Arnold Schwarzenegger
Governor

RANGE MANAGEMENT PRACTICES TO REDUCE WIND TURBINE IMPACTS ON BURROWING OWLS AND OTHER RAPTORS IN THE ALTAMONT PASS WIND RESOURCE AREA, CALIFORNIA

Sheep graze on Vasco Caves Regional Park. Photo by K. S. Smallwood.

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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), conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

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Range Management Practices to Reduce Wind Turbine Impacts on Burrowing Owls and Other Raptors in the Altamont Pass Wind Resource Area, California is the final report for a project conducted by the East Bay Regional Parks District, K. Shawn Smallwood and Lee Neher, with contributions from Albion Environmental, Inc. This project was conducted as part of the Avian-Transmission System Mitigation Program (Contract Number 500-01-032). The information from this project contributes to PIER's Energy-Related Environmental Research Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/pier or contact the Energy Commission at 916-654-5164.

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Abstract

The East Bay Regional Park District studied the impacts of wind turbines on raptors at its properties in the Altamont Pass Wind Resource Area (APWRA). Several studies were conducted to provide information useful to reducing impacts to raptors due to construction or repowering of wind farms. The studies' objectives included determining whether vegetation height can be managed to affect the distribution of small mammals near wind turbines to reduce risk to raptors, determining the effectiveness of seasonal wind turbine shutdowns to reduce raptor collisions with wind turbines, relating burrowing owl population size to mortality, determining factors that affect raptor behavior and spatial distribution, estimating scavenger removal rates of bird carcasses, and assessing wind turbine repowering scenarios.

Keywords: Altamont Pass Wind Resource Area, East Bay Regional Park District, wind turbines, vegetation management, grazing, raptor flight behavior, raptor mortality, small mammal burrow distribution, scavenging rates, mortality estimates, GPS, digital elevation model, wind farm repowering, Vasco Caves Regional Preserve, *S*ouza parcel

Executive Summary

Introduction

Energy produced from wind is an attractive alternative to burning fossil fuels because it is renewable and has a very small carbon footprint. The Altamont Pass Wind Resource Area (APWRA), located in the eastern San Francisco Bay Area, is the oldest wind energy generation facility in the United States. Due to favorable winds, an abundant prey base, its location within migratory corridors, and adjacency to some of the densest concentrations of nesting raptors, the APWRA might have the highest raptor use of any wind generation area. Unfortunately, APWRA also the highest known kill rates for raptors as well as high mortality for other birds and bats.

The East Bay Regional Park District (EBRPD) recently acquired a 249.7-hectare (617.0-acre) property (the Souza parcel) within the APWRA. The Souza parcel came with two wind farm leases for 63 privately owned wind turbines. These leases will expire in 2014. Adjacent to the Souza parcel is a 292.3-hectare (722.3-acre) preserve also managed by EBRPD, Vasco Caves Regional Preserve, which is devoid of wind turbines. The EBRPD is concerned about the impact of wind farm operations on nesting and foraging raptors on its lands, including burrowing owls, golden eagles, falcons, and other sensitive species. The EBRPD is also interested in finding ways to reduce the impacts of wind farms on wildlife to improve the "green energy" component of wind farm operations.

Purpose

This study assessed the avian impacts of the wind farms located on EBRPD land and investigated whether range management practices, via changing vegetation, can affect the distribution of raptor prey (small mammals) and raptor foraging behavior. The results will be used to assist the EBRPD Board of Directors in deciding whether to retain the wind energy development on its property.

Project Objectives

- Implement grazing management plan using sheep to create treatment plots of grazed and ungrazed parcels in the study area and to measure grazing pressure and changes in vegetation associated with treatment.
- Estimate burrowing owl nesting density and productivity, so that burrowing owl mortality can be related to the population size.
    - Test the effectiveness of an empirical model predicting burrowing owl nest density based on the size of the study area.
    - Test the effectiveness of an empirical model predicting burrowing owl nest burrow locations, based on slope attributes, and characterize the degree to which burrowing owl burrow locations are influenced by slopes versus wind turbine presence.

- Determine how small mammals (raptor prey) and raptors respond to changes in vegetation height and density by documenting the shifts in small mammal distributions and raptor foraging patterns that accompany manipulation of vegetation by sheep grazing and variable grazing pressure[1]. This will help determine if prey populations and associated raptor foraging behavior can be distributed away from immediate wind turbine areas. Additionally, the study will determine if switching from cattle to sheep grazing helps these objectives.
- Test whether wind turbines affect the spatial distributions and behaviors of raptors.
- Test whether raptor flights and specific behaviors relate more to landscape attributes or to spatial distributions of prey items.
- After one year of bird behavior observations in the study area, test whether bird flight and perching locations shift with the relocation of half the artificial rock piles. (This objective was not achieved because the study duration was decreased from a planned three years to 17 months.)
- Estimate scavenger removal rates of bird carcasses.
    - Identify the species that scavenge bird carcasses and the nature of scavenging events including carcass persistence in the environment.
    - Distribute the scavenger trial carcasses individually and at intervals, rather than in large numbers all at once, to test the degree to which scavenger swamping might bias conventional trials.
- Estimate mortality of bird species killed by wind turbines. Compare mortality measured as fatalities per kilowatt-hour (kWh) of electric power generated by wind turbines to explore the utility of this mortality metric.
- Assess repowering scenarios on the Souza parcel to guide the siting of new-generation wind turbines and to manage the range to minimize bird fatalities.

Project Results

This research generated a vast amount of geo-referenced[2] data essential for understanding raptor flight behavior and for devising ways to reduce turbine impacts on APWRA wildlife. Highlights are summarized below:

Grazing Effects. Heavy spring rainfall in 2006 spawned unusually prolonged and high grass growth that outpaced sheep grazing pressure, whereas drought in 2007 supported very little grass growth. The 2006 grazing treatment design was compromised by a wildfire that occurred after sheep were removed but before vegetation measurements could be taken. Within-treatment residual dry mass (RDM) measurements varied widely due in part to variation in

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[1] Variable grazing pressure refers to differences in the strength and time of grazing.

[2] To geo-reference something means to establish its location in terms of map projections or coordinate systems.

slope and aspect[3] within each treatment plot. There was no significant difference in overall mean RDM or mean effective vegetation height between grazed and ungrazed plots within years and between years, due in part to the extreme growing season of 2006. Effects of sheep grazing on raptor prey were masked by extreme variations in vegetation growth between years and within seasons during each year.

Burrowing Owls. The number of breeding burrowing owls detected in the study area nearly exceeded previous population estimates for the entire APWRA. The breeding pair density of burrowing owls on the project site was at least 4.61 per 100 hectares (1.87 per 100 acres) in 2006 and 3.87 per 100 hectares (1.57 per 100 acres) in 2007, closely agreeing with predictions from an empirical model previously developed by Smallwood et al. (2007). Most owl burrows were found along the lower third of slopes as predicted by a fuzzy logic model[4] previously developed by Smallwood and Neher (2008). Assuming all 10 of the turbine-related fatalities were resident owls, an estimated 19 percent and 31 percent of the study site burrowing owl population were killed by wind turbines in 2006 and 2007, respectively. The impact of these fatalities on the local population is unknown, but they suggest the APWRA could represent a population sink for the burrowing owl.

Fossorial (Burrowing) Mammal Distribution. The Vasco Caves parcel was dominated by pocket gophers, and the Souza parcel was dominated by ground squirrels, possibly due to the difference in grazing management over the past five years. Vasco Caves was switched from year-round cattle grazing to seasonal sheep grazing several years before the Souza parcel. Pocket gophers mostly occupied the upper reaches of slopes, whereas ground squirrel colonies occupied the lower half to lower third of slopes. Ground squirrel complexes were abandoned or unoccupied more often where vegetation was either bare or very tall; the squirrels fared best in grasses 5 to 50 centimeters high. Their burrows were reamed by mammalian carnivores more often where vegetation was tall, and squirrels may have been more vulnerable to raptor predation where the ground was bare, suggesting alternate predation risks are associated with ground squirrels living in burrow complexes associated with tall versus little vegetation.

Raptor Behavior. The number of raptors observed per hour was similar to past studies in the APWRA. Differences in detections over the last decade included an apparent 56 percent decrease in golden eagles, a 19 percent increase in red-tailed hawks, and an 80 percent increase in northern harriers. Although timing differed among species, overall raptor abundance peaked during February, May-June, and November, and was lowest during January and August. The data support seasonal wind turbine shutdowns as a means to reduce collision risks during peak abundances.

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[3] Aspect refers to the direction to which a slope faces.

[4] Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. Fuzzy logic usually uses IF-THEN rules, or constructs that are equivalent.

Each species exhibited unique suites of behavior under varying conditions—thus precluding micromanagement efforts, such as turbine shutdown according to time of day or wind speed, to mitigate collision risks across all raptor species.

Hovering and kiting, the flight behaviors associated with the greatest risk of blade strikes, occurred most often on the upper reaches of south- and southwest-facing slopes where declivity winds were strongest and most prevalent. Assuming new tower heights of 45 to 60 meters, the hovering and kiting flights observed here would be within the blade sweep of most repowered turbines.

The presence of wind turbines and turbine operations may affect raptor flight behavior. Data suggest that given a choice, raptors may prefer turbine-free landscapes. Overlap of turbine locations with favorable slope attributes and wind patterns may account for greater-than-expected frequencies of raptor flights in the immediate vicinity of turbines, especially while the turbines were not operating. Golden eagles were the only raptor species that appeared to ignore the presence of wind turbines.

The relationship between raptor flight activity and fossorial mammal prey distribution was complex. In a study area where prey populations are relatively uniformly distributed, raptor flight patterns appear to relate more strongly to specific topographic features such as slope than to actual prey distribution.

Scavenger Removal. In conventional scavenger removal trials, all the bird carcasses are set out at once, which can overwhelm scavengers with more carcasses than can be consumed before they rot. To avoid this "scavenger swamping," the research team distributed carcasses a few at a time, a rate assumed to be more typical of deposition by wind turbines. Carcass removal was much faster than previously documented. A logarithmic function based on this study's results predicts that after a 15-day search interval, only 35.4 percent of small-bodied, non-raptor birds, and 42.1 percent of medium- and large-bodied raptors, respectively, will remain in the landscape. Scavengers included coyote (most frequent) and common raven, and, less frequently, red-tailed hawk, striped skunk, great horned owl, and raccoon. Some carcasses were visited multiple times by several scavenger species before the carcass was removed.

Mortality at Wind Turbines. The study found 58 bird carcasses or wounded birds and one bat carcass. However, 69 percent of the birds were found farther away than typically would be considered wind turbine–caused injuries or fatalities. Although the latter were not included in mortality rate calculations, some of these casualties exhibited injuries consistent with wind turbine collisions, including a golden eagle with compound fractures to its humerus and ulna.

The wind turbines attributed to bird fatalities were those predicted to be more dangerous by the tier classification of Smallwood and Spiegel (2005). Wind turbines classified as either Tier 1 or 2 were associated with all the burrowing owl fatalities, 15 of 16 raptors, and 86 percent of all birds, even though these turbines composed only 14 percent of the turbine field in the study area.

Mortality estimates based on a conventional model of scavenger removal rate indicated that about 28 raptors and 59 birds are killed annually in the study area, though the confidence intervals indicated the numbers could be as high as 50 and 119, respectively. Mortality estimates based on a new "unswamped" scavenger removal rate showed that red-tailed hawk mortality more than doubled, overall raptor mortality nearly doubled, and overall bird mortality was 1.6 times greater. The new scavenger removal data combined with the new fatality data yielded new estimates for the number of birds killed annually in the study area: approximately 50 raptors, including approximately 26 burrowing owls, 10 red-tailed hawks, 10 barn owls, and 3 ferruginous hawks, are killed annually by the wind turbines on EBRPD property. Overall, an estimated 95 birds are killed annually at the property, though the confidence interval indicates the number could be as high as 190 birds. This study found evidence that suggests the APWRA may be a population sink for golden eagles as well as burrowing owls.

Avian mortality declined with increasing electric power output from the Howden wind turbines. This inverse pattern was driven by the fact that the number of fatalities at each turbine were relatively constant compared to variation in the power output, so dividing a relatively constant numerator by a highly variable denominator yields a ratio—used to express mortality—that is inversely related to its denominator. Identifying this relationship will be very useful not only for interpreting mortality estimates from wind farms, but also in singling out wind turbines of low production but which still killed birds. These wind turbines might serve as candidates for efficient turbine shutdowns to achieve minimal power loss while reducing bird fatalities.

This study found evidence suggested the APWRA may be a population sink for golden eagles as well as burrowing owls.

Implications for Repowering. Repowering—that is, replacing several older, smaller turbines with a more powerful new turbine—is generally assumed to decrease overall turbine-caused mortality. This study predicts variable effects from repowering at the Souza parcel. Fewer burrowing owls and American kestrels may be killed due to the increased tower height. However, the proposed locations for new turbines include sites where the most burrowing owl fatalities were found. In addition, five of the six proposed new turbine sites are on ridge lines having significant southwest-trending slopes that coincide with high raptor use. Golden eagles are especially susceptible to turbine collisions on multiple slope settings and appear to ignore operating turbines. Particular flight behaviors, such as kiting and hovering, have the potential to bring raptors such as red-tailed hawks and American kestrels into the rotor zone of the newer turbines. Bats, with their higher fly zones, will also face increased risk with taller towers.

To reduce the impacts of repowering, the following measures are recommended:

- Site turbines away from current high-mortality locations.
- Maximize tower height.
- Avoid placing towers on ridge crests or hills with substantial slopes facing south, southwest, or west. If towers are placed in such locations, they should at the very least

- Cluster towers rather than placing them in strings to reduce the number of isolated or end-of-row towers such as Tier 1 and 2 towers.
- Leave some prominent hills and slopes devoid of towers to give raptors a choice of turbine-free hills for engaging in particular flight behaviors.

Benefits to California

This report offers guidance on siting and operating new or repowered wind turbines in a manner that minimizes collision risk for birds. Compared to past studies, this research provides much greater resolution in raptor observations relative to the landscape and environmental conditions. In addition, the study shows scavenger swamping to be a significant effect in conventional scavenger removal trials. Accordingly, this study greatly improves estimates for wind turbine–caused raptor and avian mortality in the APWRA. Although results from the use of range management practices were inconclusive, this study sets the framework for improving the design of future studies on the effects of grazing treatments on small mammals and raptor flight behavior. The digital elevation model developed herein should prove extremely useful in studying future wind farm sites and in lessening their impacts. Collectively, the study results can be used to reduce impacts to raptors when constructing or repowering wind farms.

1.0 Introduction and Background

Policy makers have hoped that wind energy generation in the Altamont Pass Wind Resource Area (APWRA) will contribute to meeting both the state's growing energy demand and the recent mandates on California's energy portfolio. According to the State of California's *Energy Action Plan* (2003), Californians use 265,000 gigawatt-hours of electricity per year, and this consumption is growing 2% annually. Nearly 60% of this electricity was generated from fossil fuels and only 10.4% was generated from renewable sources, but these percentages are mandated to change. The *Energy Action Plan* calls for 20% of California's energy to be generated from renewable sources by 2010. Wind energy is the renewable source being pursued most aggressively, and until recently, the APWRA was the largest wind farm in California. However, wind turbines in the APWRA are known to kill thousands of birds each year (Smallwood and Thelander 2004, 2005, 2008; Altamont Pass Avian Monitoring Team 2008; Smallwood 2008). Potential mitigation strategies to reduce and minimize bird collisions in the APWRA have been proposed (Smallwood and Thelander 2004, 2005) but need to be tested.

The East Bay Regional Park District (EBRPD) recently acquired a 249.7-hectare (ha) property in the APWRA called the Souza parcel, where 63 wind turbines operate under two leases that will expire in 2012. These wind turbines are rated at 330 kW (Howden models) and 65 kW (Nordtank models) in output capacity, and together represent about 21.9 MW of rated capacity. EBRPD needs to decide whether to renew the wind leases when the extant leases expire and allow repowering to new-generation wind turbines. This study will help inform the EBRPD's decision by assessing whether annual avian impacts are significant and whether those impacts can be reduced to levels consistent with the goals and mission of the EBRPD.

1.1. Souza and Vasco Properties: A Unique Study Opportunity

The Souza parcel is located adjacent to a 292.3-ha holding of the EBRPD known as Vasco Caves Regional Preserve, which is devoid of wind turbines. Together, the two properties support a relatively large number of burrowing owls as well as other raptors known or suspected to be killed at high rates by wind turbines in the APWRA. Their adjacency offered an opportunity to compare spatial distributions and behaviors of raptors with and without wind turbines, thereby for the first time investigating whether and to what extent wind turbines affect habitat suitability and behavior patterns of raptors in the APWRA.

In an effort to intensively manage grazing for restoration of native grassland habitat, the EBRPD switched from cattle to sheep grazing on the Souza parcel in 2005 and had already done so two years previously at Vasco Caves Regional Preserve. Using sheep as an experimental tool, this study implemented several range management measures recommended by Smallwood and Thelander (2004, 2005), who reported on the factors contributing to biologically substantial levels of avian mortality in the APWRA. Changes in range management practices, including altering vegetation height around turbines to distribute small mammal (raptor prey) populations away from turbines, were tested to see if raptor flight paths were similarly displaced. Such a result could reduce the frequency of raptor/turbine encounters.

1.2. Study Area

The study area is in Contra Costa County, approximately 6.4 km southwest of Byron, California, within the northern confines of the Altamont Pass Wind Resource Area. The site consists of two parcels managed and operated by the EBRPD: The 292.3-ha Vasco Caves Regional Preserve and an adjacent 249.7-ha property referred to as the Souza property (Figure 1). Vasco Caves Regional Preserve is managed primarily for resource protection, including vernal pool habitat for fairy shrimp, numerous species of raptors that nest within a series of sandstone rock outcrops at Vasco Caves, and significant Native American cultural resources. The Contra Costa Water District is a partner in the management of Vasco Caves. Vasco Caves Regional Preserve does not have wind turbines on the property.

The district's Souza property, however, supported up to 76 wind turbines that operated under lease agreement prior to district ownership (Figure 1). In recent years this number was reduced to 62 turbines representing about 21.9 megawatts (MW) of rated capacity. Forty-three turbines, located throughout the middle-to-western portions of the Souza parcel, are Howden models (Photos 1–3) belonging to the Tres Vaqueros Wind Farm owned by Babcock and Brown, Inc. Twenty turbines, located in the northeast portion of the Souza parcel, are Nordtank models (Photo 4), which are owned and operated by Northwind, Inc. Additional wind farm infrastructure is scattered throughout the property and includes above-ground power lines, roads, and the remnants of numerous defunct wind turbines.

The EBRPD Board of Directors is responsible for approving renewal of the wind farm leases, which expire in 2012. Northwind, Inc., has indicated it is not planning on renewing its lease. Babcock and Brown, Inc., plans to renew the lease and repower the facility by replacing its 43 Howden turbines with 6 turbines having a rated capacity of approximately 1 MW each.

Both properties are surrounded by extensive wind farms of the APWRA. On December 28, 2006, the newly repowered Buena Vista Wind Farm, located across Vasco Road to the southeast of the study area, began operating 38 1-MW Mitsubishi wind turbines (www.mhi.co.jp/power/e_power/topics/2007/mar_01.html, accessed 12/26/07).

1.2.1. Geology and Topography

The study site encompasses the Inner Coast Range geomorphic province where it borders the Central Valley province. Elevations range from about 70 m to 300 m. Topography is steep, with hills ranging from about 180 m to over 300 m in elevation. Hill slopes of the study area are composed of well-drained clays and silty clay loams. Uplift of the Coast Ranges during the last two million years created remnant sandstone outcrops on Vasco Caves Regional Preserve known as inselbergs (Sloan 2006). Subsequent weathering of the inselbergs has produced cave formations, vernal pools, and countless shelves and potholes in the rocks that provide extensive nesting habitat for raptors and offered shelter for ceremonial Native American use (Fentress 1996).

1.2.2. Riparian Habitat

Several riparian corridors exist at the study site along with various stock ponds and springs. Brushy Creek, which parallels Vasco Road, flows in a northeasterly direction along much of the southern and eastern boundaries of the study site. Two major tributaries of this creek drain the bulk of Vasco Caves and the Souza property, respectively. A third creek forms a major drainage along the northwestern flanks of both properties. All creeks tend to be intermittent, but plunge pools and cattail-filled washes may contain water year-round. Depending on water conditions, up to six stock ponds located throughout the site may retain water.

1.2.3. Flora

The major plant community at Vasco Caves and the Souza property is California Annual Grassland, dominated by nonnative annuals such as rye grass (*Lolium multiflorum*), wild oat (*Avena fatua*), soft chess (*Bromus hordaceus*), and ripgut brome (*Bromus diandrus*). Native perennial grasses, scattered throughout both properties, include creeping wild rye (*Leymus triticoides*), purple needlegrass (*Nassella pulchra*), and one-sided bluegrass (*Poa secunda secunda*). Native and nonnative wildflowers, typical of Diablo Inner Coast Range habitat, are present. Great Valley gumplant (*Grindelia camporum camproum*), short pod mustard (*Hirschfeldia incana*), big tarplant (*Blepharizonia plumosa*), and brittlescale (*Atriplex depressa*) are common. The latter, indicative of alkaline habitats, is present in several drainages.

Shrub growth is limited to patchy areas near and among rock outcrops as well as in some drainages. Common shrub species included California sagebrush (*Artemisia californica*), matchweed (*Gutierrezia californica*), poison oak (*Toxicodendron diversilobum*), bush monkeyflower (*Mimulus aurantiacus*), blue witch nightshade (*Solanum umbeliferum*), and elderberry (*Sambucus mexicana*). Valley oak (*Quercus lobata*), and California buckeye (*Aesculus californica*) occur in isolated groves around rock outcrops and along some slopes at Vasco Caves. Also present at Vasco Caves is an isolated population of Palmer oak (*Quercus palmeri*). Riparian woodland exists along creeks mostly in Vasco Caves and consists of willow, buckeye, and cottonwood (*Populus fremontii fremontii*). Herbaceous wetland plants include sedge (*Carex* spp.), rush (*Juncus* spp.), rabbitsfoot grass (*Polypogon monspeliensis*), hedge nettle (*Stachys albens*), loosestrife (*Lythrum hyssopifolium*), and salt grass (*Distichlus spicata*). Several unusual bryophyte and lichen species were found among the rock formations. No known threatened or endangered species of plants have been identified on the properties.

1.2.4. Fauna

Common mammals observed at the properties include coyote (*Canis latrans*), bobcat (*Felis rufus*), raccoon (*Procyon lotor*), badger (*Taxidea taxus*), striped skunk (*Mephitis mephitus*), California ground squirrel (*Spermophilus beecheyi*), desert cottontail (*Sylvilagus audubonii*), California vole (*Microtus californicus*), Botta's pocket gopher (*Thomomys bottae*), and deer mouse (*Peromyscus maniculatus*). Vasco Caves lie within the range of the state-threatened and federally endangered San Joaquin kit fox (*Vulpes macrotis mutica*).

Raptors known to breed at Vasco Caves include red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), prairie falcon (*Falco mexicanus*), great horned owl (*Bubo virginianus*), barn owl (*Tyto alba*), and burrowing owl (*Athene cunicularia hypugea*). Golden eagles (*Aquila chrysaetos*) have bred at Vasco Caves, but none have bred there in at least the last decade.

Breeding songbirds include western meadowlark (*Sturnella neglecta*), savanna sparrow (*Passerculus sandwichensis*), song sparrow (*Melospiza melodia*), and grasshopper sparrow (*Ammodramus savannarum*). Common raven (*Corvus corax*), Say's phoebe (*Sayornis saya*), loggerhead shrike (*Lanius ludovicianus*), and rock wren (*Salpinctes obsoletus*) are also common.

Of the reptiles, northwestern fence lizard (*Sceloporus occidentalis*), western sagebrush lizard (*Sceloporus graciosus*), variegated skink (*Eumeces gelberti cancellosus*), and Pacific gopher snake (*Pituophis catenifer*) have been regularly observed, and the northern Pacific rattlesnake (*Crotalus oreganus*) is abundant on both properties.

Three species of amphibians are common at this location: Pacific chorus frog (*Pseudacris regilla*), California red-legged frog (*Rana aurora draytonii*), and California tiger salamander (*Ambystoma californiense*). The latter two species are listed as federally endangered and threatened, respectively.

Finally, the long-horned fairy shrimp (*Branchinecta longiantenna*) and vernal pool fairy shrimp (*Branchinecta lynchi*), both federally listed, occur in the unique rock basin vernal pools at Vasco Caves.

1.3. Management History

Vasco Caves Regional Preserve was created through a 1995 agreement between the East Bay Regional Park District and the Contra Costa Water District to acquire, protect, and manage the property as part of a long-term mitigation requirement for the Los Vaqueros Dam and Reservoir Project. The primary mitigation requirement was to protect cultural resources, kit fox, and fairy shrimp habitat. Since the adoption of a Resource Management Plan in 2000 (EBRPD 2000), Vasco Caves has been managed by the East Bay Regional Park District as a Regional Preserve, with a primary mission to "preserve and protect significant natural or cultural resources" (EBRPD 2000).

Prior to the EBRPD taking over management of Vasco Caves, the property was managed as a private cattle ranching operation for over a century. The cattle operation continued after the EBRPD took over, but grazing was managed under lease agreement according to a grazing management plan that established stocking rates to meet specific standards of range health such as maintaining sufficient residual dry mass (RDM) and erosion control. The cattle operation was discontinued in 2002.

In 2003 sheep were brought onto the property as part of a grazing program designed to restore native bunchgrass and other perennials at Vasco Caves. As opposed to the more cumbersome cattle operations, sheep were used in this program because of the ease with which they could be moved and corralled in simple electric fence enclosures for setting up experimental grazing treatments. Concomitant with sheep grazing, the University of California, Berkeley, began an intensive grassland monitoring project on the property to closely define the existing grassland makeup, measure effects of changed grazing conditions, and identify possible avenues for improving native grassland restoration.

In 2005, a 54.53-ha portion of Vasco Caves was removed from sheep grazing to establish an ungrazed study plot, while the remaining pastures of Vasco Caves (233.31 ha) were grazed under varying treatments. In 2005, the EBRPD took over management of the adjacent Souza property, which, like Vasco Caves, had been managed for cattle grazing for over a century. Cattle were removed from the property at the end of 2005, and sheep grazing treatments were set up on the property in conjunction with the current study (Photos 5 and 6).

The presence of wind turbines on the Souza property, adjacent to the Vasco Caves property which has no turbines, offers unique conditions in the APWRA to compare raptor flight behavior and burrowing mammal distribution in response to changing grazing conditions in plots with and without wind turbines. Both the Vasco Caves and Souza properties have existing and proposed easements for mitigation and conservation purposes for San Joaquin kit fox, burrowing owl, fairy shrimp, and California red-legged frog.

1.4. Research Objectives

An important objective of the study was to understand whether and how land management measures in the wind farm can modify small mammal distributions and raptor foraging patterns in manners to reduce and minimize bird collisions with wind turbines while also generating adequate power from wind. This study intended to document the shifts in small mammal distributions and raptor foraging patterns that accompanied manipulation of vegetation via sheep grazing and variable grazing pressure. Another objective was to improve understanding of impacts to the local burrowing owl population and nearby nesting raptors due to wind turbines and land management practices, and another was to improve understanding of habitat preferences of burrowing owls in the APWRA, and how these preferences might be used to reduce or minimize wind turbine-caused impacts. Also, studying small mammal burrow distribution and bird flight patterns on the Souza and Vasco Caves parcels provided an opportunity to learn how these species behave in the absence or presence of wind turbines within the APWRA, which had not been possible during previous research in the APWRA. These objectives benefit California by contributing guidance on the siting of new wind turbines in a manner that minimizes collision risk with birds and assesses possible effects of repowering.

The research objectives can be summarized as follows:

- Implement grazing management plan using sheep to create treatment plots of grazed and ungrazed parcels in the study area and to measure changes in vegetation height and density associated with treatment.
- Estimate burrowing owl nesting density and productivity, so that burrowing owl mortality can be related to the local population size:
    - Test the effectiveness of an empirical model that predicts burrowing owl density based on the size of the study area.

  - Test the effectiveness of an empirical model that predicts burrowing owl nest burrow locations based on slope attributes, and characterize the degree to which burrowing owl burrow locations are influenced by slopes versus wind turbine presence.
- Determine how small mammals (and other raptor prey) and raptors respond to changes in vegetation height and density induced by variation in sheep stocking rates by documenting the shifts in small mammal distributions and raptor foraging patterns that accompany manipulation of vegetation via sheep grazing and variable grazing pressure.
- Test whether wind turbines affect the spatial distributions and behaviors of raptors.
- Test whether raptor flights and specific behaviors relate more to landscape attributes or to spatial distributions of prey.
- After one year of observing bird behavior in the study area, test whether bird flight and perching locations shift with the relocation of artificial rock piles away from wind turbines.
- Estimate scavenger removal rates of bird carcasses:
  - Identify the species in the study area that scavenge bird carcasses and the nature of scavenging events, including carcass persistence in the environment.
  - Distribute the scavenger trial carcasses individually and at intervals, rather than in large numbers all at once, to test the degree to which scavenger swamping may bias conventional trials.
- Estimate mortality of bird species killed by wind turbines. Compare mortality measured as fatalities per megawatt hour of electric power generated by turbines to explore the usefulness of this mortality metric.
- Assess repowering scenarios on the Souza parcel to guide the siting of new-generation wind turbines and to manage the grazing range to minimize bird fatalities.

Objective 6—testing the effects of shifting artificial rock piles—had to be dropped because the duration of the study provided insufficient time to translocate rock piles and then test whether it affected raptor foraging patterns.

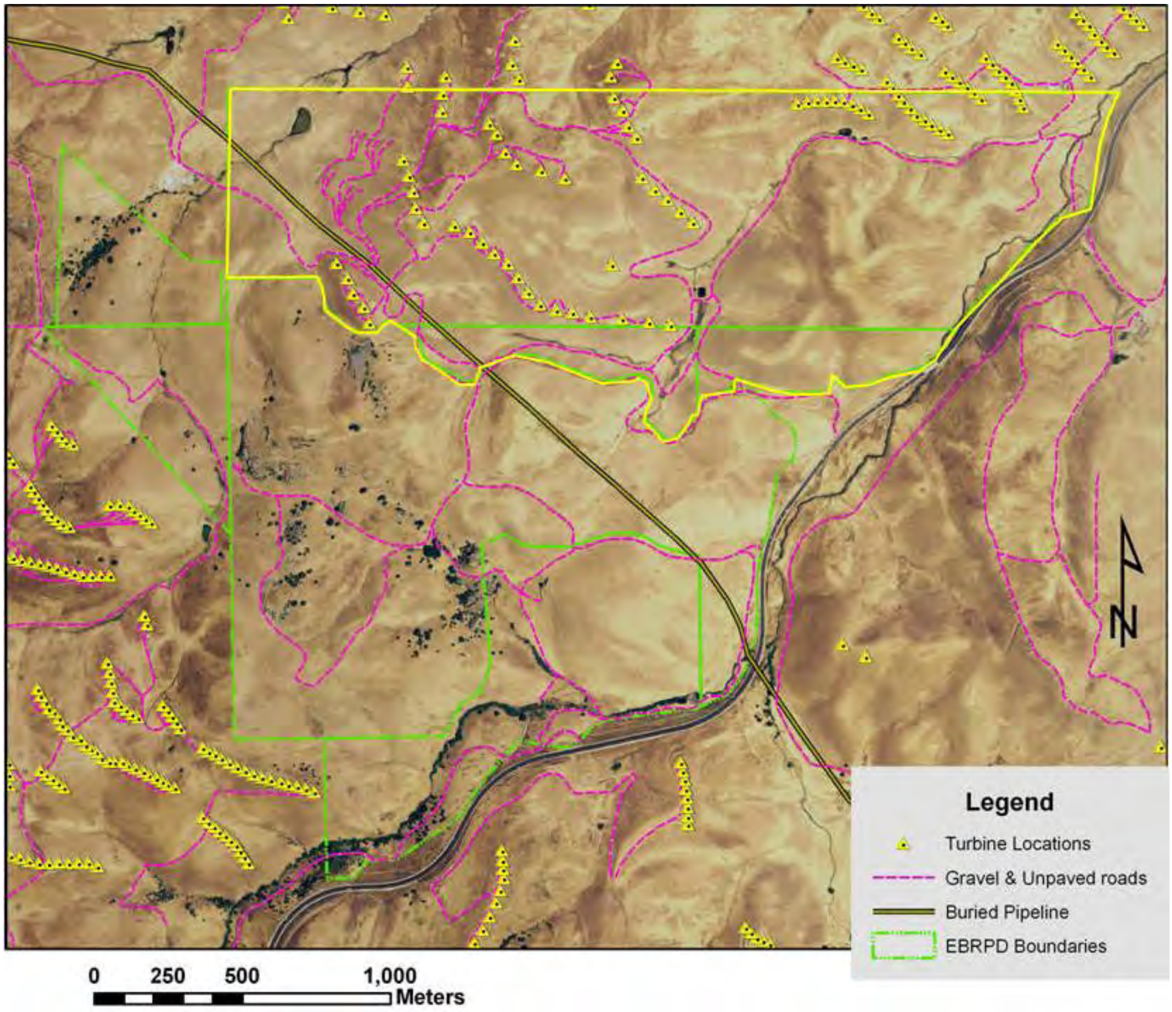

Figure 1. Study area. The yellow boundary on the north side encompasses the East Bay Regional Park District's Souza property, and the rest of the green boundary to the south and west encompasses the EBRPD's Vasco Caves Regional Preserve. Note the absence of wind turbines in the Vasco Caves portion of the Regional Preserve.

Photo 1. Howden 330-kW wind turbines on the study area's Souza parcel. An avian fatality was found at the turbine in the foreground during the study. Photo by K. S. Smallwood.

Photo 2. View northeast toward Souza parcel from Vasco Caves Regional Preserve. Photo by K. S. Smallwood**.**

Photo 3. The H string of Howden 330-kW wind turbines, view west, Souza parcel. The study found avian fatalities—including a burrowing owl and red-tailed hawk—at the first two turbines in the foreground. Photo by K. S. Smallwood.

Photo 4. The G string of Nordtank 65-kW wind turbines on the study site, view west-northwest, Souza parcel. Photo by K. S. Smallwood.

Photo 5. Sheep appear in the foreground on the Souza parcel, which the year before 2006 was grazed by cattle (background, on the property north of Souza). Photo by K. S. Smallwood.

Photo 6. Sheep graze a portion of Vasco Caves Regional Preserve. Photo by K. S. Smallwood.

2.0 Grazing Management

This chapter reports on the effectiveness of using sheep grazing to change vegetation conditions within the study area. It presents important background information for the chapters to follow, including the basis for testing whether species of wildlife shift their numbers or distribution in response to changes in vegetation structure brought about by sheep grazing management.

Evidence had been previously reported that habitat management could be used to control the spatial distribution of ground squirrels (Klitz 1982). Smallwood and Thelander (2004, 2005) therefore recommended altering grazing regimens to allow vegetation around turbines to grow taller, thereby reducing both habitat suitability for certain small mammal species and visibility of prey to foraging raptors. It was hypothesized that these two factors could potentially reduce the frequency of raptor foraging around wind turbines and lessen the number of raptor/turbine blade strikes.

Seasonal sheep grazing replaced year-round cattle grazing at Vasco Caves Regional Park in 2004 and at the Souza parcel in 2006. This presented an opportunity to test the effectiveness of using sheep to manage grassland vegetation. Sheep grazing is more easily controlled than cattle grazing at smaller scales using portable electric fencing, so exclusion zones and grazing intensity could be manipulated experimentally. This also allowed for testing whether the spatial patterns of small mammal burrows and foraging patterns of raptors responded to shifts in vegetation structure, particularly vegetation height.

The switch from year-round cattle grazing to seasonal sheep grazing permitted investigation of additional factors that may attract raptors to wind turbines. Cattle have been known to spend significant amounts of time resting in the immediate vicinity of wind turbine towers. The presence of cattle around wind turbines can attract raptors in two ways: (1) via their waste, i.e., cattle pats, which can attract insect prey of some raptors, and (2) by creating vegetation conditions through grazing and physical trampling that promote small mammal prey. Cattle pats attract grasshoppers, which in turn attract burrowing owls and other raptors that forage on grasshoppers. Burrowing owls are known to also collect cattle pats for use around their burrow entrances as dung beetle lures (Levey et al. 2004; Smith 2004) or to mask their scent from mammalian carnivores (Green and Anthony 1989). Smallwood and Thelander (2004, 2005) thus recommended excluding cattle from wind turbine areas to prevent the accumulation of cattle pats which attract invertebrate raptor prey and to allow vegetation to grow taller.

This chapter summarizes results from a 17-month field study in which sheep grazing management was carried out through two growing seasons.

2.1. Methods

Prior to the start of each grazing season in 2006 and 2007, treatment pastures with grazing and without grazing were mapped out for both the Vasco Caves and Souza parcels. Sheep fencing was installed and managed by sheep ranchers in accordance with study objectives and EBRPD grazing agreements. Sheep and fencing were moved to achieve average grass heights to facilitate the restoration of native plants, and to test whether and how fossorial (burrowing) mammals and raptors respond to habitat manipulations in grazed plots compared to ungrazed plots. In consultation with the sheep ranchers, within-season adjustments and between-year changes were made to treatment pastures to accommodate local conditions such as water availability for the sheep and to account for extreme differences in the growing season between the two years. A grazing season began in January or February and continued until range conditions were such that forage production ceased.

All boundaries of each treatment pasture were input into geographic information system (GIS) shape files to create a map of exclusive, final grazing treatments for each grazing season. The 2006 grazing treatments are shown in Figure 2, and the 2007 treatments are shown in Figure 3. In 2006, a wildfire burned 55.5 hectares in Vasco Caves, after the sheep were removed from the property but before vegetation measurements were taken. Thus, the burn area was accorded its own "treatment" polygon in the 2006 grazing map.

2.1.1. Vegetation Measurement

Vegetation sample plots were established by walking through a given treatment pasture and throwing a 1 ft^2 (0.3048 m^2) wire quadrat, with one side open, 2–20 m in various directions. Two vegetation measurements were taken within the quadrat along with its GPS (global positioning system) location using a Trimble Geo-XT unit. The next vegetation sample plot was established by walking another 3–40 m and tossing the wire frame as above. The process was repeated until it was felt that most slopes, aspects, and residual vegetation representative of the given pasture had been sampled.

The measurements were taken in the fall for both grazed and ungrazed plots. For ungrazed plots, considerable thatch from the previous season's productivity was present in most sample plots. Two methods were employed to measure the amount of grassland vegetation remaining in each pasture after grazing treatment:

1. <u>Residual dry matter (RDM)</u> measures the amount of grassland vegetation remaining after grazing treatment, and combines the effect of a season's forage production with its consumption by grazing (Bartolome et al. 2002). RDM was taken by first removing all leaves and woody material from the sample quadrat and then clipping all grassland vegetation as close to the ground as possible without disturbing the soil. The clipped vegetation was placed in a small paper bag and then air dried prior to weighing. Clippings for RDM measurements were taken after the effective height of vegetation had been measured. The amount of dried grass in the bag, minus the tare, was weighed to the nearest 0.01 g with an Ohaus Scout Pro Balance. Each RDM measurement was then converted to kilograms per hectare (kg/ha).
2. <u>Effective height of vegetation</u> (board density) measures the height at which 90% of a board is obscured by vegetation when viewed from a distance 3 m away and 1 m above the ground (see Green and Anthony 1989). It is a measure of visual obscurity or the amount of horizontal cover afforded by vegetation (Higgins et al. 1996). The board used here measured 25.4 x 40.6 cm and was divided into 2.54 x 2.54 cm alternating black and

white squares, checkerboard fashion. Each vegetation sample plot yielded an effective vegetation height measurement that was taken prior to RDM clipping.

2.1.2. Animal Units

Animal unit months (AUM) were calculated for each grazing treatment based on the number of sheep that grazed the pasture and the length of time it was grazed. AUM measures grazing intensity and is the equivalent of the effect of grazing by one cow for 31 days. In the case of sheep, 1 AUM = 5 adult animals grazing for one month (Ruyle and Ogden 2001). Since the number of AUM per pasture varied, the AUM per hectare was calculated for each pasture to assess overall grazing intensity and assign grazing intensity values of light, moderate, intense, or none, as in the case of ungrazed pastures. Further, the amount of forage consumed per pasture was calculated using the industry average of 363 kg of forage consumed per AUM.

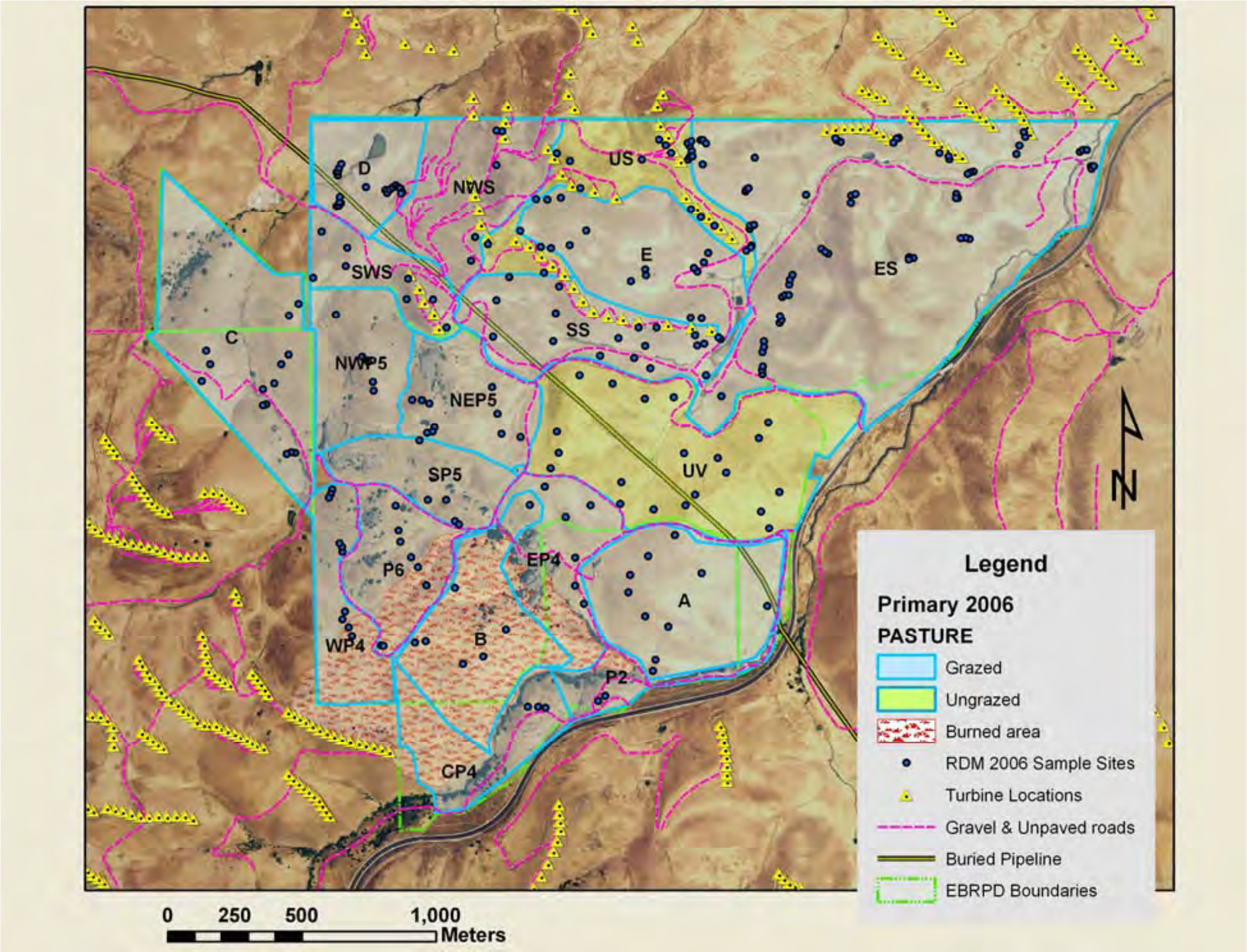

Figure 2. Distribution of grazing treatments and residual dry matter (RDM) sampling sites in 2006. The number located inside of each pasture is the average RDM for that pasture in pounds per acres (lbs/ac). The 2006 growing season was characterized as a "wet" year for the Mediterranean-like climate of California.

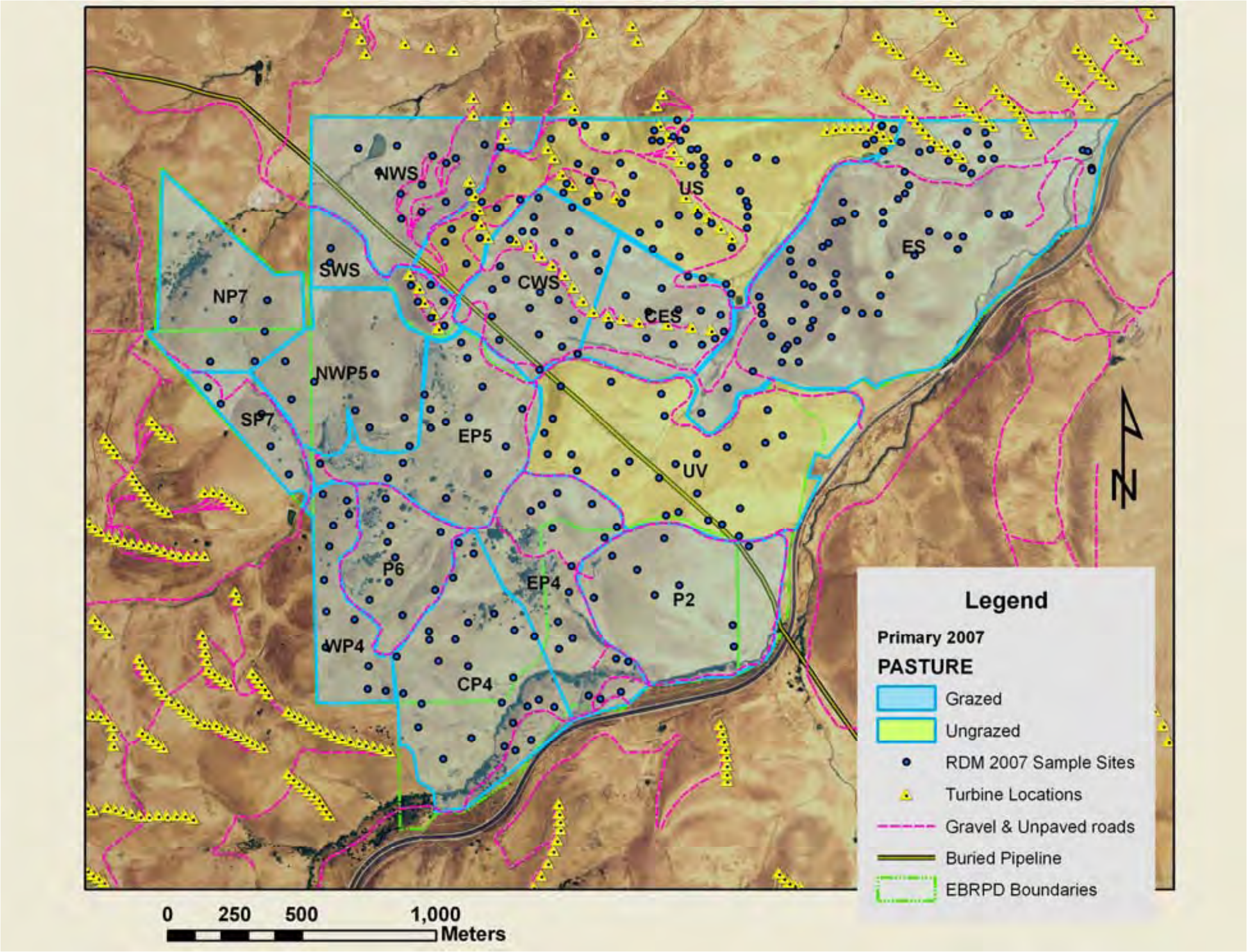

Figure 3. Distribution of grazing treatments and residual dry matter (RDM) sampling sites in 2007. The number located inside of each pasture is the average RDM for that pasture in lbs/ac. The 2007 growing season was characterized as a "dry" year for the Mediterranean-like climate of California.

2.2. Results

The first year of the study experienced unusually high rainfall during the spring, resulting in prolonged growth of grass species across the study area. Annual rainfall totals in Stockton, California, were 45.1 cm in 2006 and 18.4 cm in 2007, and almost 50% of the 2006 total fell in March, April and May, whereas only 22% of the 2007 total fell during these months (http://cdec.water.ca.gov). In 2006 the sheep could not graze the grass fast enough, and by June most grazing paddocks were visually indistinguishable from ungrazed paddocks. The sheep ranchers agreed to leave the sheep on paddocks for an extra two months, which helped reduce grass height, but still did not achieve the intended effect for use in the study. However, omitting the late-season grazing pastures, RDM still correlated with grazing intensity (Table 1, Figure 4).

Drought in 2007 affected the second year of the study. Grasses did not grow tall and were sparser than usual. Sheep grazing resulted in paddocks with variable or reduced grass cover by June. In 2007 RDM tended to decrease with increasing grazing intensity, though still not to the degree preferred for testing whether grazing can affect fossorial mammal and raptor flight distributions (Table 2, Figure 4).

Although the extent and shape of most grazing treatments differed between years, comparison of those plots that remained the same in extent shows the result of markedly different growing seasons. For example, Treatment Plot A in Vasco Caves had a mean RDM of 2762 and 1954 lbs/acre in 2006 and 2007, alternating wet and dry years, respectively (Figures 2 and 3). The large ungrazed plot in Vasco Caves (Treatment plot UV) yielded mean RDM of 4936 and 5324 lbs/acre, in 2006 and 2007, respectively (Figures 2 and 3). In this case, the higher RDM value in 2007 reflects the thatch remaining from the wet 2006 season added to the grass growth in 2007.

In both years, it was discovered that sheep grazing intensity within a given treatment plot varied, due to the animals' propensity to congregate around water sources and in nighttime bedding areas. This resulted in uneven vegetation height within grazed treatment plots (compare RDM ranges, Tables 1 and 2).

Table 1. Summary of grazing treatments in 2006

Treatment Plot	Hectares	AUM	AUM/ha	Mean RDM	RDM Range
A	32.06	123.5	3.85	3095.46	376-4550
B	2.25	5.1	2.28	4065.61	4066-4066
C	42.13	71.8	1.70	2296.32	226-3807
CP4	10.48	15.9	1.52	2857.40	2420-3721
D	14.52	34.7	2.39	2091.96	54-4786
E	29.26	68.4	2.34	3921.75	409-10239
ES (east Souza)	108.72	117.5	1.08	2771.73	269-10261
EP4	14.54	22.0	1.51	2167.25	688-4367
NW (NW Souza)	25.67	13.5	0.53	3581.61	2065-5324
NWP5	19.32	32.3	1.67	2060.77	1183-2345
P2	8.19	19.8	2.42	1892.99	731-3055
SS (south Souza)	26.59	50.2	1.89	1858.33	226-6184
SWS (SW Souza)	13.37	50.5	3.78	2164.56	462-4474
SP5	14.92	27.6	1.85	2693.20	807-3894
US (ungrazed Souza)	55.09	0.0	0.00	3577.70	592-8777
UV (ungrazed Vasco)	54.53	0.0	0.00	5531.06	2194-8906
WP4	8.62	15.6	1.81	1844.58	850-3237
NEP5	18.77	31.7	1.69	2579.19	882-4765
P6	11.38	7.5	0.66	1927.94	796-3227
Burned area	51.55	95.4	1.85	193.60	65-667

AUM refers to animal unit months, where 1 AUM = 5 adult sheep grazing for 31 days.

RDM refers to residual dry matter in kg/ha.

Table 2. Summary of grazing treatments in 2007

Treatment Plot	Hectares	AUM	AUM/ha	Mean RDM	RDM Range
CES (central east Souza)	20.04	9.2	0.46	2101.37	98-3991
CWS (central west Souza)	26.21	3.7	0.14	3044.72	892-7327
CP4	40.71	85.2	2.09	1528.01	17-4062
ES (east Souza)	93.76	68.7	0.73	2165.91	219-5384
EP4	29.14	43.8	1.50	1981.11	251-6063
EP5	30.90	49.5	1.60	2649.53	559-4929
NWS (NW Souza)	30.16	20.1	0.67	1422.58	188-3955
NP7	26.04	39.9	1.53	2109.60	742-3450
NWP5	28.58	38.8	1.36	2486.96	205-4657
P2	35.62	75.3	2.11	2189.96	294-5328
P6	17.59	37.4	2.13	3027.82	300-4499
SWS (SW Souza)	10.33	5.7	0.55	3043.56	1893-4666
SP7	9.01	13.2	1.46	3561.60	1560-7545
US (ungrazed Souza)	63.60	0.0	0.00	3502.61	171-7675
UV (ungrazed Vasco)	54.79	0.0	0.00	5965.58	1527-11420
WP4	15.46	27.7	1.79	2091.42	285-4313

AUM refers to animal unit months, where 1 AUM = 5 adult sheep grazing for 31 days.

RDM refers to residual dry matter in kg/ha.

Another unanticipated event affecting the study was a grass fire that occurred in June 2006 (Photo 7). This fire affected 55.5 ha of the study area, in the southeast portion of Vasco Caves Regional Preserve. Obviously, the effect of grazing was lost in this area, but the fire did present an opportunity to document how burrowing animals and foraging raptors responded to the burned area.

Effective vegetation height (board density) was indexed from a checkerboard extending from the ground and viewed 3 m away. The effective height was that at which 90% of the 2.54-cm squares on the 30.5 cm-wide board were not obscured by vegetation. Not surprisingly, both RDM and effective vegetation height were lower in grazed versus ungrazed paddocks (Figure 5).

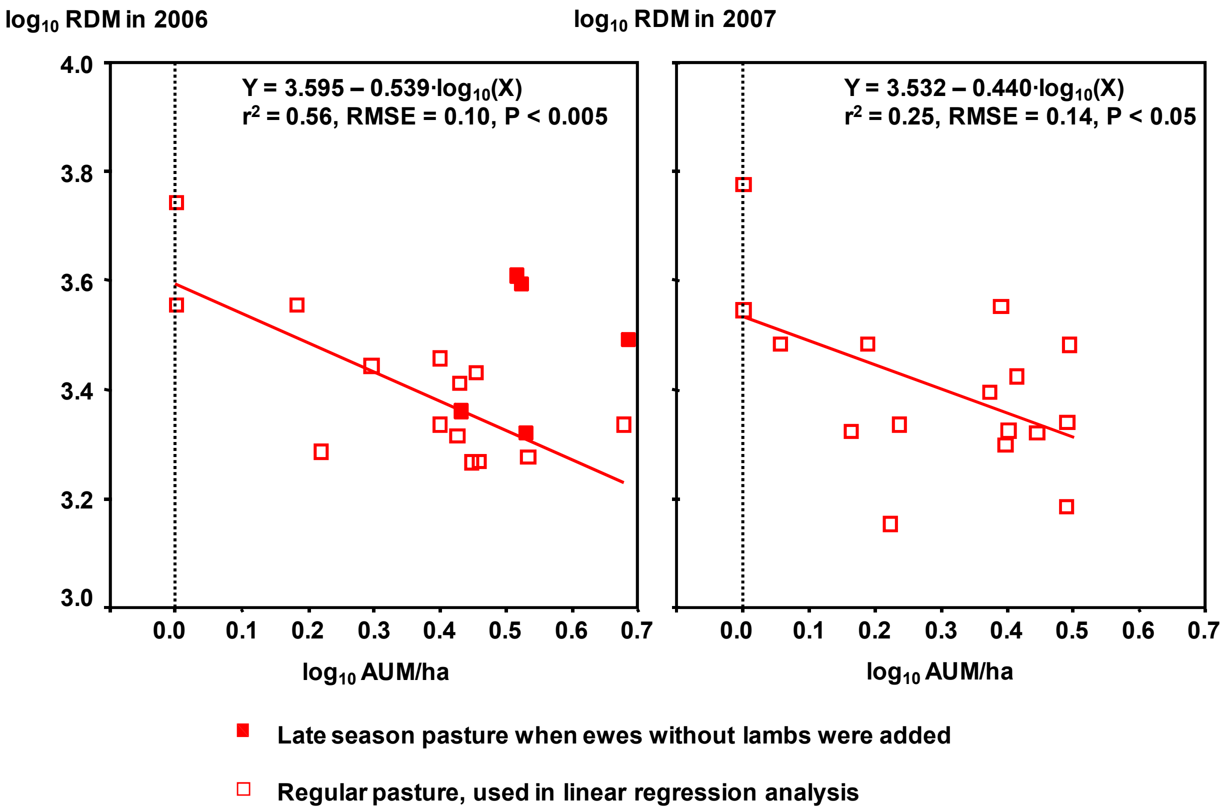

Figure 4. Average residual dry matter (RDM, in kg/ha) in 2006 (left) and 2007 (right)

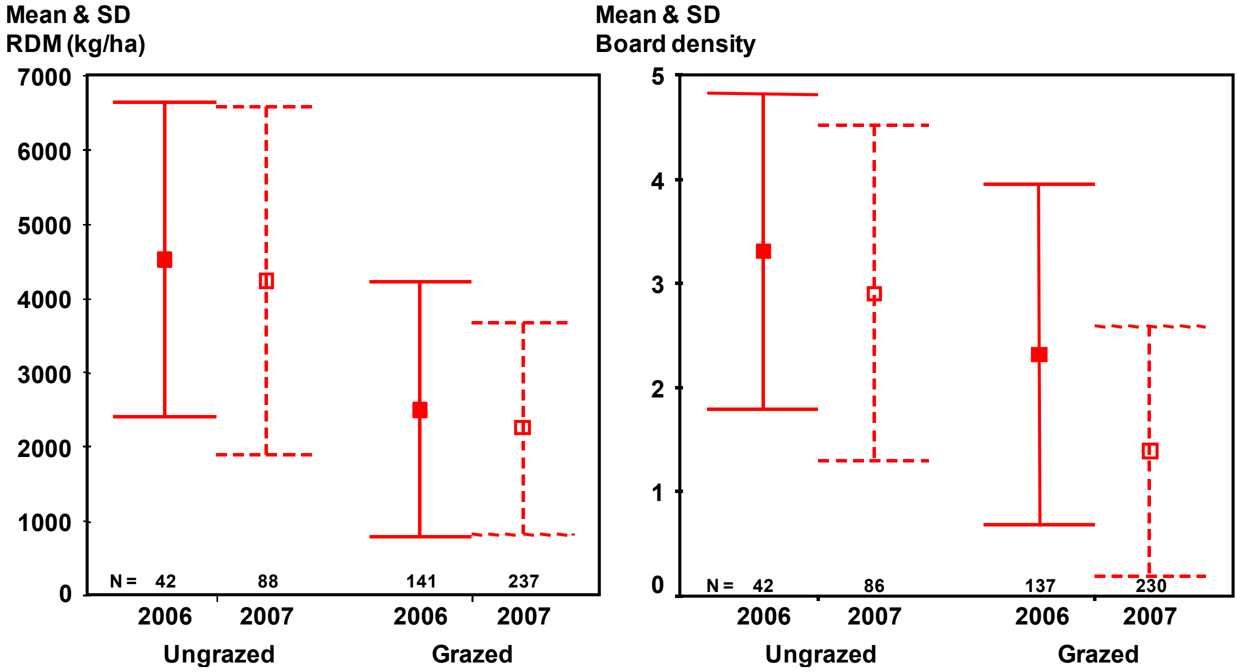

Figure 5. Mean differences in RDM (left graph) and effective height of vegetation (right graph) between grazed and ungrazed pastures, and between years

Photo 7. North-northwest edge of 2006 burn in Vasco Caves, view southwest. Photo by K. S. Smallwood.

2.3. Discussion

The duration of the study was too short to absorb the effects of extreme weather experienced both years. The spring of 2006 was unusually wet in the Altamont Pass, and grass growth exceeded levels previously seen by the investigators. The sheep grazing plan was overwhelmed by grass growth, and toward the end of June it was sometimes difficult to determine visually if paddocks had been grazed due to regrowth. The sheep ranchers were generously willing to work with the EBRPD to keep sheep on designated paddocks for two months beyond when they were scheduled to be removed in order to meet the goals of the study. But even with sheep on paddocks until mid-July 2006, the amount of forage remaining on the landscape after the grazing season, indicated by RDM, related only weakly to animal stocking rates in 2006. Such low effect on vegetation from sheep grazing in this wet year was unlikely to affect fossorial mammal spatial distribution or raptor foraging patterns, thereby reducing the likelihood of detecting a treatment effect.

Following the extreme grass growth of 2006, 2007 was a dry year, resulting in reduced emergent grass which the sheep quickly consumed. Nevertheless, average RDM declined insufficiently with increasing sheep grazing intensity, expressed as animal unit months per hectare (AUM/ha), to detect a treatment effect on fossorial mammal distribution and raptor foraging patterns. Within a given grazing treatment, sheep grazing was nonuniform, in part because they tended to graze certain portions of the terrain and congregate around water sources and in bedding areas, the latter for protection from predators. These grazer behavioral traits, combined with variable forage growth due to differing physiographic features (e.g., slope, aspect, soil type etc.) within the large plots used here resulted in highly variable RDM measurements within each treatment (compare RDM ranges in Tables 1 and 2). Extreme within-treatment variation in RDM also likely contributed to masking any effects on fossorial mammal burrow distribution or raptor foraging patterns.

The grazing study could be improved by establishing smaller grazing treatments and interspersing more control plots. The area of grazing and control treatments should be of a scale to encompass specific fossorial mammal burrow systems to better measure effects of treatment. In addition, using smaller plots would allow for greater control of sheep to effect more uniform grazing pressure. Ungrazed areas should be more interspersed among the grazing paddocks, and small, hectare-sized exclusion plots should be established in a strip-like fashion to span slopes from valley floor to ridge crest. These strip-like control plots could be sampled for residual dry matter and grass height to better differentiate grazing pressure from the effects of slope on vegetation growth. Ultimately, these actions would improve quantifying the degree to which grazing increases exposure of prey to raptors.

Another improvement would be to improve communication between scientists, sheep ranchers, and ranch hands to maintain more accurate maps of the grazing treatment boundaries and to exert more control over sheep movement patterns within treatments. Funding should be directed toward a staff member to monitor and direct the sheep grazing program in order to respond more quickly to changes within a growing season.

3.0 Burrowing Owls

The burrowing owl is one of the four focal species recommended for monitoring by the APWRA Scientific Review Committee to assess wind farm impacts on raptors. The Vasco Caves/Souza properties were known to harbor breeding burrowing owls, but their population size was unknown. Therefore, primary objectives of this study were to:

- Census burrowing owls and map their nest burrows to estimate burrowing owl nesting density and productivity so that burrowing owl mortality could be related to the population size and to measure possible shifts in nest burrow distribution in relation to vegetation management.
- Test the effectiveness of a previously developed empirical model that predicts burrowing owl density based on the size of the study area (Smallwood et al. 2007).
- Test the effectiveness of an empirical model (Smallwood and Neher, in review) that predicts burrowing owl nest burrow locations based on slope attributes, and characterize the degree to which burrowing owl burrow locations are influenced by slopes versus the presence of wind turbines.

Prior estimates of APWRA-wide, annual burrowing owl mortality caused by wind turbines range between 99 to 380 (Smallwood et al. 2007) and 440 (Smallwood and Thelander 2008). These estimates translate to 0.17 to 0.76 burrowing owl fatalities per MW of rated capacity per year. Extending these mortality estimates to the wind turbines operating on the Souza parcel would equal about 4 to 16 burrowing owls killed per year, assuming mortality is uniform across wind turbine models and sites within the APWRA. This study sought to refine this mortality estimate for the Vasco Caves and Souza parcels to better assess the impacts of wind turbine operations on the EBRPD properties.

Obtaining a mortality estimate is just one step in determining the impact of a mortality factor on local and regional populations. Information is needed on survival rates of all age classes (juveniles, adults) and immigration/emigration rates) and the degree to which the mortality factor affects each age class. To this end, it would be useful to know how many burrowing owls reside in and around the Souza parcel, their productivity, and to what extent their young disperse to other areas in the APWRA and California. Finally, it would be important to determine the proportion of resident to migrant owls that are killed in the wind farms. Only then can population impacts resulting from the mortality factor be put into context at the local and regional level. Obtaining much of this information was beyond the scope of this study.

An empirical model of burrowing owl density provided a prediction of how many nesting pairs might occur on the study site (Smallwood et al. 2007). The model predicted 16 (10 to 21) pairs of owls on the 249.7-ha Souza parcel and about 20 (11 to 29) pairs of owls within the 542 ha of the combined Souza and Vasco Caves parcels. The estimated annual fatalities of 4 to 16 burrowing owls by wind turbines might remove 20% to 38% of the estimated adult population. That the killed owls are likely from the resident population was suggested in Smallwood et al. (2001), who reported greater mortality of burrowing owls caused by wind turbine strings that included a greater number of burrowing owl burrows within 55 meters of the turbines. It appeared burrowing owl burrows near wind turbines may more frequently expose burrowing owls to wind turbine collision.

The degree to which wind turbine siting guidelines can minimize burrowing owl collisions depends on how strongly the spatial distribution of burrowing owl burrows relates to mapped elements of the landscape. Past investigations in the APWRA indicated that burrowing owl burrows are not randomly distributed. Burrowing owls tend to reside on the lower third of slopes, and just above the valley and ravine bottoms. This pattern and others yet to be identified can be used to develop a predictive model of nest locations selected by burrowing owls. The digital elevation model (DEM) created by Smallwood and Neher (2004) provided the opportunity to relate maps of burrowing owl burrows on the EBRPD properties to slope aspect, slope grade, slope curvature, and slope features in the Altamont Hills, all relationships of which can be tested statistically.

3.1. Methods

3.1.1. Nest Surveys[5]

Albion Environmental, Inc., initially searched all roads to identify optimal observation points that afforded wide views of the ground surface. Observation points numbered 33 in 2006 and 39 in 2007. At the observation points, surveys were performed using 10 x 40 binoculars and a 25 x 60 spotting scope from both inside and outside an automobile. Fifteen surveys (54 hours) were performed from 24 May to 2 August 2006, and 11 surveys (44 hours) were performed from April 3 to 27 June 27, 2007. Each year, 11 surveys were initiated during the morning, generally lasting from about 08:00 hours to 13:00 hours.

During each observation session, the number of burrowing owls was recorded at each primary nest burrow location, along with age class and sex when possible. The positions of primary burrows were recorded, as well as satellite burrows which usually were located within 30 m of the primary burrow. Only the positions of nesting burrows (as opposed to satellite burrows (refuge burrows) were reported, and these had to have a breeding pair in attendance on more than one occasion. The maximum number of emergent juveniles between two and four weeks old were recorded at each nest location to represent productivity of the pair at that nest.

3.1.2. Non-Nesting Surveys

During the mapping of fossorial mammals across most of the study area (see Chapter 4), burrows showing sign of use by burrowing owls were also mapped using a Trimble Geo-XT GPS. The types of sign (pellets, feathers, excrement, prey remains, etc.) observed at the burrow were recorded as attribute data associated with each burrow. This mapping effort did not rely on observations of owls to determine whether the burrow had been occupied, but it did rely on certain evidence on the ground to do so.

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[5] See Attachments I and II for further details on nest survey methods.

3.1.3. Association With Landscape Attributes

Mapped burrowing owl burrows were characterized as point features in ArcMap GIS and layered onto a digital elevation model (DEM) of the study area. The location of each burrow was examined for overlap with an empirical model developed by Smallwood and Neher (in review) using data collected from throughout much of the rest of the Altamont Pass Wind Resource Area. The model tested was developed from measured slope attributes which were related to burrow distribution using a fuzzy logic approach (Tanaka 1997; Kainz 2004). The model resulted in a likelihood surface area for burrowing owl burrows, and had performed well against the data used to develop it, but which had yet to be tested in another area on a new set of burrowing owl burrows. The following geoprocessing steps were used to express slope attributes that were both used to develop the fuzzy logic model and to test specific hypotheses between landscape features and nest productivity.

An existing USGS 10-m DEM was used as a starting point for characterizing the terrain of the study area. From the final DEM of the study area, the statistical analysis was limited (masked) to data within the areas searched for burrows. The resulting analytical grid for the burrow mapping area was composed of 38,139 10-m x 10-m cells.

The Curvature function in the Spatial Analysis extension of ArcGIS 9.2 (Environmental Systems Research Institute, Inc.) was used to calculate the curvature of a surface at each cell center. A positive curvature indicated that the surface was upwardly convex at that cell, a negative curvature indicated the surface was upwardly concave, and a value of zero indicated the cell surface was flat. The curvature data (-51 to 38) were classified using the NaturalBreaks (Jenks) function with three classes of curvature—convex, concave, and mid-range. The break values were then adjusted through visual inspection to minimize the size of the mid-range class. A series of geoprocessing steps using expand, shrink, regiongroup, and majority filter tools were used to enhance the primary slope curvature trend of a location. The result was a surface almost exclusively defined as either convex or concave. The convex surface areas consisted primarily of ridge crests and peaks, hereafter referred to as ridges, and the concave surface areas consisted primarily of valleys, ravines, ridge saddles, and basins, hereafter referred to as valleys.

Line features representing the estimated average centers of ridge crests and valley bottoms were derived from the following steps. ESRI's Flowdirection function was used to create a flow direction from each cell to its steepest downslope neighbor, and then the Flowaccumulation function was used to create a grid of accumulated flow through each cell by accumulating the weight of all cells flowing into each downslope cell. A valley started where 50 cells had contributed to it, and a ridge started where 55 cells contributed to it. The Flowdirection and Flowaccumulation functions were applied to the ridges by multiplying the DEM by -1 to reverse the flow. Line features representing ridges and valley bottoms were derived from ESRI's gridline and thin functions, which feed a line through the centers of the cells composing the valley or ridge. Thinning put the line through the centers of groups of cells ≥40 in the case of valleys.

The horizontal distance (m) of each DEM grid cell was then measured from the nearest valley bottom and the nearest ridgeline, referred to as *distance to valley* and *distance to ridge*, respectively. These distances were measured from the DEM grid cell to the closest grid cell of a valley bottom or ridgeline, respectively, not including vertical differences in position. The total distance across the underlying slope was the sum of the distance to the valley bottom and the distance to the ridgeline, and expressed the size of the slope (*total slope distance*). The DEM grid cell's position in the slope was also expressed as the ratio of the distance to the valley and the distance to the ridge, referred to as the *distance ratio*. This expression of the grid cell's position on the slope removed the size of the slope as a factor.

The vertical differences between each DEM grid cell and the nearest valley bottom and nearest ridgeline were measured as elevation differences, and the elevation difference between the nearest valley bottom and the nearest ridgeline also expressed the size of the slope, but this time was referred to as *elevation difference*. In addition to the trend in slope grade at each DEM grid cell, the *gross slope* was measured as the ratio of *elevation difference* and *total slope distance*. The DEM grid cell's position on the slope was also expressed as the ratio of the elevation differences between the grid cell and the nearest valley and the grid cell and the nearest ridge, referred to as the *elevation ratio*. Log_{10} and natural log (ln) transformations were used to better fit normal distributions.

Each DEM grid cell was classified by *slope aspect* according to whether it faced north, northeast, east, southeast, south, southwest, west, northwest, or it was on flat terrain. For analysis, slope aspect was aggregated into five categories: northeast and east, southeast and south, southwest and west, northwest and north, and no aspect (flat terrain). Each grid cell was categorized as to whether its center on the landscape was windward, leeward, or perpendicular to the prevailing southwest and northwest wind directions recorded during the behavior observation sessions.

A principal components Analysis (PCA) was used to identify factors expressed by the measured slope variables, and will be used in subsequent research to select variables for use in developing fuzzy logic models of burrowing owl burrow locations. Additionally, one-way analysis of variance tests were performed on the measured slope variables to test for differences between where burrowing owl burrows were found and not found . Due to considerable shared variation in these slope attributes, interpretation of results was limited to only one attribute per principal component (PC), or sometimes to the PC itself.

3.2. Results

3.2.1. Nest Surveys

During the 2006 nesting census, burrowing owls were sighted from observation points 582 times, while in 2007 burrowing owls were sighted 337 times, or 10.8 times per hour in 2006 and 7.7 times per hour in 2007. In 2006, 25 (76%) of 33 locations were classified as nest burrows (Table 3, Figure 6). In 2007, 21 (54%) of 39 locations were classified as nest burrows (Table 3, Figure 6). Of the 25 breeding pairs in 2006, 19 produced at least one emergent young for a nest success rate of 76%. Of the 21 breeding pairs in 2007, 12 produced at least one emergent young for a nest success rate of 57%. One site was seen to support only one adult throughout the surveys of 2007, so this adult was used with the nesting pairs to compute adult productivity.

In 2006 a minimum of 68 nestlings were raised by 15 pairs on the Souza parcel (4.53 juveniles/successful pair), and 18 nestlings were raised by 4 pairs on the Vasco Caves parcel (4.5 juveniles/successful pair); detailed data appear in Attachment I. In 2007 a minimum of 31 nestlings were raised by 9 pairs on the Souza parcel (3.44 juveniles/successful pair), and 10 were raised by 3 pairs on the Vasco Caves parcel (3.33 juveniles/successful pair); detailed data appear in Attachment II. In 2006 the combined parcels supported 25 nesting pairs and 86 young for a minimum productivity of 3.44 juveniles/pair. In 2007 the combined parcels supported 21 nesting pairs and 41 young for a minimum productivity of 1.95 juveniles/pair. Juveniles were first observed emerging from nest burrows on June 12 in 2006, and on May 22 in 2007.

Table 3. Burrowing owl burrow occupants on the indicated date of observation. Burrow numbers correspond with the numbers appearing in Figure 6.

Burrow	Date	No. of adults	No. of juveniles	Burrow	Date	No. of adults	No. of juveniles
1	5/24/2006	2	3	1	4/3/2007	2	8
2	5/24/2006	2	3	3	4/3/2007	2	5
4	5/24/2006	2	1	5	4/3/2007	2	6
5	5/24/2006	2	4	6	4/3/2007	2	3
6	5/24/2006	2	0	8	4/3/2007	2	2
7	5/24/2006	2	5	10	4/3/2007	2	0
8	5/24/2006	2	3	12	4/3/2007	2	0
10	5/24/2006	2	6	15	4/3/2007	2	0
11	5/24/2006	2	0	18	4/3/2007	2	2
12	5/24/2006	2	7	19	4/3/2007	2	0
13	5/24/2006	2	7	21	4/10/2007	2	3
14	5/24/2006	2	0	22	4/10/2007	2	0
15	5/25/2006	2	0	25	4/10/2007	2	4
16	5/25/2006	2	5	27	4/10/2007	2	0
18	6/5/2006	2	4	30	4/24/2007	2	1
19	6/5/2006	2	0	31	4/24/2007	2	0
20	6/5/2006	2	3	32	4/24/2007	2	3
21	6/5/2006	2	4	33	5/7/2007	2	0
22	6/5/2006	2	0	34	5/7/2007	2	0
23	6/5/2006	2	8	35	6/6/2007	2	1
24	6/6/2006	2	7	36	6/6/2007	2	3
25	6/6/2006	2	3				
26	6/19/2006	2	3				
27	6/30/2006	2	5				
31	7/21/2006	2	5				

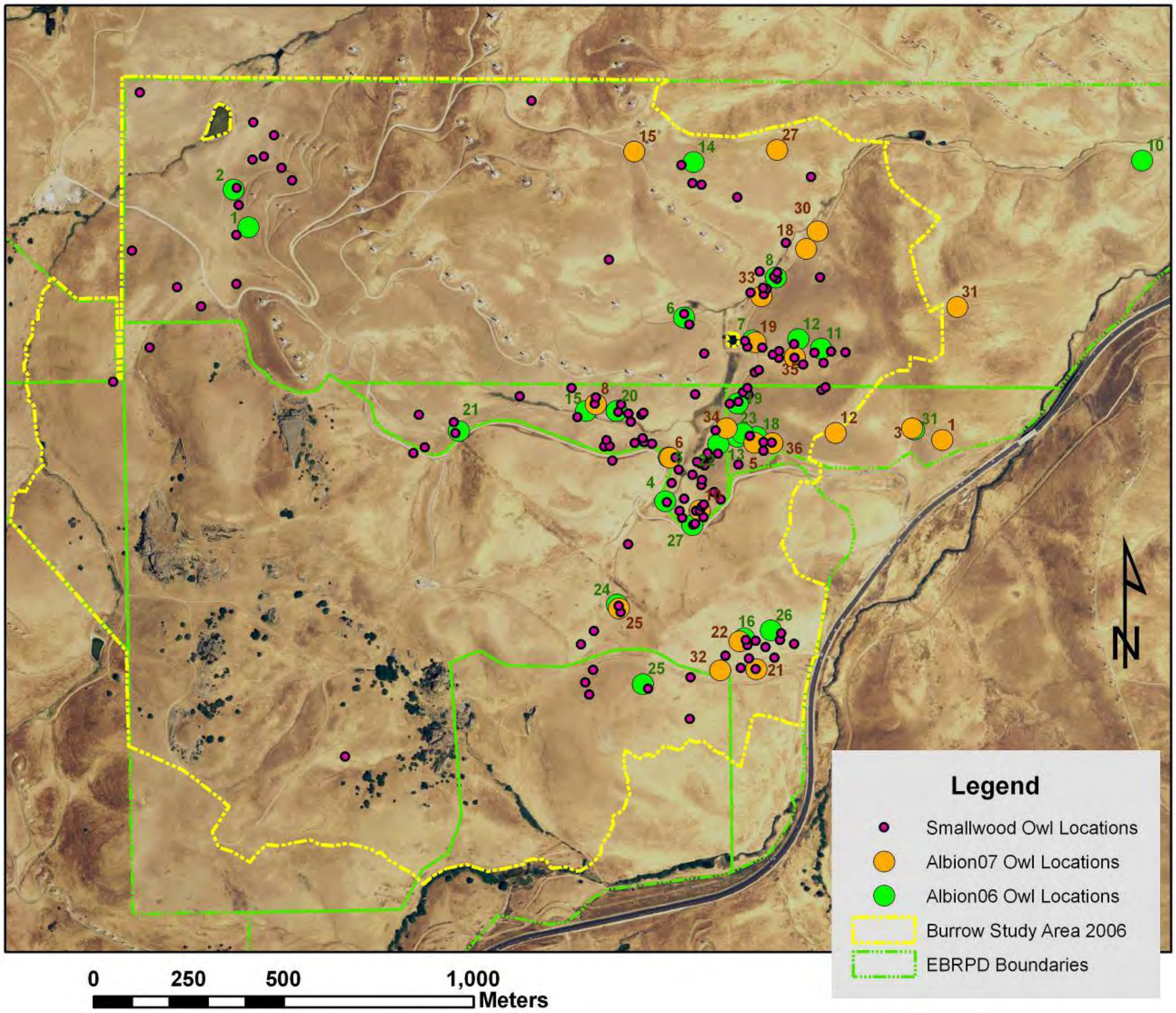

Figure 6. Distribution of burrowing owl burrows located during owl nest censuses by Albion Environmental, Inc., in 2006 (green circles) and 2007 (orange circles), and during fossorial mammal burrow mapping by Smallwood in 2006 and 2007 (maroon circles). Numbers correspond with the burrow numbers in Table 3. See also Attachments I and II.

Among nest burrows in which young were observed, the number of young correlated with the natural log of the distance ratio, i.e., the ratio of the distance from the valley to the distance from the ridge ($R_P = 0.42$, $n = 31$, $P < 0.05$) (Figure 7), and negatively with the $\log_{10}$ distance from the nearest ridge crest ($R_P = -0.46$, $n = 31$, $P < 0.05$). More young were produced from burrows located farther from the valley bottom and closer to the ridge crest. These relationships suggest the production of young per successful nest tended to increase while nest failures also increased in burrows approaching the ridge crest (Figure 7). Among burrows closer to the valley bottom, production was lower than observed among burrows farther up the slopes, but nests were more often successful. An examination of the map of burrow productivity (not produced for this report) indicated a higher proportion of the burrows peripheral to the population cluster had failed, and most of these were either at the valley bottom or very near the ridge crest.

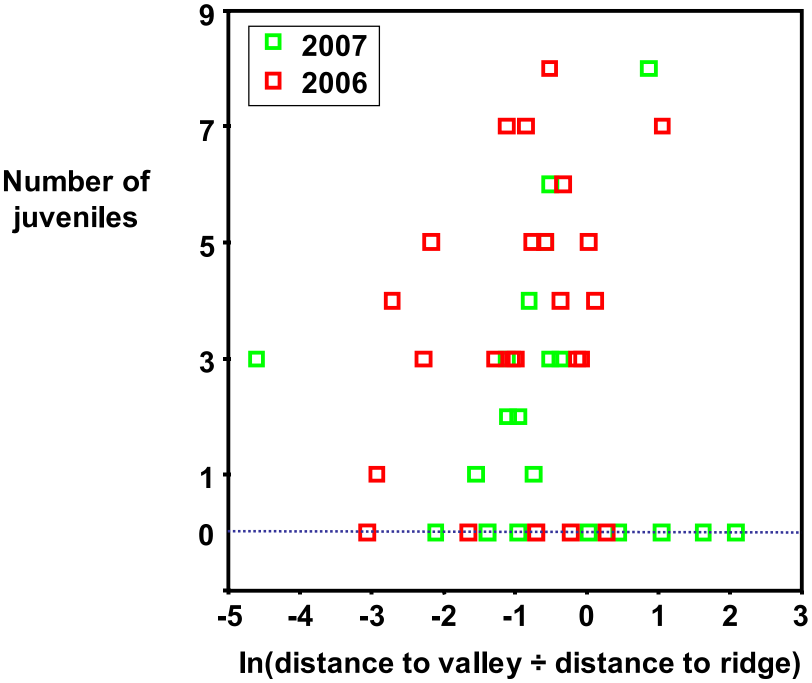

Figure 7. Relationship between the number of juveniles produced from the nest and the horizontal position of the burrow between the nearest valley bottom and nearest ridge crest. When the natural log value of the ratio of horizontal distances was -4, the burrow's distance from the valley was only 0.018 times its distance from the ridge crest. When the value was -2, the burrow's distance from the valley was 0.135 times its distance from the ridge crest. When the value was 0, the burrow was equidistant between the horizontal positions of the nearest valley bottom and nearest ridge crest. When the value was 2, the burrow's distance from the valley bottom was 7.389 times its distance from the nearest ridge crest. Burrows located at distances from the nearest valley at least 0.6 times those to the nearest ridge crest either failed to produce young or produced at least three young, with an increasing number of young the farther from the valley bottom and closer to the ridge crest.

3.2.2. Nesting Density

The breeding pair density of burrowing owls on the project site was at least 4.61 per 100 ha in 2006 and 3.87 per 100 ha in 2007. These densities were slightly higher than predicted by the model in Smallwood et al. (2007), but well within the confidence interval. The nesting burrowing owls on the EBRPD study site clustered on the landscape in the same manner they have at all study sites reported to date.

3.2.3. Non-Nesting Surveys

While mapping fossorial mammal burrows in fall 2006, the research team detected 143 burrowing owl burrows, 107 of which were classified as refuge burrows, and 36 of which were classified as nest burrows (Figure 6). Because this classification relied on sign at the burrows, and not on actual owl sightings, it was less reliable than the previous classification. On the other hand, the foot search discovered burrows—including burrows showing intensive use—that were not detected by relying on viewsheds from roadways.

3.2.4. Association With Landscape Attributes

The predictive model developed by Smallwood and Neher (in review) correctly predicted the locations of most of the burrowing owl burrows detected during this study (Figure 8), even though the model was developed from data collected in other parts of the APWRA. The fuzzy logic likelihood surface developed by Smallwood and Neher covered 40.9% of the total area of the 2006 burrow mapping area (only the 2006 data were assessed in this analysis), but contained 69% of all the owl burrows that Smallwood detected during fossorial mammal burrow mapping. This overlap of burrows with the fuzzy logic surface was 1.68 times other than expected. Of the owl nest burrows mapped by Albion Environmental, Inc., 63% were located in the fuzzy logic surface, which was 1.55 times other than expected. These loadings were smaller than the loading achieved with the data used to develop the predictive model, which was to be expected, especially considering most of the search effort during fossorial mammal mapping was higher on the slopes, near wind turbines. Additionally, 61% of all the juveniles produced from the burrows monitored by Albion Environmental, Inc. were from the fuzzy logic surface, or nearly 1.5 times other than expected.

