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EXECUTIVE SUMMARY

An unexpected impact of widespread wind turbine development in California has been the deaths of birds from collision with turbines. These deaths have generated controversy about the potential impacts of wind turbine facilities on bird populations. Information about avian mortality at wind turbine sites is limited. A recent study by the California Energy Commission (CEC 1989) reviewed the existing data on many windfarm-related avian injuries and deaths throughout California and concluded that the number of mortalities was high enough to warrant further investigation. The potential impacts of windfarm developments and their supporting network of transmission lines include mortality from collision with structures or wires, electrocution, changes in foraging or migratory patterns, habitat reduction, and prey base changes. Of particular concern is the impact of windfarms on raptors (birds of prey), which are protected by both state and federal laws.

To address these concerns, Alameda, Contra Costa, and Solano counties sponsored a two-year study that was funded by the California Energy Commission and conducted by BioSystems Analysis, Inc. The purpose of the study was to evaluate the extent and significance of the impact of wind turbines on birds, to identify the causes and factors contributing to bird deaths, and to recommend mitigation measures. The study was a cooperative effort among county governments, state agencies, and the windfarm industry. This report presents the results of our study.

The study areas included the Altamont Pass Wind Resource Area (WRA) in Alameda and Contra Costa counties and a WRA under development in Solano County. The Altamont Pass WRA is the largest wind turbine development in the world. At present, over 7,000 turbines catch the wind blowing across the open grasslands and rolling hills of the Altamont Pass. Both study areas provide important foraging habitat for at least 13 species of resident and migrating hawks, eagles, and vultures. Because Solano County had no developed windfarm sites when the study began, most of the data were gathered in Altamont Pass. All mortality data were collected in the Altamont Pass WRA.

We conducted six seasons of field work (1989 to 1991) within the Altamont Pass. Our study included searching the ground near turbine and transmission line structures for injured or dead birds, measuring the rate of bird carcass removal by scavengers, assessing the ability of observers to locate bird carcasses, determining the relative abundance of birds in the area, and observing bird behavior in relation to the turbine and transmission line structures.

We observed 15 species of raptor in the Altamont Pass WRA and 9 in the Solano County WRA. Red-tailed hawks, golden eagles, turkey vultures, and American kestrels were common resident species. Ferruginous and rough-legged hawks migrate into or through the study areas during fall and winter.

Of 182 dead birds found within the sample sites, 119 (65%) were raptors. Most carcasses were old and decomposed when found; only 19 carcasses were fresh. Most of the dead raptors were red-tailed hawks, followed by American kestrels and golden eagles. We also discovered a few dead turkey vultures, owls, and common ravens. Only four injured raptors were discovered.

We attributed fifty-five percent of all raptor deaths within our sample sites to collisions with turbines, 8 percent to electrocutions, 11 percent to collisions with wires, and 26 percent to unknown causes. Most of these deaths resulted from amputation injuries. Immature golden eagles and red-tailed hawks were killed by colliding with turbines more frequently than would have been predicted from their relative abundance in the population.

Most electrocutions occurred at riser poles. This type of pole, which is common in the study area, has more potential points for electrical contact than most other pole types. Only larger birds (i.e., red-tailed hawks, golden eagles, and common ravens) were electrocuted; the wing span of these birds is large enough to complete an electrical circuit.

Our data indicated that raptor mortality was significantly higher at end-row turbines than at in-row turbines. Mortality rates also were significantly higher at turbines in close proximity to canyons than at those farther from canyons. These two variables were more strongly associated with mortality than were any other variables we measured. Our analysis showed that each factor was independently associated with mortality and that, when both were present, their combined effect on mortality was synergistic. Neither variable was significantly associated with non-raptor mortality.

Elevation and structure density (the number of structure rows around a site of mortality) were also significantly associated with mortality. Raptors were killed more frequently at higher elevation, whereas non-raptors were killed more frequently at lower elevation. Elevation was, however, correlated with other variables associated with mortality, so we are uncertain of its biological significance. Our analysis indicated that turbines with lower structure density had significantly higher raptor and non-raptor mortality rates than those turbines with higher densities.

Mortality differed among turbine types and was greater at three-blade lattice turbines than at any other turbine type. Furthermore, mortality at end-row turbines and turbines close to canyons was higher at three-blade lattice turbines than at other turbine types. It is, however, difficult to determine whether differences in mortality at different turbine types are related to the turbine type itself, to topographic features more commonly associated with one turbine type than another, or to some other variable we did not measure.

We found no consistent seasonal trends in death rates in our study. The high winter death rates reported in the California Energy Commission (CEC 1989) study may have been an artifact of reporting methods. While the effect of weather on death rates was inconclusive, since many birds were killed in clear conditions, inclement weather is probably not a critical factor.

We never observed a bird flying into a wind turbine, so it is difficult to determine the specific circumstances under which these deaths occur. A raptor stooping on prey may be less aware of or misjudge the distance to rotating turbine blades. Many of the birds we observed flew close to the turbines and seemed unaware of the potential danger of the rotating blades. Foraging was common around operating turbines and birds appeared to be accustomed to the presence of turbines; habituation may be an important factor contributing to the death rate.

Our study showed that mortality among the five most common species was not related to the abundance of those species. American kestrels, red-tailed hawks, and golden eagles were killed more often than we would have predicted from their abundance in the study area. In contrast, fewer turkey vultures and common ravens were killed than their abundance in the study area would suggest. Based on our mortality and abundance data, golden eagles, red-tailed hawks, and American kestrels were three to nine times more likely to be killed than were turkey vultures. These differences may reflect species-specific foraging behavior and flight characteristics (flight height, distance of flying birds to turbines and turbine blades, and frequency of perching on turbine structures) that could make some species more susceptible to collisions than others.

Differences in foraging behavior among these five species may broadly explain differences in their mortality rates. Golden eagles, red-tailed hawks, and American kestrels hunt primarily by stooping on their prey. By contrast, turkey vultures and common ravens rely more on scavenging, which does not typically involve high-speed flying or highly-focused concentration. Based on foraging behavior, susceptibility to collision for golden eagles, red-tailed hawks, and American kestrels was high and so was their relative mortality, whereas susceptibility for turkey vultures and common ravens was low, as was their relative mortality.

Flight characteristics could further explain why some species appear to be more susceptible to collision than others. Based on flight characteristics, the susceptibility of American kestrels to collision was high and, in fact, their relative mortality was high. Conversely, susceptibility of turkey vultures to collision was low, as was their relative mortality. Relative mortality of golden eagles and red-tailed hawks was high, but the contribution of flight characteristics to susceptibility was ambiguous. Flight characteristics also did not explain mortality for common ravens, for which susceptibility was high and relative mortality was low.

Our estimate of the number of raptors killed by windfarm-related injuries within the entire Altamont Pass WRA varied from 403 in the first year of the study to 164 during the second year. Of these raptor deaths, we conservatively estimated that 39 golden eagles were killed each year. Sixty-nine percent of all golden eagle deaths were attributed to collisions with turbines. These estimates have a large potential for error because of the number of variables involved and the small number of fresh carcasses found. Also, yearly variation was high; we found 16 fresh carcasses on our sample sites during the first three seasons of our study and only 3 fresh carcasses during the second three seasons. Nevertheless, we believe our estimates are cause for concern, especially for golden eagles which are federally protected under the Bald Eagle Protection Act and are a California species of special concern. Furthermore, the Altamont Pass WRA is considered an important wintering area for golden eagles (CEC 1989). Regardless of whether raptor populations are significantly affected by turbine-related mortality, the California Energy Commission (CEC 1989) states that efforts should be made to mitigate raptor losses. Even low mortality rates may be significant for rare or protected bird species.

We first presented recommendations for minimizing windfarm bird fatalities from electrocution in our progress report. These have been adopted by Alameda, Contra Costa, and Solano counties. In this report, we present recommendations regarding turbine-related mortalities that include suggestions for experimental studies to further investigate contributing factors and to determine the effectiveness of turbine and habitat alterations that could potentially reduce deaths. Alameda, Contra Costa, and Solano counties are currently reviewing their general plans and windfarm development implementing documents to address this problem.

ACKNOWLEDGMENTS

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We would also like to thank the East Bay Regional Parks for allowing the use of camping facilities at Del Valle Regional Park.

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1.0 INTRODUCTION

1.1 BACKGROUND

The use of wind turbines to generate power is increasing in California. An unexpected impact of this development has been the death of birds from collision with turbines. These deaths have generated controversy about the potential impacts of wind turbine facilities on bird populations. Consequently, the California Energy Commission (CEC) recently conducted a preliminary survey to collect information on avian mortalities in all California wind resource areas (WRAs), or windfarms (CEC 1989). Mortality data were solicited from U.S. Fish and Wildlife Service (USFWS) agents, California Department of Fish and Game (CDFG) wardens, wildlife rehabilitation centers, and windfarm operators. This survey showed that windfarm-related bird deaths were numerous enough to be an environmental concern and warranted further investigation. These results were of interest to regulatory agencies, public interest groups, public utilities, and the windfarm companies. As a result, studies were begun by both the windfarm industry (Howell and DiDonato 1991) and county agencies. Alameda, Contra Costa, and Solano counties, through a grant from the CEC, contracted BioSystems Analysis, Inc. (BioSystems), to evaluate the effects of wind turbine development on avian (especially raptor) activity and habitat use in the Altamont Pass and Solano County WRAs.

The Altamont Pass WRA, located in Alameda and Contra Costa counties, is the largest wind turbine development in the world. Construction of the Solano County WRA has only recently begun. Both WRAs are situated on important winter foraging areas and migration corridors for a number of species of raptors (CDFG 1983; Jones and Stokes Assoc., Inc. and EDAW, Inc. 1975). The open grasslands of Altamont Pass support a large rodent population (particularly California ground squirrels, *Spermophilus beecheyi*) that provides an important prey base for many raptor species in this area. The Solano County WRA is near Suisun Marsh, an important wetland for wintering waterfowl along the Pacific Flyway. The importance of Suisun Marsh and its adjacent uplands to both waterfowl and raptors is well documented (Jones and Stokes Assoc., Inc. and EDAW, Inc. 1975; USFWS 1978).

Although each windfarm approved for construction poses a minimal threat to wildlife provided standard mitigation measures are followed, the cumulative impact of current and potential developments may be significant. Both the presence of turbines and the noise and movement associated with their operation may affect habitat use or migration patterns of birds, particularly the open-country raptors most common in the area. Potential impacts of windfarms and their associated transmission lines include:

- collisions with turbines or associated structures,
- electrocution on transmission lines or towers,

- collision with transmission line wires,
- change in raptor foraging or migratory use patterns,
- habitat reduction, and
- prey base changes.

Furthermore, large predators, such as coyotes (*Canis latrans*), may be attracted to the carcasses of birds killed by turbines. These predators pose a threat to other sensitive wildlife species such as San Joaquin kit foxes (*Vulpes macrotis mutica*).

Even low mortality may affect the future of rare and endangered species. Sixteen bird species with special legal or management status actually or potentially occur within the two WRAs or are likely to migrate over the area; 14 of these are raptors (Table 1.1). Several of these species nest locally, including burrowing owls (*Speotyto cunicularia*), northern harriers (*Circus cyaneus*), black-shouldered kites (*Elanus caeruleus*), Cooper's hawks (*Accipiter cooperii*), prairie falcons (*Falco mexicanus*), and golden eagles (*Aquila chrysaetos*) (CDFG 1983). All raptors are protected by the federal Migratory Bird Treaty Act and by California Fish and Game codes. Information on habitat requirements and general life history of raptors that occur in this area is presented in Appendix A.

The goals and objectives of our study were to:

- assess the extent and significance of avian mortality throughout the WRAs,
- determine the causes of avian mortality,
- identify factors contributing to mortality in the study area,
- identify the most hazardous siting conditions in the study area,
- determine if and how raptor use patterns and activity are affected by wind turbine development, and
- develop mitigation measures to avoid, minimize, or compensate for any adverse effects.

The field techniques employed in our study were adapted from similar studies of avian collision mortality along transmission lines (Anderson 1978, Beaulaurier 1981, James and Haak 1979, Meyer 1978, Scott 1972, McCrary et al. 1987). Our study included searching the ground near turbine and transmission line structures for injured or dead birds, measuring the rate of bird carcass removal by scavengers, assessing the ability of observers to locate bird carcasses, determining the relative abundance of birds in the area, and observing bird behavior in relation to the turbine and transmission line structures.

Table 1.1. Special status birds potentially or actually occurring in the study areas.

SPECIES	MANAGEMENT STATUS
Bald eagle (*Haliaeetus leucocephalus*)	FE,CE,CP,EA
American peregrine falcon (*Falco peregrinus anatum*)	FE,CE,CP
Golden eagle (*Aquila chrysaetos*)	CP,EA,SS
Swainson's hawk (*Buteo swainsoni*)	CT,F2
Osprey (*Pandion haliaetus*)	SS
Prairie falcon (*Falco mexicanus*)	SS
Merlin (*Falco columbarius*)	SS
Northern harrier (*Circus cyaneus*)	SS
Ferruginous hawk (*Buteo regalis*)	F2,SS
Cooper's hawk (*Accipiter cooperii*)	SS
Sharp-shinned hawk (*Accipiter striatus*)	SS
Black-shouldered kite (*Elanus caeruleus*)	CP
Burrowing owl (*Speotyto cunicularia*)	SS
Short-eared owl (*Asio flammeus*)	SS
Aleutian Canada goose (*Branta canadensis leucopareia*)	FT
Long-billed curlew (*Numenius americanus*)	F2,SS

STATUS LEGEND

FE: Federally Endangered
CE: California Endangered
F2: Federal Candidate species - Category 2 (taxa which may warrant listing but for which existing biological information is inadequate)
CT: California Threatened
CP: California Fully Protected
EA: Protected under Bald Eagle Protection Act
SS: Species of Special Concern (CDFG 1991)

The results of the first year's study were presented in March 1991. An additional year of monitoring was funded by CEC and that field work was completed in February 1991. This report synthesizes and presents the results of both years of study. Because Solano County had no developed windfarm sites when our study began, most data were gathered in the Altamont Pass WRA.

1.2 LITERATURE REVIEW

The amount of literature on avian collisions with man-made structures has greatly increased over the last several decades; however, much of this literature concerns tall buildings, radio and television towers, lighthouses, and overhead electrical wires. Collisions with such man-made structures have contributed significantly to avian mortality in the United States (Avery et al. 1980). It is estimated that from 5 million to over 80 million birds die annually from such collisions (Banks 1979, Klem 1979). Avery et al. (1980) summarized the literature on avian collision mortality throughout the United States. Olendorff and Lehman (1986) reviewed and summarized field observations of raptor collisions with powerlines in California.

Passerines (songbirds) migrating at night under overcast skies appear to be the birds most vulnerable to collision. Waterfowl also may be at high risk, particularly when structures are located near water (Jones and Stokes Assoc., Inc. 1985). Weather conditions have been implicated in large-scale bird kills (Cochran and Graber 1958, Kemper 1964, Weir 1977). Although collision mortality has been studied extensively, most research has addressed tall structures and nocturnal migrants east of the Rockies. These studies are not readily applicable to California wind turbine investigations.

There are few specific studies on the effects of wind turbines on birds, probably because wind energy technology is relatively new. The potential problem of collision mortality was first suggested relatively early in the development of this new technology (Rogers et al. 1977, Haussler 1980). The following summary emphasizes the most relevant studies to date.

Most windfarm studies have focused on non-raptorial birds. Southern California Edison Company (Edison) conducted several studies in southern California on the effects of wind turbines on birds (McCrary et al. 1983, 1984, 1986). Nocturnally-migrating birds were studied using a mobile image-intensifier radar system. Most of the birds observed during nocturnal migrations were passerines. Forty dead birds were discovered during ground surveys, but only one was a raptor. Although it was estimated that as many as 6,800 birds are killed annually, Edison concluded that this mortality was insignificant when compared to the large numbers of passerines migrating through the area each year. The study showed that many nocturnal migrants fly at altitudes low enough to collide with wind turbines and their associated structures, but most birds avoid hitting obstacles. The final results of this study have not yet been published.

The Mod-2 turbine, which was located in Solano County (it has since been removed), has been studied extensively by the Pacific Gas and Electric Company (PG&E) (Gruenhagen and Byrne 1981, Byrne 1983, Electric Power Research Institute 1985, BioSystems in prep.). Information on the number and altitude of birds migrating at night was gathered by ceilometer and radar techniques. Four birds, including one raptor, were killed at this turbine and three at its associated structures (Electric Power Research Institute 1985). An estimated 62 deaths may have occurred annually. This number was also judged to be insignificant in relation to the number of migrants that pass through the area each year.

Studies in Sweden (Karlsson 1983), Denmark (Moller and Poulsen 1984), and the Netherlands (Winkelman 1985) also have documented collision mortality. A summary and analysis of the European studies are presented in Berkhuizen and Postma (in press). In most of these studies, disturbance to birds was more of concern than mortality. These studies, however, involved only one or a few turbines and focused primarily on passerines or waterfowl.

Studies emphasizing the effects of windfarm development on raptors are scarce. BioSystems (BioSystems in prep.) conducted the post-construction phase of the two-part raptor use study of the Mod-2 turbine initiated by Gruenhagen and Byrne (1981). Preliminary analysis suggested that the Mod-2 turbine did not affect bird behavior.

Four pre-construction raptor and waterfowl monitoring studies were recently completed in Solano County (BioSystems 1987a,b; Howell and DiDonato 1988a,b; Howell et al. 1988; Jones and Stokes Assoc., Inc. 1987). Plans for three of these proposed windfarm developments were discontinued, so only the pre-construction phase of the studies was completed. The fourth proposed project included a post-construction survey that was recently completed (Howell et al. 1991a). This study reported that five birds, three of which were raptors, were killed at the 230 turbines surveyed weekly for one year. These studies have provided valuable information on the distribution, flight altitudes, and flight direction of birds under different weather conditions. This information will help assess the potential for collisions in Solano County.

The recent CEC study (CEC 1989) reviewed the effects of wind energy development on avian populations and summarized existing information on windfarm-related avian injuries and deaths throughout California from 1985 to 1988. An average of 11 eagles and 17 hawks have been reported injured or killed annually in the Altamont Pass WRA.

A parallel single-year study (Howell and DiDonato 1991) of avian use patterns and mortality in the Altamont Pass WRA was begun in 1989 by U.S. Windpower, an independent windfarm operator. This study was similar to ours, but was limited to two U.S. Windpower sites. Seventeen raptor mortalities were reported for 359 turbines surveyed every other week for one full year. U.S. Windpower also is supporting another study to test whether increasing the contrast of turbine blades by painting them will reduce turbine mortalities (Howell et al. 1991b). The results of this experiment are encouraging and studies are continuing for another year.

Other studies speculate on the effects of windfarms on raptors or extrapolate from largely qualitative studies of raptor mortality and behavior (Rogers et al. 1976, 1977; USBR 1979; Payne 1982; 3-C Energy Systems 1983; Hillier and Zortman 1984; Ingram 1984). Several authors have speculated on the response of waterfowl to turbines (Avery 1978, Windfarm Ltd. 1982, McCrary et al. 1983). Leitner (1982) summarized the literature on avian collision mortality and noise effects related to wind energy development.

In summary, the few investigations that have attempted to quantify bird mortality at windfarm structures have been concerned with only one or a few turbines or have focused on nocturnal migrants (primarily passerines or waterfowl) in dissimilar study areas. The two studies pertaining to mortality at large windfarms, one in Solano County (Howell et al. 1991a) and one in the Altamont Pass WRA (Howell and DiDonato 1991), have only recently become available.

2.0 STUDY AREA AND METHODS

2.1 STUDY AREA

The two study areas included in this project were the Altamont Pass (Contra Costa and Alameda counties) and Solano County WRAs (Figure 2-1). The Altamont Pass WRA encompasses approximately 80 mi^2, with elevations ranging from 50-2,000 ft. The Solano WRA encompasses approximately 65 mi^2, with elevations ranging from 50-900 ft. The topography of Altamont Pass is more varied and rugged, with rolling to steep hills transected by shallow to deep drainages levelling into broad valleys. The topography at the Solano County WRA is not as diverse, consisting mostly of rolling hills. Annual grasses with a few scattered trees are the dominant vegetation on both sites. Considerably more dry-land agriculture and large trees occur at the Solano County WRA than at Altamont Pass. Plant cover in both areas is sparse as a result of many years of grazing; this has been exacerbated by drought.

Steady southwest winds blow across Altamont Pass from about April to October. These winds are the result of differential air temperatures formed as the warmer Central Valley east of Altamont Pass draws in the cooler, marine air of the Bay Area to the west. At other times of the year, winds are more erratic and can come from any direction. Updrafts are produced when winds blow over hills and ridges or through canyons. These updrafts are used by foraging and migrating raptors and other birds. Many birds also make use of rising columns of warm air, called thermals, for gaining altitude. Fog can occur in Altamont Pass in both the summer and winter. Fog in the winter comes from the tule fog of the Central Valley and, in the summer, from coastal fog.

The large population of California ground squirrels in Altamont Pass provides an excellent prey base for many raptors. Ground squirrels thrive in the sparse grassland vegetation of Altamont Pass. Windfarm development may have benefitted ground squirrel populations to some extent: road construction creates friable berms that ground squirrels can readily use for denning. Because of the large population, anticoagulant poisons are frequently used to reduce ground squirrel numbers at Altamont Pass. Compound 1080, which is known to kill non-target animals that eat poisoned ground squirrels, is seldom used. Fewer ground squirrels were found at the Solano County WRA, probably because of the increased amount of dry-land agriculture.

Natural perches from which raptors occasionally hunt were scarce before the development of the Altamont Pass WRA. Turbines and transmission poles and lines now provide abundant perch sites.

2.2 METHODS

2.2.1 Sample Site Selection

To select our sample sites, we obtained information from maps on the extent, type, and location of existing turbines in the Altamont Pass WRA and reviewed aerial photos depicting all windfarm developments in the WRA. The layout of wind turbines in the Altamont Pass WRA is presented in Figure 2-2. We grouped turbine types into eight categories according to their structural features (Figure 2-3); these categories and the number of turbines falling into each are presented in Appendix Table B.1. Of these eight, we selected five turbine types that represent either the most widely-used types (three-blade lattice, medium tubular, and guyed-pipe) or unique types (vertical axis and windwall).

Eighteen sample sites (depicted in Figure 2-2) were chosen randomly within each of these five types. The percentage of turbines sampled within each turbine type was roughly proportional to the percent occurrence of turbines of that type in the WRA (Appendix Table B.1). We decided on the number of sites we wanted to sample in each turbine type at the outset of the study. During the first season (spring 1989), we collected mortality and observation data on only 10 sample sites (two within each turbine type). Eight additional sampling sites were included in the five subsequent seasons (Table 2.1). We decided to increase the number of sample sites after the spring season because our spring scavenger surveys revealed that few bird carcasses were being removed by scavengers. As a result, we were able to reduce our searching effort at each site without a significant number of dead birds disappearing before we found them. This increased the time available to sample more sites. The spring sample sites included 8.5 percent (625/7340) of the turbines in the Altamont Pass WRA; sample sites during subsequent seasons represented 15.9 percent (1169/7340).

Sample site selection involved generating random coordinates and plotting them on a map; the coordinates constituted the center of the sample site. One or two random points were rejected because of limited vehicle access or a scarcity of turbines. Most sample sites contained only one turbine type; if other types were present, we surveyed only one type.

We divided sample sites into 8 or 12 sample plots (Figure 2-4). We estimated that we could adequately survey a maximum of 12 plots in one day, but the two windwall sample sites did not contain enough turbines to include 12 plots, so only 8 were surveyed on these sample sites (see below). From the randomly generated center point of each sample site, we established sample plots. Plot selection was constrained by location of turbines, mixture of turbine types, and turbine row length. Location of sample plots determined the size and shape of each sample site. To incorporate an adequate number of sample plots of a particular turbine type, some sites were larger than others. All turbines within a plot were sampled.

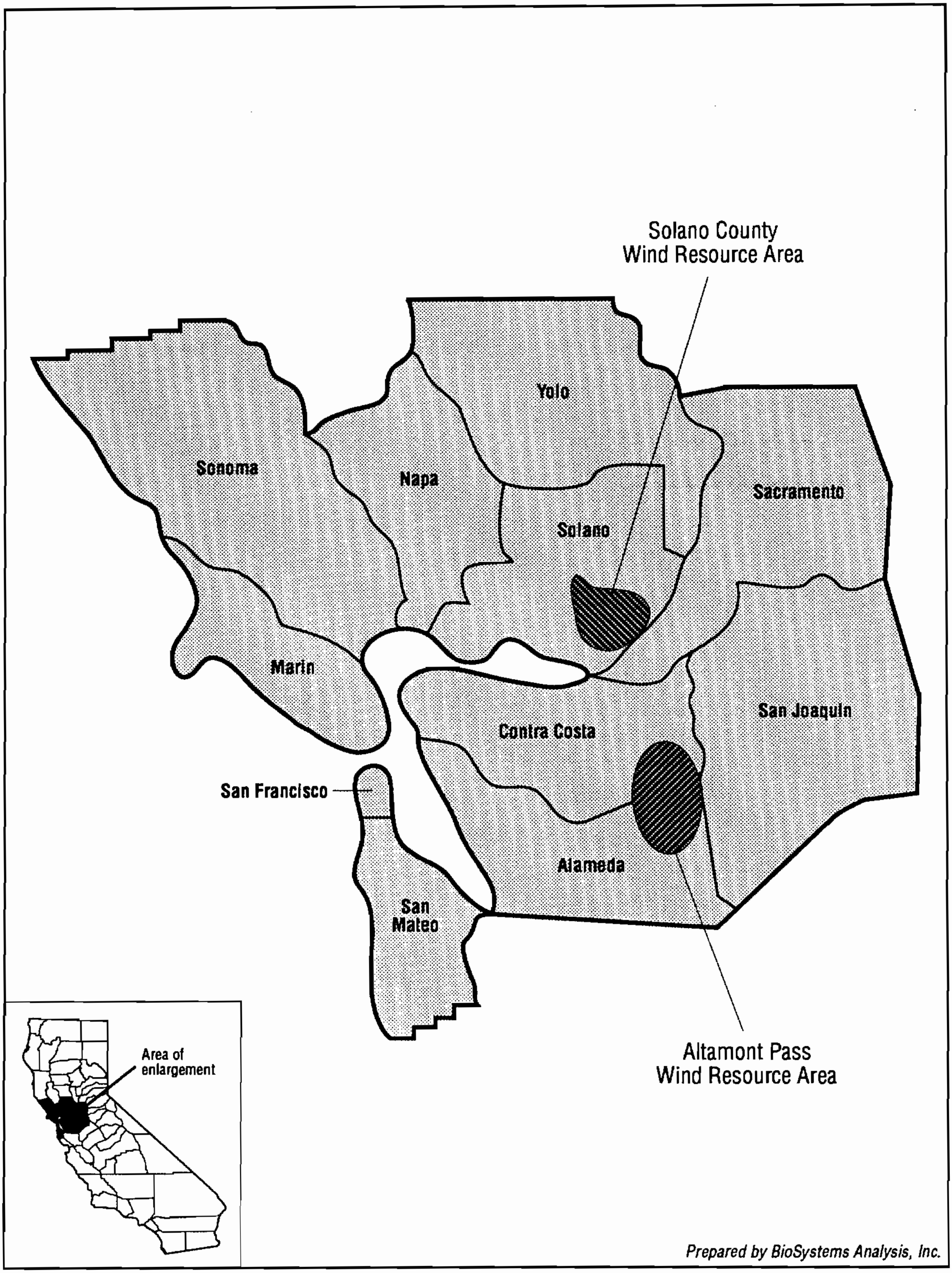


Figure 2-1. Altamont Pass and Solano County wind resource areas.

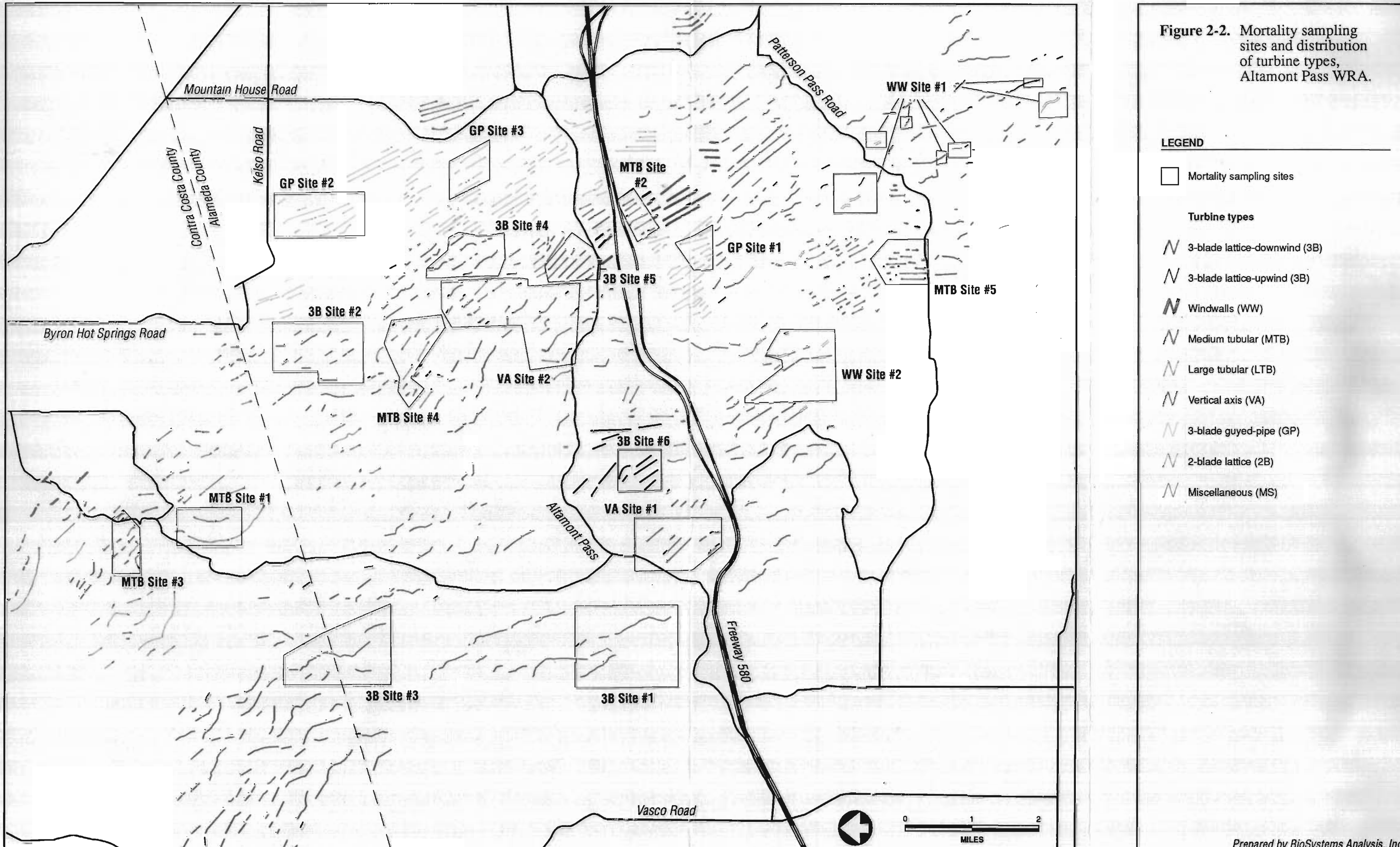
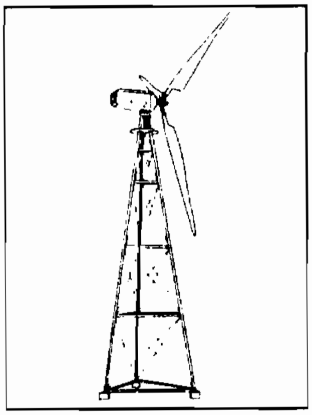
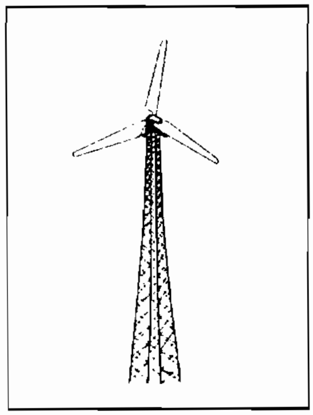
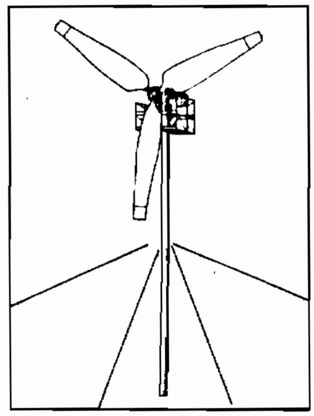


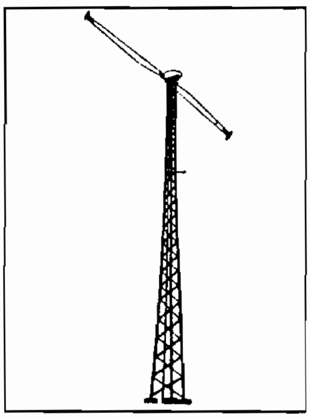
Figure 2-2. Mortality sampling sites and distribution of turbine types, Altamont Pass WRA.

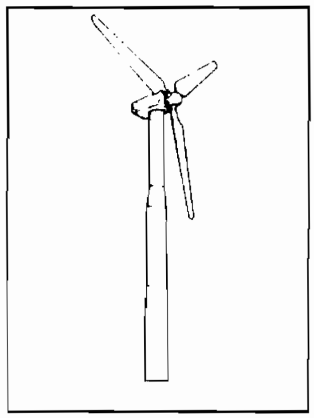


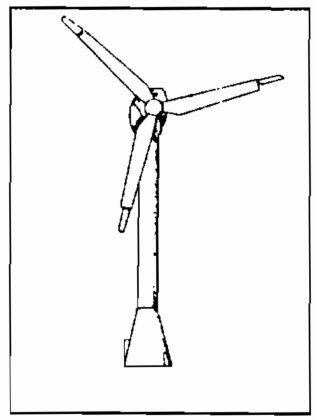




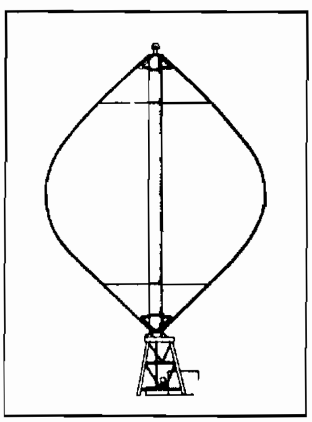
Turbine type:	Three-blade Lattice (downwind)	Three-blade Lattice (upwind)	Three-blade Guyed-Pipe Tower
Tower height:	60-80 feet	45-80 feet	40-60-80 feet
Rotor diameter:	59 feet	50-56 feet	33-80 feet
Description:	Downwind, free yaw	Upwind	Downwind
Number:	3,359 (1989) 3,640 (1990)	248	1,559

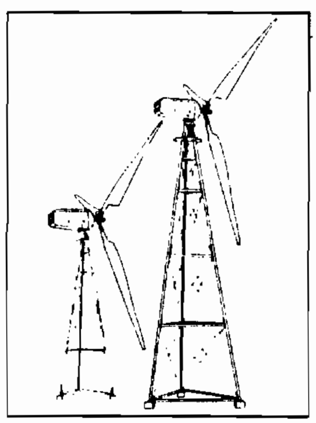






Turbine type:	Two-blade Lattice (downwind)	Medium Tubular	Large Tubular
Tower height:	80 feet	100-150 feet	82 feet
Rotor diameter:	54 feet	50-82 feet	102 feet
Description:	Downwind, free yaw	Upwind	Upwind
Number:	346	1,421	135





Turbine type:	Vertical Axis	Windwall
Tower height:	90-106 feet	140 feet
Rotor diameter:	56-62 feet	59 feet
Description:	-	Downwind, free yaw
Number:	169	103

Prepared by BioSystems Analysis, Inc.

Figure 2-3. Eight categories of turbine types at the Altamont Pass WRA 1989-1991.

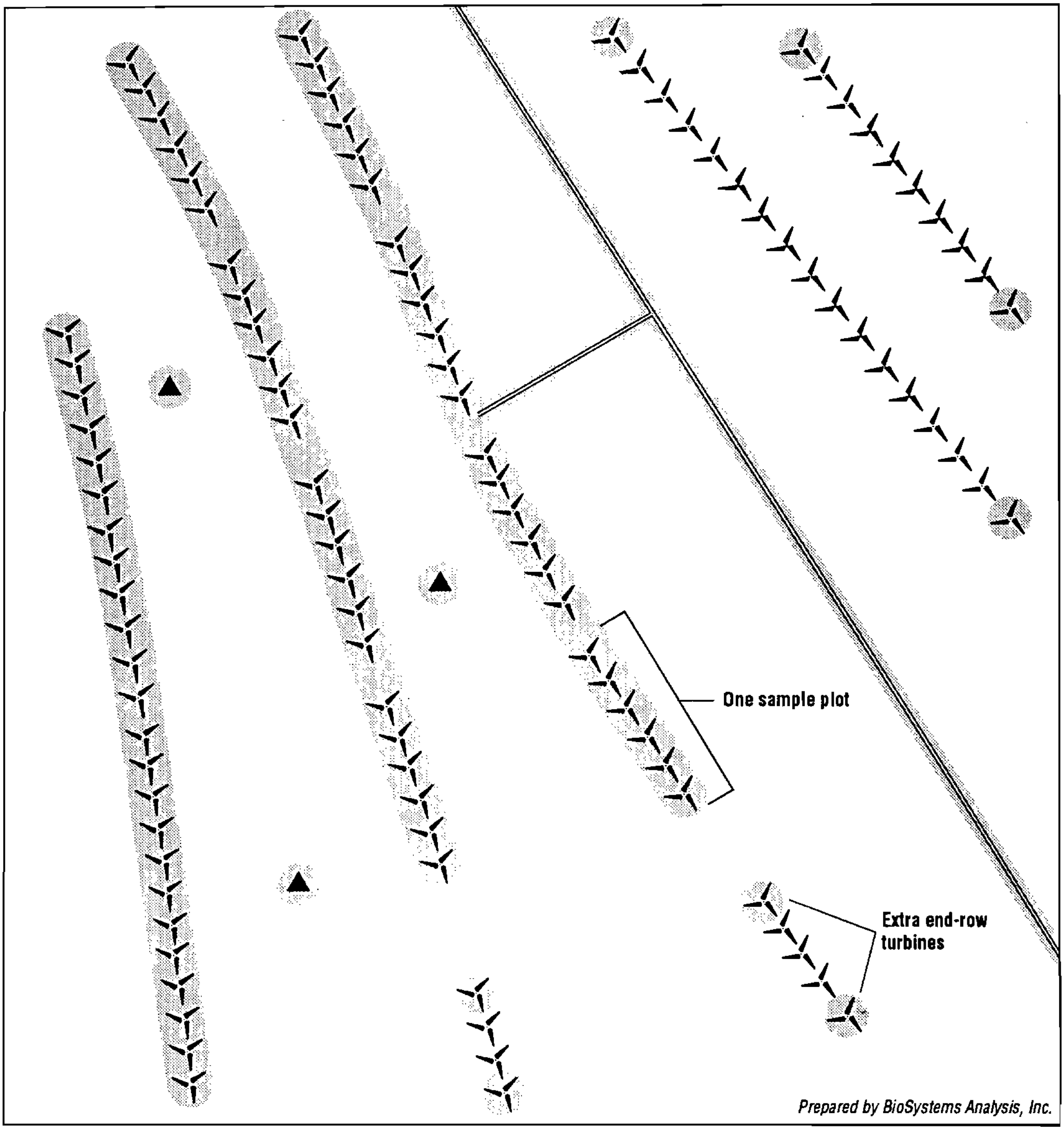


Figure 2-4. Example of a sample site. Each site typically included 12 sample plots as well as meteorological towers, transmission lines, and additional end turbines. All shaded areas were surveyed for dead birds.

Legend

▲ Meteorological tower

Turbine

Transmission line

Table 2.1. Number of mortality sampling sites surveyed each season by turbine type, 1989-1991, Altamont Pass WRA.

TURBINE TYPES	SPRING - 1989	SUMMER - 1990 FALL/WINTER - 1989-1990
Three-blade lattice - (downwind and upwind)	2	6
Guyed-pipe tower	2	3
Medium tubular	2	5
Vertical axis	2	2
Windwall	2	2
TOTAL	10	18

Within the 18 sample sites there were 208 sample plots. The size of each sample plot was approximately 500 by 400 ft (200 ft on each side of the turbine row). Turbines are spaced every 80-150 ft, depending on the type, so each plot included three to six turbines. In addition to sample plots, we also searched for dead or injured birds around additional end-row turbines (turbines at the ends of rows), all meteorological towers, and all transmission lines within each sample site (see Section 2.2.3.1 Mortality Surveys). Table 2.2 provides a list of sample sites and the relevant characteristics of each site.

Windwalls are one of the unique turbine types we surveyed. They combine two sizes of three-blade lattice turbines placed back-to-back in a densely-packed array. This arrangement has been used because it increases the amount of power generated in a minimum of additional space. We used two windwall sample sites for comparisons among the five turbine types and also to compare mortality at windwalls with mortality at regular three-blade lattice turbines. Each windwall sample site contained both windwall and regular three-blade lattice turbines. We developed a matched-pair comparative study design in these sample sites; four windwall plots (experimental sites) were matched with four, three-blade lattice plots (control sites). We matched each experimental plot as closely as possible in topography and siting conditions to its control.

Table 2.2. Summary of sample site characteristics.

SITE[1]	TURBINE TYPE	NUMBER OF PLOTS	TOTAL NO. OF TURBINES	EXTRA END TURBINES[2]	METEOROLOGICAL TOWER	TRANSMISSION LINE LENGTH (ml)
3-B #1	3-blade lattice; downwind	12	81	9	3	.7
3-B #2	3-blade lattice; downwind	12	81	11	2	.6
3-B #3	3-blade lattice; downwind	12	78	6	2	1.2
3-B #4	3-blade lattice; downwind	12	83	11	2	.8
3-B #5	3-blade lattice; downwind	12	73	3	5	2.7
3-B #6	3-blade lattice; upwind	12	77	5	2	- -
WW #1	3-blade lattice/windwalls	8	29/45[3]	13	3	2.9
WW #2	3-blade lattice/windwalls	8	35/27	16	3	1.6
GP #1	3-blade lattice guyed pipe	12	85	14	1	1.8
GP #2	3-blade lattice guyed pipe	12	77	7	5	1.2
GP #3	3-blade lattice guyed pipe	12	74	3	2	1.1
VA #1	Vertical axis	12	42	6	3	1.8
VA #2	Vertical Axis	12	40	4	1	1.5
MTB #1	Medium tubular	12	38	2	1	1.2
MTB #2	Medium tubular	12	45	5	5	2.2
MTB #3	Medium tubular	12	52	4	3	1.8
MTB #4	Medium tubular	12	54	6	2	1.8
MTB #5	Medium tubular	12	53	5	3	.8
		208	1,169	130	48	25.7

[1]See Figure 2-2 for locations in study area
[2]Included in total number of turbines
[3]3-blade lattice/windwalls

2.2.2 Observation Surveys

We collected observation data at the Altamont Pass WRA through both driving and site-specific surveys. In Solano County, we only conducted driving surveys. The purpose of driving surveys at both sites was to quantify the general use and distribution of birds (i.e., relative abundance and species composition). We were also able to compare relative abundance and species composition seasonally from data collected in the Altamont Pass surveys. Site-specific surveys provided data with which to compare the relative abundance and species composition of birds using our sample sites to the relative abundance and species composition of dead birds found in the same areas. We recorded characteristics of bird behavior we thought might influence vulnerability to collision or electrocution. These factors included flight height and distance from structures. We recorded and identified to species all raptors and waterfowl we observed whenever possible; we also recorded the presence of common ravens (*Corvus corax*) because they sometimes serve as indicators of disturbance. On all surveys (driving and site-specific), we recorded windspeed and direction, temperature, percent cloud cover, and we described fog conditions.

Raptors were defined as all birds in the orders Falconiformes (vultures, eagles, kites, hawks, harriers, falcons) and Strigiformes (owls). The term "buteo" is used throughout this report to refer to those hawks in the genus *Buteo* observed in the study area: red-tailed hawks (*Buteo jamaicensis*), ferruginous hawks (*Buteo regalis*), and rough-legged hawks (*Buteo lagopus*). The term falcon refers to birds in the family Falconidae and, in this report, refers only to American kestrels (*Falco sparverius*) and prairie falcons.

Statistical tests were applied to many of our observation data to look for significant relationships among variables. We applied both parametric and nonparametric bivariate tests, depending on the data. The parametric tests we used were t-tests and one-way analyses of variance (ANOVAs). We applied nonparametric tests, such as chi-square and Kruskal-Wallis, to data that violated assumptions of parametric tests. Chi-square and Kruskal-Wallis tests were used when data were categorical (e.g., yes-no variables or distance categories), while t-tests and ANOVAs were used with continuous data.

