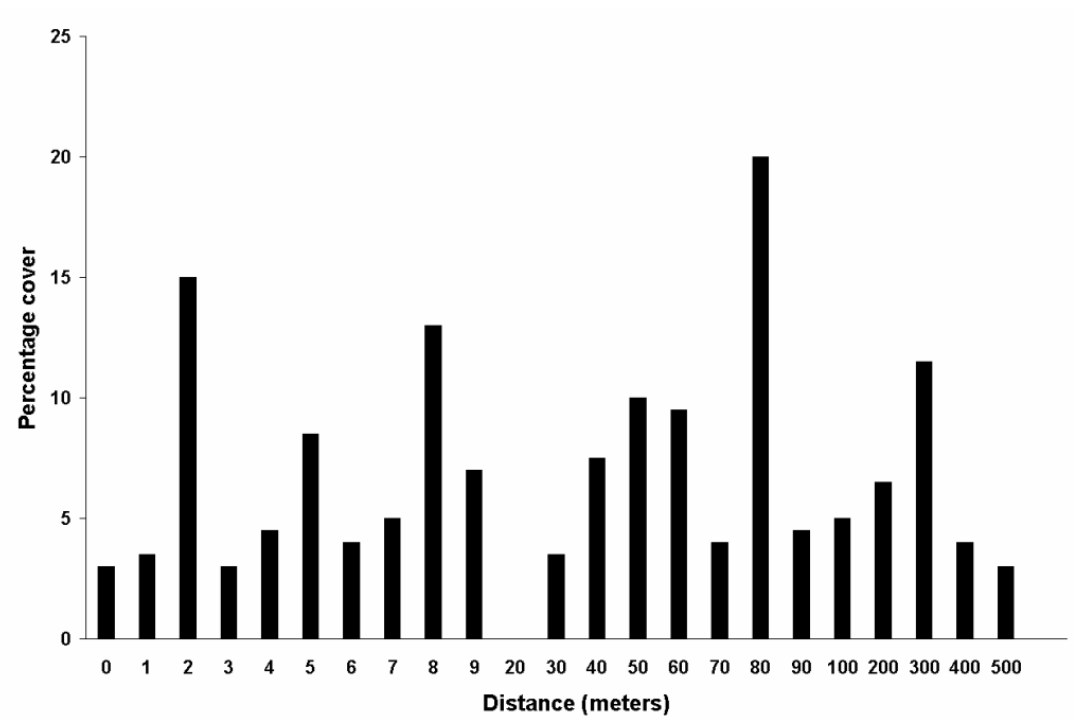

Figure 8. Median percent cover of Kern mallow at various distances from roads. Kern mallow did not occur in any sampled quadrats 20 meters from the road.

3.3 Objective 3: Population Stability

Objective 3: *Collect data that will help determine whether the Kern mallow population is stable or declining overall.*

Outcome 3A: *Overall, 81.5% of the Kern mallow seedlings present in February survived to the flowering stage, but only 45.1% survived to fruiting (seed production).*

Flowering data and fruiting data were collected only three weeks apart. The large discrepancy between the two survival rates is attributable to sheep grazing during the interim. Plants that remained alive after sheep grazing and produced fruits before the end of the growing season are included in the total survival to fruiting. Other details on survivorship were reported under Objective 1.

Outcome 3B: *No seeds of Kern mallow were found in the first eight soil samples examined (one from each study plot), so that aspect of the study was discontinued.*

Seeds of other small-seeded plants such as peppergrass and red-stemmed filaree were observed during soil examination, as were body parts of small insects such as ants. It is reasonable to assume that if we were able to observe those seeds and insect parts, which are similar in size to seeds of Kern mallow, we would have observed Kern mallow seeds as well. The examination of soil samples under a dissecting microscope was very time-consuming, and a continued effort did not seem reasonable in light of the initial results. Moreover, Mazer et al. (1993) did not have any Kern mallow seeds germinate from 48 soil samples collected from the Lokern area in April. They had watered the soil samples and intended to count the number of Kern mallow seedlings that emerged. We hypothesized that the lack of seedling emergence in their study was due to germination inhibitors in the seeds, which was why we examined soil samples instead of attempting the germination technique. Mazer et al. (1993) found viable Kern mallow seeds in the soil in November; they demonstrated that those seeds had been produced during the growing season that same year and were therefore not part of the long-term soil seed bank.