The landscape in the study area differed in some ways from the landscape used to develop the fuzzy logic likelihood surface depicted in Figure 8 (see Smallwood and Neher in press).

A principal components analysis using a correlation matrix and varimax rotation explained 82% of the variation in the measured predictor variables among the 38,139 grid cells within the grid used for burrow distribution analysis, which was the number of PCs and the same percentage of variation explained in Smallwood and Neher (in press). The three principal components are presented in Table 4, presenting only those rotated factor loadings >0.1. Component 1 can be interpreted as position on the slope. It differed from Smallwood and Neher (in press) by loading stronger on elevation and dropping percent slope. Component 2 can be interpreted as the slope's rate of change, i.e., steepness. It differed from Smallwood and Neher by loading more weakly on elevation, but much stronger on percentage slope. Component 3 can be interpreted as the slope's size. Only one variable with a high loading will be used from each component for subsequent predictive model development, though all variables and transformed variables were tested for a relationship with burrow locations. The predictive models will be developed in follow-on work to this report.

ANOVA (analysis of variance), showed that most measured slope attributes differed between sets of grid cells where burrowing owl nest burrows were found and where they were not found (Table 5). Grid cells with burrowing owl nest burrows averaged 73% of *distance to valley* compared to grid cells without nest burrows, and grid cells with nest burrows averaged only 3% of the *distance ratio* compared to grid cells without owls (Table 5). Grid cells with burrowing owl nest burrows averaged 33% of the *elevation ratio* compared to grid cells without nest burrows. Thus, nesting burrowing owls tend to select locations low on the slope and near the valley floor. The slope attributes measured here are important to nest burrow location.

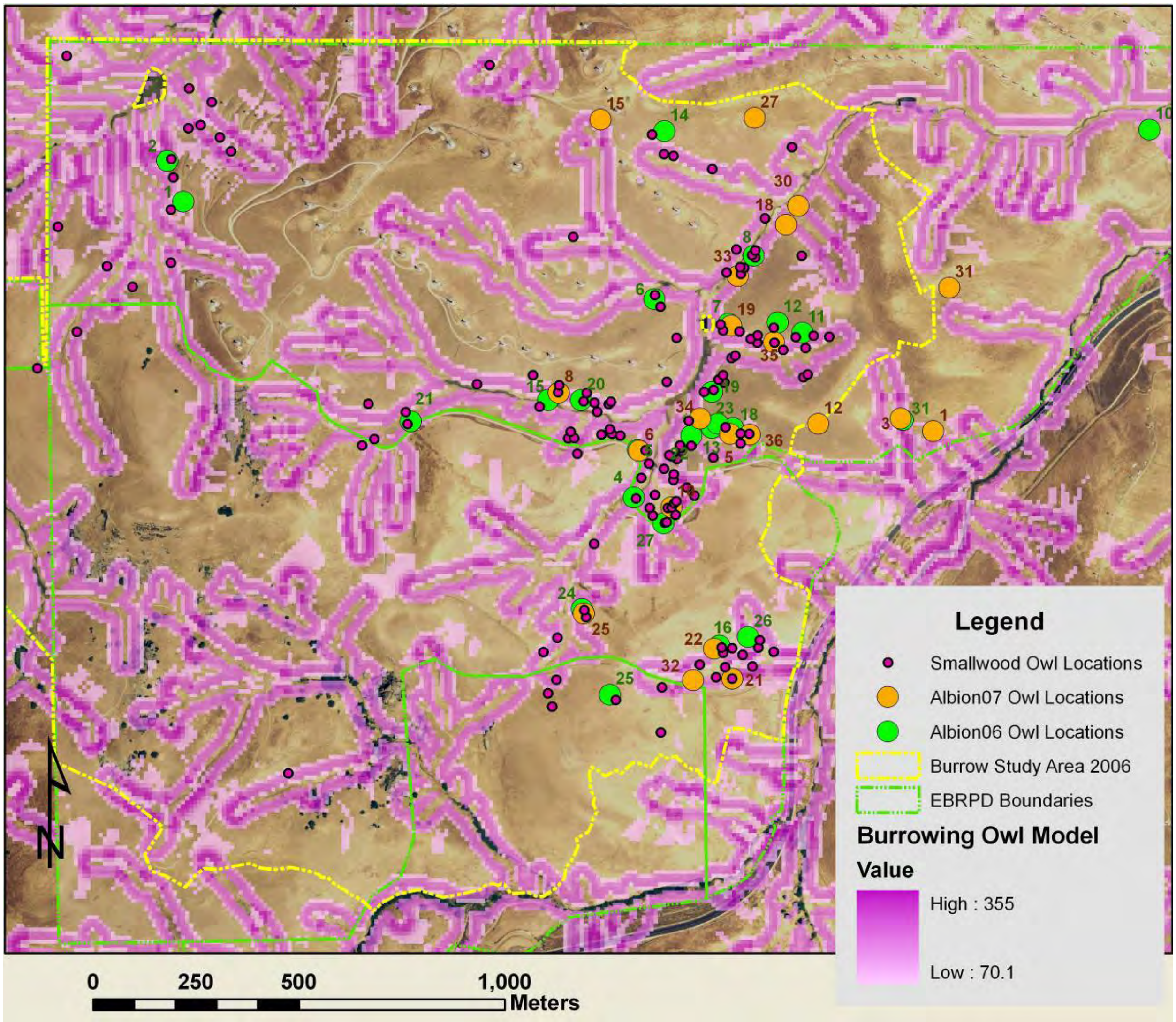

Figure 8. Most of the burrowing owl burrows mapped by Smallwood during fossorial mammal burrow mapping and by Albion Environmental, Inc. during owl nest censuses were located within the fuzzy logic surface developed by Smallwood and Neher (in review), the surface of which is indicated here in shades of purple.

Table 4. Principal components and standardized coefficients for each variable following varimax rotation in PCA for the burrow study area (2006)

Variable	Component 1 Position on slope	Component 2 Steepness of slope	Component 3 Size of slope
ln Distance ratio	0.979		
ln Elevation ratio	0.921		
$\log_{10}$ Distance to ridge	-0.851		0.332
$\log_{10}$ Distance to valley	0.807		0.472
Elevation	0.437	0.234	-0.211
Gross slope		0.909	
Elevation difference		0.775	0.549
Slope (percentage)		0.745	
$\log_{10}$ Total slope distance			0.959

Table 5. Mean comparisons between sets of grid cells where burrowing owl nest burrows were not found (n = 37,970) and where they were found (n = 41) in 2006 and 2007

	Burrowing Owl Nest Burrows				
	Not Observed		Observed		ANOVA
Variable	Mean	SD	Mean	SD	F-value
Distance to valley (m)	59.00	40.58	43.27	33.31	6.16 *
$\log_{10}$ Distance to valley	1.61	0.45	1.45	0.58	5.46 *
Distance to ridge (m)	59.60	41.88	83.37	32.73	13.19**
$\log_{10}$ Distance to ridge	1.61	0.48	1.88	0.20	13.48**
Total slope distance (m)	118.60	40.97	126.64	40.76	1.58 ns
$\log_{10}$ Total slope distance	2.05	0.16	2.08	0.12	2.33 ns
Distance ratio	26.91	3717.71	0.80	1.39	0.00 ns
ln Distance ratio	0.01	1.82	-1.01	1.57	12.83**
Elevation (msl)	198.98	45.90	143.56	21.39	59.77**
Elevation difference; near ridge – near valley	25.73	14.87	24.83	12.67	0.15 ns
$\log_{10}$ Elevation difference	1.29	0.50	1.34	0.23	0.32 ns
Gross slope	0.22	0.10	0.20	0.07	1.74 ns
Slope (percentage)	27.06	12.54	24.61	10.63	1.56 ns
Elevation ratio	5.15	9.55	1.69	6.99	5.38 *
ln Elevation ratio	0.10	1.95	-1.03	1.36	13.74**
Principal component 1, position on slope	0.00	1.00	-0.70	0.75	19.98**
Principal component 2, slope steepness	0.00	1.00	-0.34	0.69	4.66 *
Principal component 3, slope size	0.01	1.00	-0.21	0.96	6.55 *

Significance of ANOVA tests: * indicates $P < 0.05$; ** indicates $P < 0.005$; and no symbol (ns) indicates $P > 0.05$.

Most measured slope attributes differed between sets of grid cells where burrowing owl burrows were found and where they were not found during foot searches (Table 6). Grid cells with burrowing owl burrows averaged 59% of *distance to valley* compared to grid cells without burrows, and grid cells with burrows averaged only 2% of the *distance ratio* compared to grid cells without owl burrows (Table 6). Grid cells with burrowing owl burrows averaged 15% of the *elevation ratio* compared to grid cells without burrows. The burrowing owl burrows found during foot searches were closer to the valley bottoms than were the nest burrows detected during the nesting survey (also see Figure 9). Note that foot searches were conducted after the breeding season, so they did not attempt to distinguish between nesting and satellite burrows. In Figure 9, the 129 "burrowing owl burrows" reflect the results of foot searches as opposed to nest surveys.

Table 6. Mean comparisons between sets of grid cells where burrowing owl burrows were not found (n = 37,880) and where they were found (n = 131) during foot searches in 2006

	Burrowing Owl Burrows (Foot Searches)				
	Not Observed		Observed		ANOVA
Variable	Mean	SD	Mean	SD	F-value
Distance to valley (m)	59.07	40.60	34.73	23.97	47.02**
$\log_{10}$ Distance to valley	1.61	0.45	1.42	0.36	24.08**
Distance to ridge (m)	59.53	41.89	85.80	28.90	51.40**
$\log_{10}$ Distance to ridge	1.61	0.48	1.91	0.16	50.63**
Total slope distance (m)	118.60	40.99	120.53	33.89	0.29ns
$\log_{10}$ Total slope distance	2.05	0.16	2.07	0.12	1.69ns
Distance ratio	26.97	3722.11	0.52	0.65	0.01ns
ln Distance ratio	0.01	1.82	-1.12	1.00	50.71**
Elevation (above mean sea level)	199.10	45.87	147.02	26.43	168.75**
Elevation difference; near ridge – near valley	25.74	14.88	21.47	11.69	10.76 *
$\log_{10}$ Elevation difference	1.29	0.50	1.19	0.61	5.26 *
Gross slope	0.22	0.10	0.18	0.08	17.26**
Slope (percentage)	27.07	12.55	23.87	9.75	8.50 *
Elevation ratio	5.16	9.56	0.77	1.61	27.70**
ln Elevation ratio	0.10	1.95	-1.17	1.25	55.85**
Principal component 1, position on slope	0.00	1.00	-0.74	0.55	72.33**
Principal component 2, slope steepness	0.00	1.00	-0.47	0.74	29.26**
Principal component 3, slope size	0.00	1.00	0.27	0.74	9.48 *

Significance of ANOVA tests: * indicates $P < 0.05$; ** indicates $P < 0.005$; and no symbol (ns) indicates $P > 0.05$.

Compared to the average position on the slope of grid cells in the study area, burrowing owl burrows were much lower, averaging less than half way up the average grid cell's position (Figure 9). Burrowing owl burrows were also located lower on the slopes than was the average ground squirrel burrow complex (Figure 9).

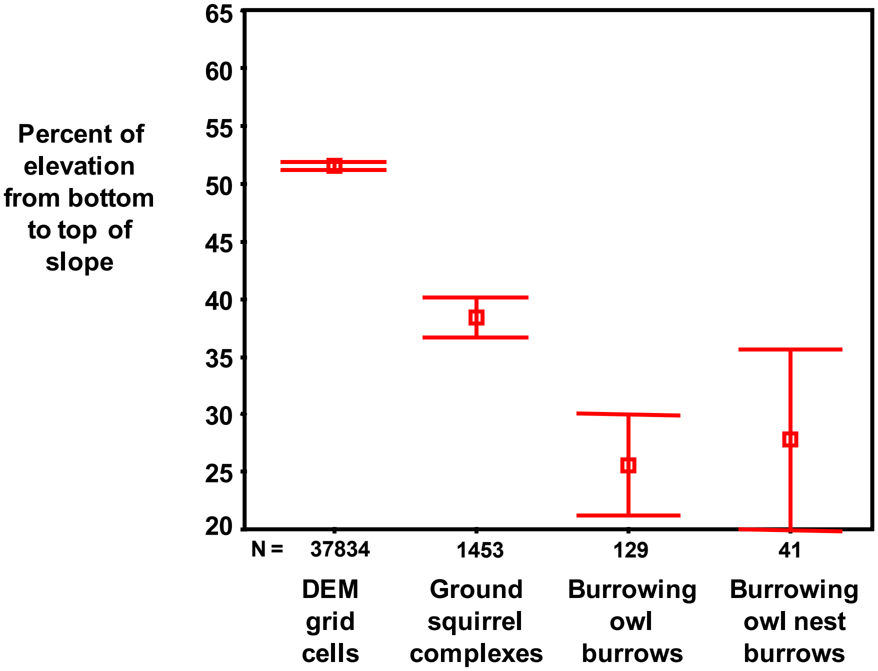

Figure 9. Mean and standard error of percent of elevation from the bottom to the top of the slope on which the grid cell is located. On average, ground squirrel burrow systems were lower on the slope than the average grid cell. Burrowing owl burrows were lower yet, whether they were detected during the fall foot searches or the spring-summer nest surveys.

3.2.5. Response to Grazing Treatments

The total number of breeding burrowing owl pairs decreased 16% between years and appeared to shift burrow locations between years (Appendix A), but too few grazing treatment plots (see Chapter 2 included burrowing owl burrows to test for the effects of grazing.

3.3. Discussion

The population size of burrowing owls in the study area nearly exceeded a previous estimate for total population size in the entire APWRA (DeSante et al. 2007). However, the burrowing owl nesting census yielded a population that was consistent with the density predicted by an empirical model developed by Smallwood et al. (2007). Given the area of the study site, the model predicted 11 to 29 breeding pairs, and the nesting census found 25 pairs in 2006 and 21 in 2007. However, the fossorial mammal burrow mapping effort detected additional owl burrows. The nesting census, which was largely conducted from roadways and trails, focused on detecting nesting *owls* rather than *burrows*. Some of the additional owl burrows may have been nest burrows, therefore the actual number of nesting pairs might have been larger than reported by Albion Environmental, Inc. (Attachments I and II), perhaps nearly as numerous in 2006 as the upper end of Smallwood et al.'s (2007) estimate of 29 breeding pairs.

The census also validated the predictive model of burrowing owl burrow locations developed by Smallwood and Neher (in press). The model was developed in another part of the APWRA and applied to the Vasco Caves/Souza study area. The model correctly predicted the locations of 69% of the burrows detected during the foot searches, whereas the area predicted to contain burrowing owl burrows was only 40.9% of the area searched. Where the model predicted burrowing owls to occupy burrows nearby wind turbines, the model generally failed. When given a choice, it appeared burrowing owls occupied areas without wind turbines. However, one burrowing owl was observed to travel from its burrow upslope to a ridge with wind turbines (Appendix B).

Burrowing owl productivity differed strongly between years, perhaps reflecting the extreme wet/dry weather patterns. In 2006 a minimum of 3.44 juveniles per nesting pair was produced, whereas in 2007 minimum productivity was only 1.95 juveniles per nesting pair. Increased sightings of owl pairs in late June 2006 may have been due to heavy spring rains which could have delayed nesting phenology.

Ten burrowing owl fatalities were found near wind turbines on the Souza parcel (see Chapter 7), all of which turned out to be the Tier 1 and 2 turbines that Smallwood and Spiegel (2005) classified as the most hazardous to raptors. Using mortality estimates from previous studies in the APWRA, the authors had predicted 4 to 16 fatalities per year on the Souza parcel's wind farms. Incorporating both conventional and new scavenger removal data led to new mortality estimates of 18 (range 7–29) and 26 (range 9–43) burrowing owls killed per year, respectively. The point estimate of 18 owl fatalities was slightly higher than the upper end of the predicted range of annual fatalities.

Whether this level of mortality causes significant adverse impacts to the resident burrowing owl population remains unknown, despite being able to relate the mortality to population numbers (see Chapter 7). It is interesting to note that from 2006 to 2007, total pairs nesting on the study site declined 16%. The significance of this decline is unknown, because occupancy of burrowing owl nest burrows varies greatly year-to-year, and surveys in just two years are inadequate to discern population trajectories. However, DeSante et al. (2007) show that burrowing owls declined in the San Francisco Bay Area an average of 6% per year between the 1980s and early 1990s. Certainly, the relatively high mortality estimates associated for burrowing owls in the APWRA imply the area could be a population sink for the burrowing owl. Continued population monitoring is strongly advised, as is an APWRA-wide population census.

The high level of burrowing owl mortality at wind turbines in the Vasco Caves/Souza study area also refuted Smallwood and Thelander's (2004, 2005) hypothesis that higher concentrations of cattle pats near wind turbines throughout most of the APWRA might attract burrowing owls. Because cattle tend to spend inordinate amounts of time near wind turbines, it was hypothesized that their dung might attract burrowing owls seeking the grasshoppers and other prey items that feed on cattle pats. The Vasco/Souza study area was grazed by sheep, which left widely spread dung that did not appear to accumulate grasshoppers as seen on cattle pats elsewhere. In the absence of cattle pats, burrowing owls not only continued to die near wind turbines, but their mortality was even higher than previously reported.

An additional two burrowing owl carcasses were found far from wind turbines, though one was not far enough away to rule out wind turbines as the cause of death. Assuming both these fatalities were unrelated to wind turbines, they confirm that background mortality exists, but they also demonstrate it is of relatively low frequency. The fact that nest failure was likely greatest when burrows were situated nearest valley bottoms and ridge crests suggests that predation on the periphery of nesting burrowing owl colonies could be a factor in nest failures and contribute to background mortality.

It cannot be ruled out that burrowing owls are often killed by predators when they are near wind turbines for some reason. Most of the burrowing owl fatalities detected during this study consisted of feathers, and the main portions of the carcass were missing by the time of discovery. Predators might be exploiting a situation that exposes burrowing owls to successful attacks near wind turbines, or scavengers might detect carcasses rapidly and remove most of the carcass almost immediately. One might assume that naïve owls, such as juveniles, might be more vulnerable to predation than adults. It would be valuable in future studies to note whether burrowing owl feather spots found in turbine search areas originated from juvenile or adult owls.

Given that grazing treatments had no measurable effect on ground squirrel burrow distributions during the short duration of this study, that ungrazed treatment plots had too few owl nesting burrows, and that there was a 16% drop in the nesting population between study years, it was not possible to measure an effect of grazing treatment on burrowing owl nest burrow distribution.

4.0 Fossorial Mammal Distribution

A primary objective of the fossorial mammal survey was to determine how small mammals respond to varying levels of vegetation management induced by sheep grazing treatments. A follow-up objective, presented in Chapter 5, was to test whether the locations of flights of foraging raptors correspond with the distribution of fossorial mammal burrows. These objectives were important for concluding whether vegetation management could be used to distribute small mammals away from the immediate vicinity of wind turbines, and thus encourage raptors to forage farther away from the turbines and thereby reduce their risk of blade strikes. In addition, although a direct before-and-after comparison could not be made, the effect on small mammals of switching from year-round cattle grazing to seasonal sheep grazing was investigated.

Smallwood and Thelander (2004, 2005) reported that raptors fly disproportionately close to wind turbines, flying within 50 meters of wind turbines between seven and ten times more often than expected by chance. Smallwood and Thelander theorized this relationship might be caused by wind turbines sited to exploit the same declivity winds that are used by raptors, or it might be caused by clustering of small mammals around wind turbines in areas subjected to rodent control. Raptor mortality was higher where rodent control was intense and lower where it was not practiced, and this difference might have been due to the difference in rodent prey distributions. Under rodent control, surviving rodents clustered more around turbines and wind farm infrastructure than elsewhere because they had free choice to select sites and it was at turbine pads and infrastructure where survivors could burrow under hard roofing and into cut slopes for laydown areas and access roads. This clustering, it was hypothesized, could have led to higher turbine-caused raptor mortality. In areas not subjected to rodent control, raptors may have foraged farther from wind turbines because prey were more uniformly distributed across the landscape, thus reducing the encounter frequencies between flying raptors and operating wind turbines.

Smallwood and Thelander (2004, 2005) suggested creating more suitable habitat conditions for fossorial mammals farther away from wind turbines, a.k.a. “farming for pocket gophers.” The ongoing grassland and wetland restoration efforts on Vasco Caves Regional Preserve and the newly acquired Souza parcel enabled a test of this measure. To test the effectiveness of “farming for pocket gophers” and other fossorial mammals, it was necessary to map the distribution of small mammal burrows, burrowing owl burrow sites, and spatial patterns of foraging raptors in relation to the spatial array of sheep grazing and stocking rates.

4.1. Methods

From August through November 2006, a Trimble Geo-XT GPS was used to map the approximate centers of burrow systems of pocket gophers, ground squirrels, voles and other fossorial mammals. Transects spaced about 12 to 15 m apart were walked across the entire study area where burrows were mapped. The pacing method of Smallwood and Erickson (1995) was used to map the approximate centers of ground squirrel and pocket gopher burrow systems whenever signs of these systems were continuous and the boundaries between systems obscure. In this way, the research team mapped burrow *systems* rather than individual burrow entrances, which can vary from a few to many per individual pocket gopher. Ground squirrel burrow complexes are typically composed of multiple burrow entrances and support multiple squirrels. The 381 ha area mapped included most of the Souza and Vasco Caves parcels and included most of the areas where bird behavior observations were made (compare Figures 10 and 17).

During September and October 2007, burrows were mapped again using a stratified random sample of 12 plots from within the 2006 study area (Figure 10). Sampling plots were selected from the Souza and Vasco Caves parcels to monitor if changes in the distribution of small mammal burrows resulted from altering grazing treatments. Plot boundaries were watershed boundaries modified by grazing paddock boundaries, and were selected randomly from the contiguous pool of plots. Three monitoring plots each were selected from (1) areas not grazed over the past five years (Vasco Caves parcel), (2) not grazed the year preceding the study (Souza parcel), (3) lightly grazed, or (4) heavily grazed. For statistical comparisons, plots subjected to varying grazing intensity were pooled into a single category of "grazed."

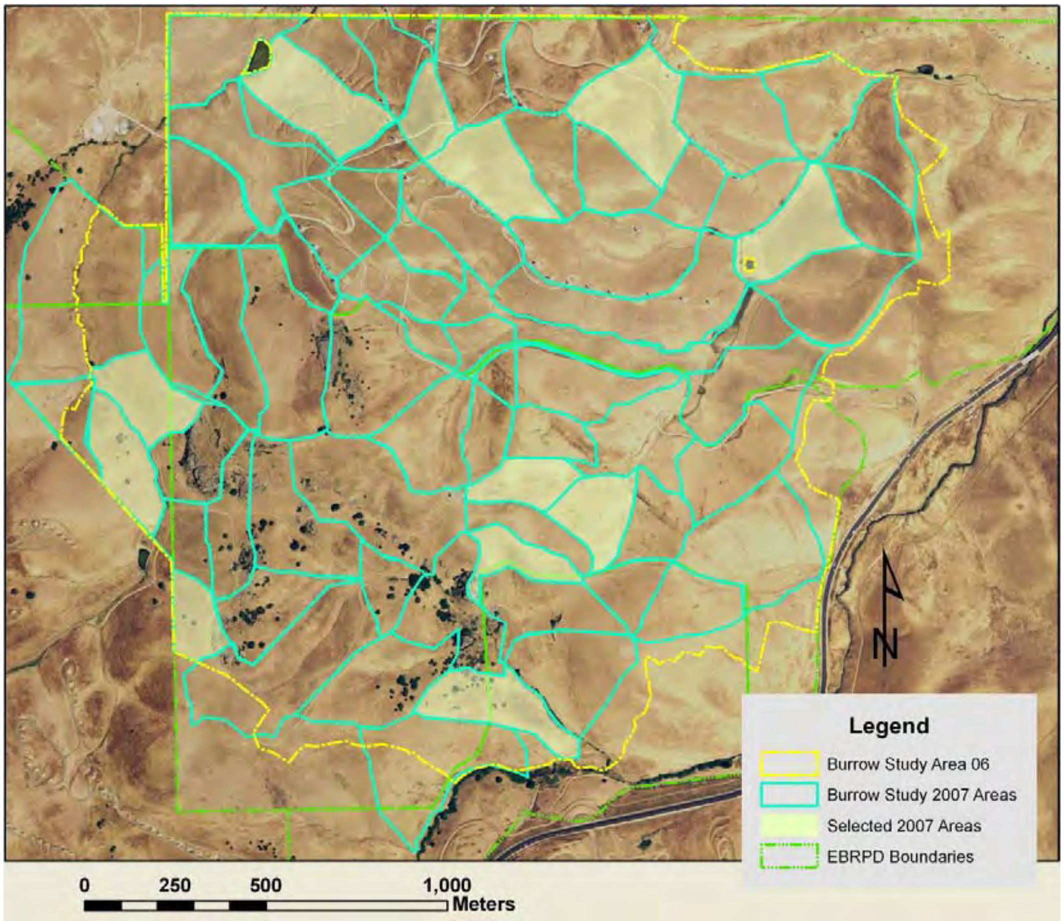

Figure 10. Extent of 2006 burrow mapping area on the Souza and Vasco Caves parcels, and the 2007 monitoring plots that were mapped after selecting them in a stratified random design based on grazing treatments

Burrow attributes were recorded for each burrow mapped, including whether the burrow was constructed into matrix soil, fill soil (e.g., soil covering a buried pipeline), a berm (i.e., artificially constructed soil mound or ridge), cut slope (e.g., for wind turbine laydown areas and access roads), natural rock formations, artificial rock piles, under a concrete pad, under asphalt, into or under woody debris, or under artificial covers. Burrows were categorized as single burrows (e.g., refuge burrow, satellite burrow, or one complete burrow system), nest burrows, or multi-occupancy complexes with or without extensive mounding of excavated soil. Burrows were recorded as indicating recent use (fresh), abandonment, or ambiguous sign of recent use. Burrow assignments to species were reported as certain or uncertain. It was noted whether burrows had been reamed by a carnivore, and whether the reaming was recent or old, based on the condition of the soil heap. Records were made of whether the burrow occupant had taken over a burrow originally constructed by a pocket gopher, ground squirrel, carnivore, or other species. Each burrow was characterized by the condition of plants surrounding the burrow, such as whether the plants were erect, lain down, burned, lightly grazed, or intensively grazed. The average height of plants around the burrow was categorized as barren, <5 cm, 6 to 20 cm, 21 to 50 cm, 51 to 100 cm, or >100 cm. Each burrow was classified according to whether it had no herbaceous plant cover, one or a few species distinctly occurring with the burrow or burrow system, a distinct patch of herbaceous species, or was within an extensive stand of one or more herbaceous species. Notes and photos were also recorded for anything unusual about the burrow.

Following the methods used in Chapter 3, ground squirrel and pocket gopher burrow locations were related to landscape attributes measured from the digital elevation model (DEM) of the study area. The principal components analysis in Chapter 3 was applied to the landscape in which the fossorial mammal burrows were mapped. Also, univariate tests were performed for differences in slope attributes where burrow systems were found and not found, keeping in mind that these variables share considerable variation. Study results will be used to develop predictive models of ground squirrel and pocket gopher burrow systems (similar to the predictive models for burrowing owls discussed in Chapter 3) using no more than one variable from each principal component to develop each model.

4.2. Results

In 2006 a total of 7,165 burrows or burrow systems were mapped within an area overlapping 38,139 of the DEM grid cells (367.4 ha, which was 14 ha smaller than indicated by the number of grid cells, because some grid cells overlapped the study area boundary). Of these burrow systems, 2,676 were constructed by pocket gophers, 4,153 were constructed by ground squirrels, 119 were thought to belong to kangaroo rats, 209 were burrow complexes used by California voles, and 8 were used by mammalian carnivores, including coyote, badger, and fox species. Additionally, 4 above-ground woodrat nests were located and mapped.

Of the 4,153 ground squirrel burrow locations, 1,791 were complexes including multiple burrow entrances supporting several squirrels. These centers of squirrel social activity were the burrow systems where raptors were most likely to see squirrels. The other 2,251 ground squirrel burrows were single burrows that were mapped according to the pacing protocol used, and served more as an indicator of the spatial distribution of ground squirrel foraging and exploration activities. Many of these burrows were near the ground squirrel burrow complexes, and some were raids into pocket gopher burrow systems.

Most of the pocket gopher burrow systems were on the Vasco Caves parcel, and most of the ground squirrel burrow systems were on the Souza parcel (Figure 11), perhaps reflecting the historical difference in land management. Pocket gopher burrow system density was 9.67 per ha on the Vasco Caves parcel (206.4 ha mapped) and 2.16 per ha on the Souza parcel (161 ha mapped), so pocket gophers were about 4.5 times as dense on the Vasco Caves parcel compared to the Souza parcel. The density of ground squirrel burrow complexes was 5.68 per ha on the Souza parcel and 2.58 per ha on the Vasco Caves parcel, so ground squirrels were about 2.2 times as dense on the Souza parcel as on the Vasco Caves parcel.

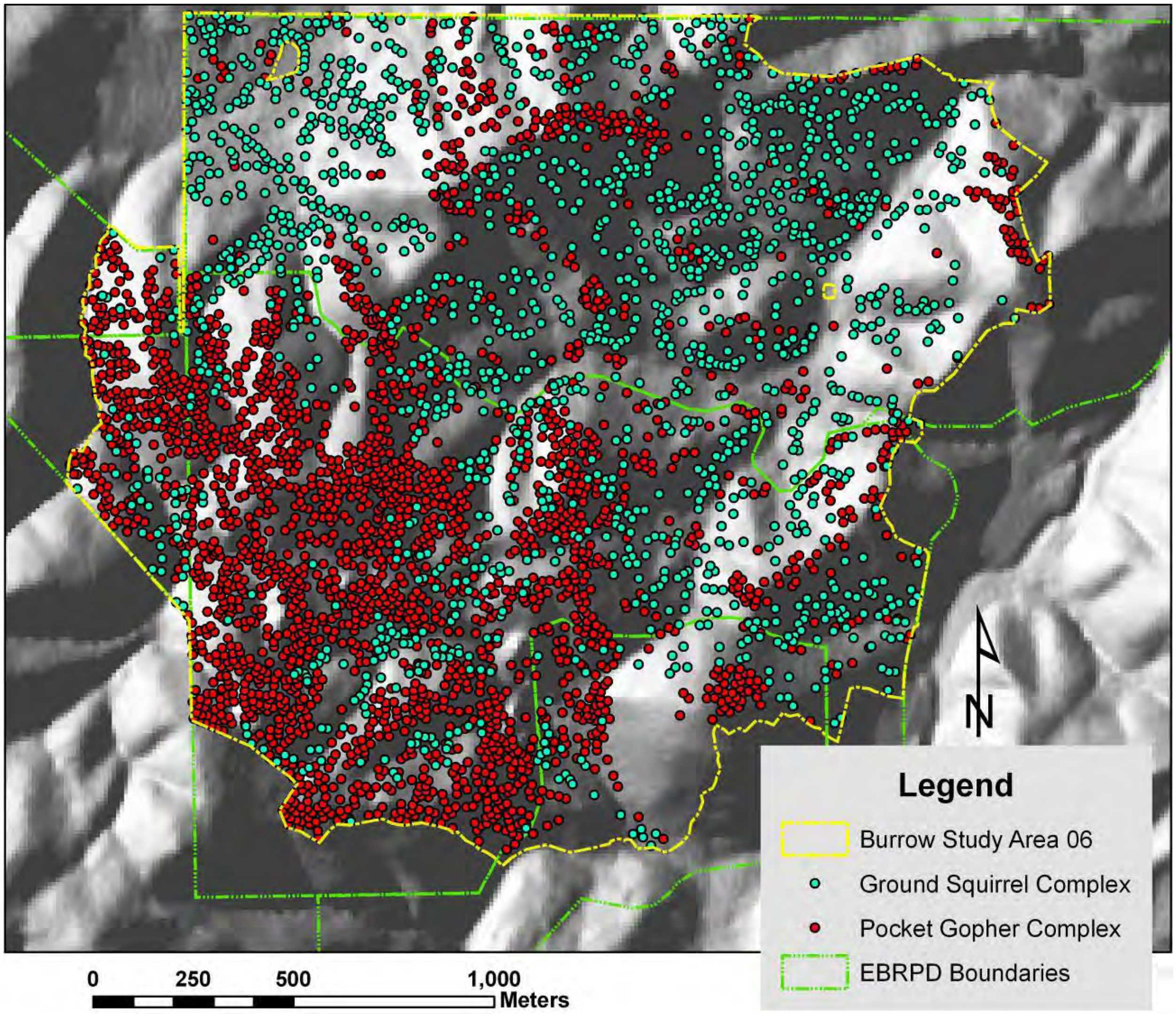

Figure 11. Distribution of pocket gopher burrow systems (red) and ground squirrel complexes (green) in the study area in 2006

Ground squirrel burrow systems were categorized according to their visibility to foraging predators and their apparent age or time in use (Table 7). Some of the burrow systems appeared relatively newly constructed because extruded soil had not raised the ground surface of the burrow system relative to the ground surrounding the system. These burrow systems were simply holes dug into the ground, and if they lacked soil pilings adjacent to the burrows an observer looking across the ground surface would not see them. A raised complex, on the other hand, could easily be seen while looking across the ground surface, because the underlying soil of the system had piled up after years of squirrel excavations. At these systems, long-term use modified the topography by forming a mound structure, into which the squirrels continued to maintain burrows.

Distinct occurrence of herbaceous plants on burrow systems also indicated their long-term use by ground squirrels. Sometimes one or a few herbaceous species, typically fiddleneck, black mustard, lamb's quarters, goosefoot, or bull thistle, occurred on burrow systems but not in the grassland surrounding the system. These species often occurred in high density and formed distinct tall patches on burrow systems, most often on the raised systems (Table 7). Raised burrow systems and systems with distinct herbaceous cover were categorized here because these attributes are likely used as cues by predators foraging for ground squirrels. Conceivably, a foraging raptor might use local topography and plant species cover to distinguish burrow systems long used by ground squirrels.

Table 7. Number of California ground squirrel burrow systems categorized by profile on the landscape and presence of herbaceous cover, both indicating time the burrow complex has been in use, as well as its visibility to predators

Effect of Burrow System on Ground Surface	Herbaceous Vegetation at Burrow System	In or Under Rock Formation or Rock Pile	Burrow Systems (Complexes)
Minimal	None	No	372
Raised	None	No	86
Minimal	Low density	No	80
Minimal	Distinct patch	No	177
Raised	Low density	No	50
Raised	Distinct patch	No	819
Minimal	Extensive cover	No	25
Raised	Extensive cover	No	10
Minimal	None	Yes	70
Minimal	Low density	Yes	8
Minimal	Distinct patch	Yes	30
Raised	None	Yes	17
Raised	Low density	Yes	6
Raised	Distinct patch	Yes	41

Of the 1,791 ground squirrel burrow complexes, 90 were located on bare ground, 191 were in areas with <5 cm prevailing grass height, 232 were in areas where the prevailing grass height was 6–20 cm, 873 were in areas where the prevailing grass height was 21–50 cm, 287 were in grasses of 51–100 cm, 5 were in grasses >100 cm, and the grass height was not recorded for 113 systems. Thus, the majority of ground squirrel complexes were associated with a grass height of 21–50 cm.

Old or ambiguous signs of squirrel activity indicated burrow systems were abandoned, with vegetation height categories at the rates of 16.7% on bare ground, 0% in <5 cm (these were areas intensively grazed), 1.7% in 6–20 cm, 0.8% in 21–50 cm, 4.9% in 51–100 cm, and 20% in grasses >100 cm. Of 3,606 ground squirrel burrows or burrow systems, mammalian carnivores reamed 0.4% of those in grasses of <5 cm tall, 0.7% of those in grasses 6–20 cm, 1.2% of those in grasses 21–50 cm, 2.6% of those in grasses 51–100 cm, and none of the 8 burrows in grasses >100 cm.

Considering the total number of burrows and the percentages that were reamed, these results suggest ground squirrels fared best in grasses of 6–50 cm tall, perhaps due to balancing greater mammalian predation pressure in taller grasses against greater avian predation pressure in shorter grasses and on bare ground.

4.2.1. Associations With Landscape Attributes

Ground squirrel burrow complexes generally occurred in bands low on the slopes (Figure 11). Pocket gopher burrow systems were generally found near or on the tops of ridges and hills (Figure 11). The number of burrow systems within 50 m of each DEM grid cell increased for pocket gophers and decreased for ground squirrels with increasing elevation (Figure 12), nearness to the crest of the slope (Figure 13), and slope steepness (Figure 14). However, pocket gopher burrow system density decreased with increasing elevation higher than 288 m (Figure 12) and with slopes steeper than 50% (Figure 14). Pocket gopher burrow systems were higher on the slope than the average grid cell, and much higher than those with ground squirrel burrow complexes (Figure 15).

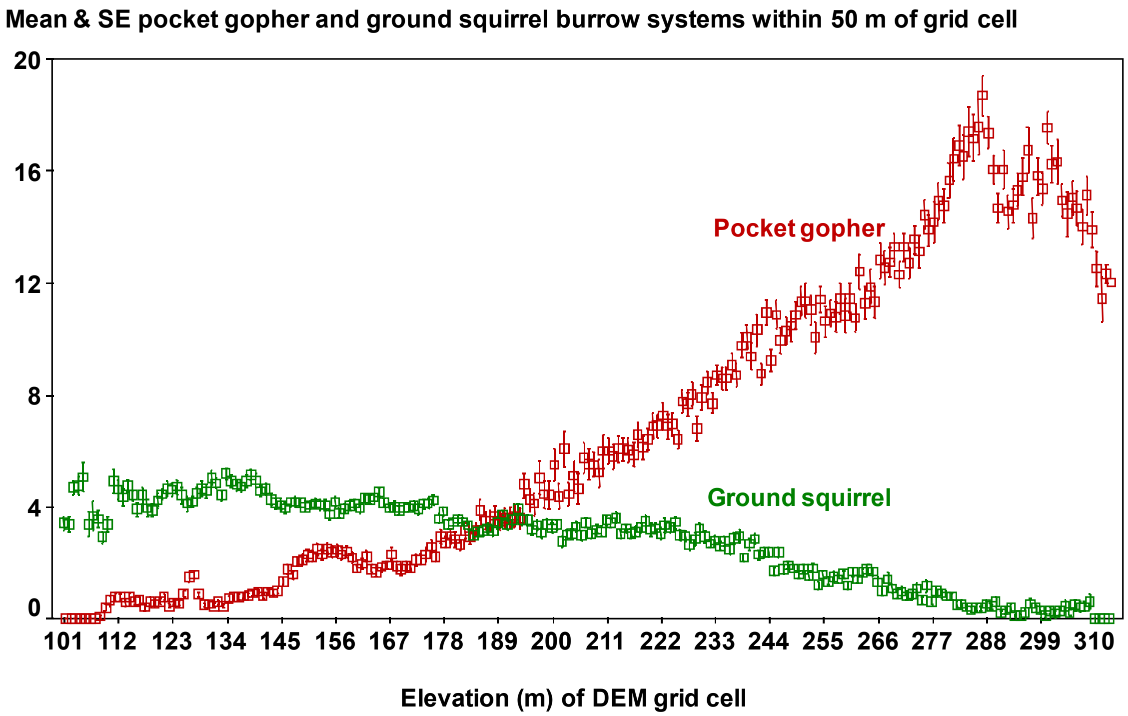

Figure 12. Distribution of pocket gopher and ground squirrel burrow complexes among elevations at 38,139 DEM grid cells (each cell $10m^2$) in the Vasco Caves and Souza parcels

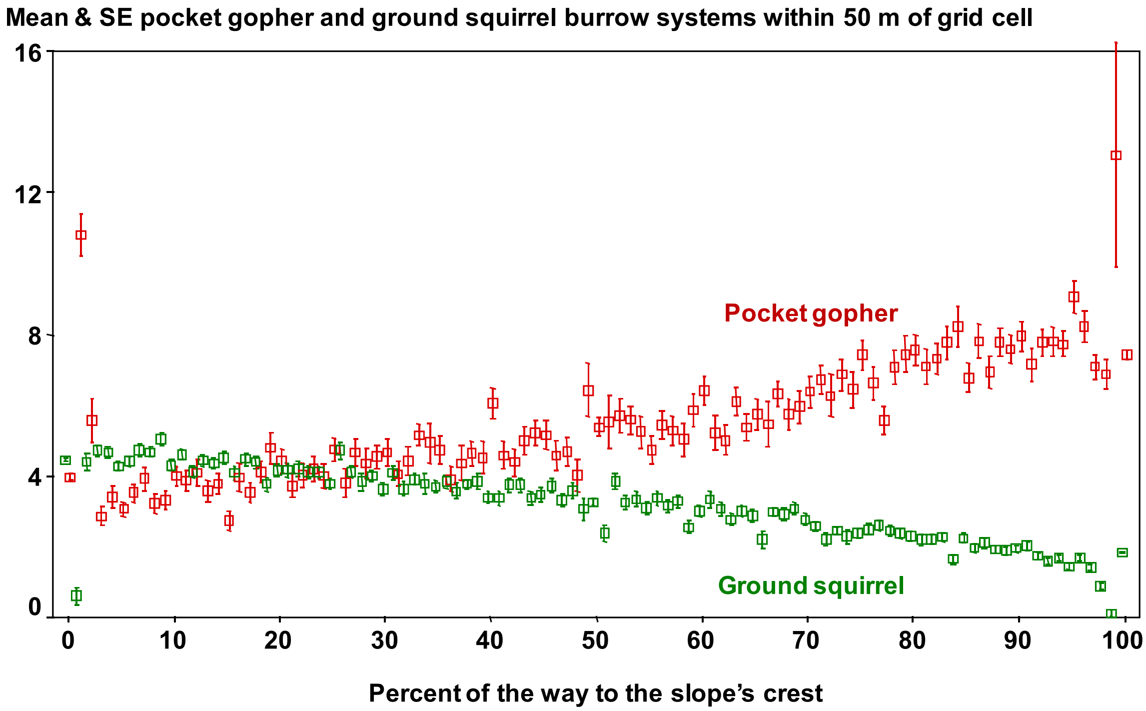

Figure 13. Distribution of pocket gopher and ground squirrel burrow complexes among positions on the slope of 38,139 DEM grid cells in the Vasco Caves and Souza parcels

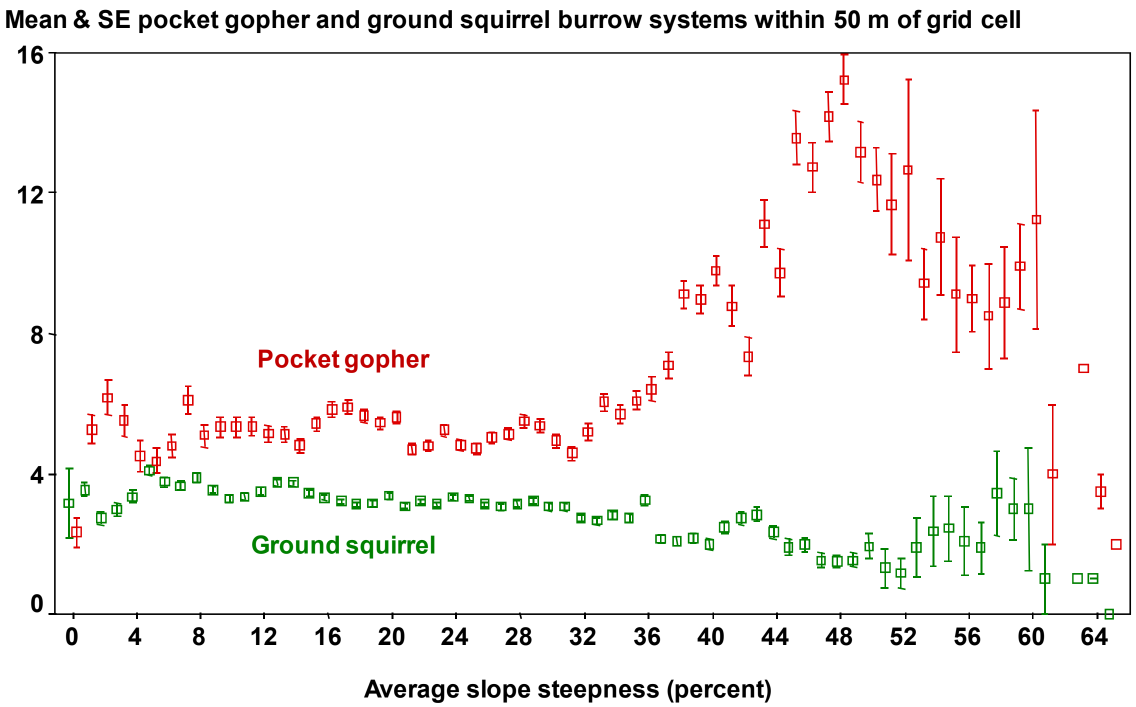

Figure 14. Distribution of pocket gopher and ground squirrel burrow complexes among 38,139 DEM grid cells varying by slope grade in the Vasco Caves and Souza parcels

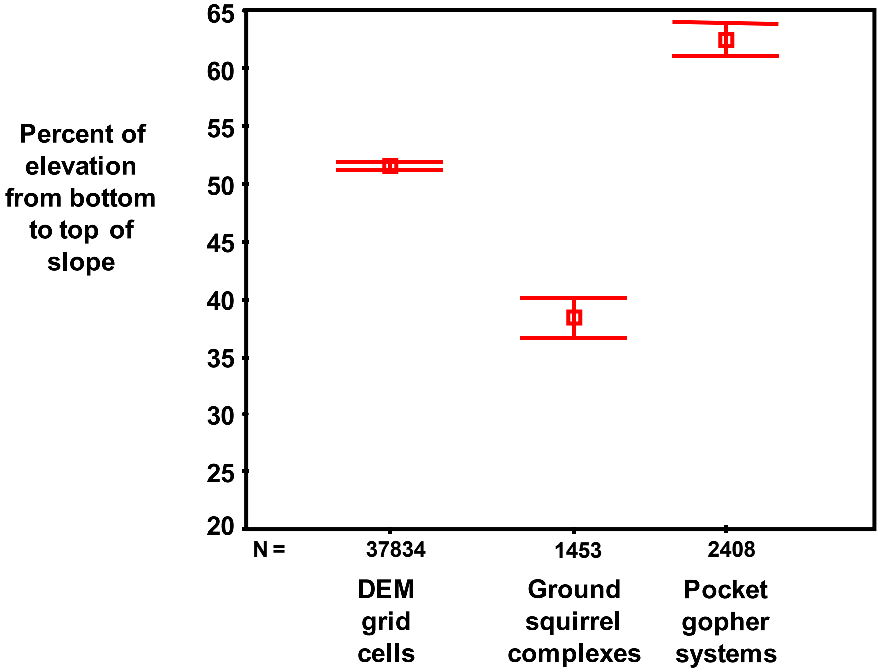

Figure 15. Mean and standard error of percent of elevation from the bottom to the top of the slope on which the grid cell is located. On average, ground squirrel burrow systems were lower on the slope than the average grid cell, and pocket gopher burrow systems were higher on the slope.

DEM grid cells with ground squirrel burrow complexes were 77% of the distance to the nearest valley bottom as the average grid cell without ground squirrel burrow complexes, and they were 47% of the elevation ratio of grid cells without squirrel burrows (Table 8). They were 26% farther from the top of the slope than where ground squirrel burrows were not found. Comparing principal component (PC) scores, grid cells with ground squirrel burrow complexes were lower on the slope, on shallower slopes, and on slightly larger slopes.

DEM grid cells with pocket gopher burrow systems were 16% farther from the nearest valley bottom as the average grid cell without pocket gopher burrow systems, and they averaged 50% larger elevation ratios of grid cells without pocket gophers (Table 9). They were 23% closer to the top of the slope than where pocket gopher burrows were not found. Comparing PC scores, grid cells with pocket gopher burrow systems were higher on the slope, on steeper slopes, and on smaller slopes.

Table 8. Mean comparisons between sets of grid cells where ground squirrel burrow complexes were not found (n = 36,547) and where they were found (n = 1,464) in 2006

	Ground Squirrel Burrow Complexes				
	Not Observed		**Observed**		**ANOVA**
Variable	**Mean**	**SD**	**Mean**	**SD**	**F-value**
Distance to valley (m)	59.51	40.74	45.84	33.90	160.72**
$\log_{10}$ Distance to valley	1.62	0.45	1.50	0.46	98.79**
Distance to ridge (m)	59.05	41.75	74.00	42.56	180.55**
$\log_{10}$ Distance to ridge	1.60	0.48	1.76	0.37	162.88**
Total slope distance (m)	118.56	40.93	119.84	42.01	1.38ns
$\log_{10}$ Total slope distance	2.05	0.16	2.05	0.15	1.31ns
Distance ratio	27.83	3789.25	3.26	26.77	0.06ns
ln Distance ratio	0.04	1.83	-0.62	1.58	180.49**
Elevation (msl)	199.63	46.06	181.19	38.10	228.78**
Elevation difference; near ridge - near valley	25.79	14.93	24.17	13.25	16.66**
$\log_{10}$ Elevation difference	1.30	0.50	1.27	0.53	4.05*
Gross slope	0.22	0.10	0.20	0.09	17.48**
Slope (percentage)	27.07	12.58	26.83	11.57	0.49ns
Elevation ratio	5.26	9.65	2.48	5.83	119.99**
ln Elevation ratio	0.13	1.95	-0.60	1.73	199.60**
Percent to top of slope	52.09	36.26	38.31	33.17	203.05**
Principal component 1, position on slope	0.02	1.00	-0.39	0.85	227.55**
Principal component 2, slope steepness	0.00	1.00	-0.11	0.95	18.03**
Principal component 3, slope size	0.00	1.00	0.05	0.99	4.40*

Significance of ANOVA tests: * indicates $P < 0.05$; ** indicates $P < 0.005$; and no symbol (ns) indicates $P > 0.05$.

Table 9. Mean comparisons between sets of grid cells where pocket gopher burrow systems were not found (n = 35,587) and where they were found (n = 2,424) in 2006

Variable	Pocket Gopher Burrow Systems				ANOVA F-value
	Not Observed		Observed		
	Mean	SD	Mean	SD	
Distance to valley (m)	58.38	40.46	67.88	41.35	124.83**
$\log_{10}$ Distance to valley	1.61	0.46	1.69	0.44	81.48**
Distance to ridge (m)	60.57	41.99	45.69	37.59	288.93**
$\log_{10}$ Distance to ridge	1.62	0.47	1.44	0.54	325.44**
Total slope distance (m)	118.95	41.15	113.57	37.87	39.27**
$\log_{10}$ Total slope distance	2.05	0.16	2.03	0.15	34.28**
Distance ratio	27.91	3839.88	11.75	46.88	0.04ns
ln Distance ratio	-0.03	1.81	0.58	1.92	259.20**
Elevation (msl)	196.56	45.28	233.69	40.91	1546.62**
Elevation difference; near ridge - near valley	25.64	14.70	26.96	17.14	17.73**
$\log_{10}$ Elevation difference	1.29	0.49	1.29	0.56	0.38ns
Gross slope	0.21	0.10	0.23	0.11	55.10**
Slope (percentage)	27.07	12.47	26.92	13.60	0.33ns
Elevation ratio	4.99	9.42	7.49	10.95	156.33**
ln Elevation ratio	0.06	1.94	0.67	1.98	228.76**
Percent to top of slope	50.82	36.14	62.45	35.98	233.26**
Principal component 1, position on slope	-0.03	0.99	0.39	1.03	407.28**
Principal component 2, slope steepness	-0.01	0.99	0.18	1.13	85.08**
Principal component 3, slope size	0.01	1.00	-0.21	0.96	119.06**

Significance of ANOVA tests: * indicates $P < 0.05$; ** indicates $P < 0.005$; and no symbol (ns) indicates $P > 0.05$.

4.2.2. Response to Grazing Treatments

Across nearly all monitoring plots in the study area, pocket gopher burrow systems decreased substantially in abundance between 2006 and 2007 (see Figure 16 and Appendix A,). In the one plot that was grazed in 2006 but not in 2007, pocket gopher density increased (Figure 16), but overall the grazing treatments did not significantly affect pocket gopher density.

Ground squirrel burrow complexes changed in number between years, but with no apparent trend up or down overall (Figure 16, Appendix A,). The density of ground squirrel burrow complexes did not relate significantly to grazing treatments, but there was a slight increase in density in plots that were not grazed in both years and a decrease in density in plots that were grazed in both years. The one plot that was grazed in 2006 but not in 2007 showed a small increase in burrow density.

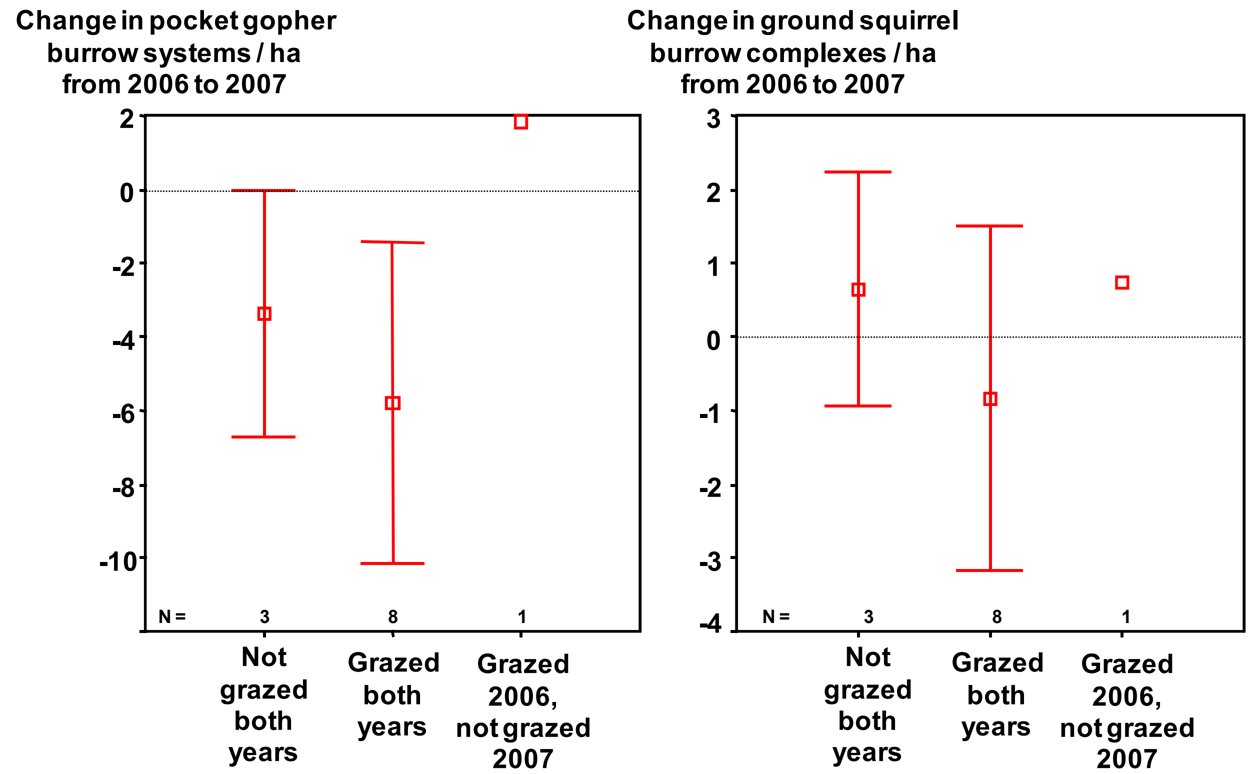

Figure 16. Shifts in number of pocket gopher burrow systems per hectare (left) and ground squirrel complexes per hectare (right) in response to grazing treatments

4.3. Discussion

Significant shifts were not detected in the distribution of small mammal burrows in response to grazing treatments, likely due to the fact that there were no significant differences in mean RDM (residual dry mass) or in effective vegetation height in grazed versus ungrazed plots within and between years (Figure 5, Chapter 2). As discussed in Chapter 2, the two spring growing seasons spanned by this study could be characterized as alternating wet and dry years, with the wet year essentially swamping any effects due to grazing.

The Vasco Caves and Souza parcels differed markedly in the abundance and distribution of pocket gophers and California ground squirrels (Figure 11). Pocket gophers were much more numerous at Vasco Caves than at Souza, whereas ground squirrels were much more numerous at Souza. These differences may reflect differences in range management over at least the last five years since Vasco Caves was converted to sheep grazing from cattle grazing. The flora of Vasco Caves appears different from Souza, including an apparently increasing cover of native bunch grasses and flowering plants. Seasonal sheep grazing may be easier on the native plant species than year-round cattle grazing, enabling a release of native plants from the seed bank. It is possible that pocket gophers have responded positively to this changing flora, whereas ground squirrels are discouraged by the overall taller stands of vegetation.

It is also possible that the differences in fossorial mammal distribution reflected ecological differences between the two parcels. Vasco Caves supported more than 468 trees (mostly California buckeyes, Palmer oaks, arroyo willows, and Valley oaks), whereas Souza supported 4 trees (all willows). Vasco Caves also supported a stand of black sage, whereas Souza did not, and Vasco Caves had multiple large rock formations. On Vasco Caves it was also common to find ground squirrel burrow complexes under California buckeyes (Photo 8).

Pocket gophers and ground squirrels also differed in where on the landscape they tended to establish burrow systems. Ground squirrels established burrow complexes relatively low on hill slopes, while most pocket gopher burrows were on hilltops or the upper reaches of ridges (Photo 9). Many of the ground squirrel complexes supported distinct patches of herbaceous vegetation, which caused the burrow complex to further stand out from the matrix vegetation (Photos 10 and 11). These herbaceous vegetation patches may be biologically significant because they might serve as cues to foraging raptors of the likely occurrence of ground squirrels or commensal species at the site (e.g., desert cottontails often use ground squirrel burrows and sit near soil mounds and under surrounding herbaceous cover).

Photo 8. California ground squirrel burrow complexes on Vasco Caves are often associated with California buckeyes. In this photo the burrows are visible around the downhill side of the tree canopy. Photo by K. S. Smallwood.

Photo 9. Ground squirrel burrow complexes typically occurred on the lower third of slopes, such as on this south-facing slope on the Souza parcel. At the top of the slope depicted, and at the top of the slope from where the photo was taken, occurred pocket gopher burrows. Photo by K. S. Smallwood.

Photo 10. The herbaceous vegetation in the foreground covers a ground squirrel burrow complex, and the three herbaceous patches in the background cover another three ground squirrel complexes. Photo by K. S. Smallwood.

Photo 11. The herbaceous vegetation patch in the foreground and the two in the background cover ground squirrel burrow complexes. Photo by K. S. Smallwood.

5.0 Raptor Behavior

Major objectives in observing raptor behavior were (1) to establish whether raptor flight patterns and foraging behavior relate more to landscape attributes or to spatial distributions of prey and (2) to test whether the spatial distributions and behaviors of raptors are affected by the presence of wind turbines.

Wind farm impacts on birds can be caused by more than collisions with blades (Drewitt and Langston 2006). Researchers have documented changes in habitat suitability due to the proximity of wind turbines, where habitat suitability was indicated, for example, by density of nesting pairs of grassland birds (Leddy et al. 1999) or flyover frequency by waterfowl (Larsen and Madsen 2000). Erickson et al. (2003) reported pre- to post-construction declines in densities of grassland nesting songbirds along transects oriented perpendicular to the wind turbine strings on the border between Oregon and Washington. Declines were as high as 40% for some songbirds and were strongest within the first 50 m of transect. Schmidt et al. (2003) reported horned lark abundance averaged 16 times greater in grasslands located off the National Wind Technology Site, Colorado, compared to on site.

Raptor abundance was twice as great on the wind farm site, but raptors flew and perched higher in the wind farm as compared to off site, suggesting that the presence of wind turbines altered their flying and perching behavior (Schmidt et al. 2003). Kerlinger (2002) reported a 90% reduction of raptors after installation of the Green Mountain Wind Power Project near Searsburg, Vermont, as well as a loss of half the raptor species and more than a fourth of the breeding songbird species. Kerlinger et al. (2005) compared post-construction bird activity to pre-construction activity in the High Winds Wind Project area in Solano County, California. They reported substantial reductions in bird use of the project site for numerous species, including 75% for golden eagle and horned lark, 100% for rough-legged hawks, and ranges from 55% to 100% for many passerine species. Johnson et al. (2003) also reported a 60% abandonment of raptor nests after installation of the Klondike Wind Power Project in Sherman County, Oregon. A meta-analysis of 15 reports revealed significant reductions in bird abundance among various species within wind farms (Stewart et al. 2005).

Practices such as rodent control intended to reduce visitation by raptors can also affect birds adversely, such as reducing the availability of burrowing owl nest sites due to the collapse of ground squirrel burrows not maintained after the squirrels were poisoned (Smallwood and Thelander 2004). Researchers need to estimate both the number and spatial distribution of a species such as the burrowing owl in order to establish baselines for estimating wind farm impacts. They also need reference sites, or sites lacking wind turbines.

Anderson et al. (1999) recommended the before-after, control-impact or BACI design as the standard research design for bird study in wind farms, and this standard design has been recommended by others since (e.g., Smallwood and Thelander 2004). However, a BACI design cannot be implemented in the APWRA, at least not in the classic sense. The BACI approach requires pre-construction surveys and is therefore precluded in the APWRA by more than 20 years of wind turbine operations which have already occurred.

Nonetheless, the availability of Vasco Caves Regional Preserve presented an opportunity to study how burrowing owls and other raptors use a portion of the Altamont Hills in the absence of wind turbines. Facilitating this opportunity was the 10-m resolution DEM of the Altamont Hills created by Lee Neher (Smallwood and Neher 2004), which enabled hypothesis testing of how birds specifically use the landscape under various wind conditions where wind turbines are present or absent.

Just as the spatial distribution of burrowing owl burrows could be related to the DEM of the Altamont Hills to develop a predictive model of burrowing owl nest site selection (Smallwood and Neher (in review), so might raptor flight behaviors. Similarly, intensive study of bird flights could be studied at a reference site lacking wind turbines (i.e., Vasco Caves) for comparison to sites with wind turbines. Study in a reference site was particularly important because Smallwood and Thelander (2004) reported multiple lines of evidence indicating that the APWRA's wind turbines have substantially affected flight patterns of some species, including burrowing owls.[6] Study at Vasco Caves would yield flight patterns in the Altamont Hills where no wind turbines were present to affect the flight patterns.

This chapter focuses on whether raptor flights and specific behaviors relate more to landscape attributes or to spatial distributions of prey, and whether wind turbines affect the spatial distributions and behaviors of raptors. Common ravens were also observed to serve as a point of comparison for many behaviors. To facilitate interpretation of the results, the observation sessions are summarized, including the environmental conditions in which the sessions were performed. The behavior work revealed unanticipated patterns, which are presented here to improve understanding of how raptors use the APWRA landscape in the presence and absence of wind turbines, and to help formulate measures to reduce or minimize bird collisions with wind turbines.

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[6] For example, Figure 5-105 in Smallwood and Thelander (2005) shows most bird species monitored flew within 50 m of turbines 7–12 times longer other than expected, including burrowing owls, which perched 51–100 m away from turbines about 5 times longer other than expected. Burrowing owls, loggerhead shrikes, horned larks, and American kestrels flew disproportionately longer near wind turbines that were not operating, and disproportionately less near wind turbines that were operating (Smallwood and Thelander 2005; Fig. 5-130). Flights through the rotor zone were much more common for most species while the turbines were not operating or broken, as were the number of flights within 50 m and at blade height within 50 m (Smallwood and Thelander 2005; Figs. 5-132 through 5-135). Multiple species spent disproportionately more time flying nearby vertical axis turbines than other tower types (Smallwood and Thelander 2005; Figs. 5-136 and 5-139), and most species were seen flying disproportionately more often nearby turbines at the ends of rows, indicating efforts to fly around the turbine row (Smallwood and Thelander 2005; Figs. 5-146 and 5-147). Most species flew disproportionately more often near wind turbines not arranged in wind walls, in lower-density turbine fields, and at the edges of turbine fields (Smallwood and Thelander 2005; Figs. 5-149, 5-151, and 5-154). Similar patterns were reported in Smallwood and Thelander (2004), based on a different data set and analysis.

5.1. Methods

Observation points (OPs) were selected from the study landscape to maximize visibility of ground surface within 400 m of the observer. A ground search for candidate OPs was performed, and GIS was used to assess the efficiency of each OP. Using a digital elevation model of the study area, a point was extruded from each OP at 2 m above ground to represent the view of an observer. The ground surface that could be seen from that point was then color-coded so the viewshed from each OP could be examined and compared. About half of the candidate OP locations were discarded due to viewshed overlap or inadequacy in coverage area. The fifteen OPs that were used maximized orthogonal viewshed areas, but overlap was unavoidable and was mitigated by weighting underlying grid cells of the DEM by the number of OPs that could provide a view of them.

Observers were rotated among the OPs (Figure 17) and each OP was visited for 60 minutes per week. This time span was longer than used by Smallwood and Thelander (2004, 2005) because Smallwood and Thelander found that the frequency distribution of the time to bird observations steadily increased through time and did not asymptote until nearly the end of the 30-minute sessions they used. It appeared that the behavior observation sessions routinely experienced a lag of bird observations from the start of the session, either due to observer bias or due to birds avoiding the area occupied by the observers during the first 15 to 20 minutes. Either explanation warranted a lengthening of the observation session from 30 minutes to 60 minutes.

Bird observations were recorded at one-minute scan intervals using a letter/number code representing the individual bird or group of birds observed and the sequence of observations for that individual bird. The first individual or group seen was represented by the letter A, and the minute into the session was recorded next to A—for example, if A was recorded on the third minute into the session, then the observation was coded A3. A bird that left the viewable area and then reentered the viewable area was assigned a different letter designation unless the observer was sure it was the same bird, such as a golden eagle missing a tail or a ferruginous hawk missing wing feathers.

Using digital voice recorders and handheld maps, observers recorded the species, number of individuals being observed at the mapped location, perch used, flight behavior (e.g., kiting versus gliding, height above ground, and positions of each observation on the maps carried by the observers (see Appendix C for observation protocol). The observers also recorded temperature, average wind speed, maximum wind speed, and wind direction at 0, 15, 30, and 45 minutes into each session. Precipitation and general weather conditions were noted. Also, the observers circled on the map the wind turbines that were operating, and drew triangles around those that were moving slowly (usually these were turbines that were feathering).

In addition to data collected each minute, particular behavior events were also recorded whenever they occurred during the session. For example, observations of birds flying through wind turbine rows or diving and interacting with others were noted. Records were made whenever birds entered or exited the sampling area. These "event" observations were recorded on the half-minute interval as well as the minute interval.

Each observation was plotted on a handheld map of the OP and surrounding landscape (see Appendix D). Each map consisted of color orthophotos warped onto a digital elevation model of the study area, and depicted wind turbines, rock formations, trees, and roads as seen from the air. Grid cells atop ridges were colored blue so that the observer could easily discern ridge features on the map. This helped the observer to orient him/herself and accurately record bird observations on the map. The locations of bird observations were digitized using ArcMap GIS 9.2.

Data reflecting bird flight patterns were analyzed for association with sheep grazing patterns, rock pile locations, zones of proximity to wind turbines, and the distributions of small mammal burrow systems. This analysis—in conjunction with future work—is intended to lead to effective variable combinations in predictive models developed using fuzzy logic (Tanaka 1997; Kainz 2004).

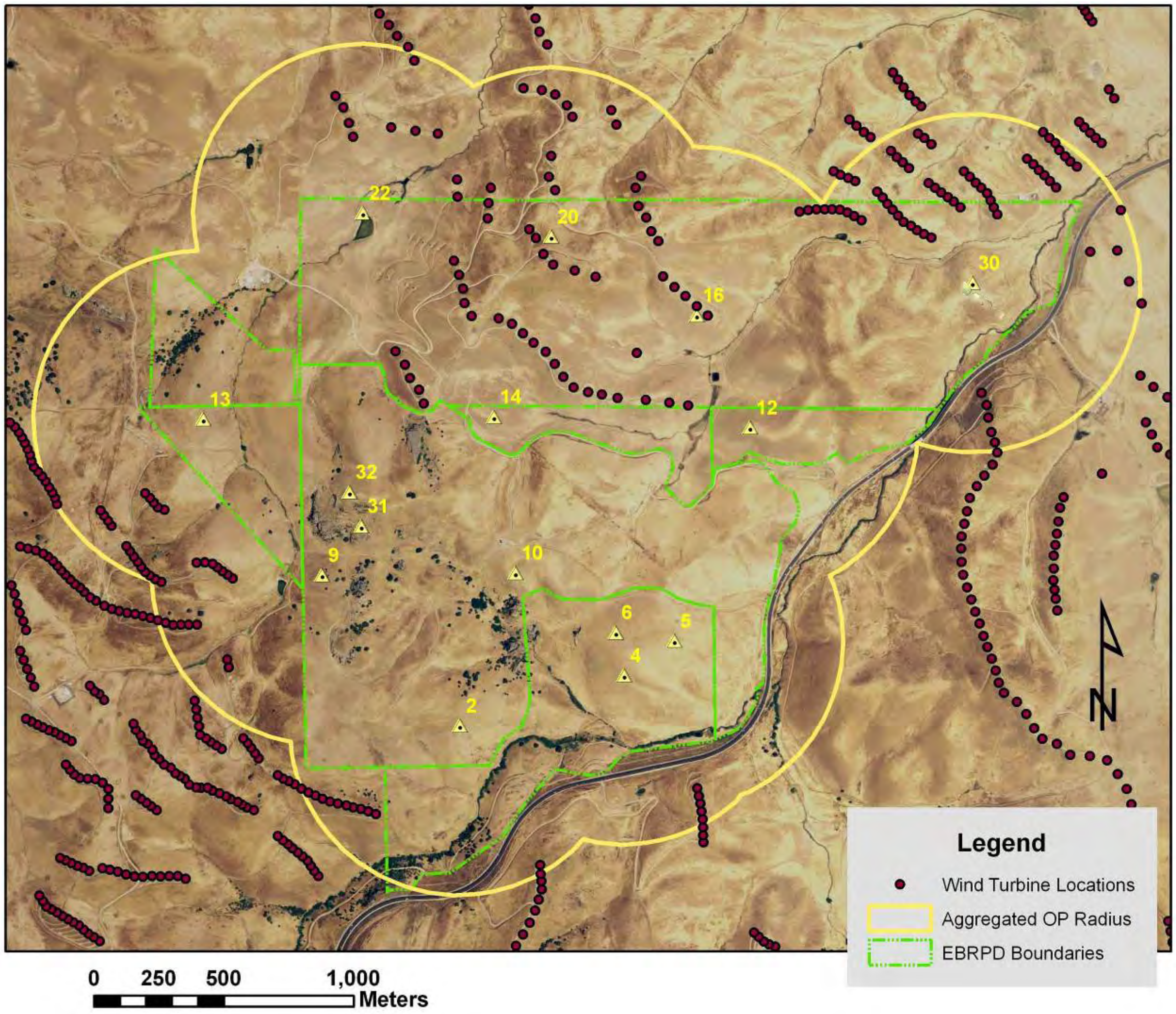

Figure 17. Distribution of observation points (OPs) used to record bird locations and behaviors during the study. The aggregated OP radius of 650 m is shown as the yellow border; this was the extent to which bird observations were made from the OPs.

5.1.1. Influence of Wind Turbines on Raptor Flights

Observed flights of raptors were related to the expected number of flights as a ratio at particular distances from wind turbines,

$$\frac{Observed\ \ number}{Expected\ \ number}$$

where the number of flights at each grid cell was normalized for the number of 650-m OP survey boundaries that overlapped the grid cell; that is, the number of flights at a grid cell was divided by the number of OP survey boundaries overlapping the grid cell. The expected number of flights was the total number of observations, *N*, multiplied by the incidence of the DEM 10-m grid cells (see Chapter 3 and below) within the 25-m distance interval, C_i, among all the grid cells, C_T, within the total area compared:

$$Expected = N \times \frac{C_i}{C_T}$$

These ratio values were derived from chi-square statistics and are used herein as measures of effect (Smallwood 1993, 2002). The ratios of observed to expected number of flights were calculated using only flights that were categorized as ≤ 85 m above ground. This height was chosen to reflect the maximum reach of turbine tower/blade combinations expected should repowering of the wind farm occur. Thus, it is the height below which potential raptor-wind turbine collisions would occur.

Flight heights were also examined within and outside a 200-m aggregated radius around the wind turbines in the study area (Figure 18). To increase the comparability of flight heights between these zones, only those raptor locations that were at least halfway up the slope (elevation ratio ≥1) and only those raptor flights made in wind speeds >8 kilometers per hour were selected. ANOVA (analysis of variance) was used to test for significant differences in flight height. Common raven flights were also compared.

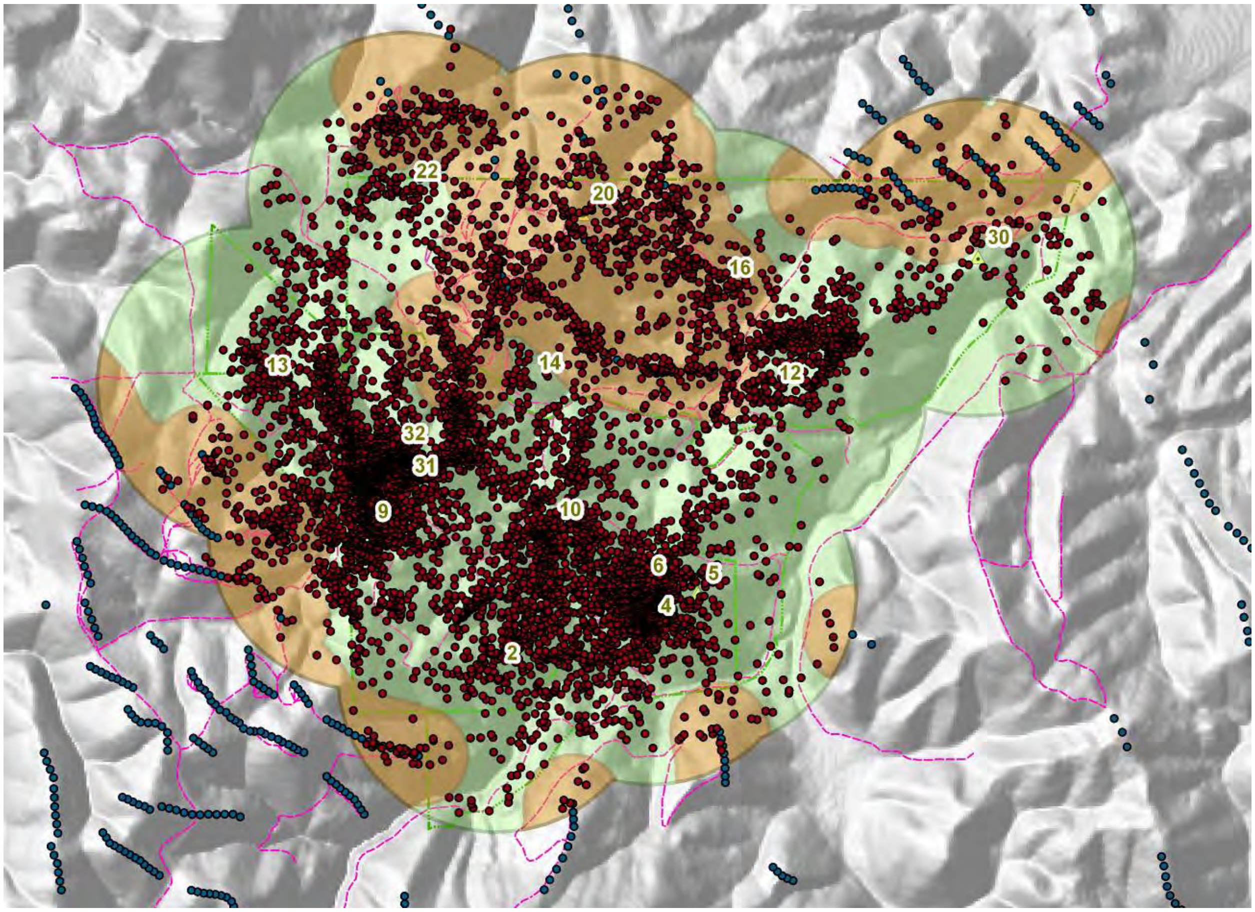

Figure 18. The heights of raptor flights (red circles) were compared within 200 m of wind turbines (dark blue circles in brown polygons) and farther than 200 m from wind turbines (green polygon). Numbers denote observation point locations.

5.1.2. Association of Raptor Flights With Landscape Attributes

Mapped raptor flight and perching locations were characterized as point features in ArcMap GIS and layered onto a digital elevation model (DEM) of the study area. The location of each raptor observation was characterized by slope aspect, slope grade, rate of change in slope, direction of change in slope, and elevation. These slope attributes and others were defined using the geoprocessing described in Chapter 3, which is largely repeated here in the following text.

A USGS 10-meter DEM was used as a starting point for characterizing the study area terrain. From the final DEM of the study area, the statistical analysis was limited (masked) to data within the areas surveyed for raptor flights. The resulting analytical grid was composed of 38,101 10x10 meter cells (the burrow mapping area).

The Curvature function in the Spatial Analysis extension of ArcGIS 9.2 (Environmental Systems Research Institute, Inc.—ESRI) was used to calculate the curvature of a surface at each cell center. A positive curvature indicated that the surface was upwardly convex at that cell, a negative curvature indicated the surface was upwardly concave, and a value of zero indicated the cell surface was flat. The curvature data (-51 to 38) were classified using the NaturalBreaks (Jenks) function with three classes of curvature—convex, concave, and mid-range. The break values were then adjusted through visual inspection to minimize the size of the mid-range class. A series of geoprocessing steps using expand, shrink, regiongroup, and majority filter tools was used to enhance the primary slope curvature trend of a location. The result was a surface almost exclusively defined as either convex or concave. The convex surface areas consisted primarily of ridge crests and peaks, hereafter referred to as ridges, and the concave surface areas consisted primarily of valleys, ravines, ridge saddles, and basins, hereafter referred to as valleys.

Line features representing the estimated average centers of ridge crests and valley bottoms were derived from the following steps. ESRI's Flowdirection function was used to create a flow direction from each cell to its steepest downslope neighbor, and then the Flowaccumulation function was used to create a grid of accumulated flow through each cell by accumulating the weight of all cells flowing into each downslope cell. A valley started where 50 cells had contributed to it, and a ridge started where 55 cells contributed to it. The Flowdirection and Flowaccumulation functions were applied to the ridges by multiplying the DEM by -1 to reverse the flow. Line features representing ridges and valley bottoms were derived from ESRI's gridline and thin functions, which feed a line through the centers of the cells composing the valley or ridge. Thinning put the line through the centers of groups of cells ≥40 in the case of valleys.

The horizontal distance (m) of each DEM grid cell was then measured from the nearest valley bottom and the nearest ridgeline, referred to as *distance to valley* and *distance to ridge*, respectively. These distances were measured from the DEM grid cell to the closest grid cell of a valley bottom or ridgeline, respectively, not including vertical differences in position. The total distance across the underlying slope was the sum of the distance to the valley bottom and the distance to the ridgeline, and expressed the size of the slope (*total slope distance*). The DEM grid cell's position in the slope was also expressed as the ratio of the distance to valley and the distance to ridge, referred to as the *distance ratio*. This expression of the grid cell's position on the slope removed the size of the slope as a factor.

The vertical differences between each DEM grid cell and the nearest valley bottom and nearest ridgeline were measured as elevation differences, and the elevation difference between the nearest valley bottom and the nearest ridgeline also expressed the size of the slope, referred to here as *elevation difference*. In addition to the trend in slope grade at each DEM grid cell, the *gross slope* was measured as the ratio of *elevation difference* and *total slope distance*. The DEM grid cell's position on the slope was also expressed as the ratio of the elevation differences between the grid cell and the nearest valley and the grid cell and the nearest ridge, referred to here as the *elevation ratio*.

Each DEM grid cell was classified by *slope aspect* according to whether it faced north, northeast, east, southeast, south, southwest, west, northwest, or if it was on flat terrain. For analysis, slope aspect was aggregated into five categories: northeast and east, southeast and south, southwest and west, northwest and north, and no aspect (flat terrain). Each grid cell was categorized as to whether its center on the landscape was windward, leeward, or perpendicular to the prevailing southwest and northwest wind directions recorded during the behavior observation sessions.

Log_{10} and natural log transformations were used to better fit normal distributions, and then chi-square tests for association and principal components analysis (PCA) were used to further understand how the variables related to each other and to raptor locations. The study plan was to select no more than one predictor variable from each principal component for any model developed to classify grid cells according to whether they associated with raptor locations. The first intended modeling approach was to be discriminant function analysis (DFA), and the second was to be fuzzy logic (Tanaka 1997, Kainz 2004). Both can produce likelihood surface areas, one referred to as the DFA surface and the other as FL surface. Model development will follow the research documented in this report. In the interim, the authors performed the PCA and tested specific hypotheses of association between slope attributes and raptor flight and perching locations.

5.2. Results

5.2.1. Characteristics of the Observation Sessions

From June 2006 to October 2007, 774 one-hour observation sessions were performed. Some areas were observed more often than others, due to overlap of the outer survey radii from the observation points (Figure 19). Sessions began from 06:00 to after 18:00 hours, but most started during the mid-morning (Figure 20). More sessions were performed in summer (Figure 20), due to the study spanning two summers but only one fall, winter, and spring season. Most sessions were done during moderate temperatures, from 12° to 32°C (Figure 21).

The most frequent wind direction during the sessions was from the southwest, followed by the south, north, and northwest directions (Figure 21). These wind directions were related to slope aspects in the study area to identify where the birds would be located if they were using the winds to hover or kite or perform other behaviors that exploit declivity winds (Figure 22). The most commonly recorded wind speed was 1.6 to 3.3 m/s, followed by 3.4 to 5.4 m/s (Figure 23). Average wind speeds were highest from the south and southwest directions (Figure 23), during the spring and summer months, and during early morning and evening hours (Figure 24).