2.2.2.1 Driving Surveys

We conducted four driving surveys in Altamont Pass in 1989 and 1990. Surveys were conducted for eight days each season; spring surveys took place from 21 February - 2 March 1989, fall surveys from 12 September - 21 September 1989, winter surveys from 12 December - 21 December 1989, and summer surveys from 17 July - 27 July 1990. Two survey routes (one northern and one southern) covered the entire WRA. We established 25 random points along each route (Figure 2-5); each point afforded an unobstructed view of the surroundings and was at least 0.5 mi from all other survey points to minimize duplicate observations. Two teams of two observers surveyed both routes simultaneously for eight days. Each day, observers conducted one 10-min raptor count (scan) at each of the 25 sample points, for a total of 50 scans per day. To avoid temporal bias, we altered starting points each day. Because 10-min scans were considered to be independent of each other, they were used as replicates for statistical tests.

We surveyed the Solano County WRA one season for eight days from 31 October - 7 November 1989. Because this resource area was smaller, only one team of two observers was needed to cover the survey route, which consisted of one 10-min scan at each of 20 survey points, for a total of 20 scans per day (Figure 2-6). Data from this survey were compared to data from the Altamont Pass fall driving survey.

In both WRAs, we recorded and mapped the location of each raptor seen during the 10-min counts and noted the species, age class (adult or immature), time of day, distance to observer, distance above ground, distance to closest structure (and whether it was a turbine or transmission structure), and direction of flight. Altitude and distance were visually estimated and recorded in one of five categories (categories are shown on sample data sheets in Appendix C). We also noted if the closest structure to a bird (when first observed) was an end turbine (turbines at the ends of rows) and if turbines nearest birds were operating. To assess raptor abundance for the Altamont and Solano WRAs relative to similar locations, we compared our data to information collected for other local studies.

We digitized raptor sightings recorded on field maps during driving surveys into our Geographic Information System (GIS) and derived a set of X,Y map coordinates for each observation. We assumed that each bird recorded on a driving survey had not previously been seen or recorded that day; we believe that spacing of survey stops minimized duplicate observations. From this, we generated a list of all raptors seen within an area of a half-mile radius (0.78 mi^2) centered on each survey stop each season. We then calculated the average number of raptors seen per day in this area, extrapolated out to 1 mi^2. These data were entered into a program called Surfer (Golden Software, Inc.) which took our irregularly-spaced data (raptor sightings at each survey stop) and created regularly-spaced data points across the study area through a process of interpolation. From these interpolated data, maps of raptor density contours were created for both the Altamont Pass and Solano County WRAs. These raptor density maps are similar to topographic maps. On a topographic map, contour lines connect points of equal elevation. On our raptor density maps, contour lines connect points of equal raptor density measured in mean number of raptors per square mile. Appendix D includes more detail on the methods used to generate raptor density contours.

Four maps were created for Altamont Pass, one for each season; only one driving survey was conducted in Solano County so there is only one map. The maps graphically

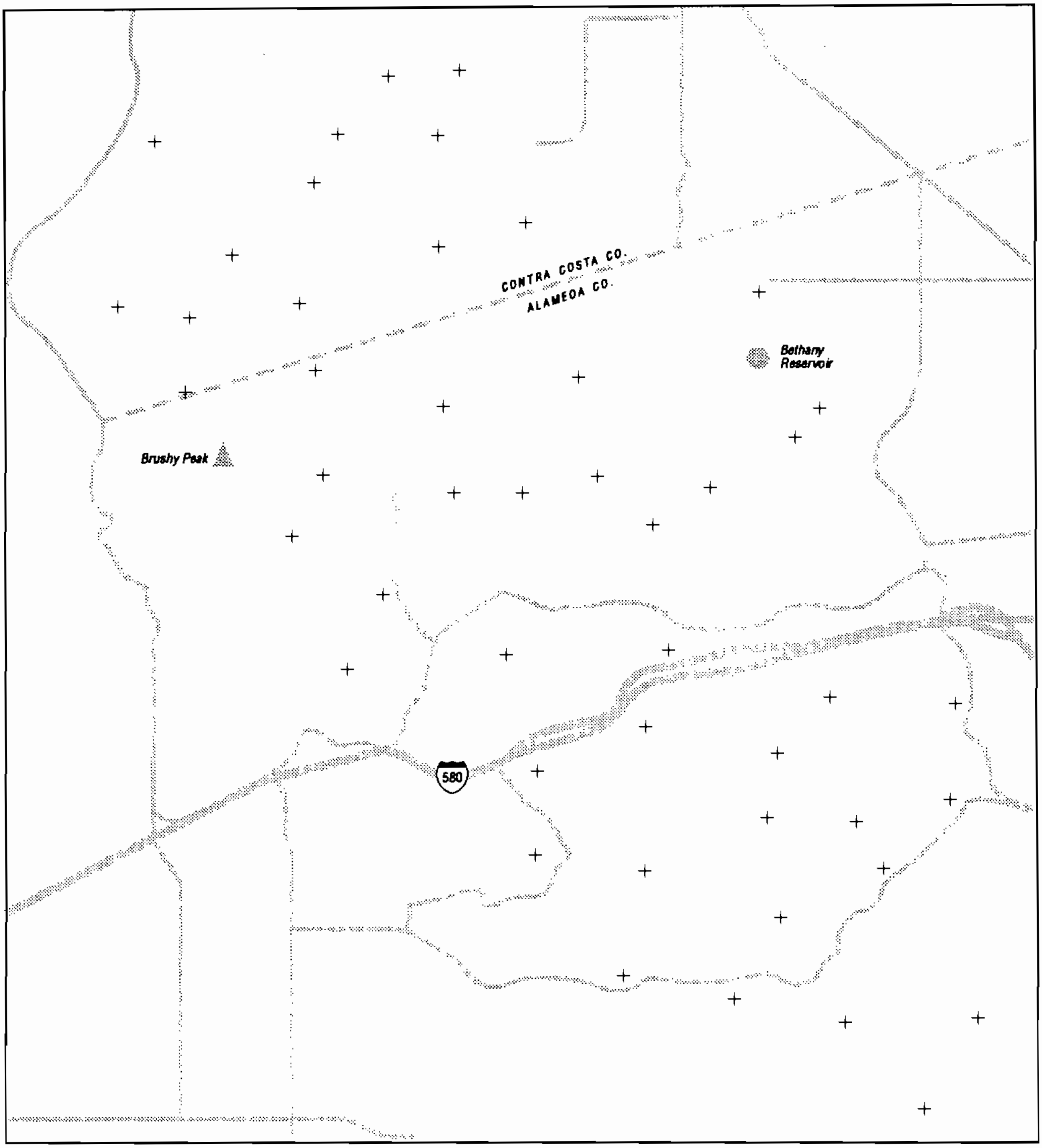


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Figure 2-5. Locations of survey points on driving survey routes, Altamont Pass WRA.

Legend

Roads

+ Survey points

0 .5 1 1.5 2 2.5 miles

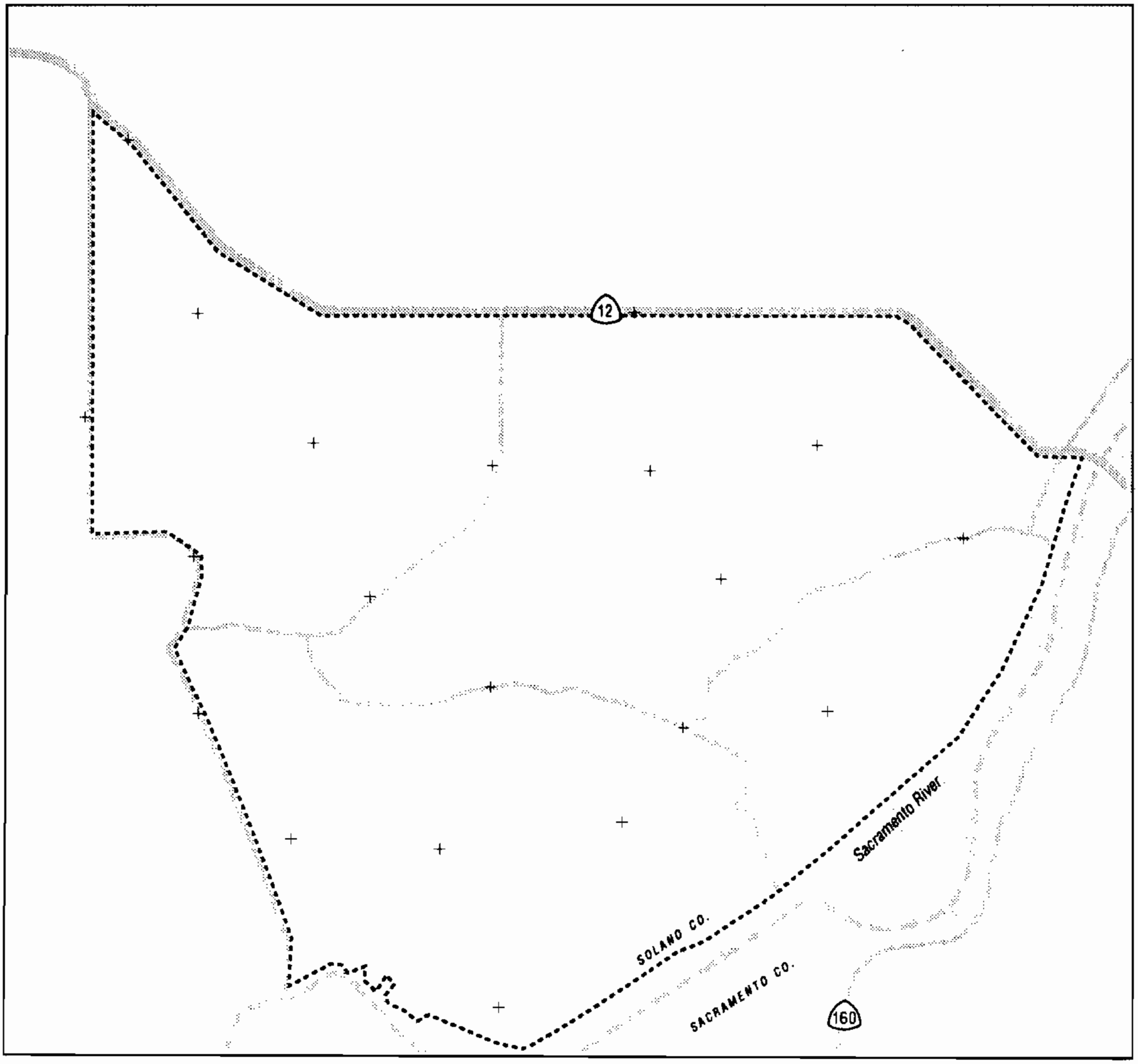

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Figure 2-6. Locations of survey points on driving survey route, Solano County WRA.

Legend

Roads

\+ Survey points

WRA boundary

0 1 2 3 miles

demonstrate areas of relatively high or low raptor density, and we used them to compare raptor density to the locations of turbines and sites of raptor mortalities.

2.2.2.2 Site-specific Surveys

We also collected site-specific observation data within the sample sites where we searched for dead birds (sample sites are described in Section 2.2.1). We recorded raptor abundance and flight characteristic data in each of these sample sites each season to assess relationships among bird behavior, abundance, and mortality in the study area. These surveys were conducted concurrently with mortality surveys (see Section 2.2.3 Bird Mortality Surveys). During the first spring season, our observations at each sample site consisted of one 10-min count per day at each of three established points, twice a week for five weeks, and three full days of observation at each site (35 10-min periods). During subsequent seasons, when we increased the number of sample sites from 10 to 18 (see Section 2.2.1 Sample Site Selection), we sampled three points in each site each day, but we reduced the frequency to once a week for five weeks and one full day of observation at each site (30 10-min periods). We considered each 10-min scan a discrete sample, and each sample site had the same number of scans. By using discrete rather than continuous observations, we equalized the sampling effort and standardized the census times.

We did not use 10-min scans as replicates for statistical purposes with our site-specific data because these scans were not independent and, therefore, their use would be pseudoreplication. We considered days to be more independent so, for statistical tests, we used days as replicates. To determine whether differences in seasonal abundance were statistically significant, we used only data on raptors observed per day during the all-day surveys (many surveys were not conducted throughout whole days).

During each observation, we recorded the species, sex, age class, and behavior (e.g., perching, foraging, or unusual behavior) of each bird. We also noted if a bird was on or off the sample sites; if at any time during a 10-min scan we observed a bird within the sample site, it was recorded as on site. We sequentially numbered each bird seen and recorded the time of the observation. Birds *known* to be individuals we had seen in earlier scans were identified by using their original observation numbers. We were, therefore, able to more accurately estimate, not only overall use (by including repeat observations), but also total number of birds using an area in any given time period (by excluding repeat observations). All of our calculations include repeat observations (unless otherwise specified), because we assumed the overall use of the study area and turbine-related collision mortality were related. The term relative abundance, found throughout this text, is used to represent overall bird activity and includes all bird observations. Unknown species were placed into groups such as raptor, falcon, or buteo. All sightings were mapped. Sightings made outside sampling periods or of species other than waterfowl, raptors, ravens, or water birds were recorded as incidental observations.

Three distance and altitude variables were measured: distance above ground, distance to structure, and minimum distance to turbine blades. Distance above ground, also called flight height, was the altitude at which a bird was flying when first observed. Distance to structure was the distance from a bird, when first observed, to any structure (turbine or transmission line). Minimum distance to turbine blade was the minimum distance a bird flew to turbine blades *at any time during the 10-min scan period*. Altitude and distance variables were estimated visually and recorded into one of five categories. For distance above ground and distance to structure variables, these categories were: 0 ft, >0-50 ft, >50-100 ft, >100-200 ft, >200-300 ft, and >300 ft. After the first spring and fall, we estimated the flight height (distance above ground) in feet (up to 300 ft) rather than in distance categories, and later converted estimates to categories when necessary. Actual flight heights were estimated relative to known turbine heights. The minimum distance to turbine blade variable was recorded in the following categories: 0 ft, >0-10 ft, >10-25 ft, >25-50 ft, >50-100 ft, and >100 ft.

2.2.3 Bird Mortality Surveys

We searched selected sample sites for injured or dead birds during six seasons and analyzed these data to determine the extent of and specific factors contributing to raptor mortality. We calculated correction factors for survey biases (scavenger removal and observer error) to more accurately assess mortality, and extrapolated an annual site-wide mortality rate from our sample data. The methods used to conduct mortality surveys and to estimate mortality and survey biases are discussed below.

2.2.3.1 Mortality Surveys

We conducted spring mortality surveys in the Altamont Pass WRA from 6 March - 7 April 1989, year-one fall surveys from 25 September - 27 October 1989, year-one winter surveys from 8 January - 9 February 1990, summer surveys from 31 July - 31 August 1990, year-two fall surveys from 1 October - 2 November 1990, and year-two winter surveys from 14 January - 16 February 1991. We surveyed each sample site for five weeks: twice a week in spring and once a week in five remaining seasons.

Within each sample site, we searched mortality sample plots, meteorological towers, transmission lines, and additional end-row turbines. The area around meteorological towers was searched because the guy wires that are sometimes needed for their support pose a potential threat to birds. The search area was circular with a radius varying from 100 to 200 ft around the tower center, depending on the size and height of the tower. We surveyed transmission lines situated within the sample sites because transmission lines contribute to mortality through electrocution and collision with wires. With the exception of one site where transmission lines were underground, we surveyed approximately 1.5 linear miles of line per sample site. Searches were conducted within 100 ft of the center line. Because preliminary evidence from windfarm companies indicated that end-row turbines may be associated with higher rates of mortality than non-end-row turbines, we surveyed additional end-row turbines in each sample site; the number depended on how many were present and varied from 2 to 16 per site. The search area for these additional turbines was a circle with a radius of 200 ft around the turbine center. Data from additional end turbines were not used for estimating mortality nor were they included in the analysis of factors contributing to mortality. They were included only in general summary statistics such as species composition and age structure of dead birds, types of injuries sustained, and location of carcasses relative to turbines.

We carefully surveyed all search areas on foot, identified and mapped the location of bird carcasses, and recorded site-specific information. If carcasses were too old for accurate species identification, they were categorized into groups such as buteo, raptor/non-raptor, passerine, or unknown bird. Bird carcasses were labeled and stored for later identification. We removed all remains to avoid confusion on subsequent surveys.

Occasionally we discovered raptor carcasses outside our sample sites (off site). Also, on occasion windfarm operators would inform us about an off-site mortality. We collected the same data on these birds as for birds found on site. Off-site mortality data were added to our on-site results to increase our database for use in general summary statistics such as species composition and age structure of dead birds, types of injuries sustained, and location of carcasses relative to turbines.

For each dead bird, we recorded a number of site-specific variables (these are listed in Appendix C). An attempt was made to determine the cause of death. Four categories for cause of death were used: collision with turbine, collision with wire, electrocution, and unknown. We used an index of probability (1 to 10) to indicate the biologists' level of certainty about the judgement. In the field, biologists made judgements about cause of death by evaluating a variety of factors including type of injury, distance to turbine, and proximity of other structures that may have caused the death. Severe traumatic injuries such as amputations or a body torn in half were frequently attributed to collision with turbines. The cause of death was usually less clear for birds found farther from turbines than for birds found near turbines. If other structures such as transmission lines were near a dead bird and if injuries did not appear to be severe, the cause of death was usually attributed to collision with wires rather than with turbine blades. Electrocuted birds typically had singe marks on their bodies and were found under power poles. Dr. Sanders of Cottage Veterinary Hospital in Walnut Creek performed necropsies on all dead birds (with the exception of old skeletal remains) found every season except the first spring. We used the necropsy results to modify the index of probability or certainty about cause of death.

We estimated the time of death from presence of fresh blood, condition of eyes, condition of feathers and flesh, and presence of insect infestations. We recorded detailed descriptions of the animal's condition and exact location.

We evaluated structural and habitat variables that could potentially influence or contribute to collision-related mortality at windfarms (see Appendix C). Among the structural factors recorded at each site of a mortality were distance to next closest structure, structure density, orientation of structure rows, and whether the site of the mortality was an end-row turbine or was located in a first turbine row (see Figure 2-7). The site of a mortality was defined as the closest *structure* to where a dead bird was found.

The first three structural factors described above (distance to next closest structure, structure density, and orientation of structure rows) are aspects of the physical layout of structures that contribute to "congestion," which we theorized might cause disorientation or confusion in birds. We measured the distance from the site of a mortality to the next closest turbine row. Structure density refers to the number of structures or structure rows occurring within 500 ft of a site of mortality. For example, dead birds from two different sites may both have had two structure rows within 500 ft (i.e., the same structure density), but the distance to the next closest structure may have been much less on one site than on the other. Orientation of structure rows refers to whether rows were parallel or perpendicular to each other. We designated a row as perpendicular if any one row within 500 ft of a site of mortality was not parallel to the other structure rows in the area, otherwise we classified them as parallel.

We recorded habitat variables for each site of mortality including distance from canyons, number and degree of slopes, aspect of slope, and ground squirrel density. Because canyons funnel winds and canyon walls create updrafts, canyons may concentrate birds, making structures close to canyons more probable sites of mortality. We evaluated the number, degree, and aspect of slopes because these were basic topographic units with which to characterize topography at sites of mortality. We estimated ground squirrel density to evaluate the possibility that raptor deaths might be more common near higher concentrations of prey. We estimated ground squirrel density visually by ranking the abundance of ground squirrel burrows within 500 ft of the site of a mortality as none, rare, scattered, common, or abundant. We theorized that mortality could be related to higher raptor density at prey concentration areas, or to raptors being distracted while foraging and, therefore, not being as aware of their surroundings. Other variables we recorded included distances to water, valleys, and trees, and general weather conditions such as temperature, percent cloud cover, fog, and wind speed. Windfarm operators also provided information on hourly average wind speeds at each of the sample sites.

We distinguished between old and "fresh" bird carcasses. Birds that appeared to have been dead for only one week were called "fresh." On the first survey of each season we cleared the search areas of bird carcasses, and then assumed that all fresh carcasses found after the first survey were of birds that had died during the previous week.

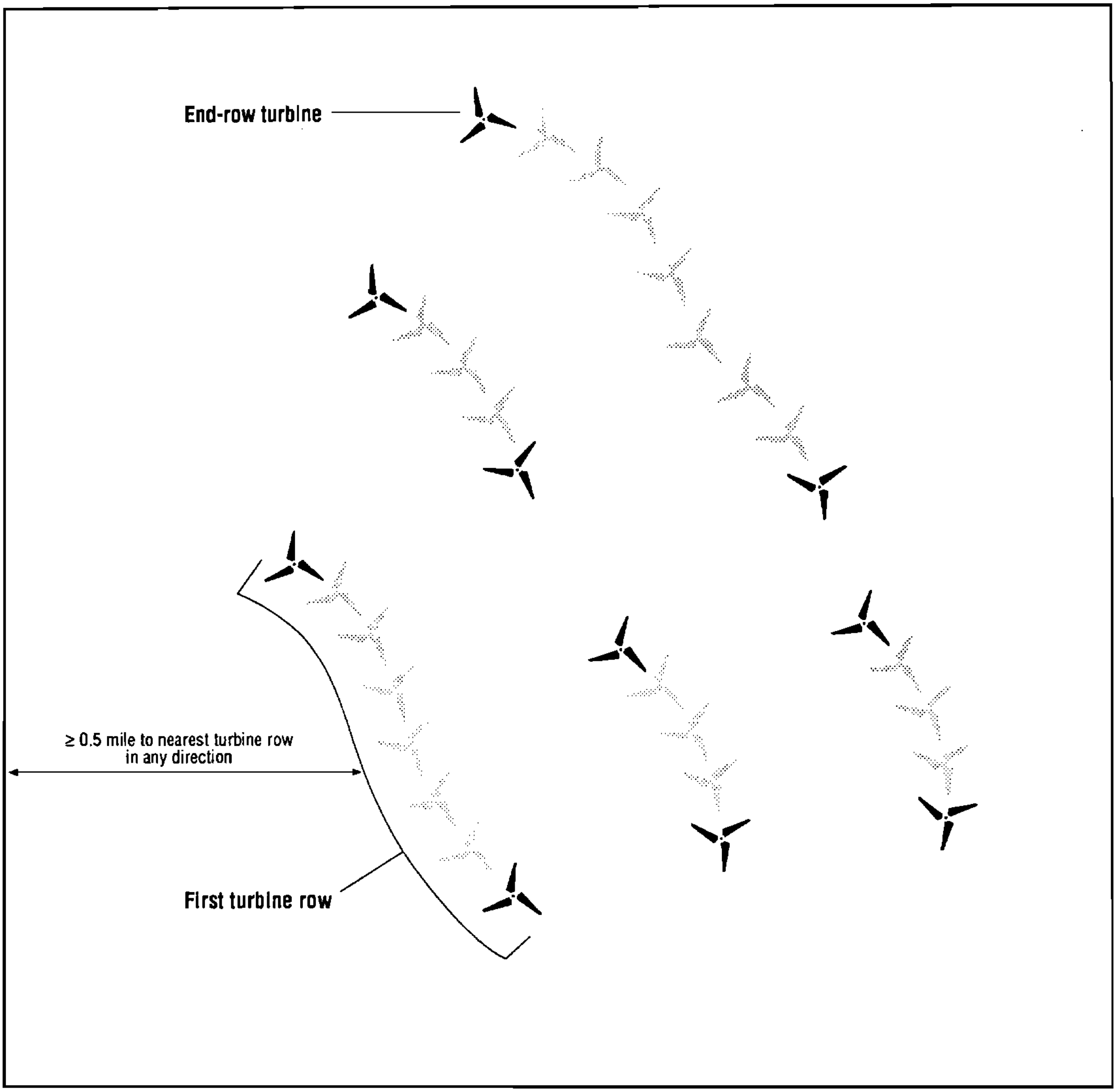

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Figure 2-7. Schematic representation of first turbine rows and end-row turbines.

Because we included birds we believed had died within one week prior to the beginning of the survey, we considered our survey periods to be six weeks long. This is important for the mortality estimates described in Section 2.2.3.3.

All potential structure and habitat factors that may have contributed to mortality were statistically evaluated using either multivariate techniques (two-way ANOVA and discriminant analysis), or bivariate analysis (chi-square, t-test, one-way ANOVA), or both. Chi-square tests were used when data were categorical (e.g., yes-no variables or distance categories), while t-tests and ANOVAs, were used with continuous data. Mortality data used in this analysis consisted of only those deaths we were confident were turbine-related that occurred within our mortality sample plots (on site).

Our analysis of mortality was based primarily on comparing the turbines (or plots) at which we found dead birds to those turbines (or plots) at which we did not find dead birds within our sampling period (see Section 2.2.4 Habitat Characterization). Obviously, we cannot say that a particular turbine had never or would never kill birds just because we did not find dead birds during our sample period. Mortality sampling effort was equal among all turbines, whether they killed birds or not, and we assumed that other biases (e.g., scavenging) were also equal among turbines that killed raptors and those that did not. We decided that using turbines that did not kill raptors within our sample sites as our baseline for comparison was more appropriate than using the random turbine sites we used in our first report (Orloff et al. 1991), because random turbine sites may have contained turbines that killed birds within the sampling period. Our multivariate discriminant analysis involved deriving a formula for independent variables such as end-row, elevation, and structure density that would best discriminate between two groups of turbines: turbines that killed raptors and turbines that did not kill raptors. We also analyzed differences between turbines that killed non-raptors and turbines that did not kill non-raptors.

We evaluated the relative risk of mortality for all of the raptor species (excluding owls and raptors which were rarely seen) we observed in Altamont Pass WRA; we also included common ravens in this analysis. We compared the number of individuals of a species (abundance) observed on our sample sites (including repeat observations) with the number of individuals of that species found dead. We limited abundance data to observations within 500 ft of the observer and 200 ft above the ground to minimize bias toward larger species which are more visible at greater distances. We used only those deaths we attributed to collision with turbines, including both fresh and old carcasses found on our sample sites. We then compared this ratio (number found dead/number observed) among species to get a risk factor for each species relative to other species. We also calculated an expected mortality for each species and applied a chi-square test to test whether mortality was related to abundance.

2.2.3.2 Mortality Survey Biases

We investigated the role of two factors that could bias mortality survey results: 1) scavenging and removal of bird carcasses by animals, and 2) differences in the observational abilities of field biologists. Past studies have shown that scavengers and predators may remove bird carcasses before observers discover them, and that observers do not always find all existing bird carcasses during a search (Meyer 1978, James and Haak 1979). For each bias, we calculated correction factors based on our field tests and incorporated them into annual site-wide and seasonal estimates of mortality extrapolated from our mortality sample data.

Scavenging tests consisted of randomly placing 4 to 10 bird carcasses of three size classes (small, medium, and large, representing small, medium, and large raptors) at each sample site. The feet of test carcasses were marked with inconspicuous tape so we could distinguish between test carcasses and other carcasses. We checked the test carcasses every day for seven days in the spring and every other day for seven days in subsequent seasons to assess scavenging and removal. The ratio of the number of carcasses removed to the number placed provided a basis for determining a scavenging rate, or scavenging correction factor (SCF). The formula used for calculating the SCF was:

$$SCF = \text{the number of carcasses remaining after X days} \div \text{the number of carcasses placed.}$$

The SCF was estimated by season and carcass size class. We performed these tests in all of our sample sites at the end of each mortality survey each season except the second winter. Because of a shortage of raptor test carcasses, we combined the scavenging tests for the second fall and winter seasons by conducting the survey between the two seasons.

Some of the bird carcasses used in the spring tests were feathered chickens (Rhode Island reds). We did not use chickens during the following seasons, however, because we found they were removed more readily than wild bird carcasses (such as raptors, seabirds, and pigeons); all carcasses used in the following seasons were of wild birds obtained from rehabilitation centers and windfarm operators. Only 20 percent of the carcasses used in the spring were raptors, but that increased to 25-50 percent in the following seasons, depending on availability. We conducted scavenging tests at the end of the mortality surveys so that we would not encourage scavenging at sample sites. After we finished scavenging tests, we continued to monitor test carcasses periodically throughout the study.

We assessed observer bias, or differences in the ability of observers to locate carcasses, on the first two days of the scavenging surveys by testing if observers found bird carcasses placed for scavenging tests. The number and placement of carcasses was not known to the observers; they were told to survey the plots in their usual manner and to record the number of marked carcasses they found. The ratio of the number of carcasses found to the number placed provided a basis for determining observer success rate, or observer correction factor (OCF). We used the following formula to calculate observer correction factor:

OCF = the number of carcasses found by observers + the number of carcasses placed.

We determined OCF for three size classes and for each season.

2.2.3.3 Estimating Mortality

We estimated raptor mortality by year and by season and with and without correction factors. Annual and seasonal site-wide (the entire Altamont Pass WRA) estimates were calculated using only data on "fresh" carcasses found within sample plots and along transmission lines within our sample sites; we excluded data from carcasses found near the extra end-row turbines we surveyed. Estimates of annual site-wide mortality for the first and second years of the study were calculated by extrapolating from mortality data for those years. Even though there were only data from three seasons for each year, the differences in seasonal mortality were not consistent from the first year to the second so we felt that basing an estimate on data from only three seasons would not result in unreasonable bias in the estimate. Estimates were based on mortality data for all turbine types combined. We used only data from fresh carcasses for which we had assessed the cause of death with a high (≥ 7) level of certainty, referred to as "high-probability mortalities." High-probability mortality records excluded questionable data by eliminating records of carcasses where the cause of death was not assessed with a high level of certainty and of carcasses that possibly died outside the survey period[1]. All mortality estimates were further divided into estimates of small, medium, and large raptors. Formulas used and their applications are described below. Ninety-five percent confidence intervals were calculated for all mortality estimates. Confidence intervals were based on year-to-year variability within each size class of raptor.

__Seasonal Mortality__ - We estimated raptor mortality by season using the following formula:

$$EM = (C \div OCF) \div SCF$$

where:
EM = estimated seasonal mortality,
C = number of fresh carcasses found each season,
OCF = observer correction factor, and
SCF = scavenger correction factor.

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[1] Birds found at the beginning of each mortality survey were included in the sample if we believed they died less than one week prior to the start of the survey. However, because time since death was sometimes difficult to establish, high-probability calculations excluded raptors for which the time of death could not be accurately placed within one week prior to the start of the survey.

Annual Altamont WRA Mortality - We extrapolated annual site-wide mortality from sample data. A "baseline" mortality estimate was calculated to which correction factors were later applied (see Total Mortality below). We calculated the baseline estimate using the following formula:

$$FM = (SMSP \text{ or } SMSU + SMFA + SMWI) \times (NWY \div NWS)$$

where:

- FM = estimated baseline full-year mortality for all turbine types combined, by size class,
- SMSP = seasonal mortality, spring
- SMSU = seasonal mortality, summer
- SMFA = seasonal mortality, fall
- SMWI = seasonal mortality, winter
- NWY = number of weeks in a year (52), and
- NWS = number of weeks of survey (18).

We calculated seasonal mortality rates using the following formula:

$$SMSP \text{ (or } SMFA, SMWI, SMSU) = CM \div (TS \div TT)$$

where:

- CM = fresh carcass of a particular size class and certainity level in a particular season,
- TS = number of turbines surveyed, and
- TT = total number of turbines in the Altamont Pass WRA.

For example, if one large raptor carcass was found in spring, one in fall, and one in winter, and 7.2 percent of the turbines were surveyed in spring, while 14.1 percent were surveyed in the other two seasons (these percentages exclude extra end turbines), we would calculate the mortality rates for each season as:

$$SMSP = 1 \div 0.072 = 13.88$$
$$SMFA = 1 \div 0.141 = 7.09$$
$$SMWI = 1 \div 0.141 = 7.09$$

and we would calculate the extrapolated baseline mortality as:

$$FM = (13.88 + 7.09 + 7.09) \times (52 \div 18) = 81.$$

Total Mortality - Total site-wide annual mortality incorporated correction factors as follows:

$$TM = (FM \div OCF) \div SCF$$

where:
- TM = total mortality,
- FM = extrapolated baseline mortality,
- OCF = observer correction factor, and
- SCF = scavenging correction factor.

2.2.3.4 Scent Stations

We established scent stations during the first season of the study to determine the species composition of predators foraging in the Altamont Pass WRA. Twenty stations were set, two at each sample site. Stations consisted of 1 by 1 m aluminum plates heavily sooted with a kerosene flame and baited with bird carcasses. The soot provided a medium in which a predator's footprints were left when it came to investigate the carcass. We lifted tracks from the aluminum sheet with transparent tape and saved these track outlines in notebooks for future reference. We identified tracks to species using standard field guides.

2.2.4 Habitat Characterization

To assure that our sample sites adequately represented the topographic, development, and biological features of the study area, two types of comparison were conducted. In the first comparison, we characterized (using maps) the turbine locations within our sample sites, as well as an additional 100 random turbine sites throughout the WRA, by habitat and development features. Variables were chosen that we felt best characterized the sites' potential effects on mortality. We then statistically compared our sample sites to random sites within turbine types to determine whether our sample sites represented the entire study area for these variables. For continuous variables, a t-test was applied; for categorical variables, chi-square tests were applied. In the second comparison, we compared raptor abundance on our driving surveys to raptor abundance on site-specific surveys. We assumed that driving surveys provided data representing the entire Altamont study area, whereas site-specific surveys provided data representing our sample sites.

We also collected field data on habitat and turbine variables on the 208 sample plots within sample sites (see Section 2.2.1 Sample Site Selection). In a preliminary discriminant analysis, we compared all variables between sample plots containing turbines that killed birds and sample plots not containing turbines that killed birds to determine which variables appeared to be most closely associated with bird deaths. We felt it was more precise, however, to make turbine to turbine comparisons (turbines that killed versus turbines that did not kill) when possible, but some turbine-specific variables were only recorded in the field for turbines that killed birds. Therefore, when it was possible for us take turbine-specific data off maps, such as elevation and structure density, we made turbine to turbine comparisons. Some data, such as ground squirrel abundance, could not be determined from maps, so for these variables we did sample plot to sample plot comparisons using field data collected for the 208 plots. We specify in our results and discussion which variables were compared plot to plot and which were compared turbine to turbine.

2.2.5 Raptor Nesting Surveys

We surveyed for nesting raptors in mid-April at both the Altamont Pass and Solano WRAs; Altamont Pass WRA was surveyed in 1989 and Solano County WRA was surveyed in 1990. We used aerial photos to identify potential nesting habitat (e.g., trees and cliffs), and then intensively ground-searched these areas for evidence of nesting raptors. We mapped all nests on or within 0.5 mi of the study areas and recorded data on habitat, type of nest, number of nestlings and their stage of development, and distance to the nearest turbine site or other human structure.

2.2.6 Self-monitoring Program

We developed a self-monitoring program to allow windfarm operators to document and assess bird mortality on their windfarms. We reviewed other self-monitoring systems, as well as the recent CEC study (1989), and developed a standardized system for windfarm operators to use when they find dead birds in the field. We developed a data form for recording specific information about dead birds and designed an information sheet for field personnel that defines the purpose of the program, specifies the type of information needed, and describes procedures for monitoring bird deaths.

3.0 RESULTS

3.1 OBSERVATION SURVEYS

This section summarizes the observation data from driving and site-specific surveys in the study area. The "all raptor" category shown on the figures in this section includes all known and unknown raptors seen; thus, all raptor species shown on the histograms are subsets of the "all raptor" group.

3.1.1 Abundance and Species Composition

3.1.1.1 Driving Surveys—Altamont Pass WRA

Abundance, Composition, and Seasonal Changes - We recorded 14 raptor species in 3,171 raptor sightings made during 1,756 10-min scan periods in four seasons of driving surveys (see Section 2.2.2.1 Driving Surveys). Ten observers surveyed 50 observation points throughout the Altamont Pass WRA. The number and species composition of birds recorded are presented in Appendix Table B.2. We calculated the mean number of birds seen per 10-min scan and used this as an index of relative abundance. These data are presented, by season, in Figure 3-1.

Most of the common raptors observed in the Altamont Pass WRA occur there throughout the year. These include American kestrels, red-tailed hawks, turkey vultures (*Cathartes aura*), golden eagles, northern harriers, and prairie falcons. Within the resident population, some individuals move in or out of the area and others remain. Some raptors, such as ferruginous and rough-legged hawks, are winter visitors, arriving in the fall from breeding grounds and migrating back north in the spring. A few bald eagles (*Haliaeetus leucocephalus*) also winter in the area. Altamont Pass has at times supported the largest concentration of wintering ferruginous hawks in California (American Birds 1981). Local experts (B. Walton in CDFG 1983) identify Altamont Pass as one of the few places in California where ferruginous hawks concentrate. An increase in the number of migrant buteos seen in the fall and winter, especially ferruginous hawks, was apparent during both driving and site-specific surveys.

Figure 3-2 illustrates seasonal changes in relative abundance. The mean number of raptors seen per 10-min scan was greatest in the fall (2.3 ± 2.2 SD, N=401); relative abundance was 1.9 (± 1.7 SD, N=400) in the spring, 1.6 (± 2.0 SD, N=455) in summer, and 1.5 (± 1.8 SD, N=500) in winter. Turkey vultures accounted for most of the fall increase. A Kruskal-Wallis test showed that the seasonal difference in total number of birds seen per scan was statistically significant (P<0.01).

Raptor Age Distribution - Age is most readily distinguished in two raptor species: red-tailed hawks and golden eagles. Of all red-tailed hawks for which age could be identified, we observed at least three times as many adults as immature birds each season (Figure 3-3). Of all golden eagles for which age could be identified, at least twice as many adults as immature birds were observed each season except for summer, when over 90 percent of the golden eagles of known age were immature. For all seasons combined, 16 percent of red-tailed hawks of known age were immature and 34 percent of golden eagles of known age were immature.

3.1.1.2 Driving Surveys—Solano County WRA

Abundance, Composition, and Seasonal Changes - We recorded 9 raptor species in 765 raptor sightings made during 166 10-min scan periods during the fall driving survey. Two observers counted birds from 25 survey points throughout the Solano County WRA. The number and species composition of birds recorded are presented in Appendix Table B.3 and relative abundance data are presented in Figure 3-4. As with the Altamont Pass WRA, most of the common raptor species observed in the Solano County WRA, including American kestrels, red-tailed hawks, turkey vultures, northern harriers, and prairie falcons, were present throughout the year.

Raptor Age Distribution - Of those birds for which age could be distinguished on the Solano County WRA driving survey, four times as many red-tailed hawks were adult as were immature, and three times as many golden eagles were immature as were adults.

3.1.1.3 Comparison of Altamont Pass WRA to Solano County WRA

Figure 3-5 compares the relative abundance of raptors counted on the Solano County WRA fall 1989 driving survey with the relative abundance of raptors counted during the Altamont Pass survey the same season. Raptor abundance was higher in the Solano County WRA; the relative abundance of raptors on the fall Altamont Pass driving survey was 2.3 per 10-min scan, whereas the relative abundance of raptors on the Solano County driving survey was 4.6 (± 4.5 SD, N=166). Golden eagles and common ravens were less abundant in the Solano study area than in the Altamont Pass study area, but all other raptor species we observed were more abundant.

3.1.1.4 Raptor Density Contour Maps

From observation data recorded on driving surveys, we generated contour maps of raptor density (raptors per mi^2) for each season (see Section 2.2.2.1 Driving Surveys). Figures 3-6 to 3-9 depict these contour maps for the Altamont Pass WRA. Interpolated raptor density changed seasonally in the Altamont Pass study area, but density was always highest in the northwest quadrant of the study area (up to 7 raptors per mi^2). In every season but fall, raptor density was consistently lower (as low as 0 raptors per mi^2) in the southeastern quadrant of the study area.

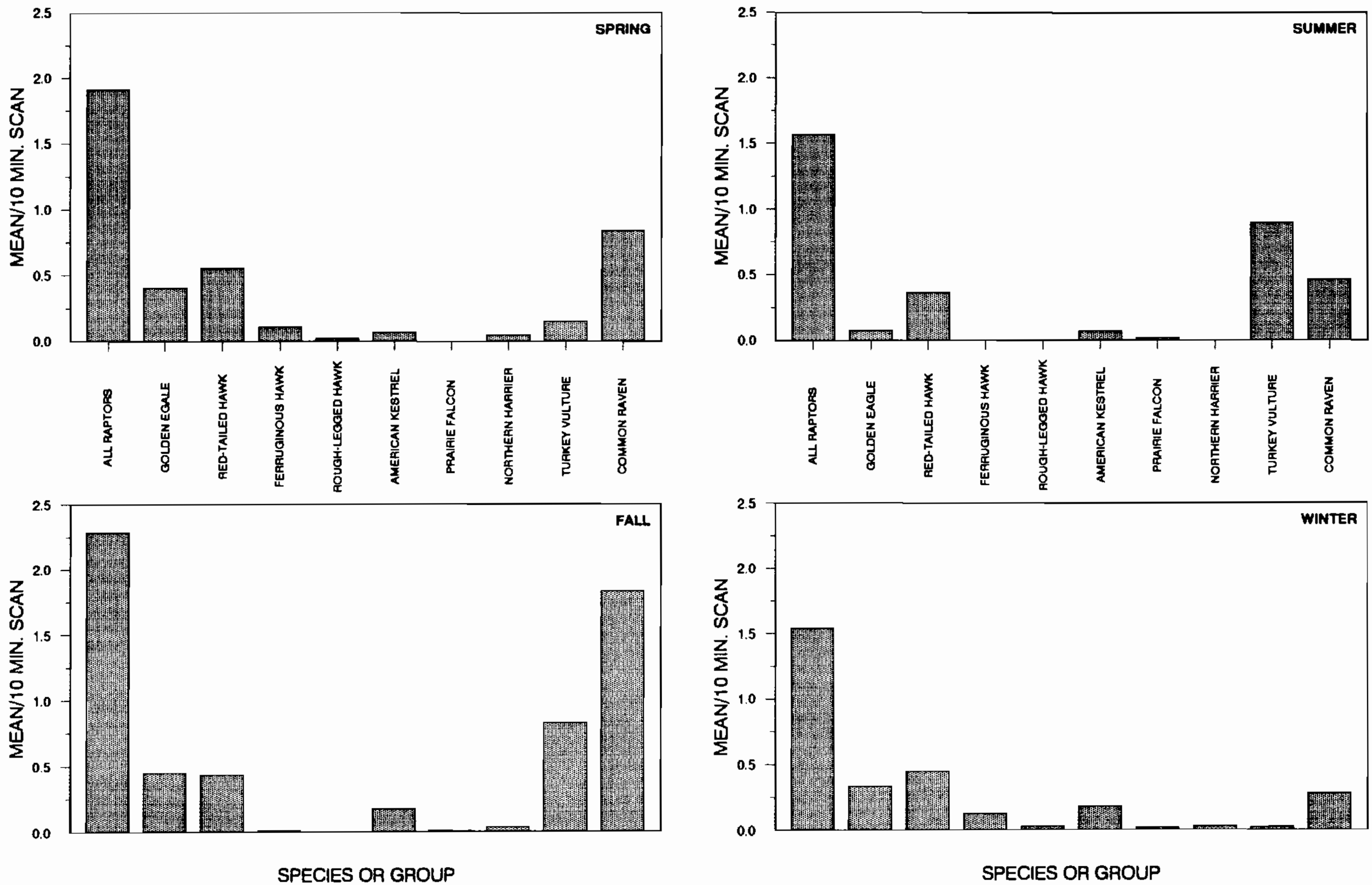


Figure 3-1. Relative abundance of raptors observed during driving surveys, each season, 1989-1990, Altamont Pass WRA.

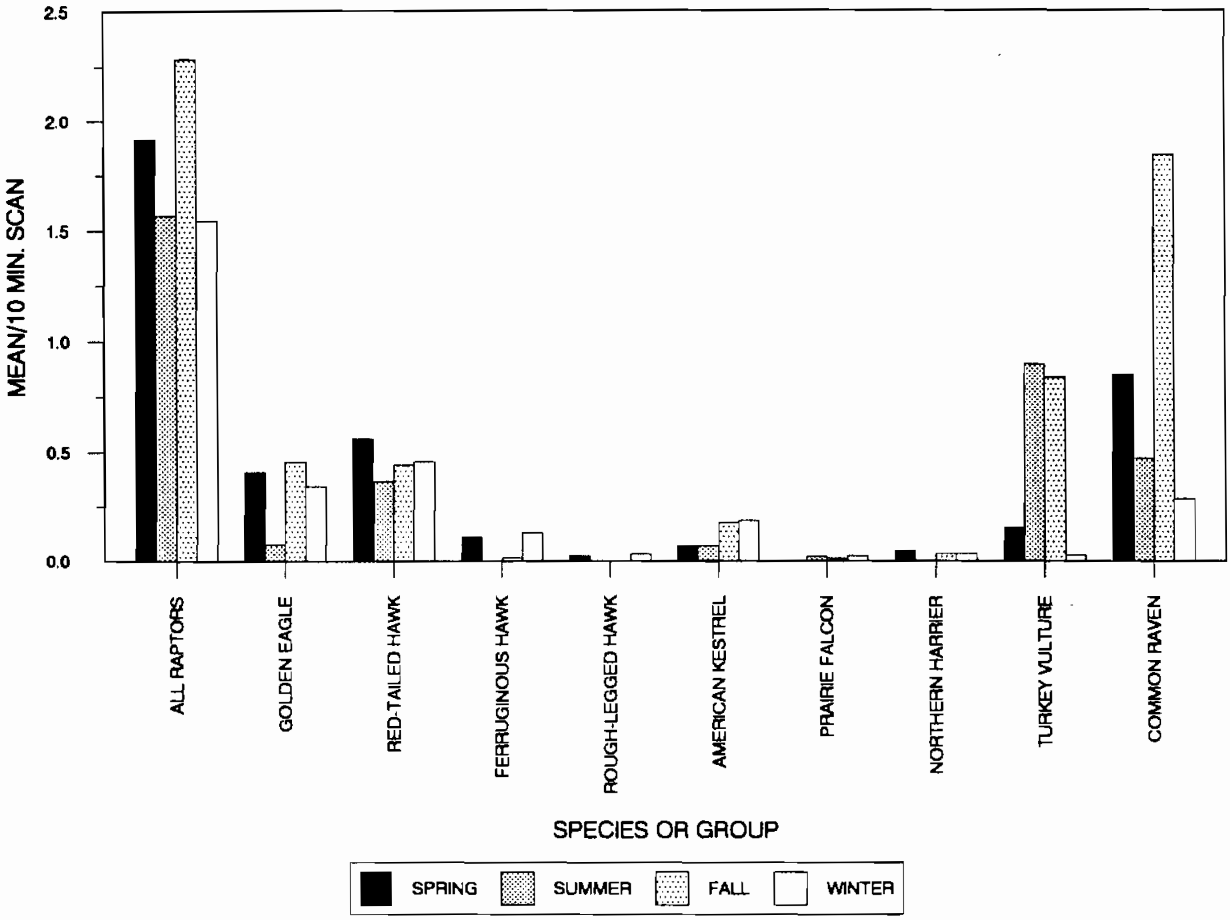


Figure 3-2. Seasonal comparison of relative abundance of raptors observed on driving surveys, 1989-1990, Altamont Pass WRA.