We can envision four alternative explanations for the lack of Kern mallow seeds in our soil samples and those in the spring samples collected by Mazer et al. (1993). One possibility is that Kern mallow may not form a persistent seed bank. However, soil seed banks are typical of annual plants, and the extreme variability in population sizes from year to year suggests that a soil seed bank is present (U.S. Fish and Wildlife Service 1998). A second possibility is that the seeds may persist more than 5 cm (2 inches) deep in the soil. This is unlikely because Kern mallow seeds are approximately 1 millimeter (0.04 inches) in diameter and would have to produce a stem 50 times the length of the seed before reaching a light source where photosynthesis would be possible. The third possibility is that Kern mallow seeds occur in such a low density in the soil that a much larger surface area must be sampled to detect them. However, we were reluctant to sample a larger surface area because it would create an unacceptable amount of disturbance to the habitat and growing Kern mallow plants. A fourth and final possibility is that seeds do not remain in the sites where they fall but are instead distributed unevenly throughout the Lokern area. Wind currents in the Lokern area create numerous “dust devils” that may disperse the seeds (E. Cypher, personal observation). We consider the third possibility to be most likely because Kern mallow plants do reappear in the same areas year after year. The fourth possibility probably contributes to the low seed density in some areas but is not likely to be the only explanation.

Outcome 3C: The seed-to-ovule ratio in Lokern was significantly lower than the desirable theoretical ratio of 0.85 for an annual plant.

The mean seed-to-ovule ratio over all plants sampled in the Lokern area in 2004 was 0.66, which was significantly lower than 0.85 ($t = -8.664$, $df = 94$, $P < 0.001$). The highest value we observed in any subpopulation in the Lokern area was 0.74. That subpopulation was not in one of the demographic study plots but was in a small, non-corridor area on U.S. Bureau of Land Management property between an agricultural field and a pistachio orchard. We included that subpopulation and several others within Lokern even though they were outside of the primary study area to document conditions for the Kern mallow population as a whole.

Among the five corridor/control study plots in which sufficient fruits matured for analysis, seed-to-ovule ratios ranged from 0.62 to 0.70.

Outcome 3D: Seed-to-ovule ratios in corridors were at least as high as those in control areas.

The overall mean seed-to-ovule ratio in corridors was 0.676 and that for controls was 0.680. The mean seed-to-ovule ratios for three corridor plots were not significantly lower than the means for their paired control plots according to the paired T test ($t = 1.644$, $df = 2$, $P = 0.121$). Thus, the presence of corridors in the Lokern area apparently is not contributing to the low overall seed-to-ovule ratio.

3.4 Summary of Outcomes

Objective 1: Determine whether Kern mallow plants growing in transmission line corridors have reduced survival or reproduction compared to plants growing in the midst of undisturbed (control) areas.

1A: Survival rates of Kern mallow were significantly lower in corridors than in control areas.

1B: Survival rates of Kern mallow differed significantly among study plots that differed in site history. Plots that had burned in the 1997 wildfire and have since been disturbed by livestock or use of corridors exhibited the poorest survival rates.

1C: Reproductive rates of Kern mallow in corridors were at least as high as those in controls.

1D: Reproductive rates of Kern mallow differed significantly among study plots that differed in site history. Plots that burned in the 1997 wildfire had poorer reproductive rates than those that did not burn. The greater the number and severity of disturbances, the lower the reproduction.

Objective 2: Determine whether nonnative plants are more abundant in transmission line corridors than in undisturbed (control) portions of the Lokern area.

2A: Distance from roads did not influence plant species composition patterns. However, soil type, burn history, and sheep grazing did influence species composition.

2B: Relative cover of nonnative species was not significantly higher in corridors than in controls.

2C: Richness of nonnative and native plants did not differ between corridors and controls.

2D: Relative cover of nonnative plants was not correlated with distance from roads.

2E: Richness of nonnative plants decreased with distance from roads, but richness of native species did not vary with distance.

2F: Kern mallow frequency and cover were not correlated with distance from roads.

Objective 3: Collect data that will help determine whether the Kern mallow population is stable or declining overall.

3A: Overall, 81.5% of the Kern mallow seedlings present in February survived to the flowering stage, but only 45.1% survived to fruiting (seed production).

3B: No seeds of Kern mallow were found in the first eight soil samples examined (one from each study plot), so that aspect of the study was discontinued.

3C: The seed-to-ovule ratio in Lokern was significantly lower than the desirable theoretical ratio of 0.85 for an annual plant.

3D: Seed-to-ovule ratios in corridors were at least as high as those in control areas.

4.0 Conclusions and Recommendations

4.1 Conclusions

These conclusions must be considered preliminary for two reasons. First, they were based on data from only one year. The growing season of 2004 experienced below-average rainfall,[27] and results could differ in a year of higher rainfall. Second, data were collected on only eight plots, which precluded the use of more sensitive statistical tests. Conclusions regarding site history were based on interpretation alone and were therefore speculative; they must be verified by collecting and analyzing data from a larger set of samples.