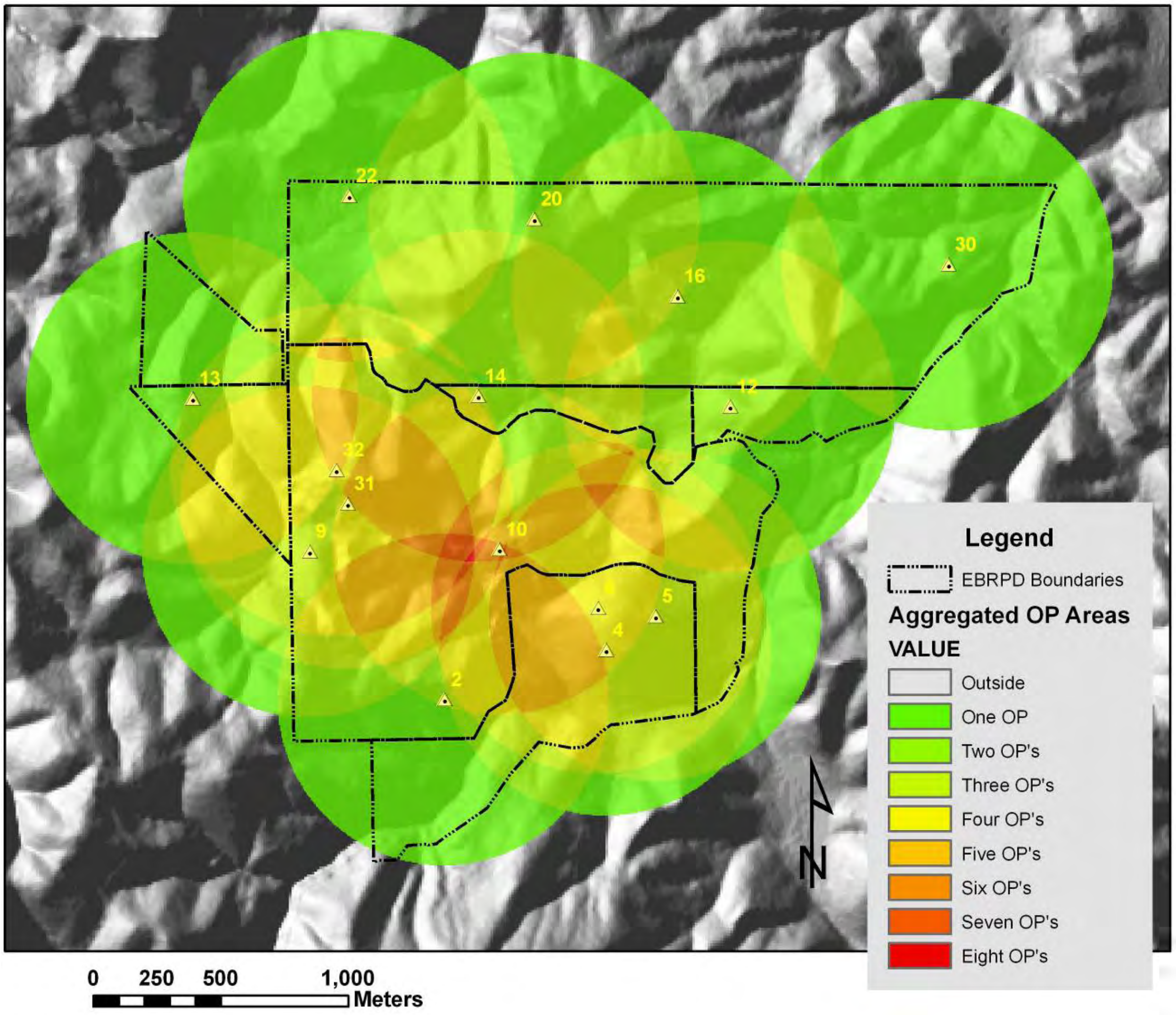

Figure 19. Areas of overlap of survey radii from the observation points (OPs) used for observing raptor flight behavior

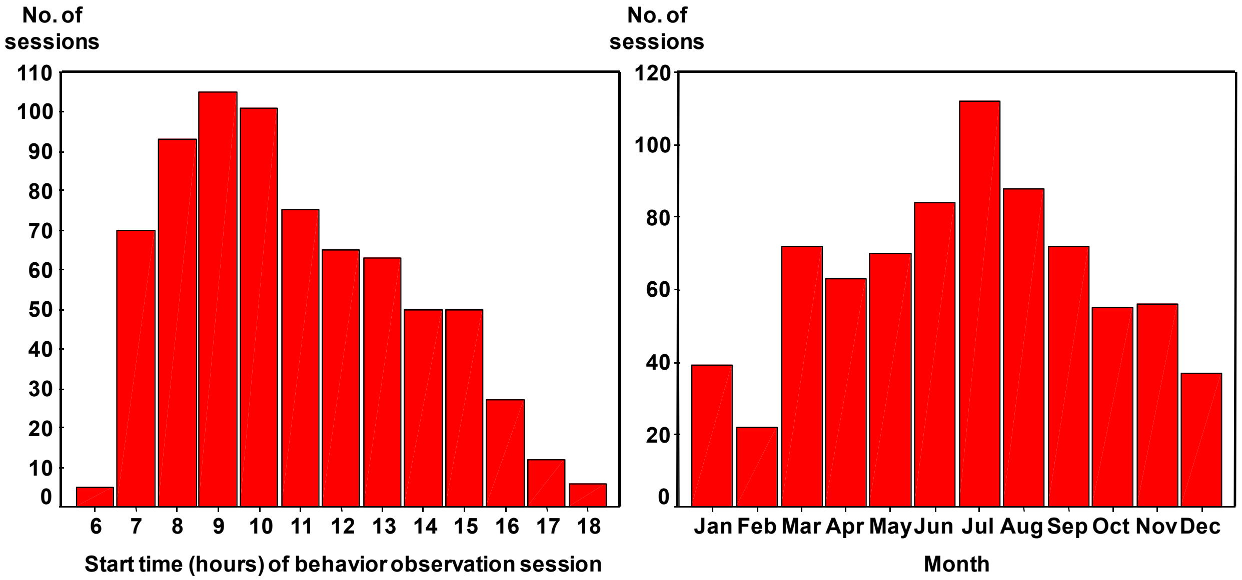

Figure 20. The distribution of start times (left graph) and month (right graph) for the 774 behavior observation sessions

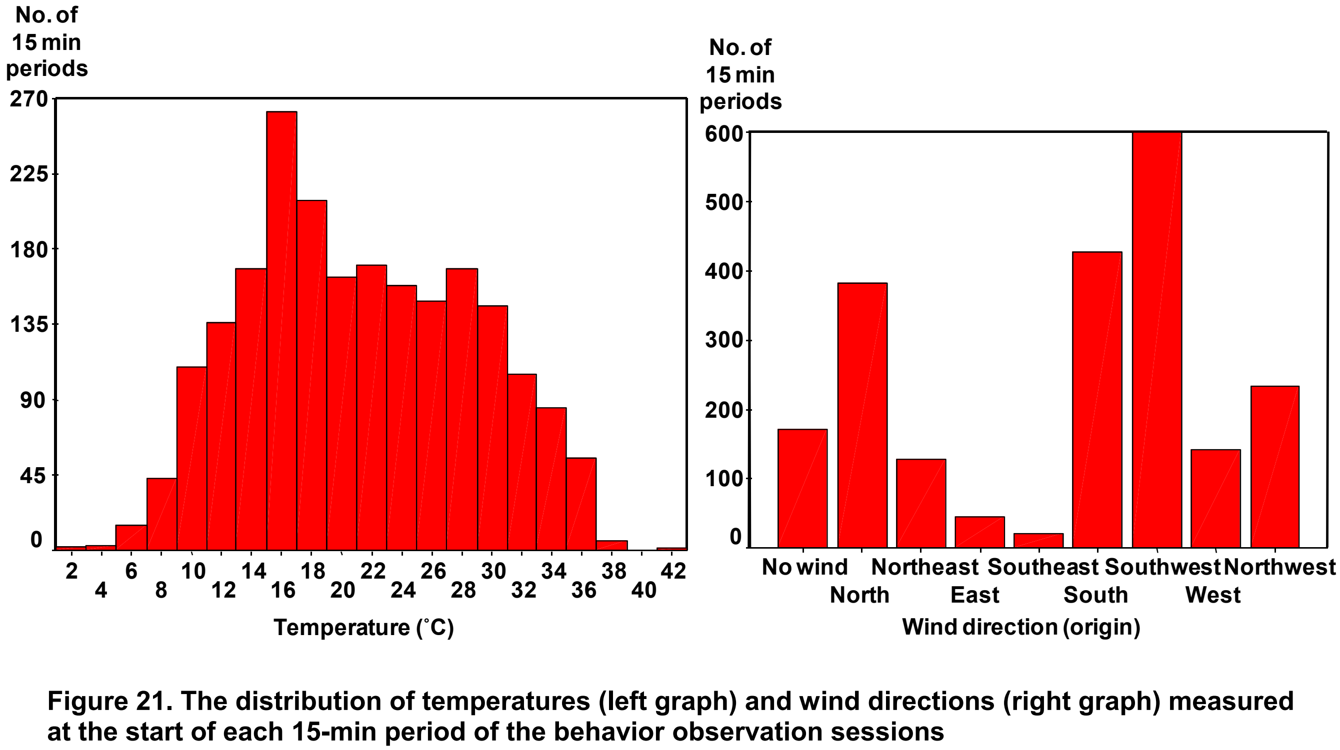

Figure 21. The distribution of temperatures (left graph) and wind directions (right graph) measured at the start of each 15-min period of the behavior observation sessions

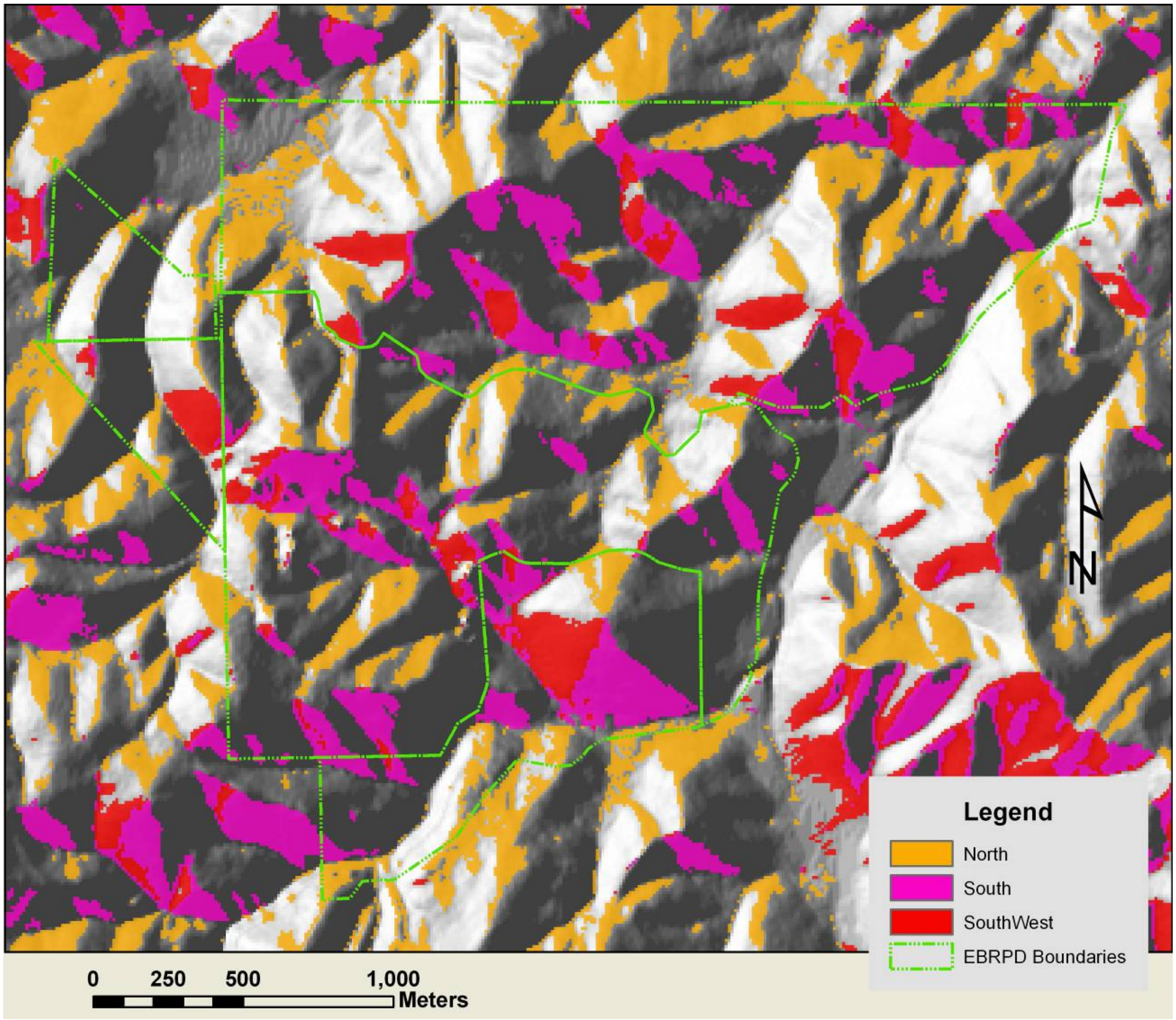

Figure 22. Slopes facing winds coming from the prevailing wind directions in the study area. Highlighted colors indicate where raptors might be expected to hover, kite, or perform other behaviors that exploit declivity winds.

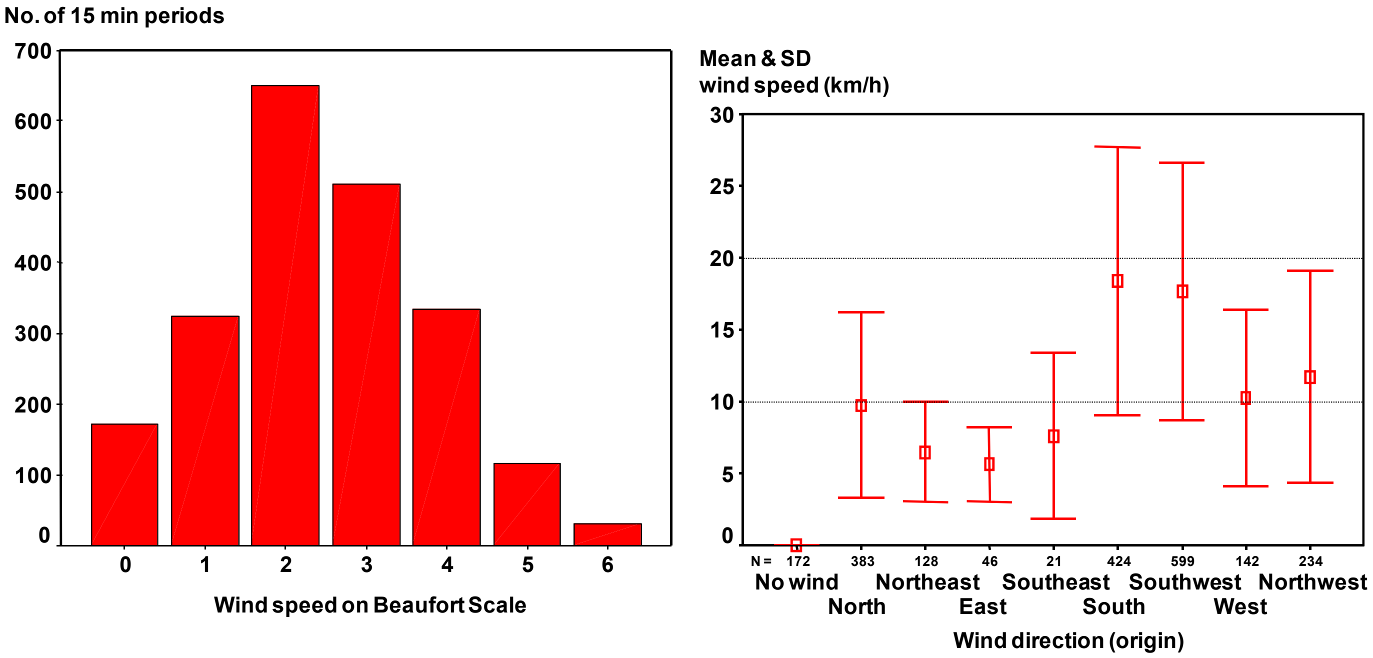

Figure 23. At left is the distribution of wind speeds at the start of each 15-min period of behavior observation sessions, where wind force was measured on the Beaufort scale: 0 (<0.3 m/s), 1 (0.3 to 1.5 m/s), 2 (1.6 to 3.3 m/s), 3 (3.4 to 5.4 m/s), 4 (5.5 to 7.9 m/s), 5 (8 to 10.7 m/s), 6 (10.8 to 13.8 m/s), and 7 (> 13.8 m/s). At right is the mean and standard deviation of wind speeds measured for winds originating from eight general directions.

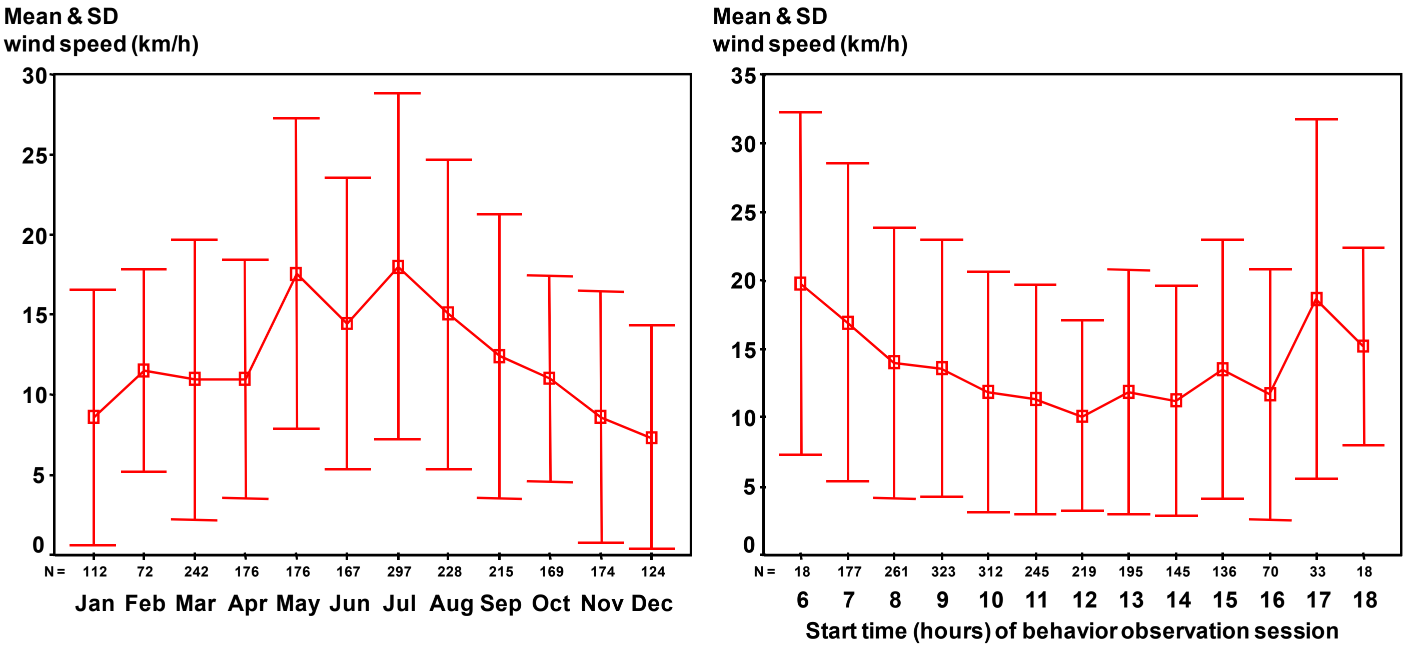

Figure 24. The mean and standard deviation of wind speed by month (left) and time of day (right)

5.2.2. Raptor Use

In the 774 observation sessions, 7,699 birds were recorded, though many of these were undoubtedly repeated observations of the same birds between or even during sessions. Of these, 3,809 were raptors, and of these 1,879 were red-tailed hawks, 1,051 were turkey vultures, and 361 were American kestrels. Compared to two previous studies in the APWRA, on a per-hour basis, turkey vulture abundance appeared to increase about 37% over the past decade, whereas golden eagle abundance appeared to decrease 56% (Table 10). Red-tailed hawk abundance may have increased about 19%. Northern harrier abundance may have increased about 80%, though this result may be spurious due to differences in location between the previous sessions and the most recent. Raptors that typically hunt amidst trees also appeared to increase, including white-tailed kite, Cooper's hawk, and red-shouldered hawk, likely because the recent study site supports more trees than did the study areas used elsewhere in the APWRA. American kestrel and burrowing owl abundance appeared similar between studies. Common ravens appeared to have increased in number more than three-fold, but this species might prefer the recent study site due to the abundance of trees and rock formations.

Table 10. The number of individuals seen per hour during studies performed in 1998–2000 (Smallwood and Thelander 2005), 2002–2003 (Smallwood and Thelander 2004), and 2006–2007 (this study) in the APWRA. The 1998–2000 study involved 1,958 half-hour sessions, or 979 hours, across the east central portion of the APWRA, the northern extent just south of the recent study area. The 2002–2003 study involved 241 half-hour sessions, or 120.5 hours, across the same area studied in 1998–2000, but only during the fall, winter, and spring seasons.

	Birds seen per hour		
Species	1998–2000	2002–2003	2006–2007
Turkey vulture	1.000	1.137	1.369
Golden eagle	0.475	0.224	0.207
Red-tailed hawk	2.048	1.809	2.439
Swainson's hawk	0.000	0.000	0.013
Red-shouldered hawk	0.000	0.000	0.001
Rough-legged hawk	0.006	0.008	0.001
Ferruginous hawk	0.012	0.133	0.016
Northern harrier	0.129	0.083	0.232
White-tailed kite	0.001	0.000	0.010
Cooper's hawk	0.002	0.000	0.008
Sharp-shinned hawk	0.000	0.000	0.001
American kestrel	0.472	1.187	0.475
Merlin	0.000	0.008	0.003
Prairie falcon	0.067	0.033	0.095
Burrowing owl	0.102	0.050	0.100
Unidentified raptor	---	0.282	---
All raptors	4.318	4.954	4.960
Common raven	1.341	---	4.382

Occurrence

The most frequently recorded species during the study was red-tailed hawk, followed by common raven and burrowing owl (Table 11). The species most frequently observed flying were common raven, red-tailed hawk and turkey vulture. Assuming that hovering, kiting, and diving are the most dangerous flight behaviors in the APWRA (Smallwood and Thelander 2004, 2005), the species exhibiting the greatest vulnerability to wind turbine collision included American kestrel (47% of flight observations), prairie falcon (31%), white-tailed kite (25%), burrowing owl (27%), and red-tailed hawk (17%) (Table 11).

Perching

Red-tailed hawks and common ravens regularly perched on wind turbines, comprising 13% and 6%, respectively, of all perch observations (Table 12). Of the red-tailed hawk perching observations, 49% were on anemometer towers. Golden eagles perched on the ground and on rock formations. Oaks and California buckeye served as common perch sites for multiple raptor species and common raven (Table 12). Fence posts were also common perch sites of American kestrel. The majority of burrowing owl observations (99.3%) were of owls perching. Of these, 42%, 54% and 4% involved perching on the ground, at their burrow, and on fence posts, respectively.

Time of Year

Red-tailed hawk flight activity in the study area peaked in November and February/March, and was lowest during summer (Figure 25). Golden eagle flight activity peaked in September and December, was high also in January and August, and was lowest during spring (Figure 25). American kestrel flight activity peaked in July, and was lowest during spring (Figure 26). Burrowing owl flight activity peaked during the fall months, especially in September, and was lowest during late winter and early spring (Figure 26). Overall, raptor activity peaked during February, May/June, and November, and was lowest during January and August (Figure 27). But as noted, August yielded the third-highest month of flight activity for golden eagle and second-highest month of flight activity for American kestrel.

Wind Speed

More red-tailed hawks were seen flying once the wind picked up, but thereafter their number steadily declined with increasing wind speed (Figure 28). The number of golden eagles seen flying was lower with no wind or very high wind, but otherwise did not show any trend with wind speed (Figure 28). The number of birds seen flying increased with wind speed for American kestrel and prairie falcon (Figure 29), but decreased for northern harrier and white-tailed kite (Figure 30). Like red-tailed hawks, more turkey vultures were seen flying when winds were blowing, but their number declined with increasing wind speed (Figure 31). Overall, observed raptor flights peaked at wind speeds of 0.3 to 5.4 m/s (Figure 31).

Time of Day

For some species, the number of individuals seen in flight related more closely to time of day than to wind speed, though time of day and wind speed were also related (Figure 24). Turkey vultures very clearly peaked in abundance during the early afternoon, and were scarce during the early morning and evening hours (Figure 32). The number of red-tailed hawks seen flying also increased from early morning until late morning, and then declined until evening (Figure 32). Golden eagle flight activity steadily increased throughout the day, until late afternoon (Figure 33). American kestrel flight activity peaked during the late afternoon (Figure 33), whereas flight activity for prairie falcons peaked in the early morning and white-tailed kites at mid- to late morning (Figure 34). The number of northern harriers seen flying generally increased throughout the day (Figure 35), but wind speed appeared to be more influential than time of day for this species.

Orientation to Wind

Raptor species expressed unique suites of behaviors with respect to wind, as summarized in Appendix E1 to E8. Figure 36 depicts how a bird's response to wind was measured, based on the bird's orientation to the wind direction measured at the observer's position (OP). A bird's flight was categorized as flying directly toward the wind (code 1), 45° to the wind (code 2), perpendicular to the wind (code 3), 45° from the wind (code 4), and with the wind (code 5). Errors in categorizing wind direction at the bird's position were unavoidable because the winds undoubtedly varied in direction with topography, differing at the bird's location relative to the observer's location. Nevertheless, general patterns were evident.

Flight Behavior (e.g., Kiting and Hovering)

Kiting and hovering are regarded as more dangerous flight behaviors in the APWRA due to greater risk of blade strike (Smallwood and Thelander 2004, 2005). Red-tailed hawks and American kestrels hovered at greater heights above ground while facing into the wind, kited at lower heights while perpendicular to the wind, and kited lowest to the ground while oriented away from the wind (Figure 37), though it is possible the wind directions at the bird locations were not always the same as measured by the observer at the OP. All categories of hovering in these two species were performed at heights that would expose them to blade strike by both old and new-generation wind turbines. Generally, more bird flights were at an angle to the wind, rather than directly into it (Appendix E1 to E8).

American kestrels and prairie falcons were often seen hovering or kiting, and so their orientations were obviously guided by the winds for these behaviors (Appendix E1 and E2), although hovering in prairie falcons is not equivalent to the classic hovering of American kestrels. Hovering in prairie falcons is very brief and punctuated by frequent changes in position. Golden eagles hovered, though less often than red-tailed hawks, but they spent more time gliding and flying-through (Appendix E3). Into the wind, golden eagles were more apt to glide, and with the wind they were more often seen soaring. Golden eagles also contoured over the terrain in various orientations to the wind. Red-tailed hawks were also often seen hovering or kiting into the wind (Appendix E4), though less often than did the falcons. Northern harriers were most often seen contouring low over the terrain (Appendix E5), no matter their orientation to the wind direction. White-tailed kites also hovered or kited, but more often at an angle to the wind (Appendix E6). Turkey vultures spent most of their flights gliding or soaring, no matter the wind direction (Appendix E7). Common ravens flew more often askance to the wind direction, and spent more time in direct flights, gliding, and circling (Appendix E8). They also were recorded mobbing other birds more often than raptors (Table 11).

Table 11. Behavior observations. Also observed were a rough-legged hawk hovering and a merlin flying through the study area.

Behavior	All birds	Golden eagle	Red-tailed hawk	Ferruginous hawk	Swainson's hawk	Northern harrier	White-tailed kite	Prairie falcon	American kestrel	Cooper's hawk	Turkey vulture	Burrowing owl	Common raven
Perched/ walking	7408	158	3196	0	2	55	74	85	207	0	36	1452	1955
Flying	9923	292	2796	19	14	294	12	97	460	11	1439	11	3953
Landing, ground-hopping	44	0	3	0	0	0	0	0	0	0	0	2	37
Fly-through	2190	39	184	7	4	27	4	22	106	2	21	6	1456
Gliding	2666	82	714	5	2	63	2	22	57	5	732	0	969
Soaring	2021	102	1003	6	1	32	1	10	25	3	430	0	376
Surfing	36	1	12	0	0	1	0	0	1	0	4	0	17
Contouring	533	32	93	0	2	137	0	3	13	0	34	0	194
Circling	1165	7	284	0	2	23	2	9	27	0	180	0	515
Hovering	748	26	422	1	1	3	0	17	123	0	14	2	136
Kiting	116	0	14	0	0	6	2	13	77	0	0	1	3
Diving	271	1	44	0	0	2	1	0	15	1	3	0	204
Mobbing	62	0	9	0	0	0	0	1	13	0	0	0	39
Mobbed or fleeing	15	2	14	0	0	0	0	0	0	0	0	0	7
Flocking	27	0	0	0	0	0	0	0	0	0	0	0	0
Feeding	21	0	0	0	0	0	0	0	1	0	20	0	0
Total	**17331**	**450**	**5992**	**19**	**14**	**349**	**86**	**182**	**667**	**11**	**1475**	**1463**	**5908**

Table 12. Sum of perch observations in the Vasco Caves/Souza study area, 2006 and 2007

Behavior	All birds	Golden eagle	Red-tailed hawk	Ferruginous hawk	Swainson's hawk	Northern harrier	White-tailed kite	Prairie falcon	American kestrel	Cooper's hawk	Turkey vulture	Burrowing owl	Common raven
Ground	1460	66	128	0	1	8	0	0	37	0	23	601	622
Burrow	769	0	0	0	0	0	0	0	0	0	0	769	2
Pond	105	0	0	0	0	0	0	0	0	0	0	0	0
Rock	421	31	148	0	0	0	0	68	13	0	10	0	152
Fallen logs	8	0	8	0	0	0	0	0	0	0	0	0	0
Fence post	419	3	34	0	0	0	43	0	56	0	20	61	201
Tree	172	8	121	0	0	0	0	0	1	0	3	0	39
Oak	126	10	78	0	0	0	0	0	0	0	0	0	38
Willow	15	0	4	0	0	0	0	11	0	0	0	0	0
California buckeye	437	17	315	0	0	0	31	0	58	0	0	0	16
Elderberry	7	0	0	0	0	0	0	0	0	0	0	0	7
Herbaceous plant	21	0	10	0	1	0	0	0	0	0	0	1	8
Post	72	0	72	0	0	0	0	0	0	0	0	0	0
Power pole	319	0	188	0	0	0	0	0	3	0	0	0	128
Powerline	109	0	0	0	0	0	0	0	33	0	0	0	78
Anemometer tower	2021	8	1479	0	0	0	0	6	0	0	0	0	530
Wind turbine	539	0	403	0	0	0	0	0	4	0	0	0	124
Housing	109	0	89	0	0	0	0	0	0	0	0	0	20
Motor	10	0	0	0	0	0	0	0	0	0	0	0	10
Blade	106	0	77	0	0	0	0	0	4	0	0	0	25
Rotor hub	97	0	96	0	0	0	0	0	0	0	0	0	1
Catwalk	132	0	107	0	0	0	0	0	0	0	0	0	25
Tower	12	0	6	0	0	0	0	0	0	0	0	0	6
Anemometer	14	0	0	0	0	0	0	0	0	0	0	0	14
Total	**7408**	**143**	**2995**	**0**	**2**	**8**	**74**	**85**	**207**	**0**	**46**	**1432**	**1945**

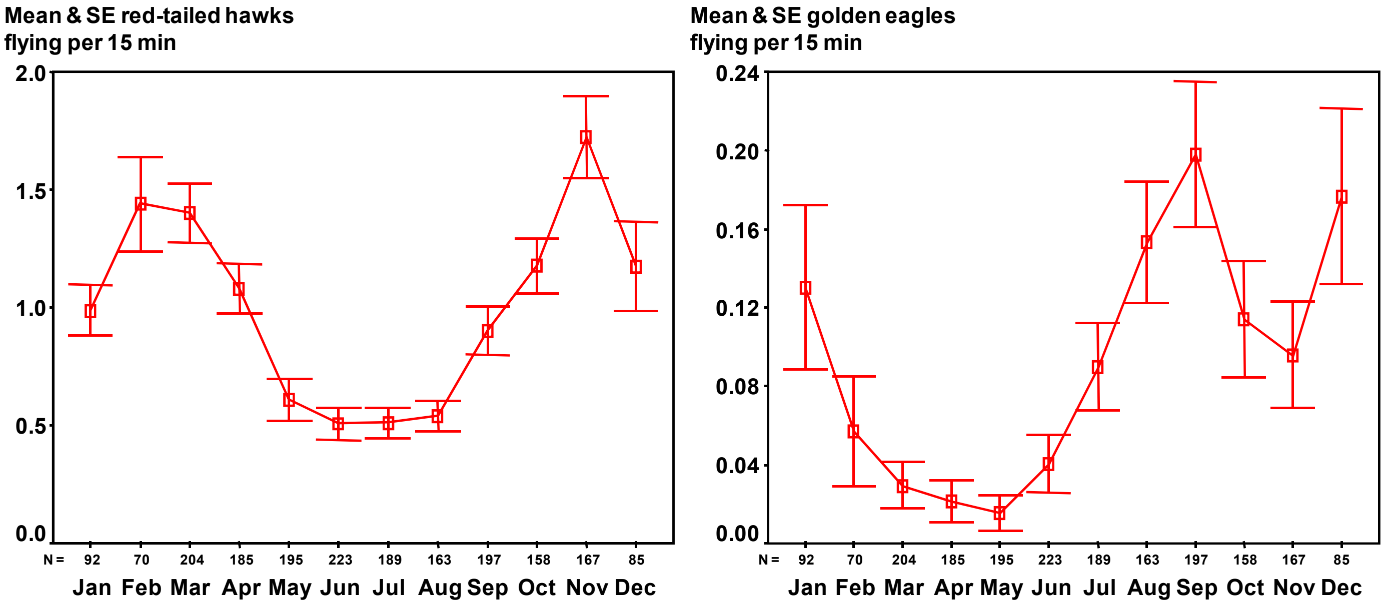

Figure 25. The mean and standard error of the number of red-tailed hawks (left) and golden eagles (right) observed flying during 15-min periods by month

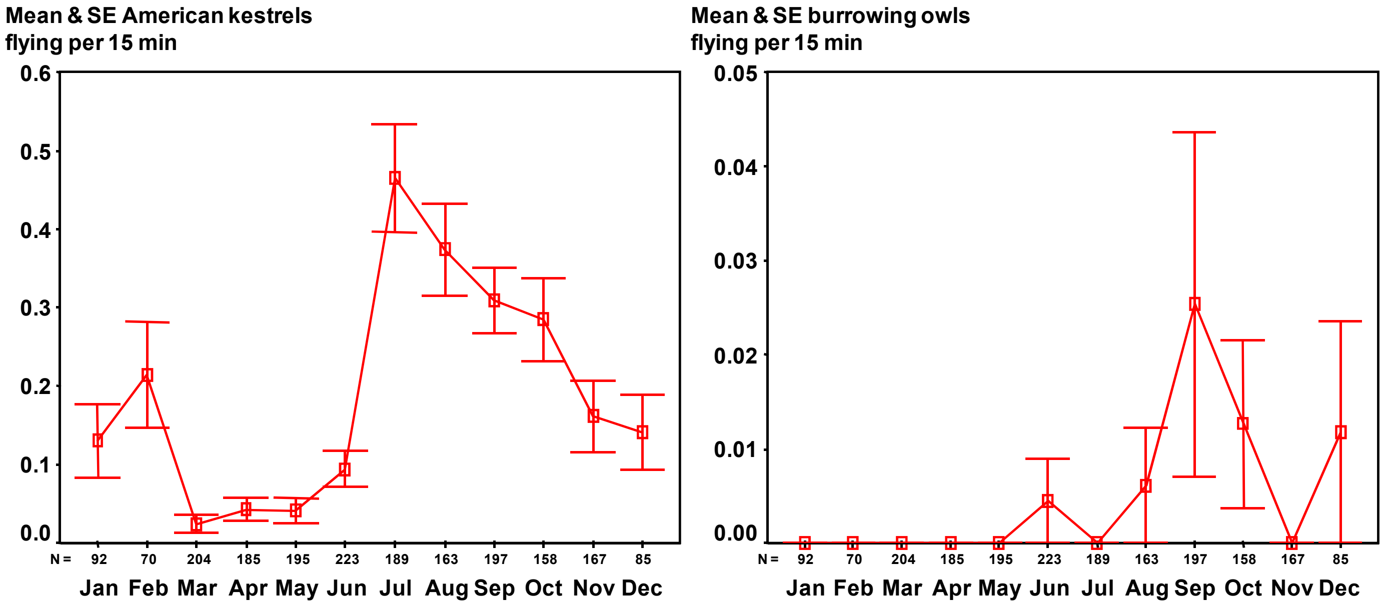

Figure 26. The mean and standard error of the number of American kestrels (left) and burrowing owls (right) observed flying during 15-min periods by month. Note the widely differing sample sizes for American kestrel (N = 460) and burrowing owl (N =11) (Table 11).

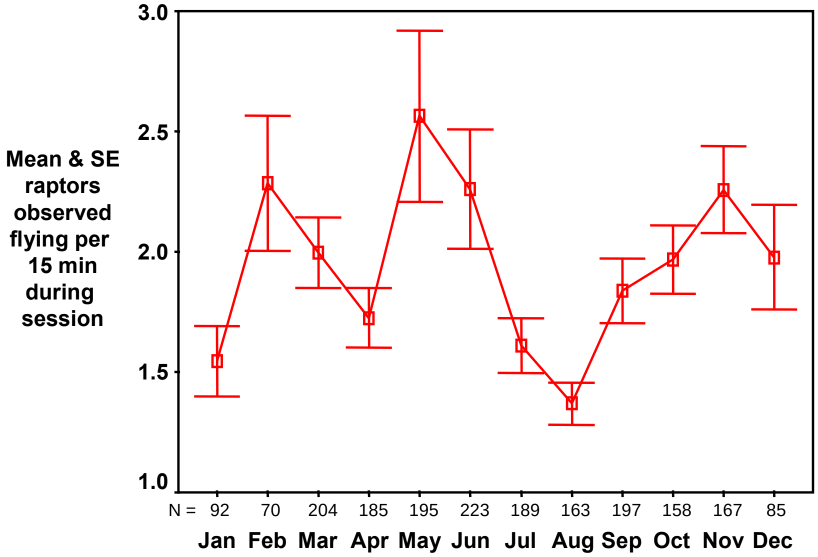

Figure 27. The mean and standard error of the number of all raptors observed flying during 15-min periods by month

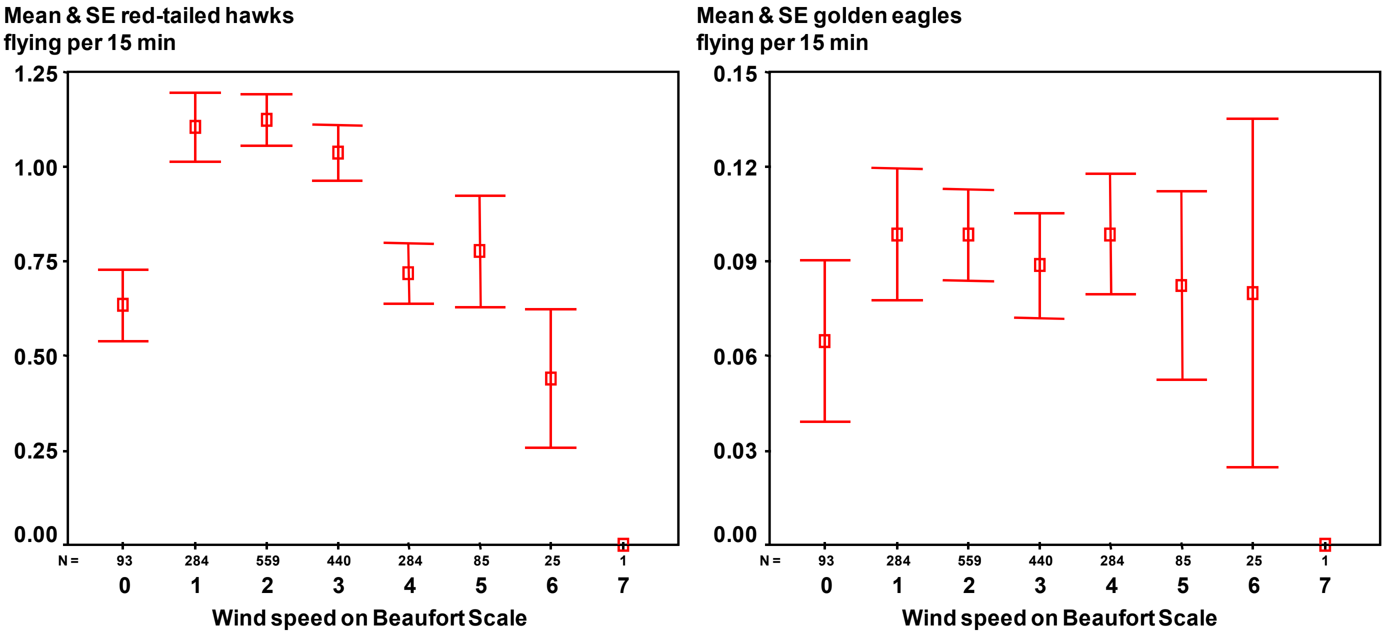

Figure 28. The mean and standard error of the number of red-tailed hawks (left) and golden eagles (right) observed flying during 15-min periods by wind speed measured on the Beaufort scale

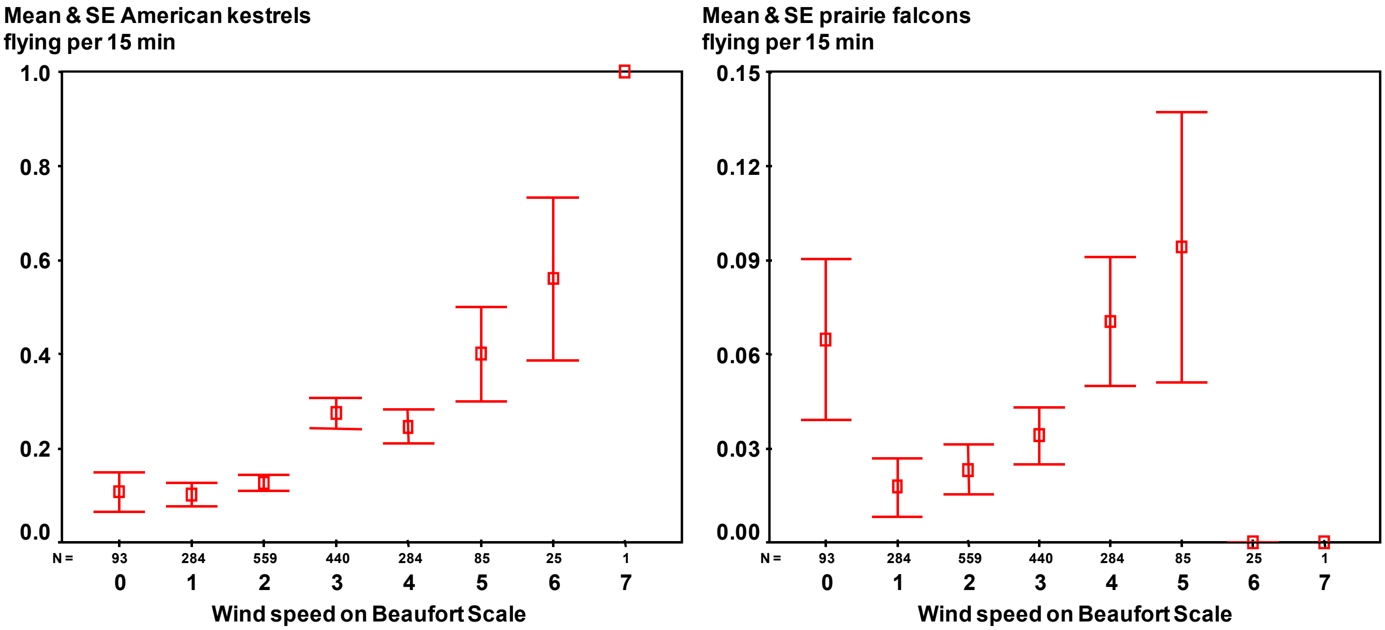

Figure 29. The mean and standard error of the number of American kestrels (left) and prairie falcons (right) observed flying during 15-min periods by wind speed measured on the Beaufort scale

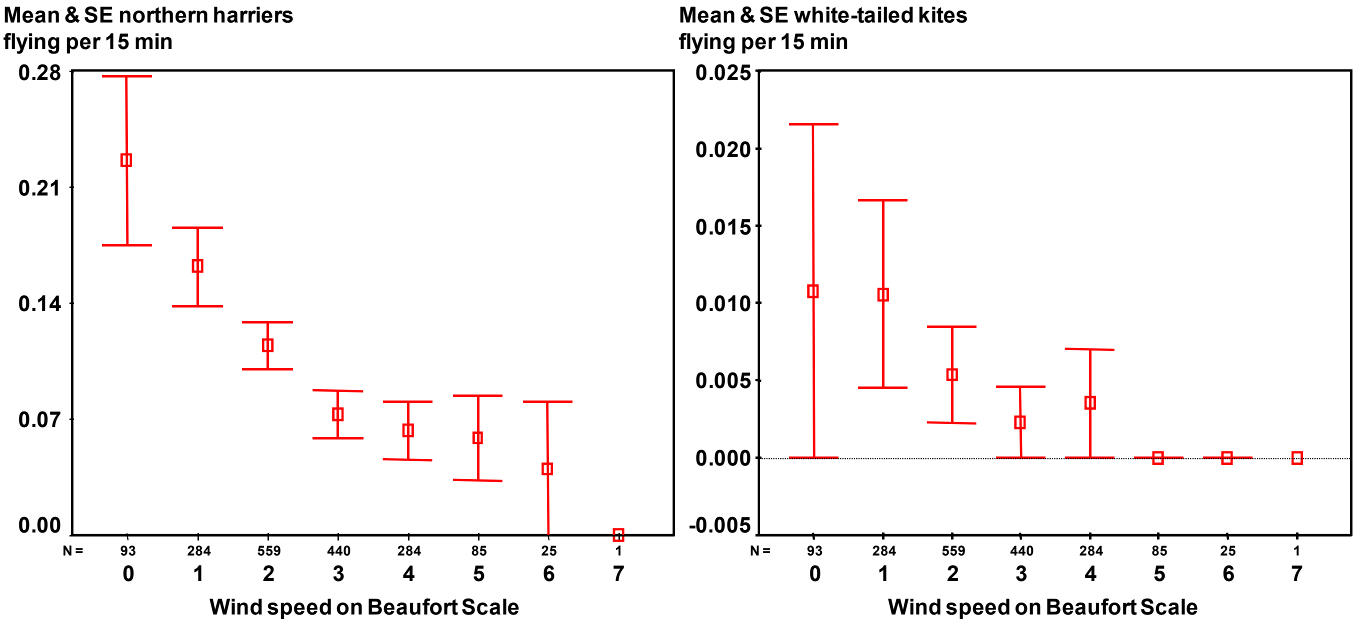

Figure 30. The mean and standard error of the number of northern harriers (left) and white-tailed kites (right) observed flying during 15-min periods by wind speed measured on the Beaufort scale

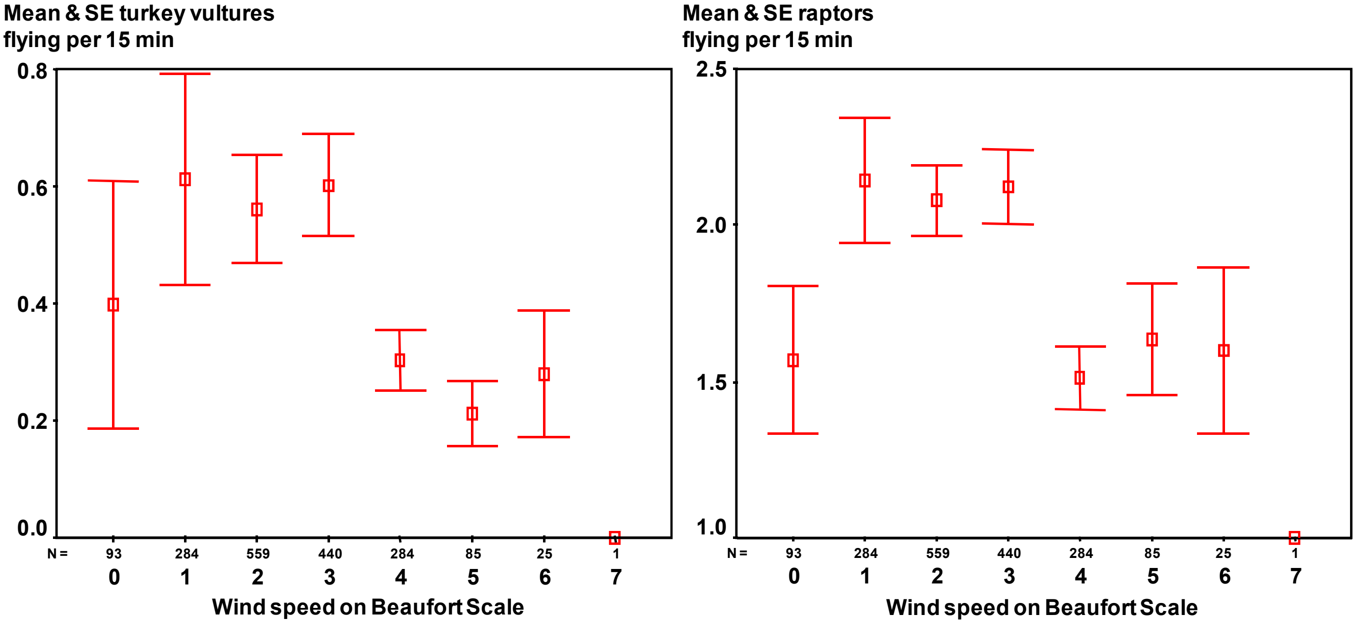

Figure 31. The mean and standard error of the number of turkey vultures (left) and all raptors (right) observed flying during 15-min periods by wind speed measured on the Beaufort scale

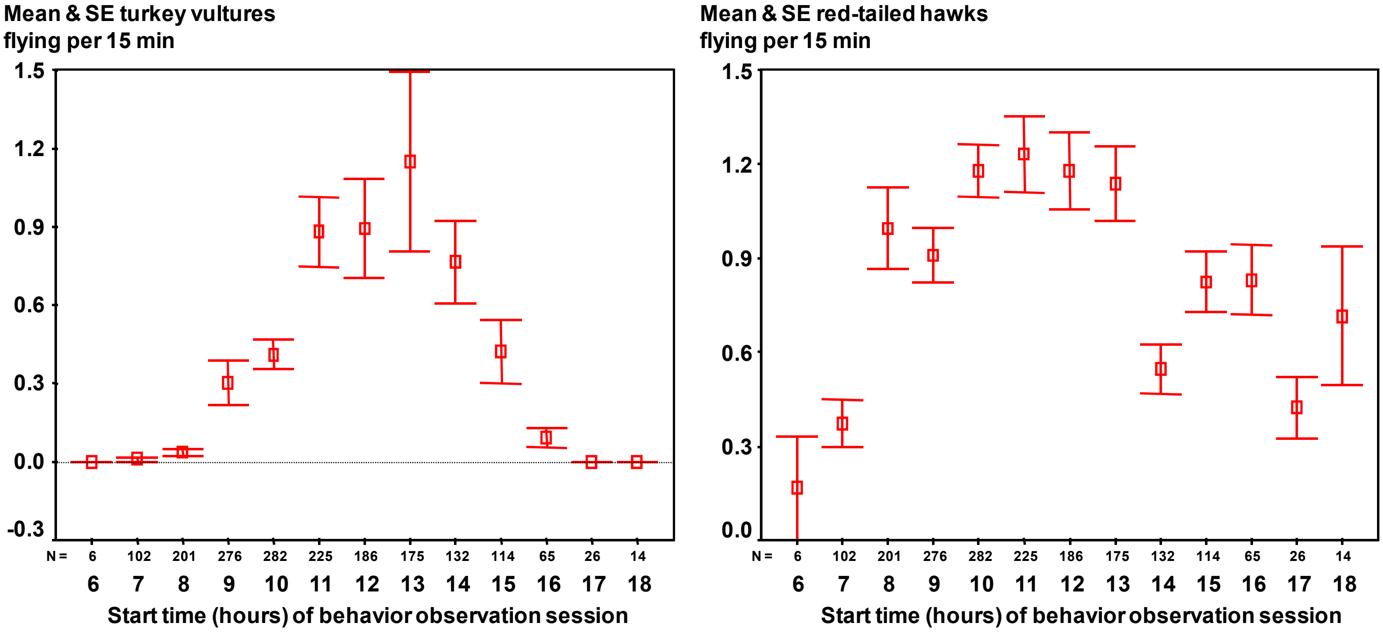

Figure 32. The mean and standard error of the number of turkey vultures (left) and red-tailed hawks (right) observed flying during 15-min periods by start time of the session

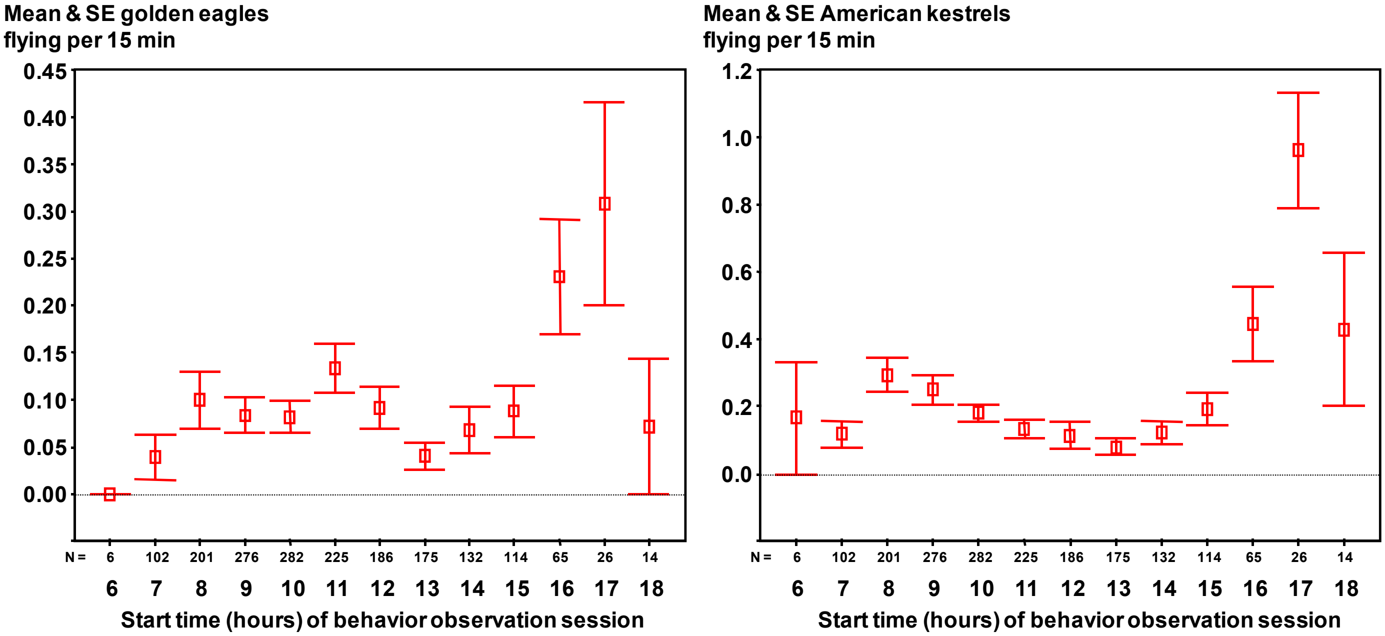

Figure 33. The mean and standard error of the number of golden eagles (left) and American kestrels (right) observed flying during 15-min periods by start time of the session

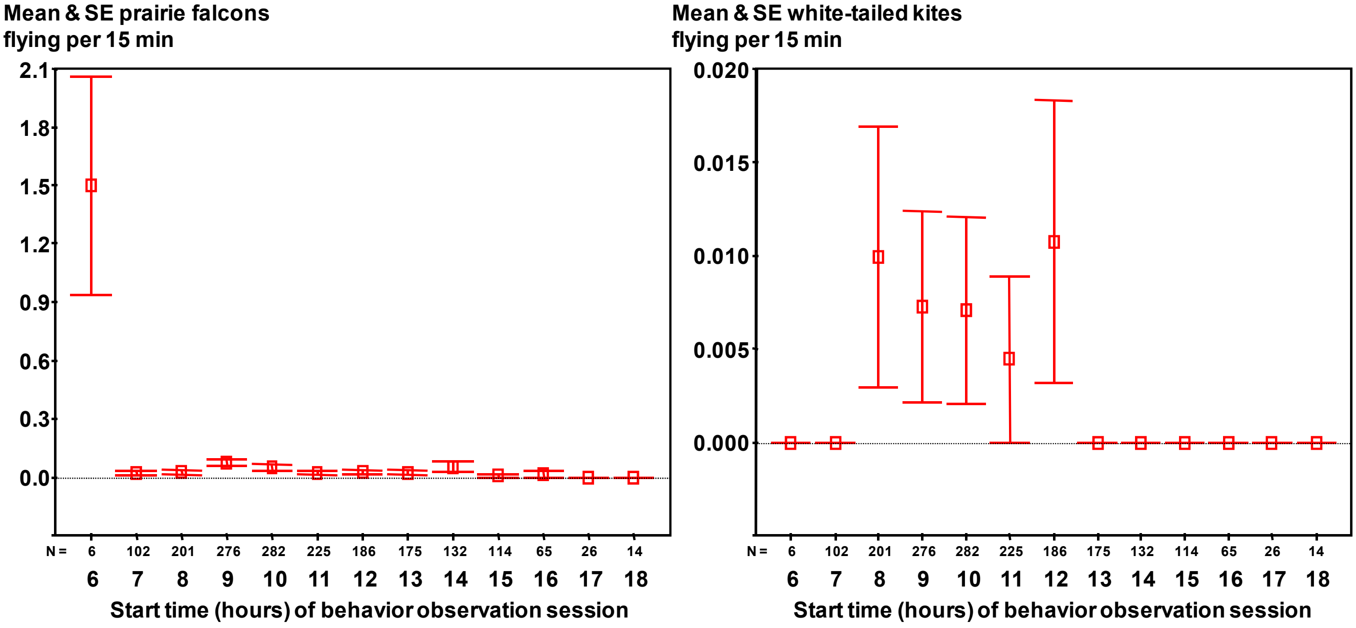

Figure 34. The mean and standard error of the number of prairie falcons (left) and white-tailed kites (right) observed flying during 15-min periods by start time of the session

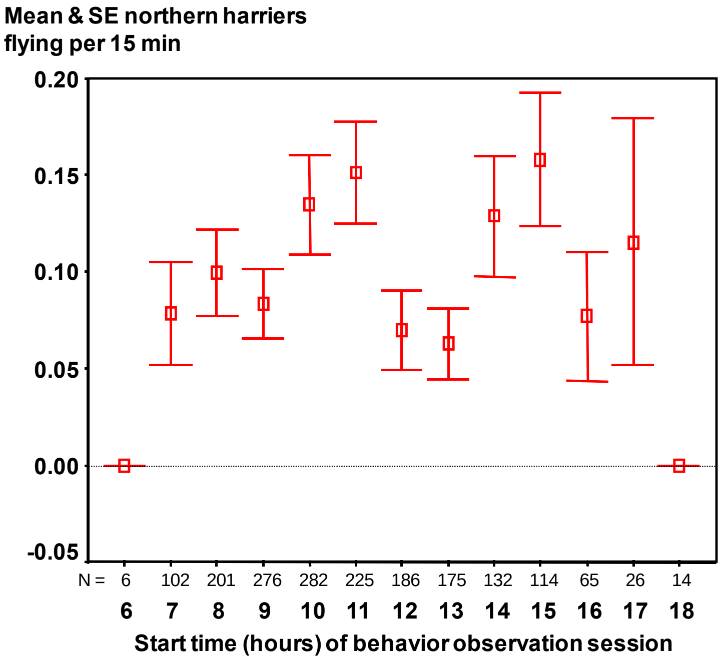

Figure 35. The mean and standard error of the number of northern harriers observed flying during 15-min periods by start time of the session

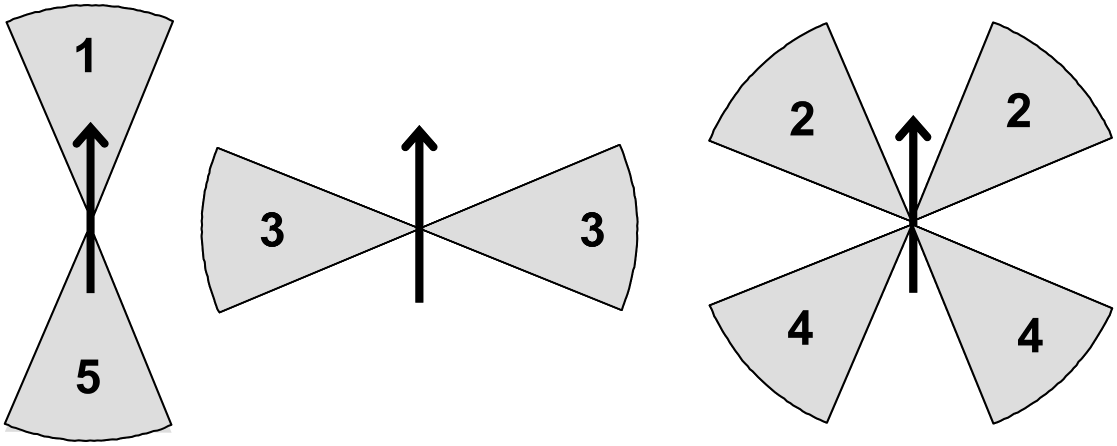

Figure 36. A bird's flight (arrow) was categorized as flying directly into the wind (1), 45˚ to the wind (2), perpendicular to the wind (3), 45˚ from the wind (4), and with the wind (5).

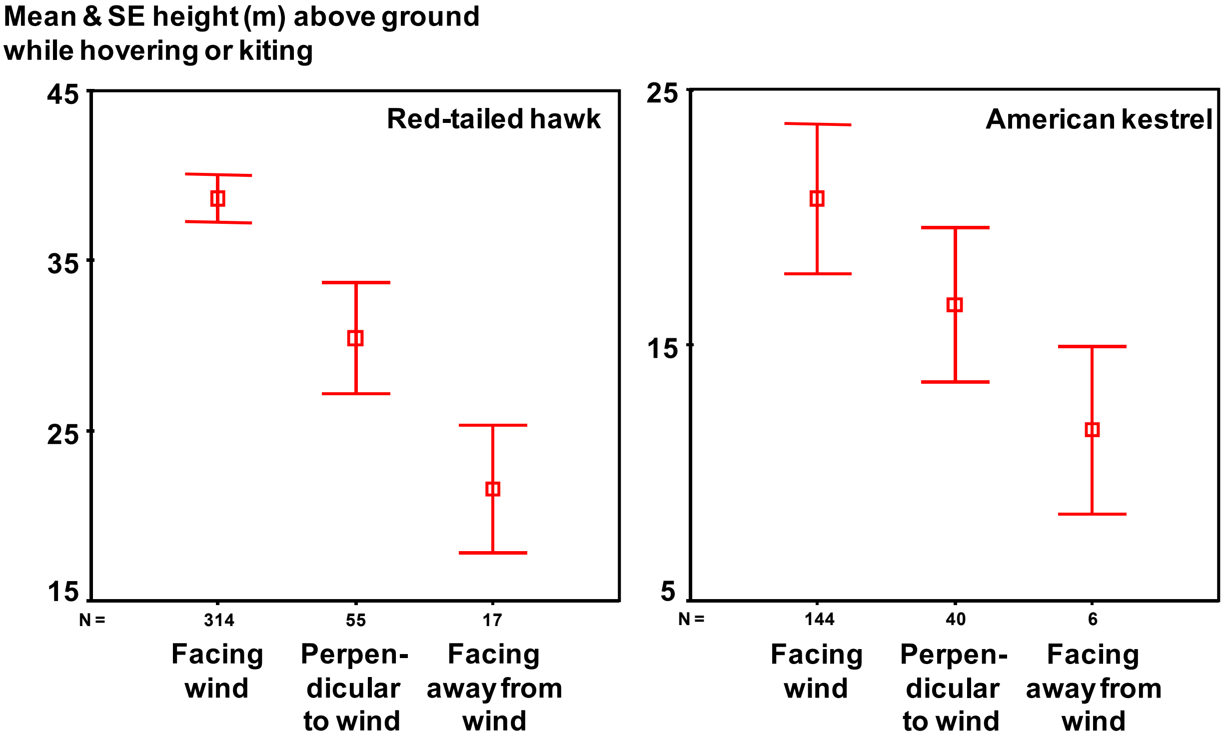

Figure 37. Red-tailed hawks hovered lower over the ground while facing away from the wind, and higher while facing the wind (left), and American kestrels hovered and kited lower over the ground while facing away from the wind, and higher while facing the wind (right). Note that facing the wind included categories 1 and 2 in Figure 36, and facing away from wind included categories 4 and 5 in Figure 36.

5.2.3. Raptor Responses to Wind Turbines

For the most part, common raven and raptor flights at heights of <85 m above ground were recorded disproportionately more often either within 25 m of the nearest wind turbine or several hundred meters away from the nearest wind turbine (Figures 38 and 39). The above-ground height of 85 m was the maximum used in this comparison because it is the anticipated maximum reach of turbine blades in the new-generation wind turbines used for repowering. However, the nearness of flights to turbines appeared to be influenced by whether the nearest wind turbine was operating, not operating, or just feathering (moving, but not generating energy).

Golden eagles flew within 25 m of turbines about 4.5 times more often other than expected when they were not operating, but also about 3.2 times more often than expected when they were operating (Figure 38). Red-tailed hawks flew within 25 m of turbines about 4.2 times more often other than expected when the turbines were not operating, but they still flew within 25 m more than twice as often other than expected even when the turbines were operating (Figure 38). American kestrels flew within 25 m of wind turbines less frequently than expected, no matter the operational status of the turbine at the time of the flight (Figure 38). Prairie falcons flew disproportionately more often within 25 m of operating turbines, but their flights were more frequent far from wind turbines (Figure 38).

Northern harriers were not observed flying within 25 m of wind turbines while the turbines were operating, but they did fly disproportionately more often between 25 and 50 m of turbines while they operated (Figure 39). Generally, northern harriers flew disproportionately more often far from wind turbines while the nearest turbines operated or feathered. Turkey vultures flew within 25 m of turbines over three times more often other than expected while the turbines were not operating, and they generally kept their distance from turbines while the turbines were operating (Figure 39). Common ravens flew within 25 m of turbines three times more often other than expected when the turbines were not operating, but only slightly more often other than expected when the turbines were operating (Figure 39). They flew between 25 and 50 m of turbines about 2.7 times more often other than expected when the turbines were operating, thereby avoiding the rotor planes but perhaps staying close enough to forage for bird carcasses. As a whole, raptor flights were disproportionately more frequent within 25 m of wind turbines, especially when the turbines were not on (Figure 39).

Golden eagles perched within 25 m of operating turbines 6.5 times more often other than expected, and otherwise perched far from wind turbines (Figure 40). Red-tailed hawks were never seen perching within 50 of operating turbines, but perched on or within 25 m of turbines more than 10 times more often other than expected while the turbines were either not operating or feathering (Figure 40). They perched between 50 and 75 m from operating wind turbines about four times more often other than expected. American kestrels perched on or within 25 m of operating wind turbines about 25 times more often other than expected (Figure 40). Burrowing owls mostly perched far from wind turbines, but did so within 25 m of turbines while the turbines were feathering (Figure 40).

Common ravens perched on or within 50 of turbines disproportionately more often while the turbines were either not operating or feathering (Figure 41). All raptors as a group were observed perching on or within 25 m of turbines between four and seven times more often other than expected regardless of turbines operations (Figure 41).

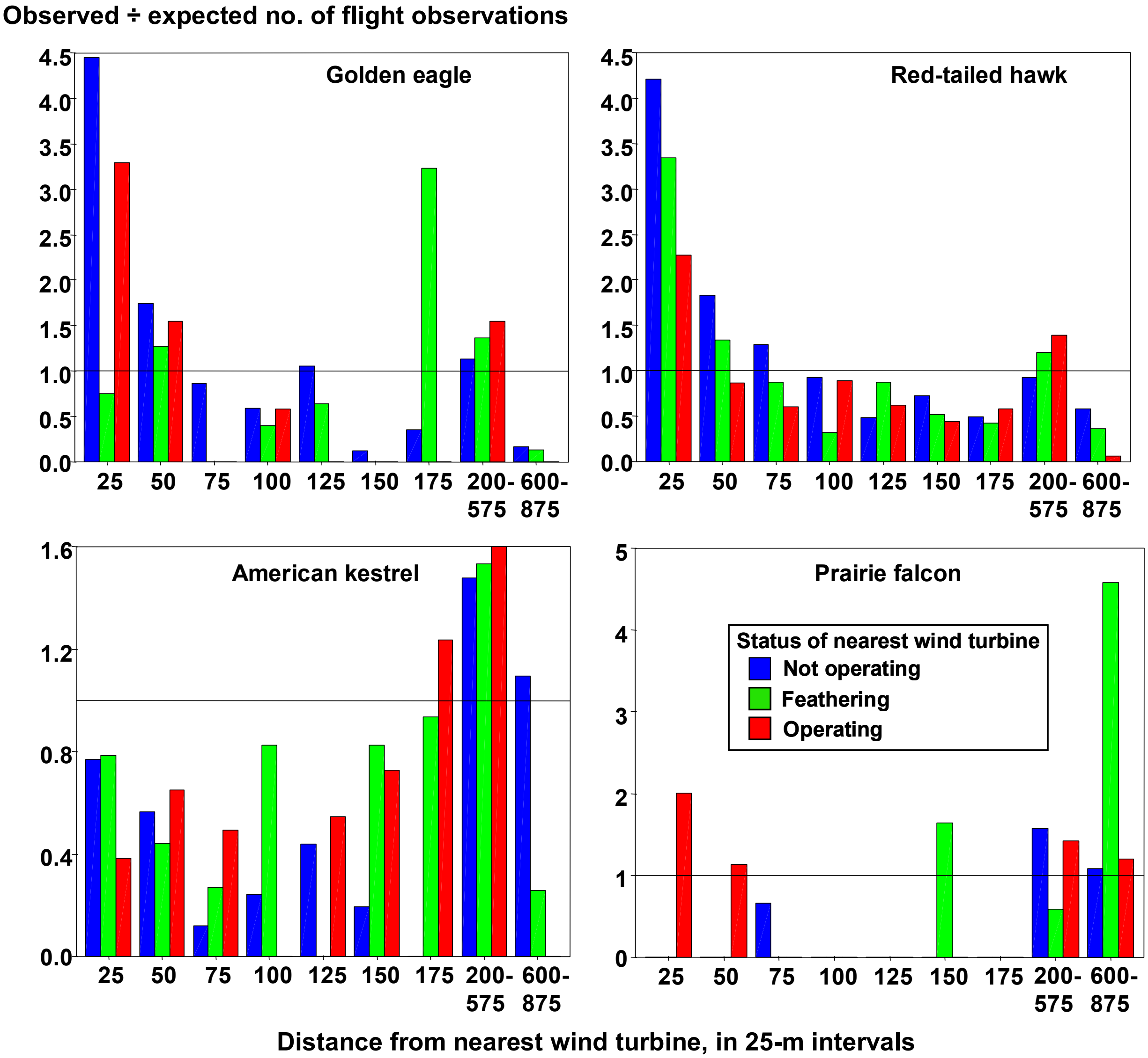

Figure 38. The ratio of observed to expected number of flight observations per OP of golden eagles (top left), red-tailed hawks (top right), American kestrels (bottom left), and prairie falcons (bottom right) at 25-m distance intervals from the nearest wind turbine, which was off, feathering, or on. Distances of 200 to 575 m and 600 to 875 m were lumped. Observed flights were no more or less common than expected at the horizontal line at 1.0.

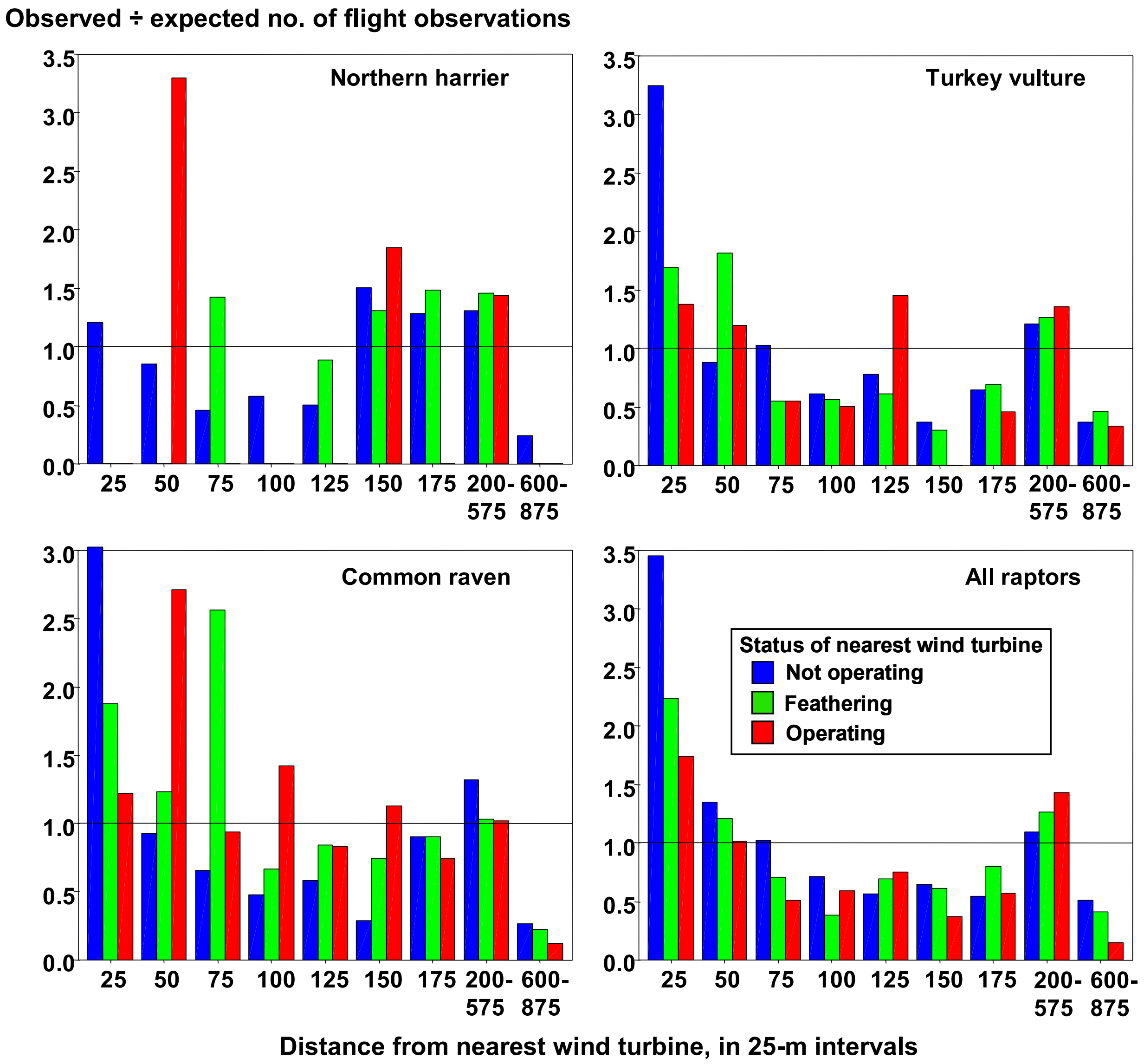

Figure 39. The ratio of observed to expected number of flight observations per OP of northern harriers (top left), turkey vultures (top right), common ravens (bottom left), and all raptors (bottom right) at 25-m distance intervals from the nearest wind turbine, which was off, feathering, or on. Distances of 200 to 575 m and 600 to 875 m were lumped. Observed flights were no more or less common than expected at the horizontal line at 1.0.

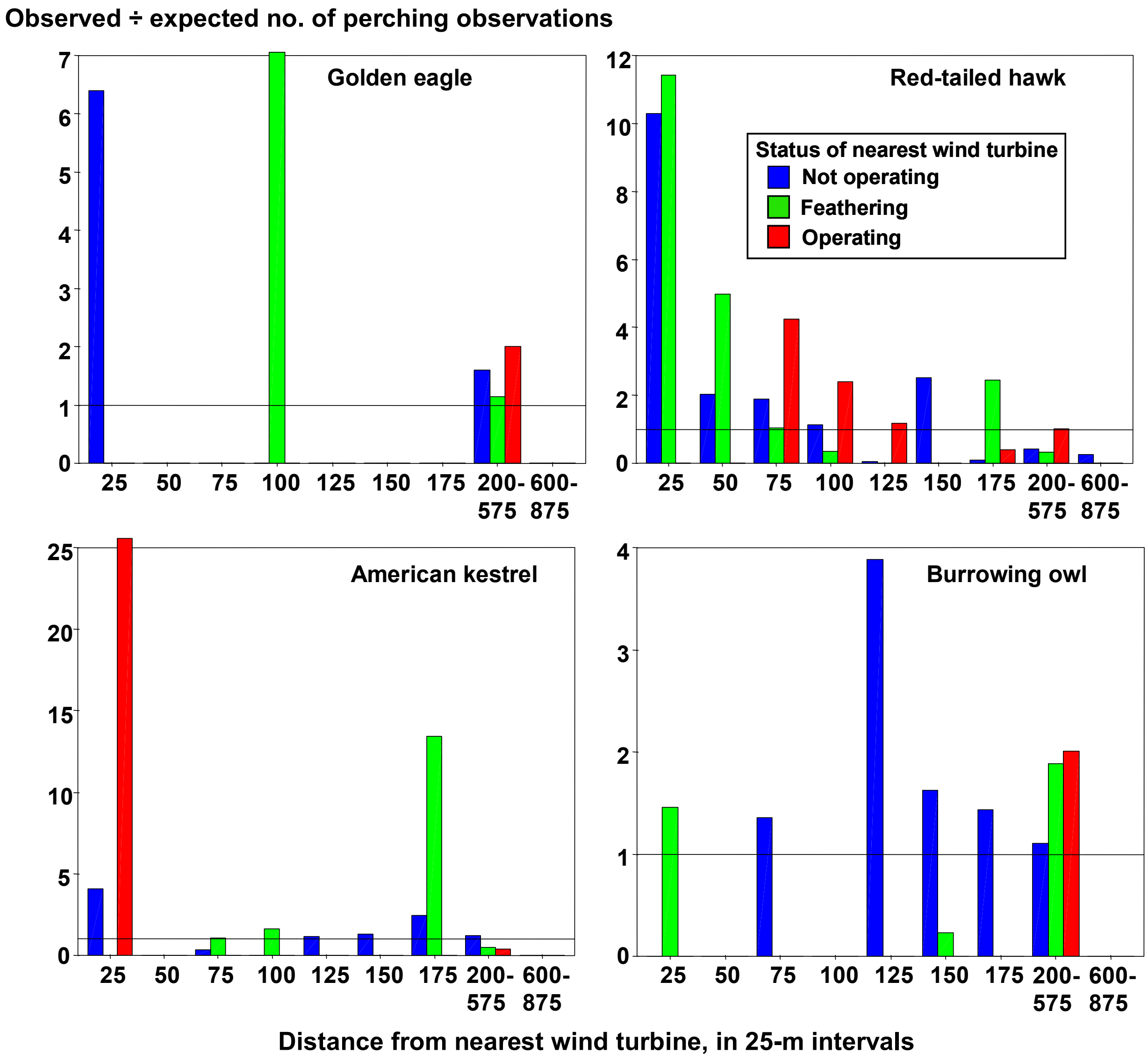

Figure 40. The ratio of observed to expected number of perching observations per OP of golden eagles (top left), red-tailed hawks (top right), American kestrels (bottom left), and burrowing owls (bottom right) at 25-m distance intervals from the nearest wind turbine, which was off, feathering, or on. Distances of 200 to 575 m and 600 to 875 m were lumped. Observed flights were no more or less common than expected at the horizontal line at 1.0.

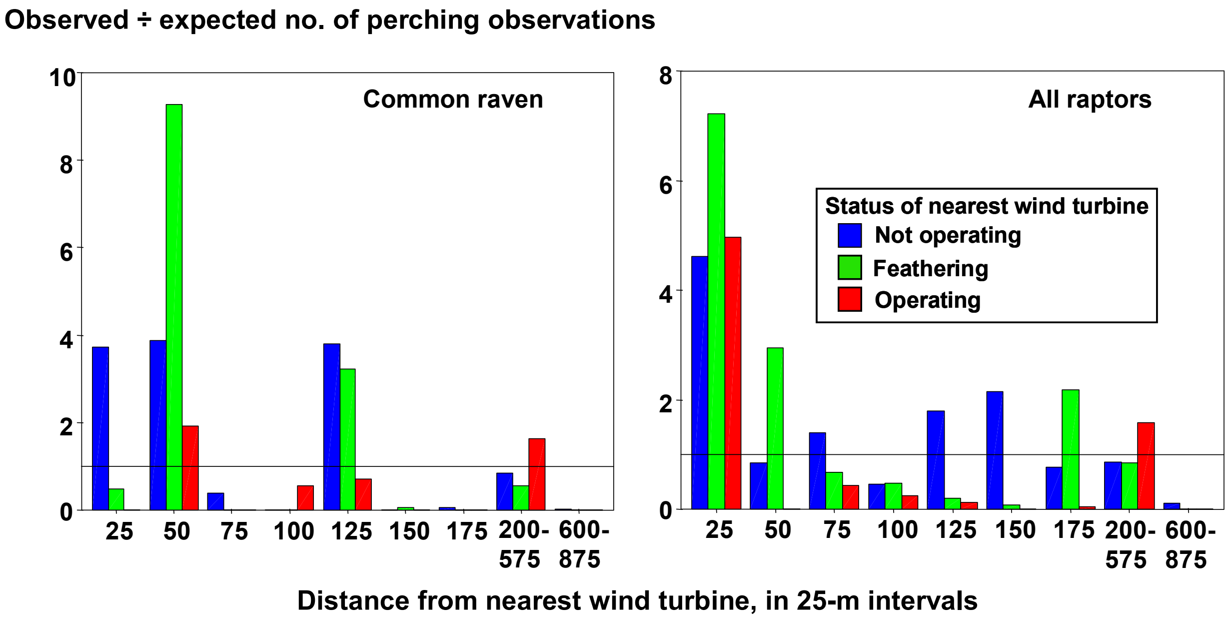

Figure 41. The ratio of observed to expected number of perching observations per OP of common ravens (left) and all raptors (right) at 25-m distance intervals from the nearest wind turbine, which was off, feathering, or on. Distances of 200 to 575 m and 600 to 875 m were lumped. Observed flights were no more or less common than expected at the horizontal line at 1.0.

Compared to past behavior studies in the APWRA, raptor flights were much less aggregated around the wind turbines (Figure 42). The wind turbines in this study area were adjacent to a relatively large area lacking wind turbines (Vasco Caves), so the birds could “choose” whether to use ridges and hills with or without wind turbines. In the previous studies, there were no turbine-free plots in the fields of observation, so there was no “choice” of turbine- free areas available to raptors. In the 1998–2000 study, golden eagles were reported flying within 50 m of wind turbines nearly seven times other than expected and red-tailed hawks were observed flying within 50 m of wind turbines nearly eight times other than expected. As mentioned above, both of these species were observed in the present study flying within 50 m of turbines at approximately twice the frequency expected (without considering the operational status of the turbines at the times the birds were observed). Burrowing owls were reported flying within 50 m of wind turbines ten times more often other than expected in 1998–2000, but not at all during this study. Earlier studies indicated northern harriers flew disproportionately more often near the wind turbines, but this study indicated that the frequency of their flights near turbines were no more common than expected.