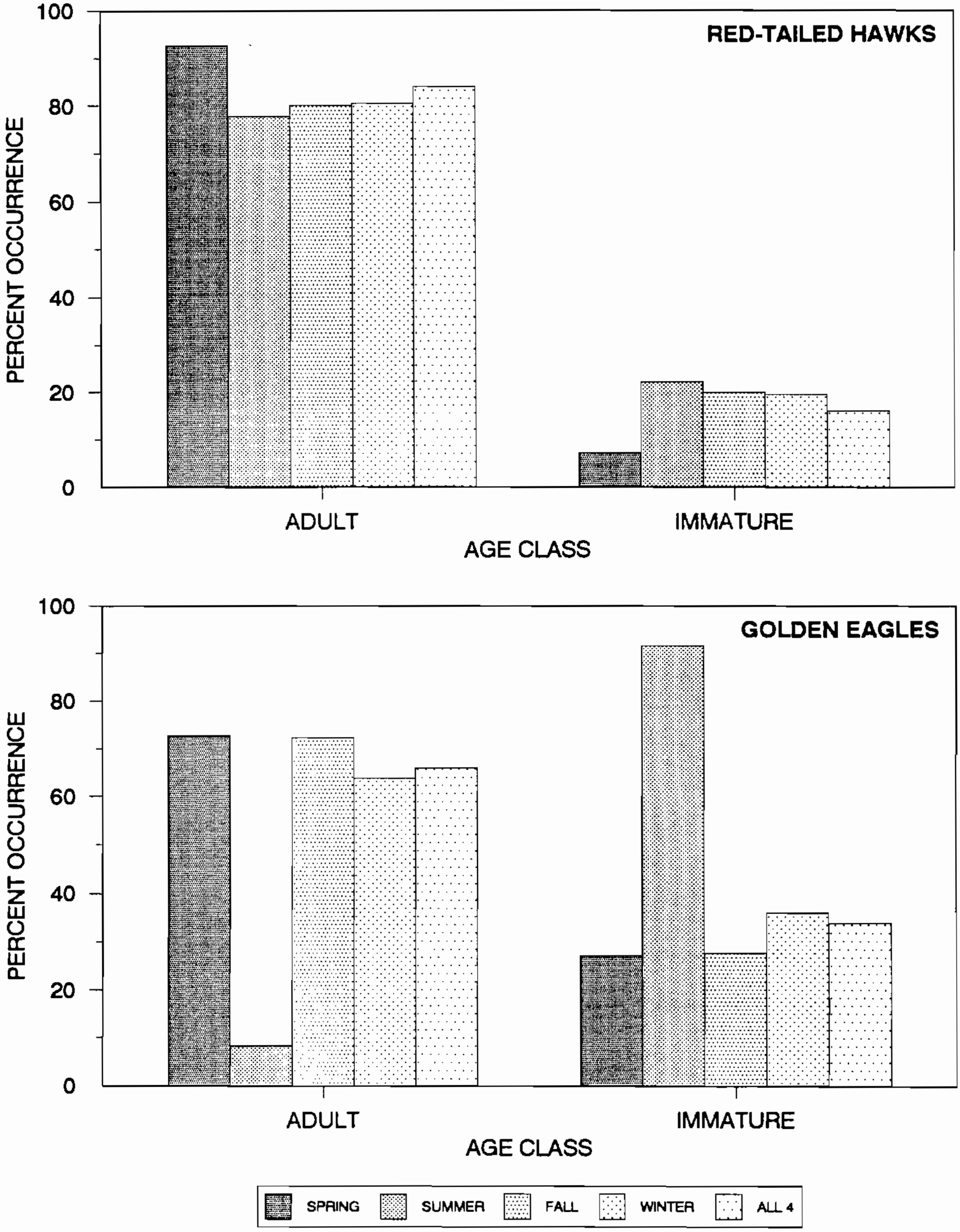


Figure 3-3. Age class comparisons of known-aged red-tailed hawks and golden eagles observed during driving surveys, by season and all seasons combined, 1989-1990, Altamont Pass WRA.

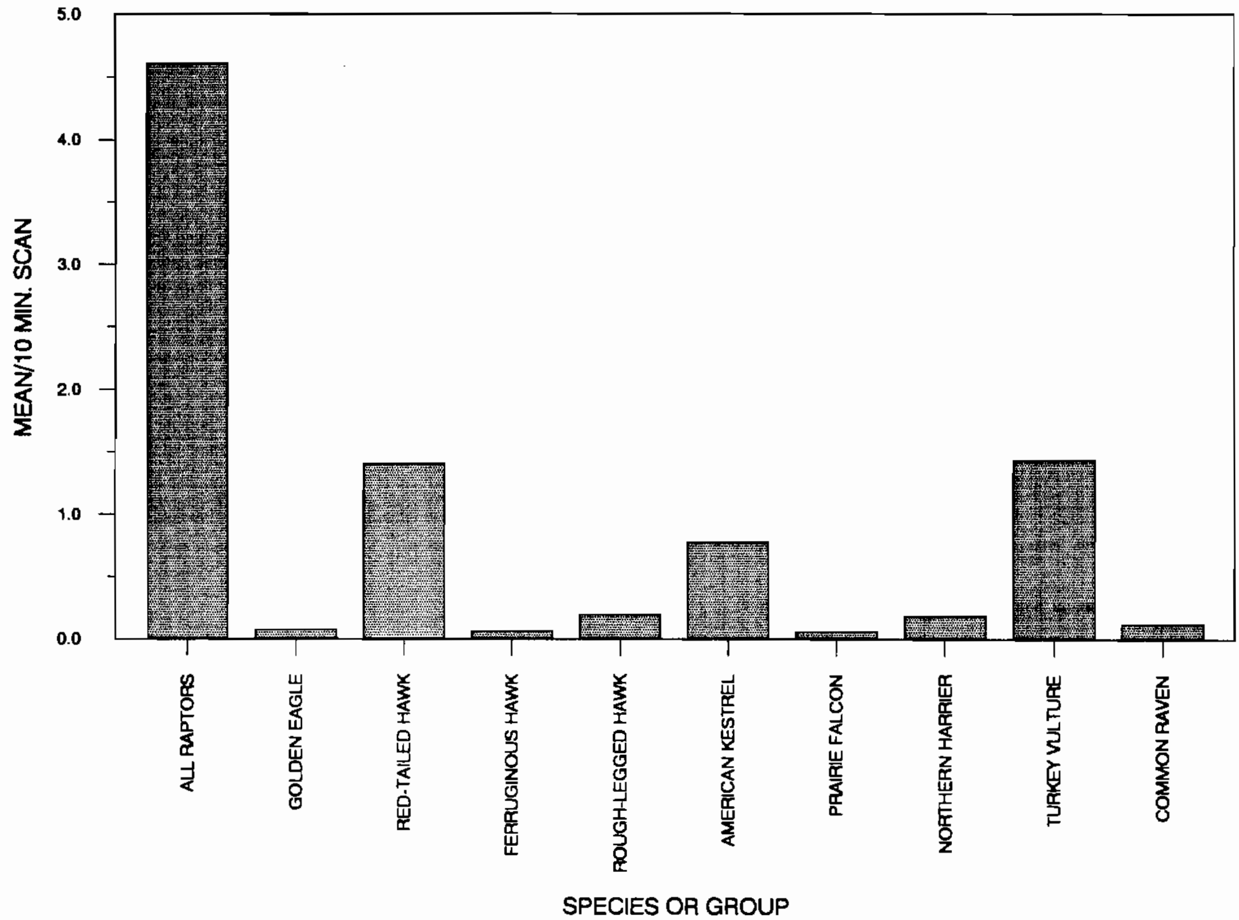


Figure 3-4. Relative abundance of raptors observed on the Solano County WRA driving survey, fall 1989.

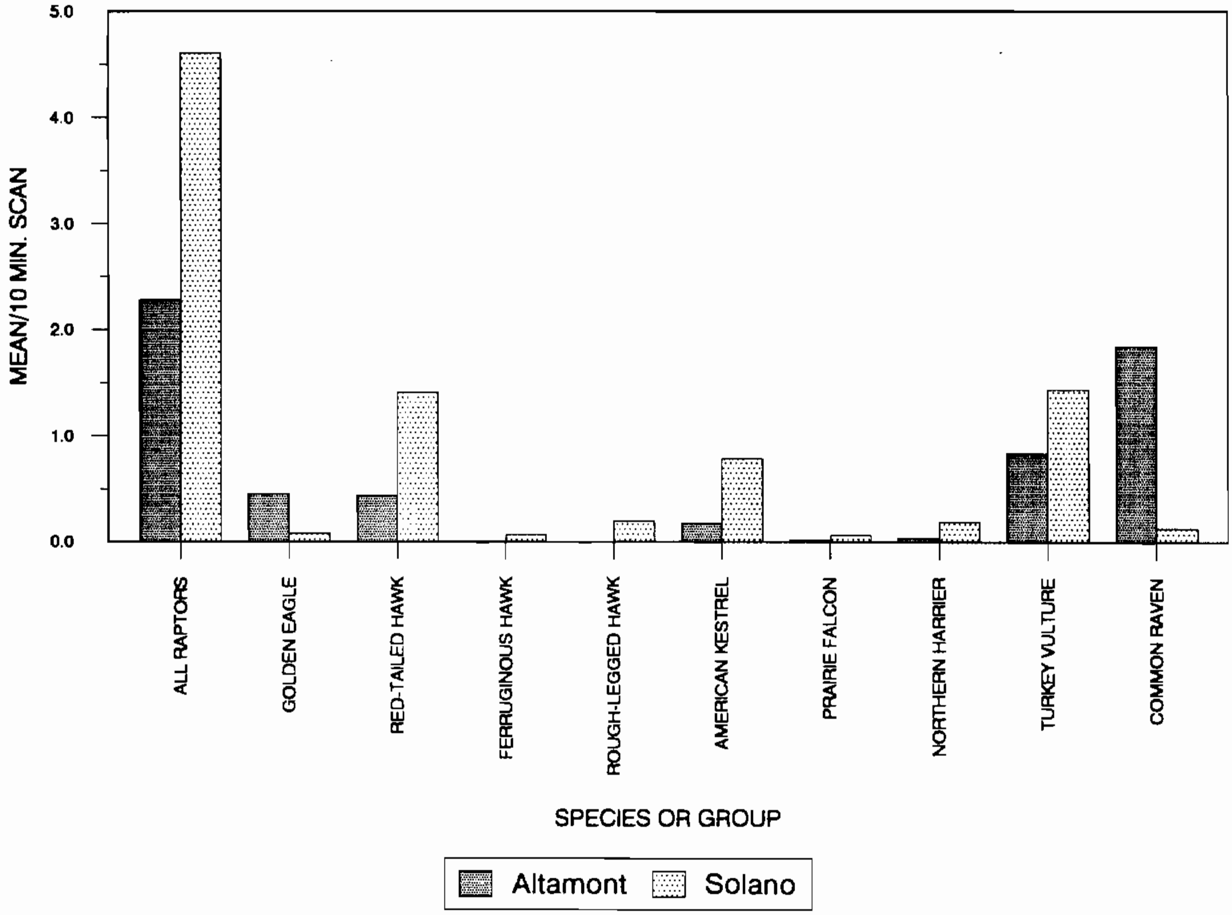
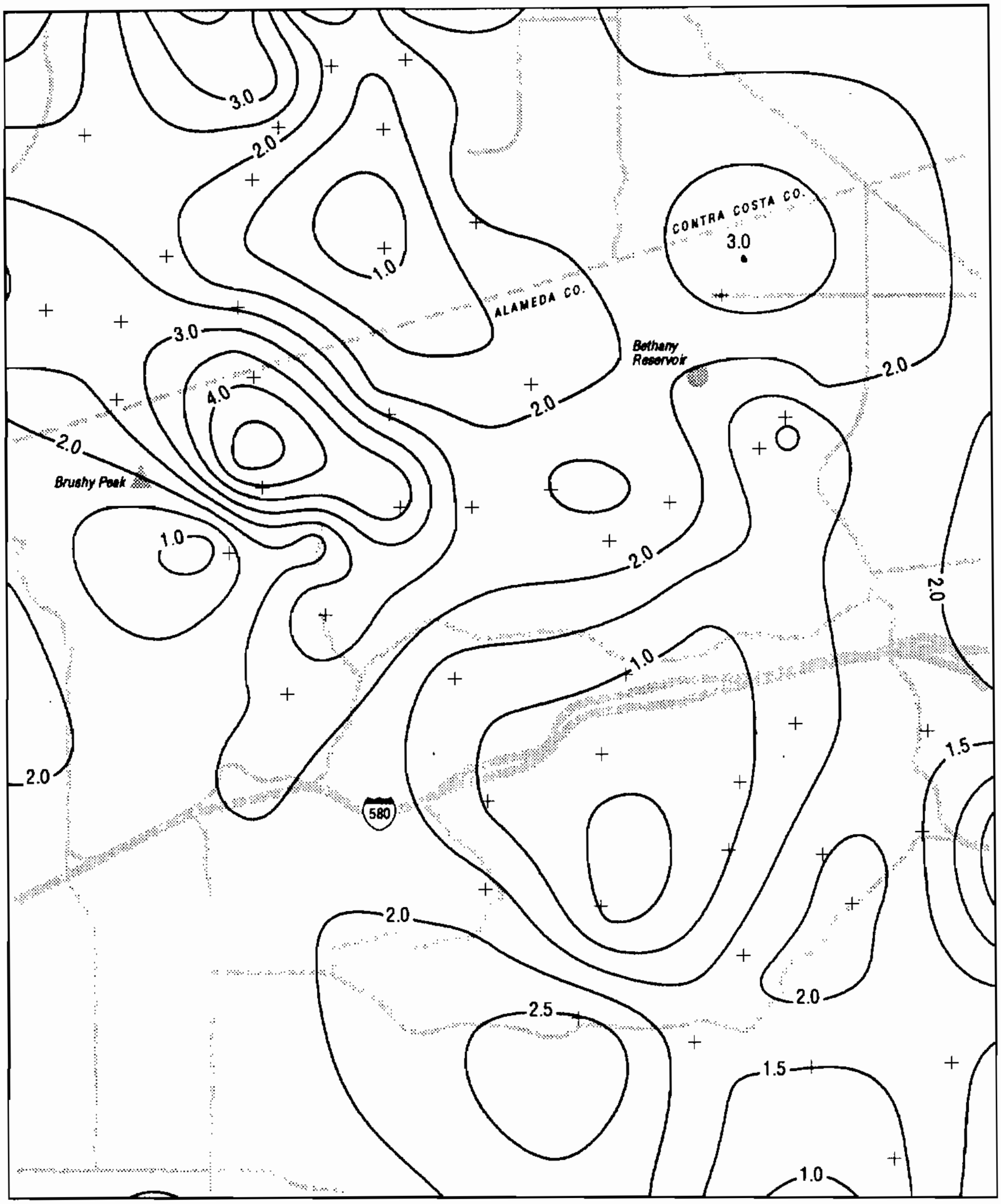


Figure 3-5. Comparison of relative abundance of raptors observed on the fall Altamont Pass driving survey with that of raptors observed on the fall Solano County driving survey, 1989.



Prepared by BioSystems Analysis, Inc.

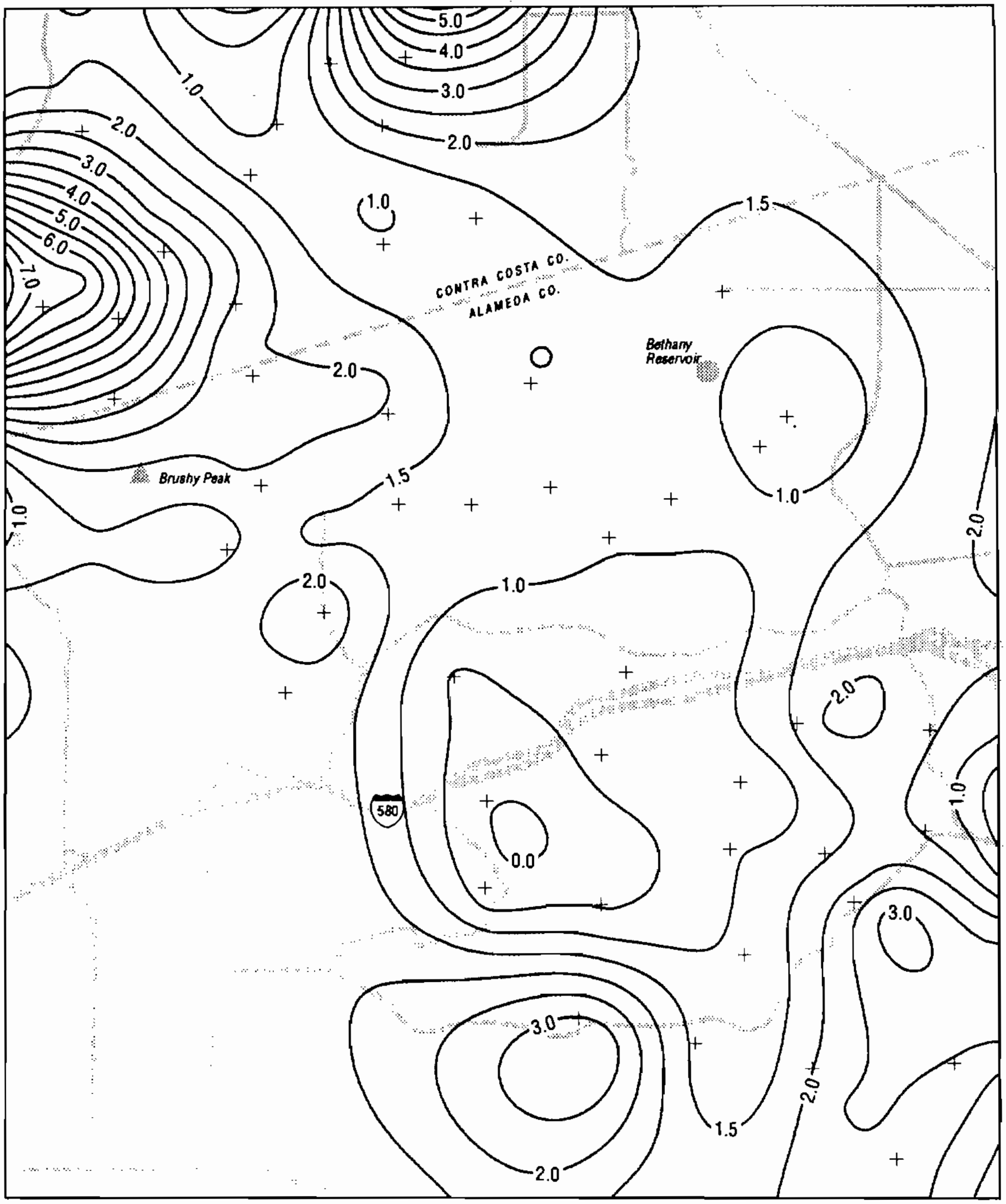
Figure 3-6. Raptor density contour map (no. of raptors per square mile), spring 1989, Altamont Pass WRA.

Legend

Roads

+ Survey points

0 .5 1 1.5 2 2.5 miles



Prepared by BioSystems Analysis, Inc.

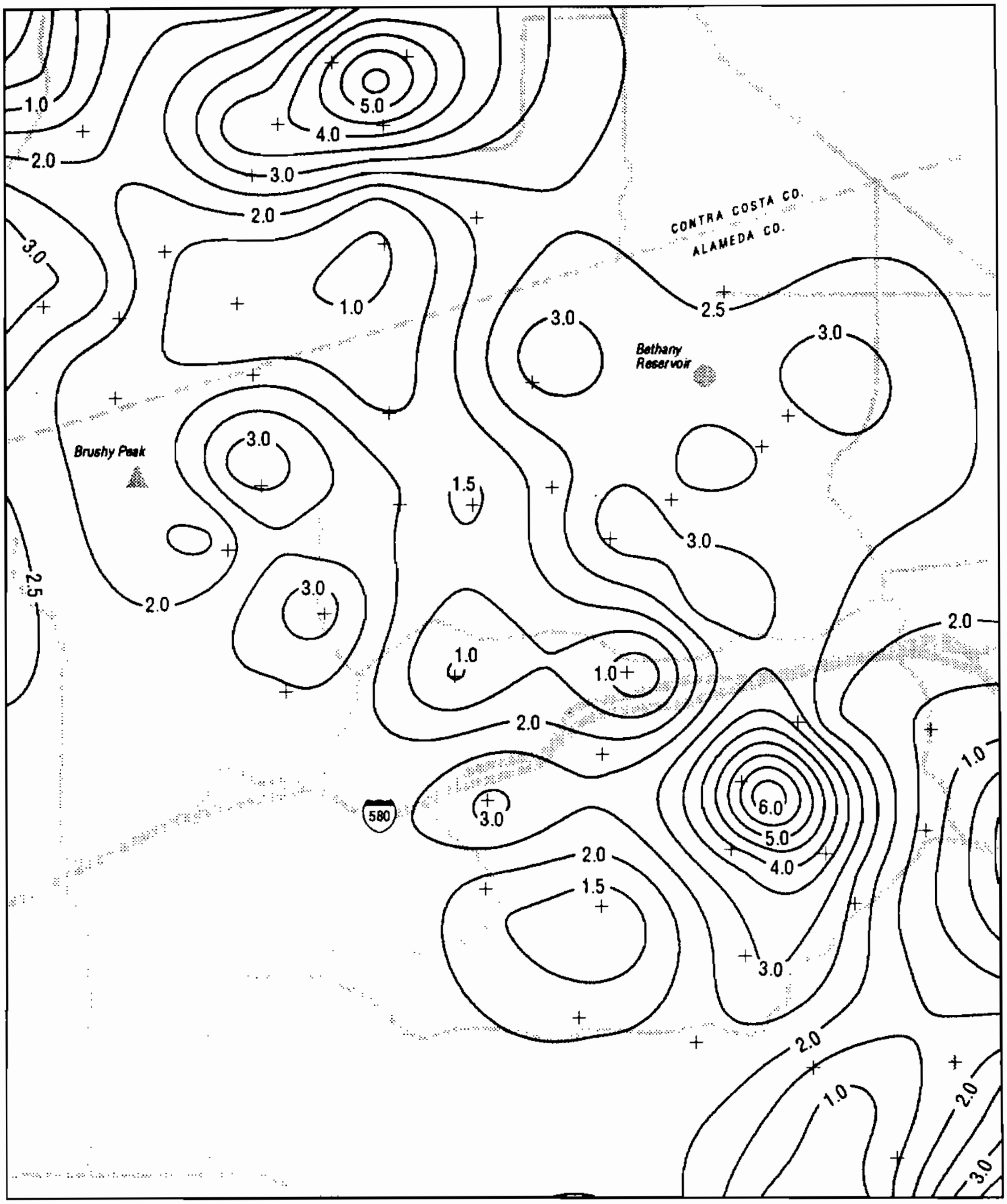
Figure 3-7. Raptor density contour map (no. of raptors per square mile), summer 1990, Altamont Pass WRA.

Legend

Roads

Survey points

0 .5 1 1.5 2 2.5 miles



Prepared by BioSystems Analysis, Inc.

Figure 3-8. Raptor density contour map (no. of raptors per square mile), fall 1989, Altamont Pass WRA.

Legend

Roads

\+ Survey points

0 .5 1 1.5 2 2.5 miles

Prepared by BioSystems Analysis, Inc.

Figure 3-9. Raptor density contour map (no. of raptors per square mile), winter 1990, Altamont Pass WRA.

Legend

Roads

\+ Survey points

0 0.5 1 1.5 2 2.5 miles

Overall, interpolated raptor density was highest during the fall, which corresponds to the highest seasonal relative abundance of raptors measured on our observation surveys. Raptor density was most uniform over the study area in spring and most variable in summer; raptor density varied from 0.5 to 4.5 raptors per mi^2 in spring, compared to a range of 0 to 7.5 raptors per mi^2 in summer. There was no evidence that raptor density was related to the locations of turbines in the study area; areas of high raptor density occurred in areas of both high and low concentrations of turbines. Turbines do not seem to be affecting raptor distribution or abundance over the study area.

We have no seasonal comparisons for the Solano County WRA contour map because we only surveyed this area once (Figure 3-10). In the fall of 1990, however, interpolated raptor density was highest (12 raptors per mi^2) on the western edge of the study area in the southwest quadrant, and another high of 9 raptors per mi^2 occurred just north of that. Raptor density was generally lowest in the eastern half of the Solano County study area. We noted in Section 3.1.1.3 that the relative abundance of raptors was twice as high in the Solano County WRA as in the Altamont Pass WRA (4.6 compared to 2.3 per 10-min scan) on driving surveys conducted in the same season, and this is reflected in the raptor density contour maps. Interpolated raptor density was as high as 12 raptors per mi^2 in Solano County, compared to a maximum of 7.5 per mi^2 in Altamont Pass.

3.1.1.5 Site-specific Surveys—Altamont Pass WRA

Abundance, Composition, and Seasonal Changes - We recorded 15 species of raptor in 6,861 raptor sightings during 5,434 10-min scans in six seasons of site-specific surveys. We surveyed 10 samples sites in the spring and 18 in all subsequent seasons. Numbers and species composition of bird sightings are presented in Appendix Table B.4. As on driving surveys, relative abundance is expressed as the mean number of raptors seen per 10-min scan. For all seasons combined, over 50 percent of raptors observed were either turkey vultures or red-tailed hawks. In descending order of abundance, raptor species observed were turkey vultures, red-tailed hawks, golden eagles, American kestrels, ferruginous hawks, northern harriers, prairie falcons, and rough-legged hawks.

As we observed on driving surveys, the relative abundance of raptors on site-specific surveys was greatest in the fall. The relative abundance of raptors was 1.68 ($\pm$ 2.02 SD, N=1624) per 10-min scan in the fall (first and second years combined), 1.21 ($\pm$ 1.63 SD, N=806) in summer, 1.07 ($\pm$ 1.36 SD, N=1355) in spring, and 1.04 ($\pm$ 1.32 SD, N=1649) in winter (first and second years combined) (Figure 3-11). The fall increase included larger numbers of turkey vultures, golden eagles, and red-tailed hawks, as well as migrating ferruginous and rough-legged hawks. Relative abundance of raptors for all six seasons combined was 1.26 ($\pm$ 1.64 SD, N=5434) per 10-min scan (Figure 3-12). The numbers of raptors seen per scan each season could not be statistically compared because scan periods were not independent (see Section 2.2.2.2 Site-specific Surveys), so instead we tested whether the numbers of raptors seen per day (excluding repeat observations) differed seasonally. A Kruskal-Wallis test showed that the seasonal difference was statistically significant ($P<0.01$).

Site-specific data were collected during two fall (1989 and 1990) and two winter (1990 and 1991) seasons. Relative abundance of raptors during the first fall survey (1.65 per 10-min scan, ± 2.15 SD, $N=817$) was similar to that of the second fall (1.71 per 10-min scan, ± 1.88 SD, $N=807$) (Figure 3-13). Relative abundance was 1.13 (± 1.38 SD, $N=850$) per 10-min scan for the first winter and declined slightly to 0.95 (± 1.25 SD, $N=799$) in the second winter. Unless otherwise specified, if a fall or winter estimate of relative abundance on site-specific surveys is reported, it will be an average of the two surveys for a season.

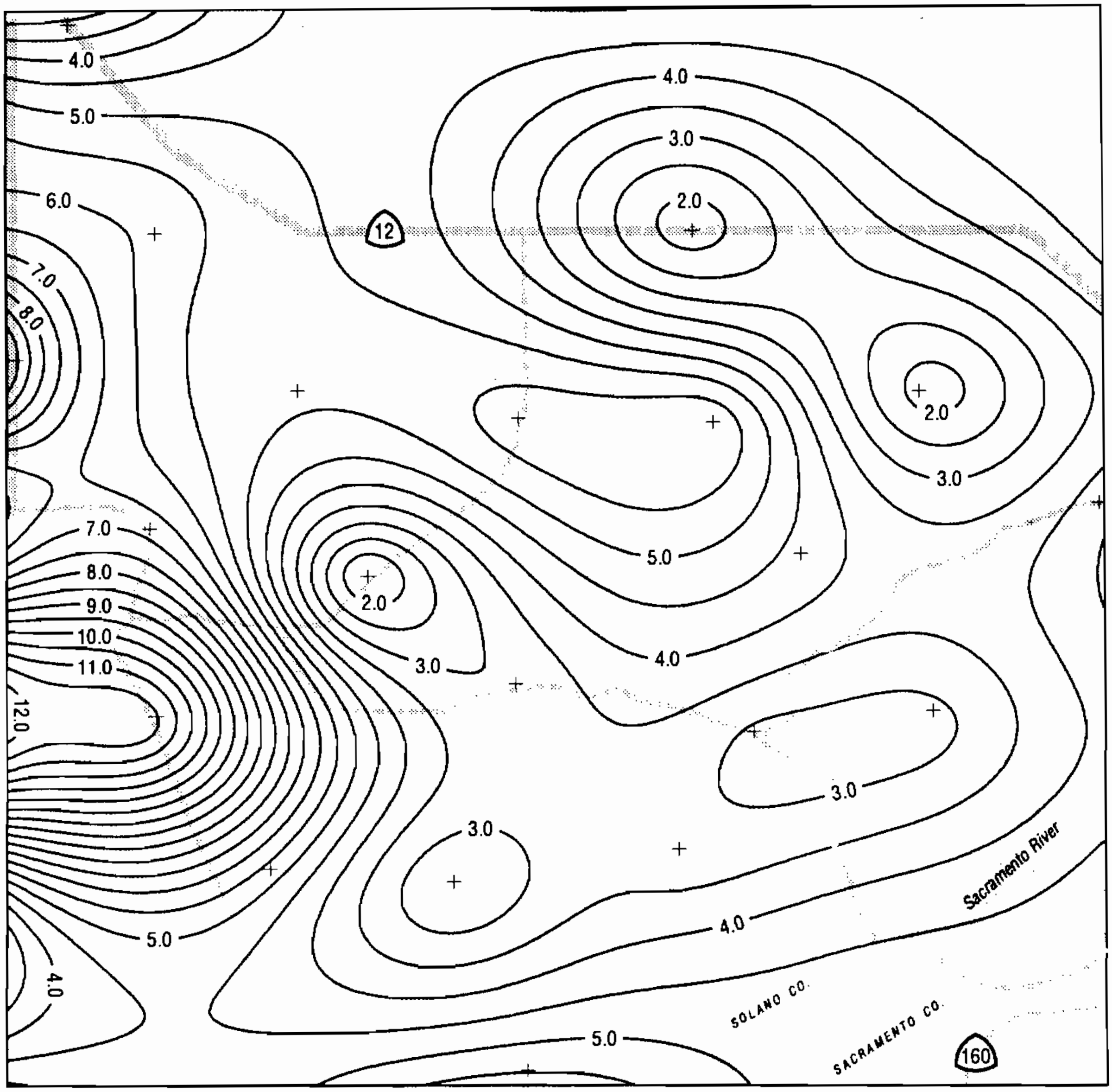
The relative abundance figures reported above were based on the total number of sightings recorded in one 10-min scan, i.e., they include repeat observations (see Section 2.2.2.2 Site-specific Surveys). We calculated that 27 percent (2,703/9,899) of all recorded sightings (raptors and non-raptors) were believed to be birds seen previously in the day. Figure 3-14 shows the difference between relative abundance and actual numbers of raptors when known repeat sightings were included and when they were excluded. Inclusion of repeat sightings in relative abundance gave us a better idea of raptor activity in the study area, whereas exclusion of repeat sightings provided a better representation of actual numbers of birds in the study area.

Raptor Age Distribution - We observed at least four times as many adult red-tailed hawks as immature hawks (of those birds for which age could be identified) in all seasons but summer; during the summer, only twice as many birds were adult as were immature (see Figure 3-15). The relative composition of adult and immature golden eagles was roughly equivalent in each season, except for summer, when three immature birds were identified for every adult. When all seasons were combined, 84 percent of red-tailed hawks of known age were adults (16% immatures) and 52.5 percent of golden eagles were adults (47.5% immatures).

Relative Abundance by Turbine Type - Relative abundance of raptors (all raptor species combined) did not vary significantly among turbine types.

Effects of Weather on Observations - Fewer birds were observed on foggy days than on clear days; 7 percent of our 10-min scans were hampered by fog. Eliminating foggy scan periods from our data resulted in a 3 to 6 percent increase in relative abundance numbers for different species. Statistical tests showed this increase was not significant.

A Kruskal-Wallis test showed that the number of birds seen per day for all seasons combined was significantly associated ($P=0.04$) with maximum daily wind speed (in wind speed categories of 0-5, 6-10, 11-15, 16-20, 21-25, and >25 MPH). Many more birds were seen when wind speed was between 6 and 10 MPH than when it was either lower or higher, but the data do not indicate any trends beyond that.

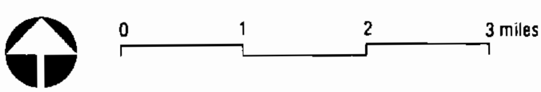


Prepared by BioSystems Analysis, Inc.

Figure 3-10. Raptor density contour map (no. of raptors per square mile), fall 1989, Solano County WRA.

Legend

Roads
+ Survey points



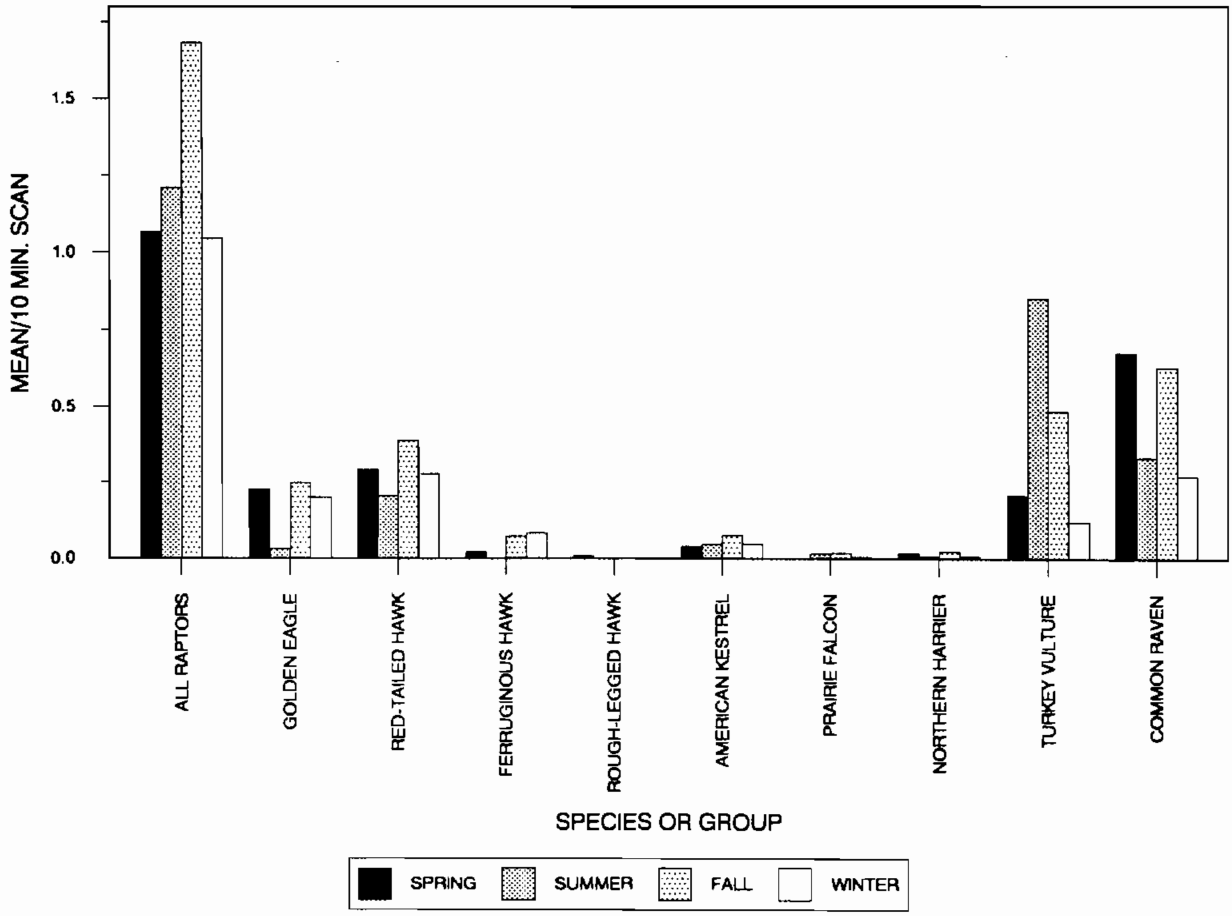


Figure 3-11. Relative abundance of raptors observed during site-specific surveys, by season, 1989-1991, Altamont Pass WRA.

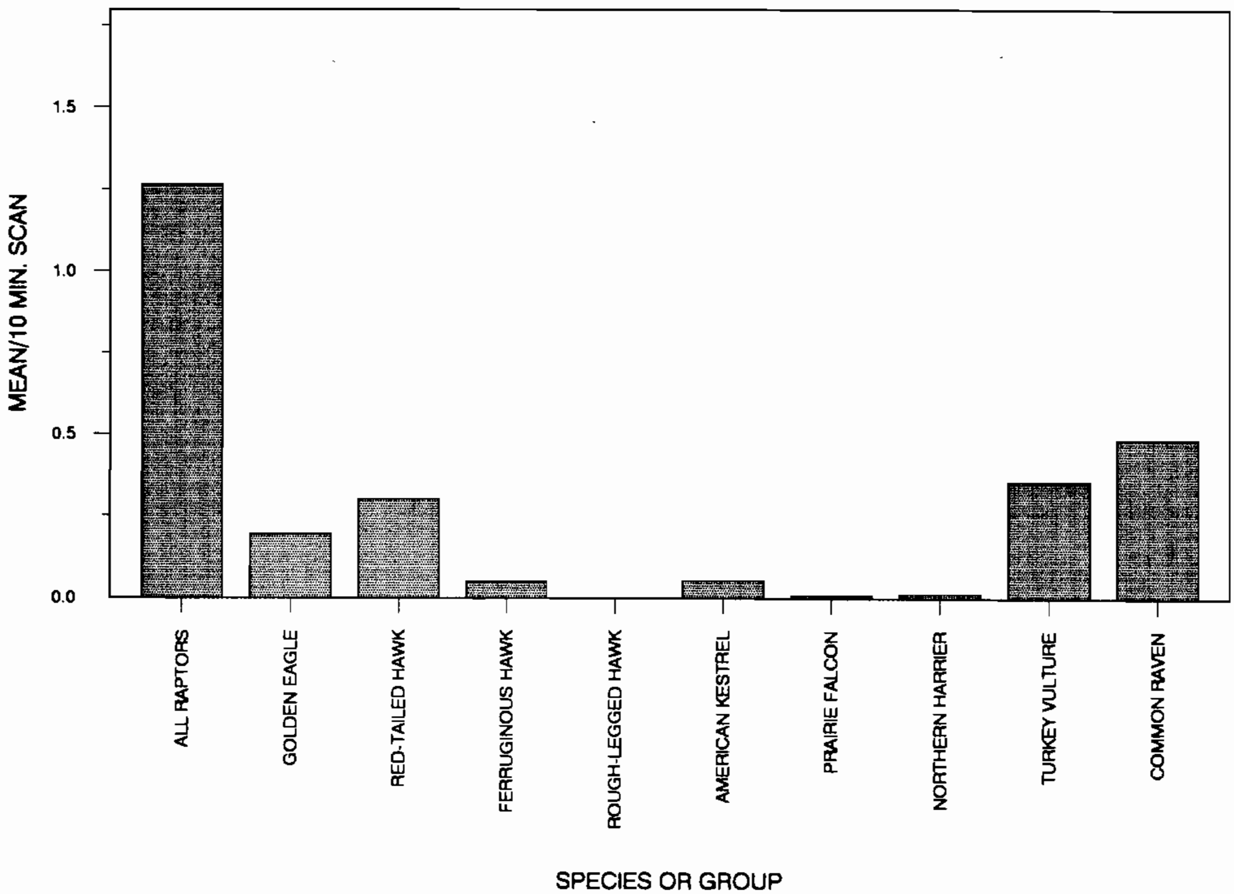


Figure 3-12. Relative abundance of raptors observed during site-specific surveys, all six seasons combined, 1989-1991, Altamont Pass WRA.

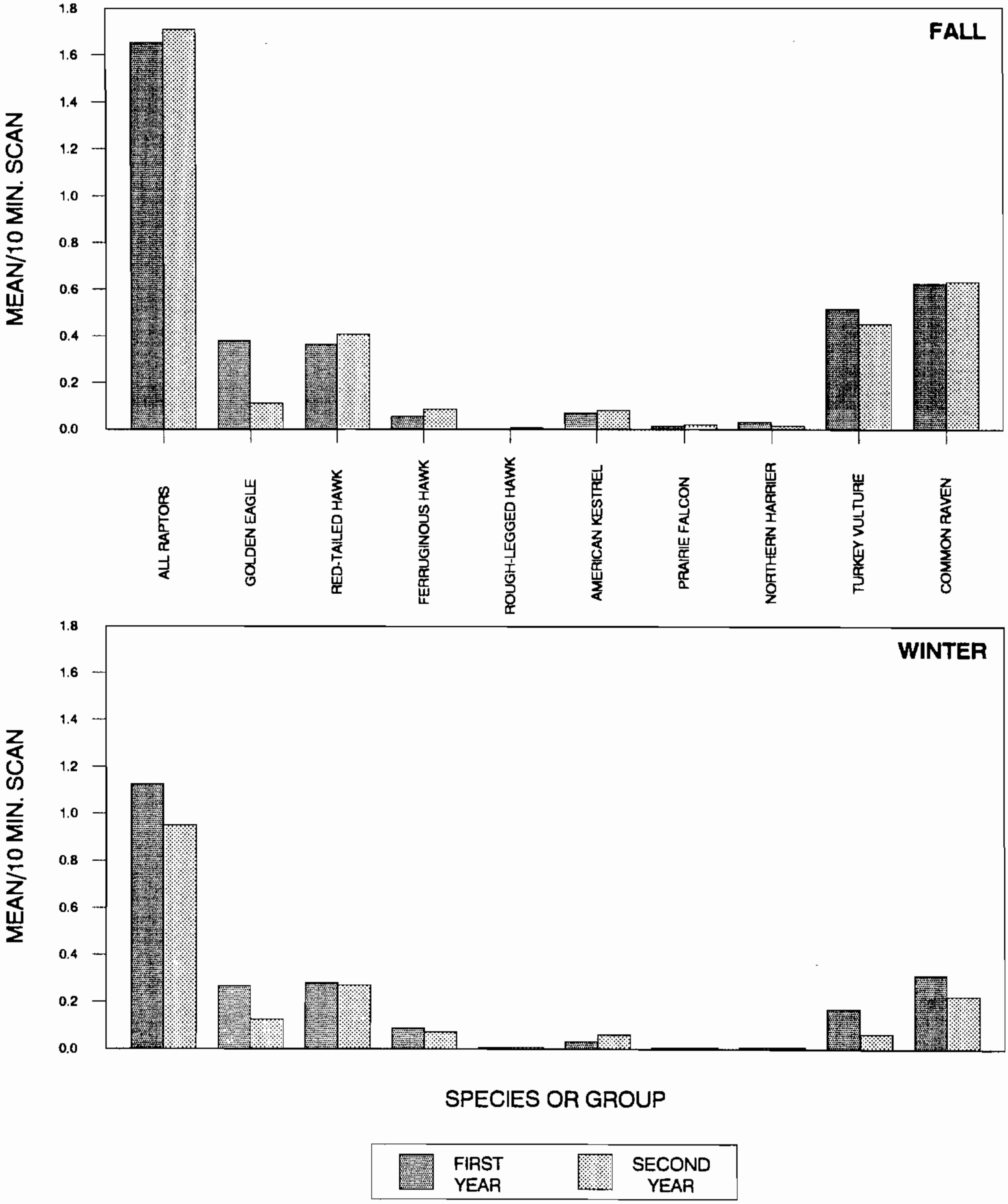


Figure 3-13. Comparison of relative abundance of raptors on first and second year site-specific surveys, fall and winter, Altamont Pass WRA.