Objective 1: Determine whether Kern mallow plants growing in transmission line corridors have reduced survival or reproduction compared to plants growing in the midst of undisturbed (control) areas.

- Road corridors reduced the overall survival rate of Kern mallow, regardless of whether or not the corridors contained transmission lines.
- Restricting access to roads is not likely to improve Kern mallow survival because reduced survival rates were found along even the most lightly traveled roads.
- Corridors alone did not have detrimental effects on Kern mallow reproduction in 2004.
- Kern mallow plants in burned areas were less tolerant of disturbance from corridors or livestock grazing than those in unburned areas.

Objective 2: Determine whether nonnative plants are more abundant in transmission line corridors than in undisturbed (control) portions of the Lokern area.

- Nonnative plants were widespread in the Lokern area, even in a dry year, but roads did not contribute to their dominance.
- Soil type, burn history, and grazing history appeared to have a greater influence on plant species composition in the Lokern area than did corridors.
- Kern mallow distribution and cover were not affected by the proximity of roads.

[27] The rainfall in Buttonwillow during the 2004 growing season (October 2003 through March 2004) was 4.6 cm (1.8 inches). Since 1948, rainfall in Buttonwillow from October through March has averaged 11.7 cm (4.6 inches) (Western Regional Climate Center 2004). In some years the growing season continues into April, but April rainfall is not included in these figures because the Kern mallow had ceased growth by early April 2004.

Objective 3: Collect data that will help determine whether the Kern mallow population is stable or declining overall.

- Stability of the Kern mallow population cannot be determined at this time because additional data are needed.
- Soil seed banks have not yet been found for Kern mallow. Either Kern mallow does not form a soil seed bank or different sampling techniques are necessary to detect buried seeds.
- Although the seed-to-ovule ratio in Kern mallow populations was comparatively low, additional data are needed to determine if the low ratio is an indication of population decline.
- The comparatively low seed-to-ovule ratio in Lokern was not a result of corridor effects.

4.2 Recommendations

The following recommendations are derived from the outcomes and conclusions of Objectives 1 through 3 as described above. Collectively, they address the original Objective 4, which was to "provide recommendations on the siting of new transmission lines and the management of existing transmission lines for the benefit of rare and endangered species in the Lokern area." Some of the recommendations do not relate specifically to transmission lines but are included because they will contribute to the long-term survival of Kern mallow. As an endangered species that occurs nowhere else, extra precautions to protect Kern mallow during any activities in the Lokern area are warranted, as are targeted actions to promote its recovery.

1. Creation of new access roads in Kern mallow habitat should be avoided. New transmission lines, wells, or other facilities could be installed along existing roads; or stretches of transmission lines and pipelines that cross Kern mallow habitat could be designated as "no vehicular access" areas. In this way, very little additional Kern mallow habitat would be lost and the amount of corridor area, which is subject to reduced Kern mallow survival, would not increase.
2. Vehicles should stay within the defined road margins in Lokern during the growing season (October through May) to avoid killing Kern mallow plants that grow immediately adjacent to roads.
3. Unavoidable construction in the Lokern area should occur during the dormant season for Kern mallow (June through September) to avoid killing growing plants. The topsoil should be salvaged and respread as soon as possible because it will likely contain viable Kern mallow seeds at that time of year.
4. Wildfires in the Lokern area should be controlled as quickly as possible to prevent detrimental effects to any more of the Kern mallow population. Management to reduce the incidence of wildfires should also be considered. Controlled burns are acceptable as a type of management.
5. Sheep should not be trailed, penned, bedded, or otherwise concentrated in portions of the Lokern area that have burned because intensive grazing severely reduces Kern

mallow survival and reproduction in burned areas. The burned areas can be easily identified by the lack of mature shrubs.

6. Follow-up research on the effects of corridors, burning, and livestock grazing should be designed to increase sample sizes for statistical analysis.
7. Future research should be considered to identify the specific factors that are limiting Kern mallow in the burned areas, followed by implementation of the appropriate restoration techniques.
8. Although nonnative plants are found throughout the Lokern area, the use of locally occurring native plants is encouraged for revegetation projects to increase the proportion of native plant cover.

4.3 Future Research

We plan to continue collecting demographic data on Kern mallow for at least one more year so we can better predict population trends. We will conduct demographic monitoring in additional portions of the Lokern area to increase the sample size, and we will explore other techniques for detecting a Kern mallow soil seed bank. To help determine if the seed-to-ovule ratio in Kern mallow is abnormally low, we plan to compare it to the seed-to-ovule ratio of a more common relative, Parry’s mallow (*Eremalche parryi*), next year. The U.S. Bureau of Reclamation has committed funding to continue this project in 2005.