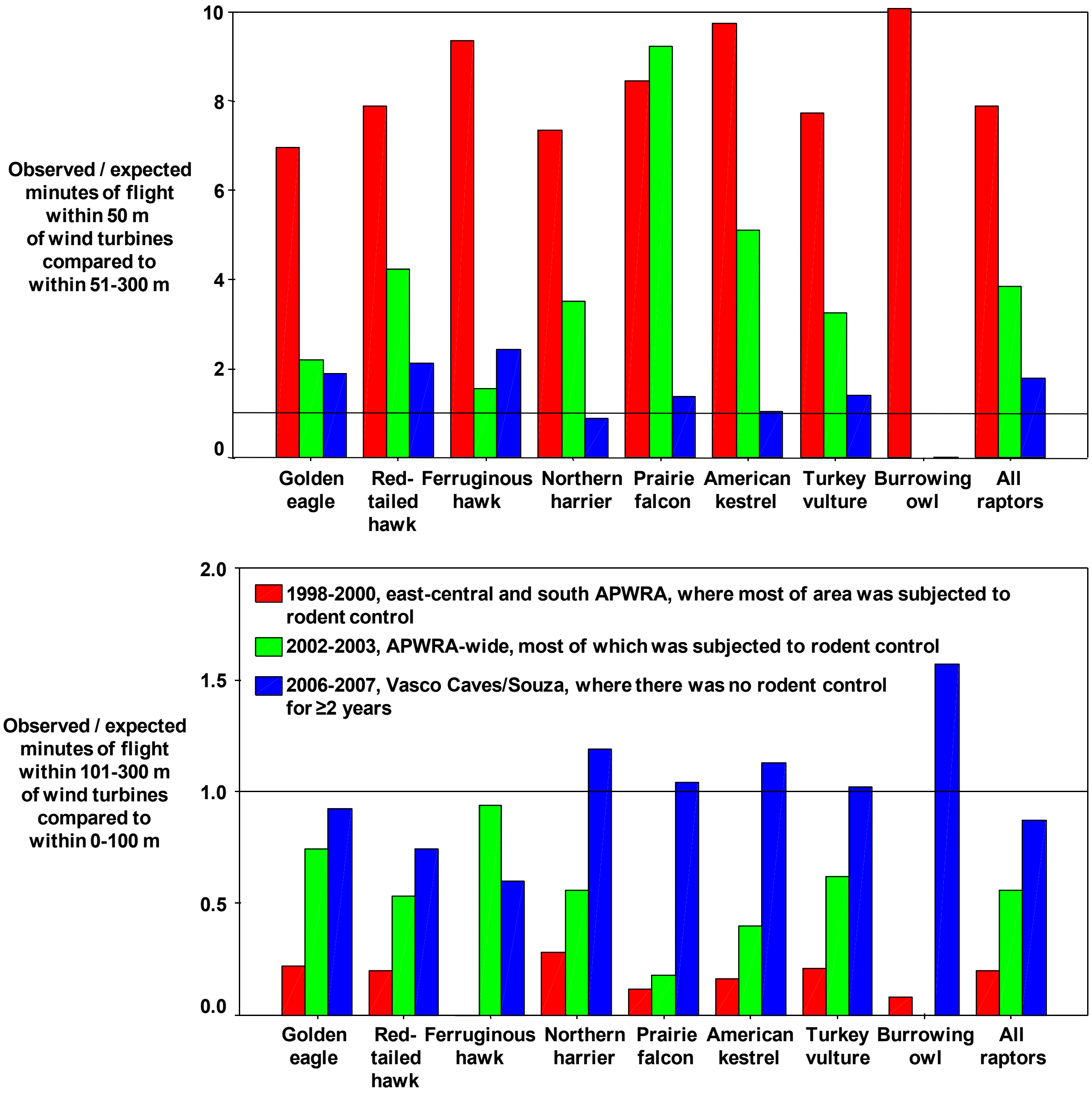

Figure 42. The ratio of observed to expected number of flight observations within 50 m of the nearest wind turbine as compared to within 51 to 300 m (top graph), and the ratio of flight observations within 101 to 300 m of the nearest wind turbine as compared to within 0 to 100 m (bottom graph). The results from three studies are shown, though the locations and methods varied. The horizontal line at 1.0 represented the condition where the observed and expected numbers of flights were equal, or the observed flights were no more common other than expected.

Comparing flight heights within and outside a 200-m aggregated radius around the wind turbines (see Section 5.1, Methods), red-tailed hawks circled/soared/surfed higher above the ground while farther from wind turbines (Table 13). All red-tailed hawk flights together were also higher farther from wind turbines, but hovering/kiting and fly-through/gliding did not differ between areas nearer and further than 200 m of wind turbines (Table 13). American kestrels hovered/kited higher above the ground while within 200 m of wind turbines, but their flight heights were no different while flying-through/gliding or circling/soaring/surfing. Golden eagle and common raven flight heights did not differ whether nearer or further than 200 m of wind turbines.

Table 13. Tests for differences in flight heights within and farther than 200 m of wind turbines

	Far from turbines (>200 m)			Near turbines (<200 m)				
Flight behaviors	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**	**F**	**P**
Red-tailed hawk								
Hovering/kiting	36.1	24.6	252	33.6	21.3	34	0.31	0.578
Fly-through/glide	40.2	35.6	266	34.6	21.3	78	1.76	0.186
Circle/soar/surf	68.7	48.6	267	47.8	34.3	83	13.24	0.000
All flights	46.4	40.5	843	37.1	28.6	216	9.99	0.002
American kestrel								
Hovering/kiting	14.7	13.8	140	54.0	21.6	4	30.51	0.000
Fly-through/glide	22.1	28.1	72	16.0	16.4	4	0.19	0.666
Circle/soar/surf	38.3	25.9	23	78.0	---	1	2.24	0.149
All flights	19.0	21.2	249	33.0	30.0	11	4.40	0.037
Golden eagle								
Hovering/kiting	37.6	14.9	18	---	---	0	No test	---
Fly-through/glide	61.3	77.2	31	38.1	34.4	9	0.76	0.389
Circle/soar/surf	106.3	108.2	29	98.9	64.3	10	0.04	0.834
All flights	63.9	83.8	89	60.8	60.3	22	0.03	0.871
Common raven								
Hovering/kiting	14.4	14.8	69	9.5	9.5	11	0.12	0.293
Fly-through/glide	22.1	22.9	411	19.1	13.5	148	2.37	0.124
Circle/soar/surf	46.9	50.2	106	54.0	86.2	35	0.35	0.555
All flights	23.4	29.4	688	23.3	38.7	217	0.00	0.963

N is sample size; F is the F-ratio in ANOVA tests; P is the P-value.

5.2.4. Raptor Response to Landscape

The DEM grid used for analysis included all 89,468 cells within the aggregated outer search radius from the OPs (Figure 19). Overall, most bird species were seen more often where OP survey limits overlapped. For example, red-tailed hawk sightings were more frequent over Vasco Caves, but this is also where more observation plots were located and more often overlapped in surveyed area (Figures 43 and 44). Therefore, tests for association needed to include a weighting for the number of times a grid cell could be seen from OPs.

The observations of birds were weighted by the number of times their locations were within an OP survey radius of 650 m, which was the farthest distance from the observer a bird could be recorded on the maps used. Actually, the weighting was applied to the underlying grid cell where the bird was positioned. Figure 45 depicts the relative use of the study area by red-tailed hawks, after weighting the observations by the number of times the site overlapped an OP survey area. These weightings were applied only to tests for association.

A principal components analysis using a varimax rotation explained 81% of the variation in the measured predictor variables among 89,468 grid cells within the grid used for raptor flight analysis. The three principal components are presented in Table 14, which shows only those rotated factor loadings >0.1. Component 1 can be interpreted as position on the slope. Component 2 can be interpreted as the slope's rate of change, i.e., steepness. Component 3 can be interpreted as the slope's size. Only one variable with a high loading will be used from each component for subsequent predictive model development, though all variables and transformed variables were tested for a relationship with raptor flight locations.

Table 14. Principal components and standardized coefficients for each variable following varimax rotation in PCA

Variable	Component 1 Position on Slope	Component 2 Steepness of Slope	Component 3 Size of Slope
ln Distance ratio	0.980		
ln Elevation ratio	0.924		
$\log_{10}$ Distance to ridge	-0.855	0.108	0.362
$\log_{10}$ Distance to valley	0.811		0.473
Elevation	0.369	0.112	
Gross slope		0.930	
Slope (percentage)		0.783	
Elevation difference		0.754	0.541
$\log_{10}$ Total slope distance		0.129	0.963

Raptors responded strongly to the landscape, performing flights, particular behaviors, and even perching in portions of the study landscape with slope attributes that were significantly different from the average grid cell location (Appendices F1 to F6). Nearly every slope attribute measured differed significantly between where raptors were observed and where they were not observed. Each species' use of the landscape and particular behaviors differed significantly from random.

Red-Tailed Hawk

While hovering or kiting, red-tailed hawk almost always used the slope aspect of a hill or ridge that faced the incoming wind (Figures 46 and 47). Doing so enabled the hawks to catch the declivity winds, using almost no energy while remaining relatively stationary at a point in space. Red-tailed hawks hovered or kited most often on slopes facing the wind, especially those in Vasco Caves where no wind turbines were located. Some slopes facing the winds in the Souza parcel had no observations of red-tailed hawks hovering or kiting over them. These were slopes that supported wind turbines.

Comparing PC scores from the PCA, red-tailed hawks hovered over higher positions on the slope, larger slopes, and steeper slopes than the averages for grid cells where red-tailed hawks were not observed hovering (Appendix F1). According to the PC scores, all red-tailed hawk flights, including hovering and kiting, were higher on the slope, and over steeper slopes and larger slopes (Appendix F2). Elevation of the DEM grid cell was also greater among red-tailed hawk flights compared to grid cells where no flights were observed. Where red-tailed hawks perched, however, was most related to position on the slope, followed by slope steepness, but it was unrelated to slope size (Appendix F3).

American Kestrel

American kestrels were observed flying most often near hill peaks and ridge crests, and the pattern of locations did not appear to relate to the number of times the site could be seen from OPs (Figures 48 and 49). The patterns of hovering and kiting locations appeared strongly tied to hill peaks and ridge crests (Figures 50 and 51). Indeed, the PC scores for position on the slope differed the most where American kestrels were recorded hovering or kiting (Appendix F4). Larger slope size was next most related to American kestrel hovering and kiting locations, followed by slope steepness.

Golden Eagle

Golden eagle flights were located over grid cells where position on the slope was closer to peaks or crests, but they were also observed over grid cells with larger and steeper slopes (Appendix F5). Golden eagle flights were recorded throughout the study area and did not appear to be related to presence or absence of wind turbines (Figure 52). They were seen using the large hill slopes, as well as the valley bottoms. Compared to other raptors, golden eagle flights appeared to be less dependent on concordance between wind direction and facing slope (Figure 53). However, when flying into southwest-trending winds, eagles most often occurred on slopes facing southwest-trending directions (Figure 54), especially when hovering (Figure 55).

Prairie Falcon

Most prairie falcon flight locations were on the four largest hills in the study area, and mostly on the two on the Vasco parcel (Appendix E1). Most of the hovering or kiting flights were recorded on hills away from the wind turbines, and most of these were on Vasco Caves (Appendix E2). Compared to American kestrels, prairie falcon hovering and kiting faced winds on hills less often facing the wind direction (Appendix E3), but nearly all hovering and kiting flights facing the prevailing southwest-trending directions were over slopes that faced these directions (Appendix E4).

General Raptor Activity

Overall, raptor activity was most intense on the southwest aspects of the largest hills in the study area (Figure 56). It was less intense on the ungrazed portion of Vasco Caves, though this area included only a relatively small southwest- facing slope. Patterns of raptor flight activity suggested that a steep-sloped canyon in the western portion of Vasco Caves that extends into northwest Souza may serve as a travel corridor. Otherwise, raptor flight activity was less frequent over relatively flatter terrain.

Common Raven

Common raven flights were also located where grid cell position on the slope was nearer the peaks and crests of hills and ridges, and they were also located on larger and steeper slopes than the average DEM grid cell in the study area (Appendix F6). Common ravens also selected sites with significantly higher elevations. Common raven activity was most intense on the largest hills in the study area, and did not appear to shy away from the wind turbines (Appendix E5). In fact, some of the most intense common raven activity clustered around wind turbines.

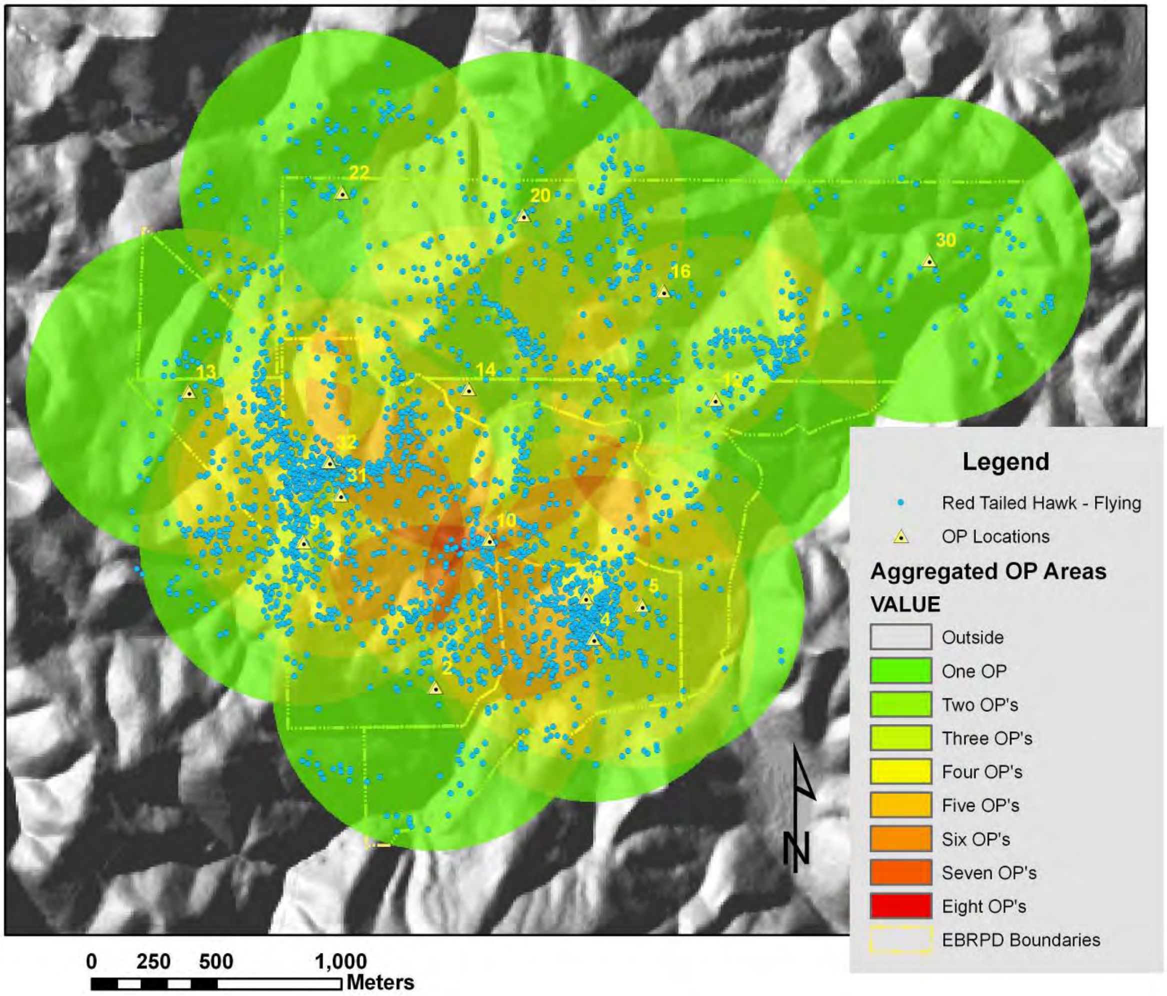

Figure 43. All locations of red-tailed hawk flight locations recorded during the study

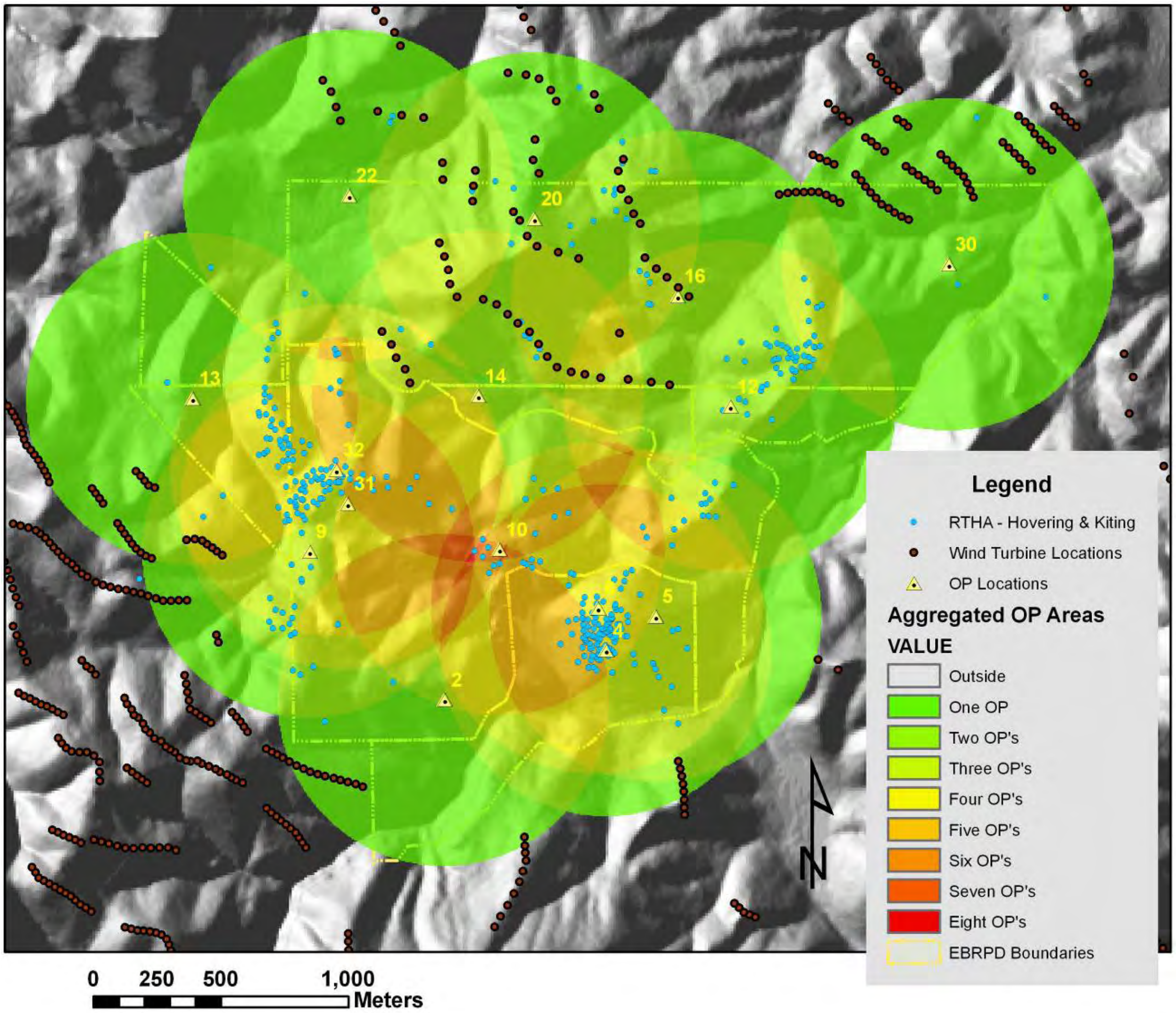

Figure 44. All locations of red-tailed hawk hovering and kiting locations recorded during the study

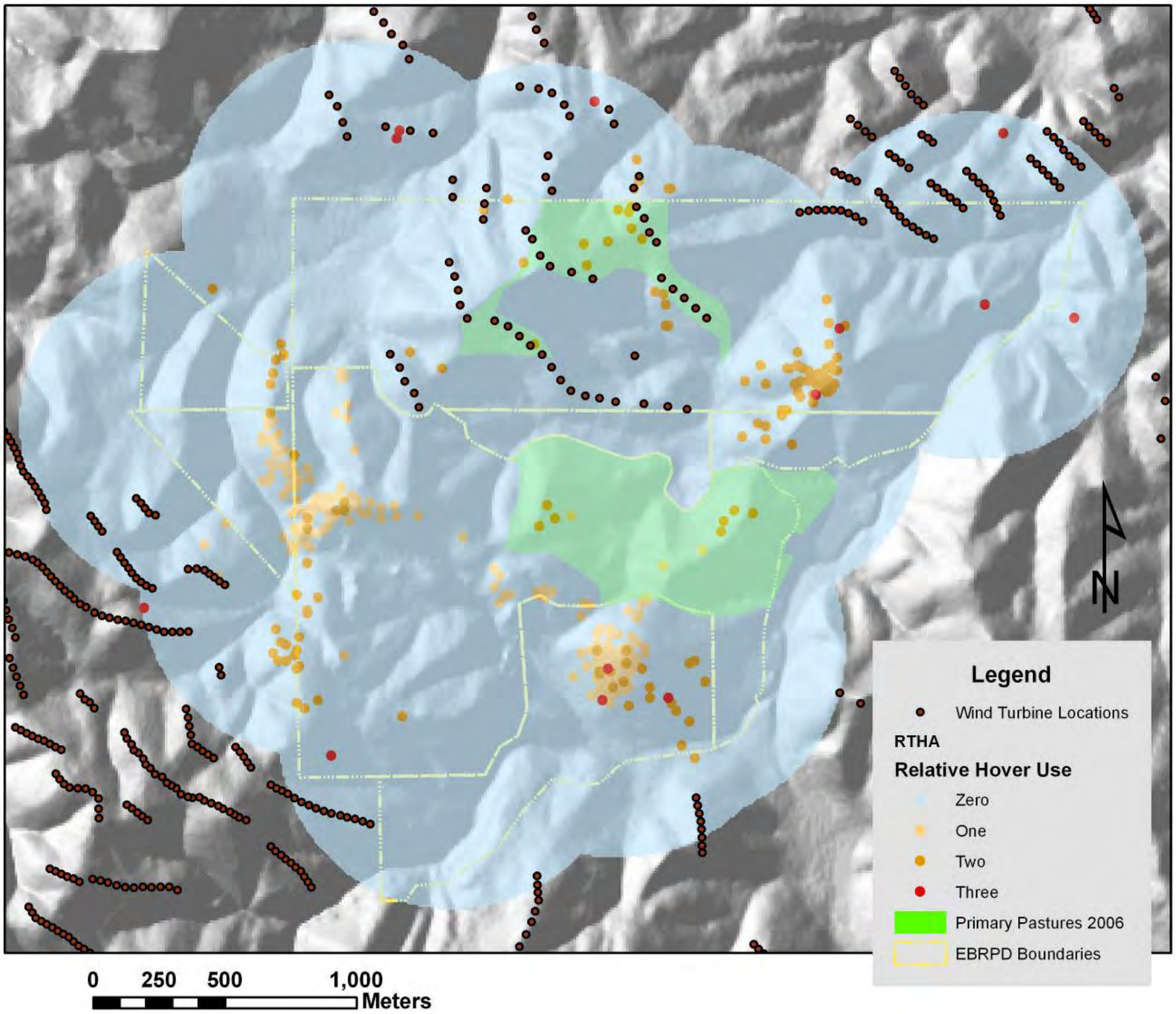

Figure 45. Red-tailed hawk hovering observations per OP from which the outer 650-m survey radius could overlap the site. Observation rates, or flights/OP, were grouped in the map: 'one = 0.17 to 0.25, two = 0.33 to 0.50, and three = 0.60 to 2.00.

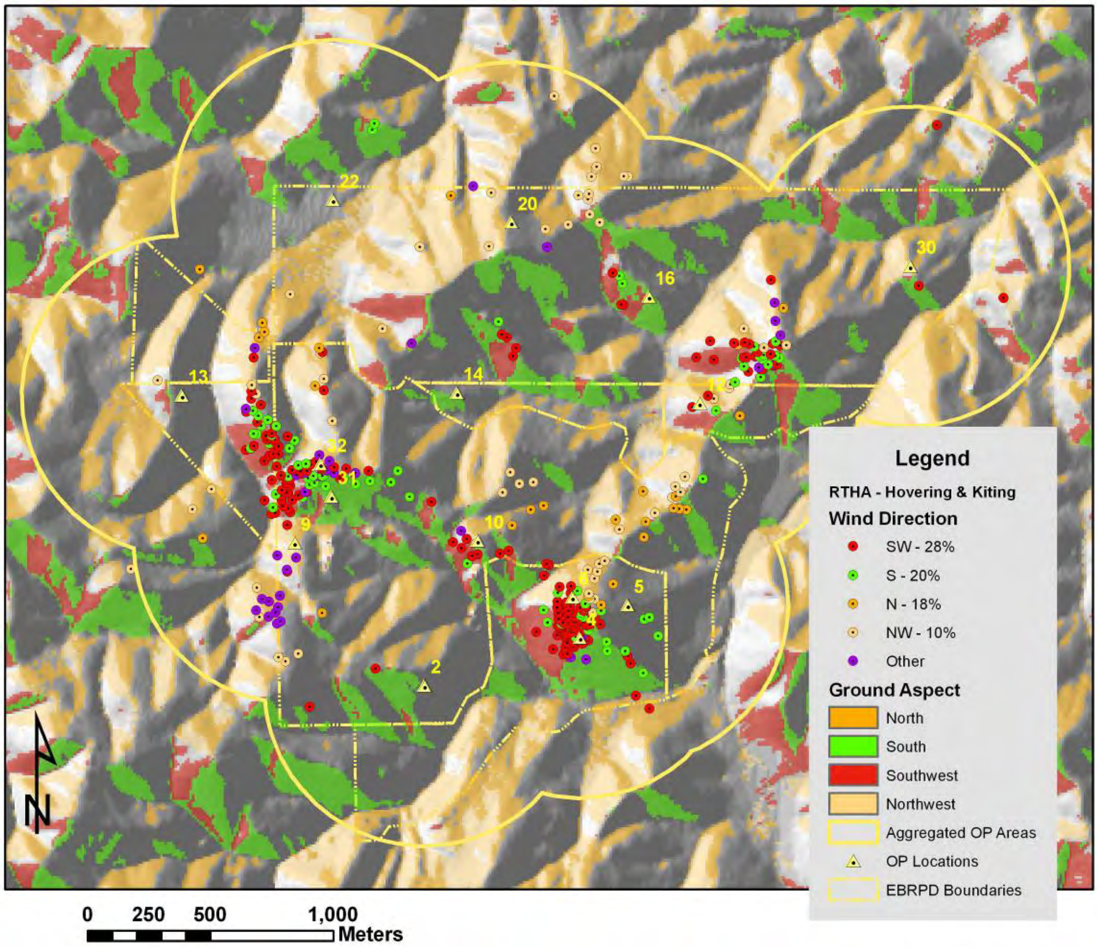

Figure 46. Locations of red-tailed hawks hovering or kiting into various wind directions. Most locations indicated the hawks hovered or kited on the slope aspect of the hill or ridge that faced the wind at the time the observation was recorded.

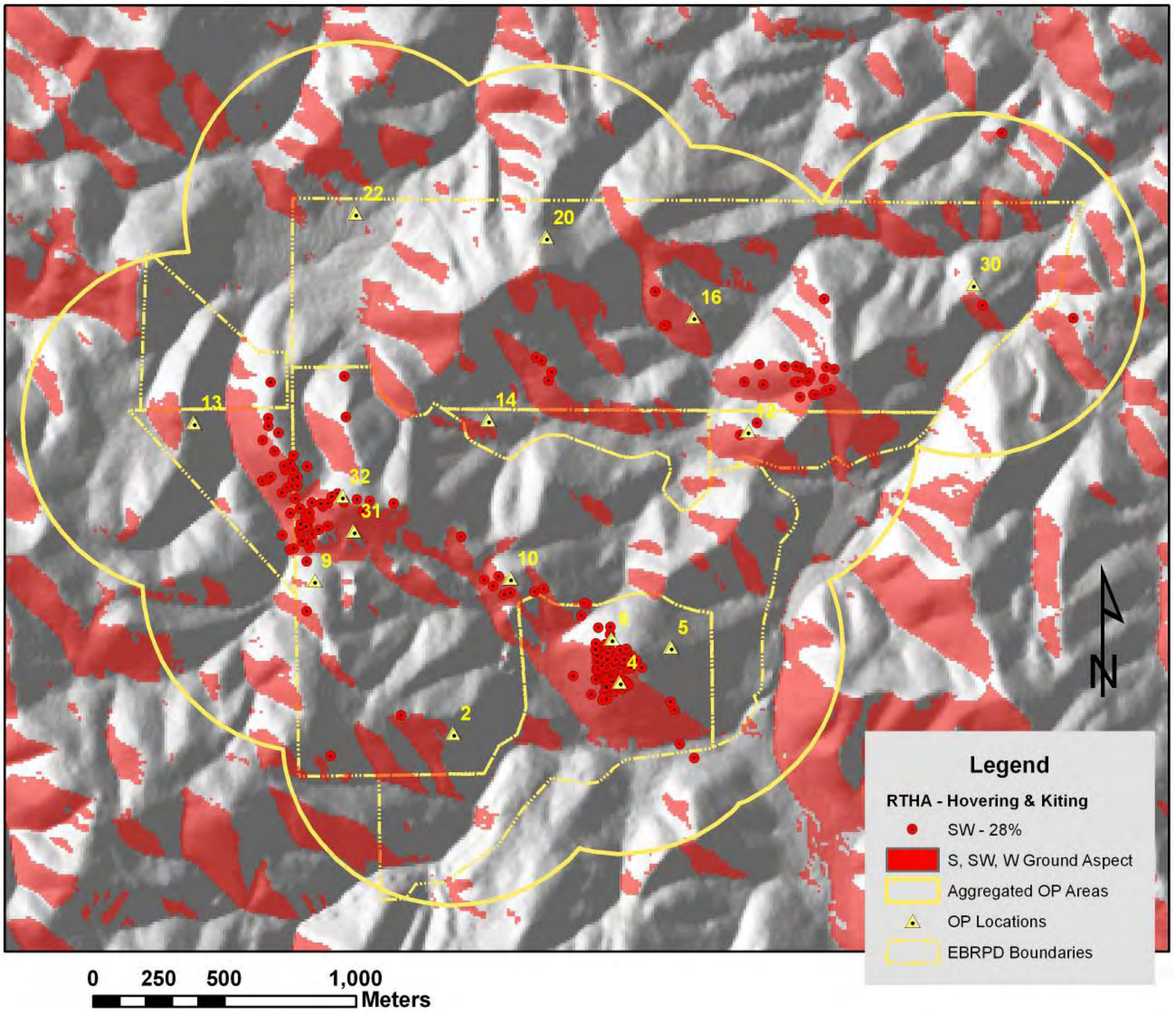

Figure 47. Locations of red-tailed hawks hovering or kiting into southwest winds. Most locations where the hawks hovered or kited were on the south-, southwest-, or west-facing slopes at the time the observation was recorded.

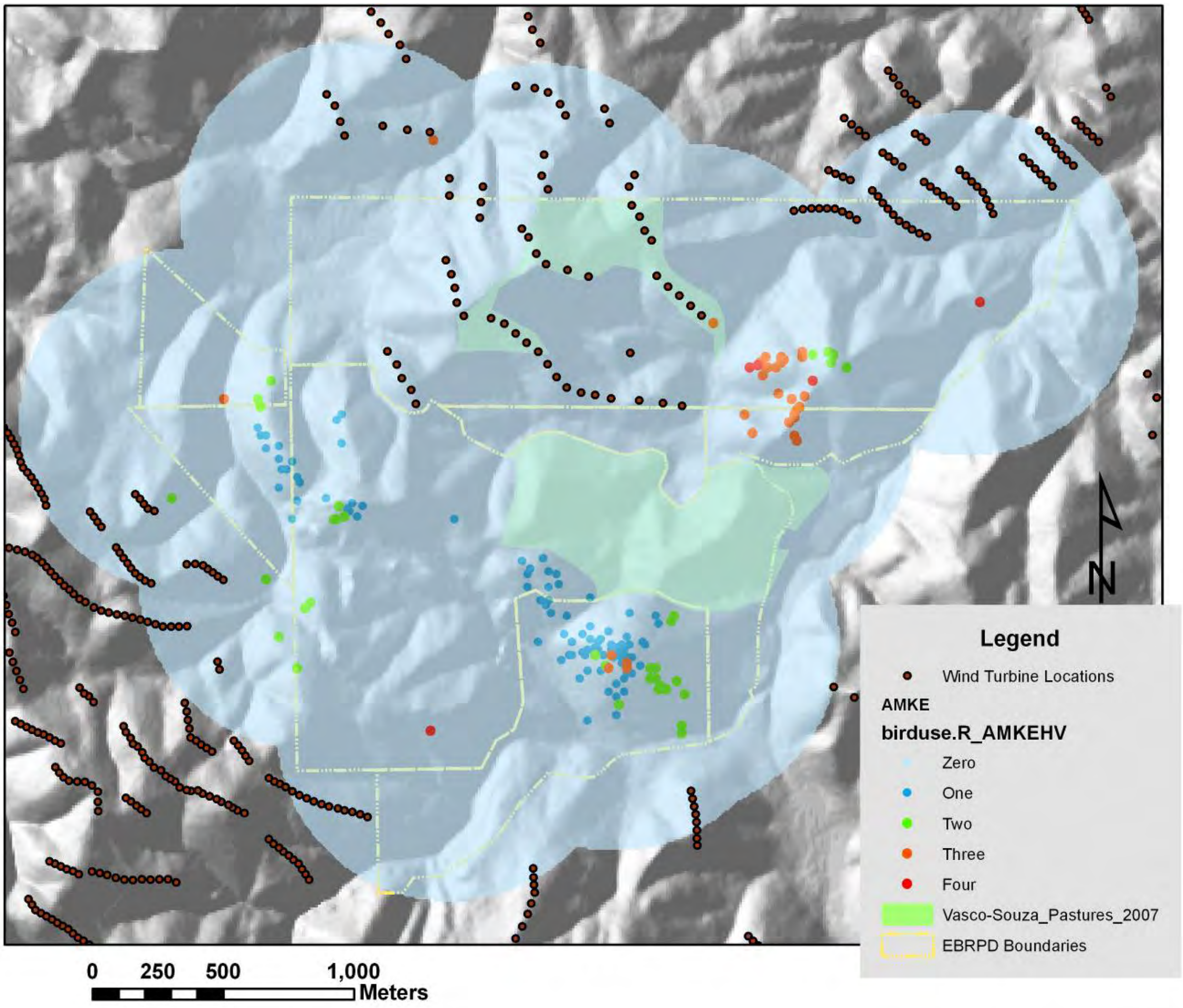

Figure 48. American kestrel hovering observations per OP from which the outer 650-m survey radius could overlap the site. Observation rates, or flights/OP, were grouped in the map: one = 0.20 to 0.25, two = 0.33 to 0.40, three = 0.50, and four = 1.00 to 1.50.

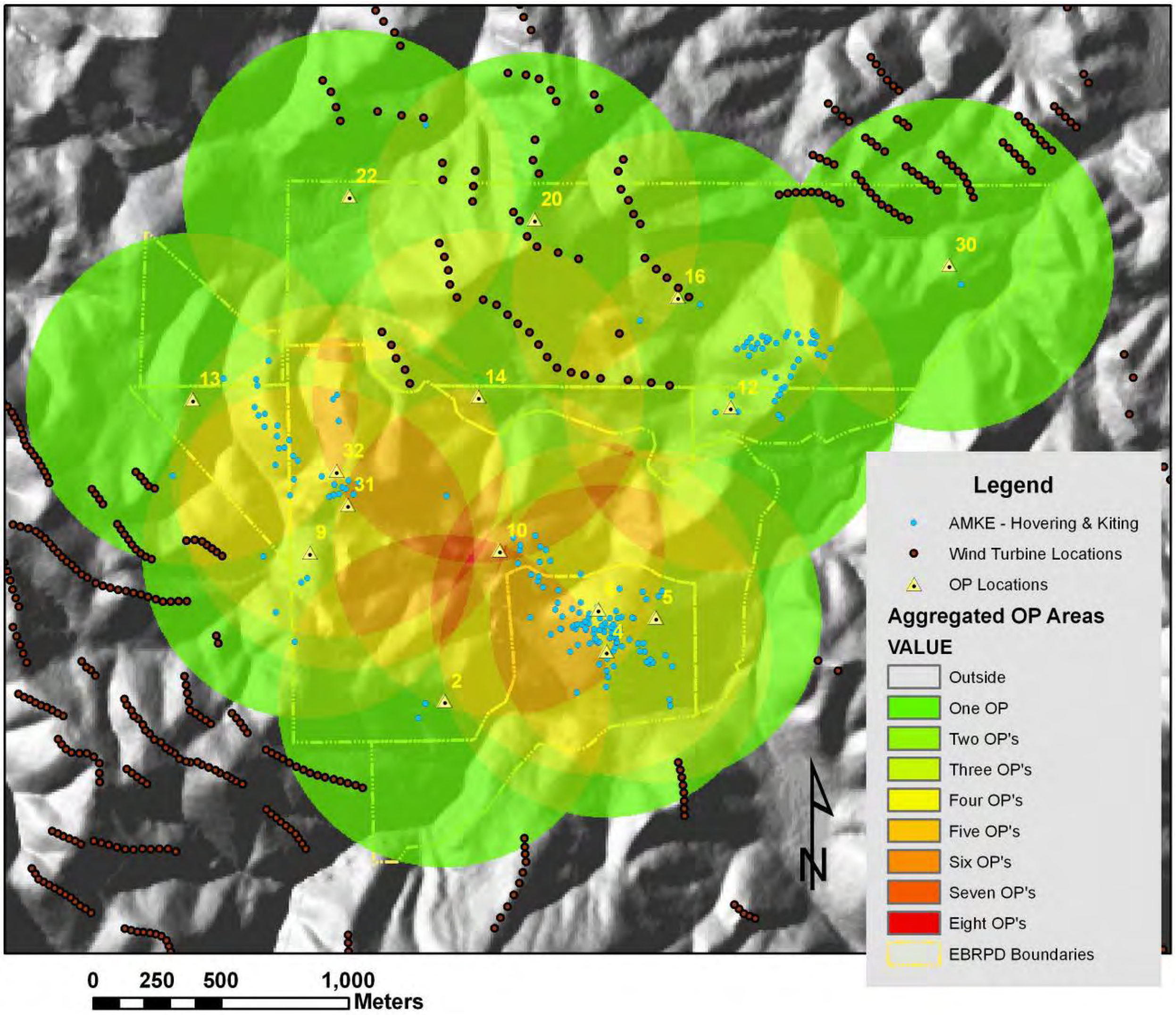

Figure 49. All locations of American kestrel hovering and kiting locations recorded during the study

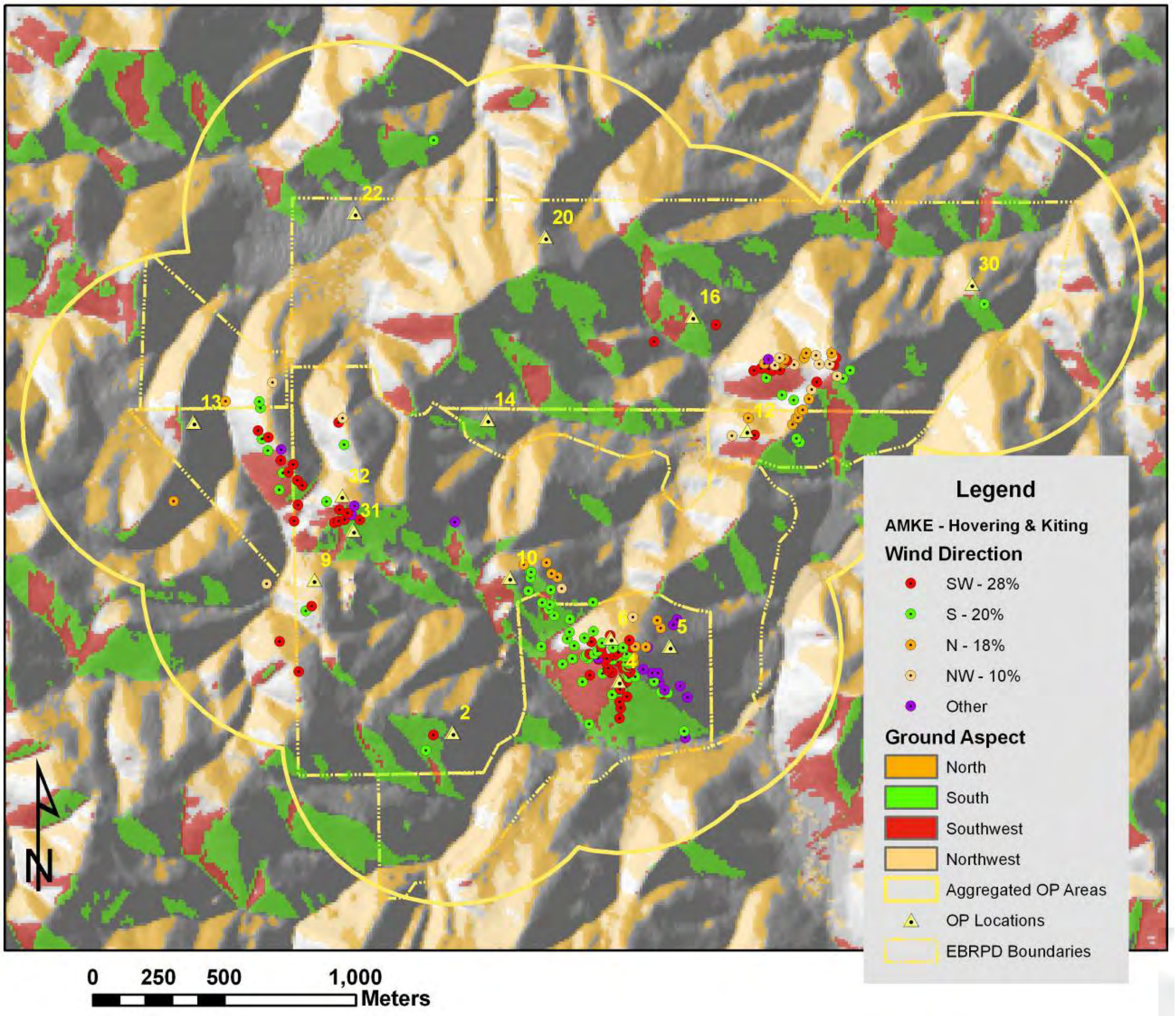

Figure 50. Locations of American kestrels hovering or kiting into various wind directions. Most locations indicated the hawks hovered or kited on the slope aspect of the hill or ridge that faced the wind at the time the observation was recorded.

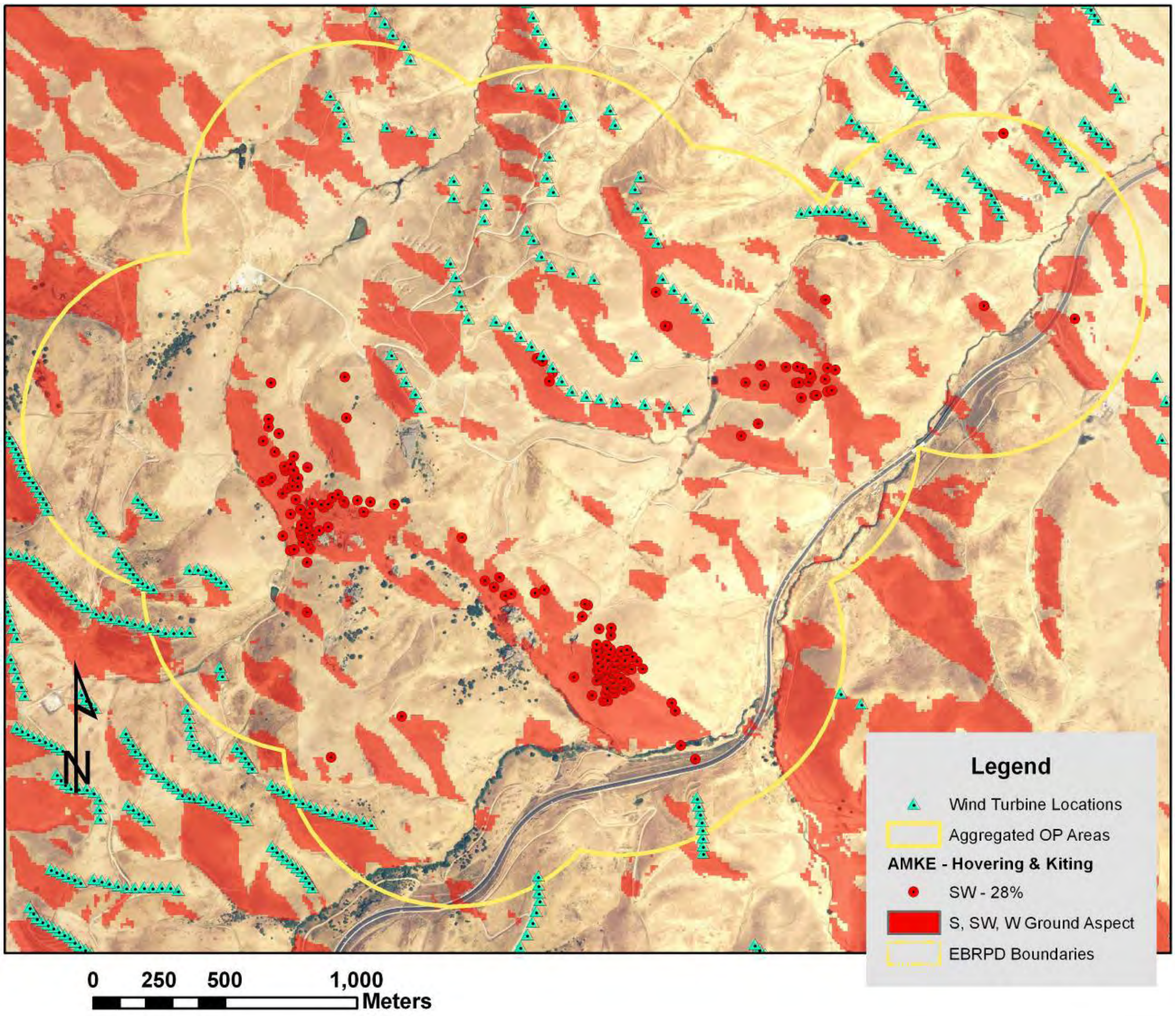

Figure 51. Locations of American kestrels hovering or kiting into southwest winds. Most locations where the kestrels hovered or kited were on the south-, southwest-, or west-facing slopes at the time the observation was recorded.

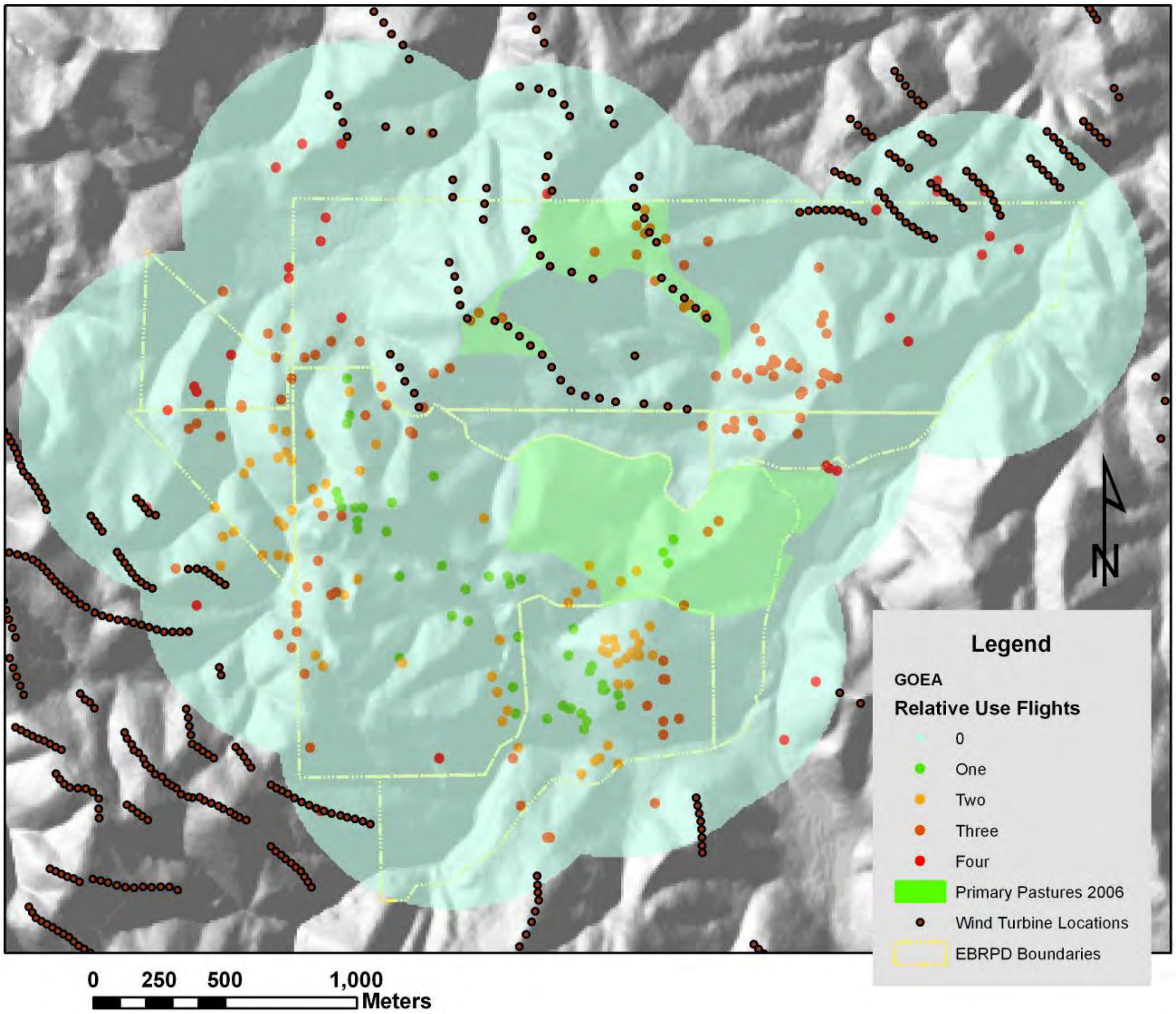

Figure 52. Golden eagle flight observations per OP from which the outer 650-m survey radius could overlap the site. Observation rates, or flights/OP, were grouped in the map: one = 0.14 to 0.20, two = 0.25, three = 0.33 to 0.50, and four = 1.00.

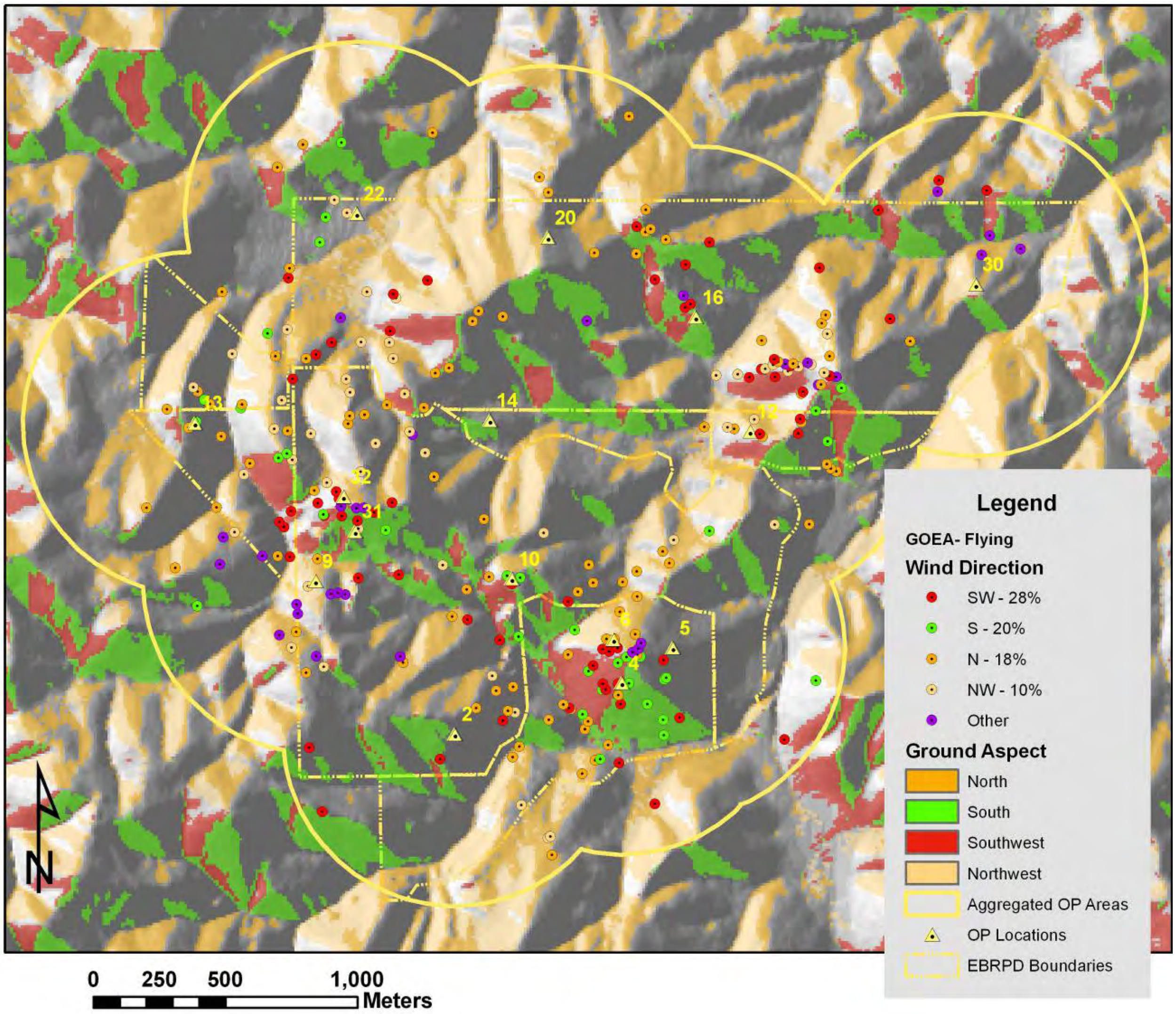

Figure 53. Locations of golden eagle flights into various wind directions. Compared to red-tailed hawks and falcons, golden eagle flight directions did not correspond as well with wind direction relative to the direction the slope faced. However, for flights into south, southwest, and west winds (Figure 54) and hovering flights (Figure 55), flight direction coincided with wind and slope direction.

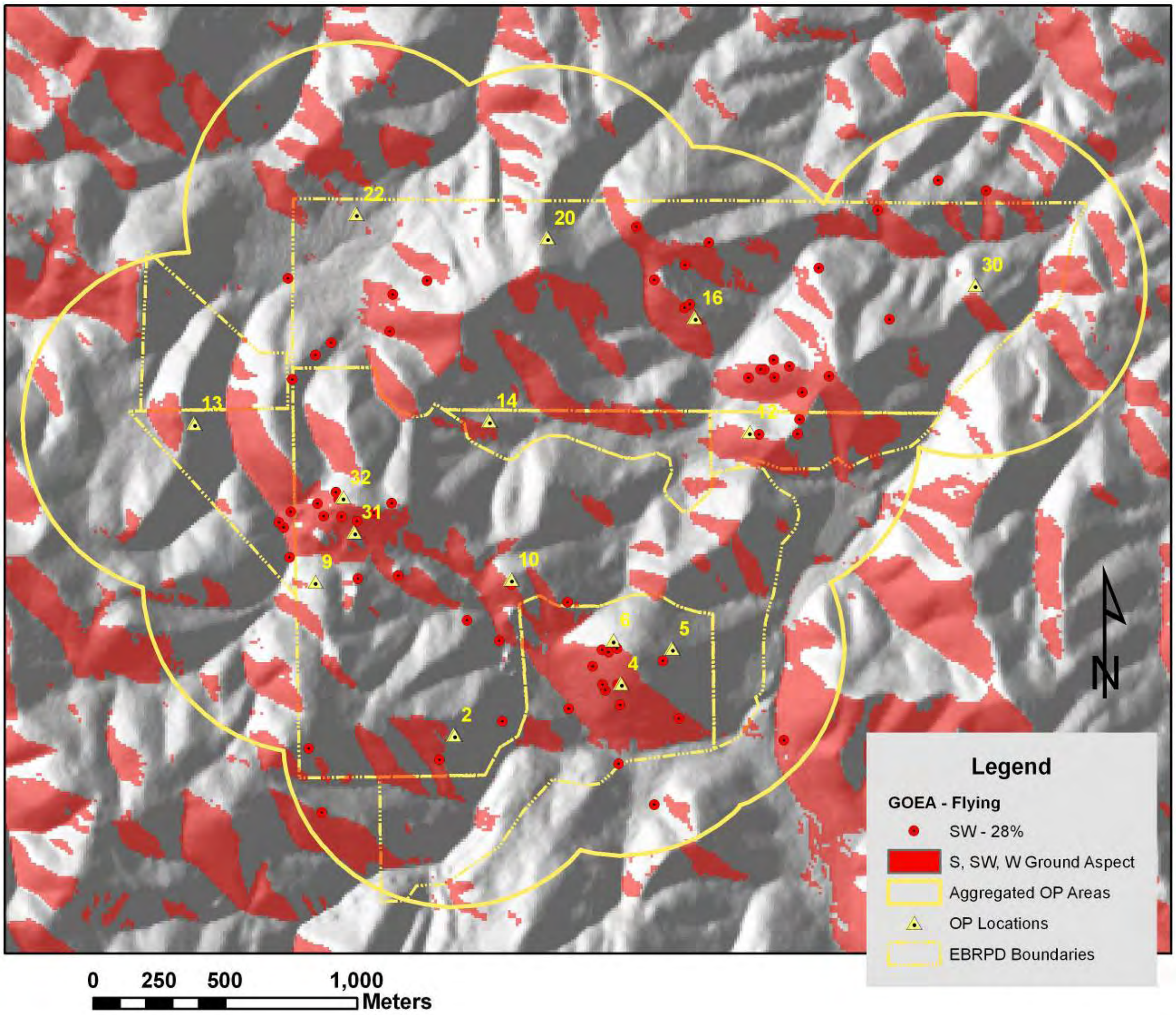

Figure 54. Locations of golden eagle flights into south, southwest, and west winds. Most eagle flights into southwest-trending winds were also on slopes facing the wind at the time the observation was recorded.

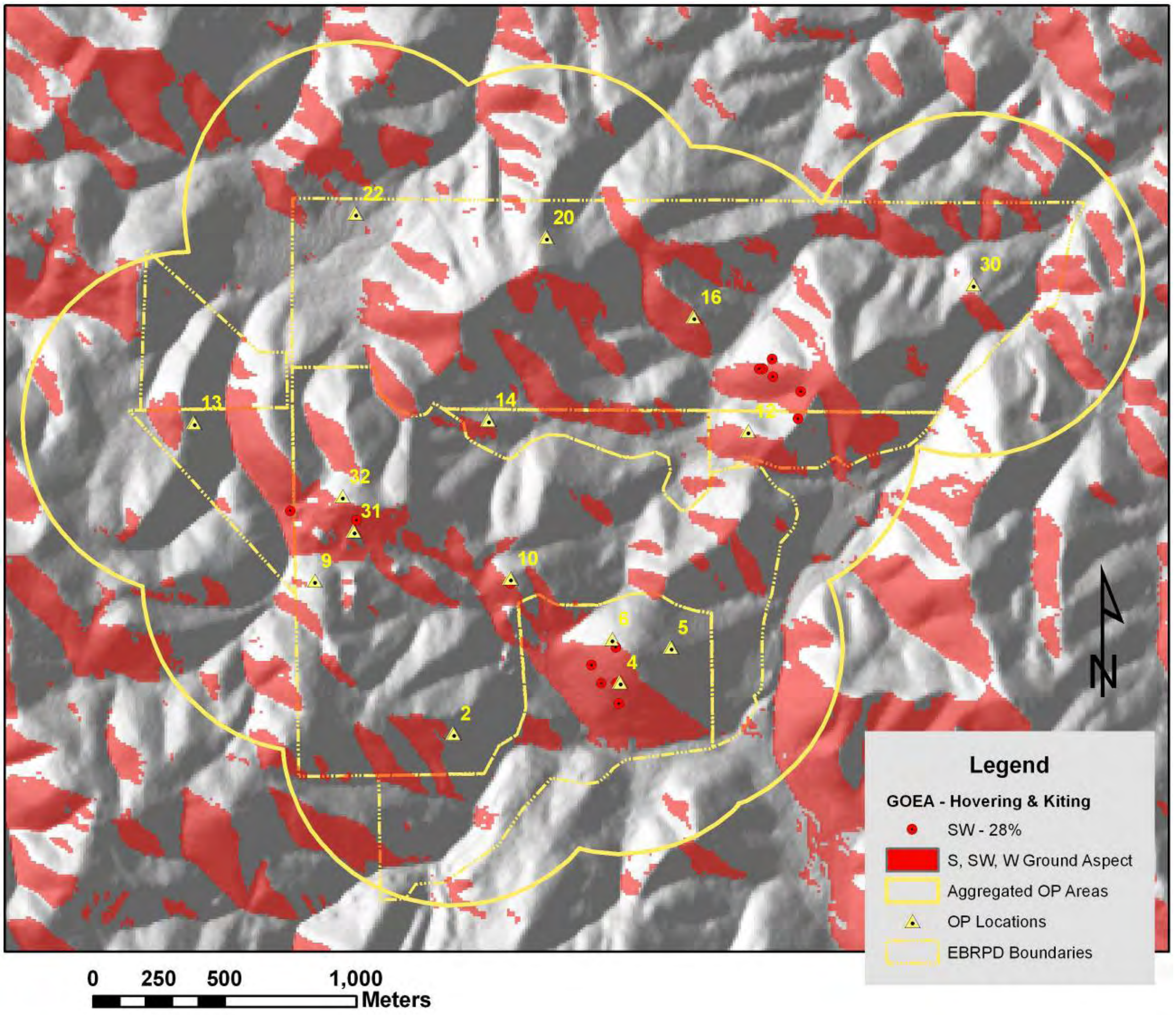

Figure 55. Locations of golden eagle hovering into south, southwest, and west winds. Almost all eagle hovering flights into southwest-trending winds were also on slopes facing the wind at the time the observation was recorded, and otherwise were on the upper boundary of the southwest-facing slope.

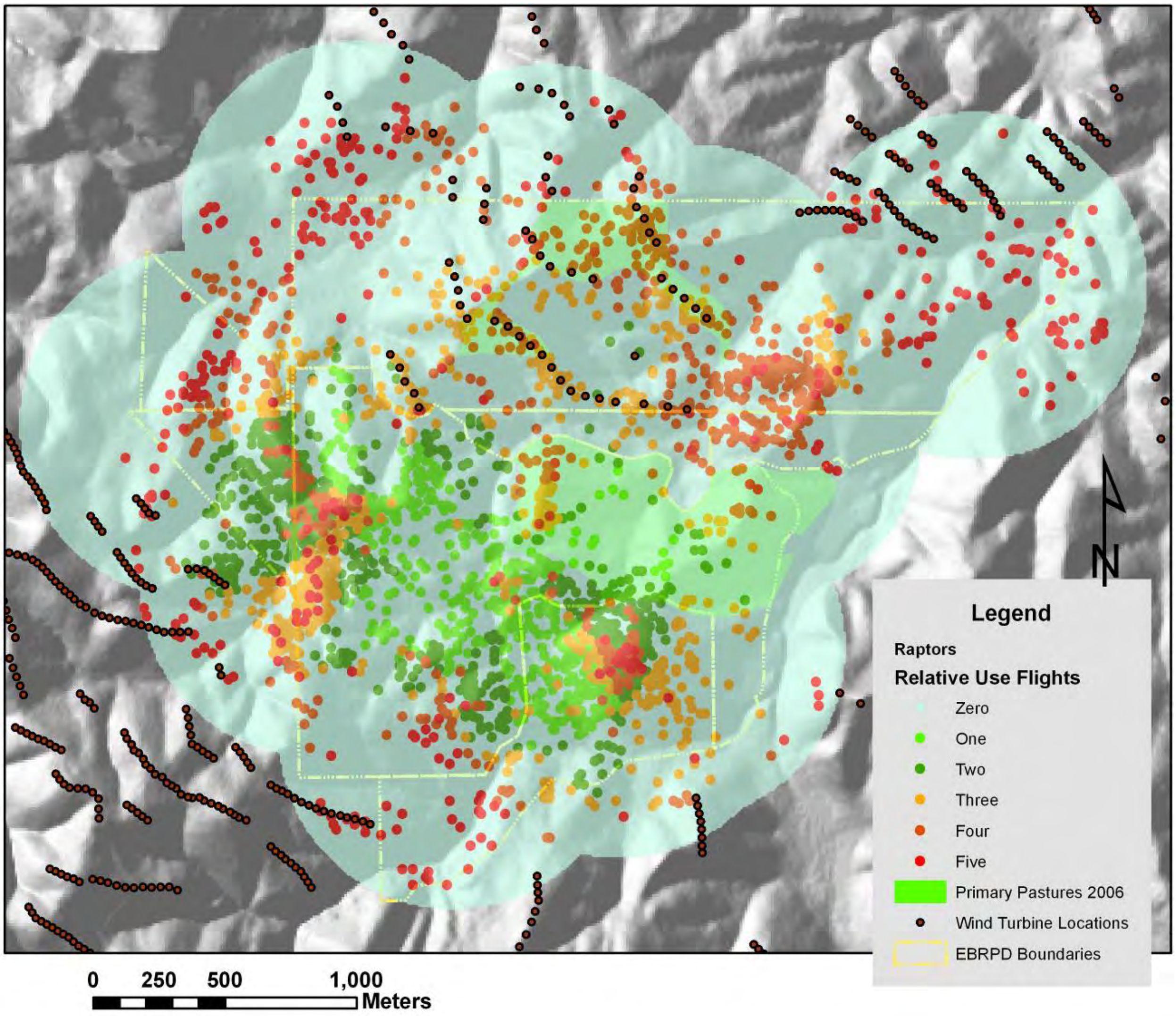

Figure 56. Raptor flight observations per OP from which the outer 650-m survey radius could overlap the site. Observation rates, or flights/OP, were grouped in the map: one = 0.13 to 0.20, two = 0.25, three = 0.29 to 0.40, four = 0.50 to 0.60, five = 0.67 to 0.80, and six = 1.00 to 2.00.

5.2.5. Raptor Response to Prey Distribution

The frequency of golden eagle flights decreased as the number of ground squirrel complexes increased within 50 m of the grid cell (Figure 57). On average, golden eagles flew over grid cells with the highest abundance of associated ground squirrel complexes 25% less frequently than they flew over grid cells where no ground squirrel complexes occurred within 50 m. Red-tailed hawks also flew more often over portions of the landscape without ground squirrel complexes, and their flight frequencies related inversely to the density of ground squirrel complexes (Figure 57). The inverse relationship between red-tailed hawk hovering and kiting flights and the density of ground squirrel complexes was even more precise, with an r^2 value of 0.97 (Figure 58). At densities of eight or more ground squirrel complexes within 50 m, red-tailed hawks were not recorded hovering or kiting at all. Red-tailed hawk perching also declined with increasing density of ground squirrel complexes (Figure 58). Similar to red-tailed hawks, the frequency of American kestrel hovering and kiting flights related inversely to ground squirrel density, but so did common raven flights (Figure 59). (The relationship between common raven flight frequencies and ground squirrel density was identified as a quasi control on the patterns observed for raptors, because common ravens do not normally forage for ground squirrels.) Overall, raptor flights decreased in frequency with increasing density of ground squirrel complexes (Figure 60).

Not surprisingly, the frequency of golden eagle flights did not relate to the density of pocket gopher burrow systems. However, the frequency of red-tailed hawk flights was a power function of pocket gopher density (Figure 61). Red-tailed hawk hovering and kiting flights increased weakly with pocket gopher burrow density (Figure 61), but perching frequency increased exponentially with pocket gopher burrow density (Figure 62). American kestrel flight frequency generally decreased with increasing pocket gopher burrow system density (Figure 62), as did common raven flight frequency (Figure 63). Overall, the frequency of raptor flights was a power function of the density of pocket gopher burrow systems within 50 m of the grid cell (Figure 63).

The mean density of pocket gopher burrow systems within 50 m of each DEM grid cell declined with increasing density of ground squirrel complexes until about seven to nine complexes within 50 m, and then increased with increasing density of ground squirrel complexes (Figure 64).

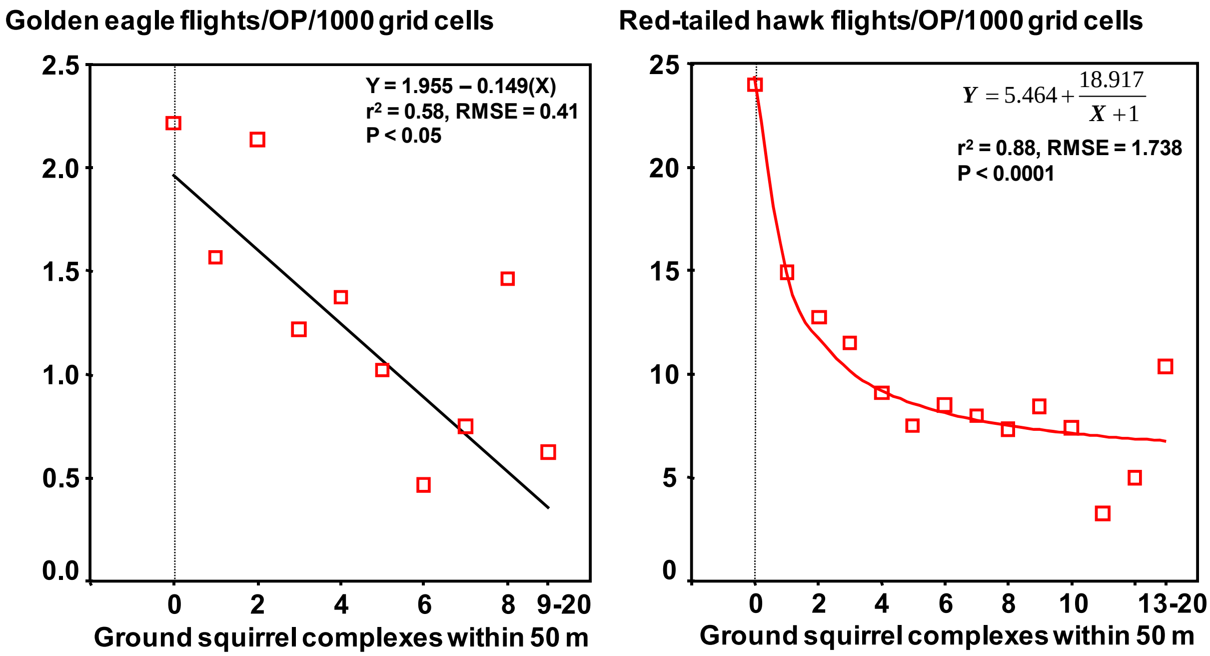

Figure 57. The frequency of flights of golden eagle (left) and red-tailed hawks (right) declined among grid cells as the number of ground squirrel complexes within 50 m of the grid cell increased.

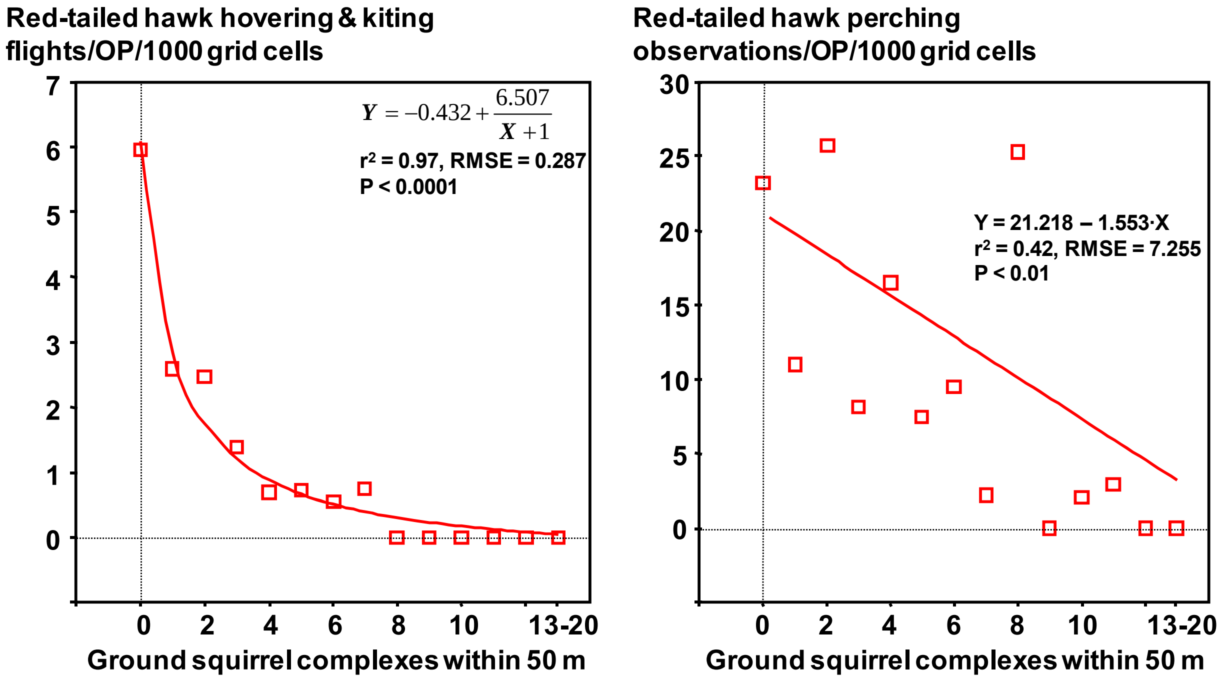

Figure 58. The frequency of red-tailed hawk hovering and kiting flights related inversely to the number of ground squirrel complexes within 50 m of the grid cell.

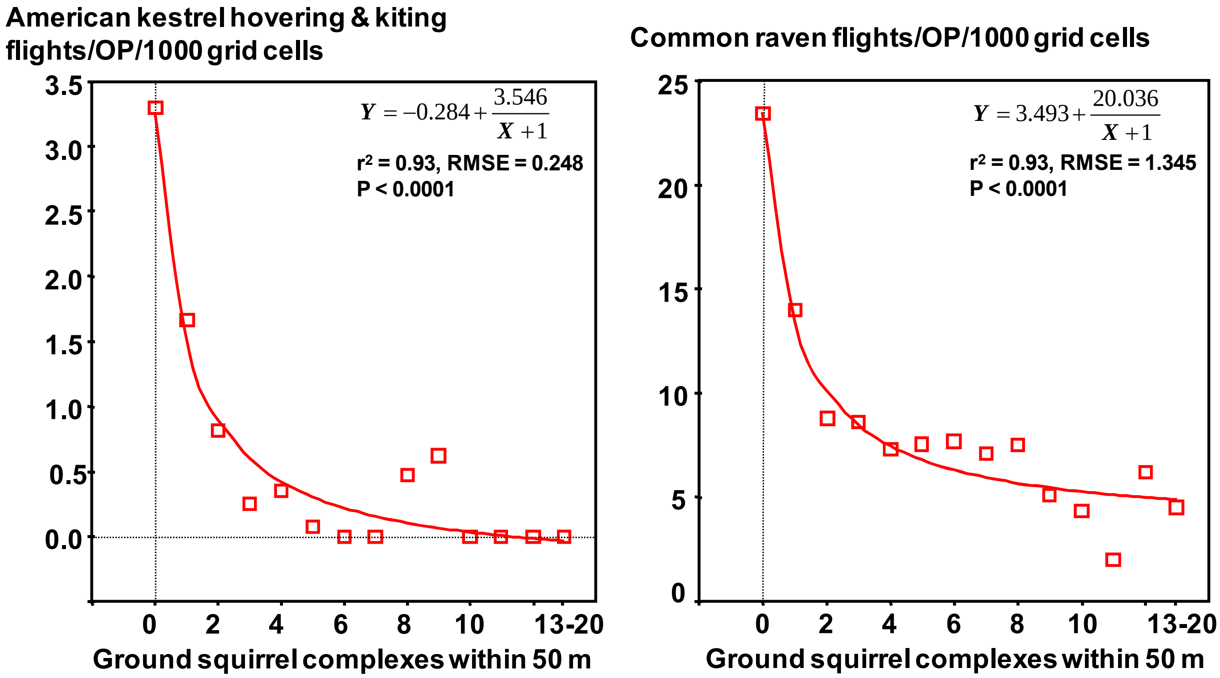

Figure 59. The frequency of American kestrel hovering and kiting flights (left) and common raven flights (right) related inversely to the number of ground squirrel complexes within 50 m of the grid cell.

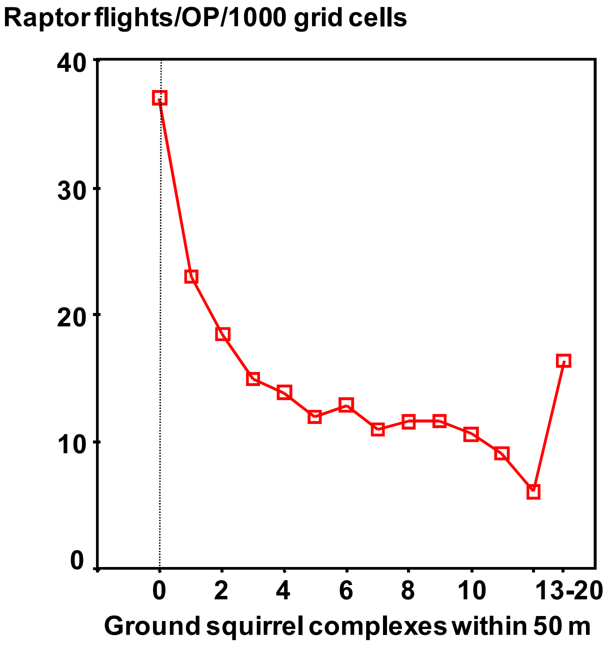

Figure 60. The frequency of raptor flights declined with increasing number of ground squirrel complexes within 50 m of the grid cell, but increased at 13–20 complexes.

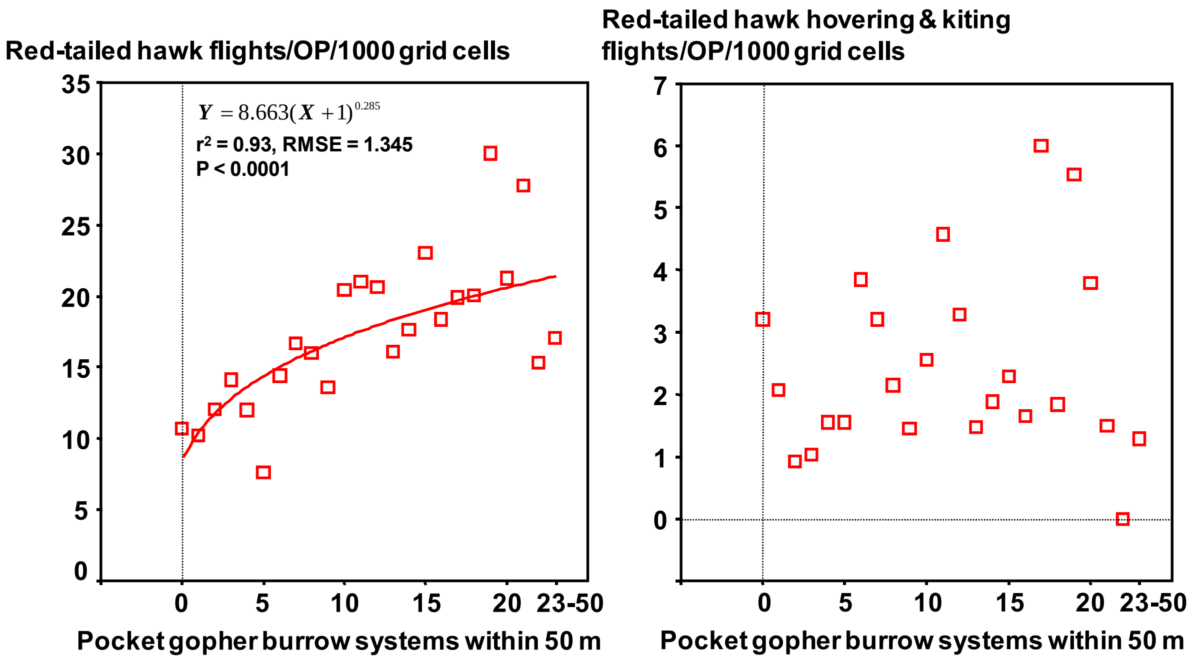

Figure 61. The frequency of red-tailed hawk flights was a power function of the number of pocket gopher burrow systems within 50 m of the grid cell (left), but the frequency of red-tailed hawk hovering and kiting flights increased weakly with the number of pocket gopher burrow systems within 50 m of the grid cell (right).

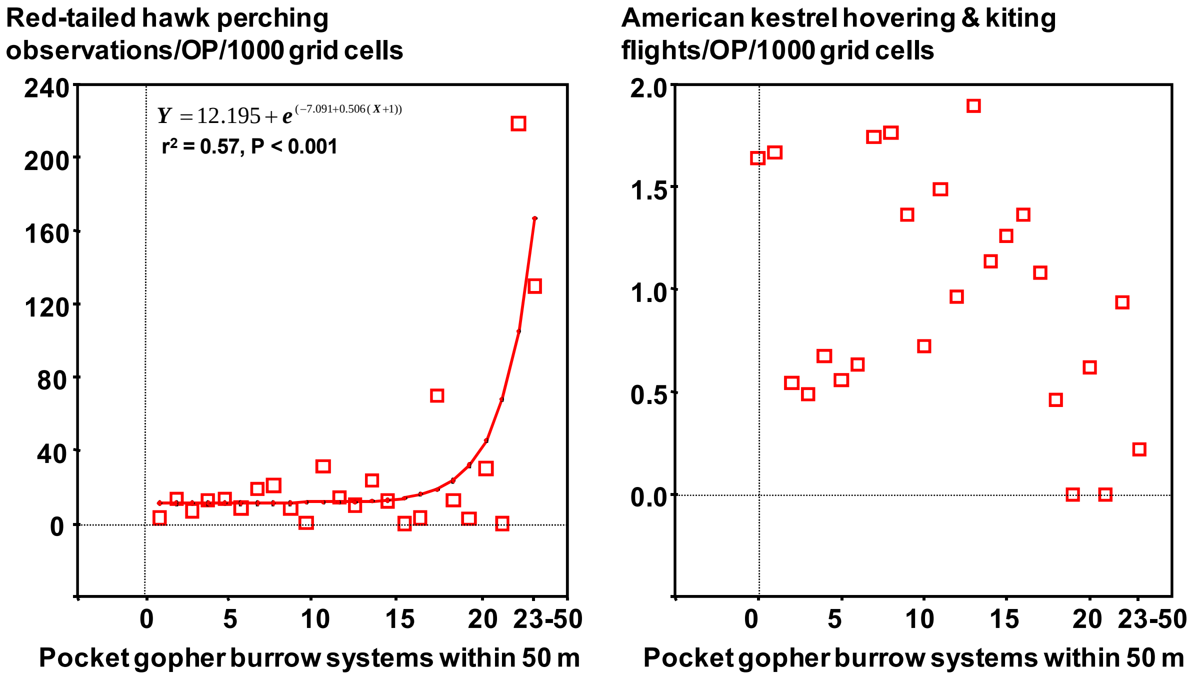

Figure 62. At left, the frequency of red-tailed hawk perching observations was a nonlinear exponential function of the number of pocket gopher burrow systems within 50 m of the grid cell. At right, the frequency of American kestrel hovering and kiting flights declined with an increasing number of pocket gopher burrow systems within 50 m of the grid cells.

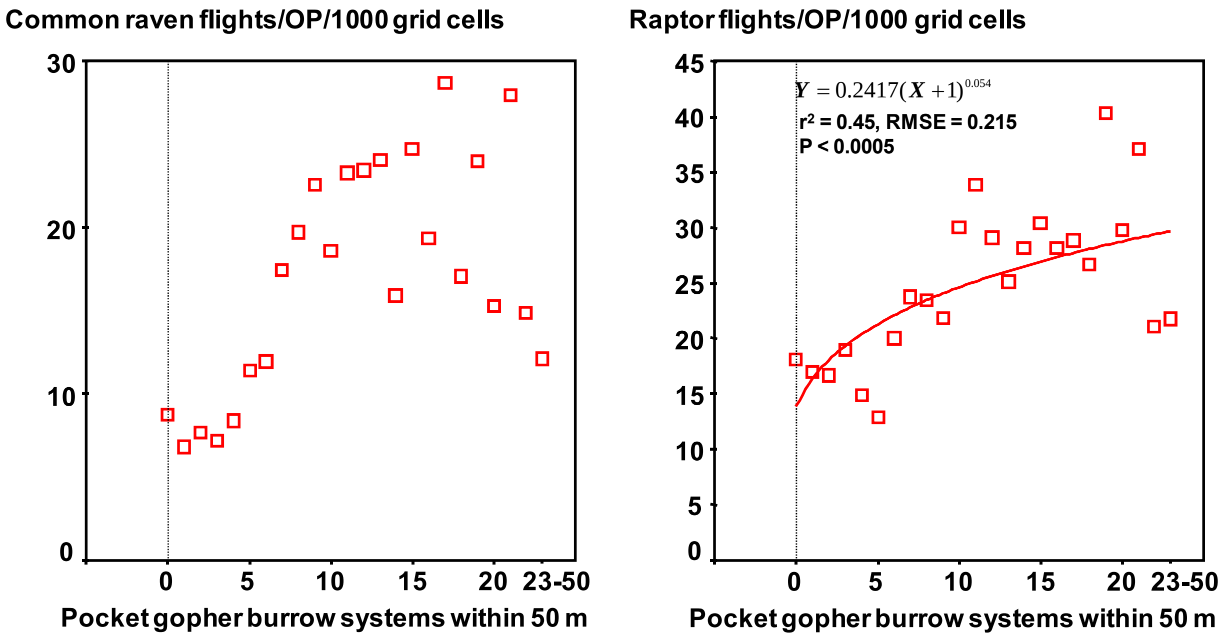

Figure 63. The frequency of common raven flights related positively to the number of pocket gopher burrow systems within 50 m of the grid cell (left), and the frequency of raptor flights increased as a power function (right).