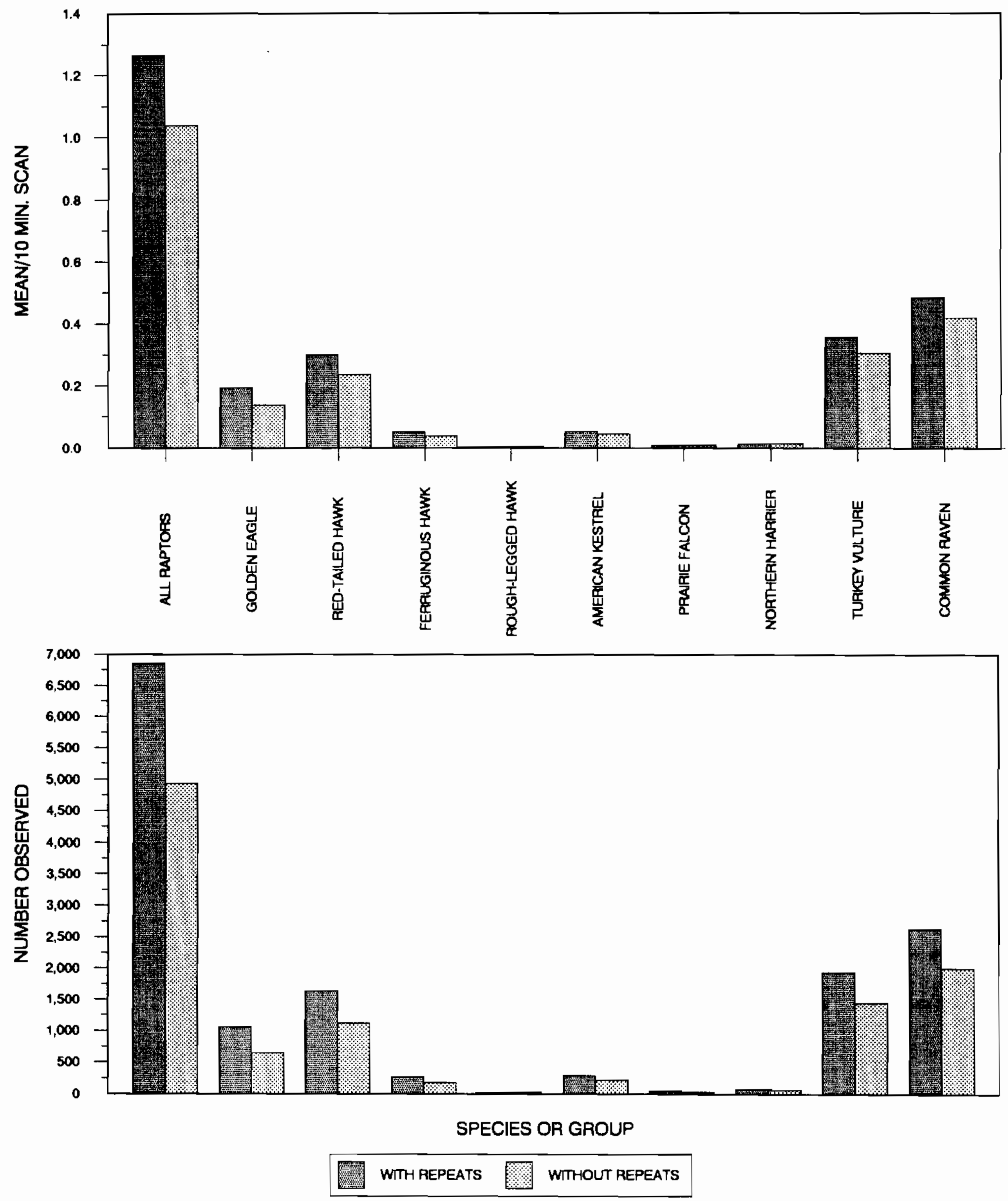


Figure 3-14. Comparison of relative abundance and actual numbers of raptors, both including and excluding repeat sightings, 1989-1991, all seasons combined, Altamont Pass WRA.

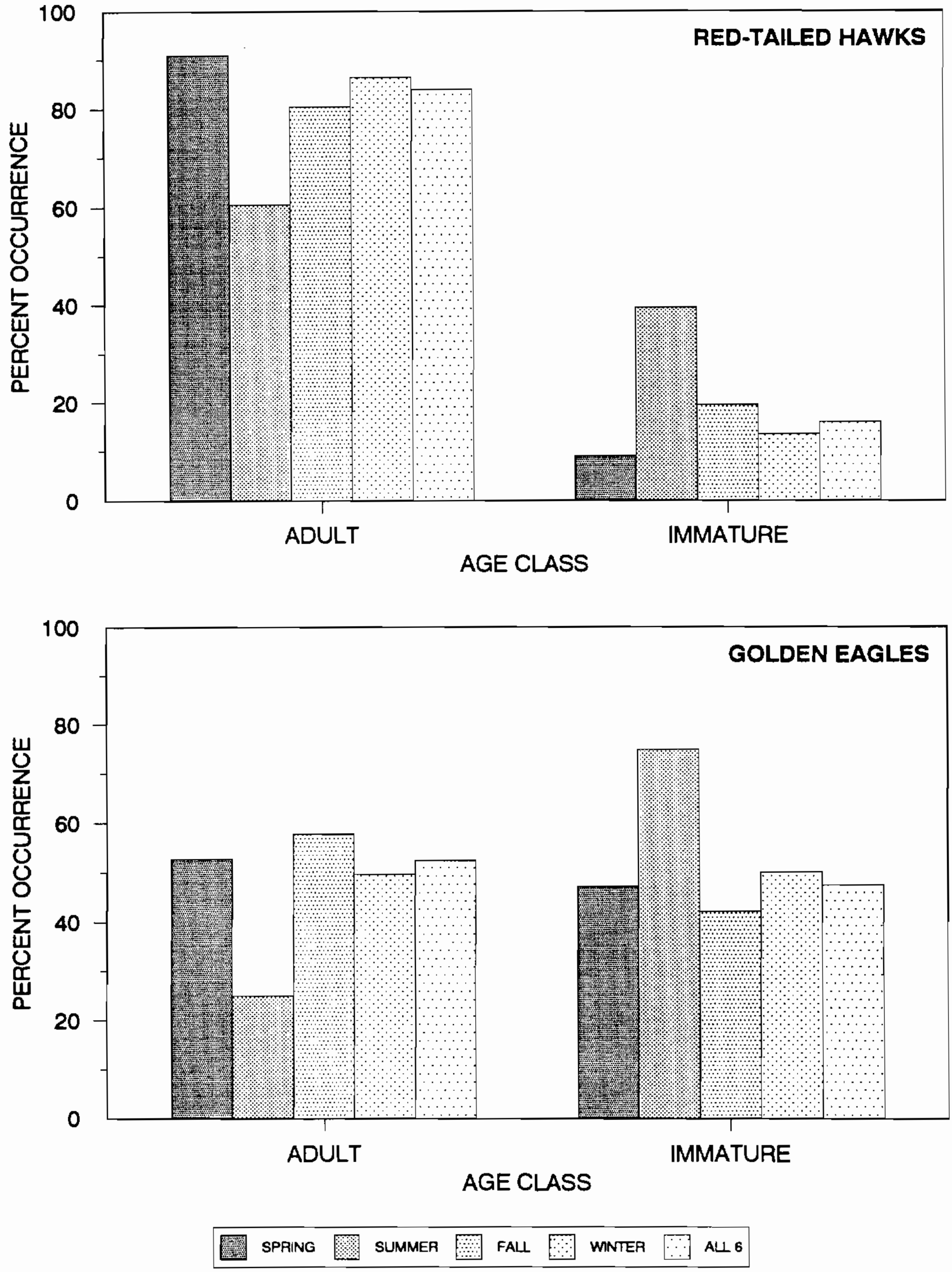


Figure 3-15. Age class comparisons of known-aged red-tailed hawks and golden eagles observed during site-specific surveys, by season and all seasons combined, 1989-1991, Altamont Pass WRA.

3.1.1.6 Comparisons to Other Studies

We compared our findings to those of other local studies. Relative abundance on raptor surveys conducted by Howell and DiDonato (1991) on two U.S. Windpower study sites within the Altamont Pass WRA was 1.11 raptors per 10-min scan for four seasons in 1988-1989. Our estimate of relative abundance for four seasons the following year was 1.2.

Most authors have reported higher raptor abundance figures for the Solano County WRA and vicinity than for Altamont Pass WRA. Relative abundance in fall and winter surveys conducted in Montezuma Hills, Solano County WRA, was 3.78 per 10-min scan in 1987-1988, 3.06 in 1988-1989, and 2.04 in 1990-1991 (Howell and DiDonato 1989; Howell et al. 1988; Howell et al. 1991a). In Cordelia Hills, near the Solano County WRA, BioSystems conducted fall and winter surveys in 1986-1987 (BioSystems Analysis, Inc. in prep.) at two sites and reported relative abundances of 1.10 and 2.65. For comparison, the relative abundance of raptors on fall and winter surveys conducted at the Altamont Pass WRA in the present study was 1.39 in 1989-1990 and 1.33 1990-1991.

The relative abundance of red-tailed hawks and *Accipiter* spp. (sharp-shinned hawks, *Accipiter striatus*, Cooper's hawks, and northern goshawks, *Accipiter gentilis*) at the Marin Headlands in Marin County during the 1987 fall migration was considerably greater than at either the Solano or Altamont Pass WRA, while the number of turkey vultures, golden eagles, and American kestrels was similar (Howell et al. 1988). Overall, however, the number of raptor sightings at Marin Headlands (number/site/day) was two to seven times that observed at the Altamont Pass WRA.

3.1.1.7 Threatened, Endangered, or Sensitive Species

Table 1.1 provides a list of threatened, endangered, or sensitive species that occur or could potentially occur on either study site. All were seen on either driving or site-specific surveys in the Altamont Pass WRA, except for Swainson's hawks, short-eared owls (*Asio flammeus*), and Aleutian Canada geese (*Branta canadensis leucopareia*). Of the four raptor species that have been state or federally listed as threatened or endangered, only the Swainson's hawk was not seen on any survey. One peregrine falcon (*Falco peregrinus*) was seen in the fall of 1989. We recorded a total of 63 bald eagle sightings on all site-specific surveys combined and 22 sightings on all driving surveys combined. Bald eagles were recorded only in winter and spring. We observed golden eagles on every survey; 1,056 golden eagle sightings occurred during site-specific surveys and 550 during driving surveys.

Only four birds from Table 1.1 were recorded during the one Solano County WRA survey in the fall of 1990. These were golden eagle, prairie falcon, northern harrier, and ferruginous hawk. We did not see any other threatened, endangered, or sensitive species.

3.1.2 Flight Characteristics

We collected data on flight characteristics to assess the susceptibility or vulnerability of birds to mortality. For example, species that frequently fly close to the ground or near turbine structures or blades may be more susceptible to collision. We evaluated susceptibility based on our flight data and compared this with results of mortality surveys to discover whether birds apparently more susceptible were, indeed, killed more frequently. This is discussed more fully in Section 4.1.2 Behavior and Flight Characteristics. We focused most closely on the five most common species—American kestrels, golden eagles, turkey vultures, red-tailed hawks, and common ravens.

Although some of the flight variables measured on site-specific surveys were also measured on driving surveys, we used only measurements taken on site-specific surveys.

3.1.2.1 Distance Above Ground

Figure 3-16 illustrates the distribution of bird species by flight-height category for all six seasons combined. American kestrels tended to fly lower than any other raptor species. In fact, more than 75 percent of American kestrels observed were within 200 ft of the ground, and over 50 percent were within 100 ft. Common ravens were also commonly observed below 200 ft. Golden eagles, turkey vultures, and red-tailed hawks, on the other hand, were seen less frequently below 200 ft of the ground. Seasonally, we found that all raptors flew at greater altitudes in fall than in the other seasons. Appendix Figure B-1 illustrates seasonal differences in flight heights.

Flight altitudes were recorded in discrete distance categories (e.g., 1-50 ft, 51-100 ft) in the spring and fall of 1989. Beginning in the winter of the first year, we recorded flight height in feet. From these data, we calculated the percent occurrence of birds observed flying below specific altitudes to determine the height at which birds fly relative to the maximum blade height of the five different turbine types. Average flight heights for all seasons during which actual flight height data were recorded are presented in Table 3.1 (data on perched birds were excluded from these calculations).

The three altitude categories used in Table 3.1 reflect categories of maximum blade height of the five turbine types we considered. The maximum height of turbine blades varies by turbine type, as follows: tubular, maximum blade height is 130 ft; guyed-pipe, maximum is 58-78 ft; three-blade lattice, 90-110 ft; vertical axis, 90-106 ft; and windwall, 170 ft. No turbines in the WRA are higher than 170 ft, and 72 percent of all turbines are less than 100 ft tall. Seventeen percent of raptors were observed flying at or below the maximum blade height of the majority of turbines in three turbine types (90 ft); 31 percent were observed below maximum blade height of four turbine types (130 ft); and 39 percent were below blade height of all five turbine types (170 ft) (percentages are cumulative).

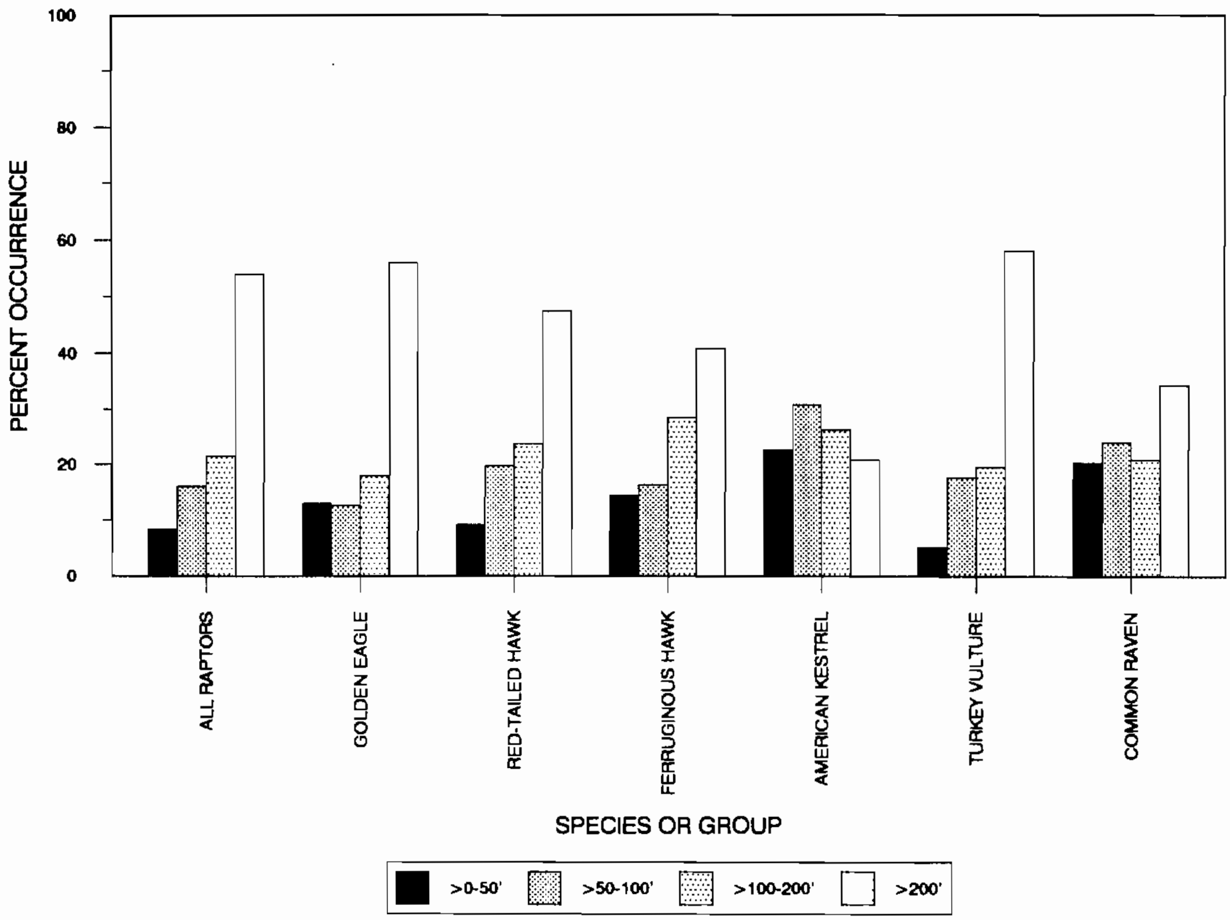


Figure 3-16. Distance above ground of birds observed during site-specific surveys, flying birds only, all seasons combined, 1989-1991, Altamont Pass WRA.

Table 3.1. Average flight heights and percentage of occurrence of birds at different heights[1].

SPECIES OR GROUP	AVERAGE FLIGHT HEIGHT (ft)	PERCENTAGE OBSERVED BELOW[2]			PERCENTAGE OBSERVED ABOVE	TOTAL NUMBER
		90 ft	130 ft	170 ft	170 ft	OF BIRDS
Non-raptors	99.92	36.08	54.36	61.53	38.47	837
All raptors	128.95	16.52	30.94	38.89	61.11	3,142
American kestrel	103.87	40.30	61.19	71.64	28.36	67
Bald eagle	185.56	8.33	8.33	8.33	91.67	12
Ferruginous hawk	120.16	22.46	36.96	49.28	50.72	138
Golden eagle	116.94	21.05	31.58	37.77	62.23	323
Northern harrier	103.91	38.46	53.85	65.38	34.62	26
Prairie falcon	83.00	37.50	62.50	62.50	37.50	8
Red-tailed hawk	125.09	17.56	37.05	47.32	52.68	672
Rough-legged hawk	124.00	13.33	40.00	53.33	46.67	15
Turkey vulture	127.55	17.36	32.21	38.77	61.23	1,158
Unknown buteo	138.20	10.37	24.39	35.37	64.63	164
Unknown eagle	135.71	8.33	33.33	33.33	66.67	12
Unknown falcon	187.50	0.00	0.00	20.00	80.00	10
Common raven	99.94	38.34	57.83	65.48	34.52	785

[1] Flying birds only; does not include birds perched on structures or on the ground.
[2] 90 ft corresponds to maximum blade height of the majority of lattice, vertical, and guyed-pipe turbine types.
130 ft corresponds to maximum blade height of tubular turbine type.
170 ft corresponds to maximum blade height of windwall turbine type.

Based on flight height data in Table 3.1, 38 percent of golden eagles and 39 percent of turkey vultures were observed flying within turbine-blade range of the ground. In contrast, 72 percent of American kestrels and 65 percent of common ravens were observed flying within turbine-blade range of the ground. About 47 percent of red-tailed hawk observations were recorded within this range.

Gruenhagen and Byrne (1981) reported that 45 percent of the raptors seen in their study were 49-328 ft above the ground. Red-tailed hawks, in particular, seemed to prefer these altitudes. Turkey vultures and buteos other than red-tailed hawks were usually observed above 328 ft, American kestrels tended to fly within 49 ft of the ground, and other species showed no clear preferences for a particular stratum. Summaries of published information on flight characteristics of raptors are presented in Appendix A.

We did not find significant differences in the flight height of birds by turbine type. Our statistical analysis of whether turbine operation affected flight height at each turbine type or at all turbine types combined was inconclusive. Although flight height was significantly associated with turbine operation at some turbine types, no meaningful or consistent trends were apparent. We were unable to conclude that birds were flying either lower or higher at operating than at not-operating turbines.

3.1.2.2 Distance from Turbines

Distance from Turbine Structure - Figure 3-17 presents data on the distance of birds from turbine structures for all seasons combined (distance to turbine structure is different from distance to turbine blades; see Section 2.2.2.2. Site-Specific Surveys for descriptions). Birds recorded at 0 ft were perched somewhere on the structure. Perching was more common among American kestrels, red-tailed hawks, and ravens than among turkey vultures and golden eagles. When data from all seasons and all turbine types were combined, 21 percent of American kestrels, 13 percent of red-tailed hawks, and 13 percent of common ravens were observed perched on turbine structures, compared to less than 2 percent of golden eagles and no turkey vultures. When all raptors were combined, perching was more common in winter (both winter seasons combined) when 11 percent of raptors were observed perching on turbine structures. By contrast, only 1 percent of raptors were observed perching on structures in the summer. American kestrels and ravens were more commonly observed flying within 50 ft of turbine structures (18% and 13%, respectively). Only 6 percent of red-tailed hawks, 4 percent of golden eagles, and 4 percent of turkey vultures were observed flying within 50 ft of turbine structures. Appendix Figure B-2 illustrates seasonal differences in distance to turbine structure for several species.

An analysis of distance to structure by turbine type (ANOVA) showed that, for all raptors combined, the frequency of birds flying within 50 ft of turbine structures did not differ significantly among turbine types. An analysis (ANOVA) of frequency of perching by turbine type, however, did show significant differences among the five turbine types ($P<0.01$). Perching was most common on guyed-pipe types, followed by windwall, lattice, tubular, and vertical types.

When we applied statistical tests to determine whether the distance of birds to structures at each turbine type was affected by whether turbines were operating, we again found significant associations at some turbine types but were unable to identify a meaningful or consistent trend. We were unable to conclude that birds were flying either farther from or closer to operating turbines than not-operating turbines.

Minimum Distance to Turbine Blades - We recorded this parameter in the field as the minimum distance from a turbine *blade* a bird reached *at any time during a 10-min scan period*. Birds recorded at 0 ft were perched on the blades themselves. When we

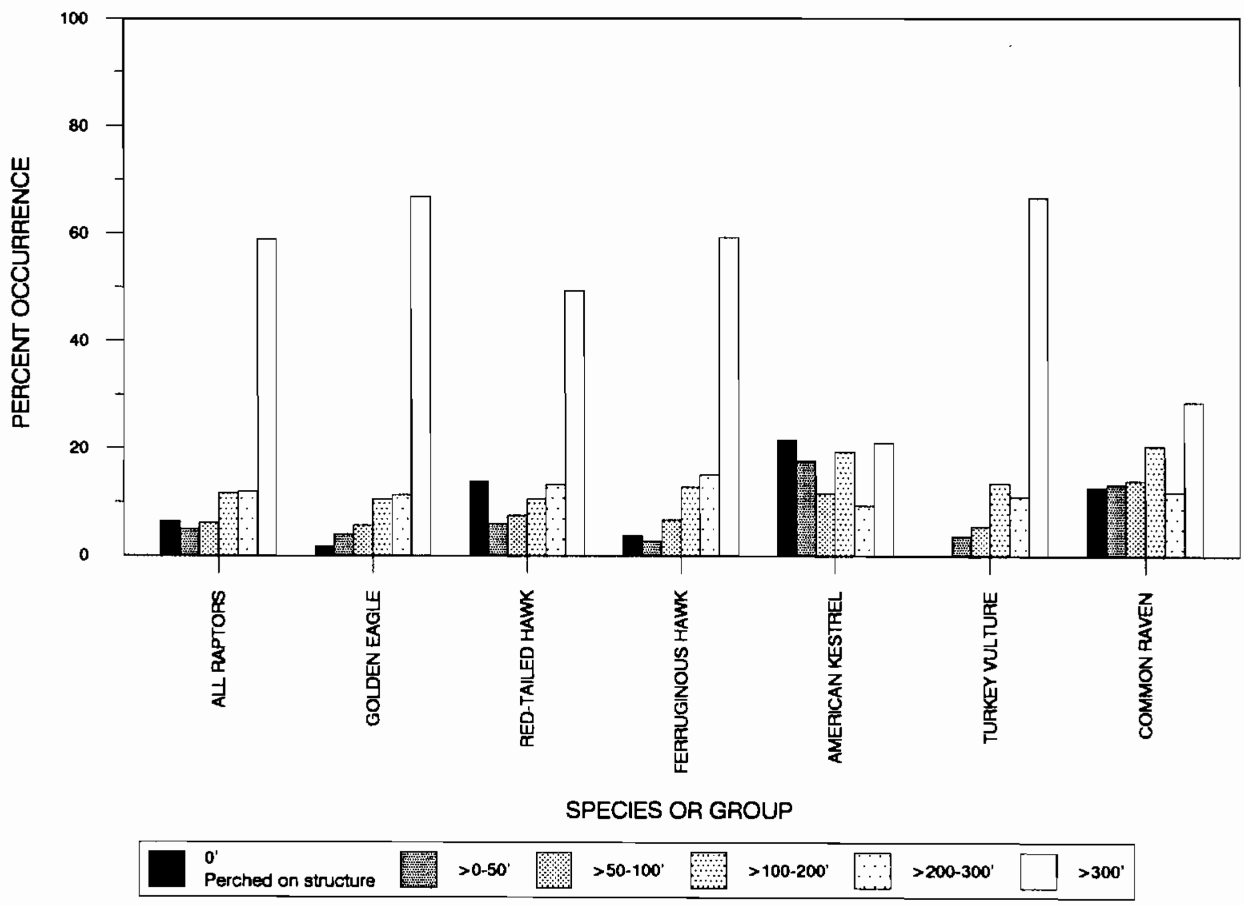


Figure 3-17. Distance from turbine structure of birds observed during site-specific surveys, all seasons combined, 1989-1991, Altamont Pass WRA.

combined observations from all seasons, American kestrels and common ravens were most frequently observed within 10 ft of turbine blades, golden eagles and turkey vultures were least frequently observed this close, and red-tailed hawks were intermediate between these two extremes (Figure 3-18). Seasonal data on minimum distance to turbine blade are presented in Appendix Figure B-3.

Our analysis of whether minimum distance to turbine blades was different between operating and not-operating turbines was, again, inconclusive. There was a significant association at some turbine types, but we were unable to conclude that birds were either closer to or farther from operating turbine blades.

3.2 MORTALITY SURVEYS

3.2.1 Species Composition and Relative Abundance of Dead Birds

During the six seasons of our study, we found 182 dead birds (Table 3.2, Figure 3-19) on our sample sites (on site). Four birds, all red-tailed hawks, were found injured. Most of the dead birds found on mortality surveys were old and decomposed. Even during the second year of our study we found old carcasses within the sample sites, probably because the vegetation became increasingly sparse as a result of the drought, revealing previously-hidden carcasses. A total of 43 "fresh" carcasses was found within our sample sites, of which 19 were raptors. Data from all carcasses, fresh and old, were used for most analyses; we used only fresh carcasses for extrapolating estimates of annual site-wide mortality.

Sixty-five percent (119/182) of the dead birds found on site were raptors. Most dead raptors were red-tailed hawks (45%), followed by American kestrels (17%), golden eagles (14%), owls (7%), turkey vultures (3%), and ferruginous hawks (2%). Eight percent were unknown raptors and 5 percent were unknown buteos. Dead owls included burrowing owls, barn owls (*Tyto alba*), and great horned owls (*Bubo virginianus*). No prairie falcons, northern harriers, or rough-legged hawks were found dead. Most of the non-raptors found were either rock doves (*Columba livia*) or passerines. Only 4 percent were common ravens. A few water birds were also found, including long-billed curlews that frequent the grasslands of Altamont Pass in winter.

We found an additional 31 carcasses off our sample sites (Table 3.2). These were discovered inadvertently during our surveys or they were reported to us by windfarm operators. Eighty-one percent (25/31) of off-site mortalities were raptors. Most were red-tailed hawks (34%) and golden eagles (22%), followed by American kestrels (6%), common ravens (6%), and unknown buteos (6%). The remainder were unknown passerines, unknown owls, and unknown birds. Off-site mortality data were used only for summaries of types of injuries and location of carcasses; they were never included in statistical analyses.

Table 3.2. Summary of on-site and off-site bird mortalities recorded during the first and second years of the study, 1989-1991, Altamont Pass WRA.

	1st YEAR		2nd YEAR		TOTAL	
	ON-SITE	OFF-SITE	ON-SITE	OFF-SITE	ON-SITE	OFF-SITE
American kestrel	15	2	5	0	20	2
Ferruginous hawk	1	0	1	0	2	0
Golden eagle	12	7	4	0	16	7
Red-tailed hawk	35	10	19	1	54	11
Turkey vulture	3	0	1	0	4	0
Owl	2	1	6	1	8	2
Unknown buteo	6	2	0	0	6	2
Unknown raptor	7	1	2	0	9	1
Common raven	2	2	3	0	5	2
Unknown passerine	20	1	26	1	46	2
Gull	4	0	0	0	4	0
Unknown	6	2	2	0	8	2
Sub-total	113	28	69	3	182 (85%)	31 (15%)
TOTAL	141		72		213	

3.2.2 Cause of Death

Of all on-site mortalities (raptor and non-raptor), 55 percent were attributed to collisions with turbines, 8 percent to electrocutions, 11 percent to collisions with wires (electrical transmission wires and guy wires), and 26 percent to unknown causes (Table 3.3). When we recalculated this breakdown using only carcasses for which the cause of death was judged with a high degree of certainty (index of probability ≥ 7 on a 10-point scale), the percentage of on-site deaths attributed to collisions with turbines increased to 78. Figure 3-20 demonstrates that collisions with turbines were judged to be the principal cause of death for the three most-commonly killed raptor species (red-tailed hawks, golden eagles, and American kestrels). Table 3.4 illustrates that the causes of death differed for raptors and non-raptors. More raptor deaths were attributed to collision with turbines than non-raptors, whereas more non-raptor deaths were attributed to collisions with wires than were raptor deaths. No deaths were attributed to collisions with meteorological towers. We never actually observed collisions with turbines or wires during this study.

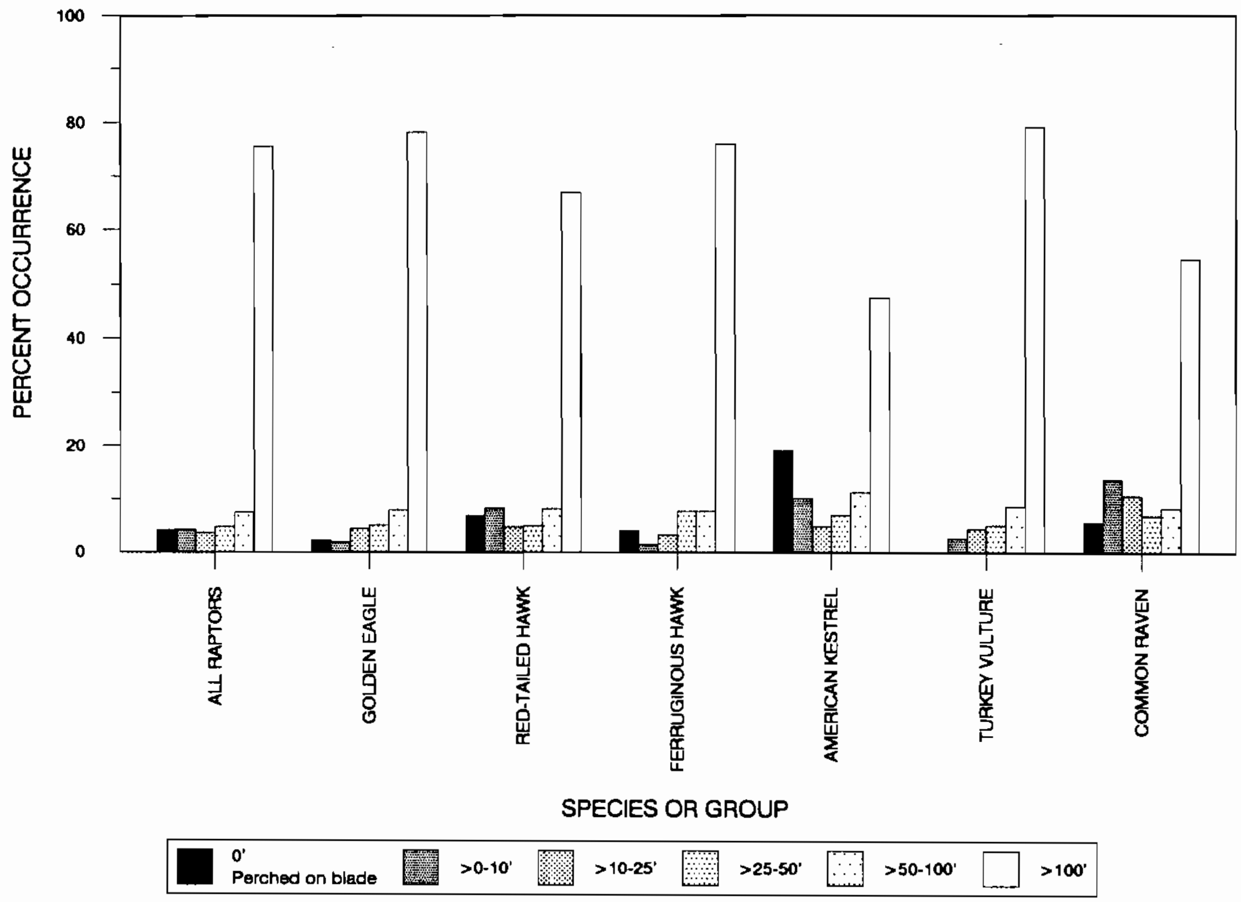


Figure 3-18. Minimum distance to turbine blades of birds observed during site-specific surveys, all seasons combined, 1989-1991, Altamont Pass WRA.

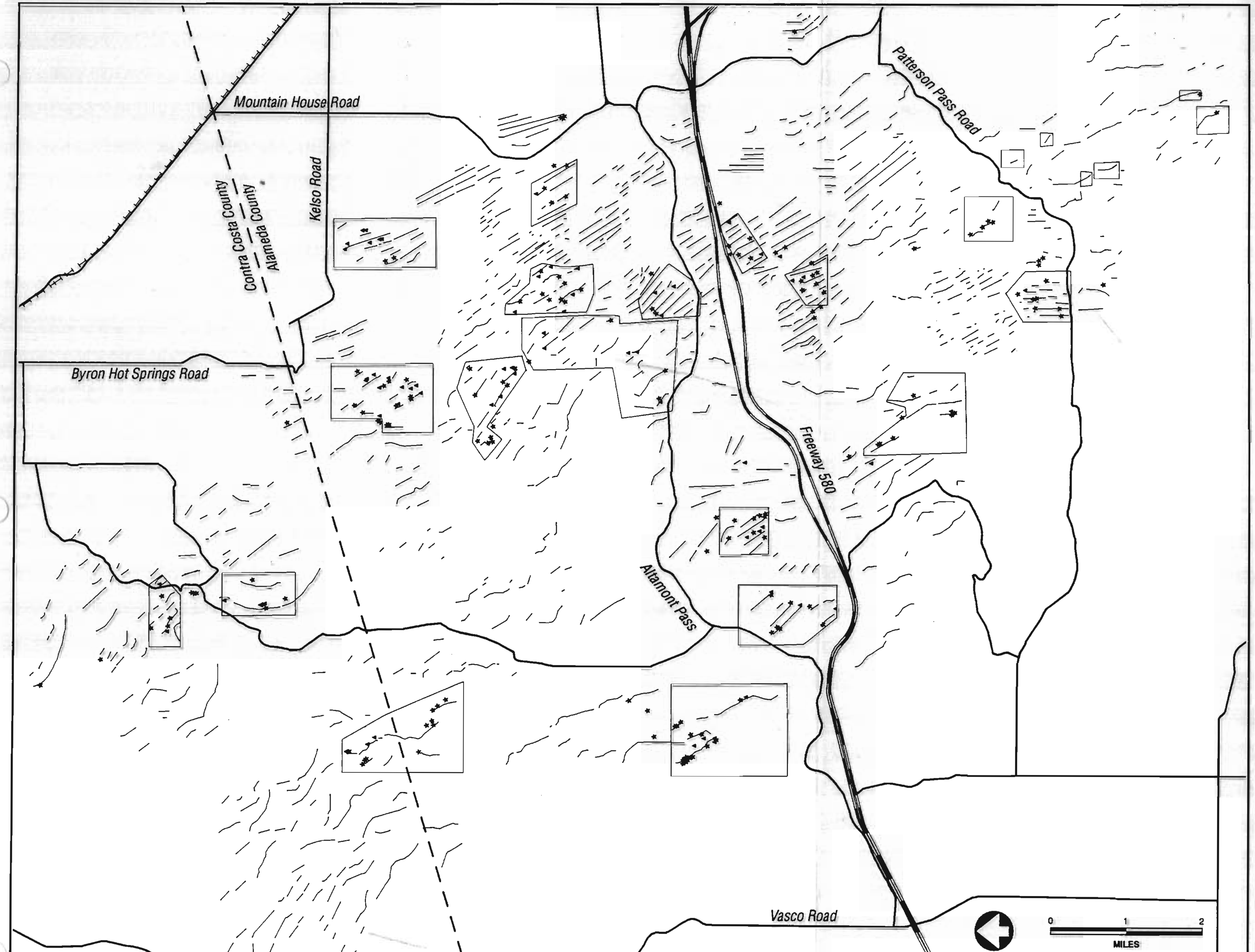


Figure 3-19. Locations of all bird mortalities, on and off sample sites, 1989-1991, Altamont Pass WRA.

LEGEND

- * Raptor
- ◄ Non-raptor

Prepared by BioSystems Analysis, Inc.

Table 3.3. Causes of on-site and off-site mortality 1989-1991, Altamont Pass WRA.

	COLLISION WITH TURBINE		COLLISION WITH WIRE		ELECTROCUTION		UNKNOWN	
	ON-SITE	OFF-SITE	ON-SITE	OFF-SITE	ON-SITE	OFF-SITE	ON-SITE	OFF-SITE
American kestrel	13	1	2	0	0	0	5	1
Ferruginous hawk	0	0	1	0	0	0	1	0
Golden eagle	11	5	1	0	3	1	1	1
Red-tailed hawk	36	3	2	1	4	6	12	1
Turkey vulture	4	0	0	0	0	0	0	0
Owl	4	0	1	1	0	0	3	1
Unknown buteo	3	0	1	0	1	1	1	1
Unknown raptor	3	0	1	0	3	0	2	1
Common raven	0	1	0	1	3	0	2	0
Gull	1	0	2	0	0	0	1	0
Bat	1	1	0	0	0	0	0	0
Unknown	4	0	1	0	0	0	3	2
Other*	21	1	8	1	0	0	17	0
TOTAL	101	12	20	4	14	8	48	8
PERCENT	55.2%	37.5%	10.9%	12.5%	7.7%	25.0%	26.2%	25.0%

*Passerine, waterbird, rock dove

Table 3.4. Causes of on-site mortality for raptors and non-raptors, 1989-1991, Altamont Pass WRA.

	COLLISION WITH TURBINE	COLLISION WITH WIRE	ELECTROCUTION	UNKNOWN
Raptors On-site				
Number of deaths	74	9	11	25
Percentage of total	62	8	9	21
Raptors On-site* (Level of Certainty ≥7)				
Number of deaths	38	3	4	0
Percentage of total	84	7	9	0
Non-raptors On-site				
Number of deaths	27	11	3	23
Percentage of total	42	17	5	36

* Includes only birds for which the cause of death was determined with a high level of certainty. Level of certainty was estimated on a scale of 1 to 10.

More immature red-tailed hawks and golden eagles were killed by collision with turbines than we would have expected from their relative occurrence on observational surveys (site-specific). Of all dead raptors (on site) whose death we attributed to collision with turbines, 63 percent of the golden eagles and 40 percent of the red-tailed hawks were immature. Observation data indicate that, of birds for which age could be identified, 48 percent of the golden eagles and 16 percent of the red-tailed hawks were immature birds.

We compared mortality attributed to collision with turbines to abundance from site-specific observations for all raptor species (except owls and those species infrequently observed) and common ravens to assess whether some species appeared to be at greater risk. A chi-square test showed that mortality was not related to abundance ($P<0.01$, Table 3.5). For example, turkey vultures were killed less often than their abundance would lead us to predict, whereas American kestrels, red-tailed hawks, and golden eagles were killed more often than their observed abundance would suggest. Observed mortality for American kestrels may be conservative. Kestrels were removed by scavengers more frequently and were detected on mortality surveys less readily than were the other raptors; therefore, we believe more were killed than were discovered (see

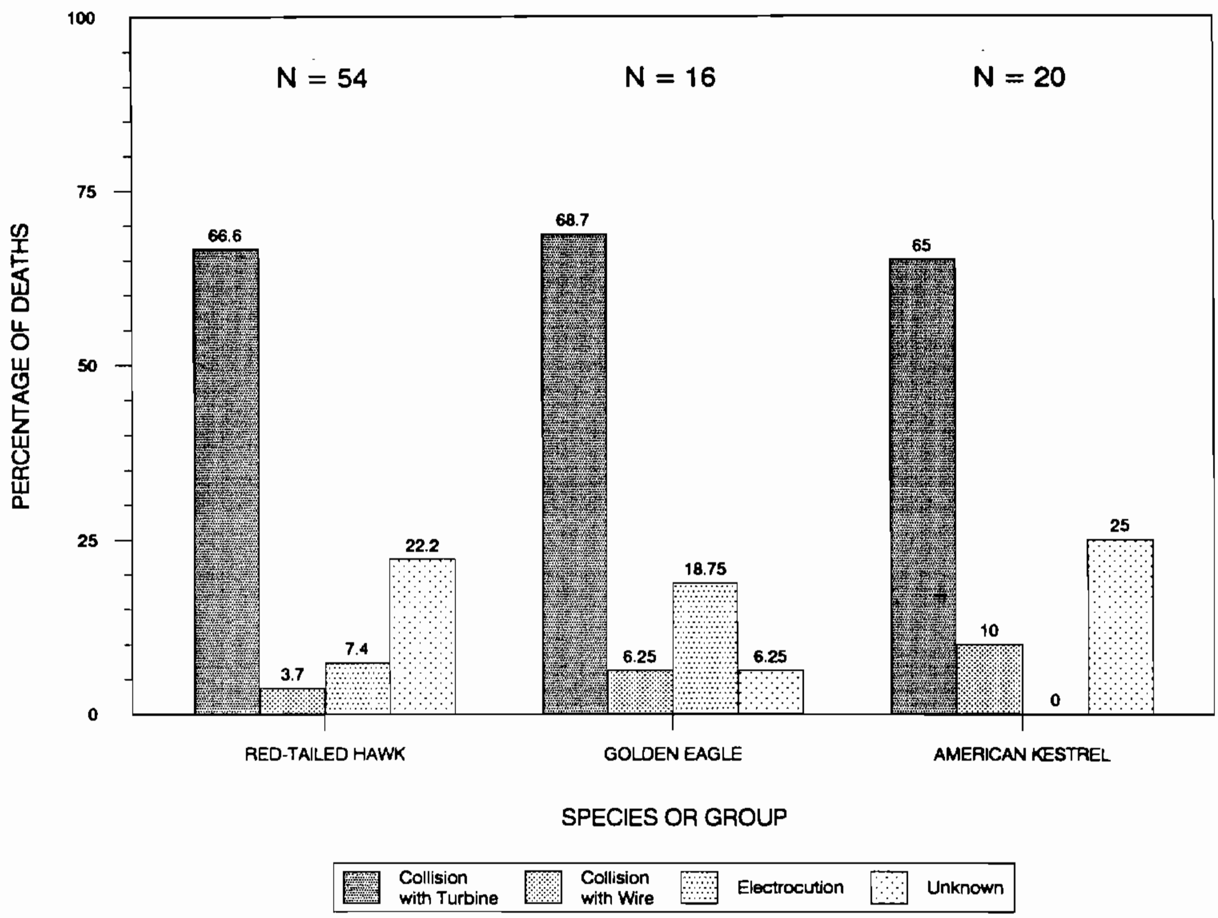


Figure 3-20. Causes of on-site deaths for three common raptor species, 1989-1991, Altamont Pass WRA.

Section 3.2.7 Tests for Survey Biases). Interestingly, the most commonly observed bird in the Altamont Pass WRA, the common raven, was never found to have been killed by collision with turbines on our sample sites.

Table 3.5. Comparison of relative abundance with turbine-related mortality of many raptor species, all seasons combined, 1989-1991, Altamont Pass WRA.

SPECIES	OBSERVED ABUNDANCE[1]	OBSERVED MORTALITY[2]	MORTALITY/ ABUNDANCE	EXPECTED MORTALITY
American kestrel	77	13	0.1688	10.31
Bald eagle	1	0	0	0.13
Common raven	148	0	0	19.82
Ferruginous hawk	17	0	0	2.27
Golden eagle	25	11	0.4583	3.35
Northern harrier	5	0	0	0.67
Prairie falcon	2	0	0	0.27
Red-tailed hawk	124	36	0.2903	16.6
Turkey vulture	79	4	0.0506	10.58
TOTAL	478	64		64
	$\chi^2 = 57.37$		$P<0.01$	

[1]Includes only birds observed on sample sites, less than 500 ft from the observer, and less than 200 ft above the ground.
[2]Includes only deaths attributed to collision with turbine.
[3]Expected mortality was calculated from data in this table as follows: (ABUNDANCE OF SPECIES/TOTAL ABUNDANCE) x TOTAL MORTALITY. For example, expected mortality of American kestrels was (77/478) x 64.