4.4 Benefits to California

This project helped resolve a potential conflict between electricity transmission and the endangered plant species Kern mallow. By identifying the environmental and habitat impacts of transmission lines and providing recommendations for appropriate management of existing transmission lines, this work will help protect rare and endangered species in the Lokern area.

If the report’s recommendations are followed, survival and reproductive rates of the Kern mallow population as a whole should improve. The study will help planners and decision makers to minimize impacts on resident species if transmission infrastructure expansion becomes necessary in the Lokern area. The methodology and the recommendations may also be helpful in other parts of California where transmission lines and roads may conflict with endangered species.

Californians will continue to benefit from the peace of mind that comes from knowing that our natural heritage is being protected without impeding delivery of our electric power supply.

5.0 References

Andreasen, K., E. A. Cypher, and B. G. Baldwin. 2002. "Sympatry between desert mallow, Eremalche exilis, and Kern mallow, E. kernensis (Malvaceae): molecular and morphological perspectives." *Madroño* 49:22–24.

Bossard, C. C., J. M. Randall, and M. C. Hoshovsky. 2000. *Invasive Plants of California's Wildlands.* University of California Press, Berkeley, 360 pp.

Brooks, M. L. 1999. "Alien annual grasses and fire in the Mojave Desert." *Madroño* 46:13–19.

Brooks, M. L. 2000a. "Competition between alien annual grasses and native annual plants in the Mojave Desert." *American Midland Naturalist* 144:92–108.

Brooks, M. L. 2000b. *Bromus madritensis* ssp. *rubens* (L.) Husnot. Pages 72–76 in *Invasive Plants of California Wildlands* (C. C. Bossard, J. M. Randall, and M. C. Hoshovsky, editors). University of California Press, Berkeley, 360 pp.

California Department of Fish and Game. 2004. "California's plants and animals: threatened and endangered species." www.dfg.ca.gov/hcpb/species/t_e_spp/tespp.shtml.

California Energy Commission. 2003. *Five-Year Transmission Research and Development Plan.* 500-03-104F.

California Energy Commission. In press. *A Roadmap for PIER Research on Biological Issues of Siting and Managing Transmission Line Right-of-Ways.* PIER Environmental Area.

Chang, K. K. 1988. *Soil Survey of Kern County, California, Northwestern Part.* U.S.D.A. Soil Conservation Service and University of California Agricultural Experiment Station, 304 pp.

Cypher, E. A. 1994. "Progress report on 1994 grazing studies for Kern mallow and San Joaquin woolly threads." Unpublished report to the U.S. Bureau of Land Management, Bakersfield, California, 22 pp.

Forman, R. T. 2000. "Estimate of the area affected ecologically by the road system in the United States." *Conservation Biology* 14:31–35.

Gelbard, J. L., and J. Belnap. 2003. "Roads as conduits for exotic plant invasions in a semiarid landscape." *Conservation Biology* 17:420–432.

Germano, D. J., G. B. Rathbun, and L. R. Saslaw. 2001. "Managing exotic grasses and conserving declining species." *Wildlife Society Bulletin* 29:551–559.

Goldingay, R. L., P. A. Kelly, and D. F. Williams. 1997. "The kangaroo rats of California: endemism and conservation of keystone species." *Pacific Conservation Biology* 3:47–60.

Greenberg, C. H., S. H. Crownover, and D. R. Gordon. 1997. "Roadside soils: a corridor for invasion of xeric scrub by nonindigenous plants." *Natural Areas Journal* 17:99–109.

Heady, H. F. 1977. "Valley grassland." Pages 491–514 in *Terrestrial Vegetation of California* (M. G. Barbour and J. Major, editors). California Native Plant Society Special Publication Number 9, Sacramento, California, 1002 pp.

Hobbs, R. J., and L. F. Huenneke. 1992. "Disturbance, diversity, and invasion: implications for conservation." *Conservation Biology* 6:324–337.

Holland, R. F. 1986. *Preliminary Descriptions of the Terrestrial Natural Communities of California.* California Department of Fish and Game, Natural Diversity Database, Sacramento, California, 156 pp.

Johnson, H. B., F. C. Vasek, and T. Yonkers. 1975. "Productivity, diversity and stability relationships in Mojave Desert roadside vegetation." *Bulletin of the Torrey Botanical Club* 102:106–115.