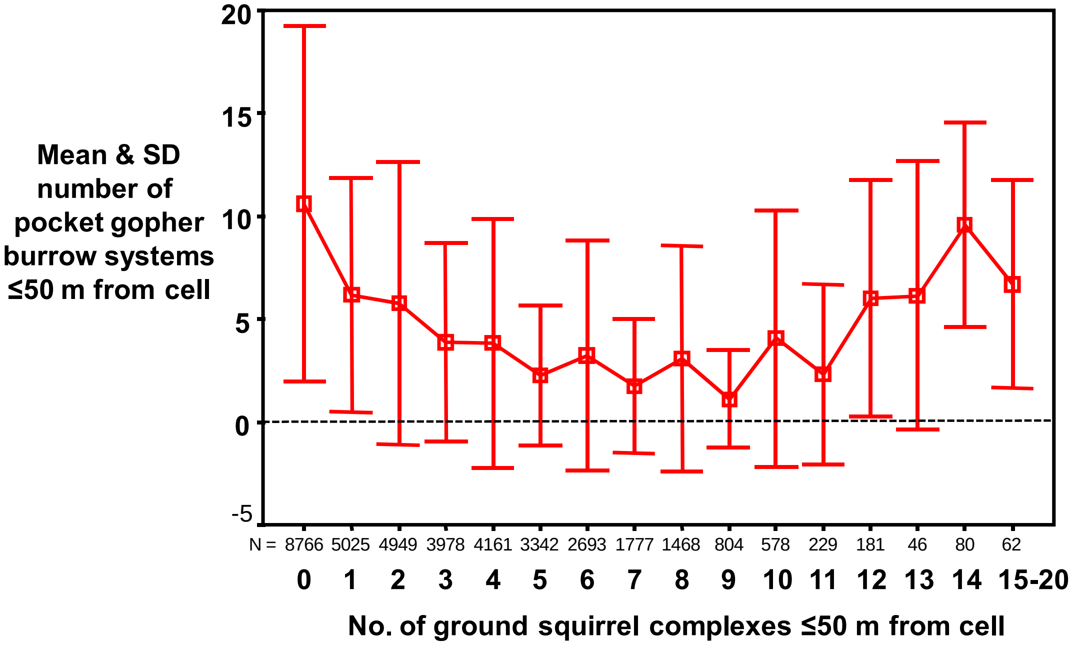

Figure 64. The number of pocket gopher burrow systems within 50 m of the grid cell declined with increasing numbers of ground squirrel complexes until intermediate numbers of complexes, and then increased with the number of ground squirrel complexes.

5.2.6. Response to Grazing Treatments

Raptor use of the grazing treatment monitoring plots (depicted in Figure 10) needed to be normalized by the sizes of the plots and the number of observation sessions when the observers could view the plots. Some plots could be viewed from only one OP, whereas others could be seen by three OPs. The number of raptor flight observations was therefore divided by the hectares of the plot and the number of sessions the plot was observed during July–September, and the changes in these ratios between 2006 and 2007 were related to changes in burrow system density of their prey species (Figure 65).

Raptors shifted their use of the plots, but with no significant relationships to shifts in the numbers of rodent burrow systems (Figure 65). For example, in plots that were grazed in both years, golden eagle flights clearly increased in one plot that experienced an increase in ground squirrel burrow complexes, but then also decreased in plots where there was no change in ground squirrel density (Figure 65). Similarly, in two plots that experienced no change and an increase in density of ground squirrel burrow complexes, respectively, there was no change in frequency of golden eagle flight observations. Similar contradictory patterns emerged for comparisons between treatment plots of frequency of red-tailed hawk flight observations and ground squirrel or pocket gopher burrow densities, although in most cases there was a trend of decreasing red-tailed hawk flight observations irrespective of grazing treatment (Figure 65). However, sample sizes were small (Appendix A) because observations of raptor numbers had to be limited to the months of July, August, and September to make direct comparisons between years. Monitoring had begun in mid-June 2006 and ended at the end of September 2007, so these months were the only ones that overlapped in field observations between years.

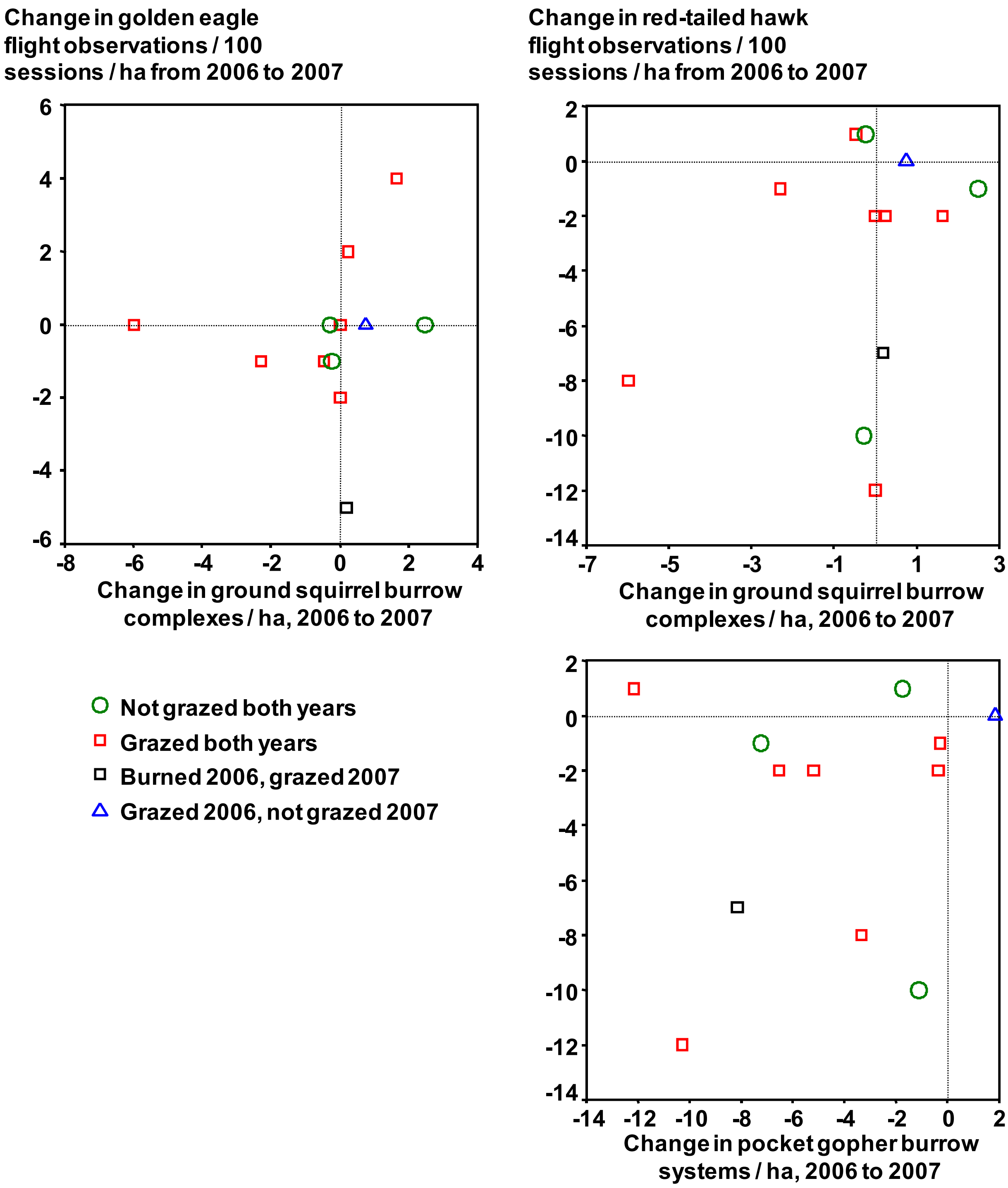

Figure 65. Shifts in golden eagle flights in response to shifts in ground squirrel complexes between 2006 and 2007 (left), and shifts in red-tailed hawk flights in response to shifts in ground squirrel complexes (top right) and pocket gopher burrow systems (bottom right).

5.3. Discussion

This behavioral observation study has advanced understanding of how raptors use the APWRA, thanks in part to adopting the suggestions highlighted in previous research efforts in the APWRA. The study benefitted from various improvements to the research approach:

- Geo-referenced ortho-photos enabled the observers to record bird positions more accurately.
- The observers recorded wind speed and wind direction at 15-min intervals, rather than once at the start of the session as was protocol during the most recent study. As a result, the raptor observations could be related more resolutely to quickly changing environmental conditions.
- Behavioral observation sessions lasted for an hour, rather than the 30 minutes, 20 minutes, or 10 minutes used in past studies. An hour allowed raptors to habituate to the human observers, thereby minimizing the avoidance bias that appears to affect the first 20 to 25 minutes of a session.
- Finally, this study collected many more observations per unit area than was achieved in past efforts.

5.3.1. Population Size

Overall, raptors were observed in this study at rates similar to those reported previously over the last decade in the APWRA, with some differences. Abundances of golden eagles may have declined, red-tailed hawks may have increased, and American kestrel and burrowing owl may have remained the same. While abundance in this case reflects use of the study site and may not be indicative of regional population trends, the decrease in golden eagle abundances by nearly half compared to the period 1998–2000 (Smallwood and Thelander 2005) may be of concern because Hunt and Hunt (2006) have concluded that the APWRA kills more eagles than can be produced by their local study population. Although this study site was relatively close to previous study sites in the APWRA, it differed by encompassing a relatively large area without wind turbines, as well as more trees and cave structures that offered nesting opportunities for many of the species observed.

5.3.2. Seasonality

The greater density of observations per unit area in this study also enabled the clear recognition of previously vague patterns, such as the season and time of day particular species peaked in abundance. For example, for the first time this study identified two peaks in red-tailed hawk abundance: early spring (February and March) and late fall (November). Late fall is when migrating red-tailed hawks move from coastal migration routes through low mountain passes, such as the Altamont Pass, into the Great Central Valley. Early spring is when these same red-tailed hawks move out of the Valley and back toward the coast en route to nesting areas. These peak periods likely correspond with spikes in red-tailed hawk collisions in the APWRA. Golden eagle observations, on the other hand, peaked in August, September, and December. The former two months may correspond to local juvenile dispersal periods.

The data presented here support seasonal wind turbine shutdowns to reduce impacts to raptors during peak abundance periods. Some shutdowns might need to be shifted slightly to target a particular species' peak abundance.

5.3.3. Wind Speed, Time of Day

Activity levels of particular species were strongly tied to wind speed and time of day. Overall, observations of flying raptors peaked at wind speeds of 0.3 to 5.4 m/s. Golden eagle observations were high at nearly all wind speeds, and the numbers seen flying would increase throughout the day. Red-tailed hawks responded with flights as wind picked up, but then tailed off as wind speed increased. Their flight frequency peaked in the early afternoon. American kestrels increased their flight activity with increasing wind speed, but were seen flying most often during the late afternoon and early evening hours. Turkey vultures were more apt to fly in slower winds, but peaked in flight activity during the early afternoon. Prairie falcons were mostly observed flying in the early morning. It seems clear that each species exhibited relatively unique distributions of flights by wind speed and time of day. Therefore, coordinating wind turbine shutdowns by wind speed or time of day would likely help particular species to the detriment of others.

5.3.4. Orientation to Wind

Each species also exhibited unique suites of flight behaviors relative to their orientation to the wind. Kiting raptors were closer to the ground while orientated away from the wind or askance to the wind, whereas they were higher off the ground while kiting or hovering into the wind. In terms of risk of blade strike, hovering is thought to be one of the most dangerous modes of raptor flight (Smallwood and Thelander 2004, 2005). Both American kestrel and red-tailed hawk were the raptors observed most frequently hovering or kiting, and they hovered at the highest altitudes when facing the wind. Their preferred hovering heights would bring them into the rotor zone of the new-generation, taller wind turbines associated with repowering efforts. Changing orientation towards the wind resulted in rapid dynamic changes in flight behaviors. For example, American kestrels would most often be seen hovering into the wind, but turned askance to the wind they would switch to flying-through or gliding, and flying away from the wind they would more often soar, surf, or circle. Not surprisingly, northern harriers were most often observed contouring, no matter what their orientation to the wind, and turkey vultures were most often seen gliding or soaring.

5.3.5. Slope Attributes

Some of the strongest patterns observed in the behavior data were how raptor locations related to slope attributes. For nearly every slope attribute measured, each species of raptor and common raven differed significantly between the average value attributed to its position and the average value across the study area. The flights of these birds, as well as their perching, were at locations in the study area that were far from average in terms of their slope conditions. The strongest pattern was the use of ridge crests and hill peaks of slopes facing south and southwest, which were principal wind directions in the study area. Raptors used these relatively small areas for most of their foraging flights, such as hovering and kiting. Red-tailed hawks used the slopes and winds in the manners summarized by Hoover and Morrison (2005), more often soaring in slow winds and kiting in strong winds, especially on slopes that faced the wind (usually southwest) and that were slightly taller than surrounding hills and ridges. Golden eagles were often recorded gliding or contouring over these locations, relying on the declivity winds to power their flights and on surprise of prey items as they crested ridges and hills. American kestrels and prairie falcons situated most of their hovering or kiting flights into southwest winds over south-, southwest-, and west-facing slopes. The flight behaviors mapped in the DEM used here clearly show that the siting of wind turbines on the ridge crests of southwest-facing slopes in the APWRA represents the highest level of risk for blade-raptor strikes.

5.3.6. Response to Turbines

Pooling all raptor flight observations at <85 m above ground showed that raptors flew more frequently than expected within 25 m of turbines on the study area, indicating that flight behavior alone will continue to put raptors at risk of collision with the taller, next-generation wind turbines. In repowered wind farms these turbines typically reach maximum heights of 75 m to 90 m, with blade reach spanning 60 m from maximum height downward. However, these risks may vary depending on species. Based on comparing frequencies of flights at heights <85 m, golden eagles and red-tailed hawks would be more at risk, while American kestrels and northern harriers would be less at risk in a typical next-generation wind farm.

Why raptors flew within 25 m of wind turbines more frequently than expected may have more to do with slope and ridge characteristics where the turbines were located than with any inherent characteristics of the turbines themselves. Turbines are not located randomly in the landscape. Other locations where raptors were observed more frequently than expected included three major turbine-less hills with extensive west-, southwest-, and south-facing slopes, so it is possible the particular slopes, aspects and associated winds were more important in explaining raptor flight prevalence than the presence/absence of turbines.

In spite of the foregoing, compared to past behavior studies in the APWRA, raptor flights were much less aggregated around wind turbines. There could be several, nonexclusive explanations for this pattern. Wind turbines in the study area were adjacent to a relatively large area lacking wind turbines, including all of Vasco Caves Regional Preserve and some of the Souza parcel, so birds in the area could choose whether to use ridges and hills with or without wind turbines. Four of the largest hills in the study area received most of the flight activity from raptors and common ravens. Of these four hills, the hill receiving the least flight activity from raptors was the western hill on the Souza parcel, which supported wind turbines. Raptors thus appeared to "avoid" areas with wind turbines and to favor turbine free areas in the Vasco Caves parcel and in the southeastern portion of the Souza parcel. The study area also differed from previous APWRA studies because rodent control had not been practiced for several years. As noted below, pocket gophers and California ground squirrels were more widely distributed, and this may have contributed to raptors spreading their flights out over the entire study area. Another difference was steeper terrain in the current study area, whereas previous studies included large areas of more gently rolling and low-elevation terrain. Finally, the trees and rock outcrops of Vasco Caves provided nesting habitat for several of the raptors species observed here. Thus, the apparent preference for turbine-free hills of Vasco Caves may have also been partly biased by nest proximity. All of these site-specific factors may have contributed to the decrease in aggregation of raptor flights around wind turbines compared to previous studies. It should be reiterated, however, that golden eagles and red-tailed hawks still flew within 25 m of turbines at double the rate expected by chance.

5.3.7. Proximity to Mammalian Burrows

Unexpected patterns were identified between raptor flight frequency and the densities of fossorial mammals, as indicated by burrow systems. These patterns suggest that raptors do not normally forage for ground squirrels by flying directly over the ground squirrel burrow complexes for extended periods. This is a significant finding because researchers have repeatedly implicated ground squirrel abundance in the APWRA, as well as greater-than-average ground squirrel abundance near the wind turbines, as a principal factor underlying high wind turbine collision rates of golden eagle, red-tailed hawk and other large-bodied raptor species (Colson 1995; Hunt and Culp 1997; Alameda County 1998; Hunt 2002; Richard Curry Associates 1997; Kerlinger and Curry 2001), despite the early evidence to the contrary (Orloff and Flannery 1992). It is significant also because range management practices have been shifting in the study area, from year-round cattle grazing to seasonal sheep grazing, and this might eventually shift the distribution and abundance of ground squirrels as well as favor pocket gophers (see Chapter 3).

The frequency of golden eagle flights decreased as the number of ground squirrel complexes increased within 50 m of the corresponding grid cell. This pattern suggests several alternative causes. One is that golden eagles select flight paths to avoid flying directly over areas occupied by ground squirrels, especially those areas with greater numbers of squirrel complexes. This flight path strategy might capitalize on a golden eagle's ability to identify vulnerable prey items from afar and plan a stealthy approach. Another explanation could be that pioneering ground squirrels are prevented from establishing where eagles fly most often because the colonists are routinely killed by eagles. A third alternative cause is that both golden eagle flight paths and ground squirrel complexes are responding to another factor, such as wind speed. It may be, for example, that eagle flight paths capitalize on stronger winds nearer the tops of slopes, where ground squirrels prefer not to live because the noise of the stronger winds interferes with the squirrels' auditory detection of approaching predators. Rabin et al. (2005) found that ground squirrels residing near wind turbines relied more on visual detection of predators because they could not rely on alarm calls from conspecifics due to the noise made by wind turbines, and were thus quicker to escape to their burrows when alarmed than squirrels relying on sound cues. An analogous situation may hold for ridge crests without wind turbines. During windy conditions, it is much noisier under the reddish zones depicted in Figure 66, as compared to lower down on the slopes where ground squirrel complexes are common.

Figure 66. Ridge crests of slopes facing south and southwest, above which flight zones (reddish-maroon color) of golden eagles, red-tailed hawks, American kestrels, prairie falcons, and other diurnal raptors were most commonly observed. The ground squirrel burrow complexes were lower on the slopes (bluish polygons), and can be seen from afar due to their patches of herbaceous growth. The red circles typify burrowing owl burrows in the study area. This view is to the northeast, and shows the large hill on the east side of the Souza parcel. Photo by K. S. Smallwood.

The hypothesis that the interaction between winds and slopes affects both the distribution of squirrels and raptor flight locations can also explain some of the patterns observed between the frequency of raptor flights and the density of pocket gopher burrow systems. Pocket gophers likely are not as affected by wind noise as are ground squirrels because the threat of predation is less due to their more subterranean existence, so establishing burrow systems on the upper reaches of a south- or southwest-facing slope might be equivalent in predation risk to establishing burrow systems elsewhere. It may be that raptors hovering or kiting over ridge crests of south- or southwest-facing slopes can just as well hunt for pocket gophers under their positions while also scanning for ground squirrels, pocket gophers, and other prey farther down the slope or even across the valley bottom to the opposite slope.

Common ravens, which do not regularly hunt ground squirrels, and raptors, which do, both showed similar patterns of flight activity in the proximity of burrow complexes. This finding points to the interaction of terrain and wind as the likely driver of raptor flight patterns as well as ground squirrel distribution. Eliminating ground squirrels from a particular hillside will unlikely shift the locations of raptor flights, as illustrated, for example, by the pile-up of raptors hovering or kiting on the upper reaches of the south- and southwest-facing slopes of a large hill on the east side of Vasco Caves. This hill had no wind turbines and its slopes supported no ground squirrels, but it still attracted foraging raptors. Although relative, the rate of raptor flight observations was higher on this turbine-free hill than on the large turbine-studded hill in the west side of the Souza parcel. Since this difference in raptor use cannot be explained by ground squirrel presence or lack thereof, this finding suggests that the mere presence of turbines may inhibit use of the immediate slopes by raptors under some conditions. This finding may suggest one way to potentially reduce frequency of raptor and wind turbine interactions. Namely, by providing in a wind farm a mosaic of hill crests and ridges with and without wind turbines, raptors may choose to fly more frequently over the turbine-free hill tops and thereby reduce the risk of possible blade strikes.

Based on past research, it is not surprising that raptor flight locations did not correspond proportionally with the spatial distribution of ground squirrel density. For example, Merriman et al. (2007) compared raptor activity between plots with and without black-tailed prairie dog (*Cynomys ludovicianus*) colonies following prairie dog eradication in half the plots in New Mexico and Texas. They found no difference in red-tailed hawk use between plots with and without prairie dogs, whereas northern harrier and ferruginous hawk were more abundant in plots occupied by prairie dogs, and American kestrels and Swainson's hawks were more abundant in plots without prairie dogs.

Relating raptor flight patterns to distribution of ground squirrel complexes in the APWRA also needs to be put into the context of scale. In the past, widespread control of ground squirrels through poisoning has been practiced and advocated, based on the fact that golden eagle mortality from blade strikes was thought to increase in areas where no squirrel control was practiced (Hunt 2002). However, alternative analyses have suggested that raptor mortality actually increased in areas of squirrel control due to clustering of surviving squirrels around structures, including wind turbines (Smallwood and Thelander 2004, 2005). Raptor flight patterns observed here suggest that raptors are keying in on landscape attributes for initiating or conducting foraging flights relatively independent of the presence or absence of ground squirrel burrow complexes in the immediate vicinity of the foraging location, especially if burrow complexes are more uniformly distributed in the landscape as opposed to being clustered.

5.3.8. Grazing Effects

The effect of grazing treatments on raptor location was difficult to detect for several reasons. First, as described in Chapter 2, the alternating wet and dry years created an extreme variation in grass growth that swamped any effects due to grazing intensity. This, in turn, constrained the study's ability to detect a treatment effect on either fossorial mammal burrow distribution or raptor flight behavior. Second, the short duration of the study yielded only three months in the late summer in which to make between-year comparisons. The raptor observations recorded over these three months were too few to measure significant responses in raptor flight activity to changes in the density of fossorial mammal burrow systems. Also, the study lacked sufficient replication of non-grazed plots and only one small area was transitioned from grazing to non-grazing between years. Furthermore, the non-grazed Vasco plot happened to be in relatively low terrain with minimal south- and southwest-facing slopes. As indicated above, this type of topography in the APWRA is less attractive to raptors for conducting foraging flights, regardless of grazing status.

However, there was no question that pocket gopher abundance was much greater in the Vasco Caves parcel, while ground squirrels were more abundant in the Souza parcel. These differences were likely due to differences in grazing management over the past five years. If this was the case, then more time is needed to record the responses of fossorial mammals to grazing treatments. The authors predict that with continued seasonal sheep grazing under controlled regimens, as opposed to cattle grazing year-round, the abundance of ground squirrels will eventually lessen on the Souza parcel, while pocket gopher density will increase as overall vegetation height and density increases.

6.0 Scavenger Removal

Vertebrate scavengers—from coyotes to birds—can carry off turbine-hit bird carcasses, thereby decreasing the fatality count in the study area. For this reason, bird/turbine studies include a "scavenger removal" factor to account for this source of bias in turbine-related mortality calculations.

In the interests of performing effective research and contributing to the scientific body of knowledge on avian mortality caused by wind turbines, the EBRPD changed its original study plan from the conventional scavenger removal trial to an approach not yet tried. During conventional scavenger removal trials, all trial carcasses are placed at once in the landscape and their rate of removal by scavengers is measured. However, placing all carcasses at once can run the risk of scavenger swamping (Smallwood 2007). When many carcasses are placed out all at once, effectively "swamping" the area with carrion, vertebrate scavengers cannot remove as many of the carcasses as if the carcasses were placed out individually or in smaller numbers, at a rate that reflects the natural deposition rate of wind turbine–caused avian and bat fatalities. Thus, in conventional removal trials, more bird carcasses are likely to remain unscavenged, biasing the scavenger removal factor in the mortality calculation.

Moreover, Smallwood (2007) identified additional potential sources of error and bias in conventional scavenger removal trials, which can introduce substantial uncertainty into the results and can compromise the usefulness of scavenger trials for adjusting mortality estimates. The EBRPD therefore sought to address some of the sources of error or bias by adopting a different approach to its scavenger removal trials. The EBRPD is not alone in its concern about the accuracy of conventional methods; for the same reasons, the Alameda County Scientific Review Committee has initiated a research program in the APWRA to quantify bias and reduce an additional source of error in scavenger removal trials.

The EBRPD designed its scavenger removal trials to accomplish the following objectives:

- Estimate the rates at which scavengers remove bird carcasses.
- Identify the species that scavenge bird carcasses to determine whether scavenger "swamping" may be real and substantial.
- Distribute the scavenger trial carcasses one at a time, rather than in large numbers all at once, to test the degree to which scavenger swamping might bias conventional trials.

The EBRPD decided to place bird carcasses at random locations in front of camera traps to photograph animals approaching and interacting with the carcasses. The advantages of using cameras were to: (1) identify animal species actually removing the carcasses and the suite of scavengers present in the study area; (2) record the exact time and date of carcass removal, which is important for estimating the mathematical function to fit the data; and (3) reduce the cost of the trial by reducing the number of trips to the study site to monitor the carcasses. To determine whether scavenger swamping (*sensu* Smallwood 2007) might serve as a source of bias, it was important to identify the species removing the carcasses. The camera traps also could reveal the direction the scavenger departed with the carcass, indicating where field personnel might travel to locate the remains of carcasses to ascertain to what parts of the environment carcasses are typically redeposited.

The disadvantage of relying on cameras was obtaining a smaller sample size than obtained by the conventional removal trials. Quantity of data was traded for quality of information, which EBRPD felt was acceptable because the Alameda County monitoring team had already performed the conventional scavenger removal trial by placing 81 avian carcasses all at once in the APWRA (their study area included this study's site, as well as to the north, south, east, and west of it).

6.1. Methods

Avian carcasses for the scavenger removal trials were obtained from a variety of sources. Some were obtained directly after collisions with automobiles, windows, and other man-made objects. Others were obtained from rehabilitation centers or public institutions. In such cases, if the birds had been euthanized under veterinarian directive at the rehab center, only those birds that had been euthanized by non-pharmacological means were used. All carcasses were stored frozen prior to use in the scavenger study. Carcasses were not restricted to the species under study for turbine collision risk (see Table 15).

Five infrared digital game cameras (Silent Image [Reconyx], Model RM30, Primos, www.silent-image.com) were deployed with volitionally placed bird carcasses in the scavenger removal trials. The cameras were triggered by animal intrusion into an infrared field, and each image taken was stamped with time, date, temperature, and moon phase. Time from triggering to image capture took less than 0.1 seconds. The cameras took a sequence of five pictures at approximately 1-s intervals upon each trigger event, with a camera recovery period of 1 s between trigger events. CF memory cards of 256 MB and 512 MB allowed for storage of up to 5,000 and 10,000 pictures per card, respectively. Images were evaluated using ACDSee image management software.

The camera/carcass combinations were deployed at randomly selected positions within the 60-m fatality search radius of the Souza parcel's wind turbines. Initial carcass site selection was accomplished by establishing 10-m digital elevation model (DEM) centroid points within the 60-m buffer around the turbine strings and then randomly selecting 20 points from the resulting GIS layer. Thereafter, carcass placement locations within turbine search areas were selected on a rotational basis to avoid swamping any one turbine area with carcasses and possibly habituating scavengers to repeated food sources.

Prior to its placement at a given location, the carcass was marked to differentiate it from fatality finds discovered during systematic fatality searches of the turbine area (Appendix F). Each carcass was marked by clipping a short section of the feather vane (approx. 1 cm) from the distal end of each rectrix (tail feather) and remige (primary, secondary, and tertiary feathers). In addition to feather clipping, a metal shoat ring or cage clip was attached to each leg at the tibiotarsus or tarsometatarsus and each wing at the humerus. Shoat rings were made of steel wire approximately 3 mm in diameter and came in three lengths: H1 or pig = 15 mm, H2 or shoat = 22 mm, H3 or hog = 25 mm. Cage clips were made of a strip of malleable metal 8 mm wide x 22 mm long. In general, cage clips were used on small birds and shoat rings on larger birds. However, after several weeks, the shoat rings were discontinued because they rusted quickly and may have had the potential to deter scavengers.

Personnel handling carcasses were instructed to wash hands before and after handing each carcass and were required to wear a fresh pair of latex gloves when handling and marking a carcass to avoid imparting human scent to the carcass. In addition, all tools used for marking carcasses were washed after use and rinsed with alcohol to eliminate human scent.

Once a carcass was volitionally placed, an angle-iron post for mounting the camera was positioned so that the camera faced north to minimize the impingement of direct sunlight on the camera's lens and infrared sensors. When the correct position was achieved the post was pounded into the ground. The camera was then armed and attached to the post. In general, camera setups were located 1–2 m from the carcass and < 1 m above the ground (Photo 12). The camera was usually tilted at a slight downward angle so that the carcass would be close to the center of the camera's field of view. The distance and bearing from the carcass to the closest wind turbine was recorded along with the GPS location of the carcass using a Trimble Geo XT unit or a Magellan Meridian Gold unit. Body orientation of the carcass was recorded in relation to north and a photograph was taken of the carcass with an object for scale. Effective vegetation height around the carcass was determined using a 25.4 cm x 40.6 cm board marked off in 2.54 cm x 2.54 cm alternating black and white squares.

Photo 12. Example of camera setup for scavenger study. Right foreground: camera attached to angle-iron post. Left foreground: volitionally placed carcass of A11 (western scrub jay).
Photo by K. S. Smallwood.

A camera was trained on the same avian carcass until the carcass was removed by a scavenger, or until 21 days after carcass placement, whichever came first. A total of five cameras was placed at any one time, each on a different carcass. The camera and carcass were checked every week, as were the remains of carcasses from which cameras had been removed. During the months of July and August the cameras were checked twice a week because the CF cards were often filled in three to four days. During this time the carcasses without cameras were only checked once a week.

During weekly or biweekly checks, information about each carcass was recorded, including time and date of the check and state of the carcass: whole (skeleton intact noting feather loss or soft-tissue loss); partial (skeletal elements missing, carcass dismembered); feather spot (only feathers remaining); or gone entirely. Condition of the flesh, if present, was noted using three designations: no decay, gooey, and dried. Rigor mortis was noted, including whether joints were stiff or loose. Soft-part colors (skin, bill, leg) were described as original color, faded, or fully bleached. Invertebrate scavenging was noted and where possible identified to family of invertebrate and life-stage present on the carcass. Presence or absence of vertebrate scavenging was recorded along with detailed descriptions of the carcass. For example, if a partial carcass was found, the location of each part and feather spot was noted and each piece was photographed and described. If the carcass was moved by a scavenger, its new location and orientation were recorded as distance and bearing to the nearest turbine. A GPS was used to record the coordinates of the new location in most instances. Appendix G describes all data fields used during carcass checks.

If a carcass had been removed by a scavenger from in front of the camera and its new location was not readily apparent, a thorough search was made within a 20-m radius of the original placement location followed by a visual scan within the 60-m search radius of the nearest turbine. If no feathers or other remains of the carcass were found, the carcass was designated as removed entirely.

The cameras' CF memory cards were changed weekly. The camera would be repositioned if the carcass had been moved out of its field of view. The camera would be removed from a scavenging trial location prior to 21 days if the carcass was removed entirely without a trace or if only a feather spot remained. Depending on the field crew and conditions, the intervals between some carcass/camera checks were longer.

For controls, remote cameras were set up without a carcass or they were set up in front of a square black rubber object approximately the size of a European starling. The process of setting up the cameras, including volitionally placing the rubber dummy, followed the above protocol for camera setup. By having the scavenger trial personnel behave as if they were setting up a real trial with an actual carcass, we sought to control for time spent at the site, human behavior and presence of vehicles as scavenger key-in points as well. Control camera trials were interspersed in time and space during the regular trials.

6.2. Results

6.2.1. Carcass Removal—Ultimate Fates

Of 64 avian carcasses that were placed before remote cameras, data were obtained on the fates of 63 carcasses (Table 15). In one instance, a killdeer was moved to another wind turbine within the search area and no subsequent information was acquired on whether trace evidence remained after the carcass was removed. For the 63 other carcasses, final scavenging outcomes

(Table 15) led to 36 carcasses (57.1%) being removed from the immediate turbine search area by scavengers without leaving a trace of evidence behind (e.g., feathers, skin, partial carcass). Of the remaining carcasses, 27 (42.9%) were removed from the immediate turbine search area with the scavenger leaving a trace of evidence at the original placement position. Trace of evidence varied from a partial carcass, to pieces of bone with feather spots, and to just feather spots (Figures 67A and 67B). The number of feathers in a feather spot varied from one to hundreds (Figure 67C). Appendix H illustrates a photo sequence for a red-tailed hawk from time of placement through several scavenging and decomposition events to its final outcome as an extensive feather spot that met the APWRA definition of a fatality 105 d after placement.

Of the 27 carcasses which were removed by scavengers but for which traces of evidence remained in front of the camera, 24 traces (38.1% of the original 63 carcasses) fit the APWRA definition of an avian fatality, i.e., a complex of 10 or more contour feathers or 5 rectrices or 2 remiges from the same wing or a piece of bone (Table 15). In three cases the evidence left behind did not meet the definition of a fatality attributed to a wind turbine. These were an Anna's hummingbird that left less than 10 contours and one rectrix as a feather spot and a mourning dove and rock pigeon that each left single feathers. The feather spots for the Anna's hummingbird and the mourning dove persisted to the end of the scavenging trials (Table 15).

Adding the carcasses that left a non-fatality trace (N = 3) to the carcasses that were removed without a trace (N = 36) indicates that 61.9% of all placed carcasses were removed entirely from the immediate turbine search area by scavengers and would not have qualified as a fatality if the search interval was greater than the time to final scavenging outcome and/or if the APWRA definition of an avian "fatality" had been applied to the trace evidence left at the end of the scavenging trial.

It is important to note that at the end of the entire scavenger trial the remains of all placed carcasses were removed, including, in a couple of cases, single feather traces. In addition, the entire fatality search area was searched for any remaining traces from placed carcasses that may have been moved by scavengers. The remains of a placed Cooper's hawk and sharp-shinned hawk were found within the greater fatality search area, while the remains of two red-tailed hawks and one great horned owl were found well outside of the fatality search area.

Table 15. Scavenger trial first and final carcass outcomes, where ID was the camera's letter and trial #, Species was the AOU acronym for species of bird carcass used, Days to first outcome was the number of days from initial placement to first time a scavenger moved or removed the carcass. A fatality was defined as any bone, 10 contour feathers, 2 primaries from the same wing, or 5 tail feathers. A carcass was "moved" if it was moved from its original location but remained within the search area of the same turbine. It was a "feather spot" if only feathers remained. It was "removed entirely" if removed without a trace. It was a "partial carcass" if some skeletal part of the carcass remained. It was "moved and partly scavenged" if the carcass was moved but remained within the search area of the same turbine and some flesh was consumed or part of the carcass was stripped.

ID	Species	Days to First Outcome	First Outcome	Days to Final Outcome	Final Outcome	Meets APWRA Fatality Definition
A1	American crow	34*	Partial carcass	34*	Partial carcass	Yes
A2	Barn owl	16	Moved & partly scavenged	?	Partial carcass	Yes
A3	Mourning dove	3.5*	Feather spot	3.5*	Feather spot	Yes
A4	Western gull	3.5*	Feather spot	3.5*	Feather spot	Yes
A5	California towhee	3.5*	Removed entirely	4*	Removed entirely	No
A6	Red-tailed hawk	11*	Feather spot	11*	Feather spot	Yes
A7	Anna's hummingbird	2*	Partial carcass	16*	Feather spot	No
A8	Lesser goldfinch	2.5*	Removed entirely	2.5*	Removed entirely	No
A9	Common moorhen	4	Removed entirely	4	Removed entirely	No
A10	Mourning dove	1.5	Removed entirely	1.5	Removed entirely	No
A11	Western scrub jay	3*	Removed entirely	3*	Removed entirely	No
A12	Cliff swallow	1*	Removed entirely	1*	Removed entirely	No
A13	Western tanager	1	Removed entirely	1	Removed entirely	No
B1	Red-tailed hawk	2	Moved	31	Other 1	Yes
B2	Green heron	8*	Moved & partly Scavenged	?	Partial carcass	Yes
B3	Lesser yellowlegs	0.06	Removed entirely	0.06	Removed entirely	No
B4	Evening grosbeak	0.02	Removed entirely	0.02	Removed entirely	No
B5	Ring-necked pheasant**	2*	Removed entirely	2*	Removed entirely	No
B6	Killdeer	11	Feather spot	11	Feather spot	Yes
B7	Mourning dove	3.5*	Removed entirely	3.5*	Removed entirely	No
B8	House finch	5*	Removed entirely	5*	Removed entirely	No

B9	Pygmy owl	2	Removed entirely	2	Removed entirely	No
B10	House sparrow	0.21	Removed entirely	0.21	Removed entirely	No
B11	Wilson’s warbler	2	Removed entirely	2	Removed entirely	No
B12	Purple martin	0.46	Removed entirely	0.46	Removed entirely	No
C1	White-crowned sparrow	0.33	Feather spot	0.33	Other 1	Yes
C2	Purple martin	16	Removed entirely	16	Removed entirely	No
C3	American goldfinch	5*	Removed entirely	5*	Removed entirely	No
C4	Killdeer	0.67	Moved	0.67	Other 2	Yes
C5	Black-headed grosbeak	16	Moved	16	Other 3	Yes
C6	Killdeer	?	?	?	Other 1	?
C7	Cooper’s hawk	2	Feather spot	2	Feather spot	Yes
C8	Purple martin	4*	Partial carcass	60.5*	Feather spot	Yes
C9	Western meadowlark	7	Removed entirely	7	Removed entirely	No
C10	Mourning dove	5.5*	Single feather	5.5*	Single feather	No
C11	Rock pigeon	0.5*	Single feather	0.5*	Single feather	No
C12	Virginia rail	1.25*	Removed entirely	1.25*	Removed entirely	No
C13	White-tailed kite	0.5	Other 4	0.5	Other 4	Yes
C14	Red-tailed hawk	4*	Removed entirely	4*	Removed entirely	No
C15	California quail**	0.75	Removed entirely	0.75	Removed entirely	No
D1	Great horned owl	2	Moved	25	Other 1	Yes
D10	Mourning dove	6	Feather spot	6	Feather spot	Yes
D11	California towhee	4*	Removed entirely	4*	Removed entirely	No
D12	Cooper’s hawk	0.54	Removed entirely	0.54	Removed entirely	No
D13	Common merganser**	0.88	Removed entirely	0.88	Removed entirely	No
D14	Western meadowlark	6	Feather spot	6	Feather spot	Yes
D2	Western tanager	12*	Removed entirely	12*	Removed entirely	No
D3	Barn owl	16*	Moved	?	Feather spot	Yes
D4	Sharp-shinned hawk	0.02	Feather spot	0.02	Feather spot	Yes
D5	Barn swallow	0.02	Removed entirely	0.02	Removed entirely	No
D6	White-throated swift	4*	Moved	25*	Removed entirely	No

D7	Mourning dove	4	Feather spot	4	Feather spot	Yes
D8	California towhee	5*	Feather spot	5*	Feather spot	Yes
D9	Red-tailed hawk	3.5*	Removed entirely	3.5*	Removed entirely	No
E1	Cooper's hawk	2	Moved	?	Partial carcass	Yes
E10	White-throated swift	6	Removed entirely	6	Removed entirely	No
E2	Red-tailed hawk	1	Moved & partly Scavenged	46*	Partial carcass	Yes
E3	American robin	11*	Removed entirely	11*	Removed entirely	No
E4	Lesser goldfinch	4	Removed entirely	4	Removed entirely	No
E5	Bewick's wren	2	Removed entirely	2	Removed entirely	No
E6	Cooper's hawk	1.5*	Removed entirely	1.5*	Removed entirely	No
E7	Great horned owl	0.33	Feather spot	0.33	Feather spot	Yes
E8	House finch	1	Removed entirely	1	Removed entirely	No
E9	Barn owl	0.67	Removed entirely	0.67	Removed entirely	No

** Carcass placed was that of a chick.
* Number of days was approximated from the middle of a range of days.
? Unknown
Other 1: Feather spot that persisted for an unknown amount of time
Other 2: Feather spot in original location. Partial carcass moved to search radius of another turbine.

Other 3: Feather spot in original location. Carcass moved outside search radius of turbine.
Other 4: Feather spot in original location. Partial carcass outside search radius of turbine.

Figure 67. Examples of scavenging outcomes resulting in trace evidence. Photos by S. A. Snyder.

Figure 67A. Feather spot with bones of barn owl carcass A2

Figure 67B. Partial carcass of green heron, B2, after unknown scavenger removed the head, stripped the legs, and moved the remains shown to another location within the search radius of the same turbine

Figure 67C. Feather spot of mourning dove carcass, A3, after unknown scavenger removed the carcass within a week of placement. Hundreds of feathers comprised this feather spot.

6.2.2. Carcass Removal—Time to Event and Persistence

Mean time to first outcome of a scavenging event, whether the scavenger left a trace of evidence behind or not, was 4.45 d (SD = 5.69, N = 63), while mean time to final outcome of all scavenging events was 5.88 d (SD = 9.18, N = 63) (Table 15). Mean time to a scavenging event in which the scavenger did not leave any evidence behind was 4.16 d (SD = 5.21, N = 36). Across all size and class categories of carcasses (small birds, medium-large birds, pigeons-doves, small raptors, large raptors), within 24 h of placement, 23.8% (15 of 63) experienced a first outcome of a scavenging event and 16% (10 of 63) were removed without a trace (Table 16). Similarly, within 7 days of placement, 84% (53 of 63) of the carcasses experienced a first outcome of a scavenging event and 54% (34 of 63) of all placed carcasses were removed without a trace (Table 16). Only one carcass, an American crow, did not have a first outcome of a scavenging event until after day 30 (Table 15). It should be noted that these data are based on placing carcasses at intervals throughout the entire 290 days of the scavenging study, and not placing them all at once.

There was no significant relationship between average weight of a carcass and time in days to the first outcome of a scavenging event. This would suggest that the overall carcass size, independent of species, had no effect on the speed at which scavengers detected carcasses. However, overall carcass size and category did appear to affect whether a carcass was removed without a trace of evidence left behind, with small birds showing the greatest effect: 16 of 19 small-bodied carcasses (84.2%) were removed without a trace of evidence (see Table 16). The proportion of carcasses leaving no trace evidence behind was lower for all other size and class categories: medium-large birds (11 of 20 carcasses; 53%), pigeons-doves (4 of 7 carcasses; 57%), small raptors (1 of 2 carcasses; 50%) and medium-large raptors (5 of 15 carcasses: 33%).

Adding the carcasses removed after the first day, second day, third day, and so on until the 21st day enabled the development of new models of carcass removal rates. The previous models were based on large numbers of carcasses placed all at once at each trial location, whereas this study placed single carcasses at random locations with longer time intervals between placements. Pooling the removal times produced the rates shown in Figure 68. Assuming a steady state of carcass deposition, the following equation was used to estimate the accumulated percentage of carcasses remaining after various search intervals:

$$R_C = \frac{\sum_{i=1}^{I} R_i}{I},$$

where R_C was the cumulative carcasses remaining, R_i was the percent of carcasses remaining by the *i*th day following the initiation of a scavenger removal trial, and *I* was the duration of a scavenger removal trial corresponding with the fatality search interval used during a mortality monitoring effort (Smallwood 2007). Thus, the expected percentage of bird carcasses remaining by the next fatality search should be R_C corresponding with the fatality search interval, *I*. These frequencies are shown in Figure 69 and Appendix I.

Table 16. Time to first outcome of carcass separated by class or size and by whether the outcome left evidence of a fatality

		Time Period to First Outcome (Days)										
		< 1		1–7		8–14		15–30		> 30		
Class/Size	**Size (g)**	**NT***	**T****	**NT**	**T**	**NT**	**T**	**NT**	**T**	**NT**	**T**	**Total**
Small birds	4–35	4	1	11	2	1	0	0	0	0	0	19
Medium/large birds	44–1000	3	1	6	4	1	2	1	1	0	1	20
Dove-pigeon	120–270	1	0	3	3	0	0	0	0	0	0	7
Small raptor	70–140	0	1	1	0	0	0	0	0	0	0	2
Medium/large raptor	340–1400	2	2	3	5	0	1	0	2	0	0	15
Subtotals		10	5	24	14	2	3	1	3	0	1	
Totals		15		38		5		4		1		63

* NT = No trace. Remains left behind by the carcass did not meet the APWRA fatality definition of any bone, 10 contour feathers, 2 primaries from the same wing, or 5 tail feathers.

** T = Trace. Remains left behind by carcass met the fatality definition.

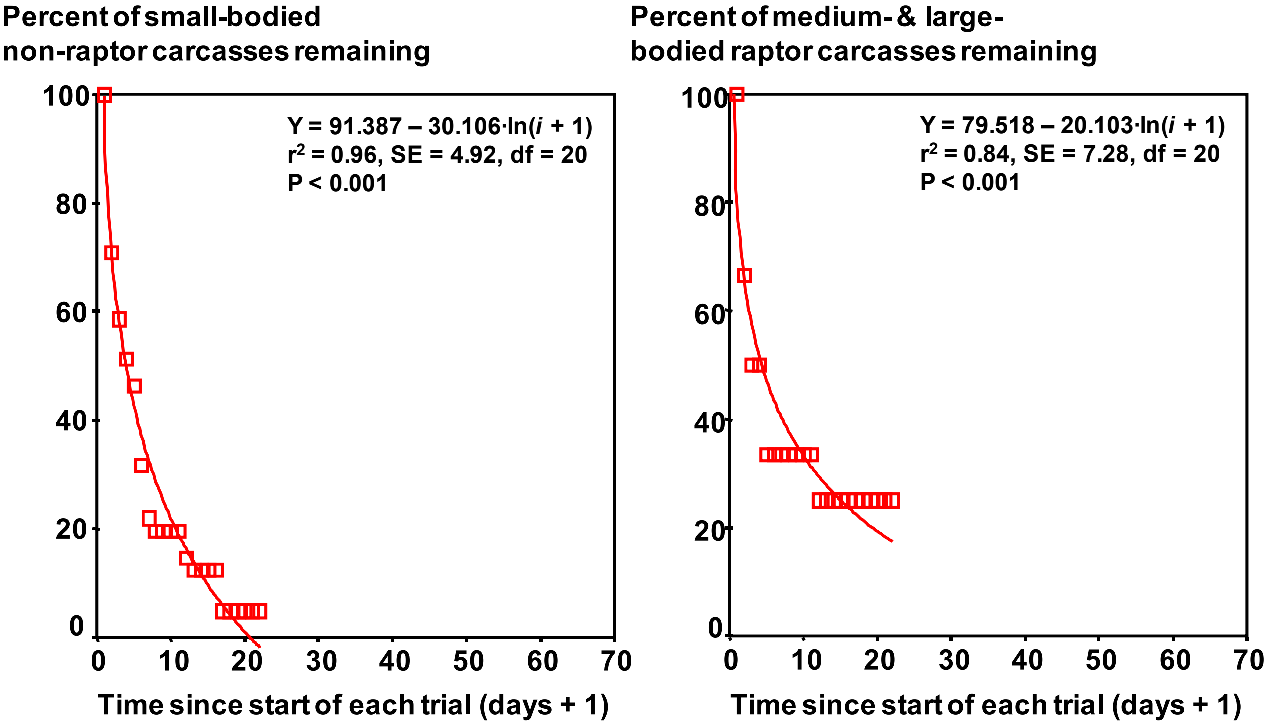

Figure 68. The percent of carcasses of small-bodied non-raptor birds (left) and medium- and large-bodied raptors (right) remaining as a logistic function of the number of days since the carcass was placed

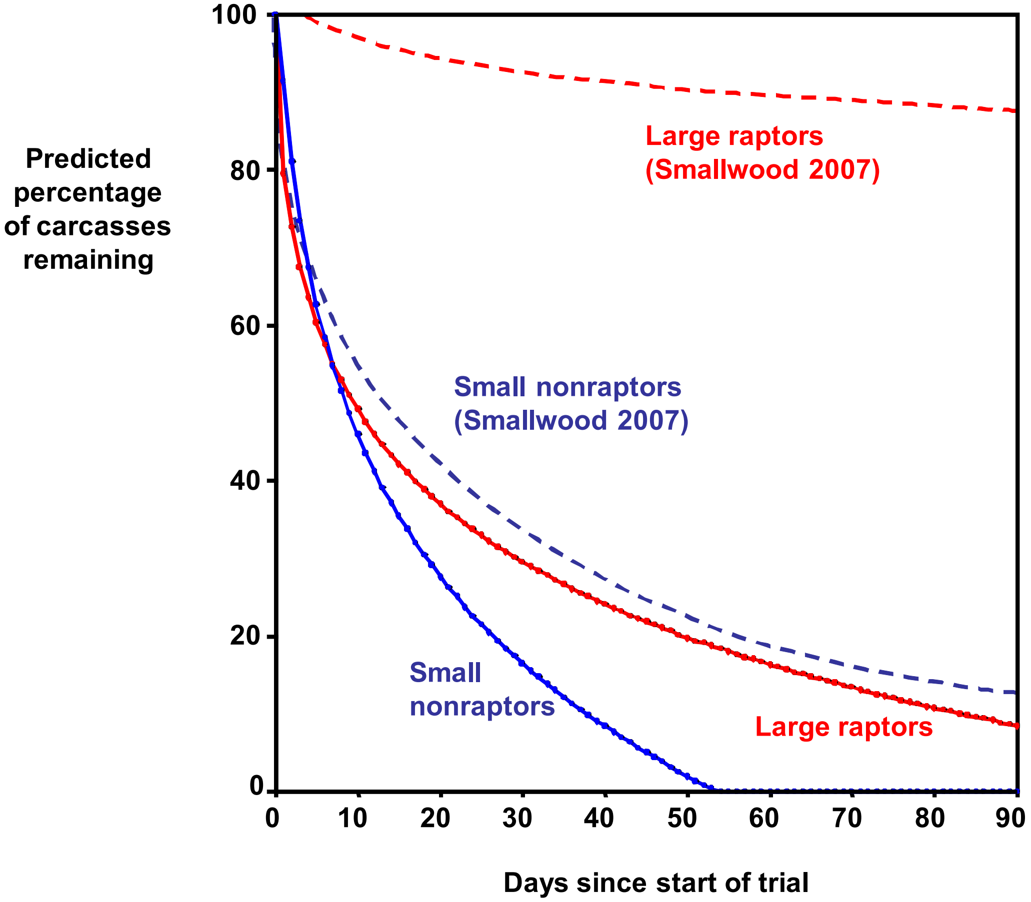

Figure 69. Estimated percentages of carcasses remaining each day into a scavenger removal trial or fatality search rotation, and assuming a steady-state frequency of bird collisions at wind turbines. The rates estimated by Smallwood (2007) are shown (dashed lines) to compare the rates estimated from the placement of large numbers of birds all at once (data in Smallwood 2007) versus 1–5 birds at approximately weekly intervals (this study).

6.2.3. Scavenger Species and Scavenging Events

A total of ten vertebrate species were photographed potentially interacting with placed carcasses (Figure 70A-I). These were, in terms of ranked-order of frequency of detections: coyote, common raven, badger, red-tailed hawk, striped skunk, turkey vulture, great horned owl, house cat, bobcat, and raccoon (Table 17). “Detection” means the scavenger was photographed and includes all behavioral categories from consuming or manipulating the carcass to other behaviors such as just sniffing the carcass or simply being photographed near the carcass (“visit”) with no physical contact.

Seven of the photographed potential scavenger species were documented either removing a carcass or consuming it on the spot. These were, in ranked order of frequency (Table 17): coyote (N = 15), common raven (N = 7), and one each for red-tailed hawk (black-headed grosbeak), striped skunk (red-tailed hawk), turkey vulture (Cooper’s hawk), great horned owl (great horned owl), and raccoon (western meadowlark). Noteworthy is the great horned owl, which landed on a great horned owl carcass, began to consume it, and then removed it, leaving trace feathers that met the APWRA definition of a fatality (Figure 71).

Figure 70. Scavenger species photographed by remote camera, including house cat near Cooper's hawk carcass E1 (top left), coyote near great horned owl carcass D1 (top right), raccoons removing western meadowlark carcass C9 (middle left), striped skunk just before removing red-tailed hawk carcass B1 (middle right), bobcat walking past red-tailed hawk carcass B1 (bottom left), and American badger more interested in camera than carcass.

Figure 70 continued. In top left photo, a turkey vulture postures over Cooper's hawk carcass C7, defending against three common ravens at left. In lower left photo, a common raven flies away with part of carcass C7. In top right photo, a red-tailed hawk grabs Cooper's hawk carcass E1.

Table 17. Species of scavenger detected at Vasco/Souza study area in order of frequency

Species	No. of Detections	No. of Carcasses Removed or Consumed	Species Scavenged
Coyote	48	15	Common moorhen, Western tanager, Killdeer, House sparrow, Purple martin, California quail, Mourning dove, Cooper's hawk, Common merganser (chick), Western meadowlark, Lesser goldfinch, Great horned owl, House finch, Barn owl, White-throated swift
Common raven	15	7	Lesser yellowleg, Evening grosbeak, Pygmy owl, Wilson's warbler, Cooper's hawk, Sharp-shinned hawk, Barn swallow
Badger	4	0	None
Red-tailed hawk	2	1	Black-headed grosbeak
Striped skunk	2	1	Red-tailed hawk
Turkey vulture	2	1	Cooper's hawk
Great horned owl	1	1	Great horned owl
House cat	1	0	None
Bobcat	1	0	None
Raccoon	1	1	Western meadowlark

As noted above, common ravens were the second most frequently documented scavenger, and they removed or consumed carcasses quicker than coyotes. Three of seven carcasses were removed in less than one hour after placement, with a mean of 0.88 d (SD = 1.05 d) to carcass removal (Table 18). Figure 71 depicts a remote camera photo sequence of a common raven removing a pygmy owl carcass two days after it was placed. The entire scavenging event lasted only four seconds and the carcass was removed without leaving any trace.

Coyotes removed or consumed the greatest number and a greatest size range of carcasses, from a common merganser duckling to an adult great horned owl (Table 19). Six of the carcasses were scavenged in less than 24 hours, with mean time to carcass removal of 2.72 d (SD = 3.10 d). Figure 72 depicts an infrared photo sequence of a coyote removing a Cooper's hawk carcass without leaving a trace of evidence behind in the original placement location.

In addition to outright removal or consumption of a carcass, several other scavenger behaviors were documented (Table 20). Coyotes exhibited the widest range of behaviors which included sniffing, scent rolling, and urinating on carcasses (Table 20). Bobcat and badger were photographed visiting carcasses, but no photos were obtained showing these species physically touching or sniffing the carcass. Red-tailed hawk and common raven were photographed manipulating carcasses (Table 20). Of particular interest is the fact that some carcasses were visited multiple times by several scavenger species before the carcass was removed. For instance, prior to its removal by a striped skunk, a red-tailed hawk carcass was visited by bobcat, badger and coyote, with the latter sniffing, urinating on and scent rolling on the carcass at intervals of several days. In the case of a great horned owl carcass, prior to its removal by a great horned owl, the carcass was visited three separate times by coyotes and visited by a badger.

Table 18. Species known to have been removed by common raven. Three carcasses were removed within 1 hour, and mean days to removal was 0.87 (SD = 1.05).

Carcass ID	Species	Days to Removal	Hours to Removal
A9	Lesser yellowleg	0.06	1.5
A13	Evening grosbeak	0.02	0.5
B6	Pygmy owl	2	>24
B10	Wilson’s warbler	2	>24
B12	Barn swallow	0.02	0.5
E7	Cooper’s hawk	2	>24
D14	Sharp-shinned hawk	0.02	0.5

Table 19. Species known to have been removed by coyote. Six carcasses were removed within 24 hours, and mean days to removal was 2.72 (SD = 3.10).

Carcass ID	Species	Days to removal
A9	Common moorhen	4
A13	Western tanager	1
B6	Killdeer	11
B10	House sparrow	0.21
B12	Purple martin	0.46
D7	Mourning dove	4
D12	Cooper’s hawk	0.54
D13	Common merganser	0.88
E4	Lesser goldfinch	4
E7	Great horned owl	0.33
E8	House finch	1
E9	Barn owl	0.67
E10	White-throated swift	6
C15	California quail	0.75
D14	Western meadowlark	6

Table 20. Observed scavenger behaviors other than carcass removal

Scavenger Species	Behavior	No. of Detections	Carcass Species
Coyote	Urinated on carcass	1	Red-tailed hawk
Coyote	Scent-rolled on carcass	3	Red-tailed hawk
Coyote	Sniffed carcass	8	American crow, Red-tailed hawk, Green heron, White-crowned sparrow, Great-horned owl, Cooper’s hawk
Coyote	Visited carcass	8	Great horned owl, White-crowned sparrow, Green heron, Red-tailed hawk
Common raven	Manipulated carcass but did not remove it	2	Black-headed grosbeak, Red-tailed hawk
Common raven	Visited carcass	3	Barn owl
Red-tailed hawk	Manipulated carcass but did not remove it	1	Cooper’s hawk
Bobcat	Visited carcass	1	Red-tailed hawk
Badger	Visited carcass	4	Red-tailed hawk, Green heron, Black-headed grosbeak, Great horned owl
House cat	Sniffed carcass	1	Cooper’s hawk

Scent roll was defined as the scavenger rubbing part of its body—usually face and back—on carcass to leave its scent or to acquire scent from the carcass. A manipulated carcass was one that was moved around within the search area, perhaps partly consumed, but sufficiently intact to be considered a fatality if found for the first time. A visited carcass was one visited by a potential scavenger, but not touched during the photo sequence.

6.2.4. Scavenger Trial Control

No scavenger species were photographed during three weeks of trials with cameras placed without a subject, and during four weeks of trials with the inorganic object placed in front of the camera. These results suggest that scavengers were not keying in on placement of the camera by researchers, the presence of cameras alone, or the presence of a camera with an inorganic object.

Figure 71. Great horned owl (left) and common raven (right) carcass removal sequences.

Figure 72. A coyote removing carcass D12, a Cooper's hawk, 13 hours after it was placed. The event lasted 13 seconds. Carcass was removed from original placement location without a trace.

6.3. Discussion

The purpose of the scavenger trials was not to calculate scavenging rates using conventional methods of placing a large number of carcasses and then noting times to removal (e.g., Smallwood 2007). In fact, the study area was too small for placing many carcasses at once. Rather, our intent was to estimate removal rates that were unbiased by scavenger swamping. Additionally, the study approach intended to identify scavenger species and their effects on carcasses during each scavenging event.

Placing single carcasses at random locations yielded much faster removal rates than measured in most if not all conventional scavenger removal trials. Logarithmic functions fit the data very well (Figure 68), and predicted that after a 15-day search interval only 35.4% of small-bodied non-raptor carcasses would remain on average, and only 42.1% of large-bodied raptor carcasses would remain. After a 30-day interval only 16.5% of small-bodied non-raptor carcasses would remain, and only 29.5% of large-bodied raptor carcasses would remain. Not only were the small, non-raptor carcasses removed faster in this type of trial, but the typically long-lasting, large raptor carcasses were removed at much faster rates. Because this type of trial more realistically simulates the carcass deposition rates from wind turbines, the authors believe these trials have produced more accurate scavenger removal rates than previously reported.

The first outcome of a scavenger event that results in the carcass being removed without a fatality trace is of primary interest for estimating scavenger removal rates. More than half of our placed carcasses (61%) were removed entirely from the immediate turbine search area with no trace, or they were removed and left a trace, but the trace did not meet the criteria of a fatality as established by the APWRA. Additionally, more than half of the carcass removals (54%) occurred within the first week since placement, a fact that is also reflected in the mean time to removal of carcasses with no fatality trace remaining: 4.15 d (SD = 5.21 d). Although all class and size ranges of birds are pooled here, the proportion of removed carcasses within 7 d appears to exceed that which would be predicted from Smallwood's (2007) estimates for numbers of bird carcasses remaining as a function of trial duration (compare Figures 3 and 4 in Smallwood 2007). Regardless, the present results suggest that more frequent fatality searches, at intervals of less than a week, would improve the precision of wind farm mortality estimates.

No significant relationship between carcass weight and days to removal was detected for all carcasses pooled by class and weight, suggesting that body size alone did not influence carcass detection rates by scavengers. This may result from the fact that carcasses were scavenged rather quickly in this study area compared to other areas. Since small numbers of carcasses were placed at regular intervals throughout the entire trial period, rather than a large number of carcasses all at once, results demonstrate that scavenger swamping, e.g., placing more carcasses than can be scavenged at one time, may bias time-to-removal estimates.

Although sample sizes for carcasses categorized by class and weight were low, study results do suggest that the majority of small bird carcasses (84%) was scavenged without leaving a fatality trace behind in the immediate turbine search area. About half of the medium- and large-sized birds, pigeons and doves, and small raptors left fatality traces behind, whereas 67% of the medium-large raptors left fatality traces.

Carcasses that are removed by scavengers but that leave behind trace evidence are of primary importance for fatality detection by searchers. Most carcasses that left behind trace evidence—23 of 26 carcasses—actually met the definition of a fatality, i.e., a group of 10 contour feathers or five rectrices or two remiges from the same wing or a bone fragment. The three cases that did not meet fatality criteria are described under in Section 6.2.1, but it is especially noteworthy that in two of the cases only a single feather was left behind. Given that results included the presence or absence of trace evidence left behind after scavenging for 63 carcasses out of 64 that were placed, these three carcasses represent 4.8% of the total number of placed carcasses or 11.5% of the placed carcasses that left trace evidence behind. The implication for fatality searches is that there remains a small but not insignificant probability that a single feather detected in a search area may have come from a scavenged fatality.

The species composition of the scavenger guild detected at Souza was larger than anticipated and revealed some surprises. A clear distinction must be made between those species photographed consuming or manipulating carcasses versus those that were simply photographed (detected) but did not make physical contact with the carcass. Coyotes scavenged the most carcasses and were also detected most frequently by the cameras exhibiting the greatest range of behaviors including urinating and scent-rolling on carcasses. It would appear that coyotes scavenged most size classes and categories of avian carcasses, from small passerines to large raptors. Coyotes removed 6 of the 15 carcasses in less than 24 h after placement, and the mean time to removal of 2.72 d (SD = 3.10 d) was a slightly shorter interval than the overall mean time to removal for all scavenged carcasses. For coyotes, the ratio of detection events to actual scavenging events was 3:1, suggesting that for this scavenger, its mere presence at a carcass does not equate with carcass removal. Raccoon and striped skunk each removed one carcass.

Three mammal species were detected by the cameras but were not recorded making physical contact with the carcass: badger, bobcat and house cat. Of the three, only house cat was photographed sniffing a carcass. The bobcat was photographed retreating from the camera's field of view. In this instance, the carcass, a red-tailed hawk, may have been previously scent-marked by a coyote. Badgers were photographed walking past carcasses, but none showed what might be construed as behavior directed specifically towards a carcass. One cannot rule out that these three species were attracted to the area of a carcass because of scent, either from the carcass itself or from other scavengers, but these results are consistent with the fact that carrion is not typically part of the diet of badger, bobcat (Jameson and Peeters 2004) or house cat.

Ground squirrels were frequently photographed near burrows adjacent to placed carcasses, but were not included in this analysis because they were never detected interacting in any way with the carcasses. However, the authors strongly suspect that ground squirrels did interact with some carcass remains, especially since some bones of carcasses were found at the entrances to squirrel burrows. In one instance, however, the remains of a red-tailed hawk were dragged into a ground squirrel burrow by a striped skunk.

Four species of birds were recorded scavenging carcasses: common raven, red-tailed hawk, turkey vulture, and great horned owl. Common raven ranked first in both frequency of detections and number of scavenging incidents, with detections being about twice as frequent as actual scavenging events. Common ravens were recorded scavenging avian carcasses ranging from small passerines to medium-sized raptors. The number of ravens recorded at a carcass ranged from one to four. One group of ravens was clearly a family group as an adult was photographed feeding at least one of its young from the scavenged carcass. Of all the scavengers, common ravens exhibited the quickest removal rates: four of seven carcasses were removed in less than two hours after placement. This would imply that ravens may have recognized humans placing carcasses. However, the control trials did not record any raven activity, suggesting that ravens were not seeking out placed cameras nor keying in on human teams setting up the camera trials.

Separate carcass manipulation and scavenging events were recorded for both red-tailed hawk and turkey vulture. Red-tailed hawks do forage on fresh carrion (Preston and Beane 1993). Given the relatively common status of turkey vultures in the Altamont, it is surprising that only two scavenging and carcass manipulation events were recorded for this species. Infrequent scavenging by turkey vultures at the study site may stem from local competition with common ravens. In both turkey vulture scavenging events, antagonistic behavior by common ravens appeared to interfere with turkey vulture scavenging.

The most spectacular scavenging species detected was the great horned owl removing a great horned owl carcass. To the authors' knowledge, this is the first recorded instance of such a conspecific scavenging event. Although great horned owls do cache food, they have not been noted feeding on carrion in recent accounts of this species (Houston et al. 1998).

6.3.1. Overall Trends Identified by Scavenging Trials

Scavengers removed from the search area more than half of all carcasses within seven days of placement, without leaving a trace of fatality evidence behind. The majority of the remaining carcasses that were removed left sufficient evidence behind to satisfy the definition of a fatality according to established fatality search protocols in the APWRA. The evidence persisted at the original placement location for the duration of each individual scavenger trial (4 to 290 d). Noteworthy is the fact that nearly 5% of all placed carcasses for which final outcomes of scavenging events were known did not leave enough evidence behind to qualify as a fatality under the fatality search protocols of the APWRA. Although sample sizes were small, it appeared that all class and size categories of birds were removed equally fast.

Remote infrared cameras detected the presence of ten medium-to-large vertebrate scavenger species—six mammal and four bird species—near carcasses. Of these, three mammal and four bird species were photographed consuming or manipulating carcasses. Among all species, coyotes and common ravens ranked first and second, respectively, in total number of detections and scavenging events. The presence of a potential scavenger at a carcass did not always result in the carcass being scavenged. This was especially true for coyotes and common ravens. Coyotes exhibited several non-scavenging behaviors at carcasses including scent marking. In some instances, carcasses were visited several times by more than one species of scavenger.

6.3.2. Lessons Learned From Use of Remote Cameras

The use of infrared, remote cameras revealed some problems. Aside from battery failures and incorrect time stamps on CF memory cards, the most perplexing problem occurred when a camera missed recording a scavenging event. In such instances, the photographic record shows the presence of the carcass at one point in time and then no carcass at a subsequent point in time.

Some of these cases might have been due to reflected sunlight or heat from the environment impinging on the camera and thus flooding its trigger sensors. Even though cameras were placed facing north to avoid direct sunlight, angle and slope of the terrain may have contributed to reflecting light back at the camera at certain times of the day. The Reconyx cameras had five sensitivity levels, and this presented a challenge to achieve the correct sensitivity level for the given environmental conditions. Under high-wind conditions, the cameras needed to be set at the lowest sensitivity level to minimize their triggering by vegetation moving in the wind. In some instances, high winds and vegetation movement conspired to keep the cameras firing until their memory cards filled or their batteries ran out.

Another possibility for missed recordings of scavenger events is that the animal was able to remove the carcass between photo shots or during the camera recovery phase. The cameras were set to take a series of five pictures at 1-s intervals when triggered. In spite of this rapid sequence of pictures, there were single shots of scavengers entering a camera’s field of view and/or leaving the field of view with no intervening photos to document what transpired. The cameras likewise had a 1-s recovery phased between firings. In summary, it is advisable to set up an initial camera test period to optimize camera operation with the environmental conditions of the study site and target animals.

The use of remote cameras does appear to have great advantages in scavenging studies, because it allows identification of the potential suite of scavenging species, their behaviors, and the fates of carcasses. In future studies it would be advisable to use as many cameras as possible to minimize the time period for camera optimization as well as to increase the time period for which a single camera is devoted to a particular carcass. This study used a camera-on-carcass period of 21 days to strike a balance between intra-trial sample size, i.e., scavenger events at a given carcass, versus inter-trial sample size, i.e., the total number of carcasses placed.

Although there is no evidence that scavengers learned to associate the cameras with carcasses, the search area in which cameras are placed should be as large as possible to minimize the habituation of scavengers to either the act of placing cameras or the presence of cameras in the landscape.

6.3.3. Future Research Directions

The ratio of clean carcass removal by scavengers (no trace) versus the extent and type of evidence left behind (trace) after a scavenging event deserves future research effort, especially in regards to the species of scavenger, as the latter may bear on how cleanly carcasses are removed. It is instructive that nearly 5% of the placed carcasses left evidence behind that did not meet the criteria defining a fatality. It would be useful to investigate methods to determine the probability that a single feather in the landscape came from a fatality. Equally important for further research is the concept of trace evidence persistence. It is possible that trace evidence is often found by searchers in wind farms but not recorded because it does not meet the operating definition of a fatality. If this is happening, then mortality estimates are likely biased low. How long trace evidence remains in the landscape in a given area, and whether that evidence meets the operational definition of a "fatality" by the search crews, would be important parameters to measure in specific wind farms.

7.0 Mortality at Wind Turbines

A primary objective of the fatality searches and scavenger removal trials was to obtain an accurate estimate of avian mortality rates at the wind turbines located on EBRPD land in the APWRA in order to assist the District's Board of Directors in deciding whether to allow repowering of the wind farms on District land.

Devoted to the conservation of natural resources, the EBRPD finds renewable energy generation attractive, but, in addition to its effect on landscape aesthetics and public access, the EBRPD is particularly concerned about the impacts wind power generation may have on birds and other organisms. After acquiring a property with wind turbine leases, the EBRPD inherited a more direct responsibility for bird and bat deaths possibly caused by wind turbines. As part of this study, therefore, the EBRPD sought to obtain superior estimates of avian mortality caused by the wind turbines on the Souza parcel. Smallwood and Thelander (2004) had searched for fatalities at these turbines only twice during 2002–2003, so their mortality estimates left much room for improvement. The EBRPD decided to improve these estimates by performing searches at six times the previous frequency and over a much longer period.

A second research objective emerged toward the end of the study. The EBRPD obtained power output data from most of the wind turbines, against which the number of fatalities could be related. This comparison has been recommended repeatedly by researchers in the APWRA (Orloff and Flannery 1992, Smallwood 2007, Smallwood and Thelander 2008), because the most reliable way to explain the variation in the number of fatalities is to account for the variation in actual power output or turbine activity among turbine models, sites, and seasons.

7.1. Methods

The ground within 60 m of wind turbines on the study site was searched for bird carcasses every two weeks during the first 13 months of the study, and then monthly during the remaining three months. Carcass search dates were recorded for all wind turbines. Field biologists searched along parallel transects separated by about 6–8 m, and extending from the axis of the row of turbines to 60 m away from the turbines. Wind turbines were searched regardless of their operational status, except for seven derelict turbines on the west side of the study area and two derelict Howden towers. These exceptions were derelicts that had not operated in many years.

A survey protocol and data sheets can be found in Appendix J. For each carcass found, at least two photos were taken, changing the angle between photos, and including an engineers' survey card in every carcass photo for scale. Each carcass was given a record number, which was entered onto a data sheet. The species was recorded, along with the date of the discovery, the investigator's name, and whether the discovery was made during a standard foot search or incidentally, e.g., while en route to a standard fatality search location. The investigators recorded the sex and age class of the bird at the time of death. The investigator in the field made an initial determination of cause of death, including blade strike, entrapment in the turbine (typically indicated by oiled feathers), collision with electric distribution lines, electrocution on electric distribution poles, auto collision, predation, West Nile virus (typically indicated by constricted feather quills; see Harness 2004), poisoning, unknown, or a specified other cause. The injury was described and any pertinent notes about the carcass or surroundings were taken.

The investigator in the field made an initial estimate of the number of days since death and rated the articulation of the carcass on a scale of 1 through 5, where 1 indicated complete disassembly of the skeleton, and 5 indicated a completely intact and articulated skeleton. The articulation rating was intended to represent decay, and not dismemberment caused directly by the collision, electrocution, or predation. For disassembled carcasses, each body part was described, assigned a number, and associated with the nearest wind turbine by turbine designation number. Data on each body part also included distance and bearing to the nearest wind turbine, and photo names or numbers. Each body part was subsequently monitored, and monitoring data included the date of each revisit along with photo numbers, carcass condition, and color. Carcass condition was categorized as D1 = no decay, D2 = gooey, or D3 = dried flesh; R1 = stiff or R2 = loose; C = enamel on culmen; T = enamel on talons; F = feathers present; B = exposed bones present; I1 = fly larvae, I2 = fly pupae, I3 = beetle larvae, I4 = beetle pupae, or I5 = beetle adult(s). The color was characterized as original, intermediate, or bleached, or not applicable.

If only bones were present, they were monitored using a different set of data. Data recorded for bones included date of revisit, the type of bone (skull, sternum, pelvis, coracoids, scapula, humerus, ulna, radius, carpometacarpus, femur, tibiotarsus, or tarsometatarsus), the number of each type of bone present, bone condition, and length and width of each bone in millimeters. Bone condition was categorized as broken, complete, smooth, or weathered.

Wind turbine–caused mortality was expressed as the number of fatalities per MW per year, where MW was the rated power output of the normally operating wind turbines composing a row of wind turbines, and the number of years or fractions of a year were the time spans over which searches were performed at that wind turbine row. Mortality estimates were estimated only from wind turbine–caused fatalities ≤90 days before the search. Unless another cause of death was determined from the evidence, it was assumed the wind turbine caused the fatality.

During the burrow mapping, bird carcasses were recorded whenever found. These records provided the means to learn where injured birds might travel or scavenged birds might be transported. Some of these birds may have been killed by predators, and some may have been injured and killed by wind turbines. They indicate the possible magnitude of either background mortality or crippling bias, respectively, in the APWRA.

7.1.1. Searcher Detection

EBRPD eliminated searcher detection trials from its study for the following reasons. Smallwood (2007) reviewed and compared the reported estimates of searcher detection rates from all over North America. In western grasslands, searcher detection rates have not varied much within size classes of bird carcasses. Furthermore, the Alameda County monitoring team had already performed searcher detection trials in the Altamont Pass Wind Resource Area that included search personnel EBRPD employed for fatality searches in this study. Repeating such trials would have been redundant and costly, therefore the EBRPD decided to rely on the available estimates of searcher efficiency.

7.1.2. Scavenger Removal

Two sets of mortality estimates were calculated: one using the earlier scavenger removal results of Smallwood (2007), and another using the new scavenger removal data from this EBRPD study (see Chapter 6 for methods and results). As discussed in Chapter 6, the 2007 Smallwood study summarized multiple other studies that employed the conventional approach of distributing all carcasses at once (and thereby possibly swamping the scavengers), whereas this study set out carcasses at intervals to avoid such swamping.

7.1.3. Analytical Methods

Within each turbine string, unadjusted mortality (M_U) was expressed as the number of fatalities per MW per yr, where MW was the sum of the megawatts (MW) of rated power outputs for all of the functional wind turbines in the row surveyed. Although individual turbines killed birds, the wind turbine string was used as the study unit because the authors have noticed that birds often react to the wind turbine string as a barrier or threat. Fifteen days were added to the number of years used in the mortality estimate to represent the time period when carcasses could have accumulated before the first search (Smallwood and Thelander 2008). A couple of carcasses found outside the search radius were included if evidence indicated the bird had been killed by a wind turbine.

Mortality estimates were adjusted (M_A) for carcasses not found due to searcher detection error and scavenger removals as follows:

$$M_A = \frac{M_U}{p \times R},$$

where M_U is unadjusted mortality expressed as the number of fatalities per MW of rated capacity per year, p is the proportion of turbine-caused bird fatalities found by searchers during searcher detection trials, and R is the estimated proportion of carcasses remaining since the last fatality search and estimated by scavenger removal trials (Smallwood 2007). The standard error of these estimates, $SE[M_A]$, was calculated using the delta method (Goodman 1960):

$$SE[M_A] = \sqrt{\left(\frac{1}{p \times R} \times SE[M_U]\right)^2} \times \left(\frac{M_U}{p} \times \frac{-1}{R^2} \times SE[R]\right)^2 \times \left(\frac{M_U}{R} \times \frac{-1}{p^2} \times SE[p]\right)^2.$$

Searcher efficiency trials were not performed in this study. Instead, the mortality calculations use estimators of searcher detection and scavenger removal rates developed by Smallwood (2007), who synthesized results from reported searcher detection trials performed in wind farms throughout the United States. Search detection rates were 51% (SE = 2.133%) for small non-raptor birds, 78% (SE = 5.384%) for medium and large non-raptor birds (including rock doves), 75% (SE = 9.129%) for small raptors, and 100% (SE = 0%) for large raptors, based on averages among reports of searcher detection trials in grasslands across the United States (Smallwood 2007).

To predict the proportion of carcasses remaining after each successive day into scavenger removal trials or into the periods intervening fatality searches, a first set of mortality estimates was calculated with logarithmic models developed using least-squares regression for small-bodied non-raptor birds (SE = 0.158), medium- and large-bodied non-raptor birds (SE = 0.129), small-bodied raptors (SE = 0.040), and large-bodied raptors (SE = 0.089), as well as a linear model developed for rock pigeons (SE = 0.080) (Smallwood 2007, Table 4). These models are based on research across North America, but are possibly biased by scavenger swamping because conventional scavenger removal trials were performed; that is, all avian carcasses were placed simultaneously in the landscape (Smallwood 2007). Therefore, a second set of mortality estimates was calculated based on data from this study's new scavenger removal trials, in which bird carcasses were placed at random locations one at a time and spaced over longer intervals. Results for the two approaches are presented in Sections 6.2.1 and 6.2.2.

Assuming wind turbines deposit carcasses at a steady state, for each species group, the above model predictions were averaged across the number of days equaling the average number of days between fatality searches:

$$R_C = \frac{\sum_{i=1}^{I} R_i}{I},$$

where R_C represents the cumulative percentage of carcasses remaining, R_i is the percent of carcasses remaining by the *i*th day following the initiation of a scavenger removal trial and corresponding with the number of days since the last fatality search, and *I* is the average number of days between fatality searches.

No adjustment was made for background mortality, which is usually small, and no adjustment was made for crippling bias. Background mortality is mortality caused by factors independent of the wind turbines and their supporting infrastructure, and would reduce the mortality estimates. Crippling bias refers to the number of birds mortally injured by the wind turbines but which died undetected somewhere else. A crippling bias adjustment would increase mortality estimates by an unknown degree by adding undiscovered fatalities to the total.

Wind power data were supplied for the Howden model wind turbines by Babcock and Brown, Inc. These operating data were presented as monthly totals for each turbine. These totals were summed across the months spanning the study, so each of these turbines was associated with the kilowatt-hours of electric power produced during the study. Bird fatalities were related to these power output data to identify patterns that could provide insight into underlying collision mechanisms and that could identify particular wind turbines killing disproportionately more birds.

7.2. Results

During the study 58 bird carcasses and one bat carcass were found (Table 21). Most of the carcasses (69%) were too far from wind turbines to be attributed to the turbines, and most of these were found incidentally or during the burrow mapping effort. Many of these carcasses might have been killed by wind turbines, some resulting in injuries enabling the bird to move away from the turbines before dying, and some resulting in a scavenger transporting the carcass to the location where it was eventually detected. An injured red-tailed hawk and an injured golden eagle were found outside of the search area, well away from wind turbines, but their injuries were consistent with turbine collisions (Photos 13 and 14). The wounded eagle was found on top of the highest hill in the turbine-free area of the eastern Souza parcel, approximately 500 m and 600 m away from the closest Howden and Nordtank wind turbines, respectively. The eagle must have walked at least this distance after being struck by a turbine blade. Both the red-tailed hawk and the golden eagle were euthanized, but neither was included in mortality estimates because it could not be established which wind turbines injured these birds.

Photo 13. Injured golden eagle found atop the eastern hill of the Souza parcel on 5 March 2007. Nordtank wind turbines are seen in the background to the north. Photo by Photo by D. A. Bell.

Photo 14. The golden eagle's wound, compound fractures to the right radius and ulna caused by blunt force trauma, was necrotic, and the bird was later euthanized. Photo by J. Gan.

Many of the bird carcasses found outside the wind turbine search areas might also have resulted from predation or other causes. One was apparently killed after colliding with an electric distribution line servicing the wind farm.

Most of the fatalities used in mortality estimation were detected during standard fatality searches (Table 21). A few were detected incidentally, including one that had been removed by the wind companies but which appeared in the companies' Wildlife Reporting and Response System. Incidental finds were included in mortality estimates if they were thought likely to have been detected by the next standard fatality searches.

Comparing fatalities with location of the associated wind turbine in a turbine string—i.e., the tower's "tier classification"—showed that the wind turbines which killed the most birds were those predicted to be more dangerous by Smallwood and Spiegel (2005) (Table 22). The tier classification was based on multiple measured variables representing wind turbine and tower attributes, landscape settings, and the arrangement of turbines on the landscape. Wind turbines composing Tier 1 were 3.2% of the 4,074 turbines used to develop the classification, and turbines in Tier 2 composed another 4%. Tier 1 was regarded most dangerous to raptors, followed by Tier 2, and so on down to the least dangerous in Tier 5. Wind turbines classified as Tier 1 killed disproportionately more birds, ranging from >3 to 4.3 times as many birds as expected (Table 22). Tier 1 and 2 turbines were associated with all the burrowing owl fatalities, 15 of 16 raptors, and 86% of all birds. This study strongly validated the tier classification developed by Smallwood and Spiegel (2005).

7.2.1. Mortality Calculated With Conventional Scavenger Removal Data

Based on the predictions from the models of conventional scavenger removal rate developed by Smallwood (2007), red-tailed hawk mortality estimated during this study was 0.35 deaths/MW/year, nearly the same as red-tailed hawk mortality estimated APWRA-wide by Smallwood and Thelander (2008) during 1998–2003 (Table 23). This mortality would translate into an adjusted mean of 4.4 red-tailed hawk turbine-related fatalities per year at the EBRPD's Souza parcel. Burrowing owl mortality, at 1.44 deaths/MW/year, was twice that estimated APWRA-wide during 1998–2003, and barn owl mortality was nearly six times greater than previously estimated APWRA-wide. For burrowing owls, the estimated mortality would translate into an adjusted mean of 18.1 turbine-related fatalities per year at the EBRPD's Souza parcel. Note that neither American kestrel nor golden eagle could be included in the mortality estimates reported here because they were found too far from wind turbines to conclude which turbines may have killed or mortally injured them (Table 21). Raptor mortality, estimated at 2.24 deaths/MW/year, was about 15% greater in this study than previously estimated APWRA-wide, and overall bird mortality was about the same. These mortality estimates indicated about 28 raptors and 59 birds are killed annually in the study area, though the confidence intervals indicated the numbers could be as high as 62 and 151, respectively (Table 24).