Our relative risk analysis showed that, relative to turkey vultures, which had the lowest mortality, American kestrels were three times more likely to be killed by collision with turbines, red-tailed hawks were six times more likely to be killed, and golden eagles were nine times more likely to be killed than turkey vultures.

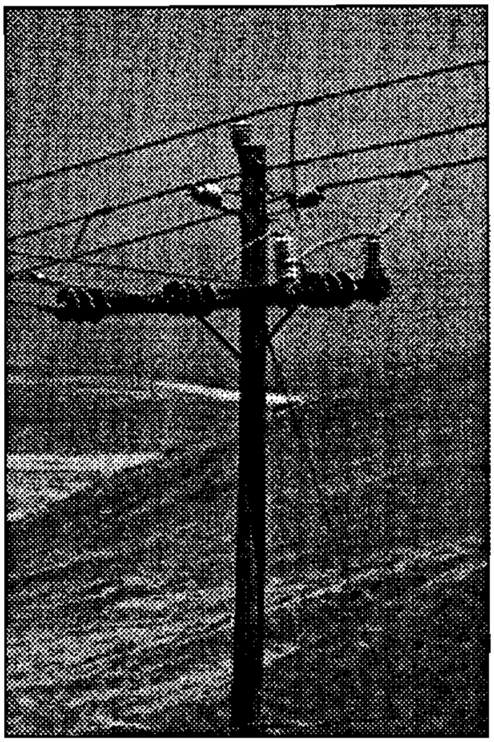
We attributed 19 percent (3/16) of on-site golden eagle deaths to electrocution, as compared to only 7 percent (4/54) of the red-tailed hawk deaths; however, the percentage of red-tailed hawk electrocutions (15%) almost equaled that for golden eagles (17%) when off-site data were included (Table 3.3). Only larger birds such as golden eagles, buteos, or common ravens were found electrocuted. No American kestrel deaths were attributed to electrocution; small birds typically do not have a large enough wing span to complete a circuit (Olendorff et al. 1981).

Seventy-seven percent (17/22) of all deaths attributed to electrocution occurred at riser poles (Figure 3-21). Riser poles have more potential points for electrical contact than most other pole types. The ratio of poles is usually one riser to 15 "regular" poles. Within our study sites, there were approximately five riser poles per linear mile of transmission line, for a total of 143. Mortalities occurred at 12 percent of these during the course of the study. Other types of poles associated with electrocutions included metering poles, juncture poles, and reclosure poles (Figure 3-21). Of the 18 poles at which electrocutions occurred (three of which were responsible for multiple kills), 17 were either not insulated or had insulated wires but no wildlife caps. Only one of the 18 appeared to be fully insulated.

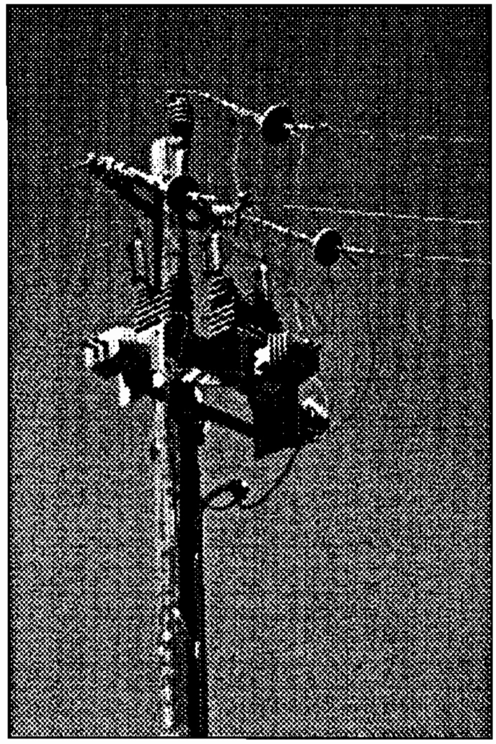
Necropsies were performed on all carcasses (with the exception of old partial skeletal remains) found after the beginning of the first fall season to corroborate our assessment of cause of death. Of 51 carcasses, only 20 were in good enough condition that our veterinarian could determine actual or probable cause of death. Of these 20, Dr. Sanders attributed 1 death to electrocution, 12 to traumatic injury (e.g., broken wing, amputation), and 5 to injuries compatible with traumatic death but the cause of death was uncertain. Illness was a probable contributing factor in the death of two birds; one had lead poisoning and the other had pox. Dr. Sanders found no evidence that any bird had been shot. We used necropsy results to modify our index of probability for cause of death.

3.2.3 Types of Injuries

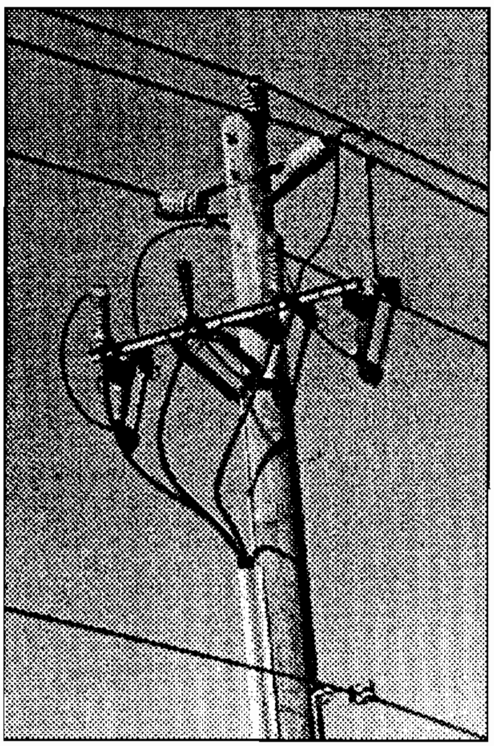
We determined the types of injuries sustained from collisions with turbines or wires for 103 dead birds found on and off site (Table 3.6). The majority of raptor injuries involved the body being torn in half or body parts being sheared off. According to raptor rehabilitation centers and the study's veterinarian, these injuries are more likely to be the result of turbine blade strikes than collisions with wires (S. Sanders pers. comm.; D. Crump pers. comm.). However, similar types of injuries have been reported from collisions with wires (Olendorff and Lehman 1986, Schroeder 1977). Neck and head injuries were also a common cause of death for all birds. Wing-related injuries, including carcasses consisting of only one wing, were associated with approximately 50 percent of all raptor and non-raptor mortalities (this number was derived from several categories listed in Table 3.6). Only one wing was found in 14 of 21 dead American kestrels. The CEC preliminary study (CEC 1989) reported that 75 percent of raptor injuries involved damage to wings or amputation of body parts. Because some injured birds may have been able to move away from the search area, non-lethal injuries resulting from collisions may not be accurately reflected in our data.



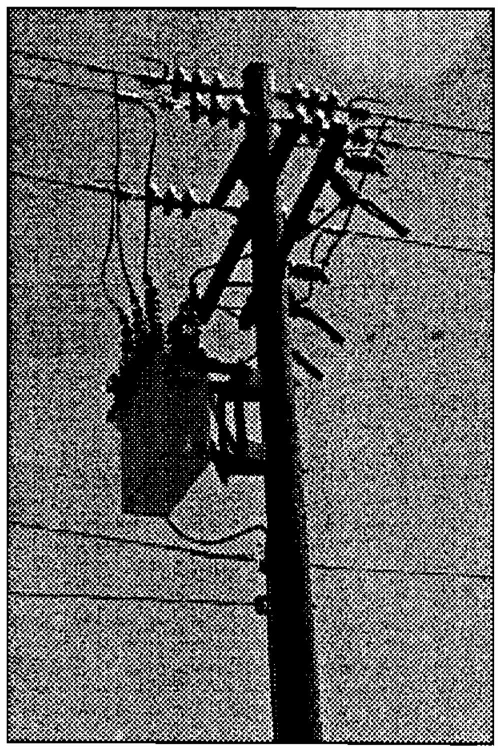
Juncture pole



Metering pole



Riser pole



Reclosure pole

Figure 3-21. Pole types at Altamont Pass WRA.

Table 3.6. Types of injuries sustained from collisions with turbines or wires, on and off site, 1989-1991, Altamont Pass WRA.

INJURY	NON-RAPTORS	PERCENTAGE OF TOTAL	SMALL RAPTORS	PERCENTAGE OF TOTAL	MEDIUM/LARGE RAPTORS	PERCENTAGE OF TOTAL
Body sheared in half or wing, head, feet sheared off	8	34.8%	16	76.2%	40	67.8%
Injury to head or broken neck	8	34.8%	4	19.0%	6	10.2%
Injury to wing or broken wing	5	21.7%	0	0.0%	7	11.8%
Multiple dismemberment	2	8.7%	1	4.8%	2	3.4%
Injury to leg or broken leg	0	0.0%	0	0.0%	3	5.1%
Injury to body	0	0.0%	0	0.0%	1	1.7%
TOTAL	23	100.0%	21	100.0%	59	100.0%

3.2.4 Location of Carcasses

Figure 3-22 illustrates that the carcasses of birds killed by turbines (on and off site) were predominantly found northeast of turbine centers, downwind of the southwest winds that prevail for six months of the year (April to October). Howell and DiDonato (1991) reported that most of their dead raptors were found to the east and secondarily to the northeast of turbines. Our data indicate that, when birds were found northeast of turbines, they were typically at upwind turbines (those that face into the wind); most birds killed at downwind turbines were found southwest of the turbine center.

For turbine-related mortalities, we found carcasses an average of 79 ft from the turbine structure believed to be responsible for the death; 77 percent were within 100 ft of the turbine, while only 4 percent were beyond 200 ft.

3.2.5 Contributing Factors

Our examination of the factors that may contribute to mortality began with an analysis of each potential variable using bivariate statistical techniques. This preliminary investigation indicated which variables were most closely associated with mortality. The variables that were shown to be statistically associated with mortality, or those we thought might have some biological relevance whether they were statistically significant or not, were then used in a multivariate discriminant analysis where these factors were compared (put in competition) with each other to determine which ones had the greatest association with mortality (see Comparison of Variables, page 3-76).

Our analysis of contributing factors was based primarily on a comparison of the turbines where we found dead birds with those where we did not find dead birds. Mortality data used in this analysis consisted of turbine-related deaths that occurred within our sample sites; data from additional end turbines surveyed were excluded. Because some variables were only recorded for turbines that killed raptors or non-raptors (and not for turbines that did not kill), we used data from our plot characterizations whenever necessary, by comparing plots in which we found dead birds to plots in which we did not find dead birds (see Section 2.2.4 Habitat Characterization). Table 3.7 provides a summary of the results presented in the following sections.

<u>End-row Turbines</u> - An end-row turbine was defined as the turbine at either end of a row (see Figure 2-7). End-row turbines were associated with a significantly higher raptor mortality rate (11.2%) than turbines that were not end-row (4.2%) (Table 3.8). In other words, mortality was nearly three times as high at end-row turbines as at non-end-row turbines ($P<0.01$).

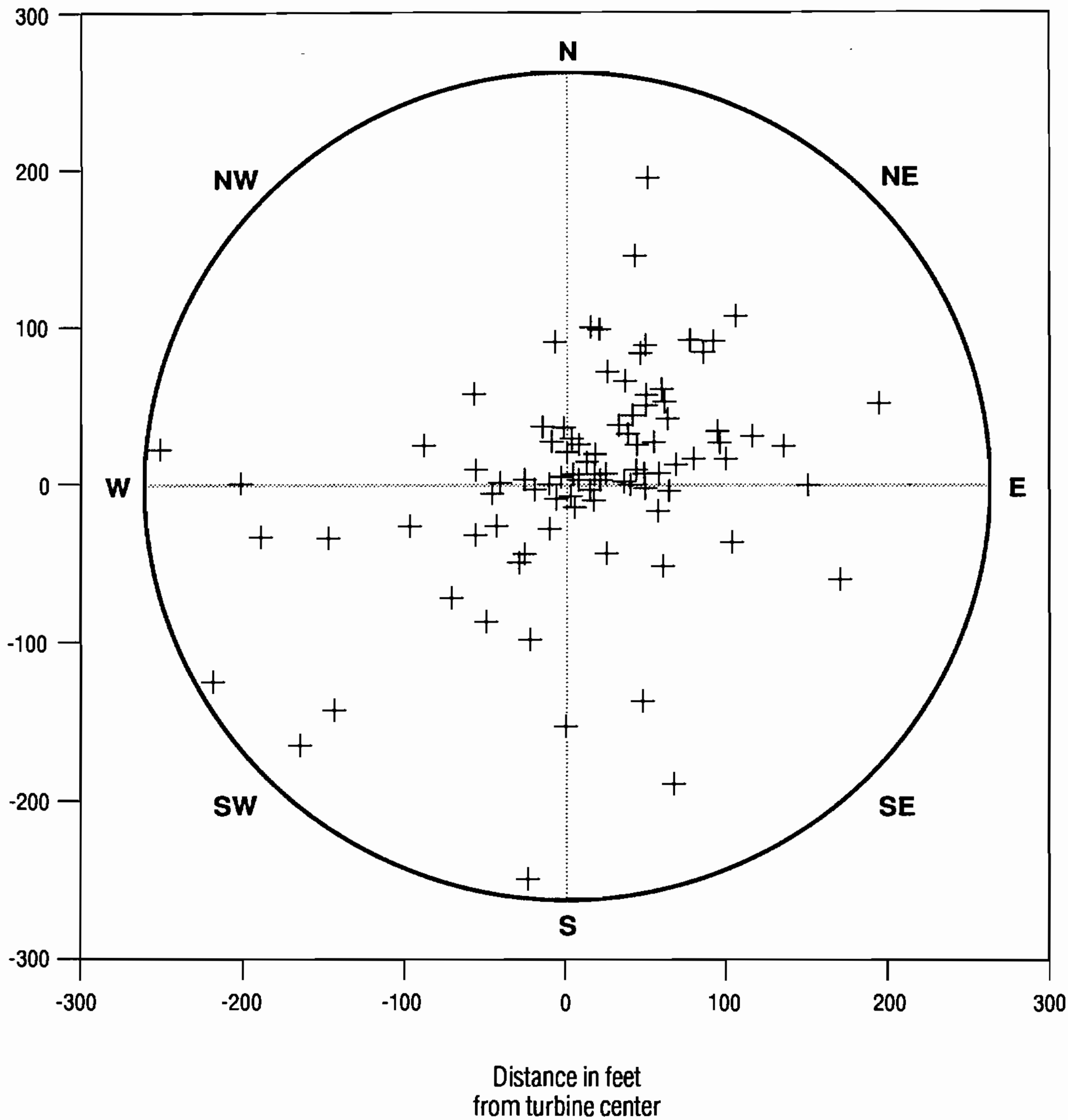


Figure 3-22. Locations of mortalities in relation to turbine centers.

Table 3.7. Summary of statistical tests.

HABITAT AND STRUCTURE VARIABLES	BIVARIATE TEST TYPE	BIVARIATE TEST VALUE	BIVARIATE P-VALUE	MULTIVARIATE DISCRIMINANT ANALYSIS P-VALUE
END ROW				
Raptor	χ^2	12.24	<0.001	<0.001
Non-raptor	χ^2	0.21	0.649	----
CLOSE TO CANYON				
Raptor	χ^2	9.69	0.002	0.002
Non-raptor	χ^2	0.40	0.526	----
FIRST TURBINE ROW				
Raptor	χ^2	2.33	0.127	0.545
Non-raptor	χ^2	1.38	0.239	----
ELEVATION				
Raptor	t-test	-2.78	0.006	0.035
Non-raptor	t-test	1.47	0.142	----
NUMBER OF SLOPES				
Raptor	χ^2	16.0	0.003	0.365
Non-raptor	χ^2	5.72	0.221	----
DEGREE OF SLOPE				
Raptor	χ^2	0.75	0.862	----
Non-raptor	χ^2	6.09	0.107	----
SLOPE ASPECT				
Raptor	χ^2	6.0	0.511	----
Non-raptor	----	----	----	----
LENGTH OF TURBINE ROW				
Raptor	χ^2	1.16	0.561	----
Non-raptor	χ^2	2.78	0.249	----
POSITION ON SLOPE				
Raptor	χ^2	4.30	0.116	0.334
Non-raptor	χ^2	2.44	0.295	----
STRUCTURE DENSITY				
Raptor	t-test	2.79	0.005	0.065
Non-raptor	t-test	1.94	0.053	----
DISTANCE TO CLOSEST TURBINE ROW				
Raptor	t-test	-1.43	0.153	0.683
Non-raptor	t-test	-1.46	0.145	----
GROUND SQUIRREL DENSITY				
Raptor	χ^2	0.100	0.751	----
Non-raptor	----	----	----	----
TURBINE TYPES[1,2]				
Lattice	----	----	----	0.267
Windwall	----	----	----	0.636
Guyed-Pipe	----	----	----	0.682
Tubular	----	----	----	0.818

[1] For raptors only
[2] The fifth turbine type (vertical) was accounted for in the analysis of the other four as an integral part of the program.

Table 3.8. Chi-square analysis of end-row turbines (turbines that killed raptors versus turbines that did not kill raptors)*.

		END-ROW				
		NO		YES		TOTAL
KILLED RAPTORS	NO	844	(95.8%)	127	(88.8%)	971
	YES	37	(4.2%)	16	(11.2%)	53
	TOTAL	881		143		1,024
	$\chi^2 = 12.24$			$P<0.001$		

*Does not include data from extra end-row turbines surveyed on each sample site.

A separate analysis of non-raptor mortality indicated that end-row turbines were not associated with higher non-raptor mortality: 2.1 percent of end turbines killed non-raptors and 1.7 percent of non-end turbines killed non-raptors (Table 3.7). Only 18 non-raptor deaths were used in this analysis, however, so these results should be interpreted with caution.

End-row turbines may be at the end of a row because topographic features, such as a canyon, prohibit the installation of another turbine. Consequently, end-row turbines could be associated with other factors linked to mortality, such as the distance to canyons and first turbine rows (no other turbine rows within 0.5 mi in any one direction). Contrary to our expectations, chi-square tests showed that end-row turbines were not significantly associated with proximity to canyons or first turbine rows. In other words, the proportion of end-row turbines that were close to canyons was similar to the proportion of non-end-row turbines that were close to canyons, and the proportion of end-row turbines that were in first turbine rows was similar to the proportion of non-end-row turbines that were in first turbine rows. Furthermore, canyon proximity was not associated with first turbine rows. The independent and interactive effects of these three variables on mortality are presented below under Proximity to Canyon and First Turbine Rows sections.

Analysis (two-way ANOVAs) of five other habitat and structural variables — elevation, number of slopes, canyon proximity, structure distance, and structure density — showed that end-row turbines were independent of these variables. Because bivariate tests had already shown end turbines to be significantly associated with mortality, this independence meant end-row turbines should also be significant in multivariate discriminant analysis.

Figure 3-23 shows that, of the deaths that occurred within the last five turbines in a row, 59 percent occurred at the end-row turbine. Ninety-four percent of the mortalities occurred within the last three turbines in a row. This assumed that the sampling effort was equal in each of the five turbine positions, which it was.

To assess whether the higher mortality at end turbines was related to more frequent bird use near end turbines, we used a t-test to compare raptor abundance within 200 ft of end turbines with raptor abundance within 200 ft of non-end turbines (200 ft equals the sample plot size). The difference was not statistically significant. This was also true for non-raptors.

Proximity to Canyon - A canyon was defined as a narrow valley with relatively steep sides, such as a drainage, ravine, or draw, that provides updrafts or corridors for bird movements. Turbines close to canyons (within 500 ft) were associated with significantly higher raptor mortality (8.5%) than turbines farther away from canyons (3.8%) (Table 3.9). Therefore, mortality was more than twice as high at turbines that were close to canyons as at other turbines ($P<0.01$).

Table 3.9. Chi-square analysis of proximity to canyons (turbines that killed raptors versus turbines that did not kill raptors).

		CLOSE TO CANYON		
		NO	YES	TOTAL
KILLED RAPTORS	NO	690 (96.2%)	281 (91.5%)	971
	YES	27 (3.8%)	26 (8.5%)	53
	TOTAL	717	307	1,024
	$\chi^2 = 9.69$		$P<0.002$	

Separate analysis for non-raptors indicated that turbines close to canyons were not associated with higher non-raptor mortality (Table 3.7). Two percent of turbines close to canyons killed non-raptors and 1.3 percent of turbines that were not close to canyons killed non-raptors. Again, only 18 non-raptors deaths were used in this analysis, so these results should be interpreted with caution.

An analysis that isolated mortality rates at turbines close to canyons from mortality rates at end turbines and then combined them revealed that, when a turbine was both close to a canyon and was an end turbine, the effect on mortality was multiplicative (more than additive) (Table 3.10). When a turbine was neither close to a canyon nor an end turbine, the mortality rate was 3.2 percent. If only one of these characteristics was present, the mortality rates were similar: close-to-canyon mortality was 6.4 percent and end turbine mortality was 7 percent. When a turbine had both characteristics, the mortality rate was 20.9 percent, a synergistic result. Also, these data indicate that, when a turbine is close to a canyon, mortality increases whether a turbine is an end-row or not.

Table 3.10. Percentage of turbines that killed raptors by proximity to canyon and end-row.

		END-ROW		
		NO	YES	TOTAL
CLOSE TO CANYON	NO	20/617 (3.2%)	7/100 (7.0%)	27/717 (3.8%)
	YES	17/264 (6.4%)	9/43 (20.9%)	26/307 (8.5%)
	TOTAL	37/881 (4.2%)	16/143 (11.2%)	53/1,024 (5.2%)

First Turbine Rows - First turbine rows are defined as rows where there are no other rows within 0.5 mi in any one direction. Turbines that were first in an area did not have a significantly higher raptor mortality (6.5%) than turbines that were not first in an area (4.4%, Table 3.11).

Separate analysis for non-raptors indicated that turbines that were first in an area did not appear to be associated with higher non-raptor mortality; 2.5 percent of first-in-area turbines killed non-raptors and 1.4 percent of turbines that were not first in an area killed non-raptors (Table 3.7).

An analysis that isolated the mortality rate of first turbine rows from rates of end-row and close-to-canyon turbines showed that first turbine rows had little association with mortality, but that the association with mortality of being end-row and close to a canyon was still present (Table 3.12). The decrease in mortality when the attribute of first turbine row was added to attributes of both end-row and close to canyon may be due to small sample sizes.

Elevation - Our analyses (t-test) showed that the elevation at which a turbine was located was significantly associated with raptor mortality ($P<0.01$); turbines that killed raptors were at an average elevation of 871 ft (± 415 SD, $N=53$), while turbines that did not kill raptors were at an average elevation of 714 ft (± 399 SD, $N=971$). Despite the *statistical* significance of this variable in raptor mortality, we question whether it is biologically meaningful for three reasons. First, the mean difference in elevation between turbines

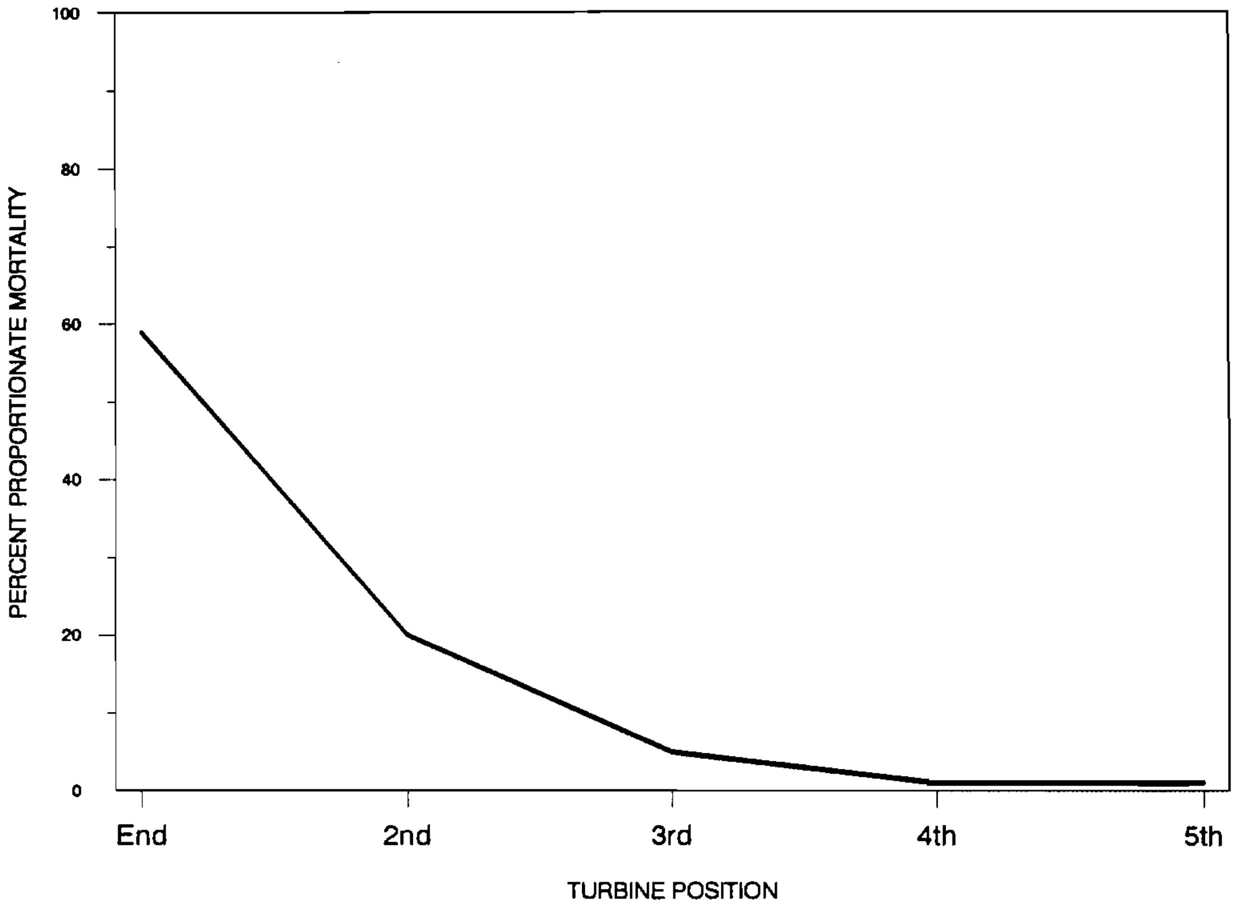


Figure 3-23. Percent proportionate raptor mortality at the last five turbines in a row.

Table 3.11. Chi-square analysis of first turbine rows (turbines that killed raptors versus turbines that did not kill raptors).

		FIRST TURBINE ROW		
		NO	YES	TOTAL
KILLED RAPTORS	NO	614 (95.64%)	357 (93.5%)	971
	YES	28 (4.4%)	25 (6.54%)	53
	TOTAL	642	382	1,024
	$\chi^2 = 2.33$		$P<0.127$	

Table 3.12. Percentage of turbines that killed raptors by first turbine row, proximity to canyon, and end-row.

		FIRST TURBINE ROW				
		NO		YES		
		NOT END	END	NOT END	END	TOTAL
CLOSE TO CANYON	NO	10/394 (2.5%)	4/62 (6.5%)	10/223 (4.5%)	3/38 (7.9%)	27/717 (3.8%)
	YES	8/161 (5.0%)	6/25 (24.0%)	9/103 (8.7%)	3/18 (16.7%)	26/307 (8.5%)
	TOTAL	18/555 (3.2%)	10/87 (11.5%)	19/326 (5.8%)	6/56 (10.7%)	53/1,024 (5.1%)

that killed and turbines that did not was only 157 ft. Second, the distribution of elevations between turbines that killed and did not kill was similar (Figure 3-24). Third, elevation was associated with two variables that were themselves related to mortality (proximity to canyon and number of steep slopes). In other words, the feature within each of these two variables that was associated with higher mortality was also correlated with higher elevation; for example, elevation was highest at mortality sites that were close to canyons (Table 3.13).

Table 3.13. Mean elevation (ft) of turbines that killed raptors by canyon proximity (sample sizes in parentheses).

		CLOSE TO CANYON		
		NO	YES	TOTAL
KILLED RAPTORS	NO	662 (690)	841 (281)	714 (971)
	YES	726 (27)	1,021 (26)	871 (53)
	TOTAL	665 (717)	856 (307)	722.19 (1,024)

Higher mortality at turbines located at higher elevations, whether biologically meaningful or not, is probably not the result of higher raptor abundance at these sites. A t-test showed that relative abundance of raptors was not significantly higher at high-elevation sample sites (> 800 ft, 1.13 birds per scan) than at lower elevations (< 800 ft, 1.05 birds per scan).

A separate analysis for non-raptors indicated that average elevation was not significantly different at turbines that killed non-raptors than at turbines that did not kill non-raptors (Table 3.7). Additional analysis (ANOVA) showed a significant difference in the mean elevations of turbines that killed raptors, turbines that killed non-raptors, and turbines that did not kill any birds ($P=0.01$). Raptors were killed more frequently at higher elevations, whereas non-raptors were killed more often at lower elevations. The average elevation of turbines that killed raptors was 864 ft (± 416 SD, $N=52$); turbines that killed non-raptors were at 584 ft (± 384 SD, $N=18$), and turbines that did not kill any birds were at 717 ft (± 400 SD, $N=953$) (this average elevation is different from that reported above because we eliminated data from one turbine that killed both raptors and non-raptors).

Number of Steep-sided Slopes - A steep-sided slope was defined as a slope of more than 20 degrees. The number of slopes we recorded varied between 0 and 4. An analysis showed that raptor mortality was highest (8.7%) at sites with two steep-sided slopes (Table 3.14, $P<0.01$). There were no significant differences in number of steep-sided slopes associated with non-raptor mortalities (Table 3.7).

Degree of Slope - This variable was defined as the slope of the steepest hill within 500 ft of a sample plot, using four slope categories (see Appendix C). This variable did not differ significantly in plots containing turbines that killed raptors and plots containing turbines that did not kill raptors (Table 3.7). Degree of slope also had no effect on non-

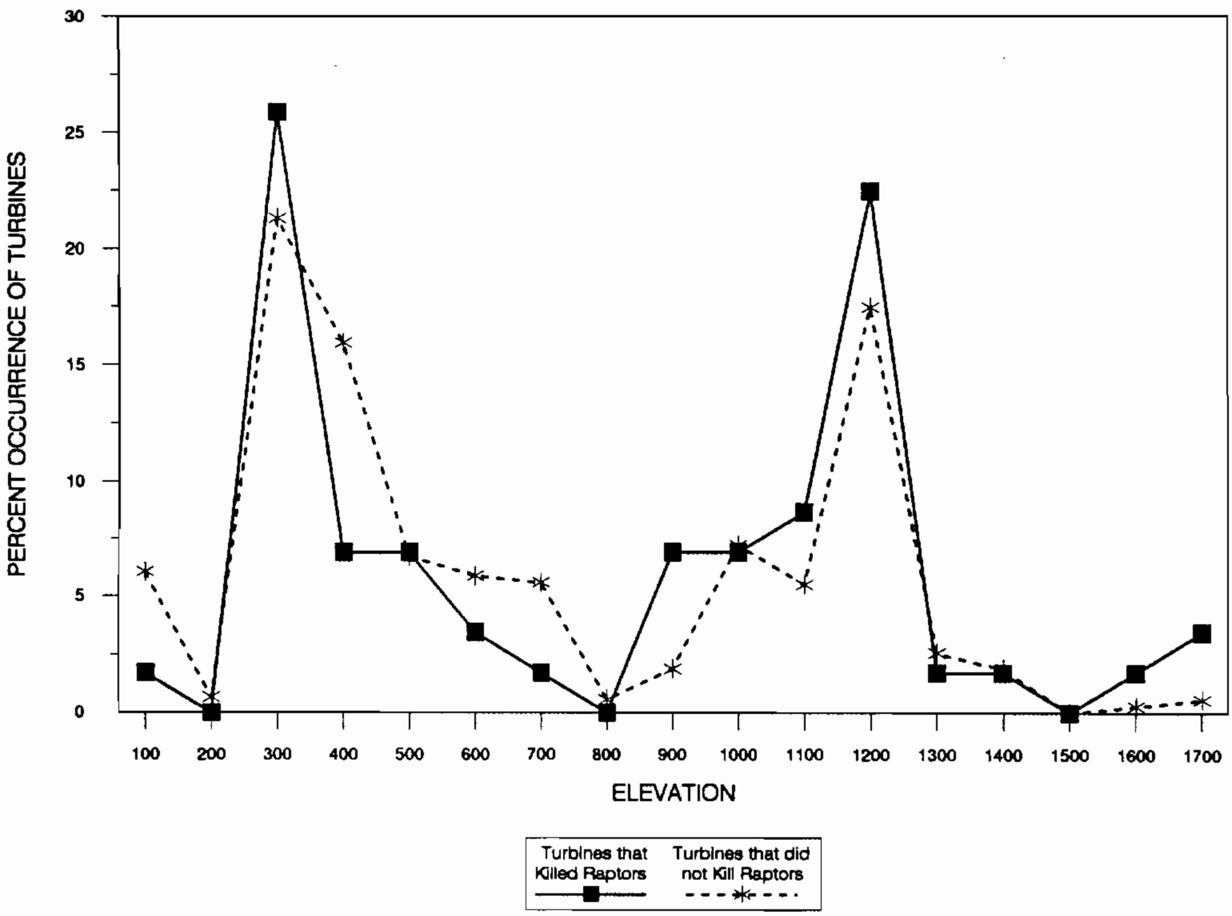


Figure 3-24. Comparison of the percentage of turbines that killed raptors to the percentage that did not kill raptors at different elevations.

Table 3.14. Chi-square analysis of number of steep slopes.

		NUMBER OF SLOPES					
		0	1	2	3	4	TOTAL
KILLED RAPTORS	NO	211 (96.3%)	206 (97.6%)	313 (91.3%)	192 (95.0%)	49 (100.0%)	971
	YES	8 (3.7%)	5 (2.4%)	30 (8.7%)	10 (5.0%)	0 (0.0%)	53
	TOTAL	219	211	343	202	49	1,029
			$\chi^2 = 16$		$P<0.003$		

raptor mortality. However, a chi-square test showed that raptors were killed on steeper slopes than non-raptors (P=0.02). These data were taken from our sample plot characterizations because we recorded this variable for sample plots but not for specific turbines.

Slope Aspect - Slope aspect was defined as the dominant aspect of the slope on which the turbine was located, using the eight major compass points. The majority of all slope aspects were in three directions: northeast (44%), northwest (29%), and southeast (15%). The percentage of turbines that killed raptors varied little among these directions: northeast (4.7%), northwest (4.9%), and southeast (6.7%)(Table 3.7). This was also true for non-raptors.

Length of Turbine Row - This variable was defined as the length of the turbine row in which a dead bird was found (short = <7 turbines, medium = <20 turbines, long = >20 turbines). No significant differences were shown between plots containing turbines that killed raptors and plots that did not contain turbines that killed raptors (Table 3.7). Row length also had no effect on non-raptor mortality. Data were taken from our plot characterizations.

Position of Turbine on Slope - The position of a turbine on a slope was classified as either top, middle, or bottom. This variable was not significantly related to raptor or non-raptor mortality. The raptor mortality rate was 3.5 percent for turbines positioned at the bottom, 7.0 percent for those in the middle, and 4.5 percent for those at the top (Table 3.15). For non-raptors, the mortality rates were 2.7 percent at the bottom, 1.0 percent at the middle, and 1.8 percent at the top (Table 3.7). However, there is some indication of differences between raptor and non-raptor mortality rates. The highest raptor mortality rate was associated with turbines on the middle of slopes, whereas the lowest non-raptor mortality occurred at turbines on the middle of slopes (Figure 3-25).

Table 3.15. Chi-square analysis of turbine position on slope (turbines that killed raptors versus turbines that did not kill raptors).

		POSITION ON SLOPE			
		BOTTOM	**MIDDLE**	**TOP**	**TOTAL**
KILLED RAPTORS	**NO**	246 (96.5%)	361 (93.0%)	364 (95.5%)	971
	YES	9 (3.5%)	27 (7.0%)	17 (4.5%)	53
	TOTAL	255	388	381	1,024
		$\chi^2 = 4.3$		P=0.116	

Analysis of variance showed that turbine slope position was significantly related to five other variables: elevation, number of slopes, proximity to canyon, distance to closest turbine row, and structure density ($P<0.01$). In other words, the means of each of these five variables varied significantly with the position of a turbine on the slope. For instance, mean structure density was lower at the top of a hill than at the bottom or middle.

Orientation of Structure Rows - We defined rows as perpendicular if any one row within 500 ft of a sample turbine was not parallel to the other turbines in the area, otherwise they were defined as parallel. The orientation of rows did not appear to be related to mortality.

Structure Density - Structure density refers to the number of structure rows (turbine or transmission line) within 500 ft of a turbine (including the row in which the turbine is situated) and ranged from 1 to 6. Analysis (t-test) indicated that turbines with lower structure density had significantly higher mortality rates than those with higher density ($P<0.01$). The mean structure density for turbines that killed raptors was lower (2.1 ± 1.1 SD, N=53) than for those that did not kill raptors (2.6 ± 1.2 SD, N=971). Of the

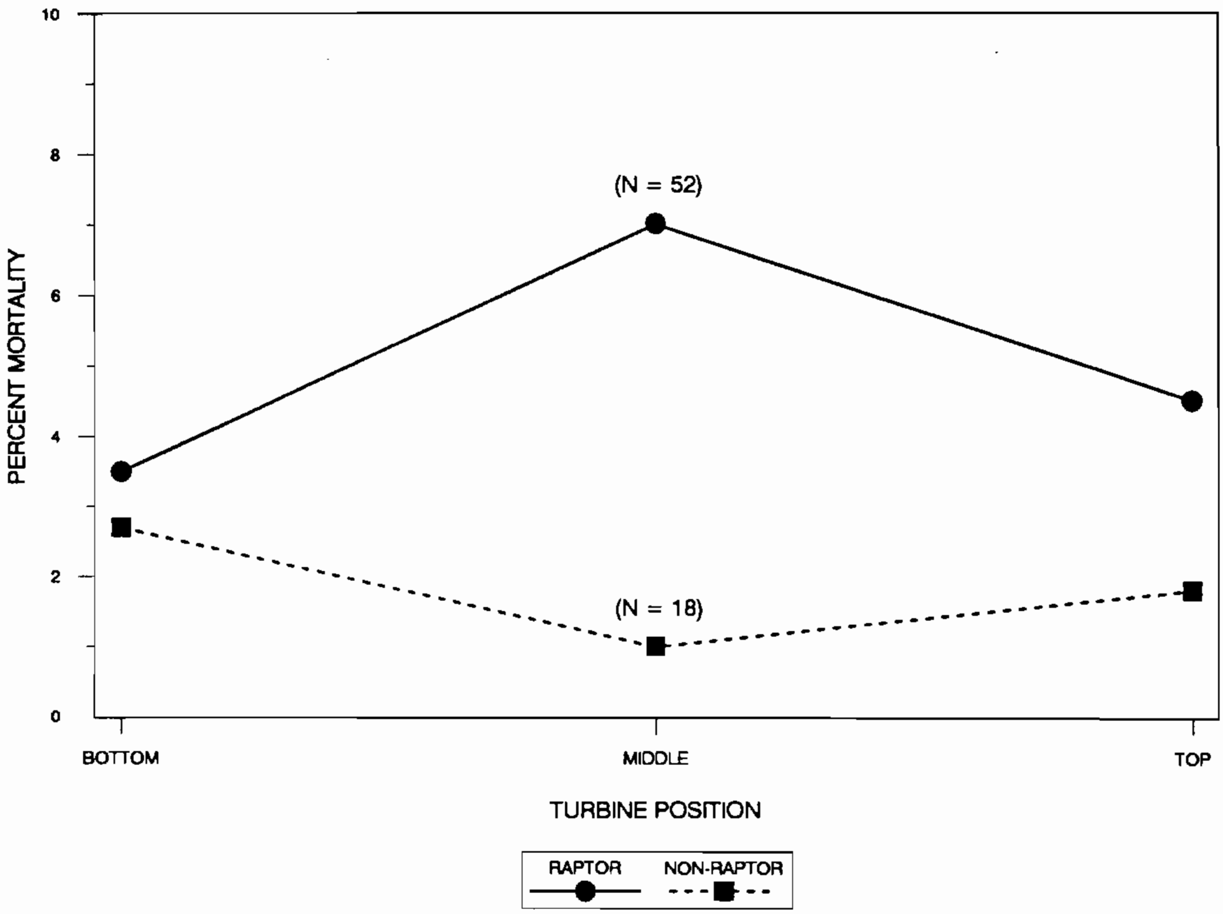


Figure 3-25. Comparison of position of turbine on slope for raptor and non-raptor mortalities.

turbines that were classified as having low density (density levels 1 and 2), the mortality rate was 7.0 percent, whereas only 2.9 percent of the turbines at higher densities (density levels 3-6) killed raptors (Table 3.16).

Table 3.16. Chi-square analysis of structure density (turbines that killed raptors versus turbines that did not kill).

		STRUCTURE DENSITY						
		1	**2**	**3**	**4**	**5**	**6**	**TOTAL**
KILLED RAPTORS	NO	197 (91.6%)	338 (93.9%)	187 (97.4%)	197 (97.0%)	44 (96.0%)	8 (100.0%)	971
	YES	18 (8.4%)	22 (6.1%)	5 (2.6%)	6 (3.0%)	2 (4.0%)	0 (0.0%)	53
	TOTAL	215	360	192	203	46	8	1,024

A t-test indicated that structure density at turbines that killed non-raptors (2.0 ± 0.8 SD, N=18) was lower than that at turbines that did not kill non-raptors (2.6 ± 1.2 SD, N=1005, P=0.05).

Distance to Closest Turbine Row - Distance to next closest turbine row was defined as the minimum distance from a sample turbine to the next row of turbines. There was no significant difference (t-test) between the mean distance to the next closest turbine row for turbines that killed raptors (657 ft ± 271 SD, N=53) and those that did not kill raptors (599 ft ± 288 SD, N=971). As expected, distance to the next closest turbine row was negatively correlated (r=-0.63) with structure density; the shorter the distance to the next row, the higher the structure density.

We found some indication that this variable still may be related to raptor mortality (Figure 3-26). Fewer turbines that killed raptors were within 300-400 ft of the next closest turbine row than turbines that did not kill raptors. More turbines that killed raptors were roughly 600 ft from the next turbine row than turbines that did not kill raptors. Beyond 600 ft, the distance to the next closest turbine row did not seem to differ significantly between turbines that killed and those that did not.

Distance to closest turbine row was not significantly associated with non-raptor mortality (Table 3.7); turbines that killed non-raptors were an average of 700 ft (± 305 SD, N=18) from the next closest row, whereas turbines that did not kill non-raptors were 601 ft (± 287 SD, N=1005) from the next closest row.

Distance to Other Habitat Features - Our analyses detected no relationship between mortality at turbines and distance to other topographic features such as water, valleys, or trees. We used information on topographic features from our plot characterizations to make these analyses.

Ground Squirrel Density - Ground squirrel abundance was recorded as abundant, common, scattered, few, or none. Data were re-categorized into high abundance (abundant and common) and low abundance (scattered, few, and none). No clear trends emerged from our analysis of the effect of ground squirrel density on raptor mortality. Ground squirrel abundance did not differ significantly in plots containing turbines that killed raptors and plots that did not kill raptors (Table 3.17). Plots with low ground squirrel density had a mortality rate of 16.9 percent, whereas plots with high ground squirrel density had a mortality rate of 15.2 percent. Since the occurrence of ground squirrels was not recorded for all turbines sampled, we used ground squirrel abundance data from plot characterizations. Only deaths of raptors that typically hunt ground squirrels were included in this analysis.

Table 3.17. Chi-square test of ground squirrel abundance (plots in which raptors were killed versus plots in which raptors were not killed).