Lathrop, E. W., and E. F. Archbold. 1980. "Plant responses to utility right of way construction in the Mojave Desert." *Environmental Management* 4:215–226.

Lovich, J. E., and D. Bainbridge. 1999. "Anthropogenic degradation of the southern California desert ecosystem and prospects for natural recovery and restoration." *Environmental Management* 24:309–326.

Major, J. 1977. "California climate in relation to vegetation." Pages 11–74 in *Terrestrial Vegetation of California* (M. G. Barbour and J. Major, editors). California Native Plant Society Special Publication Number 9, Sacramento, California, 1002 pp.

Mazer, S. J., G. LeBuhn, and D. E. Meade. 1993. "Demography and reproductive biology of Kern mallow (*Eremalche kernensis*: Malvaceae)." Unpublished report to the California Department of Fish and Game, Sacramento, 300 pp + appendices.

McCue, K. A., and T. P. Holtsford. 1998. "Seed bank influences on genetic diversity in the rare annual *Clarkia springvillensis* (Onagraceae)." *American Journal of Botany* 85:30–36.

Olson, T. E., and D. L. Magney. 1987. "Distribution of sensitive plant and wildlife species along transmission line corridors in southwestern San Joaquin Valley, California." Pages 169–184 in *Endangered and Sensitive Species of the San Joaquin Valley, California: Their Biology, Management, and Conservation* (D. F. Williams, S. Byrne, and T. A. Rado, editors). California Energy Commission, Sacramento, 388 pp.

Pavlik, B. M. 1994. "Demographic monitoring and the recovery of endangered plants." Pages 322–350 in *Restoration of Endangered Species: Conceptual Issues, Planning and Implementation* (M. L. Bowles and C. J. Whelan, editors.). Cambridge University Press, Cambridge, England, 394 pp.

Prieur-Richard, A. H., and S. Lavorel. 2000. "Invasions: the perspective of diverse plant communities." *Austral Ecology* 25:1–7.

Randall, J. M., and M. C. Hoshovsky. 2000. "California's wildland invasive plants." Pages 11–19 in *Invasive plants of California Wildlands* (C. C. Bossard, J. M. Randall, and M. C. Hoshovsky, editors). University of California Press, Berkeley, 360 pp.

Schoenherr, A. A. 1992. *A Natural History of California.* University of California Press, Berkeley, 772 pp.

Trombulak, S. C., and C. A. Frissell. 2000. "Review of ecological effects of roads on terrestrial and aquatic communities." *Conservation Biology* 14:18–30.

U.S. Fish and Wildlife Service. 1990. "Endangered and threatened wildlife and plants: determination of endangered or threatened status for five plants from the southern San Joaquin Valley." *Federal Register* 55:29361–29370.

U.S. Fish and Wildlife Service. 1998. *Recovery Plan for Upland Species of the San Joaquin Valley, California.* Region 1, Portland, Oregon, 319 pp.

Vasek, F. C., H. B. Johnson, and G. D. Brum. 1975a. "Effects of power transmission lines on vegetation of the Mojave Desert." *Madroño* 23:114–131.

Vasek, F. C., H. B. Johnson, and D. H. Eslinger. 1975b. "Effects of pipeline construction on creosote bush scrub vegetation of the Mojave Desert." *Madroño* 23:1–13.

Weiss, S. B. 1999. "Cars, cows, and checkerspot butterflies: Nitrogen deposition and management of nutrient-poor grasslands for a threatened species." *Conservation Biology* 13:1476–1486.

Western Regional Climate Center. 2004. "Monthly precipitation listings for Buttonwillow, California." http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?cabutt+sca.

Wiens, D. 1984. "Ovule survivorship, brood size, life history, breeding systems, and reproductive success in plants." *Oecologia* 64:47–53.

Zar, J. H. 1984. *Biostatistical analysis.* Second edition. Prentice-Hall, Inc., Engelwood Cliffs, New Jersey, 718 pp.

Appendix A: Photographs of the Study Area

Kern mallow (Eremalche kernensis)

A marked Kern mallow seedling. The metal circle is the size of a 50-cent piece.

Kern mallow growing in the old pavement of the 15 road plot

Setting up the 21 wooden plot. Note single row of power poles.

The 19 metal plot. Note the two separate transmission lines.

Sheep in the 19 metal plot. Note that green herbs are still visible at this time.

The 19 metal plot after sheep grazing. Note that herbs have been consumed.

Marked Kern mallow following sheep grazing

A Kern mallow plant resprouting after grazing

The 15 control plot with flags indicating locations of marked plants

Section 15 in a wet year. The California aqueduct is in the right background.