7.2.2. Mortality Calculated With New EBRPD Scavenger Removal Data

Based on the predictions from the new models of scavenger removal rate developed in this study, estimated red-tailed hawk mortality was 0.83 deaths/MW/year, or an adjusted mean of 10.4 turbine-related fatalities per year for the EBRPD's leased wind farms. The estimated mortality rate obtained here for red-tailed hawks is more than twice as high as that estimated using the older scavenger removal data, and considerably higher than past estimates for the entire APWRA (Table 25). Likewise, the mortality rate for burrowing owls reached an estimated 2.08 fatalities per megawatt per year, which yields an adjusted mean of 26.0 annual turbine-related burrowing owl fatalities at the EBRPD's leased wind farms. Overall raptor mortality was nearly twice as high as that estimated from the conventional scavenger removal data, and overall bird mortality was 1.6 times as high. The new scavenger removal data combined with the new fatality data yielded estimates that about 50 raptors and 95 birds are killed annually in the study area, though the confidence intervals indicate the numbers could be as high as 115 and 240, respectively (Table 26). Table 27 compares the mean annual fatality estimates based on both approaches to estimating scavenger removal rates.

As noted above, the crippled golden eagle (Photos 13 and 14) that was recovered on the Souza parcel could not be used in the mortality estimates because it was not known whether it was struck by Howden or Nordtank wind turbines. The true mortality rates would be larger yet if crippling bias could be accounted for.

7.2.3. Mortality and Turbine Operations

Raptor and overall bird mortality declined with increasing electric power output from the wind turbines (Figures 73 and 74). Electric power output was made available only for the Howden wind turbines in the study area, so Figures 73 and 74 depict bird mortality in response to the power output from all operating Howden wind turbines.

At the individual turbine level of analysis, much of the underlying relationship of the patterns in Figures 73 and 74 was revealed (Figure 75). Among wind turbines where only one bird fatality was detected, an inverse function nearly perfectly fit the data, which is to be expected when a constant numerator of a ratio is divided by a variable denominator (see Smallwood and Thelander 2004, p. A-8). That is, most of the inverse pattern in Figures 73 and 74 was due to a mathematical artifact caused by one fatality having been the most common number of fatalities among turbines that varied considerably in electric power output.

The wind turbines that killed more than one bird each, and which could be considered more dangerous to birds, are L3005 and G3011. The models in Figures 73 through 75 can also be used to identify wind turbines that kill disproportionately to their power output, i.e., the turbines associated with the fatalities appearing at the left side of the figures. For example, wind turbine I3002 killed a bird even though it produced very little power, so it could be considered relatively more dangerous. H3013 also killed a bird despite producing relatively little power. In an even more extreme example, turbine I3001 was associated with four fatalities, even though no power production was recorded at this turbine. These five turbines, I3001, I3002, H3013, G3011, and L3005, were all Tier 1 and 2 turbines in Smallwood and Spiegel's (2005) classification of collision threat.

Table 21. Bird mortality data, Souza parcel, 2006–2007. Species found dead or mortally wounded in the study area, number used in estimating mortality, and the listing status of each.*

Common Name	Species Name	No. Found Not Used in Mortality Estimation	No. Found Used in Mortality Estimation	Status
Bat spp.		1	---	
Golden eagle	*Aquila chrysaetos*	1	0	CSC, CFP
American kestrel	*Falco sparverius*	1	0	
Red-tailed hawk	*Buteo jamaicensis*	7	3	
Ferruginous hawk	*Buteo regalis*	1	1	CSC
Cooper’s hawk	*Accipiter cooperii*	1	0	CSC
White-tailed kite	*Elanus leucurus*	1	0	CFP
Great horned owl	*Bubo virginianus*	2	0	
Barn owl	*Tyto alba*	11	3	
Burrowing owl	*Athene cunicularia hypugea*	14	10	CSC
Rock pigeon	*Columba livia*	5	2	Exotic
Say’s phoebe	*Sayornis saya*	1	0	
White-throated swift	*Hirundapus caudacutus*	1	1	
Cliff swallow	*Hirundo pyrrhonota*	1	1	
Loggerhead shrike	*Lanius ludovicianus*	2	0	CSC
European starling	*Sturnus vulgaris*	2	2	Exotic
Common raven	*Corvus corax*	2	0	
Western meadowlark	*Sturnella neglecta*	3	1	
Passerine spp.		2	0	
All raptors		38	13	
All birds		58	18	

* CFP = California Fully Protected, CSC = California Department of Fish and Game listing of California Species of Concern. The Migratory Bird Treaty Act protects all species in the table except rock dove, European starling, and the bat.

Table 22. Performance of the tiers for priority retrofit developed by Smallwood and Spiegel (2005), where numbers of dead birds found were compared to the tiers assigned to wind turbines

Tier	Observed	Expected	Observed ÷ Expected	Chi-square
Red-tailed hawk				
1	1	0.42	2.38	
2	1	1.11	0.90	
3	0	0.74	0.00	
4	1	0.74	1.36	No test
Burrowing owl				
1	6	1.40	4.28	
2	4	3.68	1.09	
3	0	2.46	0.00	
4	0	2.46	0.00	19.99**
Raptor				
1	8	2.25	3.56	
2	7	5.89	1.19	
3	0	3.93	0.00	
4	1	3.93	0.25	21.07**
All birds				
1	9	3.23	3.10	
2	10	8.47	1.18	
3	0	5.65	0.00	
4	3	5.65	0.53	21.38**

** Significance of test results were denoted by * for P < 0.05 and ** for P <0.001.

Table 23. Summary of adjusted mortality estimates (i.e., searcher detection bias and scavenger bias included in calculation), based on conventional scavenger trial data, applied to the 12.52 MW of rated capacity in the study area, composed of 54 operating wind turbines arranged in 11 rows

	Wind Turbine-Caused Mortality (Deaths/MW/year)				
		80% Confidence Interval		95% Confidence Interval	
Species	Mean	Lower	Upper	Lower	Upper
Red-tailed hawk	0.350	-0.077	0.777	-0.303	1.002
Ferruginous hawk	0.111	-0.032	0.253	-0.107	0.329
Barn owl	0.337	0.058	0.616	-0.089	0.763
Burrowing owl	1.445	0.534	2.355	0.053	2.836
Rock pigeon	0.225	0.016	0.433	-0.094	0.544
Cliff swallow	0.459	-0.165	1.084	-0.496	1.414
European starling	0.872	-0.102	1.846	-0.618	2.361
Western meadowlark	0.230	-0.083	0.542	-0.248	0.707
White-throated swift	0.688	-0.248	1.625	-0.743	2.120
All raptors	2.242	0.483	4.000	-0.447	4.931
All birds	4.716	-0.099	9.530	-2.645	12.076

Table 24. Summary of unadjusted and adjusted annual fatality estimates, based on conventional scavenger removal estimates, applied to the 12.52 MW of rated capacity in the study area, composed of 54 operating wind turbines arranged in 11 rows

	Annual Wind Turbine-Caused Fatalities					
	Unadjusted	Adjusted	80% Confidence Interval		95% Confidence Interval	
Species	Mean	Mean	Lower	Upper	Lower	Upper
Red-tailed hawk	4.2	4.4	-1.0	9.7	-3.8	12.5
Ferruginous hawk	1.3	1.4	-0.4	3.2	-1.3	4.1
Barn owl	3.2	4.2	0.7	7.7	-1.1	9.6
Burrowing owl	6.5	18.1	6.7	29.5	0.7	35.5
Rock pigeon	2.0	2.8	0.2	5.4	-1.2	6.8
Cliff swallow	1.3	5.7	-2.1	13.6	-6.2	17.7
European starling	2.5	10.9	-1.3	23.1	-7.7	29.6
Western meadowlark	0.7	2.9	-1.0	6.8	-3.1	8.9
White-throated swift	2.0	8.6	-3.1	20.3	-9.3	26.5
All raptors	15.2	28.1	6.1	50.1	-5.6	61.7
All birds	23.6	59	-1.2	119.3	-33.1	151.2

Table 25. Summary of adjusted mortality estimates based on the new scavenging trial data, and applied to the 12.52 MW of rated capacity in the study area, composed of 54 operating wind turbines arranged in 11 rows

	Wind Turbine-Caused Mortality (Deaths/MW/year)				
		80% Confidence Interval		95% Confidence Interval	
Species	Mean	Lower	Upper	Lower	Upper
Red-tailed hawk	0.833	-0.197	1.683	-0.742	2.407
Ferruginous hawk	0.264	-0.080	0.607	-0.262	0.789
Barn owl	0.802	0.119	1.485	-0.242	1.846
Burrowing owl	2.076	0.708	3.444	-0.015	4.168
Rock pigeon	0.598	0.031	1.166	-0.269	1.466
Cliff swallow	0.613	-0.182	1.408	-0.603	1.829
European starling	1.164	-0.046	2.374	-0.686	3.014
Western meadowlark	0.307	-0.091	0.704	-0.301	0.915
White-throated swift	0.919	-0.273	2.111	-0.903	2.742
All raptors	3.974	0.550	7.399	-1.261	9.210
All birds	7.576	-0.011	15.163	-4.023	19.175

Table 26. Summary of unadjusted and adjusted annual fatality estimates based on the new scavenging trial data, and applied to the 12.52 MW of rated capacity in the study area, composed of 54 operating wind turbines arranged in 11 rows

Species	Annual Wind Turbine-Caused Fatalities					
	Unadjusted Mean	Adjusted Mean	80% Confidence Interval		95% Confidence Interval	
			Lower	Upper	Lower	Upper
Red-tailed hawk	4.2	10.4	-2.5	23.3	-9.3	30.1
Ferruginous hawk	1.3	3.3	-1.0	7.6	-3.3	9.9
Barn owl	3.2	10.0	1.5	18.6	-3.0	23.1
Burrowing owl	6.5	26.0	8.9	43.1	-0.2	52.2
Rock pigeon	2.0	7.5	0.4	14.6	-3.4	18.3
Cliff swallow	1.3	7.7	-2.3	17.6	-7.5	22.9
European starling	2.5	14.6	-0.6	29.7	-8.6	37.7
Western meadowlark	0.7	3.8	-1.1	8.8	-3.8	11.4
White-throated swift	2.0	11.5	-3.4	26.4	-11.3	34.3
All raptors	15.2	49.8	6.9	92.6	-15.8	115.3
All birds	23.6	94.9	-0.1	189.8	-50.4	240.1

Table 27. Comparison of mean adjusted annual fatality estimates, based on conventional and new scavenger removal estimates, applied to the 12.52 MW of rated capacity in the study area, composed of 54 operating wind turbines arranged in 11 rows

Species	Annual Wind Turbine-Caused Fatalities	
	Adjusted Mean Using Conventional Scavenger Removal Trials	Adjusted Mean Using New EBRPD Scavenger Removal Trials
Red-tailed hawk	4.4	10.4
Ferruginous hawk	1.4	3.3
Barn owl	4.2	10.0
Burrowing owl	18.1	26.0
Rock pigeon	2.8	7.5
Cliff swallow	5.7	7.7
European starling	10.9	14.6
Western meadowlark	2.9	3.8
White-throated swift	8.6	11.5
All raptors	28.1	49.8
All birds	59	94.9

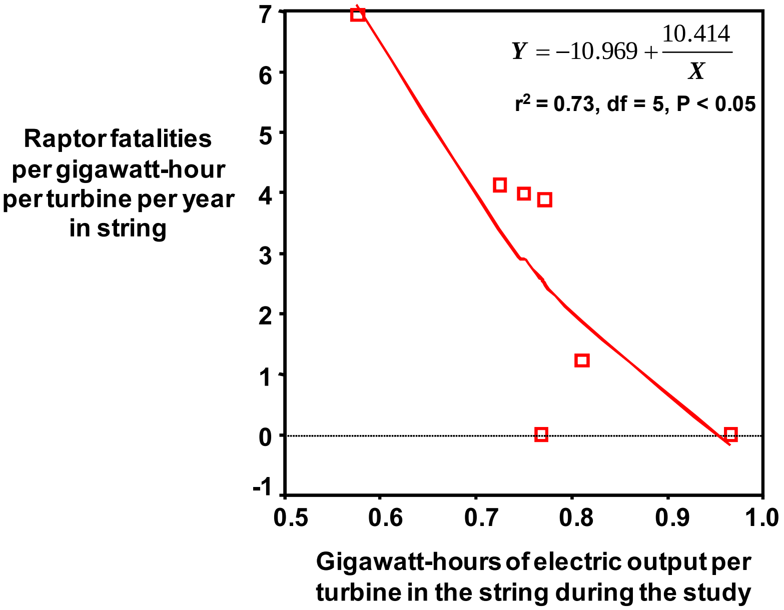

Figure 73. Raptor mortality related inversely to electric power output from the Howden turbine string. These mortality estimates were not adjusted for searcher detection error or scavenger removal rate because the adjustment would have been equally applied to all strings, resulting in no difference to the comparison.

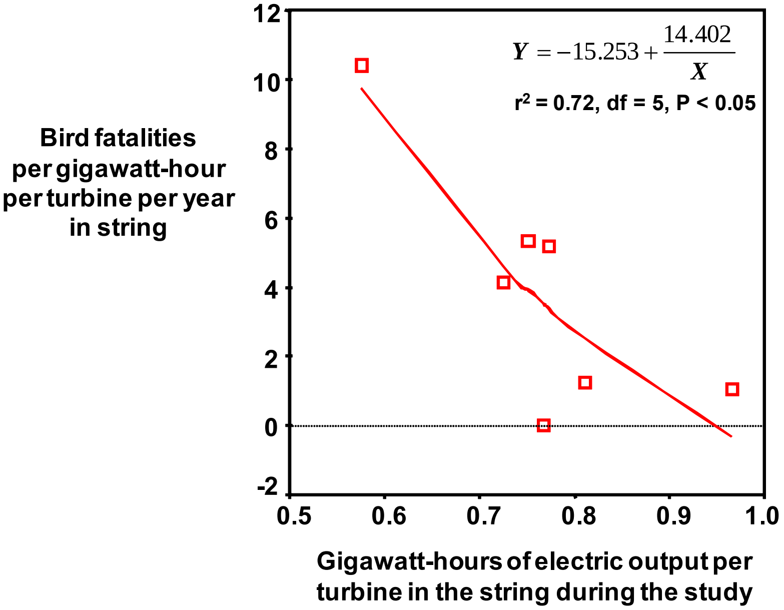

Figure 74. Bird mortality related inversely to electric power output from the Howden turbine string. These mortality estimates were not adjusted for searcher detection error or scavenger removal rate.

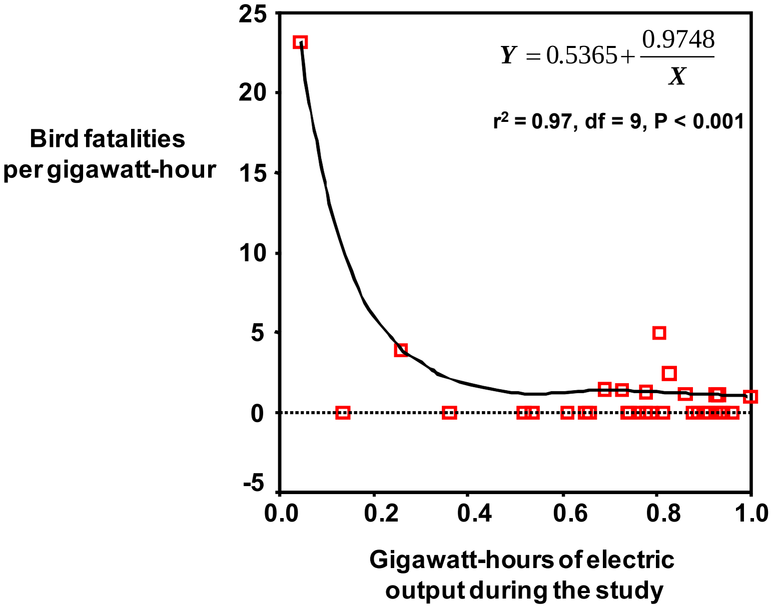

Figure 75. At wind turbines where one or more birds were killed, bird mortality related inversely to electric power output from the turbine (only these data resulted in the estimated line). These mortality estimates were not adjusted for searcher detection error or scavenger removal rate.

7.3. Discussion

The fatality searches validated the Smallwood and Spiegel (2005) tier classification developed to identify wind turbines more likely to kill birds. The Tier 1 and 2 turbines, or 14% of those in the study area, were associated with 19 of the 22 bird carcasses found near wind turbines.

Based on scavenger removal rates obtained from conventional scavenger removal trials (Smallwood 2007), bird mortality estimated in this study was about the same as estimated previously throughout the APWRA (Smallwood and Thelander 2007), though there were some dramatic species-specific differences. Burrowing owl and barn owl mortality was greater in this study area than estimated previously. The greater burrowing owl mortality might have been expected due to the study site hosting a relatively large nesting population. Not all of the APWRA supports burrowing owls, so on average burrowing owl mortality will be lower in the APWRA.

Based on older scavenger removal rates, the wind turbines in the study area were estimated to kill 28 raptors, including 4.4 red-tailed hawks, and 59 birds annually. However, using the new scavenger removal rates from this study increased the fatality estimates to 50 raptors, including 10.4 red-tailed hawks, and 95 birds annually. Mortality for American kestrel and golden eagle could not be estimated. Thus, mortality rates were obtained for only two of the four key species identified for monitoring impacts within the APWRA. The uncertainty ranges of each mortality estimate were large, suggesting that the fatality search effort did not span a sufficient time period to reduce the number of wind turbines recorded as having caused zero fatalities. If the fatality surveys were of longer duration than just the 16 months, the mean mortality estimates would likely remain similar, whereas the lower and upper bounds of the confidence intervals would shift toward the means. These new mortality rate estimates do not include crippling bias, which would increase the mortality rate estimates. Although crippling bias is known to exist, as demonstrated by incidental finds of wounded golden eagle and red-tailed hawk located well outside of the turbine fatality search areas, the study design used here could not account for crippling bias.

It remains unknown whether the estimated numbers of birds killed by wind turbines in the study area is having biological impacts at the local population or regional levels, because insufficient population data have been collected on the species being killed and because it is difficult without extensive banding to determine if in fact resident or nonresident birds are being killed. This study did obtain survey data on a significant resident population of burrowing owls in the APWRA (see Chapter 3). In 2006, 50 adult owls produced a minimum of 86 young, resulting in a total "resident" population size of 136 owls before dispersal and emigration. In 2007, 42 adult owls produced a minimum of 41 young, resulting in a total "resident" population size of 83 owls before dispersal and emigration. Using the conventional scavenger trial data yields an annual turbine-caused mortality estimate of 18 burrowing owls, or 13% and 22% of the "resident" owls in 2006 and 2007, respectively, assuming all the owls killed were locals. An annual turbine-related mortality of 26 burrowing owls, based on the new scavenger removal rates, would amount to 19% and 31% of the local owls in 2006 and 2007, respectively. The impact of these percentage losses on the local population remains unknown, due also to the fact that the number of adult versus juvenile owls killed by presumptive blade strikes is unknown. Thus, there is no way to relate wind farm mortality to adult and juvenile survivorship in the population without making numerous assumptions, including the assumption that blade strike mortality is additive to other mortality sources and not compensatory. Finally, very little is known about juvenile survivorship in burrowing owls (see Klute et al. 2007).

However, as a thought model, if one assumes that mortality due to wind turbines is additive, that adults and juveniles are killed by turbines in proportion to their occurrence in the population, that all owls killed came from the resident population, and that adult and juvenile survivorship in areas without turbines is 0.61 and 0.50, respectively (see Klute et al. 2007), then the presence of the wind farms in the study area would lower adult survivorship to a range of 0.42 to 0.53 and juvenile survivorship to range of 0.35 to 0.43, for 2006 and 2007, respectively. Given these survivorship ranges, a reproductive rate of approximately 2.50 young per pair would be required to sustain the local population (see Klute et al. 2007). The owls in the study area had reproductive rates of 3.44 and 1.95 juveniles per pair in 2006 and 2007, respectively. So in 2006 the local population would have been self-sustaining whereas in 2007 it would not have been self-sustaining. Even if the foregoing assumptions are valid, more years of data would be required to discern a trend, due in part to the fact that the burrowing owl experiences large inter-year fluctuation in occupancy and productivity rates (DeSante et al. 2007).

No estimates for golden eagle mortality were produced in this study, but the incidental find indicates that they are also being adversely affected by the District's wind farm leases. Based on an extensive radio-telemetry study and analysis of golden eagle mortality in vicinity of the

APRWA, Hunt and Hunt (2006) estimated that more eagles are killed by turbine blade strikes than can be produced by the "local" studied population of 58 pairs. In other words, the long-term impact of the APWRA on the local golden eagle population is clearly negative.

Acquiring the power output data for the Howden wind turbines provided the District the first opportunity in the APWRA to relate bird mortality to wind turbine operations. The relationship revealed was largely one of mathematical artifact. It revealed the vulnerability of ratio variables, such as mortality (deaths per unit power output), to almost entirely reflecting the value of the denominator in the ratio. The problem arises from dividing a relatively constant numerator by a highly variable denominator, and can be seen by the ratio values declining inversely with increasing power output. This pattern was recognized by Smallwood and Thelander (2004), but their use of MW of rated capacity as a denominator was much cruder than using actual power output.

Because most of the Howden turbines that killed birds over the course of the study in fact killed only one bird meant that most of the mortality values >0 were exactly inversely proportional to power output. Only two turbines killed more than one bird, so there was almost no variation in the relationship between mortality and power output other than 0 and 1 values. The value of seeing this pattern is in interpreting mortality estimates from turbine strings throughout the APWRA, and in recognizing the variation in these mortality values will likely not be explainable by predictor variables in multivariate analysis until sufficient searches have been performed at the turbines to eliminate the influence of the denominator in the mortality ratio. Another extremely important value in the pattern is being able to identify low-producing turbines that killed one or more birds, so that perhaps these could be removed if any compromise measures are to be implemented to balance wind power output with bird deaths.

8.0 Implications for Repowering

Repowering is the replacement of older-generation wind turbines with newer, substantially larger wind turbines. With tower heights at the hub up to 60 m and rotor diameters up to 80 m, the newer turbines can reach overall heights of up to 100 m (328 ft) in the environmental setting of the APWRA (elsewhere, new-generation turbines can be much larger). Because the newer-generation wind turbines are larger, they can replace the older turbines on the Souza parcel at a ratio of about 1:6 and still achieve similar energy production.

Two companies operate wind farm leases on the District's Souza parcel. Both leases expire in 2014. One company is not planning to renew its lease and will remove its 21 operating Nordtank turbines from the northeast corner of the parcel when the lease expires. The other company intends to renew its lease and repower the Tres Vaqueros Wind Farm, which encompasses portions of the Souza parcel as well as private lands and Contra Costa Water District lands to the north of the Souza parcel. As of September 30, 2007, the end of fieldwork for this study, the company intended to replace its 43 Howden model turbines on the Souza parcel with 6 new-generation turbines of about 1.1 MW capacity each.

8.1. Benefits of Repowering

Wind is a renewable energy source that has a low carbon footprint, and thus reduces rates of global warming compared to the burning of fossil fuels. The wind farm leases produce a stream of revenue to support District operations. Wind turbines also create an opportunity to incorporate a "clean energy" component to naturalist-led tours at Vasco Caves Regional Preserve. An additional benefit would accrue to the extent that repowering can reduce bird and bat mortality rates relative to the current wind farms. This topic will be discussed below.

8.2. Costs of Repowering

Due to an abundant prey base, favorable winds and its location in a migratory corridor, the Altamont Pass Wind Resource Area has the highest raptor use of any wind farm that has been surveyed for bird activity. It also has the highest known raptor kill rates of those that have been monitored for fatalities (see Smallwood and Thelander 2004, 2005). In addition to raptors, other birds and bats are killed by wind turbines.

In general, replacing older wind turbines with fewer larger turbines is thought to reduce kill rates by virtue of the fact that there are simply fewer turbines in the landscape. However, the picture is more complex than this. The newer turbines extend higher into the air column and have a much greater rotor sweep than the older turbines. Because the flight heights of various raptor species differ, the newer towers can be expected to have variable effects on raptor mortality. For example, depending on wind direction, this study showed that American kestrels hover and kite at average heights of 11 m to 21 m, while red-tailed hawks hover at average heights of 22 m to 38 m (Figure 37). For a 50-m turbine tower with a 60-m rotor sweep (30-m blade length), most American kestrel hovering flights would be below the lowest point of the sweep, i.e., below 20 m, while most red-tailed hawk hovering flights would fall entirely within the rotor sweep. However, within 200 m of wind turbines, American kestrels hovered or kited higher—well within the rotor-swept area of the proposed new turbines (note, however, that the sample size was small).

Raptor responses to turbine presence were variable and related to turbine operations. Combining all observations of raptor flights at <85 m above ground (assumed maximum height of repowered turbine/blade combinations), this study found that raptors flew more often than expected within 25 m of the closest turbines, less often than expected at intermediate distances from the nearest turbine (75 m to 350 m), and more often than expected at greater distances from the nearest turbine (375 m to 775 m). However, selection for the 25-m zone around turbines was greatest while the turbines were off and dropped sharply while the turbines were operating. Separating observations by species, results showed that golden eagles and red-tailed hawks flew closest to turbines more than expected while American kestrels and northern harriers flew closest to turbines less than expected. Although there is some evidence indicating avoidance of turbines by raptors, golden eagles were observed to be nearly oblivious to operating wind turbines and are susceptible to turbine collision on multiple slope settings.

In summary, based on flight behavior, it would appear that risk of blade strikes by the repowered turbines will likely be higher for golden eagles and red-tailed hawks, but could be lower for American kestrels and northern harriers.

Why some raptors flew closer to the turbines than expected by chance could be due to two factors: (1) presence of prey populations and/or (2) topographic features such as slope and aspect that promote favorable winds, e.g. declivity winds, for foraging flights. The study found that raptor flight behavior related more strongly to slope attributes than to prey distribution per sé. Raptors are thus keying in on the same topographic features that also provide ideal conditions for placement of wind turbines. In fact, five of the six sites proposed for the new turbines on the Souza property are on ridge lines with significant south-southwest slope aspects. These are precisely the locations where the research team observed every raptor species and category of flight behavior (Figure 76) and also where the most fatality finds were documented (Figure 77), especially of burrowing owls. Of the 81 observations recorded of bird flights within 50 m of the proposed turbine locations, 55 were of red-tailed hawks, 14 were of common ravens, 8 were turkey vultures, 1 was a northern harrier, 2 were prairie falcons, and 1 was a goose. Twelve of these observations were at elevations above mean sea level overlapping the height domain of the rotors of the proposed new turbines (Figure 78). Nine of these observations were of red-tailed hawk, 2 were turkey vultures, and 1 was the goose. However, flight heights might change after the proposed turbines are installed, possibly putting some species at more risk, and others at less risk.

Although repowering has been ongoing both in the APWRA and elsewhere, very few studies of associated changes in avian and bat mortality have been completed. Additionally, most of these studies are not directly comparable to the Souza parcel because of location or turbine type. However, Smallwood (2008, Appendix G) compared mortality estimates at a repowered wind farm in the APWRA to mortality estimates across the entire APWRA (to enable comparisons between wind farms, mortality rates can be expressed as number of deaths per megawatt of generation per year: number of deaths/MW/year). The wind farm, known as Diablo Winds, replaced 169 Flowind F-17 and F-19 vertical-axis wind turbines ("eggbeaters") with 31 Vestas V47 horizontal-axis (tubular) wind turbines. The V47 turbines, each with a rotor diameter of 47 m, were erected on towers with 50-m and 55-m hub heights. The repowered -Diablo Winds wind farm consists of 24 turbines with a maximum blade height of 73.5 m and 7 with a maximum blade height of 78.5 m. These maximum heights are lower than the 80-m height anticipated for the Souza parcel wind turbines. Compared to the entire APWRA, Smallwood (2008) found that the adjusted mean mortality per string at Diablo Winds, expressed as deaths/MW/year, was 13% lower for golden eagles, 36% lower for red-tailed hawks, 8% lower for American kestrels, and 74% lower for burrowing owls. Overall, total raptor mortality was 46% lower and total bird mortality was 29% lower than elsewhere in the APWRA. Bat mortality, however, was 800% higher than elsewhere in the APWRA. Repowering, therefore, could result in lower mortality for most birds, but higher mortality for bats.

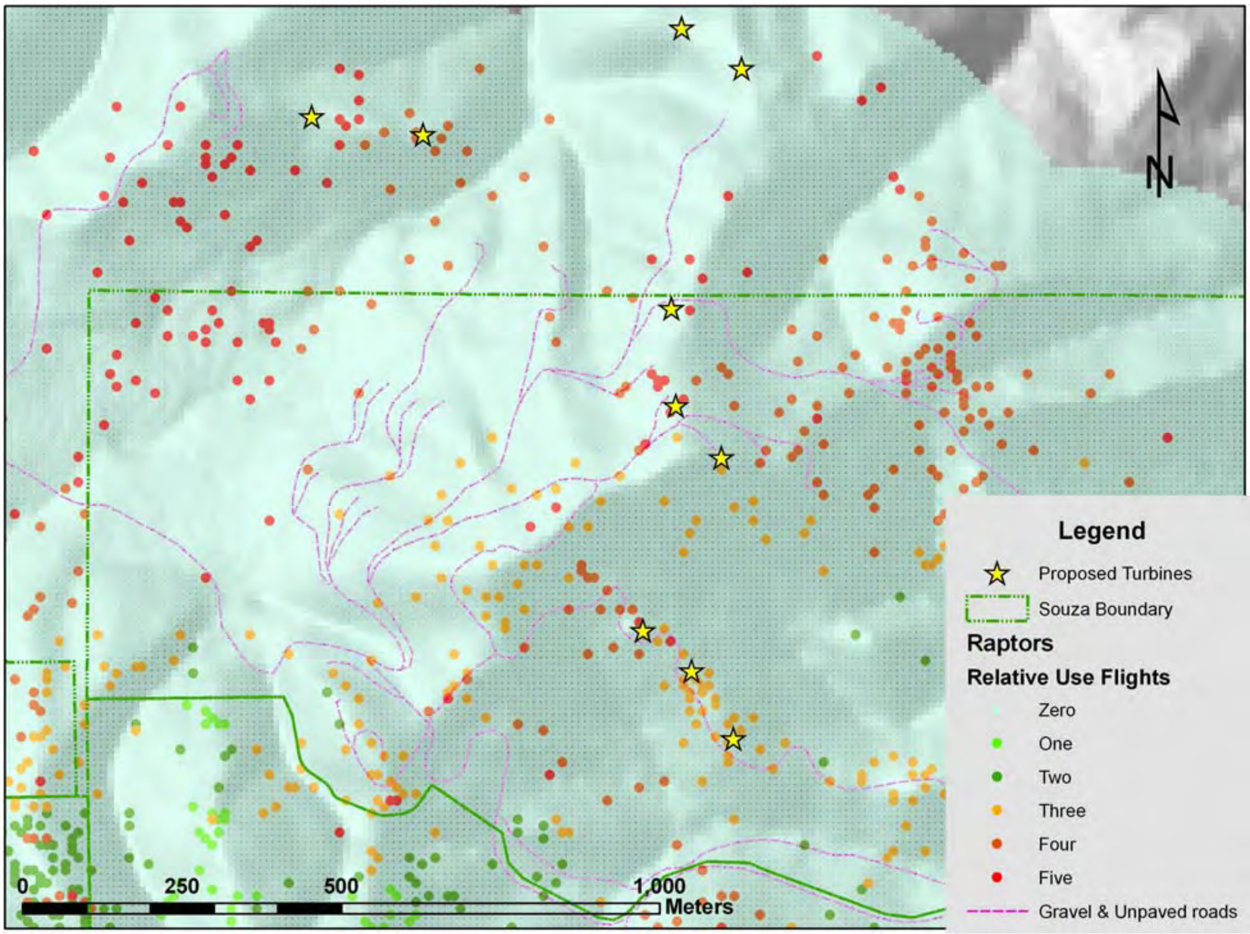

Figure 76. Raptor observations (circles) per observation point (OP) within the northwest portion of the study area where new wind turbines are proposed (yellow stars). Note that considerable raptor flight activity was recorded around five of the six proposed new turbines.

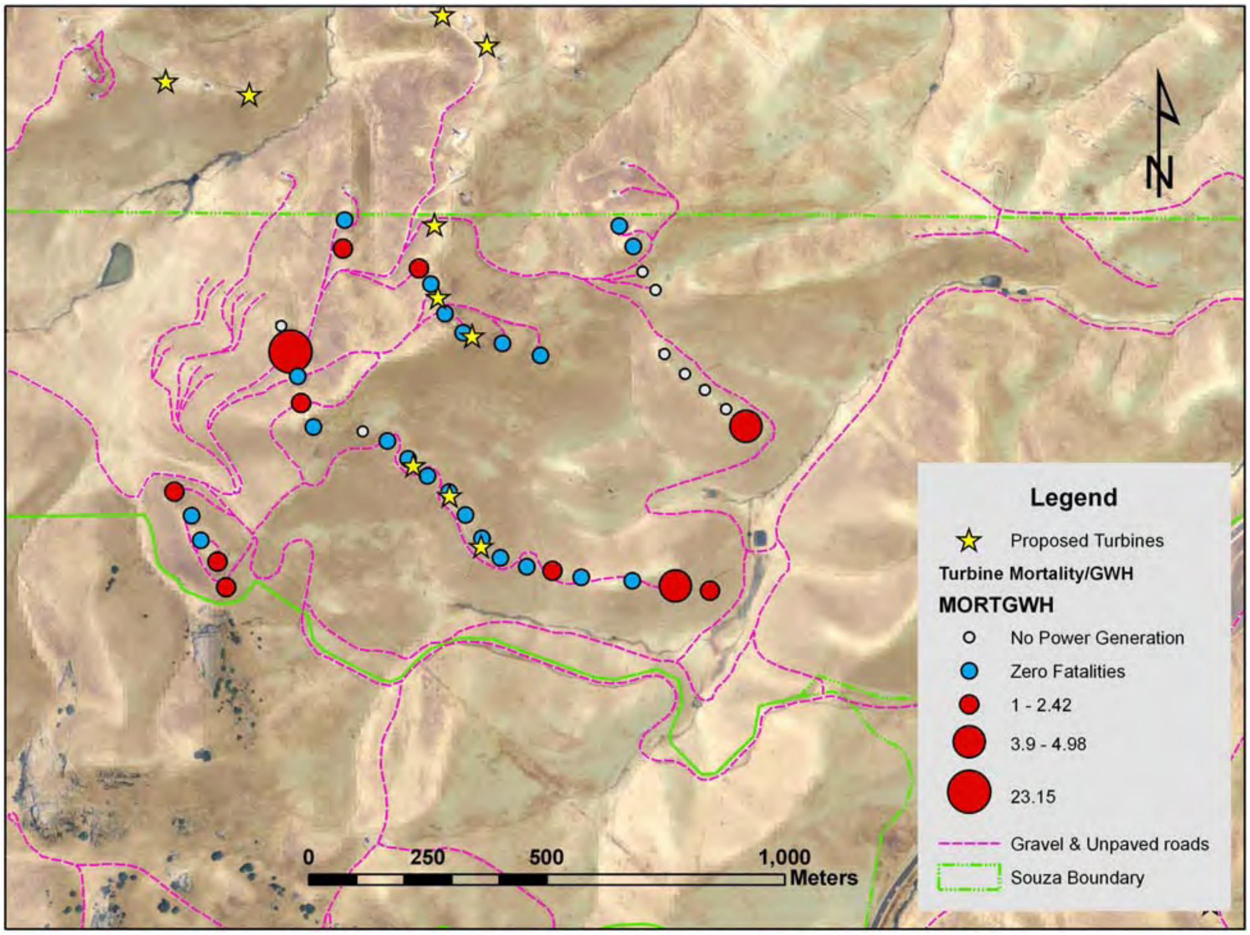

Figure 77. Bird fatalities per gigawatt-hour (GWh) generated by each Howden wind turbine during the fatality monitoring period of the study (16 months). Wind turbines associated with apparently high numbers of birds/GWh were those that generated few GWhs, so were wind turbines that operated relatively rarely or intermittently. Yellow stars denote the locations of proposed new wind turbines.

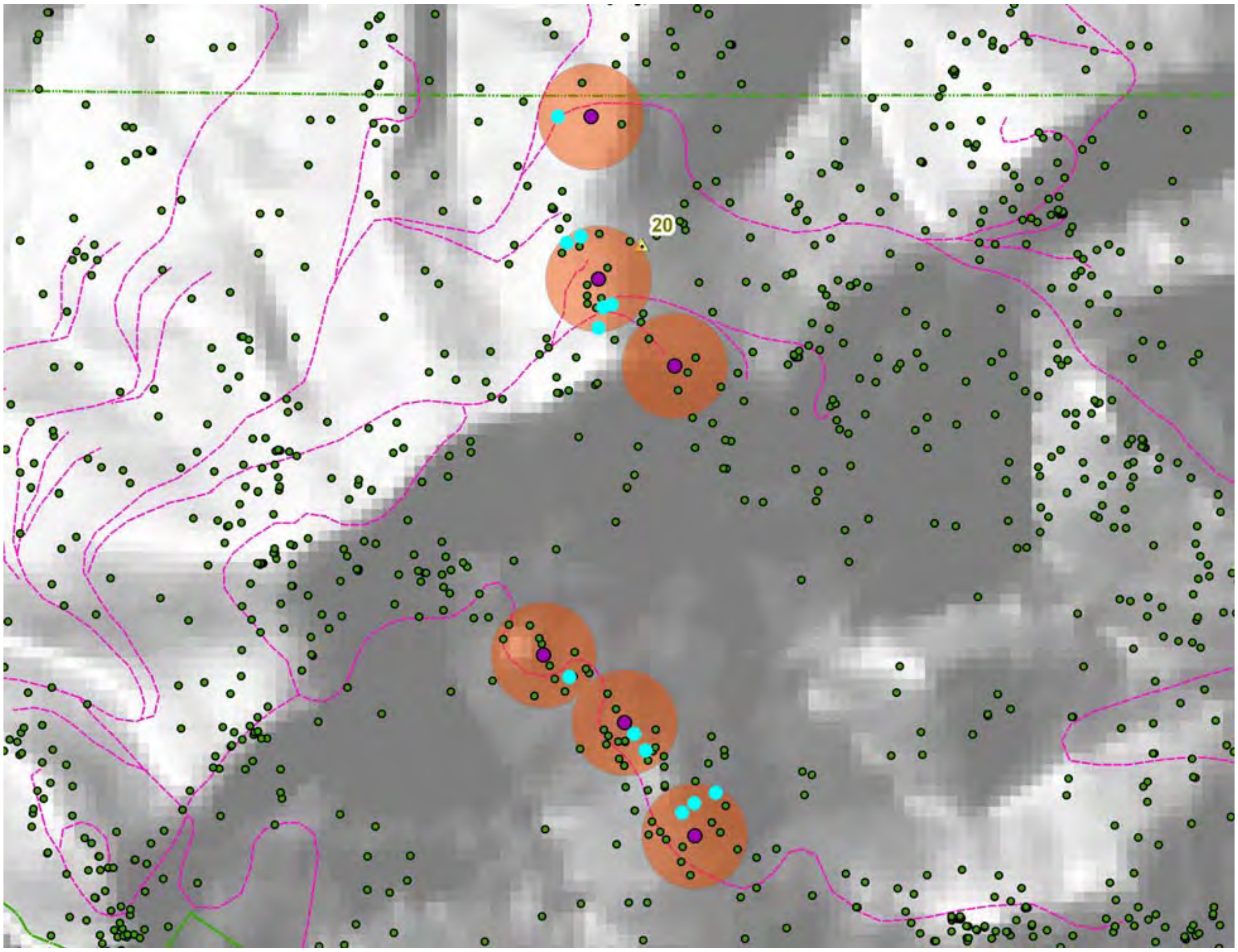

Figure 78. Of 81 raptor and common raven flights (green circles) within 50 m (orange zones) of proposed new wind turbine locations (shown as magenta circles), 12 (light blue circles) were at the mean elevation above sea level corresponding with the likely height domain of the rotors, ranging from 24.5 to 84.5 m above ground, and assuming a hub height of 55 m and a blade length of 29.5 m.

A caveat to the reduction in bird kills associated with the Diablo Winds repowering stems from this project's scavenging study, which may have more realistically measured actual scavenger rates compared to previous, conventional scavenger studies. The effect on mortality estimates at the Souza parcel was dramatic. Overall bird mortality was 160% higher, and overall raptor mortality was 200% higher, than estimates based on scavenger removal rates using conventional methods. If these higher mortality estimates hold true, then they will offset much of the supposed "reduction" in mortality achieved through repowering.

All the data presented here indicate that repowering the Souza parcel will continue to kill birds and bats, though it is possible that fewer birds will be killed due to increased tower height. It is unknown what effect continued turbine-caused mortality will have on local raptor populations. Evidence presented here suggests that turbine-caused mortality of burrowing owls could have a significant impact on the local burrowing owl population. Golden eagles are also problematic. Information from a six-year study (Hunt and Hunt 2006) on radio-tagged golden eagles in the

Diablo Range suggests that the APWRA has a negative impact on the local eagle population, i.e., eagles nesting within 30 km of the APWRA. Of 267 radio-tagged eagles, 100 fatalities were recovered. Of these, 42 birds were killed by blade strikes. This led Hunt and Hunt (2006) to estimate that about 50 golden eagles are killed per year in the APWRA under current conditions. Combining this estimate with age-specific mortality data (golden eagles require five years to reach breeding age) suggests that in order to compensate for 50 turbine-related eagle deaths per year, the reproductive output of 167 pairs is required. However, because the local population consists of only 58 active territories, immigration into this population is required to maintain its current level. Evidence from the one repowered wind farm in the APWRA (Diablo Winds) suggests that at best a 13% reduction in the golden eagle mortality was achieved. Even at this lower level of mortality, continued immigration would be required to sustain the local golden eagle population. Thus, the APWRA will likely continue to serve as a population "sink" for golden eagles for the foreseeable future.[7]

8.3. Reducing Impacts of Repowering

Unfortunately, the study results for using vegetation management as a means to redistribute fossorial mammal populations and thereby reduce raptor foraging around wind turbines were inconclusive. Nevertheless, the data suggest several possible measures that could be employed to reduce the negative impacts of repowering. If repowering moves forward, the EBRPD should make every effort to ensure some or all of these measures are adopted by the wind farm.

8.3.1. Avoid South- to West-Facing Slopes

The behavior data suggest new wind turbines should not be placed on slopes or ridge crests of slopes facing south, southwest, or west. Five of the six proposed turbine locations are situated on major SW-trending slopes in the Souza parcel where raptor flights and fatalities converged. Alternative locations in Souza should be considered. Wind turbines should be located on the slopes that are leeward to the prevailing wind directions, so long as the towers are close enough to the ridge crest or hill peak and sufficiently tall for the rotor plane to intersect with the declivity winds passing over the hill. This strategy was presented as the premier measure to minimize bird collisions in the Buena Vista Wind Energy Project on the east side of Vasco Road (Lamphier-Gregory et al. 2005).[8]

During high winds, hovering and kiting birds can be expected to be higher off the ground, and some species may be more vulnerable to collision with higher wind turbines than others. Nevertheless, tower height should be maximized, but more concern should be directed toward siting wind turbines away from areas where prevailing high winds and slope intersect.

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[7] On March 5, 2007, District staff picked up a golden eagle on the former Souza property which had been severely wounded by blade strike.

[8] It should be noted, however, that the towers actually installed at Buena Vista were sometimes shorter than promised in the EIR, and these deviations from the EIR were at risky locations.

8.3.2. Conduct a Tier Analysis

The fatality data suggest the tier classification of Smallwood and Spiegel (2005) was highly accurate in predicting which wind turbines would kill more birds in the Souza/Vasco study area. The factors contributing to this tier classification should also be considered when siting new turbines. Mitigation should be directed toward turbines at the ends of rows, those lower on slopes and ridgelines, and those more isolated from other wind turbines.

8.3.3. Cluster Turbines

The data also suggest the wind turbines might kill fewer birds if they are clustered near each other, and more habitat space is left between clusters for raptors to forage. This study showed that raptors fly much more often over areas without wind turbines. Thus, it is recommended that wind farms include a mosaic of areas with turbine clusters interspersed with turbine-free areas, particularly significant hills or ridges with major slopes facing the direction of prevailing winds. Replacing the current 40 or so Howden turbines with six larger, new-generation turbines would in itself create more turbine-free land in Souza and be a positive step. Conversely, clustering the six turbines elsewhere in the Tres Vaqueros Wind Farm, off of EBRPD land, would create a large, contiguous island of turbine-free land in the sea of turbines that is the APWRA.

8.3.4. Manage Grazing Impacts

Leaving plenty of room for raptors to forage, and continuing to graze sheep seasonally in the case of the EBRPD Souza parcel—or shifting to seasonal, rather than year-round, cattle grazing where appropriate—may influence long-term changes in prey composition and abundance and possibly encourage raptors to forage at safer distances from the wind turbines. However, the ways in which raptors forage over the complex landscape of the APWRA are unlikely to change; as the data suggest, raptors will likely continue to fly over ridge crests and hill peaks, making use of declivity winds, regardless of the abundance and distribution of pocket gophers or ground squirrels on the slopes below. Raptors will continue to be vulnerable to collision on landscapes with wind turbines.

8.3.5. Other Mitigation Options

Auditory or Visual Alerts

Dooling (2002) and Dooling and Lohr (2001) assessed the likelihood auditory warnings could be added to wind turbines to reduce bird collisions, but they concluded such warnings would be ineffective. Wind turbines already make ample noise audible by birds, so adding noise would not likely provide additional warning. Strickland et al. (2001) tested the hypothesis that ultraviolet light would improve a diurnally active bird’s ability to see wind turbines coated with a UV-reflecting covering. Preliminary results indicated that UV-coated turbine blades have no advantage over non-UV coated turbine blades (Young et al. 2003). McIsaac (2001) suggested that one explanation for this outcome was that a uniform UV color against a high-UV background might actually reduce the blade’s visibility.

McIsaac (2001) recommended applying high-contrast paint to wind turbine blades, but there are no data from the field indicating whether this measure would be effective. Similarly, Hodos

(2003) recommended precision blade painting, or painting one blade black and two white, to reduce the distance at which raptors approaching perpendicular to rotor plane experience motion smear. In the laboratory such painting schemes reduced the distance at which American kestrels experienced motion smear, but it is unknown whether this reduced distance will mean anything in an operational wind farm. If diurnal raptors get killed after they are flushed from perches at night, or if they are killed more often when approaching horizontal-axis turbine blades from parallel to the rotor plane (i.e., flying from the edge of the rotor plane toward the hub), then motion smear and the distances at which the phenomenon occurs will not matter.

Rodent Control

Hunt et al. (1999) and Hunt (2002) advocated for rodent control in the APWRA in order to reduce ground squirrel numbers and discourage golden eagles from foraging there. The wind turbine owners implemented rodent control over large portions of the APWRA from 1997 through 2002, during which time Smallwood and Thelander (2004, 2005) collected bird utilization and mortality data. Smallwood and Thelander concluded the rodent control program made little difference to golden eagle site utilization or mortality, and that it appeared to exacerbate mortality of red-tailed hawk. Smallwood and Thelander (2004, 2005) ended up recommending the rodent control program be discontinued due to its ineffectiveness and because it threatened multiple special-status species including California red-legged frog (*Rana aurora draytonii*), California tiger salamander (*Ambystoma californiense*), San Joaquin kit fox (*Vulpes macrotis mutica*), and burrowing owl.

8.3.6. Summary of Mitigation Measures

In summary, potential mitigation measures to reduce the avian impacts of repowering at the Souza property include:

- Siting turbines away from current high-raptor-mortality locations
- Maximizing tower height
- Not placing towers on ridge crests or slopes facing south, southwest, or west, or at least placing towers on slopes to the leeward of prevailing winds
- Clustering towers rather than placing them in strings to reduce the number of Tier 1 and 2 towers (end towers).

9.0 Summary of Objectives and Conclusions; Future Research

9.1. Summary of Research Objectives and Conclusions

Most of the objectives of the study were achieved, though not always to the level planned (Table 28). The original grant proposal outlined several years of work. However, the overall grant duration was reduced from three years to 18 months. Therefore, the time in the field was extremely short relative to the hypotheses being tested, especially for testing how grazing management might affect burrowing mammal distributions and raptor foraging patterns. Nevertheless, future analysis of the data collected from multiple tasks will relate specific bird behaviors to slope attributes, grazing patterns, an unplanned burn, species-specific fossorial mammal burrow densities and distributions, presence/absence and operational status of wind turbines, wind patterns, proximity of nesting sites, temperature, and seasonal variation. These additional comparisons will be possible because project data on multiple environmental factors were geo-referenced and can be related to an accurate DEM (digital elevation model). These data will be used to test additional hypotheses that should help to reduce and minimize bird fatalities by wind turbines in the APWRA.

Table 28. Summary of research objectives, results, and conclusions

Research Objective	Results and Conclusions
(1) Implement grazing management plan using sheep to create treatment plots of grazed and ungrazed parcels in the study area and to measure grazing pressure and changes in vegetation associated with treatment.	Residual dry matter (RDM), effective vegetation height, and grazing pressure, expressed as animal unit months (AUM), were measured for all plots. Extreme variation in rainfall during 2006 and 2007 grazing seasons largely swamped the experimental effects of grazing.
(2) Estimate the burrowing owl nesting density and productivity, so that burrowing owl mortality could be related to the population size.	In 2006 and 2007, burrowing owl nesting density was 4.61 pairs/100 ha and 3.87 pairs/100 ha, respectively, and productivity was 3.44 juveniles/pair (n=25 pairs) and 1.95 juveniles/pair (n=21 pairs), respectively. Assuming all turbine-related owl fatalities were residents, the wind turbines in the study area would have killed an estimated 19% and 31% of the local burrowing owl population in 2006 and 2007, respectively.
(2a) Test the effectiveness of an empirical model predicting burrowing owl nesting pair density based on the size of the study area.	For the given study area, the empirical model of burrowing owl nest density developed by Smallwood et al. (2007) predicted 11 to 29 pairs of burrowing owl; the actual number of nesting pairs of burrowing owls censused in 2006 and 2007 was 25 and 21 pairs, respectively. The model was effective at predicting nesting pair density.
(2b) Test the effectiveness of an empirical	Depending on census technique, between 63% and 69%

model predicting burrowing owl nest burrow locations, based on slope attributes, and characterize the degree to which burrowing owl burrow locations are influenced by slopes versus wind turbine presence.	of the burrows located in this study fell within the range of slope attributes predicted by the empirical model of burrowing owl nest burrow locations (Figure 8). Given the choice of using burrows closer to or farther from wind turbines, burrowing owls in the study area used burrows relatively farther from wind turbines, and their locations appeared to be strongly influenced by slope attributes.
(3) Determine how small mammals (and other raptor prey items) and raptors respond to changes in vegetation height and density induced by sheep grazing. This objective would help determine if prey populations and associated raptor foraging behavior could be distributed away from immediate wind turbine areas. Additionally, determine if switching from cattle to sheep grazing facilitated these objectives.	Grazing treatments did not significantly affect pocket gopher, ground squirrel, or raptor distributions. However, possible effects due to grazing were swamped by extreme inter-year variation in grass growth caused by alternating wet and dry years and short sample periods. Overall, pocket gopher burrow systems decreased in abundance between wet and dry years; ground squirrel abundance showed no trends. Vasco Caves, which was switched out of cattle in 2003, had greater pocket gopher abundance. The Souza parcel, which was switched out of cattle in 2006, had greater ground squirrel abundance. The absence of cattle pats around wind turbines in the study area did not appear to alter burrowing owl mortality associated with wind turbines, suggesting that excluding cattle from near wind turbines may not reduce burrowing owl mortality.
(4) Test whether wind turbines affect the spatial distributions and behaviors of raptors.	Based on frequency of flights within 25-m intervals from the closest turbine, raptors flew less frequently than expected near the wind turbine field, except for the 25-m interval closest to the turbines, where they flew more frequently than expected while the wind turbines were off or only feathering. American kestrels flew near turbines disproportionately less often other than expected, and while hovering near turbines, they did so at greater heights above ground than over similar slope conditions without wind turbines. Golden eagles appeared to ignore wind turbines, flying disproportionately more often within 25 of turbines even while the turbines operated, and performing the same flight behaviors at the same heights as over similar slope conditions away from turbines. Red-tailed hawks flew disproportionately more often within 25 m of turbines while the turbines were off or feathering, and hovered/kited lower to the ground in the vicinity of turbines. Burrowing owl flights were recorded only hundreds of meters from turbines during the daylight observation sessions. Although raptors may tend to avoid wind turbine fields, behavioral responses to wind patterns

	appear to bring them into very close proximity to turbines, especially while the turbines are off or feathering.
(5) Test whether raptor flights and specific behaviors relate more to landscape attributes or to spatial distributions of prey items.	In a study area where prey populations are numerous and relatively uniformly distributed, raptor flights related more strongly to specific slope attributes than they did to prey distributions. Where raptor flights strongly corresponded with prey distributions, the relationship appeared to be influenced by shared variation with slope attributes. In terms of blade strikes, the most dangerous raptor flight behaviors, kiting and hovering, occurred most frequently into SW winds above slopes of SW-trending aspects.
(6) After one year of behavior observations of birds in the study area, test whether bird flight and perching locations shift with the relocation of half the artificial rock piles.	Artificial rock piles were not moved over the short duration of this study.
(7) Estimate scavenger removal rates of bird carcasses.	Estimated scavenger removal rates were higher than measured in previous studies. A logarithmic function based on the current study predicted that after a 15-day search interval, only 35% of small-bodied non-raptor carcasses and 42% of large-bodied raptor carcasses would remain in the landscape. Scavenger removal rates were used in the calculation of turbine-related mortality. Fatality searches, spaced at one-week intervals or less, would improve precision of wind farm mortality estimates.
(7a) Identify the species that scavenge bird carcasses and the nature of scavenging events including carcass persistence in the environment.	Remote cameras effectively captured images of scavengers that visited and removed placed carcasses. Coyote and common raven, in order, were the species most frequently detected scavenging carcasses. Red-tailed hawk, striped skunk, turkey vulture, great horned owl, and raccoon were each detected scavenging separate carcasses. More than half (61%) of all placed carcasses were removed entirely from the immediate turbine search area with no trace, or they left a trace that did not meet the definition of a fatality in the APWRA. The definition of a fatality should be broadened, because even a single feather from a carcass can be left behind as a trace that persists in the landscape for long periods.
(7b) Distribute the scavenger trial carcasses one at a time, rather than in large numbers all at once, to test the degree to which scavenger swamping might bias conventional trials.	Placing carcasses at a rate assumed to be more typical of deposition by wind turbines reduces bias related to scavenger swamping, and the scavenger removal rates increased dramatically compared to conventional scavenger removal trials.

(8) Estimate mortality of bird species killed by wind turbines.	Based on newer scavenger removal rates, overall bird mortality was 1.6 times higher and raptor mortality was nearly 2 times higher than that estimated from conventional scavenger studies. About 95 birds, including 50 raptors, are killed annually by wind turbines in the study area. Of the four APWRA focal species—American kestrel, golden eagle, red-tailed hawk and burrowing owl—mortality could only be calculated for the latter two species (see 7a).
(8a) Compare mortality measured as fatalities per kWh of electric power generated by wind turbines to explore the utility of this mortality metric.	Raptor mortality related inversely to electric power output from the turbine string, mostly due to a relatively constant numerator (fatalities) being divided by a highly variable denominator (power output) in the ratio expression of the mortality metric. The number of fatalities was not proportional to power output. Less-productive turbines that kill raptors might warrant shutdown and removal as a means to balance wind power generation with raptor mortality.
(9) Assess repowering scenarios on the Souza parcel to guide the siting of new-generation wind turbines and to manage the range to minimize bird fatalities.	Five of the six proposed new turbine sites are on ridge lines having significant SW-trending slopes that coincide with areas of high raptor use and avian fatalities from existing turbines. New turbine locations should be set on the lee side of ridgetops away from prevailing winds, and hills with large SW slopes should be avoided. Turbine height should be maximized. Results from effects of using range management to redistribute fossorial mammal prey were inconclusive, and it appears that raptor flight behavior is more influenced by wind/slope interaction than local prey distribution. Nevertheless, seasonal grazing, as opposed to year-round grazing, may be improving conditions for native grasses and pocket gophers relative to ground squirrels, which could alter raptor foraging patterns. Repowering will not eliminate turbine-related avian or bat mortality. It may reduce bird mortality, but will likely increase bat mortality. The APWRA may serve as a population sink for the golden eagle, if not also for the burrowing owl.

9.2. Recommendations for Future Research

Converting from cattle to sheep grazing appears to be encouraging native plant species on Vasco Caves Regional Preserve, and may be increasing the density of pocket gophers over ground squirrels. These changes could benefit the environmental condition of the Altamont

Pass. Shallow-rooted annual grasses could be replaced by deeper-rooted perennial grasses, which could stabilize slopes and conserve grazing forage. Transitioning to deeper-rooted plants might also slow sediment loading of ephemeral streams, ponds, and vernal pools, thereby benefitting multiple threatened and endangered species, including long-horned fairy shrimp, vernal pool fairy shrimp, California red-legged frog, and California tiger salamander. The transition appears to be increasing the spatial distribution and abundance of pocket gopher, which is a keystone species, and provides habitat for many species of arthropod and vertebrates, the suite of which provide forage for raptors. This transition should benefit raptor conservation by enhancing the habitat and perhaps shifting some portion of raptor foraging flight patterns. Further research should be directed towards understanding why Vasco Caves supports more pocket gophers and the Souza portion supports more ground squirrels.

Now that more is known about raptor flight patterns, certain portions of the study area could be targeted for grazing manipulations. For example, it would be more informative to restrict grazing from south- and southwest-facing slopes of one or two of the four largest hills in the study area. It is now known these locations are where raptors fly disproportionately more often, so targeting these locations would provide the most powerful test for a shift in use. It would also be fruitful to allow sheep grazing on half of the non-grazed treatment plot on Vasco Caves, because this plot has not been grazed since 2002 and its rate of use by raptors and fossorial mammals has now been documented (two years of data on the mammals in this plot). Grazing a portion of this plot, and restricting grazing from at least two sizeable plots on Souza, would provide much more insight into how grazing affects small mammals and raptor flights.

Lessons learned include the need for superior controls within grazed plots. Fencing sheep from small plots or strips of grassland within grazed areas would provide the basis for calculating the effect of sheep grazing on grass height, RDM, and other variables that could affect fossorial mammal distribution and raptor foraging behavior. These fenced plots would need to be established and maintained by the EBRPD.

Another research opportunity would be to incorporate neighboring properties into the study in order to compare the effects of cattle grazing. All the land surrounding the study area was grazed by cattle. Monitoring fossorial mammals, raptor flights, and vegetation conditions to the north and south, or east and west, of the study area would more clearly document the effects of sheep grazing.

Recording the positions of flying and perched birds from observation points could be improved by using notepad computers instead of handheld maps. Use of geo-registered ortho-photos proved much superior to previous maps used for recording bird positions, but the problem of crowding reported positions remains. Observers often see birds using the same locations repeatedly, which means the position of that location needs to be recorded on a given map repeatedly. The observers cannot record multiple use of the same position without losing legibility, which is crucial when the data are digitized for incorporation into a GIS. Those who digitize the recorded positions spent inordinate amounts of time trying to interpret the writing of bird positions. This time could be eliminated, and accuracy of recording positions could be much improved, by using orthophotos depicted on notepad computers in the field. The same exact position could be entered onto a notepad monitor repeatedly without suffering the crowding issue. This would eliminate the need for observers to record the position to the right or to the left of the actual position in order to minimize crowding. The cost of the computers would be much more than offset by the time saved digitizing positions from hard-copy orthophotos.

Whether wind turbines are operating or not should be recorded along with distance to nearest turbine for every raptor observation. This will assist in determining why raptors may avoid turbines and under what conditions.

The responses of grassland songbirds to grazing treatments could be tested relatively easily by walking intercept transects across the study area during the breeding season. Abundance estimates can be made using standard methods, and these estimates could be related to grazing treatments and measured grassland attributes, such as average RDM.

Continued monitoring of the burrowing owl population on the study site would contribute to a much improved understanding of burrowing owl ecology in the area. The abundance and distribution of burrowing owls shifted considerably between 2006 and 2007, so it would be useful to learn whether these types of shifts are common, and whether core areas are routinely used from year to year. It would be useful to learn why burrows in certain slope settings yield more juveniles. It would also benefit the entire APWRA to learn how often the burrowing owls travel to the wind turbines in the evening, how long they spend there, what they are doing, and how they are dying there. Deploying low-lux cameras at these locations would likely record sufficient burrowing owl activity to learn what they are doing by turbines and how they are getting killed. (Low-lux cameras are now available for about $150.) Alternatively, night vision equipment could be used to watch the burrowing owls where they are being found dead by particular wind turbines. An APWRA-wide burrowing owl census is strongly recommended, as all indications suggest that there are more burrowing owls in the APWRA than previously thought.

The scavenger removal study should be continued and improved upon. The results of this initial trial pose serious implications for estimating mortality caused by wind turbines worldwide. Conventional scavenger removal trials have clearly biased results due to scavenger swamping, especially for the removal rates of large-bodied raptors. This study’s results indicate many more birds are killed by wind turbines than previously estimated, including in the APWRA. Placing carcasses one at a time prevents scavenger swamping and reveals much more accurate estimates of carcass removal rates. However, the study fell short in deployment of medium- and large-bodied non-raptor species, small-bodied raptors, and bats. Volitional placement of carcasses from these size and class categories would greatly benefit mortality estimation, as would placement of carcasses throughout the year in order to characterize removal rates by season. In addition, cameras with shorter firing and recording intervals should be used to capture quick-succession events.

Finally, expanding fatality searches to ridges and other areas in or near wind farms without wind turbines would be useful for estimating background mortality and for measuring crippling bias. Even for birds killed by predators, it would be useful to know whether they are killed by predators more often in the vicinity of wind turbines, which may facilitate prey-capture for some predators. Ample ridge crests are available for background mortality surveys in the Vasco Caves Regional Preserve.

9.3. Benefits to California

This research offers guidance on siting and operating new or repowered wind turbines in a manner that minimizes collision risk with birds.

Compared to past studies, this study provides much greater resolution in raptor observations relative to the landscape and environmental conditions. In addition, the study shows "scavenger swamping" to be a significant effect in conventional scavenger removal trials. Accordingly, this study greatly improves estimates for wind turbine-caused raptor and avian mortality in the APWRA. Although results from the use of range management practices to reduce wind turbine impacts on raptors were inconclusive, this study sets the framework for improving the design of future studies on the effects grazing treatments on small mammals and raptor flight behavior. The digital elevation model developed herein should prove extremely useful in studying future wind farm sites and in lessening their impacts. Collectively, the study results can be used to lessen impacts to raptors in the repowering of wind farms.

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11.0 Glossary

ANOVA	Analysis of variance, a standard statistical analysis
APWRA	Altamont Pass Wind Resource Area
AUM	Animal unit month, a measure of grazing intensity, is the equivalent of the effect of grazing by one cow for 31 days. In the case of sheep, 1 AUM = 5 adult animals grazing for one month.
BACI	Before-after, control-impact experimental design
DEM	Digital elevation model
DFA	Discriminant function analysis, a modeling approach planned for future analysis of study data
FL	Fuzzy logic, a modeling approach planned for future analysis of study data
GIS	Geographic information system
GPS	Global positioning system
msl	Mean sea level
OP	Observation point from which raptors (and common ravens) were observed
PCA	Principal components analysis, a method often used to simplify multidimensional data sets for analysis
RDM	Residual dry mass
SE	Standard error, the standard deviation of the sampling distribution of a statistic

Appendices

Range Management Practices to Reduce Wind Turbine Impacts on Burrowing Owls and Other Raptors in the Altamont Pass Wind Resource Area, California

Appendices A through C

Appendix A: Counts of Burrow Systems and Raptor Observations

Appendix B: Evening Observation of Burrowing Owls

Appendix C: EBRPD Bird Behavior Observation Protocol

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APPENDIX A

Counts of burrow systems and raptor observations in plots monitored during July, August and September of both 2006 and 2007. Plots were within boundaries of randomly selected sub-watersheds, where the boundaries were modified to fit with grazing treatments. Sessions were the number of behavior observation sessions during July, August and September when the observer could see birds flying over the plot from one or more OPs. BUOW refers to burrowing owl, GOEA to golden eagle, and RTHA to red-tailed hawk.

				Burrow systems			Flight observations		
Plot	**Treatment**	**Ha**	**Sessions**	**BUOW**	**Pocket gopher**	**Ground squirrel**	**GOEA**	**RTHA**	**All raptors**
15.2	Grazed 2006	2.71	12	0	22	2	0	0	1
15.2	Ungrazed 2007	2.71	7	0	27	4	0	0	1
20.1	Grazed 2006	6.53	12	2	2	65	1	1	3
20.1	Grazed 2007	6.53	7	4	0	50	0	0	3
22	Ungrazed 2006	7.10	25	0	13	35	1	19	27
22	Ungrazed 2007	7.10	15	0	5	33	1	1	2
36	Grazed 2006	4.54	25	0	16	58	2	12	17
36	Grazed 2007	5.43	17	0	1	37	2	3	7
67.4	Grazed 2006	5.52	13	14	2	17	3	4	13
67.4	Grazed 2007	5.52	9	1	0	26	4	2	14
83	Ungrazed 2006	4.42	35	0	47	14	0	2	3
83	Ungrazed 2007	4.42	21	0	15	25	0	0	2
93.1	Ungrazed 2006	4.00	35	0	11	29	1	0	1
93.1	Ungrazed 2007	4.00	21	2	4	28	0	1	1
95.1	Grazed 2006	4.43	29	0	39	16	0	3	3
95.1	Grazed 2007	4.43	23	0	16	17	2	0	5
95.4	Grazed 2006	4.27	29	0	71	7	1	13	22
95.4	Grazed 2007	4.27	23	0	19	5	0	11	19
97.2	Grazed 2006	2.43	35	0	35	1	2	10	21
97.2	Grazed 2007	2.43	21	0	10	1	0	0	4
100	Grazed 2006	2.60	17	0	57	0	2	1	4
100	Grazed 2007	2.60	16	0	40	0	2	0	2
110.2	Burned 2006	5.27	11	0	60	14	3	4	13
110.2	Grazed 2007	5.27	7	0	17	15	0	0	1

APPENDIX B

On the evening of 20 September 2007, K. S. Smallwood, B. Karas and M. Kitano visited the project site with the purpose of observing burrowing owls in the valleys surrounding the east end of the H row of Howden wind turbines on the Souza parcel. The purpose was to observe burrowing owl behavior at the edge of darkness, and to see whether any approach the wind turbines during this time of day. The majority of burrowing owl burrows were located in or near the valley bottoms, so relatively far from the wind turbines. The owls would have to fly to the wind turbines if they were to be seen there. The following is a chronology of what was observed.

Sunset As the sun set and the shadows from the western hills advanced to the east, burrowing owls emerged from their burrows. Each time the advancing shadows enveloped an occupied burrow, an owl would soon emerge, so the emergence of owls followed the shadows from west to east. Seven burrowing owls were eventually observed, including 2 over the ridge to the north.

6:40 PM The first sustained flight was observed, traveling about 30-40 m.

7:20 PM Burrowing owl activity was substantially greater, including ground hopping, short flights, and running. Owls were seen catching and eating prey items. They were chasing down prey items on the ground, sometimes running very quickly. Owls flew back and forth across the valley bottom, and up and down ephemeral streambeds, but the owls did not fly up any slopes.

7:30 PM One burrowing owl began advancing toward the nearest ridge supporting Howden turbines. It made short flights from perch to perch (stakes used for electric sheep fence, and stalks of dead woody plants) up the valley to the west and then up the ridge slope to the north. Once we began tracking this owl, we ignored all other owls we had been watching earlier.

7:40 PM The owl under observation arrived on a stake at the top of the ridge, only 20 meters from the axis of the wind turbine row.

7:45 PM While looking up toward the backlit sky to the west, we saw a barn owl fly through the rotor plane of a Howden turbine at hub height. The turbine was not operating, but we noticed how easy it was to see the owl due to the background glow from the direction of the sunset.

7:55 PM Having walked west along the side of the slope, and now looking toward the ridge crest to the north, we saw the burrowing owl hop up several meters from the ground and right next to a Howden wind turbine, though the turbine was not operating during our observations. We also saw the owl flit by a couple of times between the ridge crest and our location about half way up the slope. After these observations it was too dark to continue.

In summary, the burrowing owls were more active after sunset than during the day. At least one owl flew a considerable distance to position itself at the top of the ridge, where wind turbines were located. It appeared to forage at the ridge crest, and we noticed this location afforded the owl a backlit sky against which flying insects are easily observed. In fact, the burrowing owl perched on the aspect of the ridge that provided it a superior view of the backlit sky above the rest of the ridge crest to the north and northwest. Where we observed this owl was where one owl was killed by a wind turbine during the study. Additional observations of burrowing owl behavior are warranted at this time of day. It would be useful to learn whether the burrowing owl we observed typifies burrowing owl behavior in the Altamont Pass. If so, then the next step would be to learn whether burrowing owl fatalities at the ridge crests are caused by wind turbine collisions or predation, or both.

APPENDIX C

EBRPD Behavior Observation Protocol

Each behavior observation session shall last 60 minutes. At the start of each session, record onto the map of the OP the date (day/month/year), observer's initials, visibility (m), description of the weather (e.g., clear, overcast, raining, foggy), and the session start time.

Each map is used once, and each session at each OP will make use of a single map unless the map in use becomes cluttered by recordings of observations. If the map becomes too cluttered for effective, continued use, then initiate another map of the same OP and clearly indicate under Start Time that it is a continuation of the same session (also, affix the maps to each other).

Circle operating turbines at the start of the session whenever the OP includes wind turbines.

At the session start, record the temperature, wind speed and wind direction. Make additional recordings at 15 minutes into the session, 30 minutes and 45 minutes. The maps include spaces for these data entries. Take 3 readings at each interval and record the median values.

Throughout the session, scan the landscape for birds, turning slowly to all viewable areas. Each map includes radii of 200, 400 and 600 m from the OP to guide decisions whether to record the observation. Birds >600 m should not be recorded, and only large birds recognizable to species should be recorded >400 m (e.g., GOEA, TUVU, RTHA). As the study progresses we may decide to include records of small birds, but these will likely be restricted to ≤200 m.

Every 30 seconds, record the bird's position on the map with the head of an arrow indicating flight direction. Then write the record ID next to the arrowhead. Each new bird recorded will be represented by a unique letter, the first bird identified as A, the second as B, etc. Next to the letter write the minute into the session, and if the record is on the 30-sec mark, then follow the minute with a dash, e.g., A1, A1-, B1, B1-, B2, B2-. At the bottom of the maps are letters. Check off the letters as they are used to represent birds during the session. Checking them off will help maintain the correct letter sequence during the session.

Record locations of raptors whenever they cross through a turbine sting at or below the height of blades in the 12:00 position, or whenever birds fly within 15 m of any wind turbines.

For each record made on the map record the following data into the digital voice recorder.

- Record ID, e.g., A1, B5, C10, D11-, etc.
- Species, sex (if known), age group (if known)
- Height above ground
- Behavior

Record ID: Whereas records made half way through a minute will be denoted by a dash on the map, in the voice recorder they should be recorded as #.5, e.g., D11.5

Height above ground: can be recorded in meters or as number of tower heights above ground, where tower heights are the heights of the towers supporting turbines nearest the observed bird. We already know the tower heights, so these records can be converted to meters easy enough. They will be convenient for cases where the bird is flying high.

Behavior: choose from one of the flight behaviors in the list below. Flight behaviors are accompanied by short descriptions as a reminder during the study. If the bird is perched, record the type of perch in the right column, or whatever the perch happens to be.

Flight Behavior	**Description**	**Perch**
Fly through	Directional flight powered by wing flaps	Ground
Gliding	Directional flight with no wing beats	Rock (top, crevice, cave)
Soaring	Few wing beats, and gradual turning, often powered by thermals	Bush
Contouring	Flights close to the terrain, and changing directions and height with the terrain	Tree
Circling	Tight circles with some wing beats	Fence post
Kiting	Rapid wing beats keeping the bird in place	Utility pole
Hovering	Bird stays in place in high winds making only minor adjustments to wings	Distribution line
Diving	Wings recessed or folded for rapid downward flight, usually to attack prey or competitor	Transmission tower
Mobbing/chasing	Harassing a larger bird	Anemometer tower
Mobbed/chased	Evading harassment by smaller birds	Turbine tower
Surfing	Wind-powered flights usually perpendicular to the wind direction	Ladder on turbine tower
Ground hopping	Hops along the ground while foraging	Turbine nacelle
Fly-catching	Short flights to and from perch in pursuit of volant prey items	Turbine hub
Fleeing	Strong flight away from pursuer of similar or larger body size	Turbine blade
Flocking		Turbine catwalk
Flushed	Chased off perch	Turbine motor
Landing		
Copulating		
Carrying prey		
Carrying nest material		

At the end of each day, enter into a spreadsheet all the behavior data that were recorded on the digital voice recorder. Most of the data on the maps can be entered into a spreadsheet later.