		GROUND SQUIRREL ABUNDANCE		TOTAL
		LOW	HIGH	
KILLED RAPTORS	NO	118 (83.1%)	56 (84.8%)	174
	YES	24 (16.9%)	10 (15.2%)	34
	TOTAL	142	66	208
		χ^2 = .1009	P=0.751	

Comparison of Variables - Discriminant Analysis - Of the habitat and structure variables we thought might be biologically relevant to mortality, discriminant analysis showed that three variables were significantly associated with raptor mortality (Table 3.7): end-row, proximity to canyon, and elevation. Structure density was close to being statistically significant. Turbine types were used in this analysis as variables (Figure 2-3). Although three-blade lattice turbine type (lattice) did not emerge as an important variable in discriminant analysis when we used all turbine types as separate variables, it was probably being diluted by the other turbine types. Lattice was significant when other turbine types were excluded as separate variables, and mortality rates at lattice turbines were compared to mortality rates at non-lattice turbines (see Section 3.2.6 Turbine Type Differences in Mortality). Factors that were not significantly associated with mortality in

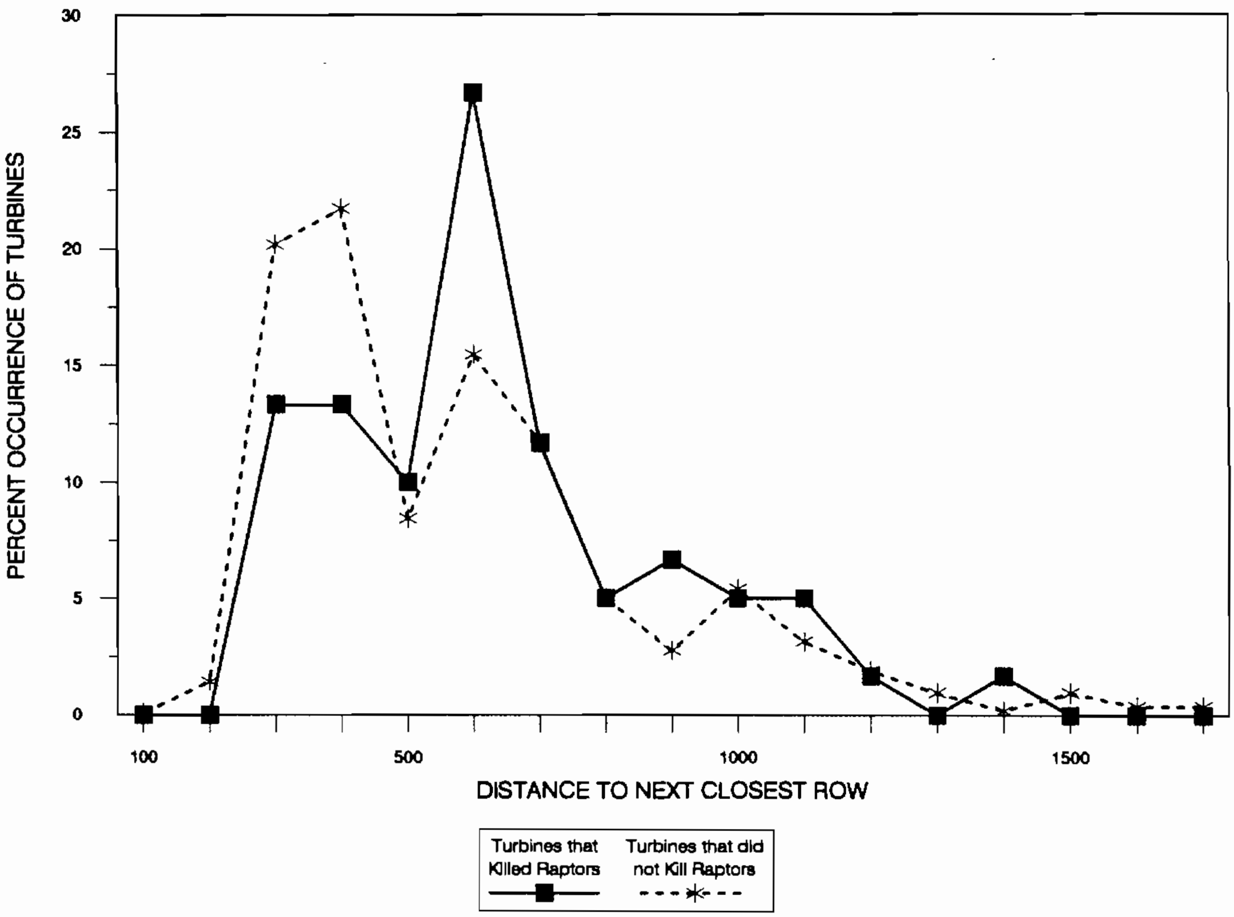


Figure 3-26. Comparison of the percentage of turbines that killed raptors to the percentage of turbines that did not kill raptors at different distances to next closest turbine row.

this analysis included: first turbine rows, number of slopes, position of turbine on slope, distance to closest turbine row, and the other four turbine types.

All variables used in combination in this analysis correctly classified 68 percent of the turbines that killed raptors and 64 percent that did not kill raptors (Table 3.18). Although discriminant analysis is predictive in a statistical sense (i.e., its predictive power is better than flipping a coin), it is not predictive in a practical sense due to excessive false negatives and false positives. For example, as can be seen in Table 3.18, 353 of the 389 turbines that the analysis predicted would kill raptors did not.

Table 3.18. Classification matrix of discriminant analysis model predictions that were correct, based on all variables, for turbines that killed raptors and turbines that did not kill raptors.

KNOWN GROUP	PERCENT CORRECT	PREDICTED GROUP NON-KILL	KILL
Turbines that did not kill raptors (971)	63.65	618	353
Turbines that killed raptors (53)	67.92	17	36
TOTAL (1,024)	63.87	635	389

The reason that some factors were not significant in the multivariate discriminant analysis but were significant in bivariate tests is that, in discriminant analysis all variables are in competition with each other and some of the less important variables get non-significant results. For example, under certain circumstances if two variables are associated with mortality but are also highly correlated with each other, then the one that shows the most association with mortality will out-compete the other and will show significance while the other will not. Correlations between variables are presented in Appendix Table B.5. In addition, multivariate analysis is based on a comparison of means, whereas some bivariate tests (chi-square) are based on differences in the distributions (frequencies) of data. Bivariate tests may show significant differences not apparent in a comparisons of means.

3.2.6 Turbine Type Differences in Mortality

3.2.6.1 Five Basic Turbine Types

The three-blade lattice turbine type (lattice) was associated with a higher mortality rate (7.2%) than all other turbine types combined (3.4%, $P<0.01$). Table 3.19 shows a comparison of mortality rates by turbine type (lattice versus non-lattice) with the two variables that also had the highest association with mortality rates (end-rows and proximity to canyons). Analysis of mortality rates shows that all three variables (lattice turbines, end-rows, and proximity to canyons) act independently of each other and interact synergistically when two or more are present. Table 3.19 shows the change in mortality that occurs when any of the three variables is held constant. Overall, the lowest mortality (2.3%) occurs when the turbines are non-lattice, not an end-row, and not close to a canyon. The highest mortality (31.3%) occurs when all three are present.

Table 3.19. Percentage of raptor mortality of lattice versus non-lattice turbines by proximity to canyon and end-row.

		NON-LATTICE END ROW		LATTICE END ROW		
		NO	**YES**	**NO**	**YES**	**TOTAL**
CLOSE TO CANYON	**NO**	7/308 (2.3%)	2/65 (3.1%)	13/309 (4.2%)	5/35 (14.3%)	27/717 (3.8%)
	YES	6/151 (4.0%)	4/27 (14.8%)	11/113 (9.7%)	5/16 (31.3%)	26/307 (8.5%)
	TOTAL	13/459 (2.8%)	6/92 (6.5%)	24/422 (5.7%)	10/51 (19.6%)	53/1,024 (5.2%)

The mortality rate at non-lattice turbines increases 12.5 percent (from 2.3% to 14.8%) when a turbine is both an end-row and close to a canyon (Table 3.19). When both end-row and close to canyon variables are present at lattice turbines, mortality increases 27 percent (from 4.2% to 31.25%). In other words, the variables of end-row and proximity to canyon are more strongly associated with mortality at lattice turbines than at non-lattice turbines.

Comparisons of the mortality associated with different turbine types are complicated by several factors. First, the proportion of important habitat and structural variables (e.g., end turbines and proximity to canyons) differs for each turbine type. Second, our analysis of habitat variables indicates that turbine types are not randomly distributed with respect to habitat characteristics within the WRA (this is discussed more fully in Section 3.3 Habitat Characterization). Some turbine types are more commonly associated with certain topographic features, so the association of topography with mortality could confound the effect of turbine type on mortality. Third, relative abundance of raptors, frequency of perching on turbines, scavenging rates, and percentage of time turbines were in operation can differ among turbines types. We address these points below.

Multivariate discriminant analysis accounts for the different contribution of each variable to mortality within turbine types. Also, the matrix table (Table 3.19) we used to compare lattice to non-lattice turbines isolated the effects of the two variables most associated with mortality: end-row and proximity to canyon. Moreover, except for structure density, the proportion or occurrence of all variables associated with mortality would have suggested lower mortality rates at lattice turbines than at other turbine types. For example, the proportion of end-row turbines within the lattice type was similar to or less than the proportion within other turbine types, and proportionally fewer lattice turbines were located near canyons than were other turbine types, except for guyed-pipe. The values of other variables at lattice turbines, such as elevation, number of steep slopes, and position of turbines on slopes, also suggest that lattice turbines would have a lower mortality rate than other turbine types.

Although habitat features are not randomly distributed among the turbine types, our analysis of habitat characteristics indicates that our sample sites adequately represent the study area (see Section 3.3 Habitat Characterization). Therefore, we believe that lattice and other turbine types are fairly represented in our samples with respect to habitat features.

Relative abundance of raptors was not significantly different among the turbine types and, thus, should not be a factor in mortality at the different turbine types. An analysis of variance showed that frequency of perching was significantly different ($P<0.01$) among turbine types, but perching on lattice turbines was intermediate among the five types. Scavenging rates were higher at lattice types, which means we may have found fewer dead birds at lattice turbines than were actually killed. As a result, mortality at lattice turbines may have been higher than we estimated.

However, high mortality at lattice turbine types may be partly attributed to the low structure density of this turbine type. Low structure density was significantly associated with mortality. The average structure density was lower at lattice turbine types (2.04) than at any other turbine types (2.76 - 3.39), except for windwalls (1.47). The structure density of windwalls could be considered actually higher than we recorded because windwalls consist of two lattice turbine rows back to back, which we counted only as one row. Structure density and mortality were significantly associated at all turbine types, except windwalls ($P=0.05$). Mortality was highest at turbine types with low structure density and lowest at turbine types with high structure density.

Mortality at lattice turbines also may be higher because these turbines may be in operation more than other turbines types, increasing the likelihood that they would kill birds. Information on frequency of operation was not available (see Section 4.1.5 Turbine Types and Power Poles).

3.2.6.2 Painted Blade Tips

We compared raptor mortality at tubular turbines with painted blade tips (some turbines green, some red) to mortality at tubular turbines without painted tips. Red-tailed hawks and golden eagles were killed at both red- and green-painted turbines, and we found no indication that color made a difference. The number of mortalities per turbine at non-painted turbines was similar to that at painted turbines, but the numbers were too small to test statistically.

3.2.6.3 Windwall Matched-Pair Tests

The mortality at windwall experimental plots was similar to that on three-blade lattice control plots (no non-raptors were found dead on these plots). Again, the numbers were too small to test statistically.

3.2.7 Tests for Survey Biases

3.2.7.1 Scavenger Removal

Tests designed to determine the rate of removal of carcasses by scavengers revealed that in each season non-raptor carcasses were taken more frequently than those of raptor, and small raptors (American kestrels) were taken more frequently than medium to large raptors (hawks and eagles). Scavenging rates for small raptors were consistently high for all seasons, but for medium to large raptors rates were fairly low except in the fall (Table 3.20). No eagle carcass was ever removed from any site. Although we conducted mortality surveys every second or third day in the spring and every seven days in the five remaining seasons, results are comparable among seasons because we used scavenger correction factors for the appropriate survey intervals to estimate the effect of scavenging for that season.

Track plates set during spring scavenging tests revealed that coyotes and red foxes (*Vulpes vulpes*) were the primary scavengers. We saw common ravens eating several test carcasses, and there was evidence that ground squirrels were taking some of the smaller birds.

We found evidence of scavenging at actual kills, not related to our tests, in 92 percent of American kestrel and 46 percent of medium to large raptor carcasses. Of non-raptorial bird carcasses, 53 percent had been scavenged. This supports our scavenging test results that showed smaller bird carcasses, such as American kestrels and passerines, were taken or scavenged more often than larger birds, especially larger raptors.

Table 3.20. Scavenger removal and observer success rates by season, 1989-1991, Altamont Pass WRA.

		FIRST YEAR			SECOND YEAR		
		SPRING	FALL	WINTER	SUMMER	FALL[1]	WINTER[1]
Cumulative Scavenger Removal (Percentage Removed)[2]							
Day 2[3]	Large raptors	0%	--	--	--	--	--
	Medium raptors	0%	--	--	--	--	--
	Small raptors	14%	--	--	--	--	--
Day 3	Large raptors	0%	--	--	--	--	--
	Medium raptors	0%	--	--	--	--	--
	Small raptors	29%	--	--	--	--	--
Day 7	Large raptors	0%	0%	0%	0%	0%	0%
	Medium raptors	0%	36%	13%	17%	50%	50%
	Small raptors	43%	50%	56%	50%	50%	50%
Scavenger Correction Factor (SCF)[4]							
Day 2	Large raptors	1.0	--	--	--	--	--
	Medium raptors	1.0	--	--	--	--	--
	Small raptors	0.86	--	--	--	--	--
Day 3	Large raptors	1.0	--	--	--	--	--
	Medium raptors	1.0	--	--	--	--	--
	Small raptors	0.71	--	--	--	--	--
Day 7	Large raptors	1.0	1.0	1.0	1.0	1.0	1.0
	Medium raptors	1.0	0.64	0.87	0.83	0.50	0.50
	Small raptors	0.57	0.50	0.44	0.50	0.50	0.50
Observer Success (Percentage Found)[5]							
	Large birds	100%	100%	100%	100%	100%	100%
	Medium birds	72%	100%	70%	73%	79%	79%
	Small birds	100%	100%	50%	50%	75%	75%
Observer Correction Factor (OCF)							
	Large birds	1.0	1.0	1.0	1.0	1.0	1.0
	Medium birds	0.72	1.0	0.7	0.73	0.79	0.79
	Small birds	1.0	1.0	0.5	0.5	0.75	0.75

1 Only one scavenger survey was conducted between the fall and winter seasons.
2 Only data on raptor carcasses were used to calculate scavenging rates but data on all bird carcasses were used to calculate observer success rates.
3 Spring mortality surveys were conducted every two to three days whereas the following five seasons searches were conducted every seven days. Consequently, spring scavenger surveys were conducted for seven consecutive days and therefore include days 2 and 3.
4 Cumulative proportion of bird carcasses not removed by scavengers. For example, by day 7 in the fall, scavenging had removed 36% of medium to large bird carcasses with 64% remaining. Therefore, the SCF for medium raptors in the fall after seven days of scavenger removal was 0.64.
5 Proportion of bird carcasses found by observers averaged over all observers.

Appendix Figures B-4 to B-7 depict scavenging test results for the first four seasons.

3.2.7.2 Observer Success

Observers located 100 percent of the large carcasses ($N=8$), 75 percent of medium carcasses ($N=47$), and 69 percent of small carcasses ($N=13$) in our tests. Success varied between 50 percent and 100 percent in each season (Table 3.20). Although our test results showed that observers located medium raptors only slightly more readily than small raptors, the ability of observers to detect the remains of small and medium birds killed by wind turbines may differ from their ability to detect those two size classes of test carcasses. Almost all American kestrel remains discovered in the field consisted of only one wing and a few feathers, making them harder to detect than the small-bird test carcasses, which were whole. In contrast, we discovered the fresh remains of medium raptors more readily than test carcasses, because damage to body and feathers from collisions made these birds more obvious than our test carcasses. Because of these differences in detectability, corrections to our mortality estimates for observer error may not necessarily increase the accuracy of the estimate.

In addition, observer acuity was based on only one visual check for test carcasses in an area. In the actual surveys, however, we checked the same area several times on a weekly basis. Consequently, unlike the acuity test, we had several opportunities to find a dead bird, as long as scavengers did not remove it.

The extent of vegetative cover in search areas is an important factor in an observer's ability to locate bird carcasses. Plant cover was greatest the first season (spring 1989) but declined steadily throughout the study; vegetative cover was extremely sparse the last two seasons (fall 1990 and winter 1991).

3.2.8 Estimating Mortality

3.2.8.1 Seasonal and Yearly Mortality

We derived seasonal differences in mortality using on-site data on "fresh" carcasses found within survey periods. We could not accurately determine the time of death for old carcasses, so these data were not used (Table 3.21). Only data on dead birds found within our sample plots and along transmission wires were used in this extrapolation; mortalities from the extra end-row turbines surveyed were excluded from the data set. Table 3.21 shows the number of fresh carcasses found within our sample sites and the estimated mortality and correction factors for each season. Although the number of medium and large raptor carcasses found increased slightly in the fall and winter months for both years, the number of carcasses was small and the differences between them relatively minor. The number of American kestrel carcasses increased markedly in the fall and winter of the first year, but this trend did not continue in the second year. In

Table 3.21. Seasonal differences in raptor mortality, 1989-1991, Altamont Pass WRA.

	FIRST YEAR			SECOND YEAR		
	SPRING	FALL	WINTER	SUMMER	FALL	WINTER
Number of On-site Fresh Carcasses						
Large raptors	1	2	1	0	0	0
Medium raptors	1	2	3	0	1	1
Small raptors	0	2	4	1	0	0
Corrected for Sample Size[1]						
Large raptors	2	--	--	--	--	--
Medium raptors	2	--	--	--	--	--
Small raptors	0	--	--	--	--	--
Average Days Between Samples	2.5	7	7	7	7	7
Scavenger Correction Factor (SCF)[2]						
Large raptors	1.00	1.00	1.00	1.00	1.00	1.00
Medium raptors	1.00	0.64	0.87	0.83	0.50	0.50
Small raptors	0.79	0.50	0.44	0.50	0.50	0.50
Observer Correction Factor (OCF)						
Large birds	1.00	1.00	1.00	1.00	1.00	1.00
Medium birds	0.72	1.00	0.70	0.73	0.79	0.79
Small birds	1.00	1.00	0.50	0.50	0.75	0.75
Estimated Mortality[3]						
Large raptors	1.00	2.00	1.00	0.00	0.00	0.00
Medium raptors	1.40	3.10	4.90	0.00	2.50	2.50
Small raptors	0.00	4.00	18.20	4.00	0.00	0.00
Total	2.40	9.10	24.10	4.00	2.50	2.50

1 The number of mortalities in spring was extrapolated to equal the larger sample size in the following seasons.
2 Based on the average number of days between searches and the corresponding scavenger removal for that size class of bird as shown in Table 3.20. If the average number of days between surveys was not a whole number (i.e., in-between days), the SCF was averaged over that period.
3 Calculated from the formula, $EM = (C \div OCF) \div SCF$.

fact, mortality varied more by year than by season. Sixteen fresh raptor carcasses were discovered during the first year of the study, compared to only three raptors the second year. Seasonal mortality did not appear to be related to the seasonal abundance of birds; all raptors were more abundant in the fall than during the three other seasons, yet mortality rates did not reflect this.

In addition, our observation data indicated that during the summer immature golden eagles out-numbered adults, and the ratio of adult to immature red-tailed hawks was lower than in other seasons. The increase in the number of immature birds observed in the summer, however, did not seem to affect the mortality rate in the summer.

The CEC's preliminary study (CEC 1989) reported higher mortality in Altamont Pass during the winter, but this may be an artifact of site-wide turbine maintenance conducted by U.S. Windpower in the winter. To perform these maintenance functions, windsmiths climb every U.S. Windpower turbine in the study area (U.S. Windpower operates over 40 percent of the turbines in the WRA); since windsmiths making repairs have an excellent view of the area surrounding each turbine, more dead birds may be discovered at this time of year. Indeed, most of the mortalities reported by CEC were from U.S. Windpower records.

Another mortality study of U.S Windpower's turbines in the Altamont Pass WRA (Howell and DiDonato 1991) also indicated little seasonal variation in raptor mortality.

3.2.8.2 Annual Site-wide Mortality

The extrapolated estimates of annual mortality for the first and second years of the study for the entire WRA were calculated using only on-site "fresh" carcasses from our sample data; we excluded data on carcasses found near the extra end-row turbines we surveyed (Table 3.22). Each year's mortality estimate was based on the three seasons of data collected that year (see Section 2.2.3.3 Estimating Mortality). We used only "high-probability mortalities," those for which we had assessed the cause of death with a high (≥7) level of certainty. We also calculated estimates for the three basic size classes of raptors (small, medium, and large). Mortality estimates and 95 percent confidence intervals are presented with and without scavenger removal and observer error correction factors. We describe the formulas used to calculate these estimates in Section 2.2.3.3.

Extrapolated baseline mortality, or the estimated number of annual site-wide raptor deaths excluding correction factors, ranged from 223 the first year to 62 the second year (Table 3.22). With correction factors applied, the estimated mortality increased greatly, but the increase in small raptor mortality was proportionally much greater than the increase in medium or large raptor mortality. This was because more small birds were removed by scavengers, increasing the scavenger removal rate for small raptors.

We estimated that 227 (± 416, 95% CI) small raptors were killed during the first year and 82 (± 451, 95% CI) the second year within the entire Altamont Pass WRA. All small raptors found dead in our study were American kestrels. We applied both

Table 3.22. Estimated raptor mortality and 95 percent confidence intervals for first and second year, Altamont Pass WRA, 1989-1990.

METHODS	EXTRAPOLATED BASELINE[1]	SCAVENGER CORRECTION[2]	OBSERVER CORRECTION[3]	TOTAL MORTALITY[4]
HIGH PROBABILITY MORTALITY				
1st Year				
Large raptors	81 ± 112[5]	81 ± 112	81 ± 112	81 ± 112
Medium raptors	81 ± 91	95 ± 107	105 ± 118	121 ± 136
Small raptors	61 ± 112	134 ± 246	102 ± 187	227 ± 416
TOTAL	223	310	288	429
2nd Year				
Large raptors	0 ± 112	0 ± 112	0 ± 112	0 ± 112
Medium raptors	41 ± 92	82 ± 185	52 ± 117	104 ± 234
Small raptors	21 ± 116	41 ± 226	41 ± 226	82 ± 451
TOTAL	62	123	93	186

All numbers are rounded off to the nearest whole number.

1 Extrapolated baseline mortality is extrapolated from on-site fresh carcass sample data to represent the entire annual site-wide mortality with no corrections for scavenger removal or observer error. Formulas in Section 2.2.3.3.

2 Scavenger correction mortality is extrapolated mortality compensating for scavenger removal of carcasses. The scavenger correction factors and the formula used to calculate them were taken from Tables 3.20 and 3.21.

3 Observer correction mortality is extrapolated mortality with correction for observer error. The observer correction factors and the formula used for calculating them were taken from Tables 3.20 and 3.21.

4 Total mortality is extrapolated mortality incorporating corrections for both scavenger removal and observer error.

5 Shaded numbers reflect our best estimate of mortality for a size class.

correction factors to derive these estimates. The use of correction factors was appropriate because scavenging of small birds was high, and because small birds were harder to detect in the field. These estimates, however, still may underestimate actual mortality because American kestrel carcasses were more difficult to locate than small-bird test carcasses (see Section 3.2.7.2 Observer Success). For this reason, our observer correction factor may be inadequate.

Our estimate of annual site-wide mortality for medium-sized raptors (e.g., buteos) ranged from 95 (± 107, 95% CI) the first year to 82 (± 185, 95% CI) the second year. These estimates are based on mortality data corrected for scavenging bias only. We considered the observer correction factor unnecessary because observer error was probably minimal for actual, fresh, medium-sized raptor kills (see Section 3.2.7.2 Observer Success).

We estimated that 81 (± 112, 95% CI) golden eagles were killed the first year and none the second year within the entire Altamont Pass WRA. Because no eagle carcasses were ever removed by scavengers in our sample sites and eagle carcasses were obvious, we did not consider it necessary to apply correction factors in these calculations. Our second-year estimate of 0 golden eagle deaths in the entire WRA is based on our finding no golden eagle carcasses the second year. However, windfarm company records show that at least five golden eagles were killed that year. This illustrates the problem associated with extrapolating from small numbers. If we had found even one dead eagle, the extrapolated site-wide estimate of golden eagle mortality would have been 20.

Using another, more conservative, method for estimating golden eagle mortality, we estimated that 39 eagles were killed each year of our study throughout the entire Altamont Pass WRA. Unlike the extrapolation method used above, which was based only on mortality data for fresh carcasses, this method is based on mortality data for all eagles thought to have been killed within the two years of our study, regardless of the age of the carcass. If golden eagles were never removed by scavengers, eagles that died outside our sample times would still be present the next time we searched the area. Therefore, we could assume we found all golden eagles killed in our sample sites during the two years of the study. Using this logic, eleven golden eagle carcasses were found within our sample sites (excluding extra end-row plots), or an average of 5.5 each year. We divided this by the proportion of turbines sampled (0.141) to derive the estimate of 39 eagle deaths per year throughout the WRA.

Because of the low number of fresh carcasses found on our sample sites and the number of variables potentially affecting mortality (e.g., scavenging, topography, weather), the estimates reported above have a large potential for error.

3.3 HABITAT CHARACTERIZATION

To determine whether our sample sites adequately represented the habitat, structural, and biological features of the study area, we made two types of comparisons. First, we compared seven habitat and structural features between our sample sites and random sites. Since habitat and structural variables differed between the different turbines types (see discussion below), we performed all tests within and not among turbine types. Windwalls were not included in these analyses because sample sizes were too small. Second, we compared raptor abundance (mean raptors seen per 10-min scan) between our sample sites (site-specific surveys) and Altamont-wide surveys (driving surveys).

Our analysis showed that most of the habitat and structural variables within our sample sites adequately represented the study area. Out of 28 statistical tests (comparing seven variables within four turbine types), only four showed significant differences between sample sites and random sites. Three variables — distance to next closest structure, first turbine rows, and number of steep slopes — were not significantly different within any of the turbines types between sample sites and random sites. Four variables were significantly different within only one turbine type; proximity to canyon ($P<0.01$) and end-row ($P=0.04$) were different within tubular turbine type, and slope position ($P<0.01$) and elevation ($P=0.03$) were different within lattice turbine type. However, the difference within lattice turbine type between the mean elevation of sample sites (822 ft) and that of random sites (949 ft) was only 127 ft. We feel that this difference in elevation may not be biologically meaningful; this is consistent with our evaluation of elevation differences found in the analysis of contributing factors (see Section 3.2.5).

Our analysis of habitat characteristics revealed that turbine types are not randomly distributed with respect to habitat features within the Altamont Pass WRA. For example, one turbine type may be more commonly situated near canyons, while another may be more commonly situated at higher elevations. Also, because of where the turbines are situated, one turbine type may have more of one structural characteristic (e.g., end-row turbines or first turbine rows) than another. All seven habitat and structural variables tested were significantly related to the five turbine types sampled, meaning that none was independent of turbine type.

When we looked at relative abundance data, we felt we could make appropriate comparisons between sample sites and the entire Altamont WRA only within the essentially non-migratory seasons of summer and winter. Since the Altamont-wide driving surveys were always conducted after the five-week-long site-specific surveys, we would expect differences in abundance between these surveys in the spring and fall because of fluctuations in the number of migratory raptors. The differences between site-specific and driving surveys within the summer (mean of 1.2 and 1.6 raptors per scan, respectively) and winter (mean of 1.1 and 1.5 raptors per scan, respectively) did not appear large enough to be biologically meaningful. The differences may be an artifact of sampling methods rather than a reflection of actual differences in abundance. Differences were not tested statistically because of differences in sampling effort that could not be reconciled.

3.4 RAPTOR NEST SURVEYS

In the Altamont Pass WRA, we discovered a total of 30 raptor nests, of which only 19 were active. Most active nests belonged to red-tailed hawks (10), followed by great horned owls (3) and barn owls (3). We found one turkey vulture, one prairie falcon, and one western screech-owl (*Otis kennicottii*) nest, and one inactive golden eagle nest. Another recent study discovered three active golden eagle nests within 1 to 2 miles of the Altamont Pass WRA (Jones and Stokes Assoc., Inc. 1989). Most of the raptor nests we found were located along the Brushy Creek drainage in the northern portion of the study area (Figure 3-27). More trees are found here than in any other portion of the WRA. We also found 14 raven nests (seven active) in the Altamont Pass. Howell and DiDonato (1991) also found more nests in the northern half of the Altamont Pass WRA than in the southern half (divided by Hwy 580).

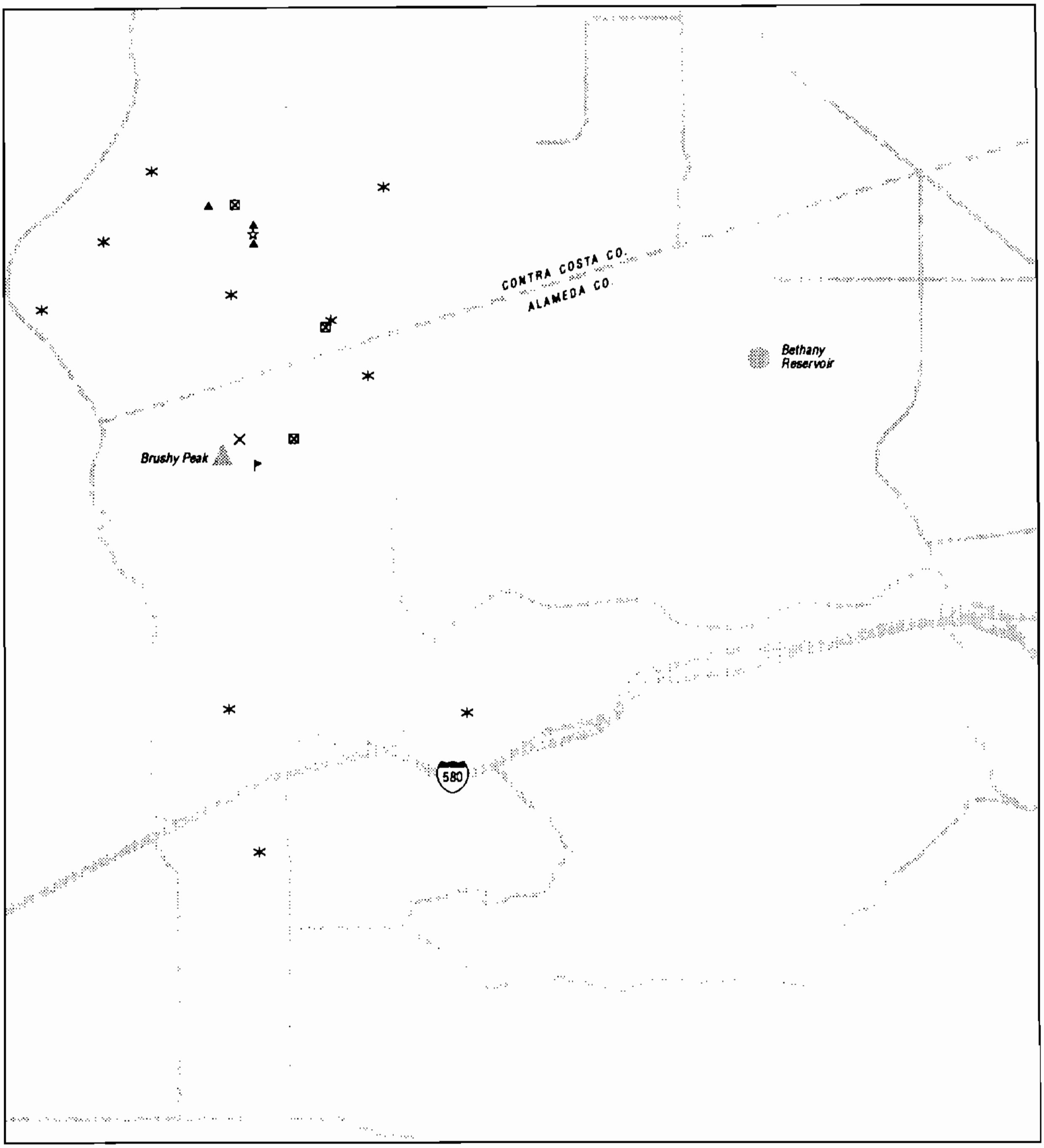
In the Solano County WRA, we found 44 raptor nests, 38 of which were active. The most common active nests were those of red-tailed hawks (19), followed by great horned owls (9) and American kestrels (7). We found only one golden eagle, one turkey vulture, and one northern harrier nest. Raptor nests were more evenly distributed throughout the Solano County WRA, except we found few around the town of Rio Vista (Figure 3-28). No raven nests were found.

The average distance from a raptor nest to the closest turbine in the Altamont Pass WRA was 0.5 mi (range of 250 ft to 2 mi). The average distance for raven nests was 0.25 mi (range of 150 ft to 0.5 mi). Nests, particularly those of ravens, were sometimes found on the turbines themselves. Windfarm companies, however, usually remove nests as quickly as they are found.

3.5 SELF-MONITORING PROGRAM

We developed a self-monitoring system to be used by all participating windfarm operators to report deaths or injuries they observe in the field. This system will allow developers and resource agencies to continue to document and assess mortality over time. We designed an information fact sheet to be given to all field personnel that defines the purpose, specifies the type of data needed, and describes monitoring procedures (Appendix E). Data sheets (wildlife incident reports) and code sheets also were developed for use with this system (Appendix E).

Unlike the CEC system (CEC 1989), which requires continual soliciting, our information retrieval system is self-sustaining. It was modeled after one developed by U.S. Windpower (U.S. Windpower 1990). U.S. Windpower's system has been in use for over five years and appears to be working well. Our proposed system will be operated by windfarm companies and will be monitored and controlled by the USFWS and the CDFG. The system will allow windfarm operators to identify problem areas that may increase the susceptibility of raptors to collisions or electrocutions. For example, it is important to keep records on electrocution deaths occurring at power poles to determine if mitigation measures suggested in this report are adequate (Section 5.0) and if poles require further modifications. This will require the cooperation of windfarm operators in releasing information and the involvement of resource agencies to ensure that data are collected properly. Windfarm operators also may be responsible for periodic mortality surveys at selected turbine sites for future mitigation monitoring studies. Each participating windfarm operator should designate one or more employees as wildlife



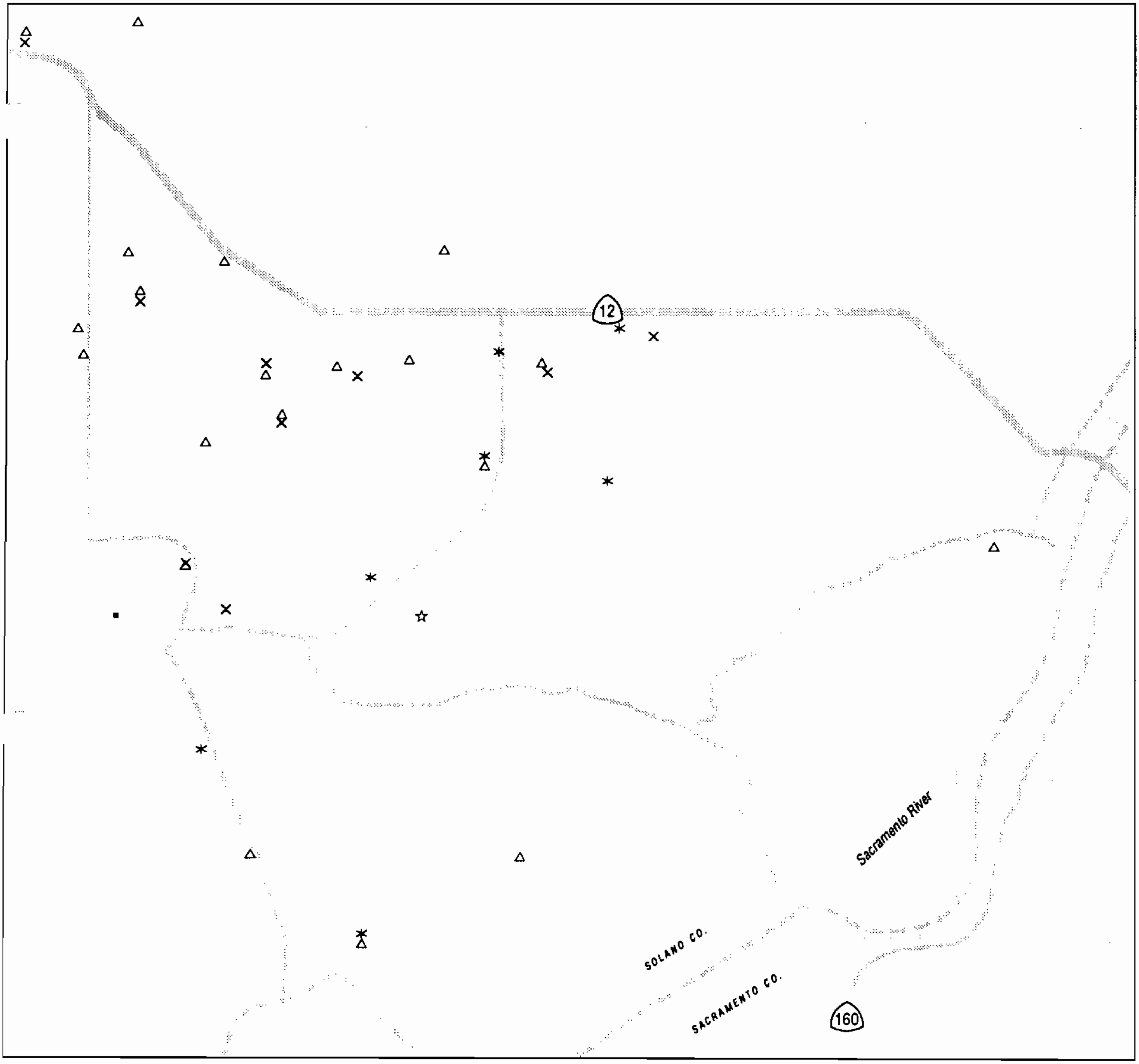
Prepared by BioSystems Analysis, Inc.

Figure 3-27. Locations of raptor nests found within the Altamont Pass WRA, spring 1989.

Legend

- ✳ Red-tailed hawk
- ⊠ Great horned owl
- ⚑ Turkey vulture
- × Prairie falcon
- ▲ Barn owl
- ☆ Screech owl

0 .5 1 1.5 2 2.5 miles



Prepared by BioSystems Analysis, Inc.

Figure 3-28. Locations of raptor nests found within the Solano County WRA, spring 1990.

Legend

- ✳ American kestrel
- ▪ Northern harrier
- × Great horned owl
- △ Red-tailed hawk
- ☆ Golden eagle

0 1 2 3 miles

managers who will be responsible for the implementation of this system. The wildlife manager will be responsible for the following tasks:

- completing wildlife incident reports,
- consolidating all raptor incident reports into a monthly listing and submitting them to USFWS,
- ensuring that incidents involving eagles are reported to the USFWS within 24 hours, as well as coordinating with the USFWS to ensure that eagles are preserved and stored properly, and
- assisting in the capture and transportation of live injured birds under the direction of a licensed rehabilitator.

To compile the mortality data, each windfarm developer must submit a monthly report that summarizes any collisions or electrocutions that have occurred that month. This report should be designed so that information can be easily transferred into a computer database if needed. Important summary information includes date of incident, type of bird, exact location (turbine or pole number), distance and direction from structure, condition of bird, and probable cause of death.

This self-monitoring system does not require equal effort among the different windfarm companies. Since smaller windfarm companies do not have as many field personnel as the larger companies, they will probably have less opportunity to find dead birds in the field. It may also present a hardship for smaller companies to participate in the periodic mortality surveys for future monitoring studies.

Data analysis can currently be easily compiled and manipulated without a computer. The local office of the USFWS does not have the computer capabilities to handle a database system and windfarm operator reports show that the number of dead birds inadvertently found is only two to six per month.

It is important for the permitting agencies (county and state) to verify that the windfarm companies are complying with the requirements of the self-monitoring program. This can be accomplished by establishing a permanent compliance monitoring program.

4.0 DISCUSSION

4.1 FACTORS AFFECTING BIRD MORTALITY

Bird mortality at windfarms may be affected by several factors, among which are species abundance and composition, bird behavior and flight characteristics, weather conditions, habitat characteristics, types of turbines, and configuration of power poles. Each of these is discussed below.

4.1.1 Species Abundance and Composition

A large and diverse population of raptors occurs in the Altamont Pass WRA. American kestrels, red-tailed hawks, turkey vultures, golden eagles, northern harriers, and prairie falcons occur throughout the year. Some species, such as ferruginous and rough-legged hawks, migrate from northern breeding grounds and either spend the winter in or migrate through Altamont Pass. Altamont Pass has at times supported the largest concentration of wintering ferruginous hawks in the state (American Birds 1981). Local experts (B. Walton in CDFG 1983) identify Altamont Pass as one of the few places in California where ferruginous hawks concentrate. A few bald eagles also winter in the area. When compared with raptor migration flyways such as the Marin Headlands in Marin County, Altamont Pass does not appear to be on a major migration corridor; a more diffuse migration of raptors, typical of the inland West (Hoffman 1985), characterizes the area.

Most birds we observed in the Altamont Pass WRA appeared to be foraging rather than flying through the area. Howell and DiDonato (1991) reported that raptors showed no obvious directional movements through the Altamont Pass WRA; flight direction was not significantly different from random.

Local bird experts and bird watchers have noticed that the number of raptors has declined in recent years throughout Altamont Pass (LSA 1986, H. Peters pers. comm., Howell and DiDonato 1991). The effects of wind turbines on avian populations, however, cannot be isolated from the effects of increased human activity and development or drought or other phenomena. Bird surveys in other parts of the Bay Area have shown the number of raptors has increased in recent years, particularly red-tailed hawks and American kestrels (A. Fish pers. comm.).

Our data indicated that turbine-related mortality of the five most common species was not related to the abundance of those species. American kestrels, red-tailed hawks, and golden eagles were killed more frequently than we would have predicted by their abundance in the study area. In contrast, fewer dead turkey vultures were killed than their abundance in the study area would have suggested. Likewise, we never found common ravens that had been killed by collison with turbines on our sample sites, even though this was the most commonly-observed bird. These differences may reflect species-specific flight characteristics and behavior that could make some species more susceptible to collisions than others (see Section 4.1.2 Behavior and Flight Characteristics).

Although we did not find any dead northern harriers, this may be because harriers were scarce in the study area; approximately 1 percent of our site-specific observations were of harriers. Northern harriers were common in Altamont Pass during the early 1980s before wind turbine development began (CDFG 1983, L. Spiegel pers. comm.). Their scarcity in the study area during our study may have been related to drought conditions.

As in our study, Howell and DiDonato (1991) found relatively few turkey vulture and raven carcasses during their mortality surveys in the Altamont Pass WRA but, in contrast to our results, they found very few American kestrels. Our research showed that the scavenging rate for kestrels was extremely high, so the apparent difference in American kestrel mortality may actually be due to the difference in survey intervals. The mortality surveys of Howell and DiDonato were conducted at two-week intervals, whereas our survey interval was one week.

Seasonal mortality did not appear to be related to seasonal abundance. There were no apparent differences in mortality among seasons for medium and large raptors (with or without correction factors), yet raptor abundance was significantly different between seasons. Although raptor abundance was highest in the fall, this was primarily because of an increase in the number of turkey vultures, which had low mortality. The number of fresh carcasses we found was so low, however, that we did not compare seasonal differences statistically.

Immature golden eagle and red-tailed hawks were killed more frequently than their proportion in the population would have suggested. This may reflect the fact that immature birds are not as agile flyers as adults. Benson (1980) found that immature golden eagles were more susceptible to electrocution because, as inexperienced hunters, they preferred hunting from perches.

4.1.2 Behavior and Flight Characteristics

It has generally been assumed that because raptors are good flyers and possess excellent eyesight, they are not likely to collide with something as obvious as a wind turbine (Olendorff and Lehman 1986, Byrne 1983). However, 83 raptor deaths were attributed to collisions with turbines during the six seasons of our study; these were primarily red-tailed hawks, American kestrels, and golden eagles. It was also commonly thought that raptors and waterfowl are more likely to collide with transmission lines or the guy wires associated with meteorological towers and other structures than with turbines because these lines are much less visible (Jones and Stokes Assoc., Inc. 1987). Other studies also have found that meteorological towers cause mortalities (Byrne pers. comm.). In our study, however, no mortalities were associated with the 48 meteorological towers surveyed (most having guy wires), and raptor mortalities attributed to collisions with wires accounted for only 8 percent of our on-site mortalities. Furthermore, the lowest mortality at any turbine type occurred at guyed-pipe turbines, which are supported by an array of guy wires. However, guyed-pipe turbines often were not operating, which may have influenced bird mortality at these sites.

Because we never saw a bird being killed, we do not know the specific circumstances under which birds collide with turbine blades. People rarely observe birds being killed by turbines because these deaths are rare and the behaviors that put raptors at risk, such as stooping on prey, may be inhibited by the presence of people. The only reported observation of a bird kill at a turbine was that of an American kestrel killed at an isolated Mod-2 turbine (S. Byrne pers. comm.). The bird was hunting near the turbine and twice drifted through the plane of the blade path before it was fatally struck. Each time the bird was buffeted by turbulence and seemed aware of the blades' presence.

It is possible that a raptor concentrating or stooping on prey might be less aware of a rotating wind turbine, or raptors may misjudge the distance to blades while foraging. If these theories are true, mortality may be higher in areas of high prey density because foraging is presumably more frequent in these areas. We found no relationship between ground squirrel density and mortality in our study, but we believe that the presence of ground squirrels or other prey items may still contribute to mortality. We believe there may be several reasons our analysis failed to show a relationship. First, it was based on the abundance of ground squirrel burrows, and not on actual ground squirrel activity (burrows are frequently vacant). Second, since most of the bird carcasses we found were old, local ground squirrel abundance could have been different at the time of death than at the time of discovery. Third, we believe there may be a threshold of ground squirrel abundance, above which the effect of abundance on mortality would not change. Since ground squirrels are common in the study area, this threshold abundance likely occurs throughout the WRA and, therefore, its effect on mortality is not detectable. This should be further investigated.

Our observations corroborated the results of studies showing that birds in flight usually take evasive action to avoid structures such as turbines (Rogers et al. 1977, McCrary et al. 1984), but other studies have shown that raptors were less likely to display avoidance behavior than any other species group (McCrary et al. 1987). Empirical evidence from our many hours of observations in the field indicates that raptors do not seem to perceive turbine blades as potentially dangerous. We have observed raptors flying very close to rotating blades and perched on blades when turbines are not operating. Other authors have reported birds successfully flying between blades operating at slow speeds (Solano County 1985, Rogers et al. 1977). Winkelman (1985) also reported that birds appear to habituate to the presence of turbines. Habituation may be an important factor contributing to mortality.

We found the majority of dead birds northeast of turbines or opposite the direction of the prevailing (southwest) winds. Howell and DiDonato (1991) found most of their dead birds east and northeast of turbines and suggested that most birds killed were flying with the prevailing southwest wind when they hit the turbine and were thrown farther along the same flight path. They also speculated that most strikes occurred among birds "in transit"; they suspected that birds were moving with the wind or shearing across the wind at an acute angle to the rotation of the turbine blades. Consequently, birds would have had difficulty seeing the moving turbine blades along their narrow axis.

Howell and DiDonato (1991) reported that turbine row length was correlated (r^2=0.41) with mortality at one sample site, but not at another; longer turbine rows were associated with higher mortality rates. They theorized that turbine strings might act like a "picket fence" creating a barrier to flight paths. Our data did not show that row length was associated with mortality.

Researchers have suggested that the number of birds killed by collisions with power lines was higher when wintering populations were new to an area, and the number of deaths declined as birds became more experienced with local conditions (M. McCrary in Howell et al. 1988a). Our data did not appear to support this. Although the relative abundance of most medium to large raptors was highest in the fall, which presumably represented an influx of migrating birds, mortality for the same period did not increase proportionately.

Howell and DiDonato (1991) also reported a possible relationship between experience with local conditions and mortality. They found more raptor nests and lower mortality in the northern portion of the study area, so they theorized that familiarity with an area may favor residents and reduce mortality among them. Figure 3-19 indicates, however, that mortalities were fairly evenly distributed throughout the portions of our study area sampled.

Foraging behavior and flight characteristics (flight height, distance of flying birds to turbines and turbine blades, and frequency of perching on turbine structures) may make some bird species more susceptible to collision than others. Susceptibility to collision, based on foraging behavior and flight characteristics, did appear to be related to the actual death rate for some species. As we already mentioned, golden eagles, red-tailed hawks, and American kestrels were all killed more frequently than we would have predicted from their relative abundance in the study area, whereas turkey vultures and common ravens were killed less often than would have been expected. Based on our mortality and abundance data, golden eagles, red-tailed hawks, and American kestrels were three to nine times more likely to be killed than turkey vultures.

Differences in foraging behavior among these five species may broadly explain differences in their mortality rates. Golden eagles, red-tailed hawks, and American kestrels hunt primarily by stooping on their prey. Turkey vultures and common ravens, however, rely more on scavenging, which does not typically involve high-speed flying or highly-focused concentration. Based on foraging behavior, susceptibility of golden eagles, red-tailed hawks, and American kestrels to collision with turbines appears to be high and so was their relative mortality, whereas susceptibility of turkey vultures and common ravens appears to be low, as was their relative mortality.

Flight characteristics could further explain why some species appear to be more susceptible to collision than others. About 39 percent of all raptors were observed flying within 170 ft of the ground. This is at or below the maximum blade height of all turbines in Altamont Pass. American kestrels frequently flew below maximum blade height or near turbine blades and were frequently observed perching on turbine structures. These factors contribute to high susceptibility to collision and, as expected, their relative mortality was high. Conversely, turkey vultures were usually observed flying at higher altitudes, away from turbine blades, and were rarely observed perching on turbine structures. These factors contribute to low susceptibility to collision and, in fact, their relative mortality was low.

Relative mortality for two species, golden eagles and red-tailed hawks, was high, but the contribution of flight characteristics to our assessment of susceptibility was ambiguous. Golden eagles usually flew at higher altitudes away from turbine blades and were rarely observed perching, which would lower their susceptibility. However, they frequently use coursing flights about 25 ft above the ground (Carnie 1954, S. Orloff pers. obs.), which would seemingly put them at greater risk of collisions with turbines and increase their susceptibility. Red-tailed hawks were mid-level flyers (relative to the other species), but we often observed them perched on turbine structures. Their flight behavior showed no clear indications that would suggest whether these birds were more or less susceptible to collision than the other species.

Flight characteristics did not help explain the low mortality for common ravens. Common ravens were frequently observed flying below maximum blade height or perched on turbine structures. These are factors that may contribute to high susceptibility to collision, but their relative mortality was very low.

We never found ferruginous hawks or northern harriers that had been killed by collision with turbines on our sample sites. The susceptibility of northern harriers to collision with turbines is unclear. They frequently forage below 30 ft, which is below the minimum blade height of most turbines in the WRA, so they may be less susceptible to collision with turine blades than other species. The flight characteristics of ferruginous hawks were similar to those of red-tailed hawks, except ferruginous hawks were observed perching on turbine structures or blades less often than red-tailed hawks. Foraging behavior of the two buteos is also similar. Differences in mortality between these two species may be related to abundance. If there were more ferruginous hawks, perhaps their mortality would have been higher.

Flight velocity is another flight characteristic that may contribute to a species' susceptibility to collision with turbines or wires. The speed at which a bird flies may affect its ability to detect an obstacle, especially a small one such as a wire, and may affect a bird's reaction time when it encounters an obstacle. Flight velocity also may affect the severity of an impact-related injury. Compared to other raptors, turkey vultures fly slowly (Palmer 1990), making them less susceptible to collision. However, measured flight velocities for raptor species are variable and overlap (see Appendix A). Perhaps more important is individual flight velocity at any given time, rather than species-specific flight velocity.

4.1.3 Weather Conditions

High winds and low visibility may magnify the impact of wind-turbine mortality. Several researchers have studied the relationship between inclement weather or poor visibility and mortality of passerines and waterfowl at man-made structures. Avery et al. (1980) found that overcast skies and fog often were associated with high mortality. Most of these reports were anecdotal and did not consider the influence of the increased density of migrating birds. James and Haak (1979) found no correlation between inclement weather and mortality in their study of collisions at transmission lines in the Pacific Northwest. A recent study by Pacific Gas and Electric (Dedon et al. 1989) found that bird mortality (primarily waterfowl) was high when visibility was low and low during periods of unsettled weather; however, they found local bird density provided the strongest predictor of mortality.

The effects of weather on mortality in our study were unclear, but since many birds were killed during periods of good weather, inclement weather does not appear to be a crucial factor. We found no marked and consistent seasonal differences in mortality, which further suggests that weather is not an integral factor in mortality. In addition, since mortality was not higher in the high-wind season (summer) than in other seasons, high winds are apparently not a crucial factor in mortality. Since bird deaths in our study were relatively uncommon, the connection between weather patterns and mortality was difficult to establish. Future mortality surveys immediately before and after a winter storm or heavy fog may clarify this relationship (see Section 5.2.2 Hypothesis Testing).

Our observation data showed that fewer raptors were recorded during foggy scan periods than during non-foggy scan periods. Although this is probably the result of reduced visibility, it may be that, during foggy weather, raptors tend to be less active because their prey are normally less active as well. If birds are less active, the potential for collision would be lower. Also, when there is dense fog there is usually not enough wind to turn turbine blades, further reducing the potential for collision. There were, however, some foggy days when the wind was quite strong.

4.1.4 Habitat and Structural Characteristics

We found that end-row turbines and turbines located close to canyons were more strongly associated with mortality than any other variables we measured. We originally hypothesized that, because end-row turbines may be associated with canyons or cliffs, the presence of these topographic features might explain the higher mortality at end-row turbines by the way they affected bird behavior or abundance at these locations. Canyons and cliffs provide corridors for bird movements and create updrafts that raptors use for foraging and migration. Our observation data, however, did not support the idea that birds were more numerous around end-row turbines. Also, contrary to our expectations, end-row turbines were not associated with canyon proximity; just as many canyons were near non-end-row as near end-row turbines. Our analysis indicated that each factor was independently associated with mortality and, when both were present, their combined effect on mortality was synergistic.

Howell and DiDonato (1991) also reported an association between mortality and the proximity of turbines to "swales and shoulders of hills." They did not find that end turbines contributed disproportionately to avian mortality, though their sample sizes were small.

Elevation was significantly associated with mortality in our analysis. It was, however, also correlated with many other variables that were linked with mortality, so we are uncertain of its biological significance. We also found a significant difference in the elevation at which raptors and non-raptors were found dead.

Structure density and mortality were significantly correlated at all turbine types with the exception of windwalls. Higher mortality was associated with low structure density and lower mortality was associated with high structure density. This may be because, when turbines are close together (high structure density), they present more obstacles. Raptors may avoid flying near dense turbine rows or dense turbine rows may be more obvious and, thus, more easily avoided. By contrast, when turbines are spaced farther apart, birds may have more room to maneuver near turbines or perhaps turbines are less noticeable.

4.1.5 Turbine Types and Power Poles

Our comparison of mortality rates among the five turbine types sampled indicated that mortality was higher at lattice-type turbines than at other turbine types. Furthermore, the effect on mortality of the two important structural and habitat variables (end turbines and proximity to canyons) was much stronger for lattice turbines than for the other turbine types.

This comparison was complicated by several factors, which we discussed in Section 3.2.6.1. Factors that are still of concern to us are discussed below. First, because turbine types are not randomly situated with respect to habitat features, it is difficult to determine whether differences in mortality by turbine type are related to the turbine type itself, to a topographic feature more commonly associated with one turbine type than another, or to some variable we did not measure. It is possible that mortality results might be different if lattice turbines were situated in different locations and were therefore associated with different habitat features. Second, scavenging rates and the percentage of time turbines are in operation differ among turbine types; both of these factors could affect mortality rates unequally.

The proportion or occurrence within sample turbine types of most variables associated with mortality suggests that mortality at lattice turbine types may have been underestimated. The scavenging rate was higher at lattice turbines than at other turbine types, which also leads to possible underestimation of mortality at lattice turbines; if scavenging had not been so high, we may have found even more dead birds. Windfarm companies provided us with information on average hourly wind speeds for all sample sites and cut-in speeds (wind speeds at which a turbine type becomes operational) from which we could infer the percentage of time in operation. Using these data, however, assumed that at the appropriate cut-in speed, all turbines of a particular type became operational; this was not the case. Because actual data on the percentage of time turbines were in operation were not available from windfarm companies, we were unable to use this information in our analysis.

Whether turbine blades were painted or not did not appear to affect mortality in our study. The turbines with painted blades sampled in our study were painted only at the tips. Research is currently being conducted by U.S. Windpower on blades that are painted intermittently along the length of the blades. Although sample sizes were small, results of that study indicate that increasing the visibility of turbine blades by painting the length of the blade may reduce the number of bird collisions (Howell et al. 1991b).

Only 9 percent of on-site raptor mortalities were attributed to electrocution. Most of these occurred at riser poles, which are fairly common throughout the study area. Reports from windfarm companies indicate that electrocutions may have been more common several years ago before they began to insulate wires. Several windfarm companies have already partially or fully insulated the types of poles that most often cause electrocutions, primarily because electrocutions often cause power outages resulting in revenue losses.

Studies have shown that between 81 and 85 percent of collisions with transmission lines involve collisions with ground wires (Faanes 1981, James and Haak 1979). Ground wires are smaller in diameter and so may be more difficult to see and avoid than conductor wires. Beaulaurier (1981) found that marking ground wires resulted in an average reduction in mortality of 45 percent.

4.2 EFFECTS OF TURBINES ON RAPTOR USE AND ACTIVITY

Raptor use and activity patterns may be affected by wind turbine developments in the following ways. Wind development structures, constituting a new habitat type, may disrupt foraging patterns of open-country raptors such as red-tailed hawks and golden eagles. Several kinds of raptors forage near ridges to take advantage of favorable wind currents. Placing turbines on ridges, which is a common practice, could be especially dangerous to these raptors. When turbines are in operation so that hunting from turbine perches is not possible, foraging near ridges could become more common.

There is evidence that the development of Altamont Pass with wind turbines has changed wind flow through the area, causing average winds to decrease and wind turbulence to increase site-wide (K. Cohn pers. comm.). The increase in air turbulence and the small vortexes caused by individual wind turbines may increase the potential for mortality by affecting a bird's control of its flight and decreasing its ability to maneuver through a maze of structures.

Foraging is common near turbines and raptors appear to be accustomed to their presence. Our relative abundance data within the Altamont Pass WRA suggested that raptor use and activity levels were not related to turbine development; the distribution of raptors in areas of high turbine development was similar to the distribution in nearby areas of low or no turbine development.

Turbines and power poles have increased the availability of perches and nest sites in the relatively-treeless grasslands of Altamont Pass. As many as 27 percent of winter raptor observations were of birds perched on turbines, and red-tailed hawks and common ravens commonly nest on turbine structures (although nests are usually removed by the windfarm companies). Perching on turbines was most common in the winter, probably because turbine operation was not as constant as in the other seasons. Perching and nesting on turbines may increase habituation of birds to these structures, and this could reduce their awareness of a potential threat.

Of the 80 mi^2 of Altamont Pass that have been developed with wind turbines, about 5 to 10 percent of the habitat has been removed for turbine pads and roads. This loss may indirectly affect raptor populations by altering prey availability. Besides direct habitat removal, small mammal populations may be disturbed by the sounds or vibrations associated with operating turbines, an effect probably restricted to a small area around each turbine. Our field observations, however, suggest that turbine noise and vibration have little effect on ground squirrel distribution. Many active ground squirrel and other rodent burrows were evident at or near turbine bases. Roads may actually increase the visibility of prey items for foraging raptors, and road construction has provided friable dirt berms for burrowing ground squirrels.

4.3 MORTALITY ESTIMATES

4.3.1 Altamont Pass WRA

Most studies have concluded that collisions with turbines will not significantly affect local bird populations. Many of these studies, however, involved only one turbine, were conducted over short periods of time, or did not involve raptors. Our estimates of annual site-wide raptor mortality from windfarm-related injuries varied from 403 in the first year to 164 in the second year (see Table 3.22 for our best estimates of mortality for each raptor size class). Although estimated site-wide golden eagle mortality ranged from 82 the first year to 0 the second year, based on extrapolation from fresh carcasses only, we know from windfarm company records that there were several golden eagle deaths outside our sample sites the second year.

Perhaps our other estimate of 39 annual eagle deaths may be more appropriate (see Section 3.2.8.2 Annual Site-wide Mortality). From this estimate, we calculated that 27 eagles were killed by turbines each year based on our determination that 69 percent of all on-site golden eagle deaths were the result of collisions with turbines (Figure 3-20).

Our estimates of annual site-wide golden eagle mortality are somewhat higher than those reported by Howell and DiDonato (1991). They estimated that approximately 10 golden eagles die per year within the U.S. Windpower facility (which constitutes approximately 40 percent of the wind turbines in the WRA). However, they state that this amounts to a significant number of eagle mortalities in light of recent state-wide (Thelander 1974, Schlorff 1986) and local (Lenihan and DiDonato 1987) surveys of nesting golden eagles. They suggest that windfarm mortality, in addition to natural and other human-caused mortality and the loss of historical nesting and foraging habitat, could affect the local recruitment of golden eagles. Other researchers (T. Cade and B. Burnham pers. comm.), however, state that golden eagle populations are not threatened or vulnerable in the western states, except locally where development destroys nest sites.

All methods of estimating site-wide mortality have a large potential for error because of the low number of carcasses found and the number of variables involved. The variation in mortality estimates presented in this report underscores not only variability in different methods of estimation or extrapolation, but year-to-year variability in mortality. For example, if we had found even one dead golden eagle the second year, the extrapolated site-wide estimate of golden eagle mortality would have changed from 0 to 20. We have also found evidence of variability in raptor mortality at different WRAs. Our preliminary study of bird mortality at the Tehachapi WRA indicated there were signficantly fewer mortalities per turbine surveyed ($P<0.01$) at the Tehachapi WRA than at the Altamont Pass WRA (Orloff 1992). Additionally, there is evidence that bird mortality within a WRA at similar neighboring structures can vary dramatically for no apparent reason (Avery and Clement 1972, Seets and Bohlen 1977).

The validity of our extrapolated estimates of annual site-wide mortality depends, in large measure, on how well our sample sites represent the study area. We believe that our sample sites provided adequate data from which to establish a range of baseline site-wide estimates of mortality for the following reasons. We feel that the proportions of the five different turbine types in our sample sites adequately represents the proportions of those types in the WRA. Although two other turbine types were not sampled, these two types comprised relatively few turbines. Also, we feel our sample sites adequately represented the study area in terms of specific habitat and structural variables; only 4 out of 28 tests showed significant differences between sample turbines and random turbines (randomly selected to represent the entire WRA).

These four differences were proximity to canyon and end-row variables (within tubular turbine types) and slope position and elevation variables (within lattice turbine type). Three of these four variables were significantly associated with mortality (proximity to canyon, end-row turbines, and elevation) in the analysis of factors contributing to mortality. The proximity to canyon variable may have been over-represented within the tubular turbine type because a greater proportion of tubular turbines were close to canyons on our sample sites than on the random sites. The end-row turbine variable may have been under-represented within the tubular turbine type because there were fewer end turbines on our sample sites than on the random sites. The elevation variable may have been under-represented within the lattice turbine type because lattice turbines on our sample sites occurred at lower elevations than they did on random sites. In addition, we calculated the number of end turbines in the entire WRA and found that our sample sites under-represented end turbines: 21 percent of all turbines in the WRA were end turbines and 15 percent of turbines within our sample sites were end turbines. However, this would, if anything, make our estimates of mortality conservative.

It is important to note that although the habitat and structural features we used to compare our sample sites to random sites were those we believed to be the factors most likely to affect mortality, we realize that mortality may not necessarily be entirely explained by these variables. There may be other factors affecting mortality that we did not measure.

Regardless of which method was used to estimate mortality, we believe the number of raptor deaths in the Altamont Pass WRA warrants concern, at least on a local level. Golden eagles are of particular concern because they are federally protected under the

Bald Eagle Protection Act as well as being a California species of special concern. Furthermore, the Altamont Pass WRA is considered an important wintering area for golden eagles (CEC 1989). The California Energy Commission (CEC 1989) states that efforts should be made to mitigate raptor losses, regardless of whether raptor populations are significantly affected by turbine-related mortality.

4.3.2 Solano County WRA

Data from our study and from others (Howell and DiDonato 1991, Howell et al. 1988, Howell et al. 1991a, BioSystems Analysis, Inc. in prep.) show that raptor abundance was generally higher in the Solano County WRA than in the Altamont Pass WRA (see Section 3.1.1.6 Comparisons to Other Studies). We found more turkey vultures, red-tailed hawks, and American kestrels and fewer golden eagles in the Solano WRA than in the Altamont Pass WRA. Open, rolling grassland habitat is common to both areas. However, elevations at the the Solano County WRA are lower and this site has fewer steep canyons and more dry-land agriculture than the Altamont Pass WRA.

Howell and DiDonato (1991) found only three dead raptors in their year-long study of U.S. Windpower's facilities in the Montezuma Hills, a portion of the Solano County WRA. Their 1991 report suggested that land-use practices (dry-land agriculture) in Montezuma Hills reduced the quantity and quality of foraging habitat for raptors by reducing ground squirrel abundance. However, they sampled only about 7 percent of the area that could eventually be developed with wind turbines. As mentioned above, the relative abundance of raptors was higher in the Solano County WRA than in the Altamont Pass WRA. This suggests that habitat quality may actually be better, overall, in the Solano County WRA. Our nesting surveys also suggest that habitat quality was better in the Solano WRA; we found comparatively more nests at the Solano County WRA.

We believe that raptor mortality in the Solano County WRA could potentially be as high as in the Altamont Pass WRA for two reasons. First, relative abundance was higher in the Solano County WRA than in the Altamont Pass WRA. Second, our research and other studies (Howell et al. 1988, Jones and Stokes Associates 1987) showed that hunting behavior and flight characteristics, which partly explained mortality for the four most abundant raptor species in the Altamont Pass WRA, were not markedly different between the two areas. We also believe that the endangered peregrine falcon may be more likely to occur in the Solano County WRA, especially in the winter, because this WRA is close to Suisun Marsh which provides abundant prey for this falcon. Peregrine falcons are more vulnerable to collision with wires (Olendorff and Lehman 1986) than most other raptor species.

4.4 GENERAL STUDY LIMITATIONS

We analyzed all variables we thought could be biologically meaningful for their relationship to mortality and to each other in an attempt to narrow the search for factors causing mortality. Any causal agent must be statistically associated with mortality, but the association of a variable with mortality does not necessarily imply causation. We do not imply that any of the variables we found to be associated with mortality were actually causing bird deaths. For example, lattice turbines were associated with significantly higher mortality than other turbine types but to claim that they caused mortality may be incorrect; it is possible that lattice turbines were operating more frequently than other turbines. Another caution in interpreting our analysis is our use of P-values. In this exploratory analysis we have used P-values as objective measures to decide which variables deserve further study and not as probability statements. We conducted so many statistical tests, it was inevitable that some results would test positive when a significant association did not actually exist; i.e., 1 out of 20 tests by chance would be a false positive result (Type I error).

We expected to determine the cause of death for birds more readily than we were able to. We also thought necropsy results would be more definitive. Cause of death could be estimated with a high level of certainty for only 38 percent of the raptor mortalities. In most cases, necropsies could not determine cause of death beyond traumatic injury, which could be attributable to collisions either with wires or turbines. Most carcasses, however, showed amputation injuries, and these are more likely to result from collisions with blades than with wires (D. Crump pers. comm.). In addition, 89 percent of the raptor deaths attributed to collision with turbines occurred where no other structures with wires were within 200 ft of the site of mortality.

Radar was not used to collect nocturnal data; our study approach emphasized diurnal data collection. Nocturnal studies using radar have been useful where the primary concern was nocturnal migrants (passerines and waterfowl). The primary concern in our study was raptors, and only 4 percent of our on-site deaths were of nocturnal raptors (owls). The use of radar as a method for observing raptors at night is seriously limited by two factors (Able 1985). First, radar cannot produce the resolution needed to determine the species, or even family or order, of birds it locates. Second, radar cannot differentiate between "a few" individuals and "many." To some extent, these limitations can be overcome by concurrent visual observations, an approach that would be feasible for studies in a restricted area. Applying radar methods to an area as large as the Altamont Pass WRA, however, would require extensive visual validation of both the number and identification of birds. Furthermore, radar operators would have difficulty recognizing relatively small objects near the ground in a maze of turbines, which are highly reflective of radar.

5.0 MITIGATIONS AND SUGGESTIONS FOR FURTHER STUDIES

5.1 ELECTROCUTIONS AND COLLISIONS WITH TRANSMISSION WIRES

The measures listed below for mitigating the loss of raptors to electrocutions and collisions with transmission lines should be included in all new Conditional Use Permits for wind energy development in Alameda, Contra Costa, and Solano counties. These measures should also be required in five-year reviews of all existing permits for wind developments. They were developed in cooperation with the Technical Advisory Committee for this study, including representatives from windfarm companies, the USFWS, and PG&E. They are based on the scientific literature (Olendorff et al. 1981, Olendorff and Lehman 1986) and windfarm company experience and should reduce bird deaths by electrocution and collisions with wires. Recommendations for reduction of electrocution hazards all have the same objective: to separate or insulate all potential conductors so that birds cannot complete a circuit.

5.1.1 Existing Overhead Power Lines

Riser poles and poles with pole-top transformers, capacitor banks, and metering sets shall be modified to reduce electrocution hazards in the following manner:

- All jumper wires shall be insulated (5kV minimum rating and preferably 10kV to 15kV).
- All exposed terminals (e.g., pot heads, lightning arresters, cut-out switches, and transformer bushings) shall be covered by wildlife boots or other insulating materials.
- All straight, aluminum-type combination arms on riser poles shall be replaced with non-conductive material (e.g., fiberglass or wood).
- Bonding of pole-top devices mounted on non-conductive arms shall be done with insulated wire.

Other types of poles with a history of electrocution (i.e., a minimum of one electrocution event) shall be modified to prevent future electrocutions on a case-by-case basis within 30 days of an electrocution.

5.1.2 New Overhead Power Lines

- All new overhead power line construction shall include the above specifications and will, additionally, comply with PG&E Standard #061149, Raptor-Protected Primary Construction Wood Pole Distribution Lines, except as modified to require bonding of pole-top devices mounted on non-conductive arms with insulated wire.
- To reduce mid-span collisions with wires, a minimum conductor wire size of 4/0 shall be used.

Proposed changes to the above standard electrocution measures may be approved by the County's Zoning Administrator. Prior to approval of any proposed changes, the County will refer the matter to the CDFG and the USFWS for their review and recommendation.

The self-monitoring program will determine the success of these mitigation techniques (Section 3.5). If raptor deaths continue, additional modifications will be necessary. Additional modifications shall include the following:

- Energized wires could be placed a safe distance apart: 60 in. for crossarm configuration, 55 in. for armless configuration. For crossarm configurations this can be accomplished by lowering the crossarm (two outer wires) or by placing the center wire on a tag pole extension. Where adequate (safe) separation of conductors and potential conductors cannot be attained, an alternative would be to install conductor insulation (i.e., PVC tubing) extending a minimum of 3 ft on either side of the pole-top insulator.

- The use of cut-outs on riser poles shall be avoided.

- Jumper leads could be reoriented from a horizontal configuration to a vertical one to reduce bird perching.

- Common neutral ground wires could be marked for better visibility (Beaulaurier 1981).

5.2 COLLISION WITH TURBINES

We still feel it is premature to develop specific mitigation measures to reduce turbine collision mortality. Much more still needs to be learned about the nature of the problem and what techniques would be most effective in reducing turbine-related mortality. Two types of studies are outlined below: 1) mitigation testing to determine the effectiveness of various mitigation strategies for reducing the collision hazard of turbines to raptors, and 2) hypothesis testing to determine the validity of or to refine some theories on raptor mortality at wind energy developments.

5.2.1 Mitigation Testing

We have designed several controlled experiments and studies to determine the effectiveness of possible mitigation measures, such as various types of turbine and habitat alterations that could potentially reduce the collision hazard to birds. In general, these alterations would make the turbine blades or the area surrounding the turbines more obvious or less attractive to birds.

Each experiment would consist of monitoring the mortality at a number of altered turbines (experimental sites) and non-altered turbines (control sites) for an extended period of time. To achieve a controlled comparison for a matched-pair design, each of the experimental sites should be paired with a control site matched as closely as possible in topographic and structural features. The McNemar matched-pair proportions test should be used for the analysis. This matched-pair design categorizes the sample sites into four different cells for analysis (Table 5.1).

Table 5.1. Layout of data in the McNemar matched-pair proportions test.

		EXPERIMENTAL	
		KILL	NOT KILL
CONTROL	KILL	A (1)*	B (12)
	NOT KILL	C (3)	D (134)

A = Number of pairs where both experimental and control sites killed.

B = Number of pairs where experimental sites did not kill and control sites did kill.

C = Number of pairs where experimental sites killed and control sites did not kill.

D = Number of pairs where both experimental and control sites did not kill.

*Each of the numbers in parentheses is an example of the number of pairs in each cell given the following:

- 150 pairs (150 experimental sites, 150 control)
- Mortality rates for cells B and C are 8% and 2%, respectively, and are based on our yearly mortality estimates (see Table 5.2).
- Mortality rates for cells A and D are <1% and 89%, respectively.

Only turbines associated with high mortality or having qualities that were associated with high mortality should be included in the experiments. This will increase the likelihood of mortality in both the experimental and control groups so that smaller sample sizes will be required to detect meaningful differences. We suggest that in order to meet these objectives and to standardize the samples, only lattice turbines be used in the experiments. This turbine type has been associated with higher mortality than other types and has the highest percentage of turbines in the Altamont Pass WRA. We also suggest that end-row turbines near canyons should be used as much as possible for these experiments, because they also were associated with higher mortality rates. Since there are only 689 lattice end-row turbines and even fewer located near canyons, we are limited in the number of experiments we can perform at one time.

The appropriate sample size depends on a projected mortality rate (number of mortalities). We assume that the number of dead birds discovered will increase with the length of time allowed for sampling. The longer the sampling time, the higher the mortality rate will be and consequently fewer sample sites will be needed to achieve statistically valid results. Our data indicate that the annual raptor mortality rate at lattice end-row turbines was approximately 7 percent (± 5%, $P<0.05$), i.e., 7 turbines out of 100 killed raptors per year. This estimate assumes a sampling effort comparable to the study effort of 15 surveys per year.

Table 5.2 demonstrates the number of sample sites (i.e., sample size) needed based on three different mortality rates and sampling times. The sampling effort used for an experiment can be selected from this table; three alternatives are offered to allow for money and time constraints. It is important to note that for Experiment A (painting blades), each of the experimental and control sites will contain three turbines (see Experiment A below). These sample size requirements were calculated to meet a Type I error rate of $\alpha = 0.05$ and a Type II error rate of $\beta = 0.20$. In other words, these sample sizes are needed to achieve a specified level of confidence in our statistical tests and reasonable error rates given these levels of mortality.

Table 5.2. Three different levels of sampling effort based on projected mortality rates.

SAMPLE SIZE[1]	SAMPLING TIME	MORTALITY RATE[2]	
		CELL B[3]	CELL C[4]
200 pairs	1 year	5%	1%
150 pairs	2 years	8%	2%
100 pairs	3 years	10%	2%

[1]Number of matched pairs. Each pair consists of one experimental and one control site.
[2]Minimum mortality rate needed for valid statistical comparison.
[3]Cell B (experimental sites do not kill, control sites do)
[4]Cell C (experimental sites kill, control sites do not)

The mortality rates shown in Table 5.2 were based on the above-mentioned estimate of yearly mortality during our study and represent a range of projections around this estimate. The percentage of mortality at experimental turbines is lower than at control sites, based on the assumption that treatments will reduce mortality. If we were to assume lower mortality rates, larger numbers of sample turbines would be required to achieve the same level of confidence.

The sampling times are estimates of how long it will take to achieve the projected mortality rates given a particular sample size. Since the projected mortality rates are rough estimates, the sampling times may need to be increased. Sampling should be conducted until the control group achieves the projected mortality, or until enough data are obtained to perform a valid statistical comparison (i.e., when the Type I and Type II error rates have been achieved).

Our original surveys were conducted at one-week intervals for five weeks for each of three seasons (or 15 times per year). To be roughly equivalent, sampling for the proposed experiments should initially be conducted at monthly intervals (or 12 times per year). Sampling frequency should be re-evaluated after six months of sampling and adjusted if it appears that appropriate mortality rates (or appropriate error rates) will not be reached by the end of the established sampling time.

Experiment A - Painting Turbine Blades

Painting turbine blades may increase their visibility to raptors and alert birds to their presence sooner so they can be avoided more easily. Experiments with painted blades are currently being conducted by U.S. Windpower. Although results have been encouraging so far (Howell et al. 1991b), the sample size is small.

In some of the experimental plots having end-row turbines, Howell et al. (1991b) painted blades on the last five turbines in a row. We suggest painting the blades of only the last three turbines in a row at each experimental site. Our data indicate that beyond the third turbine, mortality drops off markedly. We suggest painting the same pattern and color used by Howell et al. (1991b). After enough data have been obtained to determine statistical significance for these patterns and colors (i.e., when the appropriate error rates have been achieved), other patterns and colors should be tested. We suggest using a pattern that would give the illusion of forward movement of the blades (i.e., a spiral). Bright yellow is a color that birds can readily recognize in dim light (E. Colson pers. comm.).

Experiment B - Ground Squirrel Control

One of our theories is that raptors concentrating or stooping on a prey item may be less aware of rotating turbine blades and, consequently, more susceptible to collision mortality. Eliminating ground squirrel populations in the immediate vicinity of a turbine may reduce the potential for mortality at that turbine.

Since ground squirrels normally inhabit sparsely-vegetated grasslands (typically heavily grazed), we suggest creating an exclosure with a 250-ft radius around a selected number (see Table 5.2) of end turbines (experimental sites) to exclude cattle and eliminate grazing. This should discourage ground squirrels from burrowing within the exclosure. In addition, tall grass should reduce raptor visibility of ground-dwelling prey, thereby reducing raptor hunting in these areas. Periodic checks should be made of the fenced areas to assure that ground squirrels are not using them. If they are, other methods should perhaps be considered. We do not think the use of poisons to eliminate ground squirrels is wise because of the potential secondary effects of consumption of poisoned prey on raptors, the endangered San Joaquin kit fox, and other wildlife.

Experiment C - Hazing Raptors with Noise-Producing Devices

Hazing is one of a variety of techniques used to deter animal use of an area. We do not suggest testing whether noise could be used to deter raptors from turbine areas unless the other two methods prove ineffective. A literature search has indicated that this technique may not be effective. Alarm calls and noise makers may effectively disperse certain species such as Canada geese (Aguilera et al. 1991) or gulls (Blokpoel 1980) but may not be effective for territorial raptors. Taped distress signals are more disturbing to birds than sonic devices that emit pure tones or white noise (Bomford 1990), and animals may be less resistant to habituation of sounds which are biological in origin. Smith et al. (1986) found that raptors quickly habituate to noise-making devices such as sonic booms and jet noise. The high degree of tolerance to these noises suggests that hazing devices based on sound may be ineffective.

It may be more effective to install noise-producing devices that would either be emitted intermittently or only when triggered by the approach of a bird. This latter technique may be the most promising hazing method but would require a high degree of technology and money to design.

5.2.2 Hypothesis Testing

Several questions about turbine-related raptor mortality at wind energy developments still need to be addressed. The following experiments and techniques could provide valuable answers to some pressing questions.

Experiment D - Effects of Weather on Mortality

Since deaths are relatively rare, it is difficult to establish a connection between weather and mortality. Searching for dead birds immediately after a winter storm or heavy fog may help establish a relationship. We recommend a sample size of 200 turbines, as many as possible being lattice end-row turbines located near canyons (see Section 5.2.1 above). These turbines should be checked immediately before a winter storm or heavy fog (to remove any dead birds from the sites) and immediately afterwards. To establish a control, these same turbines should be checked in the same manner under clear weather conditions, i.e., control sites should first be cleared of dead birds and then later searched, with the same interval between clearing and surveying as was used for the "storm" surveys. These turbines can be the control turbines from experiments suggested above. However, any raptor found during these experiments should be marked and left in the field for subsequent surveys associated with other experiments. Sampling should continue until the control group achieves approximately 8 percent mortality, or until enough data are obtained to perform a valid statistical comparison (i.e., the error rates have been achieved — see Section 5.2.1). The McNemar matched-pair proportions test also should be used for the analysis.

Experiment E - Video Camera

Video recording an actual kill would provide information on what aspects of raptor behavior put them at risk. Our observers did not witness any deaths. Since this is a relatively rare event, the most cost-effective and reliable means of recording a mortality as it occurred would be to monitor known hot spots (turbines that we know have killed a number of raptors) with an automatic video camera. All-weather video cameras mounted on poles or turbines could be set to monitor bird movement at two to three known hot spots for extended periods of time. Cameras should record from approximately 9:00 AM to 4:00 PM in the fall or winter seasons until at least two mortalities are recorded. The base of the turbine should be checked for dead birds each time the tape is changed. If a dead bird is found, then the tape should be viewed.

Experiment F - Use of GIS

GIS (Geographic Information System) is a computer software program, similar to a relational database management system, that can manage, maintain, and manipulate spatially-referenced data. GIS provides an ideal tool for integrating natural resource information and development data.

We originally intended to use our GIS to facilitate the characterization and analysis of the habitat and structural features that may be related to mortality. Digitized 7.5-minute base maps of the study area were unavailable from the U.S. Geological Survey (USGS), and the larger-scale (low resolution) digitized base maps of the study area that were available were not detailed enough to effectively characterize the habitat. We still feel using GIS would be extremely useful to facilitate the analysis of factors affecting or contributing to raptor mortality on windfarms. The 7.5-minute USGS maps can be digitized by a private consultant. It is also possible for the CEC to request that these maps be digitized by the USGS and to share the cost with them.

A GIS analysis would clarify and validate several of the variables shown to have an effect on mortality. Some examples of what the GIS could do are listed below.

- Define the nature and characteristics of canyons that are close to turbines that have killed raptors.
- Clarify the topographic characteristics of other variables that are associated with mortality such as elevation, position of turbine on slope, and number of slopes.
- Determine the relevance of structure density and distance to closest turbine row by analyzing the habitat characteristics associated with turbines that are various distances apart.
- Analyze the effects of degree of slope on mortality.
- Facilitate selection of the sample turbines that meet specific requirements to be used in the experiments above.

- Conduct a more definitive analysis of mortality in the different turbine types.
- Facilitate development of a model to predict raptor mortality. The model would not only allow us to predict the types of habitat and structural attributes that are associated with mortality but also to locate and map areas of potentially high mortality. This would be of particular importance for future wind energy projects such as those planned for the Solano County WRA.

Experiment G - Effects of Rotor Speed and Blade Configuration on Mortality

It would be valuable to determine whether rotor speeds or blade configurations have an effect on mortality. Information on these turbine characteristics is available from windfarm companies. This experiment should be conducted using our existing mortality data. All turbines we sampled could be classified into categories of rotor speed and blade configuration. The mortality rates could then be compared between these categories. All on-site raptor mortalities (excluding those from extra end-row turbines) should be used to compare rotor and blade characteristics at turbines that killed raptors with turbines that did not. Chi-square tests could be applied to determine whether there were significant differences in the mortality rates among sample turbines with different rotor speeds and configurations.

Experiment H - Effects of Turbine Operation and Wind Speed on Mortality

It would also be of interest to determine whether average wind velocity or the percentage of time turbines are operating has an effect on mortality, and again, this should be tested using our existing data. Data on the percentage of time turbines were in operation were not available to us during our study (see Section 4.1.5); however, this information may be available from windfarm companies in the near future. Hourly and daily wind speed data are available for the locations of our sample turbines.

Average annual wind velocities and the percentage of time turbines are in operation for the year could be compared with mortality rates for turbines that killed raptors and turbines that did not. Mortality rates would be based on on-site raptor deaths excluding those associated with extra end-row turbines. Chi-square tests could be applied to determine whether there were significant differences in mortality rates between sample turbines that were frequently operating and those that were frequently not operating, and between times when wind speeds were high and times when wind speeds were low.

5.3 OFF-SITE COMPENSATION

We suggest two ways of compensating for unavoidable loss of raptor lives and direct loss of habitat as a result of windfarm development in the Altamont Pass WRA:

1. Off-site habitat could be directly purchased or rights obtained through conservation easement agreements. The amount of habitat obtained should be

commensurate with the loss of life and should be decided in consultation with resource agencies such as the USFWS and the CDFG. This habitat should then be enhanced or restored to improve the carrying capacity for raptors in the local area. Suggestions for improvement include installation of nest poles and perch sites and tree plantings.

We feel this habitat compensation is necessary for two reasons. One, effective mitigation measures to reduce turbine-related mortalities may not be available for many years. Additional studies are still needed to better understand the nature of the problem and to determine the best habitat and structural alterations for reducing turbine-related mortality (see Sections 5.2.1 and 5.2.2 above). Two, even after mitigation measures have been instituted it is unlikely that these techniques will eliminate all mortality.

2. Monies could be donated on a yearly basis to local wildlife rehabilitation centers to support their efforts at rehabilitating injured birds. Although there is no biological evidence to suggest that this will mitigate the loss of raptor lives or improve population levels in the Altamont Pass WRA, it may be a means of improving relations between the windfarm industry and public interest groups concerned about this problem.

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APPENDIX A

SPECIES NOTES

Common Name: **American kestrel**

Scientific Name: *Falco sparverius*

Occurrence: Common resident and winter migrant

Status: None

Food Habits: The main foods of the kestrel are insects, small mammals, and small birds.

Hunting/Flight: Kestrels hunt by diving on prey from perch or from soaring or hovering flight. They frequently hover 50-100 ft from the ground, especially when few perches are available. These birds migrate at speeds of 22-36 MPH. Kestrels tend to hover more as wind speeds increase.

Reproduction: Nests in tree cavities or holes in cliffs or stream banks. These birds do not build a stick nest.

Habitat: The kestrel is found in most open habitat types up to 13,000 ft in elevation. They inhabit plains, fields, deserts, agricultural areas, and suburban sites where prey and high perches are plentiful.

Distribution: The kestrel is a year round resident throughout California, moving to lower elevations in winter. Winter migrants may increase local populations.

Literature: Herron et al. (1985), Johnsgard (1990), Palmer (1988), Zeiner et al. (1990).

Common Name: **Bald eagle**

Scientific Name: *Haliaeetus leucocephalus*

Occurrence: Uncommon to rare winter migrants

Status: Federally endangered (FE)
State endangered (CE)
Fully protected in California (CP)
Bald Eagle Protection Act (BEPA)

Reasons for Listing: Historical breeding range of the bald eagle extended from coastal southern California northward through much of the central and northern portion of the state. Present nesting activity is confined to the northern third of the state. A decline in population, seen throughout the lower 48 states, is attributed to pesticide (DDE) contamination, loss of habitat generally through logging and human encroachment, human disturbance, shooting, and degradation of waterways.

Food Habits: Bald eagles hunt for fish, waterfowl, seabirds, and mammals of various sizes. They frequently feed communally on carrion.

Hunting/Flight: Bald eagles hunt by swooping down on prey from high soaring flight, low coursing flight only a few yards above terrain, or from a perch. They also frequently steal food from other birds of prey. Bald eagles are known to wade in water and catch fish with their bill. Migrating birds fly at speeds of 36-44 MPH.

Reproduction: In California, bald eagles usually nest in overstory ponderosa pine trees, in an area relatively free from human disturbance, near a large body of water supporting abundant prey. The nest tree is usually taller than surrounding trees.

Habitat: Bald eagles usually require areas of open water such as wetlands, marshes, rivers, lakes, or oceans supporting abundant prey or carrion. These areas are generally low in human activity and near protected large timber stands used for night roosting which is often communal in winter.

Distribution: The present breeding range of bald eagles in California is limited to the northern third of the state. No coastal nest sites are known. Winter (October through April) distribution includes most of California, excluding desert regions and higher elevations of the

Sierra Nevada. Sightings of bald eagles are infrequent in the Altamont Pass vicinity.

Literature: Avery (1978), Grenfell and Laudenslayer (1983), Grinnell and Miller (1944), Garrett and Dunn (1981), Palmer (1988), Teale (1951), Thelander (1973), Verner and Boss (1980), Zeiner et al. (1990).

Common Name: **Barn owl**

Scientific Name: *Tyto alba*

Occurrence: Common resident

Status: None

Food Habits: Barn owls feed primarily on small rodents and, occasionally, small birds. They are strictly nocturnal.

Hunting/Flight: They hunt at night for prey from a perch or from low hovering and searching flights 5-20 ft above ground.

Reproduction: Nest site is usually an enclosed area, often in man-made structures such as barns, old buildings, and mine shafts. These owls also nest on ledges and in tree cavities. They do not build a nest.

Habitat: Barn owls are found in many habitats. They prefer open agricultural, grassland, chaparral, and riparian areas.

Distribution: A resident bird throughout California, barn owls occur in elevations below 5500 ft. They are not migratory.

Literature: Herron et al. (1985), Zeiner et al. (1990).

Common Name:	**Black-shouldered kite**
Scientific Name:	*Elanus caeruleus*
Status:	Fully protected in California (CP)
Occurrence:	Common to uncommon resident, generally non-migratory
Reasons for Listing:	Prior to the 1940s, black-shouldered kite populations declined to near-extinction in California largely as a result of shooting. With year-round irrigation of croplands and expansion of agricultural lands, kite habitat and prey have become reestablished and black-shouldered kite populations appear to be increasing.
Food Habits:	Kites are obligate predators on diurnal small mammals. In California, voles (*Microtus californicus*) are the primary food item and kites respond nomadically to prey density.
Hunting/Flight:	Kites hunt from a hovering or soaring flight less than 100 ft from the ground. They also hunt from exposed perches. The stoop on prey is a slow, vertical descent with feet first. Their cruising flight is usually 60-215 ft above ground (Palmer, 1988). Generally, 30 percent of the kite's hunting time is spent hovering and 70 percent is spent hunting from a perch (Mendelsohn 1982).
Reproduction:	The nest site is usually 20-50 ft above ground in the crown of a tree. Kite nests are commonly constructed in oak, willow, or other broadleaf deciduous trees near open areas in riparian, blue oak savannah and digger pine-oak habitats. Dense shrubs may also serve as nest sites.
Habitat:	Kites inhabit open areas of grassland, savannah, agricultural fields, marshes, wetlands, and roadsides where rodents are common. In winter, they roost communally in stands of large trees.
Distribution:	Kites are common to uncommon year-long residents of coastal and valley lowlands, generally occurring west of the Sierra Nevada mountains and southern deserts. They are usually found below 1000 ft elevation. Black-shouldered kites are seldom found away from agricultural areas. There is some evidence that coastal populations are migratory.