Range Management Practices to Reduce Wind Turbine Impacts on Burrowing Owls and Other Raptors in the Altamont Pass Wind Resource Area, California

Appendix D:
Field Maps for Data Collection per Observation Point

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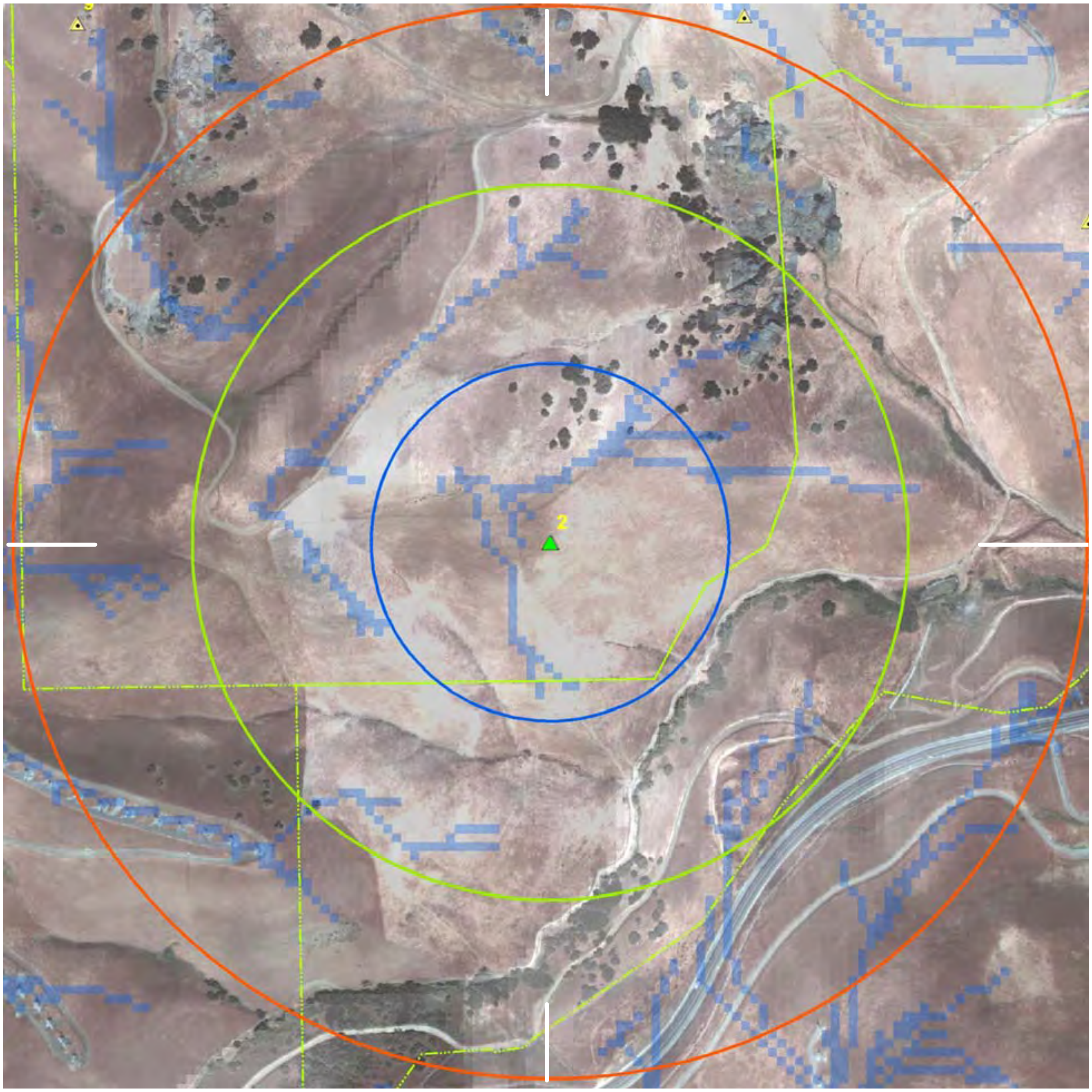
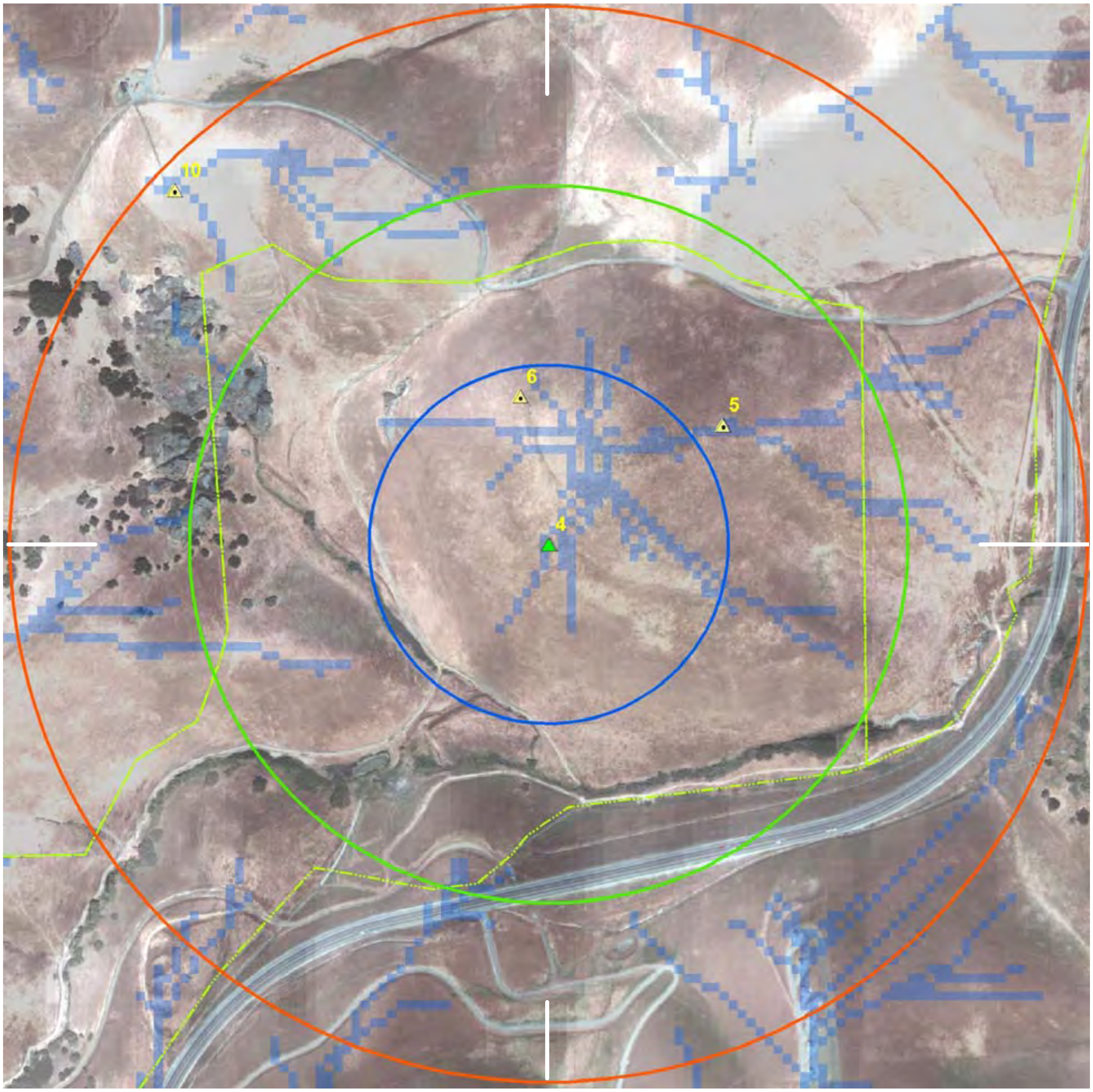
APPENDIX D



Date ________ Investigator ________ Start time _______ Weather ___________ **OP 2**

	0 Minutes	15 Minutes	30 Minutes	45 Minutes	% Cloud cover _____
Temperature	_________	_________	_________	_________	Rain _____
Max wind speed	_________	_________	_________	_________	
Avg wind speed	_________	_________	_________	_________	
Wind direction	_________	_________	_________	_________	

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



Date ________ Investigator ________ Start time _______ Weather ____________

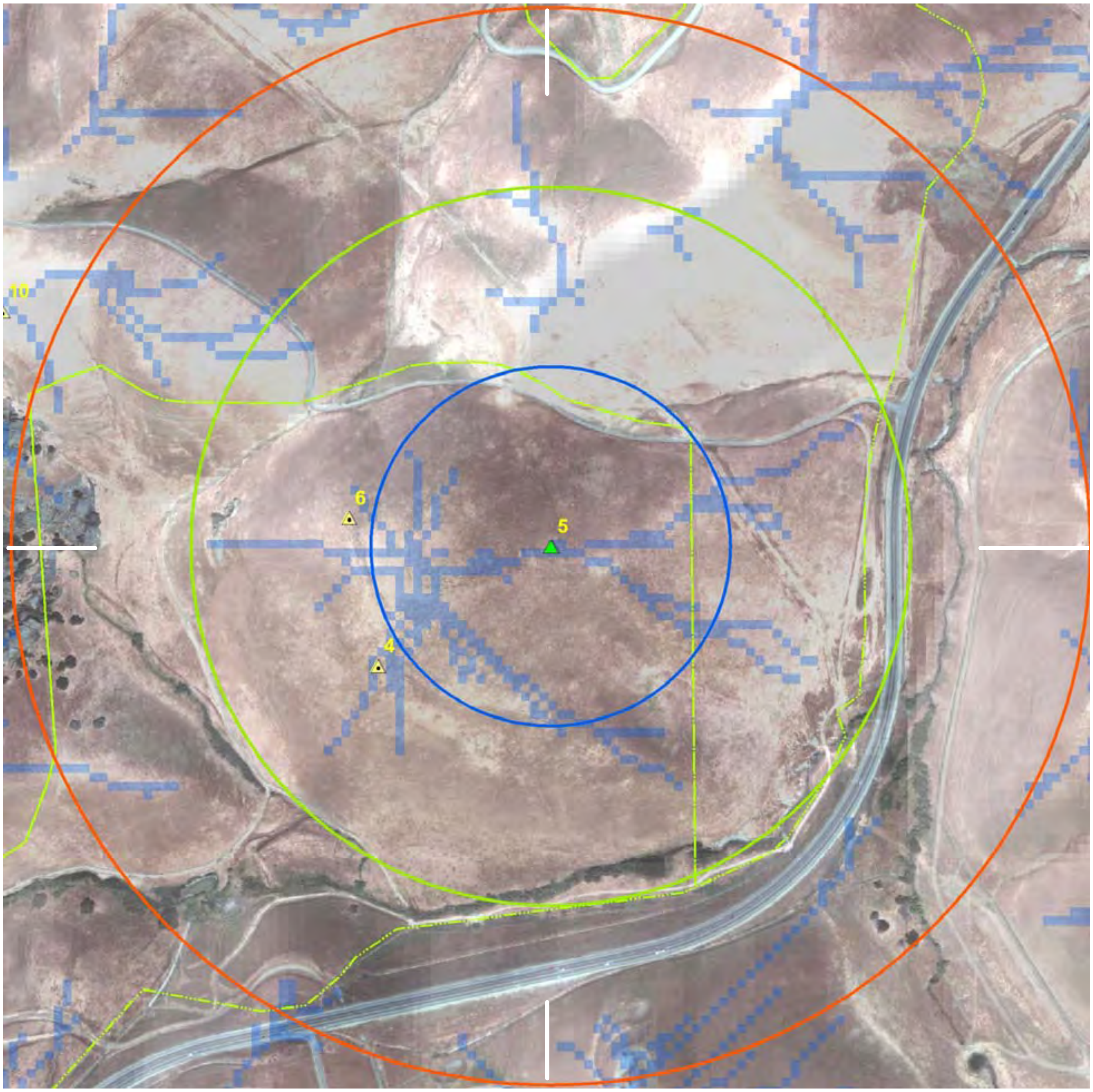
OP 4

	0 Minutes	15 Minutes	30 Minutes	45 Minutes
Temperature	_________	_________	_________	_________
Max wind speed	_________	_________	_________	_________
Avg wind speed	_________	_________	_________	_________
Wind direction	_________	_________	_________	_________

% Cloud cover _____

Rain _____

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



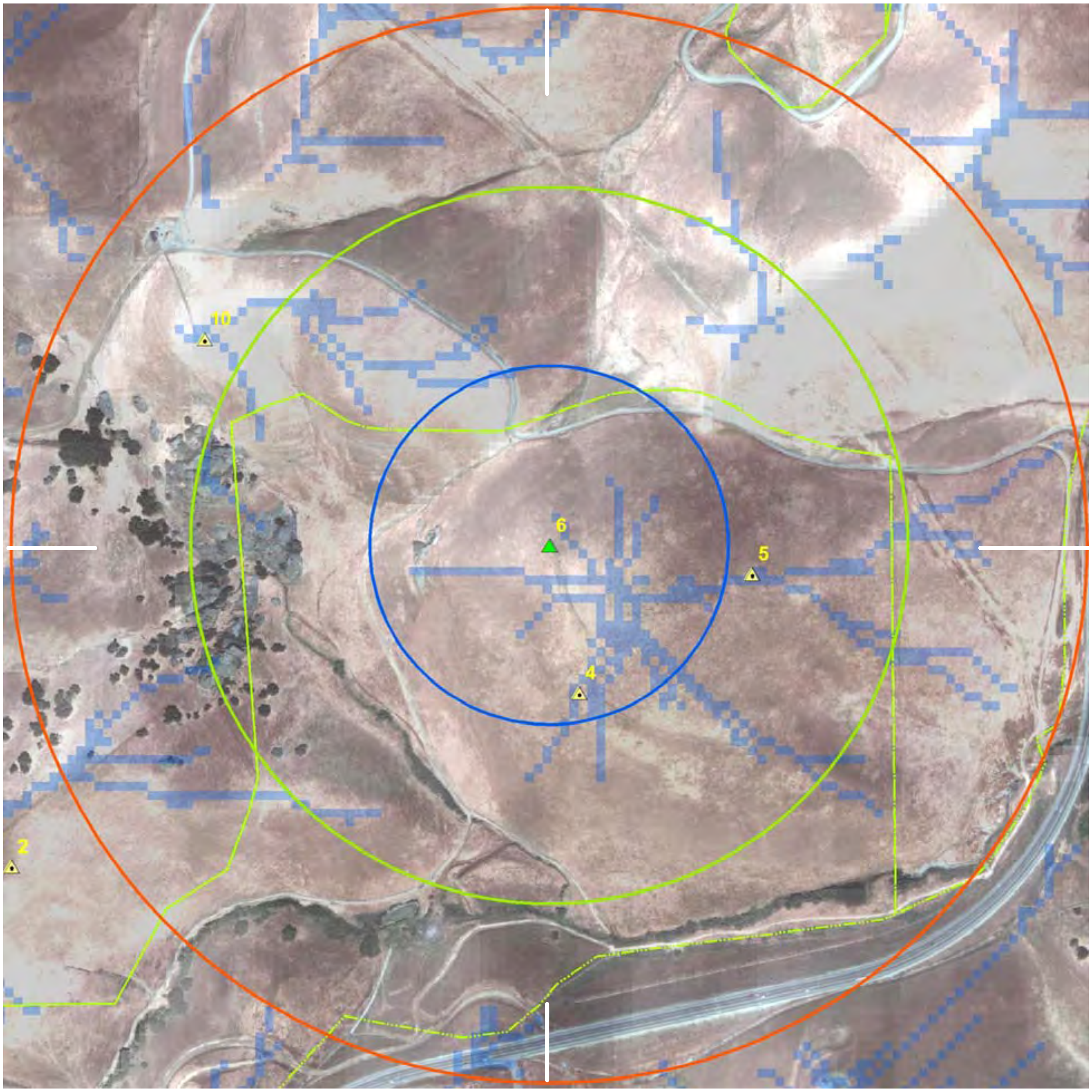
Date ________ Investigator ________ Start time _______ Weather ___________ OP 5

% Cloud cover _____

Rain _____

	0 Minutes	15 Minutes	30 Minutes	45 Minutes
Temperature	_________	_________	_________	_________
Max wind speed	_________	_________	_________	_________
Avg wind speed	_________	_________	_________	_________
Wind direction	_________	_________	_________	_________

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



Date ________ Investigator _________ Start time _______ Weather ____________

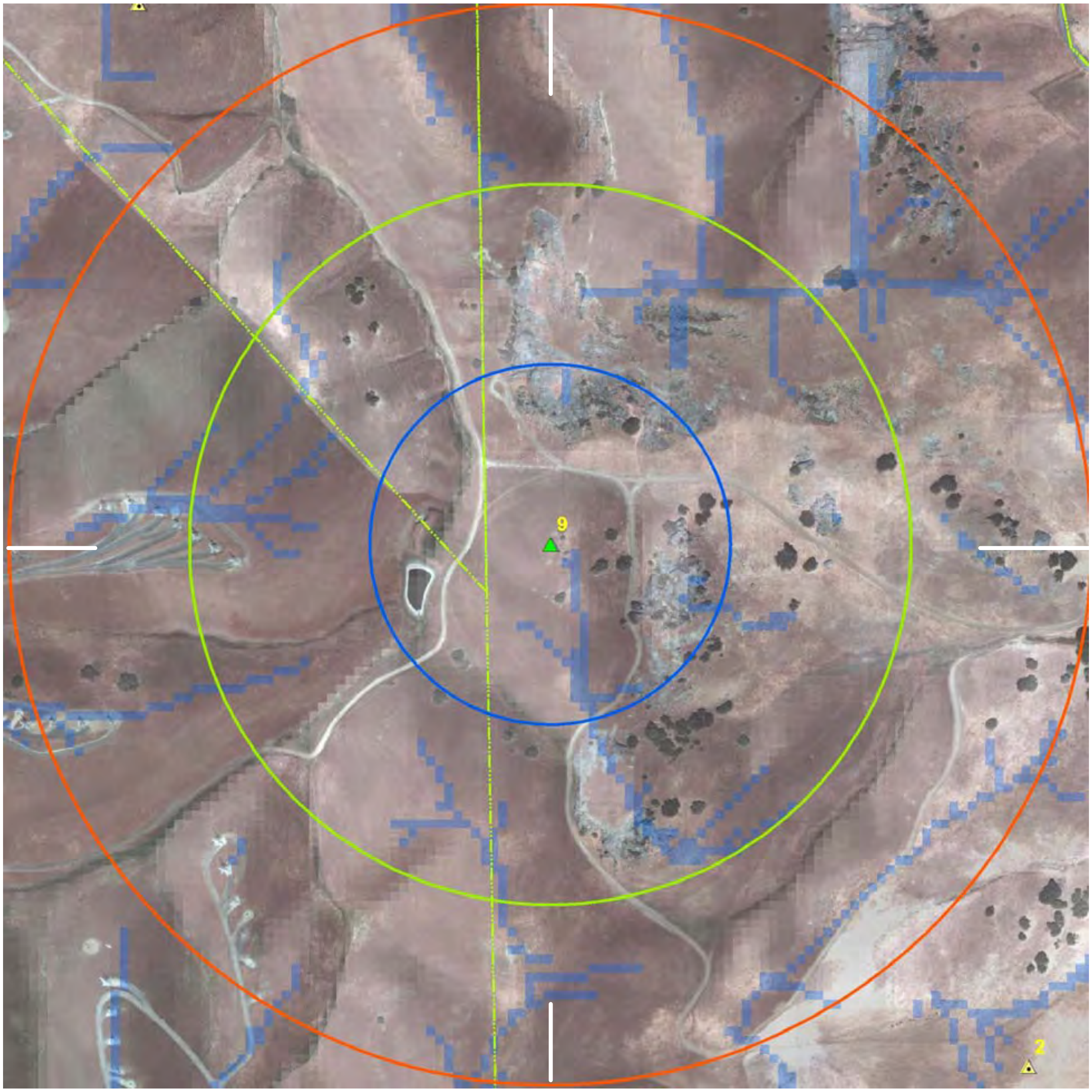
OP 6

	0 Minutes	15 Minutes	30 Minutes	45 Minutes
Temperature	_________	_________	_________	_________
Max wind speed	_________	_________	_________	_________
Avg wind speed	_________	_________	_________	_________
Wind direction	_________	_________	_________	_________

% Cloud cover _____

Rain _____

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



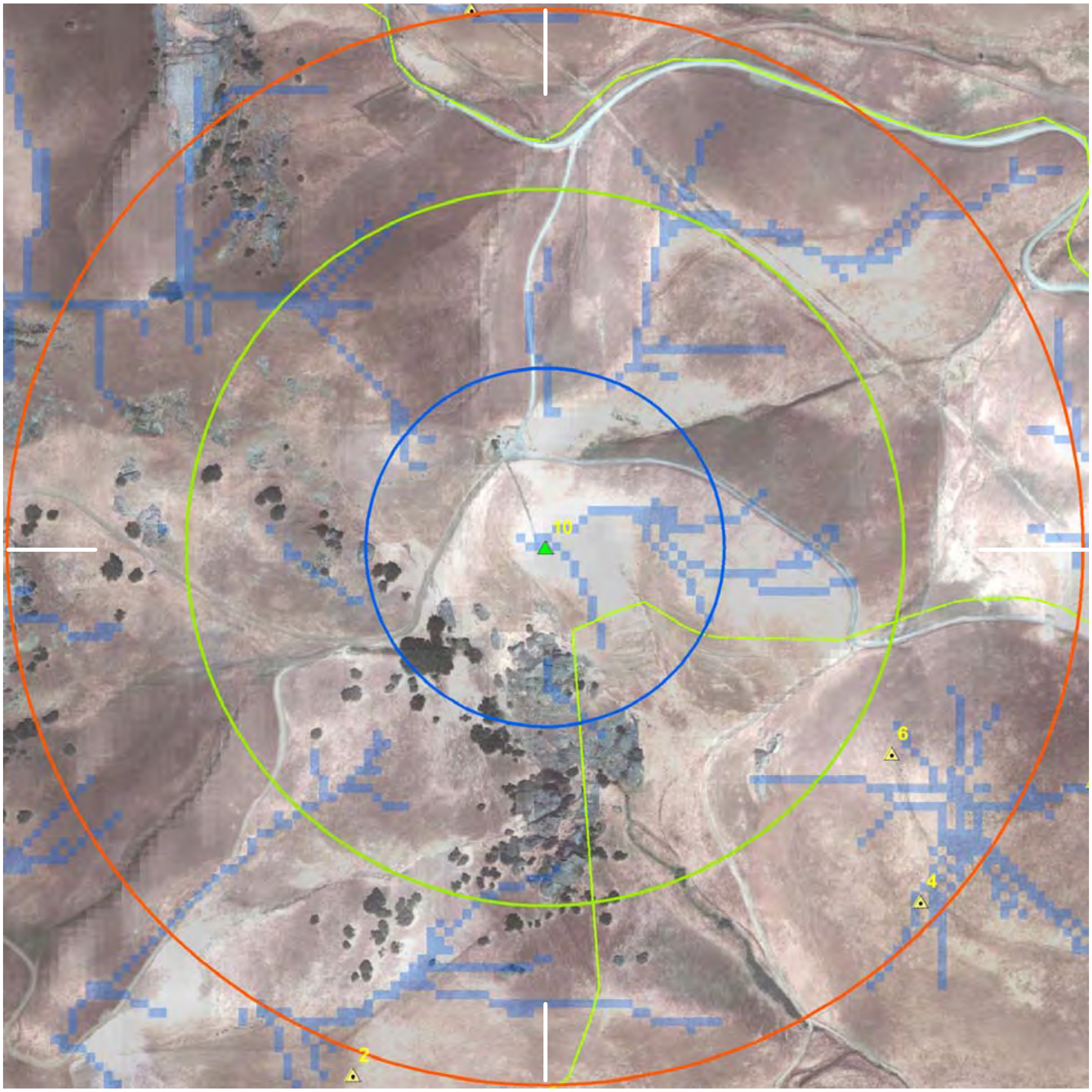
Date ________ Investigator ________ Start time _______ Weather ____________ OP 9

% Cloud cover _____

Rain _____

	0 Minutes	15 Minutes	30 Minutes	45 Minutes
Temperature				
Max wind speed				
Avg wind speed				
Wind direction				

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



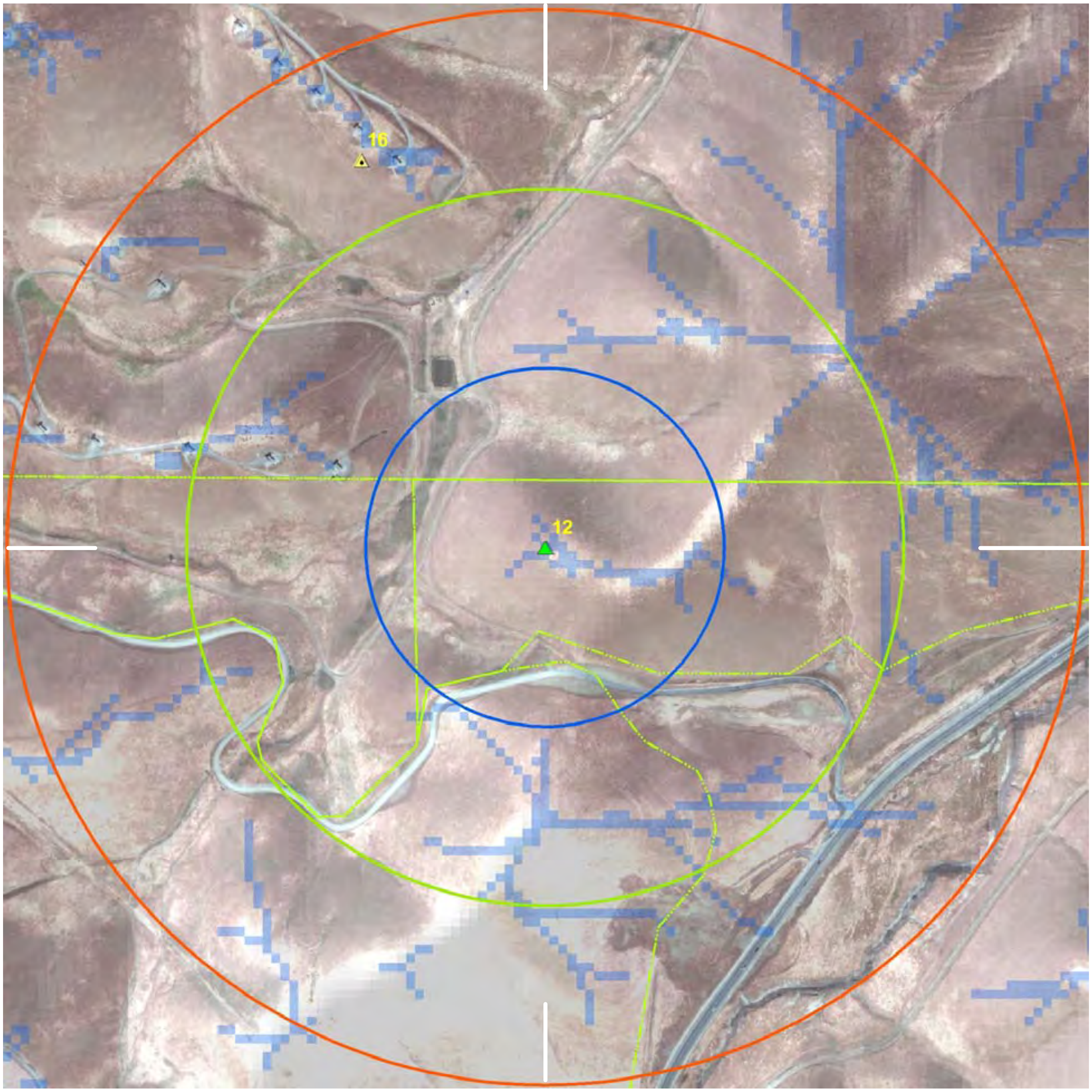
Date ________ Investigator ________ Start time _______ Weather ____________ **OP 10**

% Cloud cover _____

Rain _____

	0 Minutes	15 Minutes	30 Minutes	45 Minutes
Temperature	_________	_________	_________	_________
Max wind speed	_________	_________	_________	_________
Avg wind speed	_________	_________	_________	_________
Wind direction	_________	_________	_________	_________

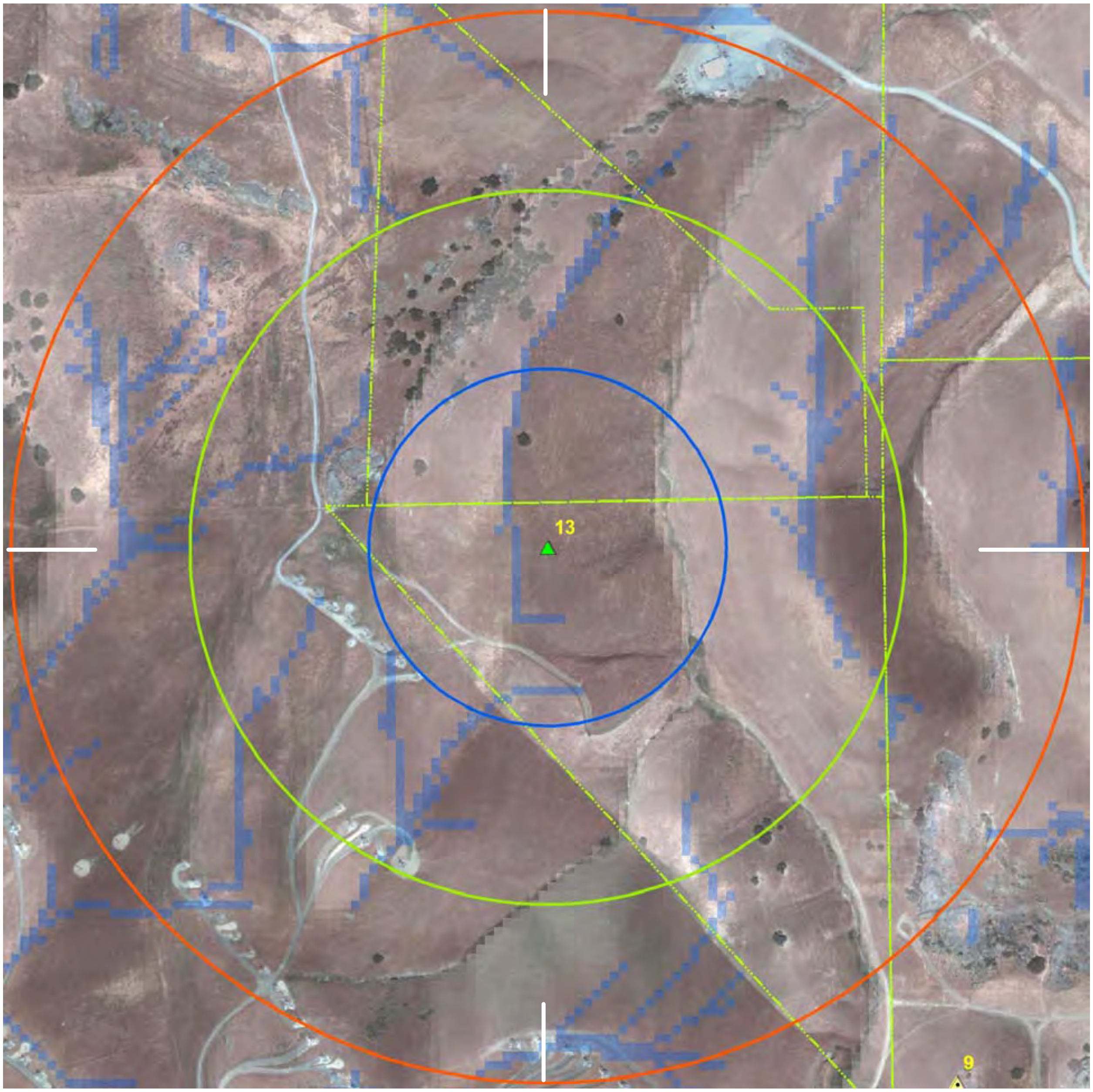
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



Date ________ Investigator ________ Start time _______ Weather ____________ **OP 12**

	0 Minutes	15 Minutes	30 Minutes	45 Minutes	% Cloud cover _____
Temperature	_________	_________	_________	_________	Rain _____
Max wind speed	_________	_________	_________	_________	
Avg wind speed	_________	_________	_________	_________	
Wind direction	_________	_________	_________	_________	

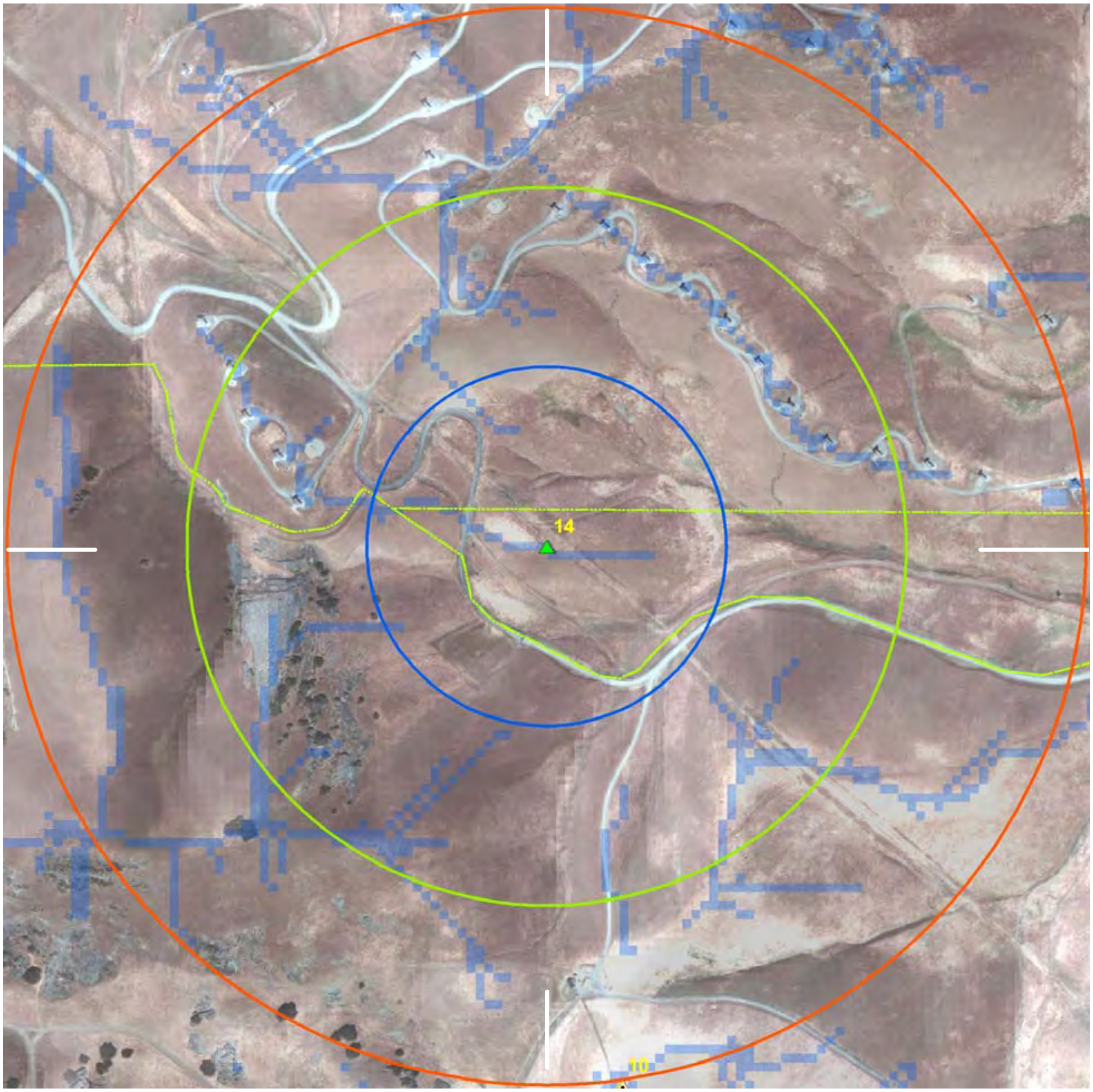
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



Date ________ Investigator ________ Start time _______ Weather ____________ OP 13

	0 Minutes	15 Minutes	30 Minutes	45 Minutes	% Cloud cover _____
Temperature	_________	_________	_________	_________	Rain _____
Max wind speed	_________	_________	_________	_________	
Avg wind speed	_________	_________	_________	_________	
Wind direction	_________	_________	_________	_________	

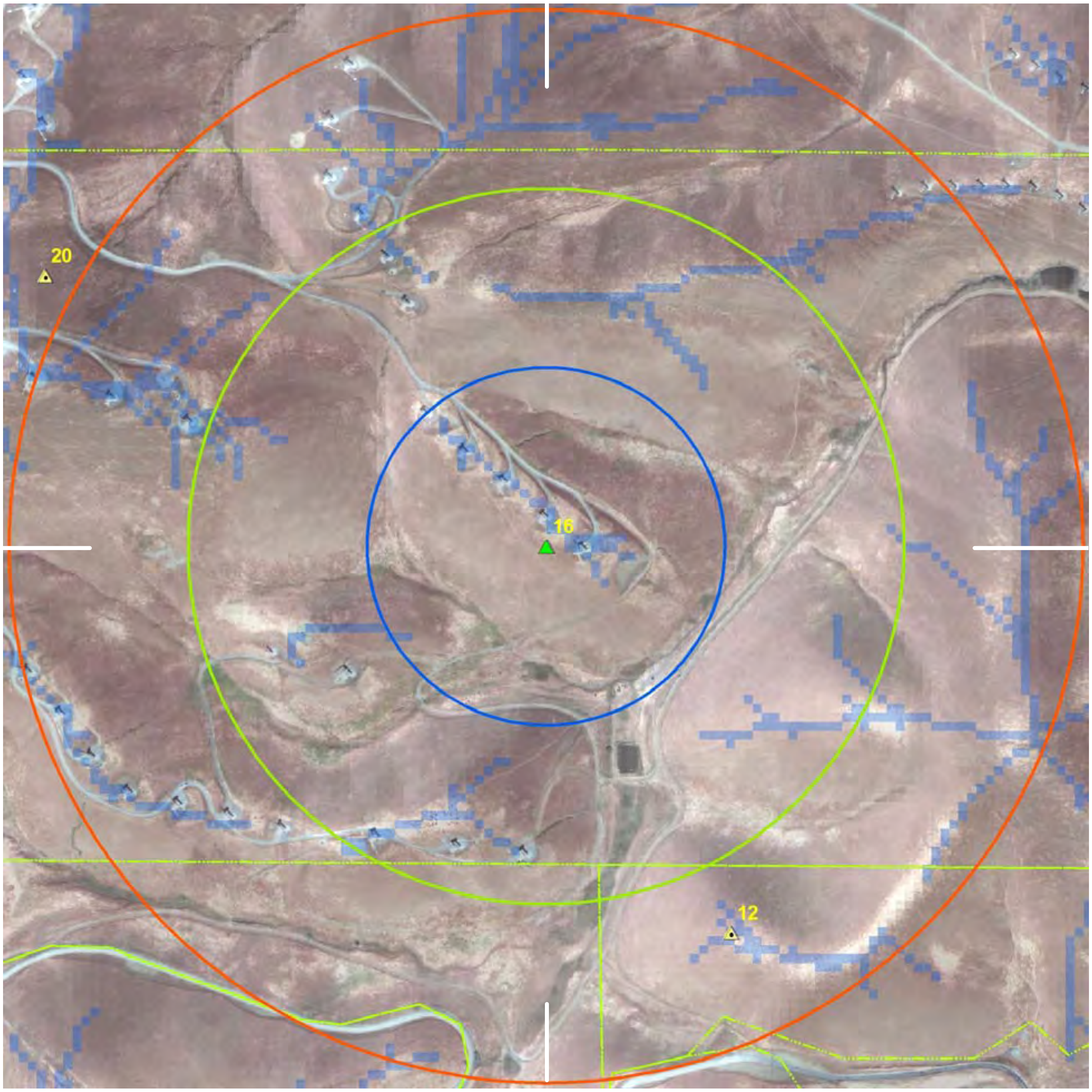
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



Date ________ Investigator ________ Start time _______ Weather ___________ OP 14

	0 Minutes	15 Minutes	30 Minutes	45 Minutes	% Cloud cover _____
Temperature	_________	_________	_________	_________	Rain _____
Max wind speed	_________	_________	_________	_________	
Avg wind speed	_________	_________	_________	_________	
Wind direction	_________	_________	_________	_________	

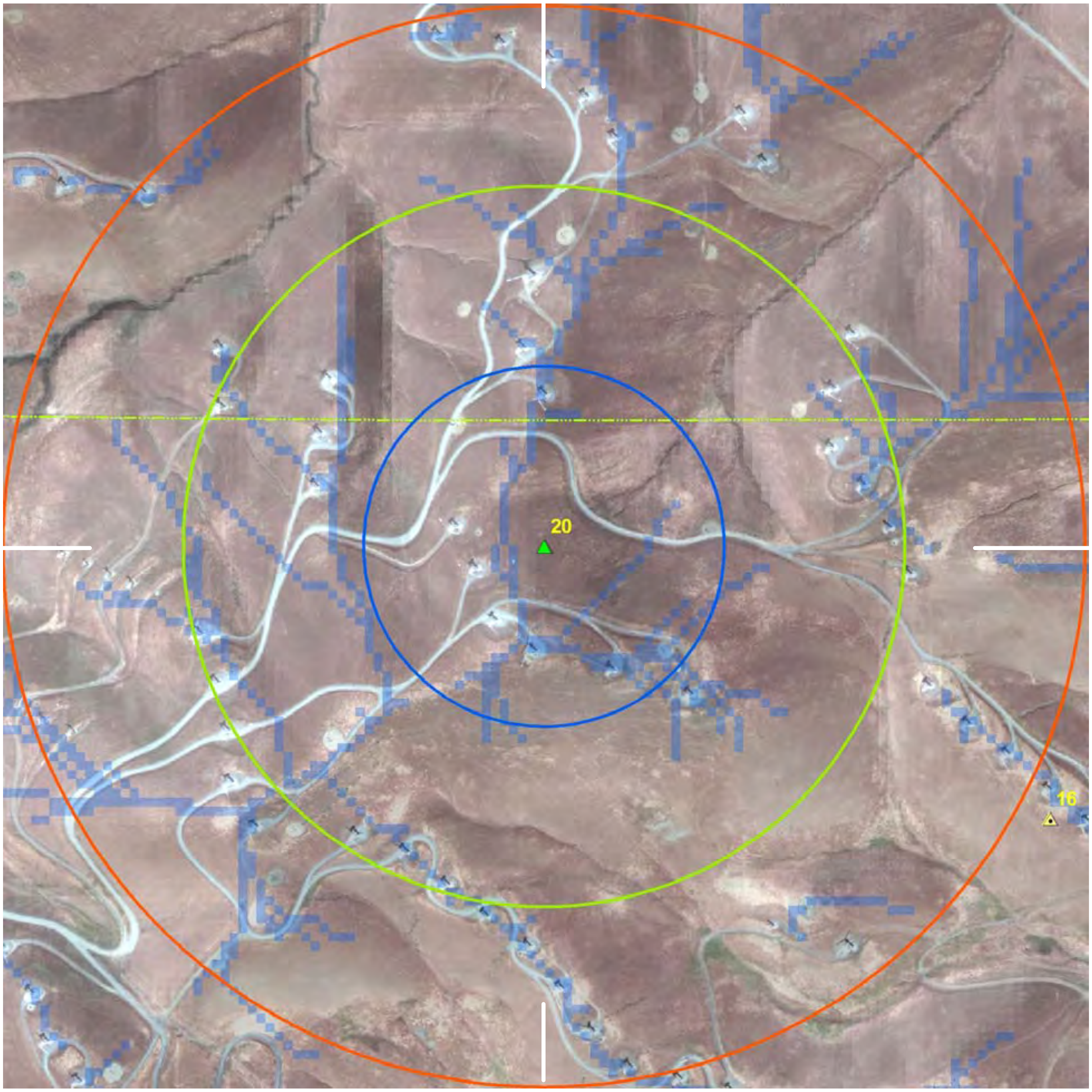
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



Date ________ Investigator ________ Start time _______ Weather ____________ OP 16

	0 Minutes	15 Minutes	30 Minutes	45 Minutes	% Cloud cover _____
Temperature	_________	_________	_________	_________	Rain _____
Max wind speed	_________	_________	_________	_________	
Avg wind speed	_________	_________	_________	_________	
Wind direction	_________	_________	_________	_________	

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



Date ________ Investigator ________ Start time _______ Weather ____________

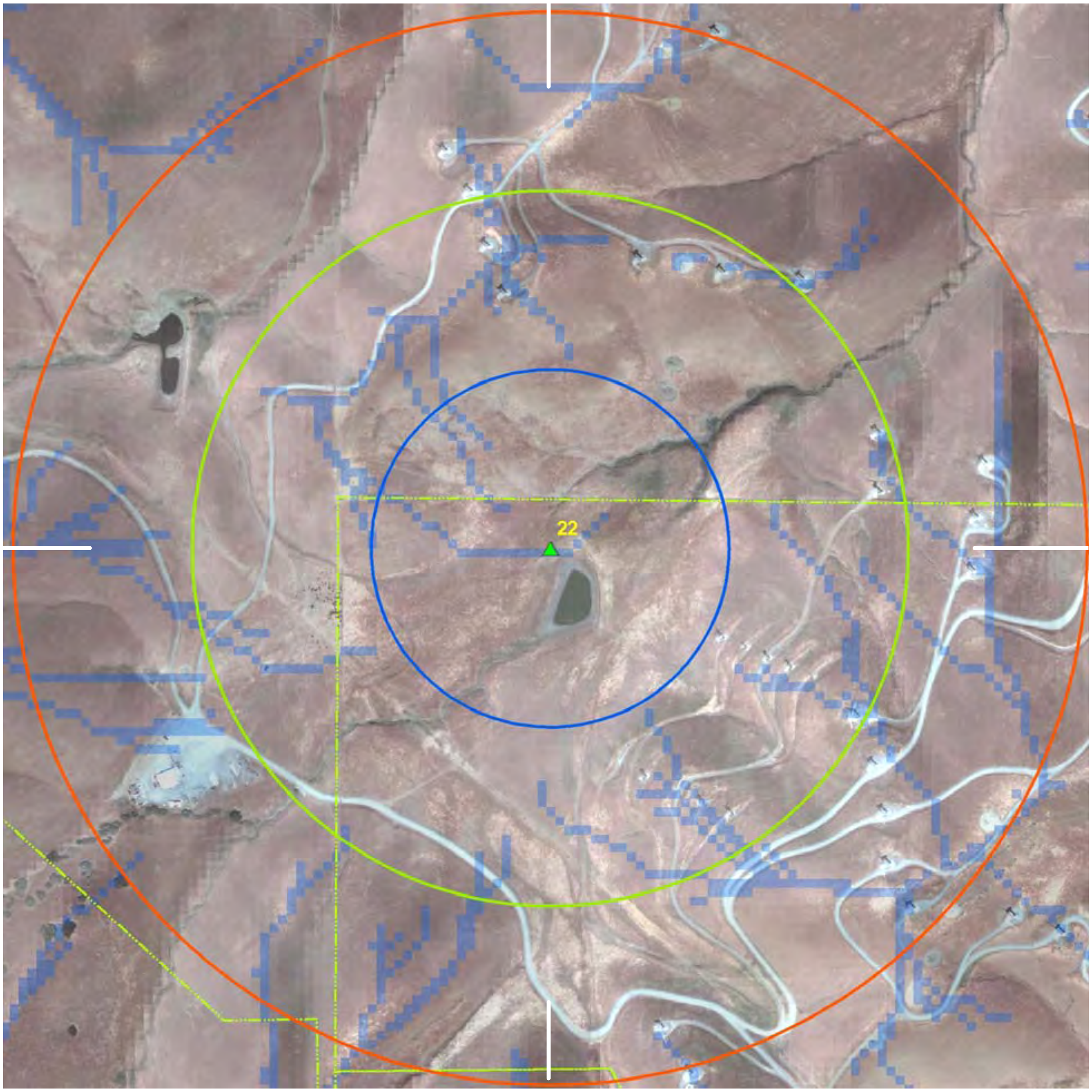
OP 20

	0 Minutes	15 Minutes	30 Minutes	45 Minutes
Temperature	_________	_________	_________	_________
Max wind speed	_________	_________	_________	_________
Avg wind speed	_________	_________	_________	_________
Wind direction	_________	_________	_________	_________

% Cloud cover _____

Rain _____

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



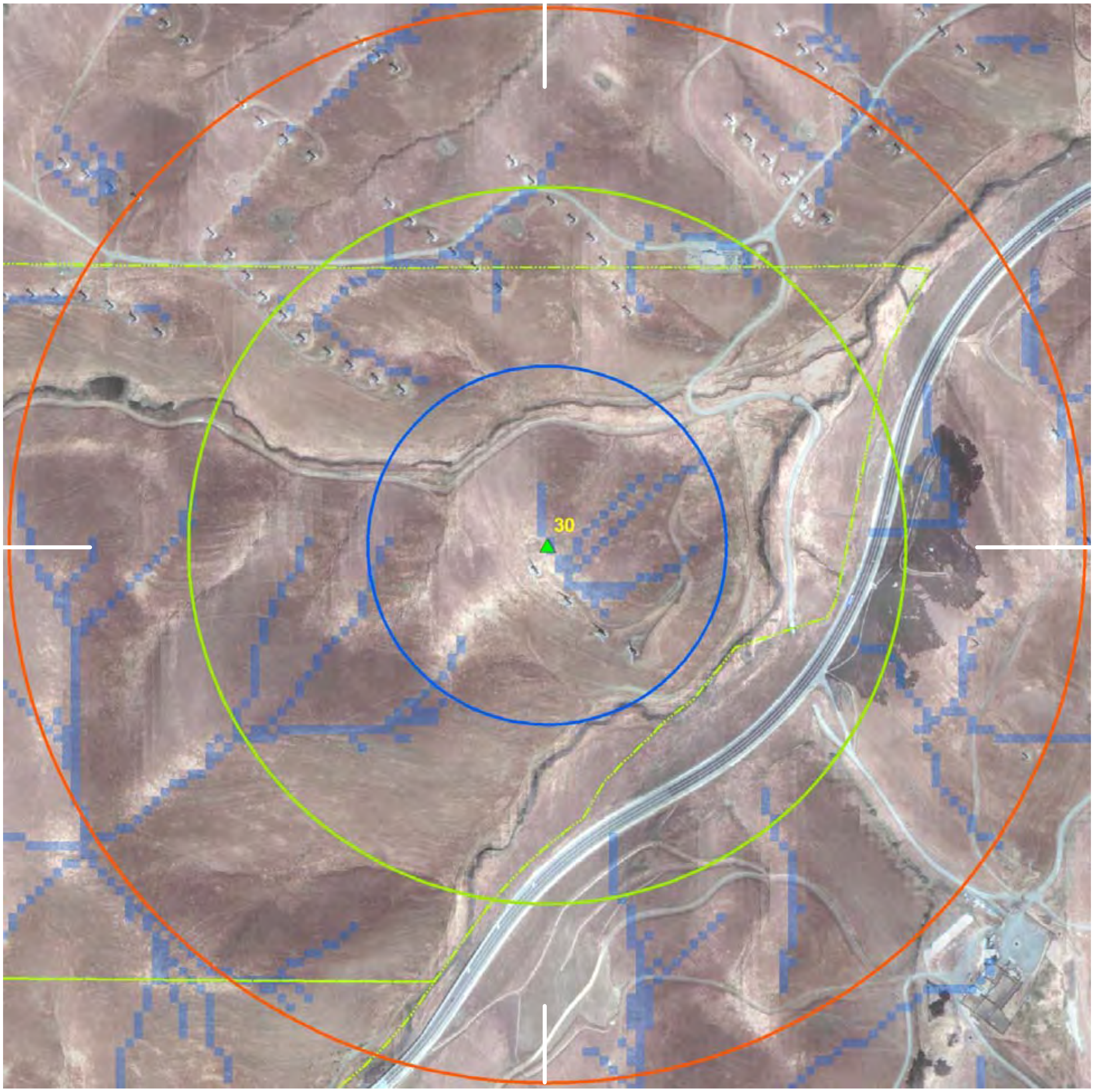
Date ________ Investigator ________ Start time _______ Weather ____________ OP 22

% Cloud cover _____

Rain _____

	0 Minutes	15 Minutes	30 Minutes	45 Minutes
Temperature	_________	_________	_________	_________
Max wind speed	_________	_________	_________	_________
Avg wind speed	_________	_________	_________	_________
Wind direction	_________	_________	_________	_________

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



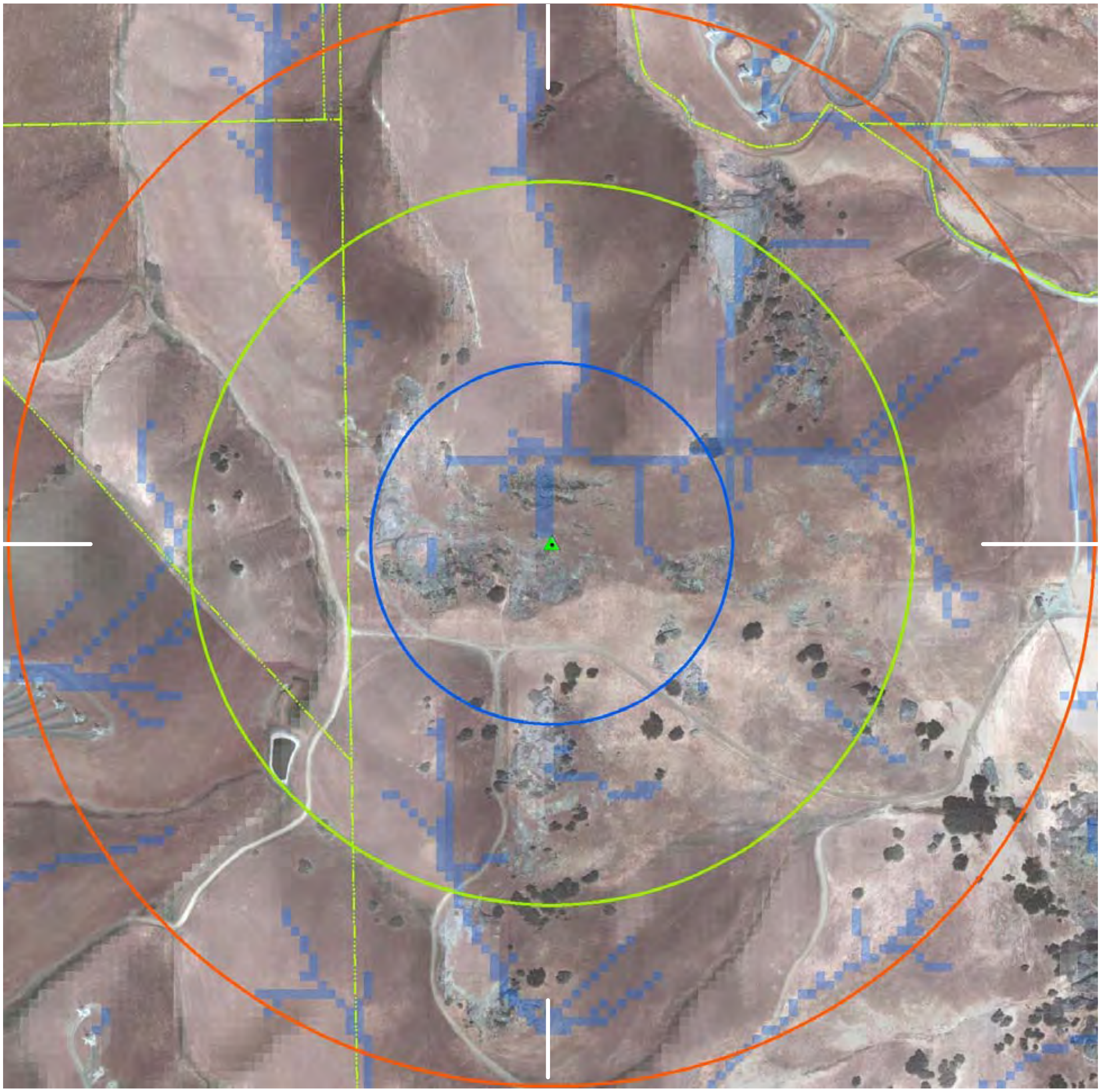
Date ________ Investigator ________ Start time _______ Weather ____________ OP 30

% Cloud cover _____

Rain _____

	0 Minutes	15 Minutes	30 Minutes	45 Minutes
Temperature	_________	_________	_________	_________
Max wind speed	_________	_________	_________	_________
Avg wind speed	_________	_________	_________	_________
Wind direction	_________	_________	_________	_________

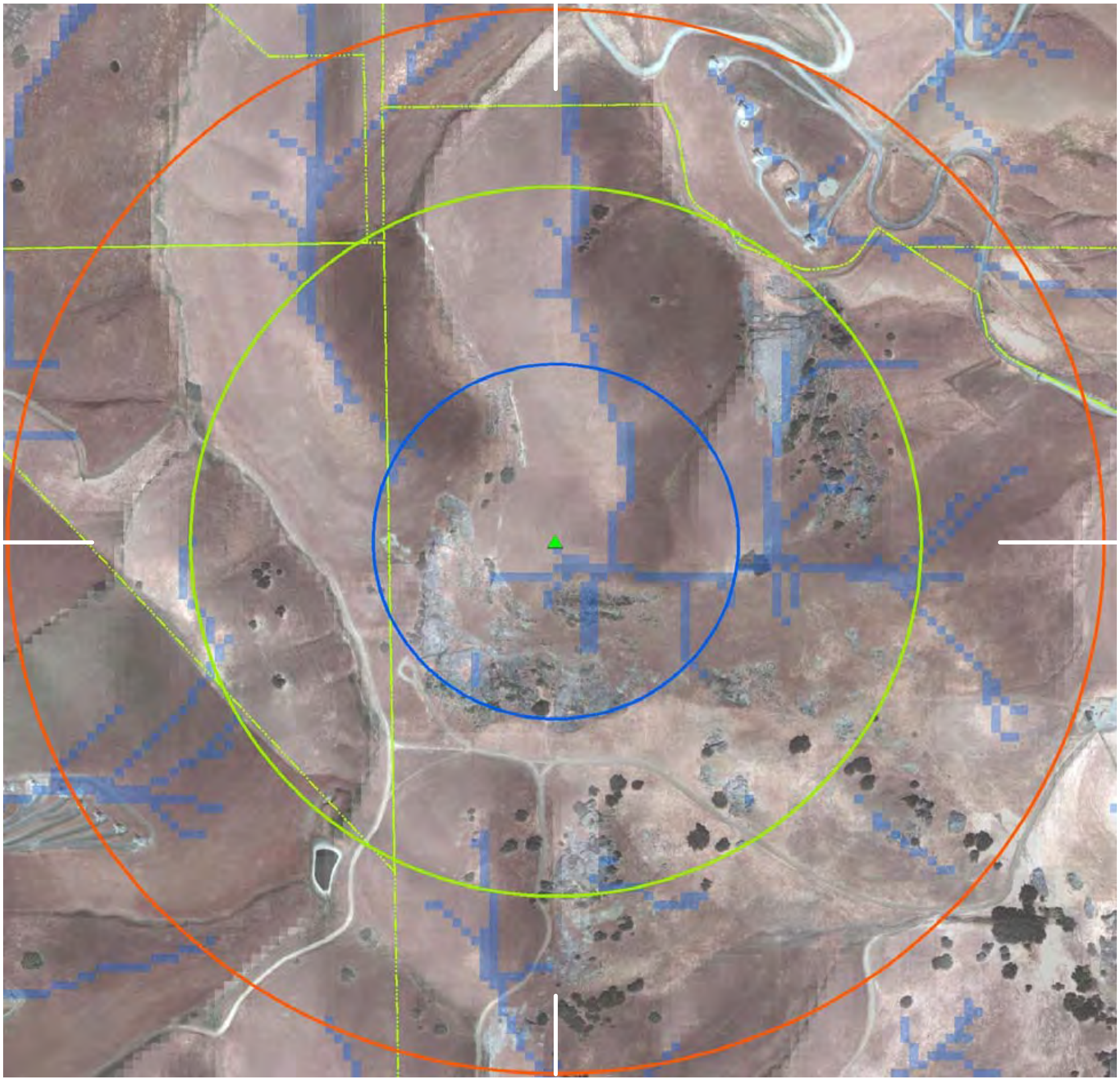
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



Date ________ Investigator ________ Start time _______ Weather ___________ **OP 31**

	0 Minutes	15 Minutes	30 Minutes	45 Minutes	% Cloud cover _____
Temperature	_________	_________	_________	_________	Rain _____
Max wind speed	_________	_________	_________	_________	
Avg wind speed	_________	_________	_________	_________	
Wind direction	_________	_________	_________	_________	

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z



OP 32

Date ________ Investigator ________ Start time _______ Weather ___________

	0 Minutes	15 Minutes	30 Minutes	45 Minutes
Temperature	_________	_________	_________	_________
Max wind speed	_________	_________	_________	_________
Avg wind speed	_________	_________	_________	_________
Wind direction	_________	_________	_________	_________

% Cloud cover _____

Rain _____

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Range Management Practices to Reduce Wind Turbine Impacts on Burrowing Owls and Other Raptors in the Altamont Pass Wind Resource Area, California

Appendices E and F

Appendix E: Raptor Flight Behaviors per Wind Direction

Appendix F: Raptor Flight Behaviors versus Slope Characteristics

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APPENDIX E

E 1. American kestrel flight behaviors exhibited per flight direction relative to the wind.

Flight behavior	**Directly into wind**	**45˚ to wind**	**Perpendicular to wind**	**45˚ away from wind**	**With wind**
Fly-through	11	39	21	18	6
Gliding	10	18	18	6	1
Soaring	0	8	6	5	3
Surfing	0	1	0	0	0
Contouring	0	6	3	4	0
Circling	2	5	10	4	2
Hovering/kiting	64	88	40	6	0
Diving	1	6	5	0	1
Mobbing	0	5	0	0	4
Mobbed or fleeing	0	0	0	0	0
Total count	88	176	103	43	17

E 2. Prairie falcon flight behaviors exhibited per flight direction relative to the wind.

Flight behavior	**Directly into wind**	**45˚ to wind**	**Perpendicular to wind**	**45˚ away from wind**	**With wind**
Fly-through	2	10	2	1	0
Gliding	0	6	8	5	1
Soaring	2	0	1	6	0
Surfing	0	0	0	0	1
Contouring	0	1	0	0	1
Circling	1	2	1	2	0
Hovering/kiting	7	9	5	1	0
Diving	0	0	0	0	0
Mobbing	0	0	1	0	0
Mobbed or fleeing	0	0	0	0	0
Total count	12	28	18	15	4

E 3. Golden eagle flight behaviors exhibited per flight direction relative to the wind.

Flight behavior	**Directly into wind**	**45˚ to wind**	**Perpendicular to wind**	**45˚ away from wind**	**With wind**
Fly-through	4	11	6	9	7
Gliding	14	22	17	17	7
Soaring	8	19	21	38	13
Surfing	0	0	0	1	0
Contouring	7	10	2	7	4
Circling	0	5	0	0	1
Hovering/kiting	10	12	4	0	0
Diving	0	0	0	0	0
Mobbing	0	0	0	1	0
Mobbed or fleeing	0	1	0	0	0
Total count	43	80	50	73	32

E 4. Red-tailed hawk flight behaviors exhibited per flight direction relative to the wind.

Flight behavior	**Directly into wind**	**45˚ to wind**	**Perpendicular to wind**	**45˚ away from wind**	**With wind**
Fly-through	22	52	38	38	11
Gliding	120	191	162	123	50
Soaring	93	204	227	231	135
Surfing	4	2	5	0	0
Contouring	15	31	17	15	8
Circling	32	69	78	59	35
Hovering/kiting	151	188	64	10	8
Diving	8	11	10	8	1
Mobbing	1	1	0	2	0
Mobbed or fleeing	4	3	1	2	4
Total count	450	752	602	488	252

E 5. Northern harrier flight behaviors exhibited per flight direction relative to the wind.

Flight behavior	Directly into wind	45˚ to wind	Perpendicular to wind	45˚ away from wind	With wind
Fly-through	2	5	6	2	4
Gliding	9	13	19	14	2
Soaring	2	7	8	10	3
Surfing	0	0	0	1	0
Contouring	20	32	33	23	15
Circling	3	0	3	4	3
Hovering/kiting	4	2	1	0	0
Diving	0	0	0	2	0
Mobbing	0	0	0	0	0
Mobbed or fleeing	0	0	0	0	0
Total count	40	59	70	56	27

E 6. White-tailed kite flight behaviors exhibited per flight direction relative to the wind.

Flight behavior	Directly into wind	45˚ to wind	Perpendicular to wind	45˚ away from wind	With wind
Fly-through	2	1	0	1	0
Gliding	0	0	1	0	0
Soaring	0	0	0	1	0
Surfing	0	0	0	0	0
Contouring	0	0	0	0	0
Circling	1	0	0	1	0
Hovering/kiting	0	1	1	0	0
Diving	0	0	0	1	0
Mobbing	0	0	0	0	0
Mobbed or fleeing	0	0	0	0	0
Total count	3	2	2	4	0

E 7. Turkey vulture flight behaviors exhibited per flight direction relative to the wind.

Flight behavior	**Directly into wind**	**45˚ to wind**	**Perpendicular to wind**	**45˚ away from wind**	**With wind**
Fly-through	5	4	4	4	2
Gliding	97	155	135	136	63
Soaring	40	93	100	73	38
Surfing	1	1	0	1	0
Contouring	3	14	7	4	6
Circling	15	69	34	34	0
Hovering/kiting	1	9	0	2	1
Diving	1	1	0	0	0
Mobbing	0	0	0	0	0
Mobbed or fleeing	0	0	0	0	0
Total count	163	346	280	254	110

E 8. Common raven flight behaviors exhibited per flight direction relative to the wind.

Flight behavior	**Directly into wind**	**45˚ to wind**	**Perpendicular to wind**	**45˚ away from wind**	**With wind**
Fly-through	149	380	320	286	92
Gliding	132	208	194	223	84
Soaring	32	78	100	94	25
Surfing	5	6	4	2	0
Contouring	33	65	37	39	6
Circling	92	130	117	124	35
Hovering/kiting	40	58	13	12	2
Diving	22	59	62	34	15
Mobbing	14	9	9	3	4
Mobbed or fleeing	0	3	0	3	0
Total count	519	996	856	820	263

APPENDIX F

F 1. Mean comparisons between sets of grid cells where red-tailed hawks were not seen hovering or kiting (n = 89,131, weighted n = 197,877) and where they were seen hovering or kiting (n = 337, weighted n = 1,211). Significance of test results were denoted by * for P < 0.05 and ** for P <0.001.

	Red-tailed hawks hovering/kiting				
	Not observed		**Observed**		**ANOVA F-value**
Variable	**Mean**	**SD**	**Mean**	**SD**	
Distance to valley (m)	56.58	39.60	108.82	57.89	2079.88**
$\log_{10}$ Distance to valley	1.59	0.46	1.94	0.35	700.24**
Distance to ridge (m)	57.57	38.40	34.97	31.08	417.96**
$\log_{10}$ Distance to ridge	1.63	0.42	1.35	0.48	510.62**
Total slope distance (m)	114.15	38.64	143.79	49.58	704.97**
$\log_{10}$ Total slope distance	2.04	0.16	2.13	0.16	472.42**
Distance ratio	3.83	10.24	11.74	20.95	703.09**
ln Distance ratio	-0.03	1.65	1.38	1.60	874.50**
Elevation (msl)	197.71	56.06	231.53	43.22	439.28**
Elevation difference; near ridge - near valley	25.53	15.95	37.35	18.00	660.18**
$\log_{10}$ Elevation difference	1.33	0.33	1.52	0.26	410.12**
Gross slope	0.23	0.10	0.26	0.08	140.63**
Slope (percentage)	27.77	13.16	28.32	13.04	2.10 ns
Elevation ratio	4.77	8.88	17.02	19.77	2234.57**
ln Elevation ratio	0.08	1.91	1.80	1.80	984.03**
Principal component 1, position on slope	0.02	1.00	0.90	0.91	947.69**
Principal component 2, slope steepness	0.05	0.96	0.29	0.73	70.17**
Principal component 3, slope size	0.02	0.99	0.56	1.00	362.10**

F 2. Mean comparisons between sets of grid cells where red-tailed hawks were not seen flying (n = 87,427, weighted n = 192,153) and where they were seen flying (n = 2,041, weighted n = 6,935). Significance of test results were denoted by * for P < 0.05 and ** for P <0.001.

	Red-tailed hawks flying				
	Not observed		Observed		ANOVA F-value
Variable	**Mean**	**SD**	**Mean**	**SD**	
Distance to valley (m)	56.11	39.29	78.87	50.34	2197.94**
$\log_{10}$ Distance to valley	1.59	0.46	1.75	0.45	873.00**
Distance to ridge (m)	57.88	38.41	45.15	35.96	738.30**
$\log_{10}$ Distance to ridge	1.63	0.42	1.47	0.48	934.67**
Total slope distance (m)	113.99	38.55	124.02	43.77	449.00**
$\log_{10}$ Total slope distance	2.03	0.16	2.07	0.16	340.93**
Distance ratio	3.74	10.02	7.76	16.77	1009.25**
ln Distance ratio	-0.04	1.64	0.69	1.76	1316.30**
Elevation (msl)	196.89	56.08	226.18	47.34	1843.52**
Elevation difference; near ridge - near valley	25.44	15.95	29.96	16.61	537.24**
$\log_{10}$ Elevation difference	1.32	0.33	1.42	0.28	507.68**
Gross slope	0.23	0.10	0.25	0.10	261.64**
Slope (percentage)	27.77	13.15	27.82	13.38	0.08 ns
Elevation ratio	4.68	8.76	9.51	14.12	1932.10**
ln Elevation ratio	0.06	1.90	0.88	2.01	1233.28**
Principal component 1, position on slope	0.01	0.99	0.48	1.05	1519.97**
Principal component 2, slope steepness	0.05	0.97	0.20	0.87	158.53**
Principal component 3, slope size	0.02	0.99	0.19	1.00	207.79**

F 3. Mean comparisons between sets of grid cells where red-tailed hawks were not seen perching (n = 89,292, weighted n = 198,518) and where they were seen perching (n = 176, weighted n = 570). Significance of test results were denoted by * for P < 0.05 and ** for P <0.001.

Variable	Red-tailed hawks perching				ANOVA F-value
	Not observed		Observed		
	Mean	SD	Mean	SD	
Distance to valley (m)	56.85	39.93	73.45	39.90	98.22**
$\log_{10}$ Distance to valley	1.59	0.46	1.77	0.32	88.26**
Distance to ridge (m)	57.49	38.40	38.26	35.26	142.70**
$\log_{10}$ Distance to ridge	1.63	0.42	1.38	0.49	200.29**
Total slope distance (m)	114.34	38.80	111.71	33.00	2.62 ns
$\log_{10}$ Total slope distance	2.04	0.16	2.03	0.13	0.25 ns
Distance ratio	3.87	10.34	8.21	16.15	99.76**
ln Distance ratio	-0.02	1.65	0.94	1.66	192.80**
Elevation (msl)	197.82	56.06	229.15	45.67	177.65**
Elevation difference; near ridge - near valley	25.59	15.99	27.09	15.56	4.95*
$\log_{10}$ Elevation difference	1.33	0.33	1.37	0.29	9.86*
Gross slope	0.23	0.10	0.24	0.11	18.44**
Slope (percentage)	27.78	13.14	27.12	18.39	1.42 ns
Elevation ratio	4.83	9.03	9.69	11.95	163.91**
ln Elevation ratio	0.08	1.91	1.14	1.88	173.14**
Principal component 1, position on slope	0.02	1.00	0.65	0.98	224.59**
Principal component 2, slope steepness	0.06	0.96	0.17	1.08	8.05*
Principal component 3, slope size	0.03	0.99	-0.02	0.82	1.35 ns

F 4. Mean comparisons between sets of grid cells where American kestrels were not seen hovering or kiting (n = 89,303, weighted n = 198,485) and where they were seen hovering or kiting (n = 165, weighted n = 603). Significance of test results were denoted by * for $P < 0.05$ and ** for $P < 0.001$.

Variable	American kestrels hovering/kiting				ANOVA F-value
	Not observed		Observed		
	Mean	SD	Mean	SD	
Distance to valley (m)	56.72	39.74	114.63	59.51	1271.46**
$\log_{10}$ Distance to valley	1.59	0.46	1.97	0.33	405.50**
Distance to ridge (m)	57.52	38.40	30.73	29.00	293.00**
$\log_{10}$ Distance to ridge	1.63	0.42	1.27	0.50	422.35**
Total slope distance (m)	114.24	38.70	145.36	51.56	387.70**
$\log_{10}$ Total slope distance	2.04	0.16	2.14	0.17	246.84**
Distance ratio	3.85	10.25	15.84	26.49	808.27**
ln Distance ratio	-0.02	1.65	1.62	1.64	597.50**
Elevation (msl)	197.85	56.08	217.91	41.00	76.98**
Elevation difference; near ridge - near valley	25.56	15.98	36.86	17.33	300.36**
$\log_{10}$ Elevation difference	1.33	0.33	1.52	0.27	192.52**
Gross slope	0.23	0.10	0.26	0.09	62.64**
Slope (percentage)	27.77	13.16	27.59	12.28	0.12 ns
Elevation ratio	4.81	8.96	17.78	19.98	1244.83**
ln Elevation ratio	0.08	1.91	1.83	1.83	505.08**
Principal component 1, position on slope	0.02	1.00	0.99	0.94	563.65**
Principal component 2, slope steepness	0.06	0.96	0.23	0.81	19.19**
Principal component 3, slope size	0.03	0.99	0.58	1.01	189.59**

F 5. Mean comparisons between sets of grid cells where golden eagles were not seen flying (n = 89,225, weighted n = 198,309) and where they were seen flying (n = 243, weighted n = 779). Significance of test results were denoted by * for P < 0.05 and ** for P <0.001.

Variable	**Golden eagles flying**				**ANOVA F-value**
	Not observed		**Observed**		
	Mean	**SD**	**Mean**	**SD**	
Distance to valley (m)	56.81	39.85	79.04	54.81	240.66**
$\log_{10}$ Distance to valley	1.59	0.46	1.71	0.51	51.60**
Distance to ridge (m)	57.48	38.40	45.96	37.19	69.91**
$\log_{10}$ Distance to ridge	1.63	0.42	1.47	0.49	104.22**
Total slope distance (m)	114.29	38.75	125.00	46.49	59.16**
$\log_{10}$ Total slope distance	2.04	0.16	2.07	0.19	31.00**
Distance ratio	3.86	10.31	8.49	19.20	155.06**
ln Distance ratio	-0.02	1.65	0.60	1.92	111.11**
Elevation (msl)	197.84	56.07	215.39	49.26	76.07**
Elevation difference; near ridge - near valley	25.58	15.98	31.09	17.85	92.16**
$\log_{10}$ Elevation difference	1.33	0.33	1.43	0.30	68.15**
Gross slope	0.23	0.10	0.25	0.09	46.54**
Slope (percentage)	27.78	13.16	27.05	13.10	2.38 ns
Elevation ratio	4.82	8.99	11.74	16.36	455.33**
ln Elevation ratio	0.08	1.91	0.90	2.25	140.68**
Principal component 1, position on slope	0.02	1.00	0.43	1.14	129.02**
Principal component 2, slope steepness	0.06	0.96	0.20	0.83	18.52**
Principal component 3, slope size	0.03	0.99	0.18	1.14	17.77**

F 6. Mean comparisons between sets of grid cells where common ravens were not seen flying (n = 87,591, weighted n = 192,651) and where they were seen flying (n = 1,877, weighted n = 6,437). Significance of test results were denoted by * for P < 0.05 and ** for P <0.001.

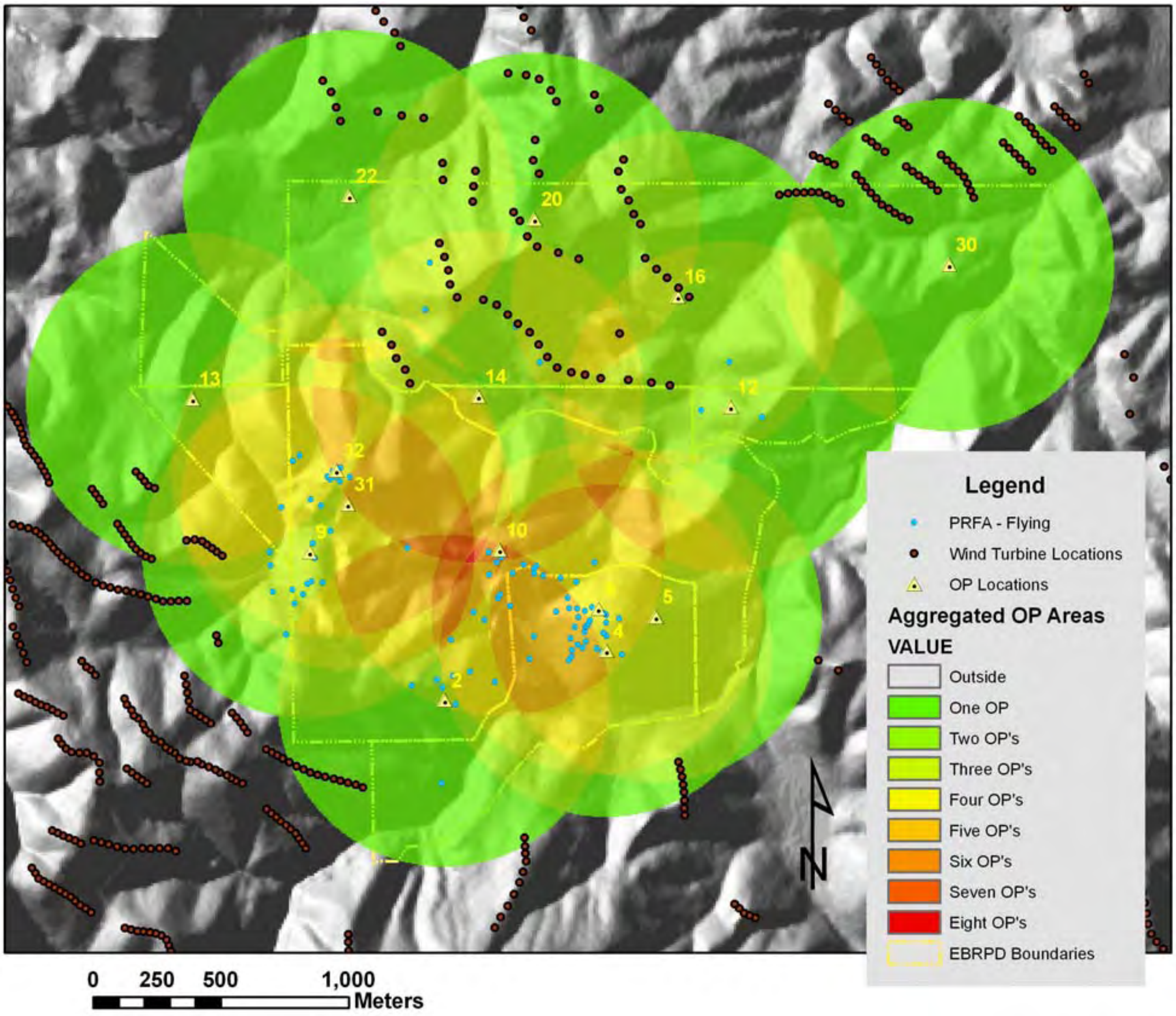
	Common ravens flying				
	Not observed		**Observed**		**ANOVA F-value**
Variable	**Mean**	**SD**	**Mean**	**SD**	
Distance to valley (m)	56.33	39.58	74.05	46.43	1234.09**
$\log_{10}$ Distance to valley	1.59	0.46	1.73	0.43	619.64**
Distance to ridge (m)	57.79	38.40	46.85	36.91	506.98**
$\log_{10}$ Distance to ridge	1.63	0.42	1.49	0.47	667.14**
Total slope distance (m)	114.12	38.69	120.90	41.08	190.70**
$\log_{10}$ Total slope distance	2.04	0.16	2.06	0.15	169.14**
Distance ratio	3.79	10.17	6.76	14.59	513.09**
ln Distance ratio	-0.04	1.64	0.59	1.73	922.86**
Elevation (msl)	196.70	55.93	234.30	46.76	2842.56**
Elevation difference; near ridge - near valley	25.48	15.97	29.23	16.25	344.20**
$\log_{10}$ Elevation difference	1.32	0.33	1.41	0.28	391.97**
Gross slope	0.23	0.10	0.25	0.10	299.25**
Slope (percentage)	27.74	13.12	28.95	14.35	53.05**
Elevation ratio	4.73	8.86	8.29	12.81	969.50**
ln Elevation ratio	0.06	1.90	0.73	1.99	761.23**
Principal component 1, position on slope	0.01	0.99	0.44	1.04	1176.16**
Principal component 2, slope steepness	0.05	0.96	0.26	0.94	305.24**
Principal component 3, slope size	0.02	0.99	0.12	0.96	54.57**

Range Management Practices to Reduce Wind Turbine Impacts on Burrowing Owls and Other Raptors in the Altamont Pass Wind Resource Area, California

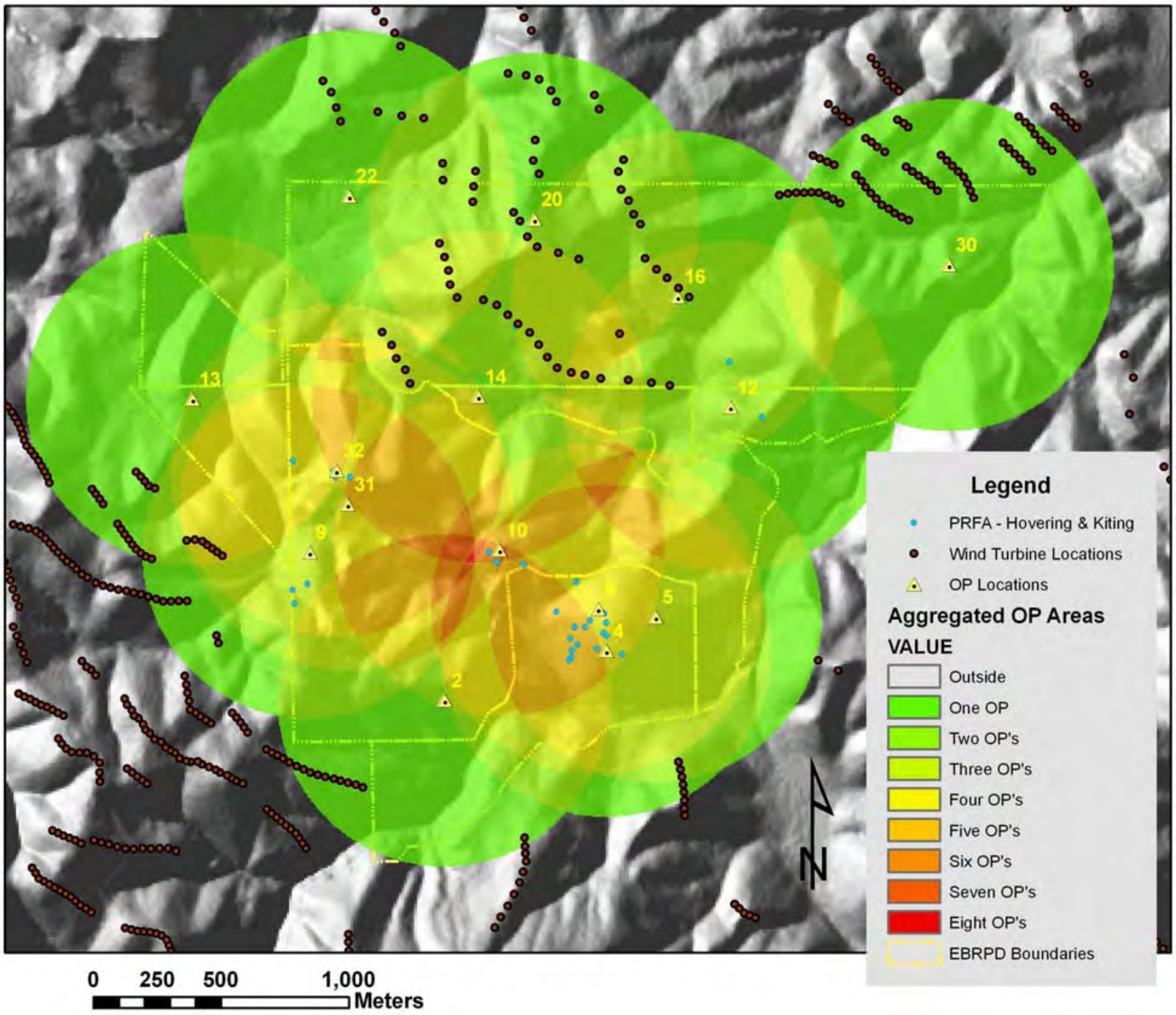
Appendix G:
Consolidated Observation Maps for Prairie Falcons and Common Ravens

CEC-500-2008-080-APG
PIER Environmental Area
California Energy Commission
October 2008

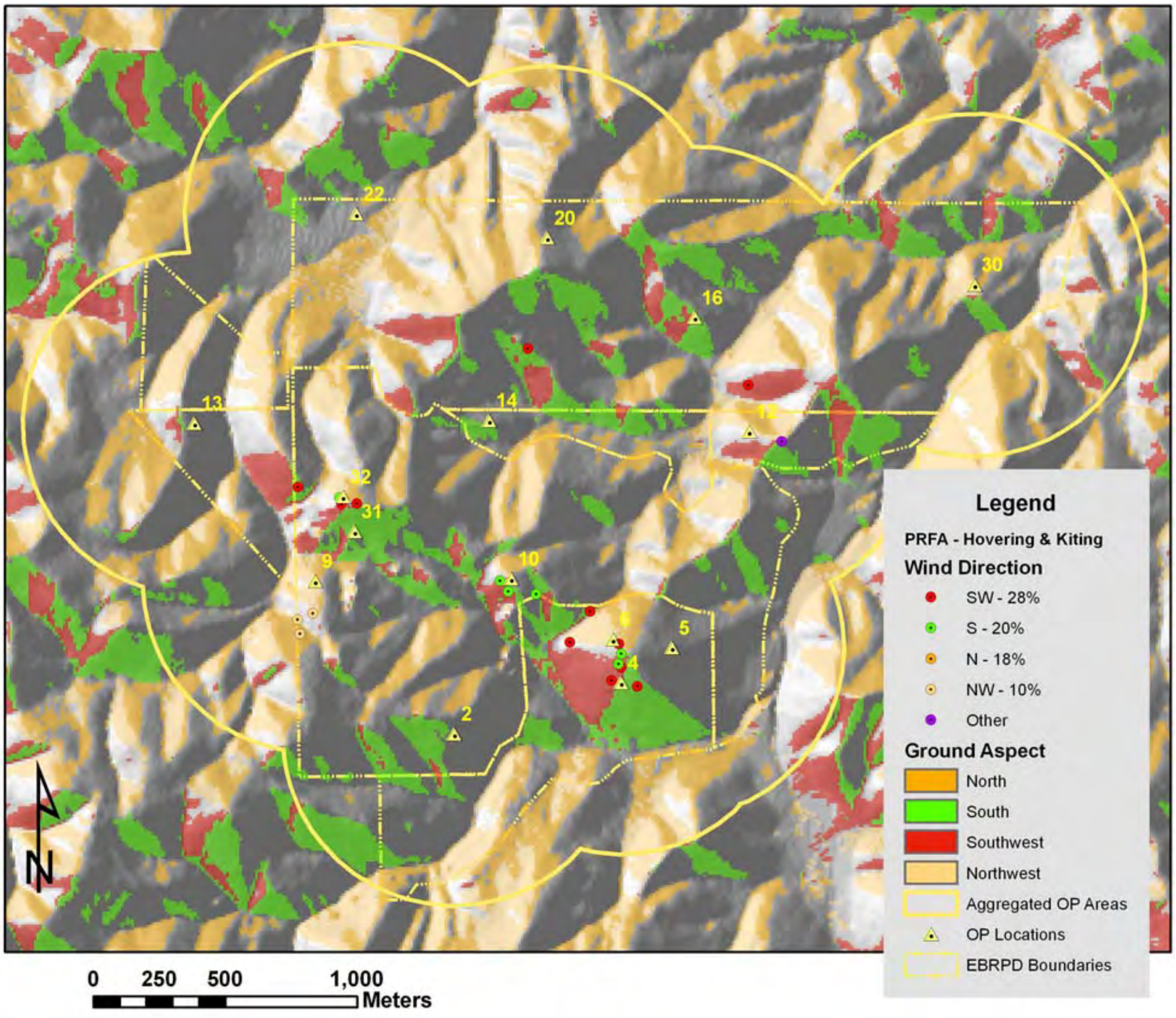
APPENDIX G



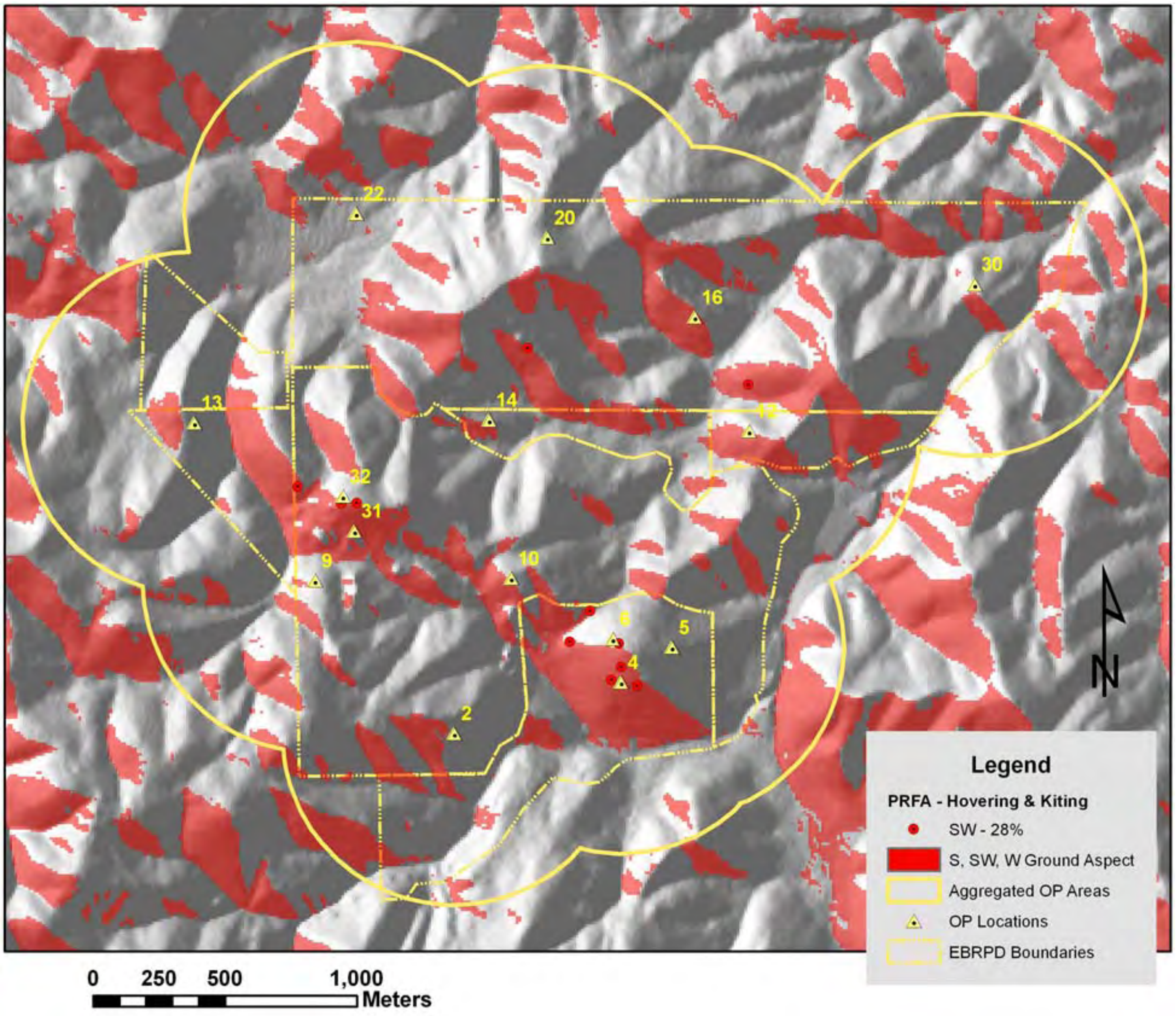
G1. All locations of prairie falcon flight locations recorded during the study.



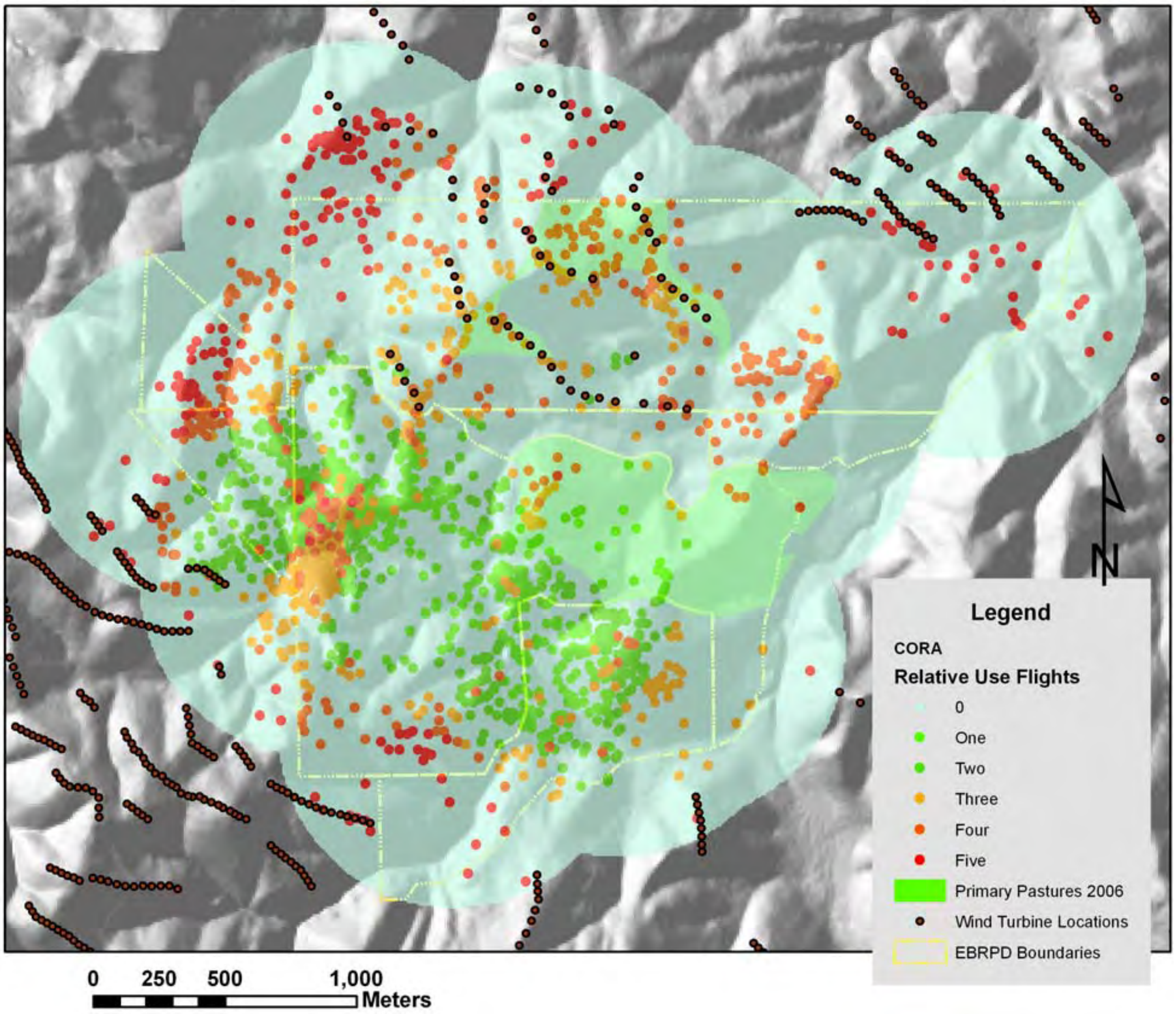
G 2. All locations of prairie falcon hovering and kiting locations recorded during the study.



G 3. Locations of prairie falcons hovering or kiting into various wind directions. Most locations indicated the falcons hovered or kited on the slope aspect of the hill or ridge that faced the wind at the time the observation was recorded, or they were close to the boundary.



G4. Locations of prairie falcons hovering or kiting into south, southwest and west winds. Most prairie falcon hovering into southwest-trending winds were also on slopes facing the wind at the time the observation was recorded.



G 5. Common raven observations per OP from which the outer 650-m survey radius could overlap the site. Observation rates, or flights/OP, were grouped in the map: one = 0.13 – 0.20, two = 0.25, three = 0.33 – 0.40, four = 0.50 – 0.67, and five = 0.75 – 3.50.

Range Management Practices to Reduce Wind Turbine Impacts on Burrowing Owls and Other Raptors in the Altamont Pass Wind Resource Area, California

Appendices H through L

Appendix H: Marking, Scavenging, and Searcher Bias Protocol

Appendix I: Carcass Check Data Sheet

Appendix J: Photo Sequence of Decomposition and Scavenging of Red-tailed Hawk

Appendix K: Predictor for Cumulative Carcasses Remaining Since Start of Scavenging Trial

Appendix L: Fatality Search Protocol

CEC-500-2008-080-APH
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Commission
October 2008

APPENDIX H

DRAFT: Marking, Scavenging and Searcher Bias Protocol

General Reporting and Data Collection

Notify Tara Happy (FPL Energy; Cell 209.304.6860; Home: 209.833.6964) within 24 hours of the location of all avian carcasses and/or parts detected during searches and report to her the carcass location with GPS and its distance and bearing to nearest turbine. Digitally photograph each carcass. Fully fill out the carcass reporting form (attached). All eagles, threatened and endangered species found will be retrieved by Tara Happy. All other species will be left to lie on site for incorporation in a scavenging study. The location of the carcasses and/or parts will be marked with stake wire flags and individual carcasses/parts will be marked as described below. Some birds will be additionally monitored with remote sensor cameras. *Notification of Tara Happy also applies for all carcasses placed in the field, as well.*

Bird Marking

Wear latex gloves when handling carcasses. Wash all utensils after use, and give them a final rinse with alcohol to eliminate human scent. Wash hands after handling all carcasses.

In order to allay concerns that feathers from found or placed carcasses will get scattered and counted as fatalities, clip a short section of the vane (0.5cm) on the flight feathers (tail and wing) on each carcass in a unique pattern. The clipping pattern should be unique enough to be able to ID from which carcass they came if feathers are scattered.

In addition to clipping, attach shoat rings to each wing and leg. The rings are made of stiff steel wire about 3 mm diameter with the ends sharpened and come opened in the shape of a C in the following open dimensions: H1 or pig = 15 mm, H2 or shoat = 22 mm, H 3 or hog = 25 mm. Use the rings like a bird band by closing them with pliers around the tarsus or wing bone. In order to mark a carcass for individual identification should the legs or wings get separated from the rest of the carcass, mark each ring by filing it with a unique pattern. This could be done by filing marks at clock positions around the circumference of the ring and recording these marks on the respective field form. Coupled with the size of the ring there should be enough unique ways to mark the rings to accommodate the number carcasses found and placed in the field. For smaller birds, use cage clips (approx. 10 mm wide). When closed they have an opening from 5 to 7 mm. They could be used on smaller birds' legs. However, the shoat rings would be better for attaching to wing bones.

Scavenger Bias Studies

All carcasses, whether left to lie in the field or placed in the field, shall be individually marked as above, digitally photographed, and the location noted with GPS. Carcasses shall be checked daily, when practical. Note state of carcass on carcass-reporting form. If a carcass is no longer present at a location, perform an outward-spiral search of the area to a radius of 20 m. Describe status and record location of any remaining parts of the carcass. Notify Tara Happy of any scavenging events. Coordinate with Joe Didonato on the set-up of remote sensing cameras (Work 510.544.7475 Cell 510.693.5521).

Searcher Bias Studies

Albion shall coordinate with District personnel on searcher-bias studies. Carcasses will be placed in the search area on the morning of a given search day.

All carcasses shall be individually marked as above, digitally photographed, and the location noted with GPS. Do not place wire flag on carcass until it has been discovered by a searcher. Once discovered, the carcass shall be left to lie in the field to be incorporated into the scavenger-bias study.

APPENDIX I

Data collected during placement of carcass and camera and on weekly carcass checks.

ID: The carcass specific ID. (Camera letter + carcass specific number)
Species: The four letter abbreviation for the carcass species.
Date: Date the carcass was placed or checked.
Time: The time the carcass was placed or checked.
Turbine #: The ID number of the turbine that the carcass was placed closest to. (Only recorded when carcass was placed or if carcass was later moved closer to a different turbine)
Distance from turbine (m): The distance from the carcass to the closest turbine. (Only recorded when carcass was placed or if carcass was moved)
Bearing to turbine: The bearing from the carcass to the nearest turbine. (Only recorded when carcass was placed or if carcass had moved)
GPS: The GPS location of the carcass. (Only recorded when carcass was placed or if carcass had moved)
Carcass Descriptor: Whether the carcass was new, whole (skeleton intact, some soft tissues or feathers may be absent), partial (skeletal elements missing or carcass dismembered), gone. If partial, the parts remaining were recorded along with their location relative to the carcasses original placement location. If the parts were spread out over a large area distance, bearing and GPS were recorded.
Flesh: Three designation: D1: No decay, D2: Gooey or D3: Dried. One of these was be used to describe what the flesh on the carcass was like.
Rigormortis: Two designations: R1: Stiff or R2: Loose. One of these was used to describe the state of the joints of the carcass.
Body Orientation: The orientation of the carcass in relation to North.
Carcass Makings: Stated whether or not flight and tail feathers were clipped, metal tags were attached to legs and/or wings and a telemeter was attached to carcass. (Only recorded when carcass was placed)
Invertebrate scavenging: Stated yes or no and then a list of the insects seen on the carcass and/or describe the marks left on the carcass by invertebrate scavenging.
Vertebrate scavenging: Stated yes or no and then describe the state of the carcass: moved, chewed on, flesh missing, feathers pulled off, parts of the carcass missing, carcass removed but feathers remained, carcass removed entirely.
Size of feather spot: If only feathers remained the following information was recorded: an approximate size of the feather spot (written as length x width in centimeters or meters), exact or approximate numbers of feathers, what type of feathers (flight, tail, contour).
Change in feather spot: If the feather spot was not new any observed changes were recorded. Some examples: an increase or decrease in size of the spot or a decrease in number of feathers.
Percent decrease in feathers = if there was a change in feather numbers then the percent decrease is listed here.
Color: Three designations for soft part colors (bare skin, legs, bill): 1: original color, 2: faded, 3: bleached.
Moved: State whether the carcass had been moved and describe the move (whether body orientation was changed or the entire carcass was moved and by how much)
Veg Height: Vegetation height was recorded in inches using a 15" (height) by 10" (width) board divided into a checkerboard of square inch increments. The whole number given denotes to what height in inches the vegetation obsured 90% of the board from view. (Only recorded when carcass was placed)
Photo #: The ID number of the still photos taken of the carcass during that weekly check
Other: Any comments that did not fall into the above categories.

APPENDIX J

Decomposition and scavenging sequence of E2 (red-tailed hawk). Photos depict aftermath of scavenger events observed during weekly carcass checks. Photo series taken by S. A. Snyder.

6-15-07: Day 0. Newly placed. Carcass was fully intact.

6-22-07: Day 7. First outcome: On 6-16 a raven was photographed by infrared camera scavenging on carcass during the first week. The photos showed the raven plucking out feathers and dragging the carcass about 0.5 m. When the carcass was examined at the first weekly check on 6-22 the right side of the chest cavity was opened up and the internal organs missing. The flesh on the neck and left side of sternum were exposed and dried. Adult beetles were observed in chest cavity.

6-29-07: Day 14. Second scavenging event: unknown scavenger moved carcass 1 m east. Hole in right side of chest cavity was larger. No flesh remained on the right side of the sternum. The feathers had been removed from the right femur exposing flesh. Some of the flesh from the femur may have been missing as well. Beetle larvae were observed on carcass.

7-6-07: Day 21. Beetle larvae observed on carcass. No new signs of vertebrate scavenging. All limbs were still intact.

7-13-07: Day 28. Beetle larvae observed on carcass. No new signs of vertebrate scavenging. All limbs were still intact.

7-18-07: Day 35. Beetle larvae observed on carcass. No new signs of vertebrate scavenging. All limbs were still intact. The Reconyx camera was removed on this date.

7-20-07: Day 42. Beetle larvae observed on carcass. No new signs of vertebrate scavenging. All limbs were still intact.

7-27-07: Day 49. Third scavenging event: position of carcass shifted slightly and some contour feathers had been pulled off the body. Beetle larvae observed on carcass. All limbs were still intact.

8-3-07: Day 56. Fourth scavenging event: unidentified scavenger dismembered and removed most of carcass, leaving left wing to ulna/radius, right wing to corocoid/scapula, tail feathers and contour feathers within a 5 x 3 m area. Left photo shows contour feathers remaining in the location where the carcass was the week before. Right photo shows right wing.

8-10-07: Day 63. Fifth scavenging event: An unidentified scavenger removed the majority of the tail feathers, the left ulna/radius and right humerus and corocoid/scapula, leaving the left carpus, right carpus, right ulna/radius and contour feathers. Contour and flight feathers were spread 40 -

90 m from placement turbine. Left photo shows right carpus with flight feathers still attached. Right photo shows left carpus with flight feathers still attached.


8-24-07: Day 77. Remains were the same as two weeks previous. Left and right photos show left and right carpus with flight feathers still attached.


8-31-07: Day 84. Remains were the same as previous week. Photo at left shows left carpus with flight feathers still attached. Photo at right shows right carpus with flight feathers still attached.

9-7-07: Day 91. Sixth and final scavenging event: The left alula, contour feathers and some flight feathers were all that remained of the partial carcass at this location. However, a feather spot extended as a feather plume out to 119m from the placement turbine.

9-14-07: Day 98. Remains were the same as previous week.

9-21-07: Day 105. Remains were the same as previous week. On this day the remains were removed from the study site. The remains met the APWRA definition for a fatality.

APPENDIX K

Predicted percentages of cumulative carcasses remaining within the search area of wind turbines, based on volitionally placed carcasses at random locations and at intervals intended to prevent scavenger swamping. Insufficient data were collected on medium- and large-bodied non-raptor bird species, and on small-bodied raptor species, so all data were pooled to estimate a model for carcasses remaining of all bird species: $Y = 86.992 - 27.210 \cdot \ln(i + 1)$, where i was days into the trial ($r^2 = 0.94$, SE = 5.75, df = 20, $P < 0.001$). All predictions resulting in negative values were converted to 0.

Days since trial start	Small-bodied, non-raptor carcasses remaining (%)	Medium- and large-bodied, raptor carcasses remaining (%)	Carcasses of all bird species remaining (%)
1	91.4	79.5	87.0
2	81.0	72.6	77.6
3	73.4	67.5	70.7
4	67.5	63.5	65.4
5	62.6	60.3	60.9
6	58.4	57.5	57.2
7	54.7	55.0	53.9
8	51.5	52.9	50.9
9	48.6	50.9	48.3
10	45.9	49.2	45.9
11	43.5	47.5	43.7
12	41.2	46.0	41.7
13	39.2	44.6	39.8
14	37.2	43.3	38.0
15	35.4	42.1	36.4
16	33.7	41.0	34.8
17	32.1	39.9	33.4
18	30.5	38.9	32.0
19	29.1	37.9	30.7
20	27.7	37.0	29.4
21	26.3	36.1	28.2
22	25.1	35.2	27.0
23	23.8	34.4	25.9
24	22.7	33.6	24.9
25	21.5	32.9	23.9
26	20.5	32.2	22.9
27	19.4	31.5	21.9
28	18.4	30.8	21.0
29	17.4	30.1	20.1
30	16.5	29.5	19.3
31	15.5	28.9	18.4
32	14.7	28.3	17.6
33	13.8	27.7	16.9

34	13.0	27.1	16.1
35	12.1	26.6	15.4
36	11.3	26.1	14.6
37	10.6	25.5	13.9
38	9.8	25.0	13.3
39	9.1	24.6	12.6
40	8.4	24.1	11.9
41	7.7	23.6	11.3
42	7.0	23.1	10.7
43	6.3	22.7	10.1
44	5.6	22.3	9.5
45	5.0	21.8	8.9
46	4.4	21.4	8.3
47	3.8	21.0	7.8
48	3.2	20.6	7.2
49	2.6	20.2	6.7
50	2.0	19.8	6.2
51	1.4	19.4	5.7
52	0.9	19.1	5.2
53	0.3	18.7	4.7
54	0	18.3	4.2
55	0	18.0	3.7
56	0	17.6	3.2
57	0	17.3	2.8
58	0	17.0	2.3
59	0	16.6	1.9
60	0	16.3	1.4
61	0	16.0	1.0
62	0	15.7	0.6
63	0	15.4	0.2
64	0	15.1	0
65	0	14.8	0
66	0	14.5	0
67	0	14.2	0
68	0	13.9	0
69	0	13.6	0
70	0	13.3	0
71	0	13.1	0
72	0	12.8	0
73	0	12.5	0
74	0	12.3	0
75	0	12.0	0
76	0	11.7	0
77	0	11.5	0
78	0	11.2	0
79	0	11.0	0

80	0	10.7	0
81	0	10.5	0
82	0	10.3	0
83	0	10.0	0
84	0	9.8	0
85	0	9.6	0
86	0	9.3	0
87	0	9.1	0
88	0	8.9	0
89	0	8.7	0
90	0	8.5	0

APPENDIX L

Fatality Search Protocol

Upon each search for fatalities, record the date of the search and the turbines searched into a log.

Search the wind turbines on foot at 6- to 8-m intervals from a central transect along the center of the string of wind turbines. Maintain parallel out to 60 m from the wind turbines.

For safety reasons, hardhats should be worn during fatality searches under wind turbines.

When carcasses are found, record the data indicated on the data sheet.

Take two or more photos of every carcass, changing the angle between photos. This is the case even if the carcass is composed of one or two bones.

Use engineers’ survey card in every carcass photo, for scale.

Be careful to not move camera while taking photo.

Make a copy or a scan of the original carcass data sheet for submission to Barclay/Smallwood, and keep original for follow-up carcass visits during future fatality searches.

Fatality search dates

Date	Turbine string	Number of turbines		
		Broken	Missing	Tower removed

Carcass Data Sheet **Date**___________ **Investigator**______ **Search type**: Standard Incidental **Record No**.:______

Species_______________ **Sex**: M F Unknown **Age group**: Adult Subadult Juvenile Unknown

Cause of death: Blade strike Trapped in turbine (oiled) Line collision Electrocution Auto Predation WNV Poisoned Unknown
Other:

Describe injury:

Notes (continue to back):

Estimated days since death: __________ **Articulation**: Dissembles | 1 2 3 4 5 | Articulated (complete & in place)

Part no.	Body part (e.g., torso, head, wing, leg...)	Sequence no. of nearest turbine	Distance (m) to turbine	Bearing to turbine	Check if GPS used	Photo 1	Photo 2	Photo 3	Photo 4

Carcass monitoring

Date:												
Part no.	Condition	Color	Photo	Condition	Color	Photo	Condition	Color	Photo	Condition	Color	Photo

Date:												
Part no.	Condition	Color	Photo	Condition	Color	Photo	Condition	Color	Photo	Condition	Color	Photo

Condition: [D1 = no decay D2 = gooey D3 = dried flesh] [R1 = stiff R2 = loose] [C = Enamel on culmen] [T = Enamel on talons]
[F = feathers] [B = bones] [I1 = fly larvae I2 = fly pupa I3 = beetle larvae I4 = beetle pupa I5 = beetle adult]
Color: 1 = original 2 = intermediate 3 = bleached 0 = n/s

Date:								
Bone(s)	**Number present**	**Condition**	**Length (mm)**	**Width (mm)**	**Number present**	**Condition**	**Length (mm)**	**Width (mm)**
Skull								
Sternum								
Pelvis								
Coracoid								
Scapula								
Humerus								
Ulna								
Radius								
Carpometacarpus								
Femur								
Tibiotarsus								
Tarsometatarsus								

Bone condition: B = broken C = complete S = smooth W = weathered

Attachments

Attachment I: 2006 Nesting Burrowing Owl Census	CEC-500-2008-080-AT1
Attachment II: 2007 Nesting Burrowing Owl Census	CEC-500-2008-080-AT1

EAST BAY REGIONAL PARK DISTRICT

2006 NESTING BURROWING OWL CENSUS

SOUZA AND VASCO CAVES PARCELS

OCTOBER 2006

ALBION ENVIRONMENTAL, INC.

EAST BAY REGIONAL PARK DISTRICT

2006 NESTING BURROWING OWL CENSUS

SOUZA AND VASCO CAVES PARCELS

OCTOBER 2006

PREPARED FOR:

EAST BAY REGIONAL PARK DISTRICT
2950 PERALTA OAKS COURT
P.O. BOX 5381
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PREPARED BY:

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J2006019

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INTRODUCTION

Albion Environmental, Inc., (Albion) is participating with the East Bay Regional Park District (EBRPD) in a two-year (2006 and 2007) study of range management practices to reduce bird mortality from wind turbines on its Souza and Vasco Caves parcels in eastern Alameda County. This study includes recording bird behavior on the 617-acre Souza parcel that contains 73 wind turbines and the 775-acre Vasco Caves parcel that contains no wind turbines. The work includes searching for bird fatalities around turbines on the Souza parcel.

This study also includes studying the abundance and distribution of nesting burrowing owls (*Athene cunicularia*) on each of the park parcels because burrowing owls are believed to be one of the most frequently killed raptors in the Altamont Pass Wind Resource Area. This report contains the results of our census of nesting burrowing owls on the Souza and Vasco Caves parcels in 2006.

STUDY AREA

The 617-acre Souza parcel and the 775-acre Vasco Caves parcel comprise a study area of 1,392 acres located on the west side of Vasco Road in eastern Contra Costa County (Figure 1). The two parcels share a common east-west running boundary that runs parallel to the main access road to the parcels from Vasco Road (Figure 1).

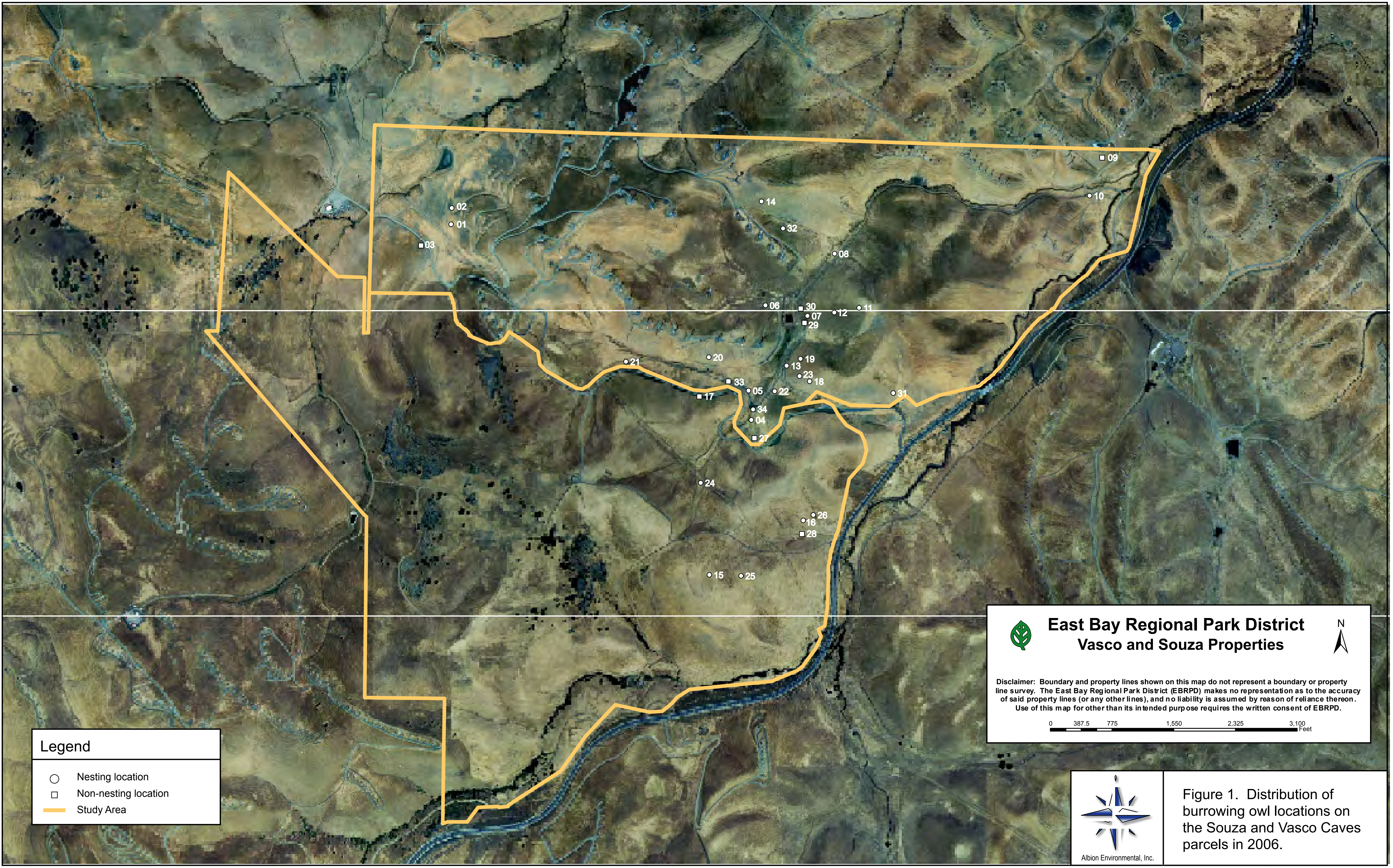
Souza

The Souza parcel contains 73 wind turbines arranged in strings of varying length and elevation (Figure 1). Terrain on the Souza parcel is highly variable with numerous hills, variable slopes and flatter basins between higher terrain. A dominant feature on the Souza parcel is an unnamed drainage that begins in a basin along the south boundary of the parcel just north of the primary access road (Figure 1). The terrain initially drains to the east forming a well-defined basin containing wetland features and two ponds with year-round standing water. This basin drains to the north where it progressively obtains more stream-like definition as it leads to the northeast corner of the parcel (Figure 1).

The vegetation on the Souza parcel is dominated by introduced cis-montain grasslands. This parcel is periodically grazed by sheep according to a plan to manage vegetation height. The only trees on the Souza parcel are small isolated willow (*Salix* sp.) trees growing in the primary drainage.

Vasco Caves

The Vasco Caves parcel (immediately south of Souza, Figure 1) contains no wind turbines. The Vasco Caves parcel is noticeably different because it contains several large rock outcroppings in the center and western portions (Figure 1). The topography is similarly variable and undulating as on the Souza parcel except it does not contain a prominent central drainage and basin. Instead, there are two drainages: one originates in the central area and drains to the south and the other crosses the western reaches of the parcel. In addition to the prominent rock outcroppings, this parcel contains numerous isolated trees and small pockets of woodland vegetation (Figure 1).



East Bay Regional Park District
Vasco and Souza Properties

Disclaimer: Boundary and property lines shown on this map do not represent a boundary or property line survey. The East Bay Regional Park District (EBRPD) makes no representation as to the accuracy of said property lines (or any other lines), and no liability is assumed by reason of reliance thereon. Use of this map for other than its intended purpose requires the written consent of EBRPD.

Figure 1. Distribution of burrowing owl locations on the Souza and Vasco Caves parcels in 2006.

METHODS

We initially traveled all roads, including access roads to wind turbines, on each parcel and identified observation points (OP) from which to visually survey for burrowing owls. We selected OP that afforded maximum visibility of the ground surface in a given view shed on each parcel. We recorded the location of each OP on an aerial photograph of the parcel and identified the ground surface area that was visible from that OP (Figure 2).

We surveyed for burrowing owls by driving to each OP and scanning the view shed for burrowing owls with 10 x 40 binoculars and a 25 x 60 spotting scope from inside the vehicle. We then usually scanned the same area with the same equipment from outside the vehicle.

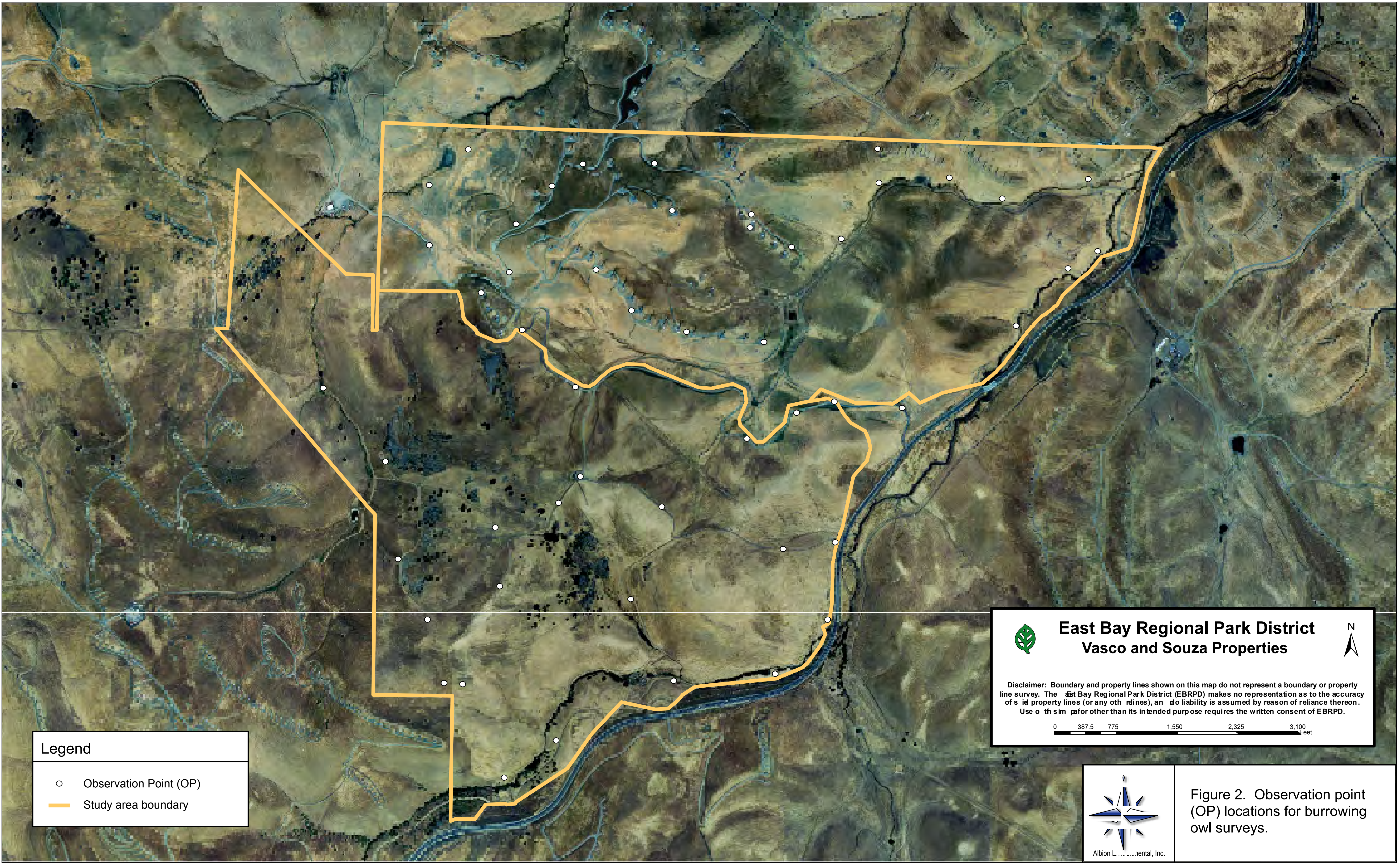
We recorded a burrowing owl sighting according to the location on the ground surface where the owl(s) was perched. Each location was identified by a primary burrow which was where we most frequently recorded owls and where we obtained UTM coordinates and other measurements (Appendix A). A location included other nearby satellite burrows generally within 30 meters of the primary burrow.

We numbered each location serially and recorded its location on an aerial photograph. We obtained Universal Transverse Mercator (UTM) coordinates of the primary burrow at each location using a Trimble GeoExplorer CE Global Positioning System (GPS) receiver. For each location we also recorded the park parcel it was in, a general location description, the date that location was first recorded, the elevation using the GPS receiver, the aspect (magnetic direction) of the land surface around the burrow and the magnetic direction of the burrow opening using a magnetic compass and the slope (in degrees) of the land around the burrow using a compass inclinometer (Appendix A). During each census we recorded the number of burrowing owls sighted at each location and their age and sex if known. We used the maximum number of emergent juveniles between 2 to 4 weeks old recorded at each nesting location as the estimate of productivity of the pair at that burrow. All location and burrowing owl observation data were entered into an Access database.

RESULTS

We recorded 582 burrowing owl sightings during 341 observations at 33 locations during 15 surveys totaling 54 hours and 10 minutes between 24 May and 2 August 2006 (Figure 3). Most surveys (11) were initiated in the early morning and generally lasted from about 8 am until 1 pm. However, the length of a survey session was adjusted based on the temperature and wind velocity as they affected burrowing owl behavior and visibility that day. If burrowing owls were still visible outside their burrows into the late morning or early afternoon we continued a survey until we felt we had obtained the best information available that day.

We classified 25 (76%) of the 33 separate locations where we recorded burrowing owls as nest locations with a breeding pair of adult owls in attendance on more than one occasion (Table 1). Nineteen of the 25 pairs of breeding owls produced at least one emergent (i.e., 2-4 week old nestling) yielding a nesting success rate of 76% (Table 2). We recorded a minimum of 68 nestlings raised by 15 successful pairs on the Souza parcel and 18 juveniles raised by 4 productive pairs on the Vasco Caves parcel (Table 2). Combining the two parcels we recorded a total of 25 nesting pairs: 19 (76%) were successful and they raised at least 86 young yielding a minimum productivity of 3.44 juveniles/pair (Table 2).



East Bay Regional Park District
Vasco and Souza Properties

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Figure 2. Observation point (OP) locations for burrowing owl surveys.

We first observed emergent juvenile burrowing owls on June 12, 2006, which was later than expected. Breeding in 2006 may have been delayed by late spring rains, which also may have caused a high incidence of initial nest failures and re-nesting attempts. The overall effect of initial nesting attempt failures is a delayed nesting phenology (Figure 3) compared to years of normal rainfall and a lower incidence of initial nesting failures.

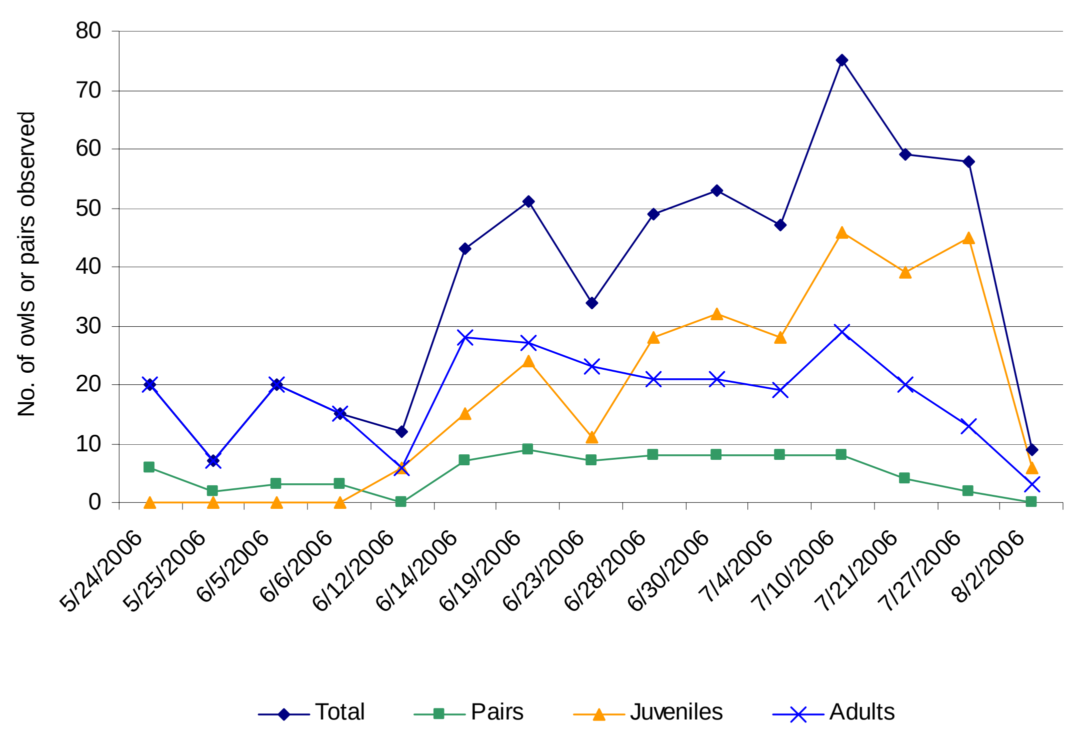

Figure 3. Chronology of burrowing owl observations on the Souza and Vasco Caves parcels in 2006.

Table 1. Status of breeding burrowing owls at locations on the Souza and Vasco Caves parcels in 2006.

Location number	Number of adults	Status	Number of juveniles
1	2	Productive nest	3
2	2	Productive nest	3
3		Non-nesting location	
4	2	Productive nest	1
5	2	Productive nest	4
6	2	Non-productive nest	0
7	2	Productive nest	5
8	2	Productive nest	3
9		Non-nesting burrow	
10	2	Productive nest	6
11	2	Non-productive nest	0
12	2	Productive nest	7
13	2	Productive nest	7
14	2	Non-productive nest	0
15 Vasco	2	Non-productive nest	0
16 Vasco	2	Productive nest	5

Location number	Number of adults	Status	Number of juveniles
17 Vasco		Non-nesting location	
18	2	Productive nest	4
19	2	Non-productive nest	0
20	2	Productive nest	3
21	2	Productive nest	4
22	2	Non-productive nest	0
23	2	Productive nest	8
24 Vasco	2	Productive nest	7
25 Vasco	2	Productive nest	3
26 Vasco	2	Productive nest	3
27	2	Productive nest	5
28 Vasco		Non-nesting location	
29		Non-nesting location	
30		Non-nesting location	
31	2	Productive nest	5
32		Non-nesting location	
33		Non-nesting location	
Totals	50		86
	25 pairs 19 productive pairs, 76% nesting success		3.44 juv./pair, 4.53 juv./prod. pair, 1.72 juv./adult

Table 2. Summary of breeding burrowing owls on the Souza and Vasco Caves parcels in 2006.

Parcel	No. of pairs	Productive pairs		Min. no. juveniles raised	Productivity (juv./pair)
		No.	% Nest success		
Souza	19	15	79%	68	3.58
Vasco Caves	6	4	67%	18	3.00
Total	25	19	76%	86	3.44

We did not begin surveys early enough in the spring (first survey on May 24) to record all initial nesting locations or show the typical cycle of burrowing owl observations throughout the nesting cycle: mostly pairs recorded in March, followed by fewer pair sightings during the egg laying and incubation phases, followed by an increase in pair sightings when females begin spending more time outside their nest burrows during the nestling stage (Figure 3). Nevertheless, Figure 3 shows an increase in pair sightings in late June, which is probably due to a locally delayed nesting phenology from spring rainfall. Observations of pairs in Figure 3 show an increase in juvenile observations in June and July and the decline in adult and pair sighting as they begin dispersing from their nesting territories.

We recorded nest burrows ranging from 383 feet to 629 feet elevation (above mean sea level) on the Souza and Vasco Caves parcels (Figure 4). The mean nest burrow elevation was 475 feet elevation and median was 448 feet.

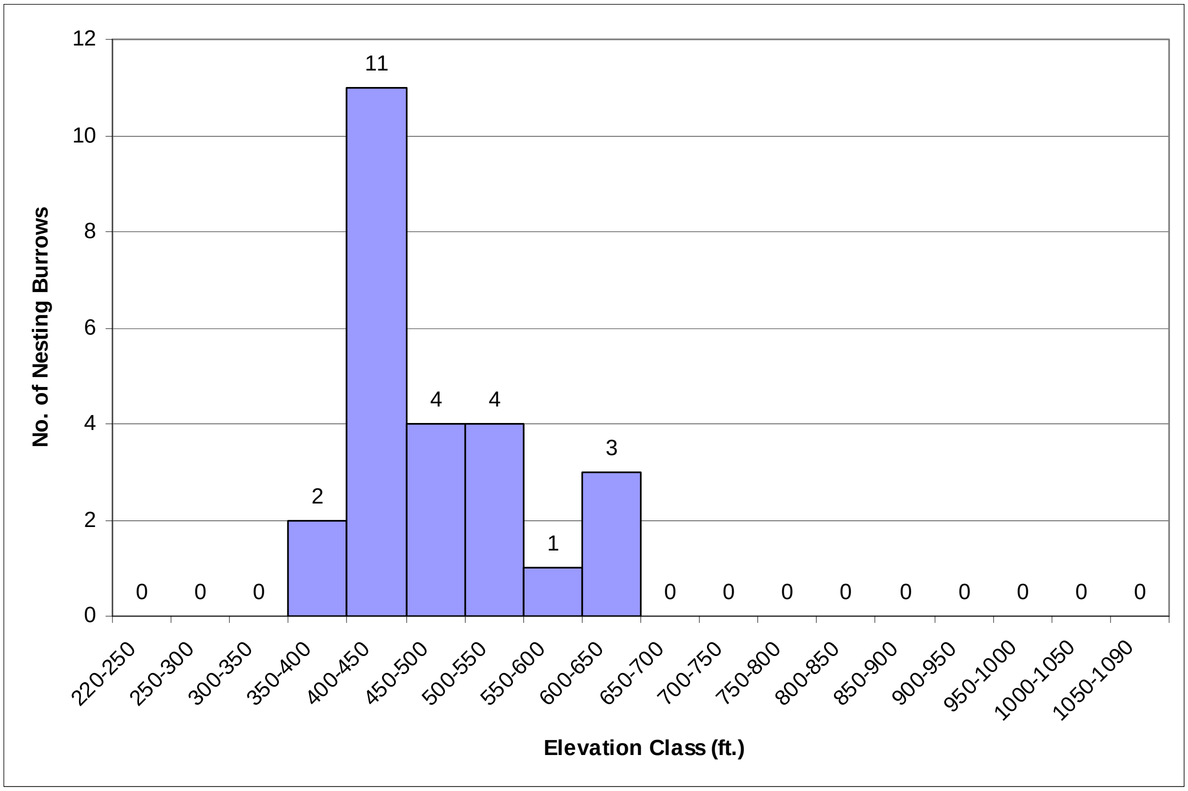

Figure 4. Elevation distribution of burrowing owl nest burrows on the Souza and Vasco Caves parcels in 2006 (min. elev. = 220 ft; max. elev. = 1090 ft).

DISCUSSION

The Souza and Vasco Caves parcels differed markedly in the number of nesting pairs of burrowing owl we recorded in 2006: 19 pairs on Souza and 6 on Vasco Caves (Table 2). As would be expected, the distribution of nesting owls on the two parcels appears closely related to the local topography and distribution of California ground squirrel (*Spermophilus beecheyi*) burrows. Most of the locations where we recorded burrowing owls on the Souza parcel were associated with the margins of the primary drainage through this parcel (Figure 1). There were only three locations in the northwest corner of Souza, two of which were nest burrows (locations 1 and 2), that were not associated with this drainage (Figure 1). Two of the six nest burrow locations on the Vasco Caves parcel (locations 15 and 24) were also associated with the same primary drainage on the Souza parcel (Figure 1). The other four nesting locations were in a short relatively steep drainage basin along the eastern boundary of the parcel (Figure 1).

Because we did not begin nesting burrowing owl census surveys until May 24, which is well into the incubation or early nestling stages of the nesting cycle, the possibility exists that we missed some nesting burrowing owls, especially pairs that failed in their initial nesting attempt and relocated. Pairs that fail at nesting usually leave their territories so we may have missed pairs that dispersed outside our study area (Rosier et al. in press). Not counting pairs that failed at nesting would have the effect of increasing (i.e., biasing high) the nesting success and productivity we estimated in 2006 (Table 2).

Burrowing owl nest burrows on the Souza and Vasco Caves parcels in 2006 occurred in a relatively narrow 246-foot elevation band within an elevation range of 870 feet (minimum of 220 feet on the

Souza parcel to a maximum of 1090 feet elevation on Vasco Caves) (Figure 4). However, 88% (23) of all nest burrows were within a narrower 180-foot elevation range from 383 to 563 feet elevation (Figure 4). This pattern of nest burrow elevation is consistent with observations of burrowing owl nests in other parts of the Altamont Pass Wind Resource Area where nesting burrowing owls tend to occur in relatively narrow elevation ranges on the lower third of slopes and around the margins of drainages and basins. The lower one-third of slopes surrounding drainages and basins appears to be where soils are deeper and better drained, hence more ground squirrel burrows, than in the bottoms of drainages where the soil remains saturated longer after rainfall or higher on slopes where the soils are shallower.

There was no statistical evidence of directedness (i.e., different from random) in the magnetic direction of the slopes (i.e., aspect, Appendix A) where we recorded burrowing owl nests in 2006 (r [mean vector] = 0.2394, *P*>0.90, Rayleigh test, Batschelet 1981) (Figure 5). In other words, there was no evidence that burrowing owls selected any range of aspects different from random for nesting in 2006. Because there was no evidence of directedness the calculation of a mean angle of the nesting slopes is impertinent (Batschelet 1981). The slope of the ground surface where we recorded nest burrows ranged from 3-23 degrees, but 44% (11) of nest burrows occurred on moderate slopes from 12-18 degrees (Figure 6).

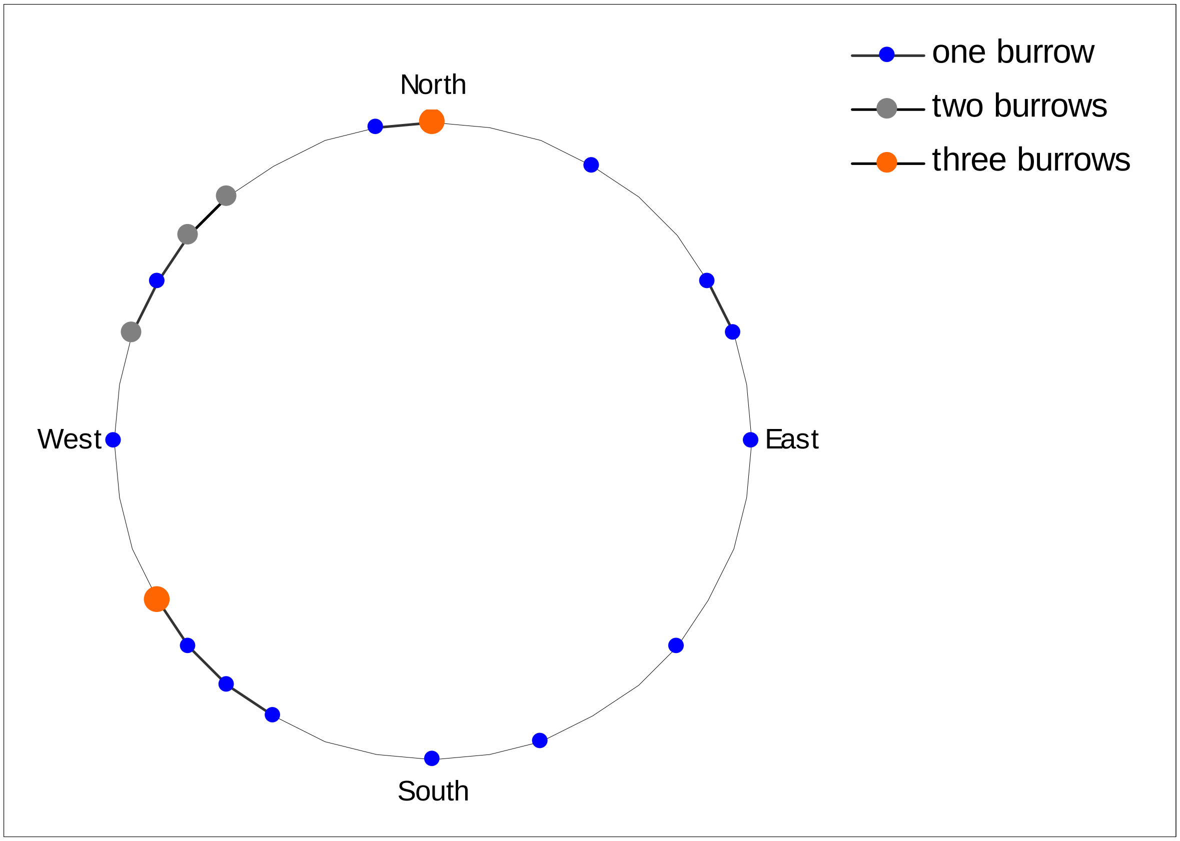

Figure 5. Aspects (i.e., magnetic directions) of the slopes where burrowing owl nests occurred on the Souza and Vasco Caves parcels in 2006.

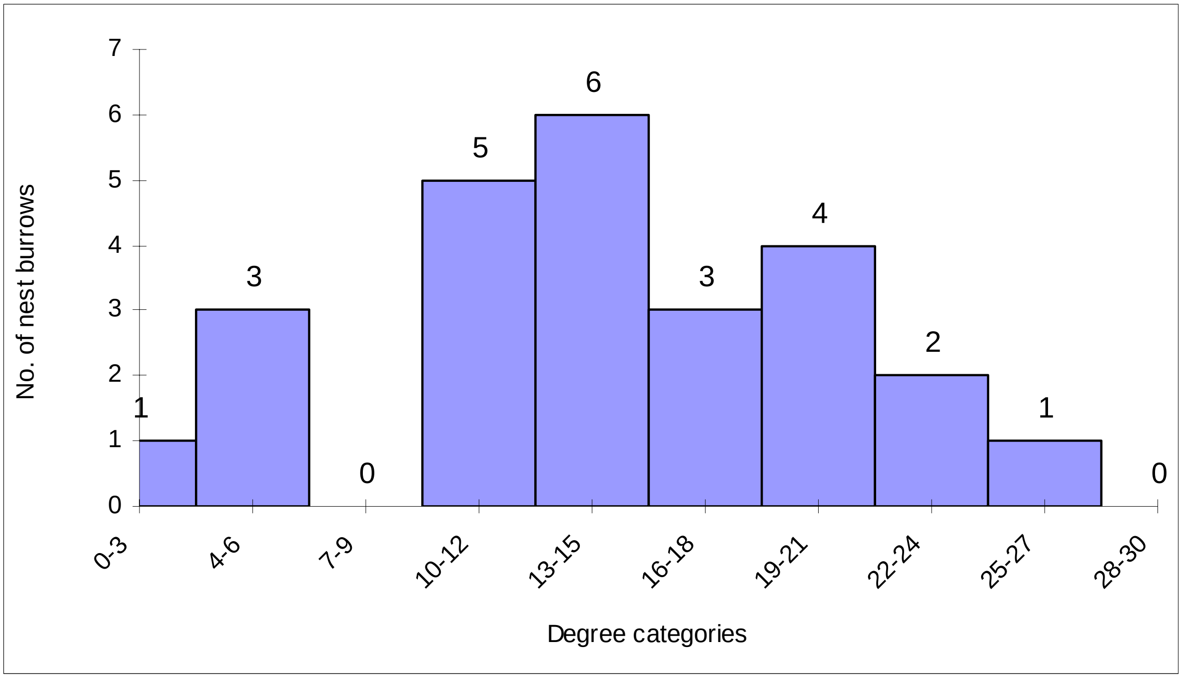

Figure 6. Slope (degrees) distribution where burrowing owl nests occurred on the Souza and Vasco Caves parcels in 2006.

We will census the nesting burrowing owl population on the Souza and Vasco Caves parcels in 2007 beginning earlier in March, which should yield better information about the initial number and distribution of nesting pairs and more accurate estimates of nesting success and productivity.

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Batschelet, E. 1981. Circular statistics in biology. Academic Press. San Francisco. 371 pp.

Rosier, J. R., N. A. Ronan, and D. K. Rosenberg. (in press). Post-Breeding Dispersal of Burrowing Owls in and Extensive California Grassland. American Midland Naturalist.

APPENDIX A

BURROWING OWL NESTING LOCATIONS ON THE SOUZA AND VASCO CAVES PARCELS IN 2006

Appendix A. Burrowing owl nesting locations on the Souza and Vasco Caves parcels in 2006.

Location No.	Park Area (Souza, Vasco)	Date First Recorded	UTM (NAD27) Northing	UTM (NAD27) Easting	Elev. (feet)	Slope (degrees)	Aspect (magnetic direction)	Burrowing Opening (magnetic direction)
01	Souza	5/24/2006	4185740	615211	610	12	270	280
02	Souza	5/24/2006	4185839	615172	563	10	320	270
04	Souza	5/24/2006	4185020	616306	429	04	060	040
05	Souza	5/24/2006	4185136	616316	409	05	090	080
06	Souza	5/24/2006	4185503	616356	473	20	360	020
07	Souza	5/24/2006	4185443	616536	405	25	240	290
08	Souza	5/24/2006	4185608	616597	383	23	310	320
10	Souza	5/24/2006	4185915	617560	473	14	360	030
11	Souza	5/24/2006	4185421	616716	514	20	220	190
12	Souza	5/24/2006	4185446	616656	489	20	230	160
13	Souza	5/24/2006	4185189	616496	414	11	290	290
14	Souza	5/24/2006	4185911	616381	541	20	165	140
15	Vasco	5/25/2006	4185257	616098	629	17	320	060
16	Vasco	5/25/2006	4184660	616514	448	13	130	120
18	Souza	6/5/2006	4185189	616547	468	15	240	220
19	Souza	6/5/2006	4185277	616496	394	10	300	280
20	Souza	6/5/2006	4185257	616178	434	17	180	180
21	Souza	6/5/2006	4185205	615764	521	15	350	360
22	Souza	6/5/2006	4185170	616446	411	04	360	020
23	Vasco	6/5/2006	4185199	616510	441	15	240	210
24	Vasco	6/6/2006	4184749	616180	506	14	310	330
25	Vasco	6/6/2006	4184540	616248	627	22	70	50
26	Vasco	6/19/2006	4184681	616584	411	17	160	160
27	Souza	6/30/2006	4184957	616378	439	03	30	360
31	Vasco	7/21/2006	4185209	616960	436	12	210	250

EAST BAY REGIONAL PARK DISTRICT

2007 NESTING BURROWING OWL CENSUS

SOUZA AND VASCO CAVES PARCELS

SEPTEMBER 2007

ALBION ENVIRONMENTAL, INC.

EAST BAY REGIONAL PARK DISTRICT

2007 NESTING BURROWING OWL CENSUS

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SEPTEMBER 2007

PREPARED FOR:

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INTRODUCTION

Albion Environmental, Inc., (Albion) is participating with the East Bay Regional Park District (EBRPD) in a two-year (2006 and 2007) study of range management practices to reduce bird mortality from wind turbines on its Souza and Vasco Caves parcels in eastern Alameda County. This study includes recording bird behavior on the 617-acre Souza parcel that contains 73 wind turbines and the 775-acre Vasco Caves parcel that contains no wind turbines. The work includes searching for bird fatalities around turbines on the Souza parcel.

This study also includes studying the abundance and distribution of nesting burrowing owls (*Athene cunicularia*) on each of the park parcels because burrowing owls are believed to be one of the most frequently killed raptors in the Altamont Pass Wind Resource Area. This report contains the results of our census of nesting burrowing owls on the Souza and Vasco Caves parcels in 2007.

STUDY AREA

The 617-acre Souza parcel and the 775-acre Vasco Caves parcel comprise a study area of 1,392 acres located on the west side of Vasco Road in eastern Contra Costa County (Figure 1). The two parcels share a common east-west running boundary that runs parallel to the main access road to the parcels from Vasco Road (Figure 1).

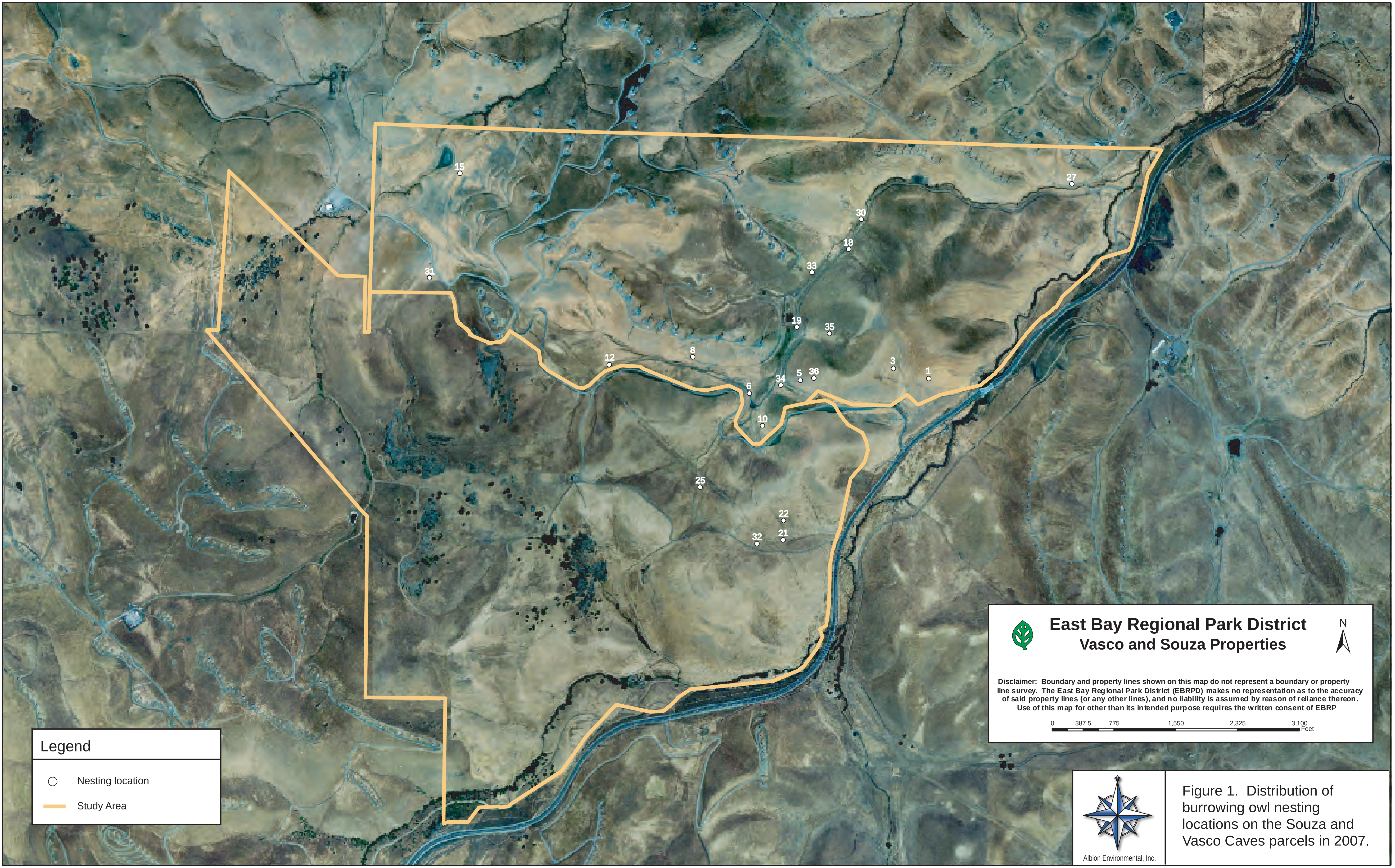
Souza

The Souza parcel contains 73 wind turbines arranged in strings of varying length and elevation (Figure 1). Terrain on the Souza parcel is highly variable with numerous hills, variable slopes and flatter basins between higher terrains. A dominant feature on the Souza parcel is an unnamed drainage that begins in a basin along the south boundary of the parcel just north of the primary access road (Figure 1). The terrain initially drains to the east forming a well-defined basin containing wetland features and two ponds with year-round standing water. This basin drains to the north where it progressively obtains more stream-like definition as it leads to the northeast corner of the parcel (Figure 1).

The vegetation on the Souza parcel is dominated by introduced cis-montain grasslands. This parcel is periodically grazed by sheep according to a plan to manage vegetation height. The only trees on the Souza parcel are small isolated willow (*Salix* sp.) trees growing in the primary drainage.

Vasco Caves

The Vasco Caves parcel (immediately south of Souza, Figure 1) contains no wind turbines. The Vasco Caves parcel is noticeably different because it contains several large rock outcroppings in the center and western portions (Figure 1). The topography is similarly variable and undulating as on the Souza parcel except it does not contain a prominent central drainage and basin. Instead, there are two drainages: one originates in the central area and drains to the south and the other crosses the western reaches of the parcel. In addition to the prominent rock outcroppings, this parcel contains numerous isolated trees and small pockets of woodland vegetation (Figure 1).



East Bay Regional Park District
Vasco and Souza Properties

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Figure 1. Distribution of burrowing owl nesting locations on the Souza and Vasco Caves parcels in 2007.

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METHODS

We initially traveled all roads, including access roads to wind turbines, on each parcel and identified observation points (OP) from which to visually survey for burrowing owls. We selected OP that afforded maximum visibility of the ground surface in a given view shed on each parcel. We recorded the location of each OP on an aerial photograph of the parcel and identified the ground surface area that was visible from that OP (Figure 2).

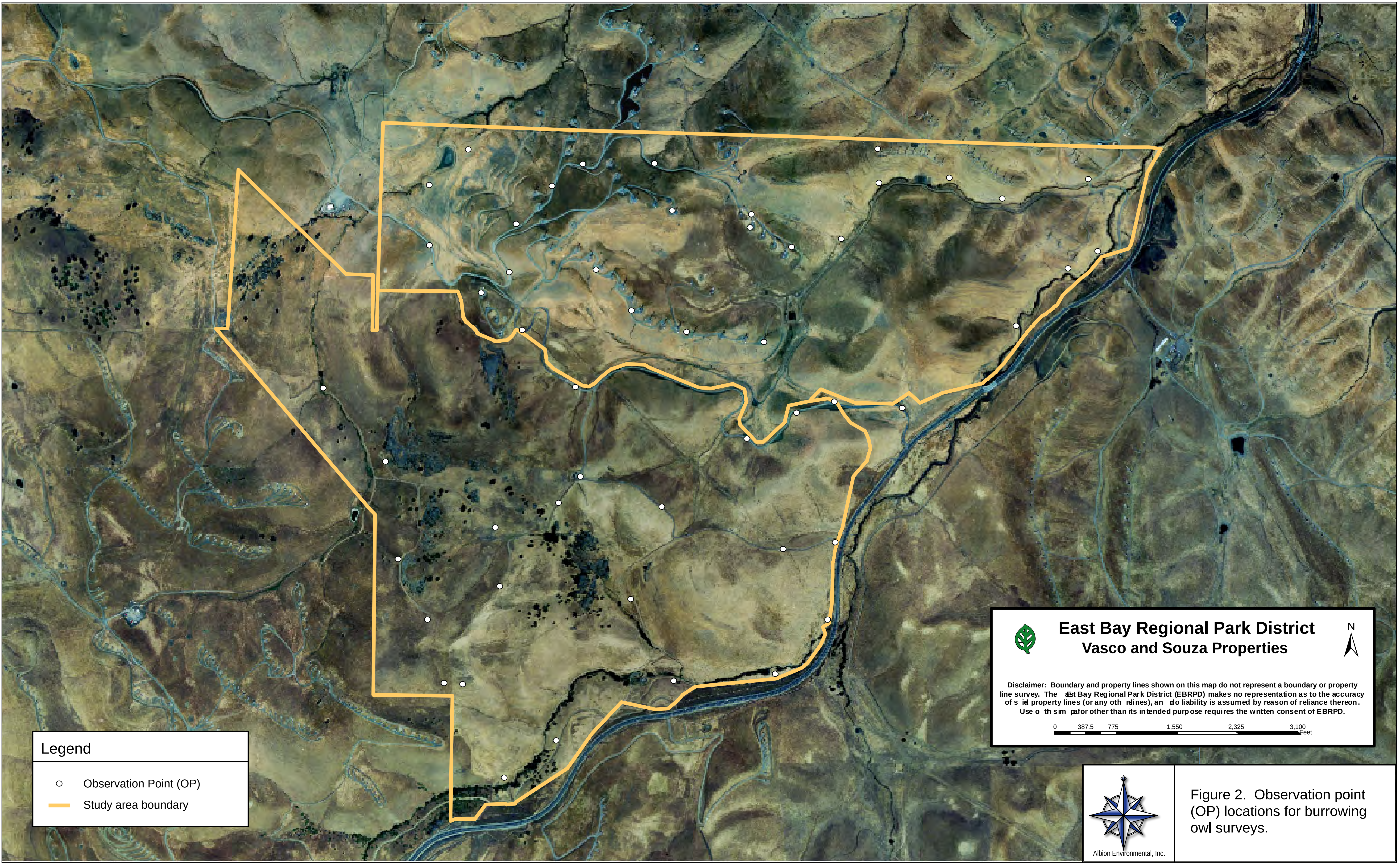
We surveyed for burrowing owls by driving to each OP and scanning the view shed for burrowing owls with 10 x 40 binoculars and a 25 x 60 spotting scope from inside the vehicle. We also sometimes scanned the same area with the same equipment from outside the vehicle. We recorded a burrowing owl sighting according to the location on the ground surface where the owl(s) was perched. Each location was identified by a primary burrow which was where we most frequently recorded owls and where we obtained UTM coordinates and other measurements (Appendix A). A location included other nearby satellite burrows generally within 30 meters of the primary burrow.

We numbered each location serially and recorded its location on an aerial photograph. We obtained Universal Transverse Mercator (UTM) coordinates of the primary burrow at each nesting location using a Magellan Explorist XL Global Positioning System (GPS) receiver (NAD 83). We do not provide GPS coordinates for non-nesting locations (Appendix A) because unlike nest burrows, these locations were usually not represented by one identifiable burrow. For each location we also recorded the park parcel it was in, a general location description, the date that location was first recorded, the elevation using the GPS receiver, the aspect (magnetic direction) of the land surface around the burrow and the magnetic direction of the burrow opening using a magnetic compass and the slope (in degrees) of the land around the burrow using a compass inclinometer (Appendix A). During each census we recorded the number of burrowing owls sighted at each location and their age and sex, if identifiable. We used the maximum number of emergent juveniles between 2 to 4 weeks old recorded at each nesting location as the estimate of productivity of the pair at that burrow. All location and burrowing owl observation data were entered into an Access database.

RESULTS

We recorded 337 burrowing owl sightings during 290 observations at 39 locations during 11 surveys totaling 44 hours between 3 April and 27 June 2007 (Figure 3). Most surveys (11) were initiated in the morning and generally lasted 3.5 to 5 hours. However, the length of a survey session was adjusted based on the temperature and wind velocity as they affected burrowing owl behavior and visibility that day. If burrowing owls were still visible outside their burrows into the late morning or early afternoon we continued a survey until we felt we had obtained the best information available that day.

We classified 21 (54%) of the 39 separate locations where we recorded burrowing owls as nest locations with a breeding pair of adult owls in attendance on more than one occasion (Table 1). We recorded only one adult on four occasions from early April to early May at location 17 so we classified this as a single adult and a non-nesting location, but used this adult in the computation of productivity per adult (Table 1). Twelve of the 21 nesting pairs of owls produced at least one emergent nestling (i.e., 2-4 weeks old) yielding a nesting success rate of 57% (Table 2). We recorded a minimum of 31 nestlings raised by nine successful pairs on the Souza parcel and 10 juveniles raised by 3 productive pairs on the Vasco Caves parcel (Table 2). Combining the two parcels we recorded a



East Bay Regional Park District
Vasco and Souza Properties

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Legend

○ Observation Point (OP)
▬ Study area boundary

Albion Environmental, Inc.

Figure 2. Observation point (OP) locations for burrowing owl surveys.

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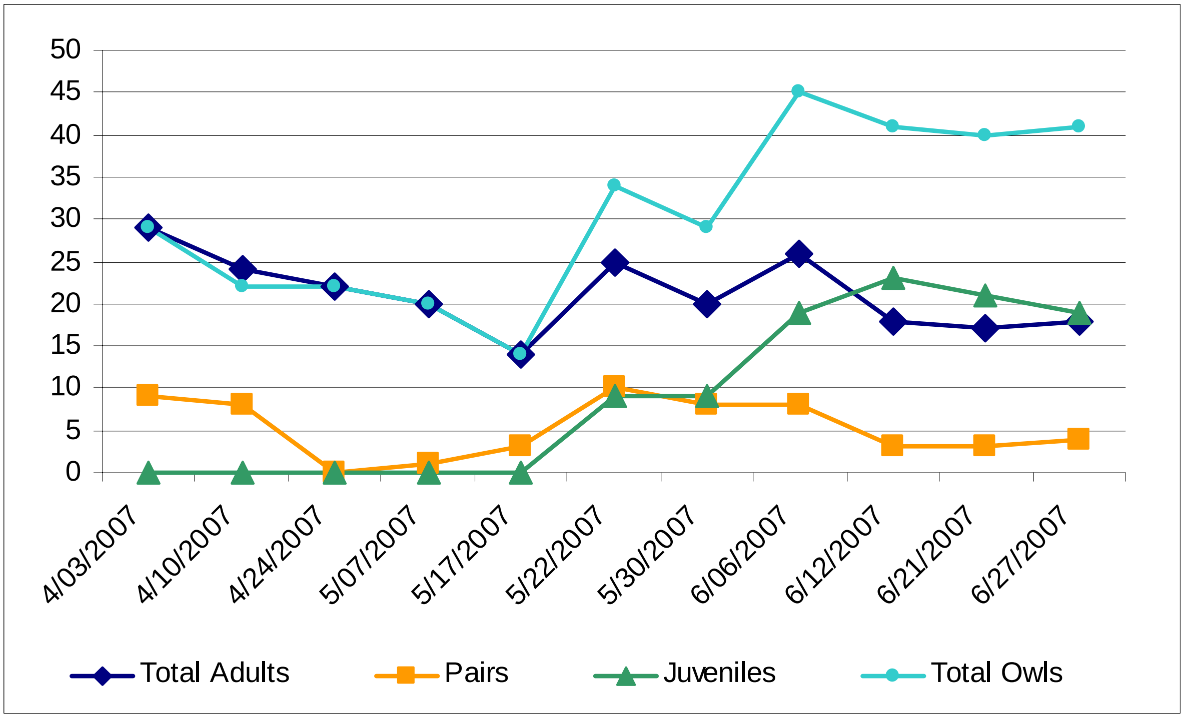

Figure 3. Chronology of burrowing owl observations on the Souza and Vasco Caves parcels in 2007.

total of 21 nesting pairs: 12 (57%) nested successfully and raised at least 41 young yielding a minimum productivity of 1.95 juveniles/pair (Table 1).

We first observed emergent juvenile burrowing owls on May 22, 2007 (Figure 3), which was over two weeks earlier than when we first observed juveniles (June 12) in 2006. Burrowing owl breeding in 2007 seemed to be consistent with the normal nesting phenology in northern California compared to 2006 when breeding may have been delayed by late spring rains (Albion Environmental, Inc. 2006).

We recorded nest burrows ranging from 247 feet to 650 feet elevation (above mean sea level) on the Souza and Vasco Caves parcels (Figure 4). The mean nest burrow elevation was 440 feet elevation and median was 431 feet.

Table 1. Status of breeding burrowing owls at locations on the Souza and Vasco Caves parcels in 2007.

Location number	Number of adults	Status	Number of juveniles
1 Souza	2	Productive nest	8
2 Souza	0	Satellite location	
3 Souza	2	Productive nest	5
4 Souza	0	Satellite location	
5 Souza	2	Productive nest	6
6 Souza	2	Productive nest	3
7 Souza	0	Satellite location	
8 Souza	2	Productive nest	2
9 Souza	0	Satellite location	
10 Souza	2	Non-productive nest	0
11 Souza	0	Satellite location	
12 Souza	2	Non-productive nest	0
13 Souza	0	Satellite location	
14 Souza	0	Satellite location	
15 Souza	2	Non-productive nest	0
16 Souza	0	Satellite location	
17 Souza	1	Non-nest location	
18 Souza	2	Productive nest	2
19 Souza	2	Non-productive nest	0
20 Souza	0	Satellite location	
21 Vasco	2	Productive nest	3
22 Vasco	2	Non-productive nest	0
23 Vasco	0	Satellite location	
24 Vasco	0	Satellite location	
25 Vasco	2	Productive nest	4
26 Vasco	0	Non-nest location	
27 Souza	2	Non-productive nest	0
28 Souza	0	Satellite location	
29 Souza	0	Satellite location	
30 Souza	2	Productive nest	1
31 Souza	2	Non-productive nest	0
32 Vasco	2	Productive nest	3
33 Souza	2	Non-productive nest	0
34 Souza	2	Non-productive nest	0
35 Souza	2	Productive nest	1
36 Souza	2	Productive nest	3
37 Souza	0	Satellite location	
38 Vasco	0	Satellite location	
39 Souza	0	Satellite location	
Totals	**43**		**41**
	21 pairs, 1 single 12 productive pairs, 57% nesting success		1.95 juv./pair 0.95 juv./adult 3.42 juv./prod pair,

Table 2. Summary of breeding burrowing owls on the Souza and Vasco Caves parcels in 2007.

Parcel	No. of pairs	No. productive pairs (nesting success)	Minimum no. juveniles raised	Productivity
Souza	17	9 (53%)	31	1.82 juv./pair
Vasco Caves	4	3 (75%)	10	2.50 juv./pair
Total	**21**	**12 (57%)**	**41**	**1.95 juv./pair**

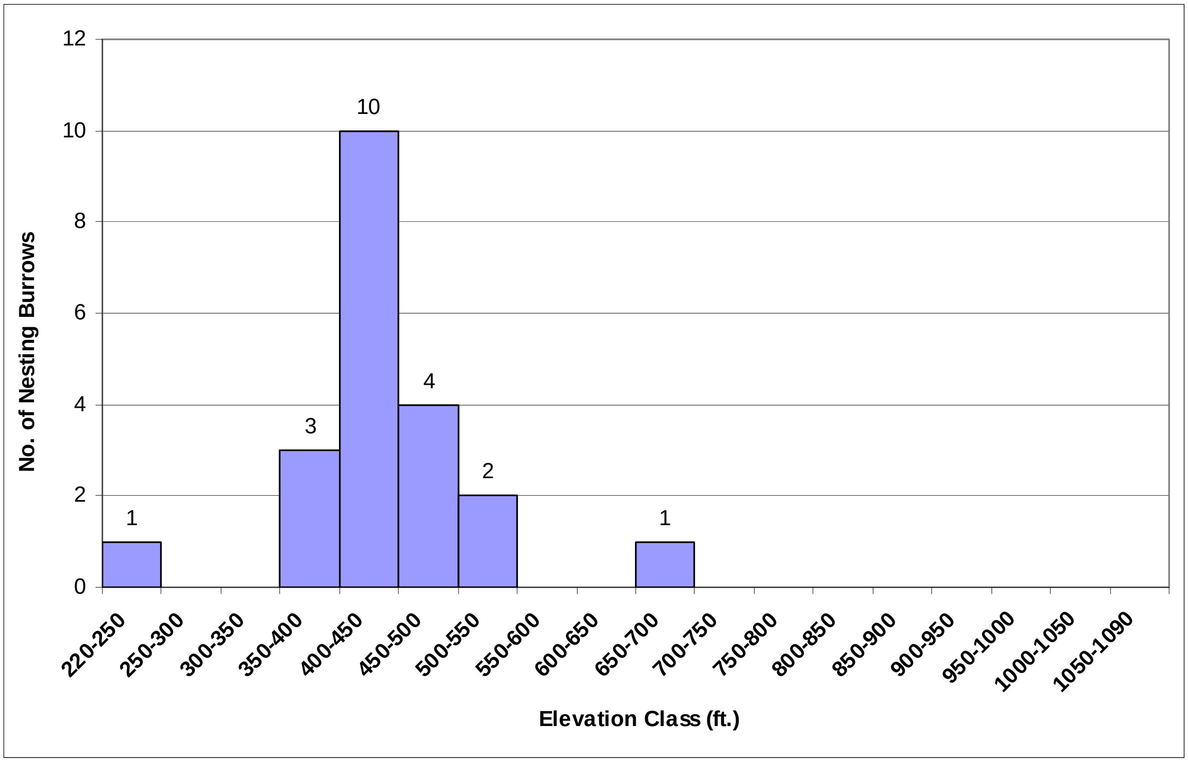

Figure 4. Elevation distribution of burrowing owl nest burrows on the Souza and Vasco Caves parcels in 2007 (n= 21, min. elev. = 247 ft., max. elev. = 650 ft.). Elevation on the Souza and Vasco Caves study site ranges from 220 ft. to 1090 ft.

DISCUSSION

The Souza and Vasco Caves parcels differed markedly in the number of nesting pairs of burrowing owls we recorded in 2006 and 2007: 19 versus 17 pairs on Souza and 6 versus 4 on Vasco Caves respectfully (Table 2). As would be expected, the distribution of nesting owls on the two parcels appeared closely related to the local topography and distribution of California ground squirrel (*Spermophilus beecheyi*) burrows. Most of the locations where we recorded burrowing owls on the Souza parcel were associated with the margins of the primary drainage through this parcel (Figure 1). There were only two locations in the northwest corner of Souza, only one of which was a nest location (location 15), that were not associated with this drainage (Figure 1). One of the four nest locations on the Vasco Caves parcel (location 25) was also associated with the same primary drainage on the Souza parcel (Figure 1). The other three nesting locations were in a short relatively steep drainage basin along the eastern boundary of the parcel (Figure 1).

Burrowing owl nesting on the Souza and Vasco Caves parcels in 2007 declined in the primary population parameters we measured. Total pairs declined 16% from 25 in 2006 to 21 this year. Nesting success declined from 75% to 56% in 2007. The minimum number of juveniles raised also declined from 86 in 2006 to 41 this year. This is reflected in the minimum productivity statistic of only 1.95 juveniles/pair this year compared to 3.44 juveniles/pair in 2006 (Albion Environmental, Inc. 2006).

The possibility exists that we missed some nesting burrowing owls, especially pairs that failed in their initial nesting attempt and relocated. Pairs that fail at nesting usually leave their territories so we may have missed pairs that dispersed outside our study area (Rosier et al. 2006). Not counting pairs that failed at nesting would have the effect of increasing (i.e., biasing high) the nesting success and productivity we estimated in 2007 (Table 2).

Elevation on the Souza and Vasco Caves terrain ranges 870 feet from a minimum of 220 feet on the Souza parcel to a maximum of 1090 feet elevation on the Vasco Caves parcel. Burrowing owl nest burrows on the Souza and Vasco Caves parcels in 2007 occurred in a 403-foot wide elevation range from 247 to 650 feet. However, excluding the minimum nest location (247 ft.) and the maximum (650 ft.) shows that 19 (91%) of all nest burrows were within a narrower 169-foot elevation range from 368 to 537 feet elevation (Figure 4). This pattern of nest burrow occurrence is consistent with observations of burrowing owl nests in other parts of the Altamont Pass Wind Resource Area where nesting burrowing owls tend to occur in relatively narrow elevation ranges on the lower third of slopes and around the margins of drainages and basins. The lower one-third of slopes surrounding drainages and basins appears to be where soils are deeper and better drained, hence more ground squirrel burrows, than in the bottoms of drainages where the soil remains saturated longer after rainfall or higher on slopes where the soils are shallower.

There was no statistical evidence of directedness (i.e., different from random) in the magnetic direction of the slopes (i.e., aspect, Appendix A) where we recorded 17 burrowing owl nest burrows locations in 2007 (r [mean vector] = 0.3245, *P*>0.10, Rayleigh test, Batschelet 1981) (Figure 5). In other words, there was no evidence that burrowing owls selected any range of aspects different from random for nesting in 2007. Because there was no evidence of directedness the calculation of a mean angle of the nesting slopes is irrelevant (Batschelet 1981).Three locations on flat terrain (i.e., no slope) are not included in this analysis. We could not identify a discrete nest burrow at location 31 where we concluded there was a pair that did not nest successfully (Appendix A), therefore we did not record the aspect or burrow opening, although we were able to obtain elevation, slope and UTM coordinates of a burrow cluster at this location (Appendix A).

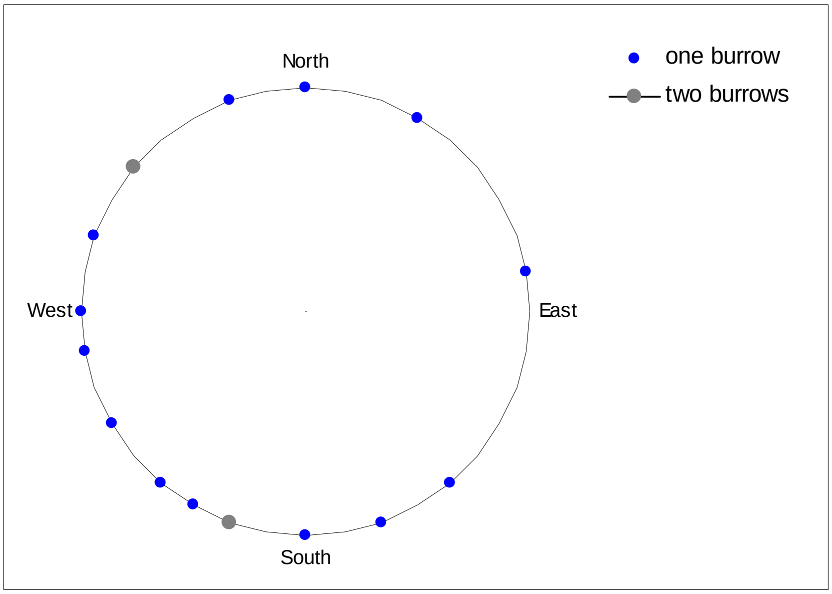

Figure 5. Aspects (i.e., magnetic directions) of the slopes where burrowing owl nests (n=17) occurred on the Souza and Vasco Caves parcels in 2007.

The slope of the ground surface where we recorded nest burrows ranged from 0-22 degrees with about half (11) of the nest burrows on gentle slopes from 0-12 degrees and the remainder (10) on steeper terrain ranging from 16-24 degrees (Figure 6).

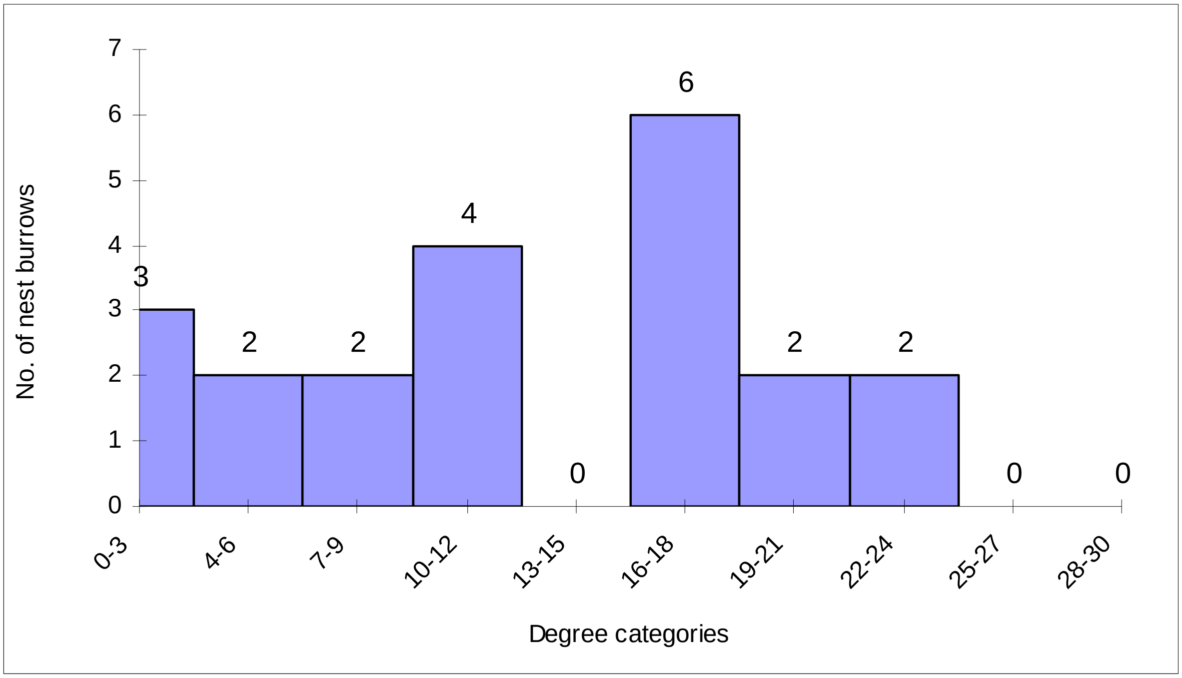

Figure 6. Slope (degrees) distribution where burrowing owl nests (n=21) occurred on the Souza and Vasco Caves parcels in 2007.

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APPENDIX A

BURROWING OWL NESTING LOCATIONS ON THE SOUZA AND VASCO CAVES PARCELS IN 2007

Appendix A. Burrowing owl nesting locations on the Souza and Vasco Caves parcels in 2007.

Location No.	Park Area (Souza, Vasco)	Date First Recorded	UTM (NAD83) Northing	UTM (NAD83) Easting	Elev. (feet)	Slope (degrees)	Aspect (magnetic direction)	Burrowing Opening (magnetic direction)
01	Souza	4/03/2007	4185377	616938	424	22	160	120
03	Souza	4/03/2007	4185408	616859	414	20	240	290
05	Souza	4/03/2007	4185370	616444	455	16	200	230
06	Souza	4/003/2007	4185330	616222	421	06	080	080
08	Souza	4/03/2007	4185471	616027	447	10	180	210
10	Souza	4/03/2007	4185192	616301	431	04	270	260
12	Souza	4/03/2007	4185395	616658	537	0	n/a	060
15	Souza	4/03/2007	4186135	616129	534	10	340	360
18	Souza	4/03/2007	4185879	616580	371	10	310	300
19	Souza	4/03/2007	4185634	616447	408	16	220	210
21	Vasco	4/10/2007	4184775	616449	419	16	360	010
22	Vasco	4/10/2007	4184848	616405	442	20	140	080
25	Vasco	4/10/2007	4184934	616088	499	16	290	290
27	Souza	4/10/2007	4186139	616504	247	0	n/a	050
30	Souza	4/24/2007	4185925	616610	368	0	n/a	070
31	Souza	4/24/2007	4185726	616977	650	22	unknown	unknown
32	Vasco	4/24/2007	4184771	616354	468	08	030	020
33	Souza	5/07/2007	4185754	616463	378	18	310	310
34	Souza	5/07/2007	4185408	616371	404	08	260	260
35	Souza	6/06/2007	4185594	616550	445	12	210	280
36	Souza	6/06/2007	4185369	616492	496	16	200	200