Literature: Faanes and Howard (1987), Garrett and Dunn (1981), Grinnell and Miller (1944), Herron et al. (1985), Johnsgard (1990), Mendelsohn (1982), Palmer (1988), Small (1974), Verner and Boss (1980), Zeiner et al. (1990).

Common Name: Burrowing owl

Scientific Name: *Speotyto cunicularia*

Occurrence: Locally common resident and migrant

Status: California species of special concern (SSC2)

Reasons for Listing: Populations of burrowing owls are declining throughout California. Reductions in ground squirrel populations have reduced the numbers of available burrows. Farming practices have reduced the available habitat through the reduction of prey species and cover. Habitat has also been lost to urban development.

Food Habits: Insects, small birds, mammals, and reptiles are the main foods of burrowing owls.

Hunting/Flight: They hunt from low perches, hovering flight, and on the ground. Burrowing owls are diurnal and crepuscular, active during the day and evening. Cottam measured the foraging flight speed of this owl at 12 MPH.

Reproduction: Abandoned ground squirrel and mammal burrows are preferred for nesting, although burrowing owls will dig burrows in soft soil covered by harder soil, in open areas. Good visibility from burrows is important. They often form breeding colonies.

Habitat: Burrowing owls prefer open dry grasslands, deserts, agricultural areas, bare open areas, and rolling hills at low elevations, although they will nest in stage alkali shrub sagebrush up to pinyon-juniper and ponderosa pine woodlands. Shrubs and fence posts are used as perches.

Distribution: Burrowing owls range in suitable habitat throughout the length of California and its large, offshore islands, except the coastal forests of the northwest, and high mountains. Most birds are resident but some may migrate short distances or as far south as Central America in the winter.

Literature: Cottam et al. (1942), Gould (1984), Grenfell and Laudenslayer (1983), Herron et al. (1985), Remsen (1978), Verner and Boss (1980), Zeiner et al. (1990).

Common Name: **Common Raven**

Scientific Name: *Corvus corax*

Occurrence: Common resident

Status: None

Food Habits: Common ravens are omnivorous and will eat carrion, small vertebrates, bird eggs and young, and insects as well as fruits, berries, nuts, and grains. They frequently feed at dumps.

Hunting/Flight: Ravens are known to pursue and catch prey. They search for food from a soaring flight or glean food from the ground. Cottam (1942) measured the flight speed of ravens as 35-39 MPH.

Reproduction: A stick nest is built on a cliff or bluff, tall tree, or on a man-made structure. The nest is usually 20-100 ft above ground. Ravens frequently use old raptor nests.

Habitat: Ravens prefer habitat with open terrain and cliffs, bluffs, or sea walls for nesting. They are found at all elevations. In the winter, they may roost communally.

Distribution: This species is a common yearlong resident throughout most of California. Ravens are rare in the Central Valley, at high elevations in the Sierras, and along the central coast of California. They are common in the western United States and in Canada.

Literature: Cottam et al. (1942), Zeiner et al. (1990)

Common Name: **Cooper's hawk**

Scientific Name: *Accipiter cooperii*

Occurrence: Uncommon resident, even during migration

Status: California species of special concern (SSC3)

Reasons for Listing: Once considered a fairly common nester throughout California, breeding populations of Cooper's hawks have declined sharply throughout the state, especially in areas of previous abundance, including the Sacramento Valley and Yosemite regions. In contrast to the breeding season population, a greater number of Cooper's hawks winter in California. The winter populations also have decreased in recent decades. Population declines are attributed to habitat destruction (especially lowland riparian areas), human disturbance, and possibly contamination by persistent pesticides (DDE).

Food Habits: Cooper's hawks feed on small to medium-sized birds and small mammals.

Hunting/Flight: These hawks mainly hunt from a perch in wooded areas. They also fly close to the ground using bushes and trees for concealment as well as stooping on prey from higher flight. Gliding and flapping flight speed ranges from 21-55 MPH.

Reproduction: Nest sites are in wooded areas with dense canopy cover.

Habitat: Cooper's hawks are generally associated with riparian areas and other woodland. Dense tree stands near water are the hawk's preferred habitat. They utilize broken woodlands and forest edges for hunting. However, they also inhabit chaparral. Their elevation range extends from sea level to over 9000 ft.

Distribution: Cooper's hawks are permanent breeding residents throughout most of western California. They commonly breed in the Sierra Nevada foothills of southern California, but occur more frequently as winter residents and migrants in desert regions and the Central Valley. Wintering populations range the length of the state except at higher elevations. During fall, birds from northern areas or areas of heavy snow migrate south and downslope, returning north or upslope in the spring.

Literature: Broun and Goodwin (1943), Grinnell and Miller (1944), Johnsgard (1990), Palmer (1988), Remsen (1978), Small (1974), Verner and Boss (1980), Zeiner et al. (1990).

Common Name: **Ferruginous hawk**

Scientific Name: *Buteo regalis*

Occurrence: Uncommon winter resident and migrant

Status: Federal candidate species, category 2 (FC2)
California Species of Special Concern, (SSC)

Reasons for Listing: Wintering populations of ferruginous hawks in California have declined from historic levels. Urban and agricultural development in central and southern California may be responsible for displacing birds from traditional wintering grounds.

Food Habits: These hawks feed almost exclusively on small rodents and lagomorphs, especially ground squirrels, jackrabbits, and cottontails.

Hunting/Flight: Ferruginous hawks hunt from an elevated perch or the ground and from low searching flight (less than 100 ft above ground) and soaring flight (over 300 ft above ground). The timed flight speed for this hawk is 30-35 MPH. Ferruginous hawks usually fly faster and "float" less than other buteos or eagles.

Reproduction: There are no records of breeding ferruginous hawks in California. Where they do breed, nests are on the ground, in trees, and on cliffs.

Habitat: Unbroken, semiarid grasslands and sagebrush with scattered trees and rock outcrops provide suitable habitat for ferruginous hawks.

Distribution: Ferruginous hawks can be found in central and eastern California during winter months. They breed from the southern Canadian prairie south to southern United States, from Nevada east to Kansas. They spend the winter in western United States and northern Mexico.

Literature: Cottam et al. (1942), Herron et al. (1985), Johnsgard (1990), Palmer (1988), Zeiner et al. (1990).

Common Name: Golden eagle

Scientific Name: *Aquila chrysaetos*

Occurrence: Uncommon resident and migrant

Status: Fully protected in California (CP)
California species of special concern (SSC3)
Bald Eagle Protection Act (BEPA)

Reasons for Listing: Golden eagle populations have declined since the 1940s, especially near human population centers. Now, their numbers are generally remaining stable, with an estimated 500 pairs nesting in California. Electrocution, shooting, human disturbance at nest sites, and agricultural conversion of grasslands are major threats to golden eagles.

Food Habits: Golden eagles' prey includes lagomorphs, rodents and other small mammals, birds, and carrion. Winter killed livestock and big game are seasonally important food sources.

Hunting/Flight: Golden eagles locate prey from soaring flight (100-300 ft), low searching (about 25 ft) flight, or from high perches, and then dive on prey. They also may forage while perched on the ground. Gliding and flapping flight is 28-32 MPH. Golden eagles usually attack upwind and avoid killing prey in downdraft areas. They are very dependent on updrafts for lift and prefer north-west winds for lift over ridges. The eagles tend to soar high on calm days, and fly closer to slopes in strong winds.

Reproduction: Nest sites are located in large trees or on cliffs with an unobscured view. In California, nest trees are usually oaks or eucalyptus. Golden eagle pairs often return to the same nest territory each year, but may switch to another territory if the previous season's breeding attempt failed. They often reuse the previous year's nest but may add new material year after year.

Habitat: Golden eagles prefer open, sloping landscapes such as foothills and canyons, with cliffs and trees for nesting and cover. Adjacent open terrain such as desert, grassland, savannahs, farms, and ranches are utilized for hunting.

Distribution: Throughout California, golden eagles are an uncommon resident and migrant species. Summer breeding distribution is correlated with concentrations of diurnally active rodents such as ground squirrels. This breeding range includes most of California except the Central Valley, the Colorado Desert and the extreme northwest coastal area. Their winter distribution is correlated with concentrations of winter killed ungulates, an area including most of California except the extreme northwest coastal area, the Colorado Desert and the higher elevations of the Sierra Nevada. Golden eagles are regular visitors in the study area, and there are several confirmed territories within the study boundary.

Literature: Avery et al. (1980), Beebe (1974), Broun and Goodwin (1943), Grenfell and Laudenslayer (1983), Herron et al. (1985), Palmer (1988), Remsen (1978), R. Schlorff (1986), Thelander (1974), Zeiner et al. (1990).

Common name: **Great horned owl**

Scientific name: *Bubo virginianus*

Occurrence: Common resident

Status: None

Food Habits: Great horned owls feed primarily on small rodents and lagomorphs, but may take larger mammals.

Hunting/Flight: These owls hunt at dusk and night from a perch. They capture prey on the ground from low, rapid flight. Cottam (1942) measured a flight speed of 40 MPH.

Reproduction: They take over the nests of other birds in trees and on cliffs and are rarely known to construct their own nest. They are one of the earliest nesting bird species.

Habitat: Wooded and riparian habitats with openings and chaparral and desert provide habitat for these birds. They prefer agricultural and riparian areas.

Distribution: Great horned owls are residents throughout California in most habitats below 9000 ft elevation. They are not migratory but moves to higher or lower elevations in response to weather.

Literature: Cottam et al. (1942), Herron et al. (1985), Zeiner et al. (1990).

Common Name: **Merlin**

Scientific Name: *Falco columbarius*

Occurrence: Uncommon to rare winter migrant

Status: California species of special concern (SSC1)

Reasons for Listing: The merlin is not known to nest in California, but the number of birds wintering in the state has dropped drastically in recent years. Reasons for the population decline include habitat destruction and reproductive failure due to DDE contamination.

Food Habits: Merlins primarily eat small birds and insects (especially dragonflies). Small mammals are an infrequent prey item. In the winter, they frequent shorelines to hunt shorebirds.

Hunting/Flight: Merlins forage during rapid flight at low altitude, chasing prey with a short dash or dive from above. Prey is captured in the air or on the ground. They also hunt from a perch or low flight 6 ft above the ground. During migration, merlins may fly late in the day. Average flight speed is 25-35 MPH.

Reproduction: There are no records of merlins breeding in California. They breed in Alaska and Canada in dense tree stands close to water. Nests are usually built in conifers.

Habitat: During the winter in California, merlins inhabit coastlines, open woodlands, savannahs, and grasslands. Merlins prefer edges, early successional stages, and open country and are often nomadic during the winter, searching for areas with abundant prey.

Distribution: The merlin occurs in California as an uncommon transient and winter visitor from late September to May. Ranging the length of the state below 3900 ft, the birds concentrate along the coast and in the Central Valley. Fall migrants pass along the coast and coastal estuaries, along inland valleys with scattered groves of trees, and in desert areas where open agricultural land is broken up with groves of trees. They rarely are seen in heavily wooded areas or in open deserts.

Literature: Garrett and Dunn (1981), Grinnell and Miller (1944), Palmer (1988), Remsen (1978), Small (1974), Verner and Boss (1980), Zeiner et al. (1990).

Common Name:	**Northern harrier**
Scientific Name:	*Circus cyaneus*
Occurrence:	Common resident
Status:	California species of special concern (SSC2)
Reasons for Listing:	Breeding and wintering populations of harriers have declined from former levels throughout California. This population decline is attributed to destruction of marsh habitat and grazing impacts on grassland.
Food Habits:	Feeds on small mammals, small birds and, occasionally, waterfowl.
Hunting/Flight:	Harriers hunt from a searching flight, coursing 3-30 ft above vegetation and diving on prey. They frequently hover and also hunt while perched on the ground or fence posts. Acoustic clues are very important for locating prey. Flapping flight during migration or when moving to and from roost is often more than 15 ft above vegetation at speeds of 24-38 MPH. Flights are usually down wind. Harriers tend to fly at lower elevations when going into a head wind.
Reproduction	Breeding birds build stick nests on the ground in grass or brush, often near water. In California, harrier breeding is concentrated in the Central Valley, the central and north coasts, northeastern California, and other scattered locations. The most concentrated breeding occurs in the ungrazed portions of state and federal wildlife refuges. In California, harriers rarely breed above 1000 ft elevation.
Habitat:	Northern harriers inhabit freshwater and saltwater marshes, grasslands, desert sinks, mountain meadows and other open habitats in the grass/forb successional stage. These birds may roost communally in winter. They are found throughout California at elevations below 9000 ft elevation.
Distribution:	Summer and winter distributions of northern harriers range the length of California. Some migratory movement into higher elevations occurs during late summer and fall.
Literature:	Broun and Goodwin (1943), Grinnell and Miller (1944), Herron et al. (1985), Palmer (1988), Remsen (1978), Small (1974), Verner and Boss (1980), Zeiner et al. (1990).

Common Name:	**Peregrine falcon**
Scientific Name:	*Falco peregrinus anatum*
Occurrence:	Uncommon to rare migrant and breeding resident
Status:	Federally endangered (FE) State endangered (CE) Fully protected in California (CP)
Reasons for Listing:	California peregrine falcon populations declined sharply in recent decades, mostly due to DDE-related eggshell thinning, loss of riparian and marsh habitat, illegal shooting, and activities of outlaw falconers. Once down to two known pairs in the mid-1970s, the present-day population in California is approximately 80 breeding pairs. This recovery is a direct result of an intensive captive breeding and release program and eyrie protection measures during the breeding season.
Food Habits:	The primary prey of inland peregrines is medium-sized birds, which are captured in the air. They rarely take mammals, fish, or insects.
Hunting/Flight:	Falcons stoop onto flying prey while in soaring or searching flight or from a perch. Their flapping flight is 25-35 MPH.
Reproduction:	Peregrine falcons usually nest in a scrape on cliffs exceeding 100 ft in height near water. Suitable gravel or soil lined ledges or caves are required. They do not build a nest.
Habitat:	Nesting territories are principally located in open areas near water supporting abundant bird life for prey. Wintering peregrine falcons utilize coastal and inland marsh and riparian areas.
Distribution:	In California, peregrine falcons are breeding and winter residents, as well as migrants. Their breeding range includes the coast and coastal mountains north of Santa Barbara, and the mountains of northern California and the Sierra Nevada. Wintering peregrine falcons are found inland throughout the Central Valley and in the northeast and southwest corners of the state, primarily near wetlands.
Literature:	Avery et al. (1980), Call (1978), CDFG (1980), Herron et al. (1985), Johnsgard (1990), Palmer (1988), Thelander (1976), B. Walton (pers. comm.), Zeiner et al. (1990).

Common Name: **Prairie falcon**

Scientific Name: *Falco mexicanus*

Occurrence: Uncommon resident

Status: California species of special concern (SSC3)

Reason for Listing: Once common throughout California, regional prairie falcon populations around the perimeter of the Central Valley showed low nest site occupancy and low recruitment during the 1960s and 1970s. Desert area populations are still high and recent surveys indicate improvements in the Central Valley perimeter population. Reasons for the decline include nest robbing by falconers, shooting, human activity disturbance, changes in land use, human control of vertebrate prey species, and possibly pesticide contamination.

Food Habits: Feeds on small birds, mammals and reptiles. Ground squirrels (*Spermophilus spp.*) are a preferred food.

Hunting/Flight: Hunts by rapid pursuit and from exposed perches mostly within 90 ft of the ground. Prey is caught on the ground or in the air from a dive off a perch or from searching flight (50-300 ft) or soaring flight (300-450 ft) above ground.

Reproduction: Prairie falcons often nest in scrapes in crevices or potholes in cliffs or rock outcrops, 30 ft to over 400 ft high, with a view of open country for hunting. They occasionally utilize stick nests built by other raptors, usually situated on cliffs with a rock overhang above the nest.

Habitat: They inhabit open arid lands and prairies such as savannah, rangeland, and desert scrub.

Distribution: Prairie falcons are an uncommon permanent resident and migrant ranging from the southwestern deserts up the inner coast ranges and the Sierra Nevada to Trinity and Shasta counties, and including the north coast and the Modoc Basin of northeastern California. They are rare on the western slope of the Sierra Nevada. Movement above timberline can occur during late summer, and they retreat to lower elevations during winter. Prairie falcons may reside in their breeding habitat during the winter, or may move into the Central Valley and coastal habitats.

Literature: Call (1978), Garrett and Mitchell (1973), Grenfell and Laudenslayer (1983), Herron et al. (1985), Johnsgard (1990), Palmer (1988), Remsen (1978), Small (1974), Verner and Boss (1980), Zeiner et al. (1990).

Common Name: **Red-tailed hawk**

Scientific Name: *Buteo jamaicensis*

Occurrence: Common resident and migrant

Status: None

Food Habits: Red-tailed hawks feed on small mammals, such as rodents and lagomorphs, birds, reptiles, and carrion. In California, their most important prey is ground squirrel. The prey is killed on the ground.

Hunting/Flight: These birds hunt by dropping down on prey from elevated, exposed perches or from soaring flight or searching flight (less than 200 ft above ground). They commonly perch on man-made structures such as power poles. Flapping and gliding flight speeds range from 20-40 MPH and aerial dives may be as fast as 120 MPH. Red-tails tend to soar high during windy weather and may not fly at all during very windy or bad weather. More updrafts for soaring are found along north-south running ridges.

Reproduction: These hawks build a large stick nest 30-70 ft above ground in the top of a tall tree. The nest tree is usually taller than surrounding trees and is often high on a slope or hill. These birds nest in virtually all habitats up to 9000 ft.

Habitat: Red-tailed hawks inhabit open grasslands, savannah, mixed woodlands, and agricultural areas. They are often found near human habitations.

Distribution: Red-tails occur as breeding birds and winter residents throughout California. Winter migrants may increase the population density in many areas.

Literature: Broun and Goodwin (1943), Herron et al. (1985), Johnsgard (1990), Palmer (1988), Zeiner et al. (1990).

Common Name: **Rough-legged hawk**

Scientific Name: *Buteo lagopus*

Occurrence: Common to uncommon winter migrant

Status: None

Food Habits: Rough-legged hawks primarily hunt small rodents, especially voles and lemmings. They feed occasionally on small to medium-sized birds and carrion. Rough-legged hawk abundance varies with prey availability.

Hunting/Flight: These hawks hunt mostly from an elevated perch in the evenings, preferring utility poles to trees. Hunting from a searching and hovering flight at 45-120 ft above ground is also common. Rough-legged hawks are less dependent on thermals than other hawks.

Reproduction: The nest site is on a cliff with overhangs where the hawk builds a stick nest. These birds will also nest on the ground in a high place.

Habitat: In its breeding grounds in northern Canada and Alaska, the rough-legged hawk inhabits open tundra. In its wintering grounds in the United States, the birds are found in open grassland, savannah, coastal marshes, and agricultural areas near riparian or wooded habitats. They favor open habitats.

Distribution: This hawk is a winter migrant to central and eastern California. In North America, it breeds in northern Canada and Alaska. The wintering grounds extend south from southern Alaska to California, southern Texas and Maryland.

Literature: Herron et al. (1985), Johnsgard (1990), Palmer (1988), Zeiner et al. (1990).

Common Name: **Sharp-shinned hawk**

Scientific Name: *Accipiter striatus*

Occurrence: Uncommon in California except in migration and as a winter resident.

Status: California species of special concern (SSC3)

Reasons for Listing: Historically, sharp-shinned hawks bred in small numbers throughout northern California, and in small numbers in all the mountain ranges of southern California as far south as San Diego County. Now the breeding population appears greatly reduced from former levels, although data are lacking. Only a few individuals are reported during the summer months, and most of these are from northern California. In contrast to the summer population, the winter population is much larger and appears stable. Since the total California breeding population is small, it is more vulnerable to potential threats including logging, habitat loss, and pesticide pollution causing eggshell thinning.

Food Habits: Sharp-shinned hawks feed primarily on small passerine birds, but also hunt for small mammals, lizards, and insects.

Hunting/Flight: These hawks hunt for prey while in rapid flight in the forest edge or canopy or attack prey from a concealed perch. They are extremely agile in flight. Birds often hunt from low gliding flight.

Reproduction: Breeding habitat for sharp-shinned hawks includes ponderosa pine, black oak, riparian deciduous, mixed conifer, and Jeffrey pine habitats. The nest is typically in a conifer stand with moderate to dense canopy cover near a forest opening and water.

Habitat: Sharp-shinned hawks prefer riparian habitats but are also found in moderate to dense woodland and chaparral. During winter, the hawks are found in all habitats, occasionally foraging in annual grasslands.

Distribution: Most breeding sharp-shinned hawks nest in northern California, although only a few individuals are reported during the summer months. Most of the birds perform long distance migrations. Sharp-shinned hawks winter in significant numbers in California, ranging the length of the state. During migrations and winter, they are the most numerous accipiter in the state.

Literature: Garret and Dunn (1981), Grinnell and Miller (1944), Palmer (1988), Johnsgard (1990), Remsen (1978), Small (1974), Verner and Boss (1980), Zeiner et al. (1990).

Common Name: **Short-eared owl**

Scientific Name: *Asio flammeus*

Occurrence: Uncommon resident and migrant

Status: Bird species of special concern (second priority) (SSC2)

Reasons for Listing: Short-eared owls have experienced loss of nesting habitat in lowland marsh and grassland habitat due to overgrazing, water diversion projects and recreational development. In the Central Valley, cultivation and marsh drainage have been key factors in habitat loss, and shooting has also significantly reduced populations.

Food Habits: These crepuscular and diurnal owls feed primarily on small mammals, especially voles and mice. Birds are important prey in the coastal wintering grounds.

Hunting/Flight: The flight pattern of short-eared owls while hunting is erratic, with frequent changes in direction and altitude. Prey is captured on the ground from a low quartering flight 3-20 ft above ground. Also hunts from a perch. Hunting occurs during the day and at dawn and dusk. Cottam (1942) measured the flight speed of this owl as 15-26 MPH.

Reproduction: Nests on the ground in tall brush or grass.

Habitat: Short-eared owls are found in open country, marshes and wet meadows, tundra, and fields. They nest in grassland below 2000 ft elevation. They also occur in blue oak and digger pine - oak woodland on the west slopes of the Sierra Nevada during the non-breeding season.

Distribution: A migratory owl, short-eared owls are more frequently found in winter in California. Their winter range includes the California coastal area, the Central Valley, and northeastern California at low elevations. Once common throughout California in suitable habitat, short-eared owls no longer breed in southern coastal areas. The only known breeding locations include areas near Davis, Yolo County; Bair Island, San Mateo County; Salinas River and Moss Landing, Monterey County; Ash Creek Wildlife Area, Lassen County; and probably Honey Lake Wildlife Area.

Literature: Avery (1978), Cottam et al. (1942), Dailey (1978), Gould (1984), Grenfell and Laudenslayer (1983), Herron et al. (1985), Zeiner et al. (1990).

Common Name: Swainson's hawk

Scientific Name: *Buteo swainsoni*

Occurrence: Uncommon breeding resident (locally common inland, especially during migration)

Status: Federal candidate species, Category 2 (FC2)
State threatened (CT)

Reasons for Listing: Once an abundant breeding raptor in the non-forested lowlands of California, Swainson's hawk populations have declined markedly during this century. This loss is attributed to conversion of grassland areas and pastureland to cropland, destruction and degradation of riparian habitat in the Central Valley, human disturbance, shooting, and possible pesticide contamination and deterioration of South American wintering grounds.

Food Habits: Swainson's hawks feed almost exclusively on rodents and large insects.

Hunting/Flight: These hawks hunts from low searching flight typically less than 100 ft from the ground, high soaring flight, or from an elevated perch. They frequently perch on the ground to hunt for ground squirrels or large insects.

Reproduction: In California, Swainson's hawks nest in broad, sparsely vegetated flatlands (valleys, plateaus, flood plains, and desert) ranging from sea level up to 7100 ft elevation. Stick nests are usually located 4-100 ft above ground in a solitary tree or small grove near grassland, sagebrush, alfalfa, and hayfields where they hunt. Central Valley nests are frequently within one mile of a riparian zone and are usually built in valley oaks or cottonwoods. Great Basin nests are almost exclusively built in junipers and are not close to riparian areas.

Habitat: Swainson's hawks are found in open grassland, woodland, savannah, and agricultural areas.

Distribution: The 1980 breeding range of Swainson's hawks included the northeast corner of California, and the Central Valley from Shasta County south to Fresno County, plus five single territories, scattered around the state. During the spring and fall migration they range the length

of the state as they travel to and from their wintering grounds in South America.

Literature: Bloom (1980), CDFG (files), CNDDB (1986), Herron et al. (1985), Palmer (1988), Remsen (1978), Schlorff and Bloom (1981), Small (1974), Stahlecher (1978), Verner and Boss (1980), Zeiner et al. (1990).

Common Name:	**Turkey vulture**
Scientific Name:	*Cathartes aura*
Occurrence:	Common resident
Status:	None
Food Habits:	Turkey vultures feed almost exclusively on carrion which they locate by both sight and smell. They prefer fresh meat and, rarely, will kill young herons and ibises. Vultures are social and gregarious when feeding.
Hunting/Flight:	Vultures forage for carrion from high soaring flight, 200 ft or more above ground, or low searching flight, just above vegetation. Their flight speed is about 20-34 MPH. Migrating birds fly between 4000 ft and 5000 ft. Flying vultures often assemble on a favorable wind current or over carrion in groups known as "kettles."
Reproduction:	The nest site is on the ground, on cliffs, or in hollow trees. Breeding birds do not build a nest.
Habitat:	Turkey vultures can be found in most habitats but seem to prefer open lowland areas with hot, dry climates. They use communal roost sites near water.
Distribution:	Turkey vultures breed throughout California but are winter residents only along the coast. Central and eastern California birds migrate south in winter to southern United States and Central America.
Literature:	Broun and Goodwin (1943), Herron et al. (1985), Palmer (1988), Teale (1951), Zeiner et al. (1990).

APPENDIX B

FIGURES AND TABLES

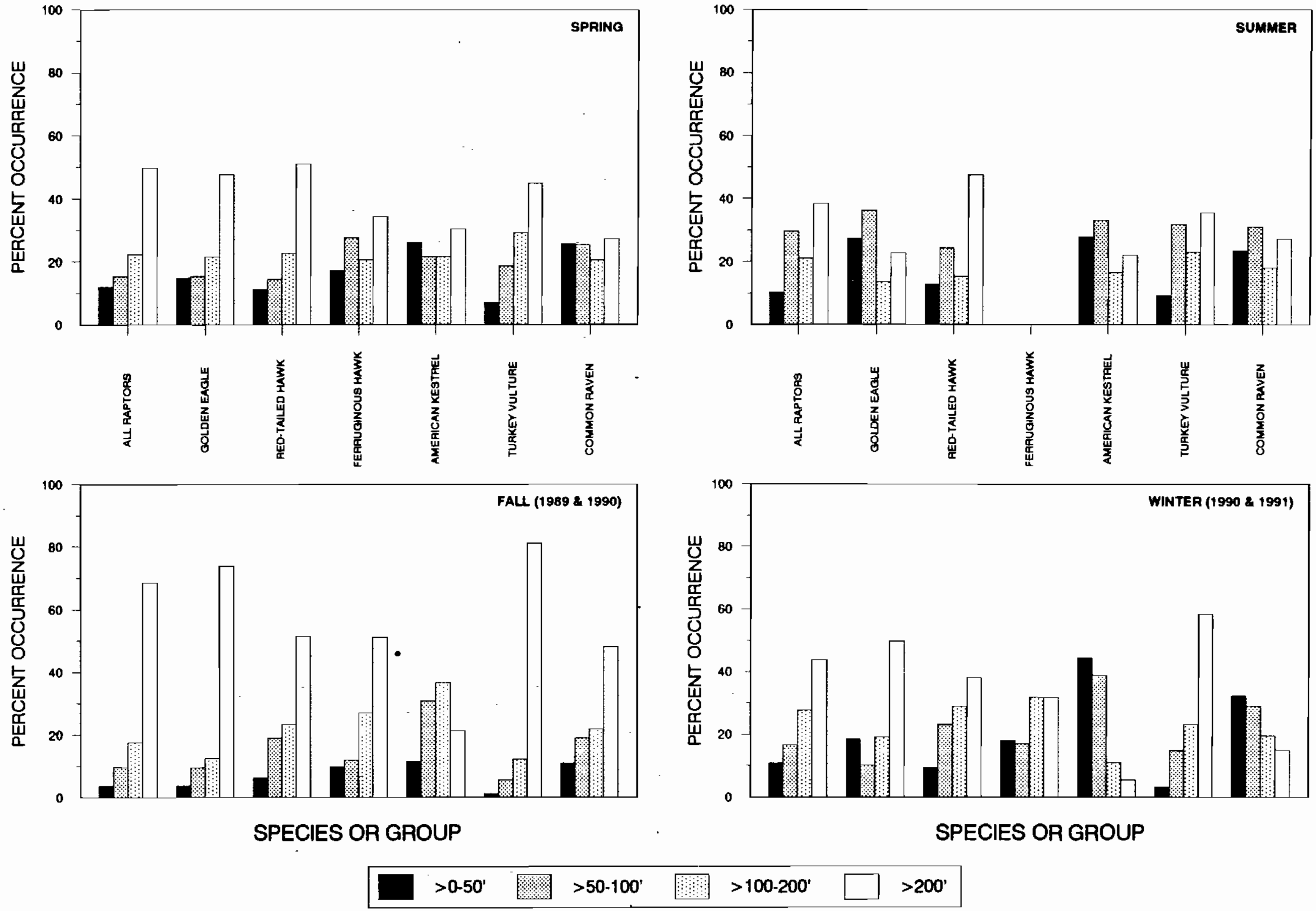

Figure B-1. Distance above ground of birds observed during site-specific surveys, flying birds only, by season, 1989-1991, Altamont Pass WRA.

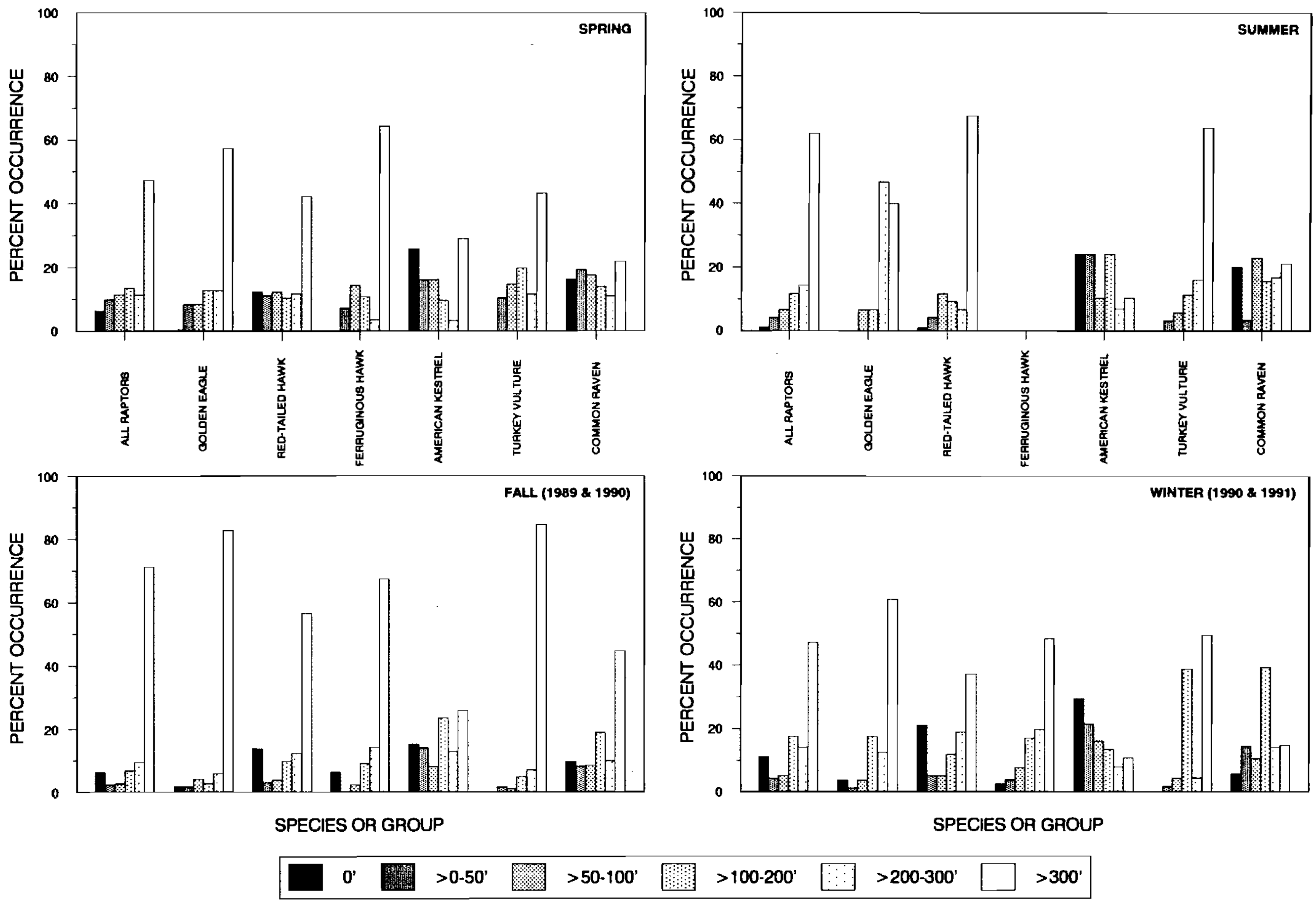

Figure B-2. Distance to turbine structure of birds observed during site-specific surveys, by season, 1989-1991, Altamont Pass WRA.

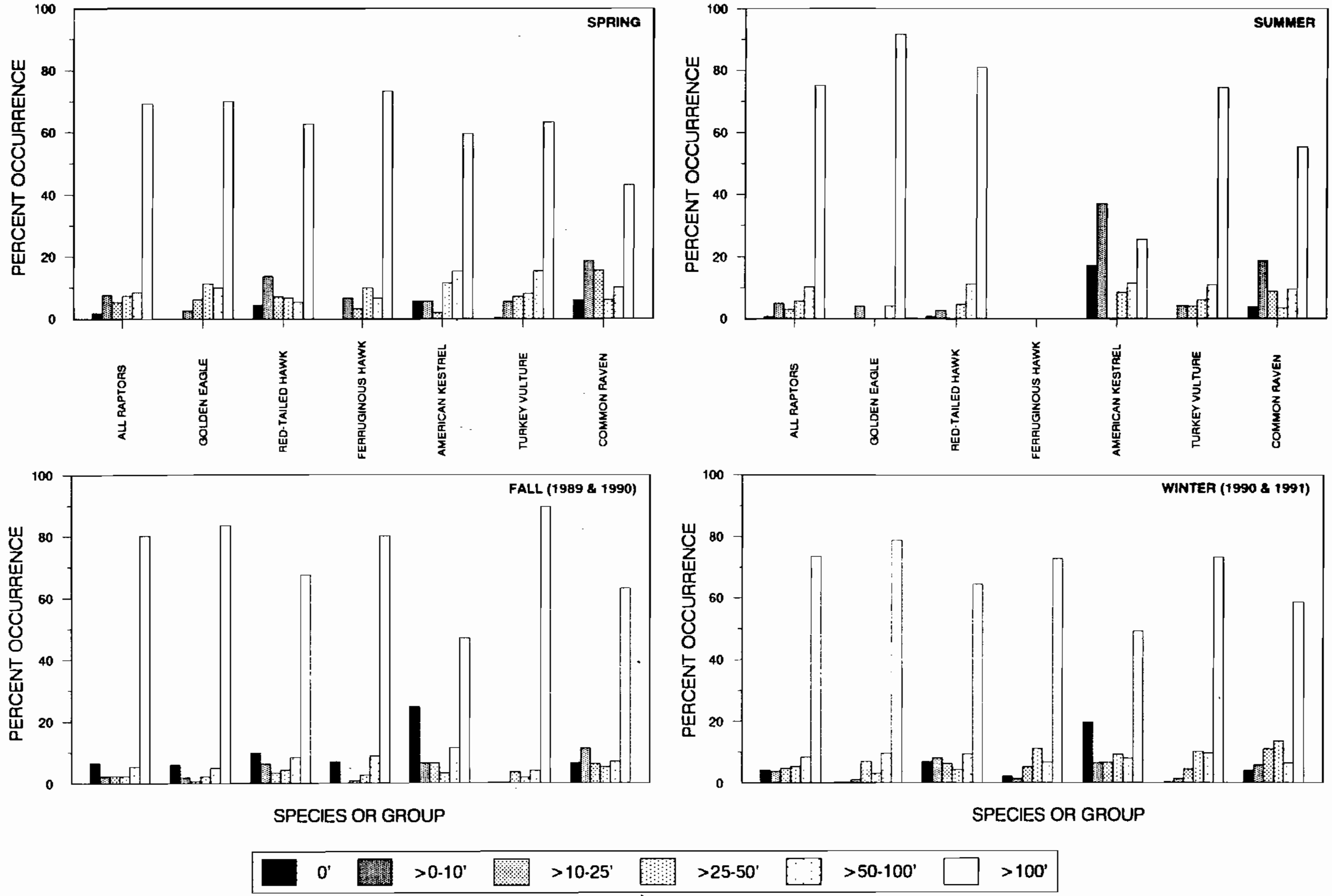

Figure B-3. Minimum distance to turbine blades of birds observed on site-specific surveys, by season, 1989-1991, Altamont Pass WRA.

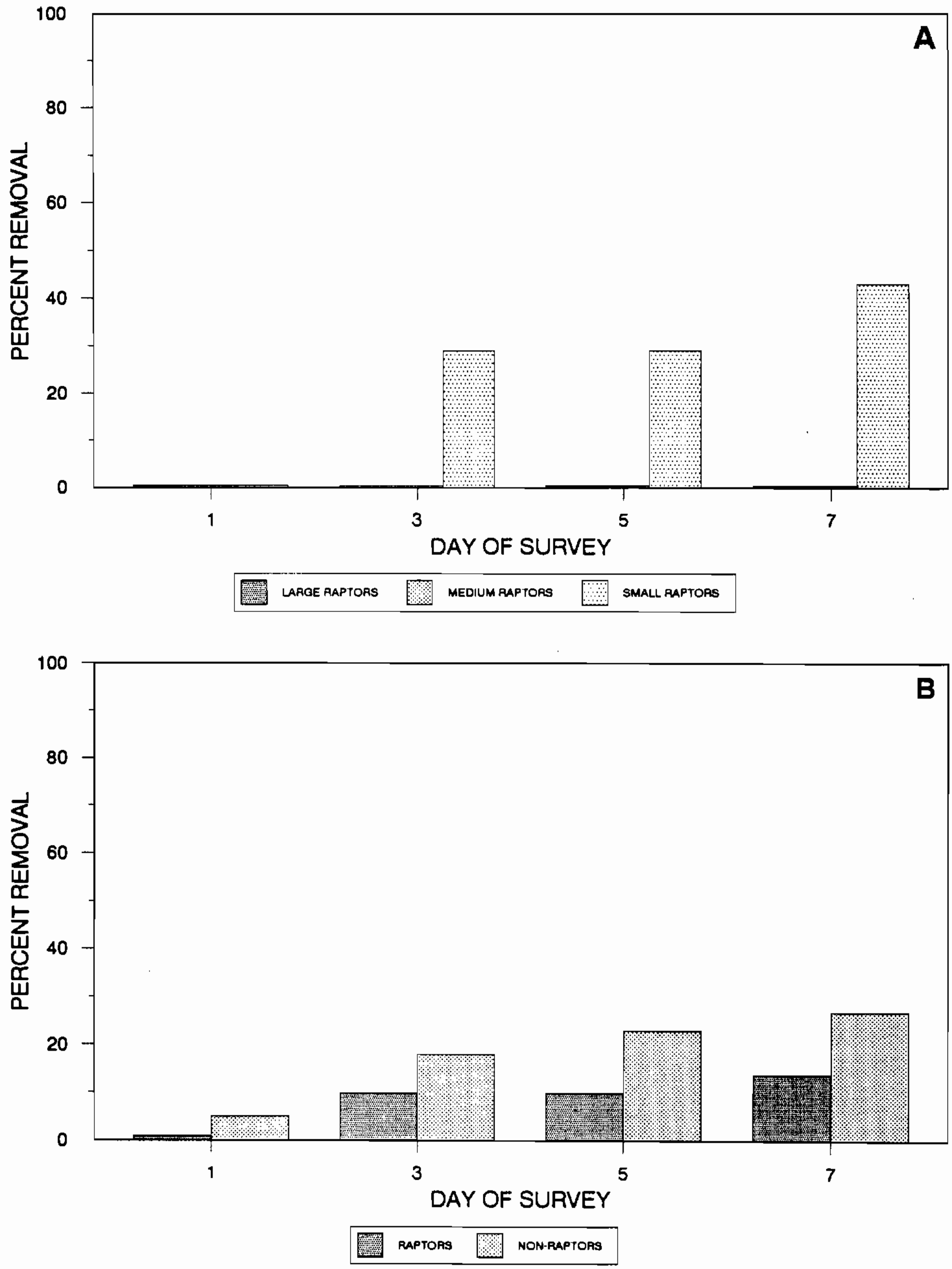

Figure B-4. Scavenger removal of A) three size classes of raptor carcasses, and B) raptor versus non-raptor (excluding chicken) carcasses, spring 1989, Altamont Pass WRA.

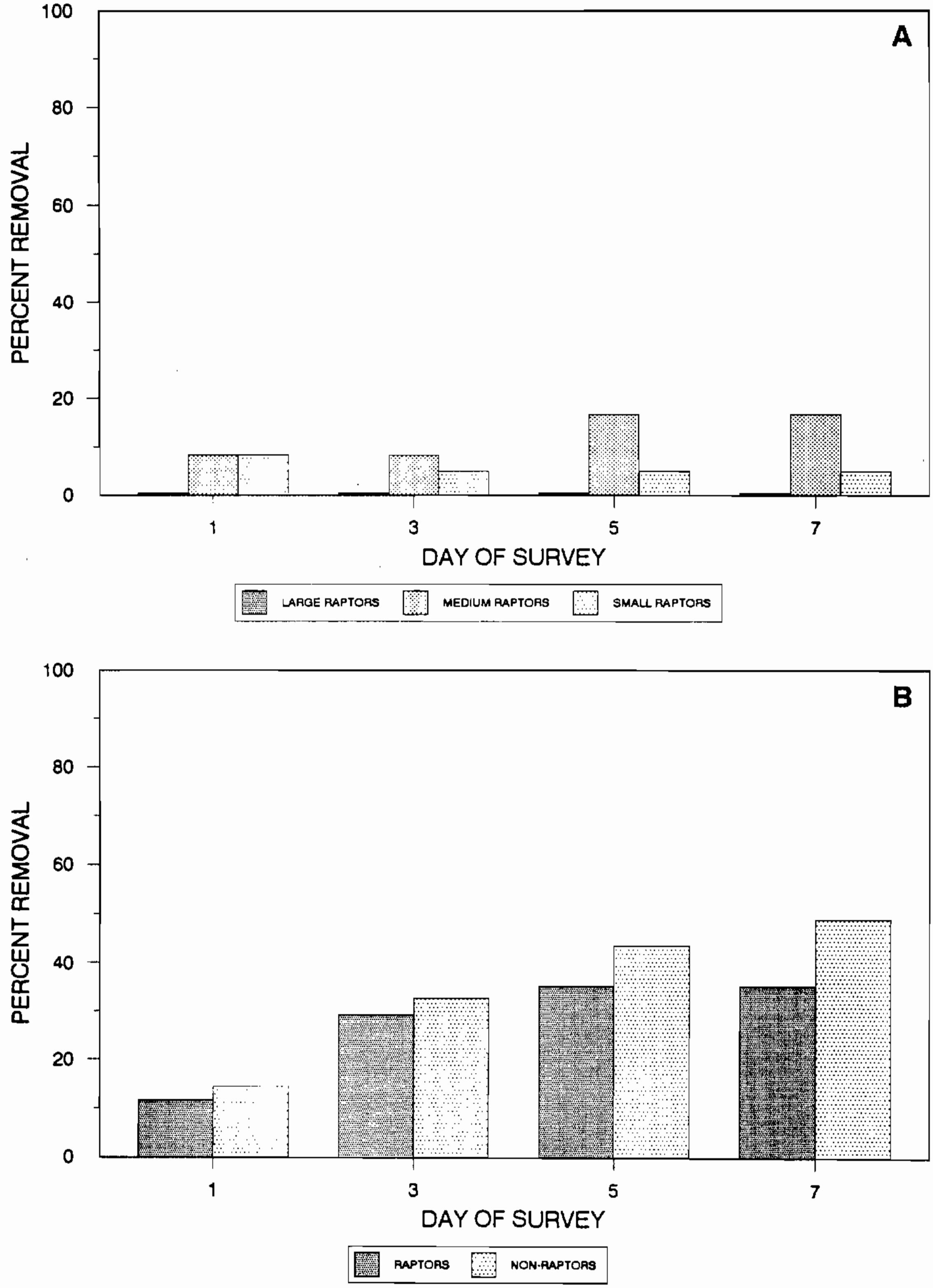

Figure B-5. Scavenger removal of A) three size classes of raptor carcasses, and B) raptor versus non-raptor carcasses, summer 1990, Altamont Pass WRA.

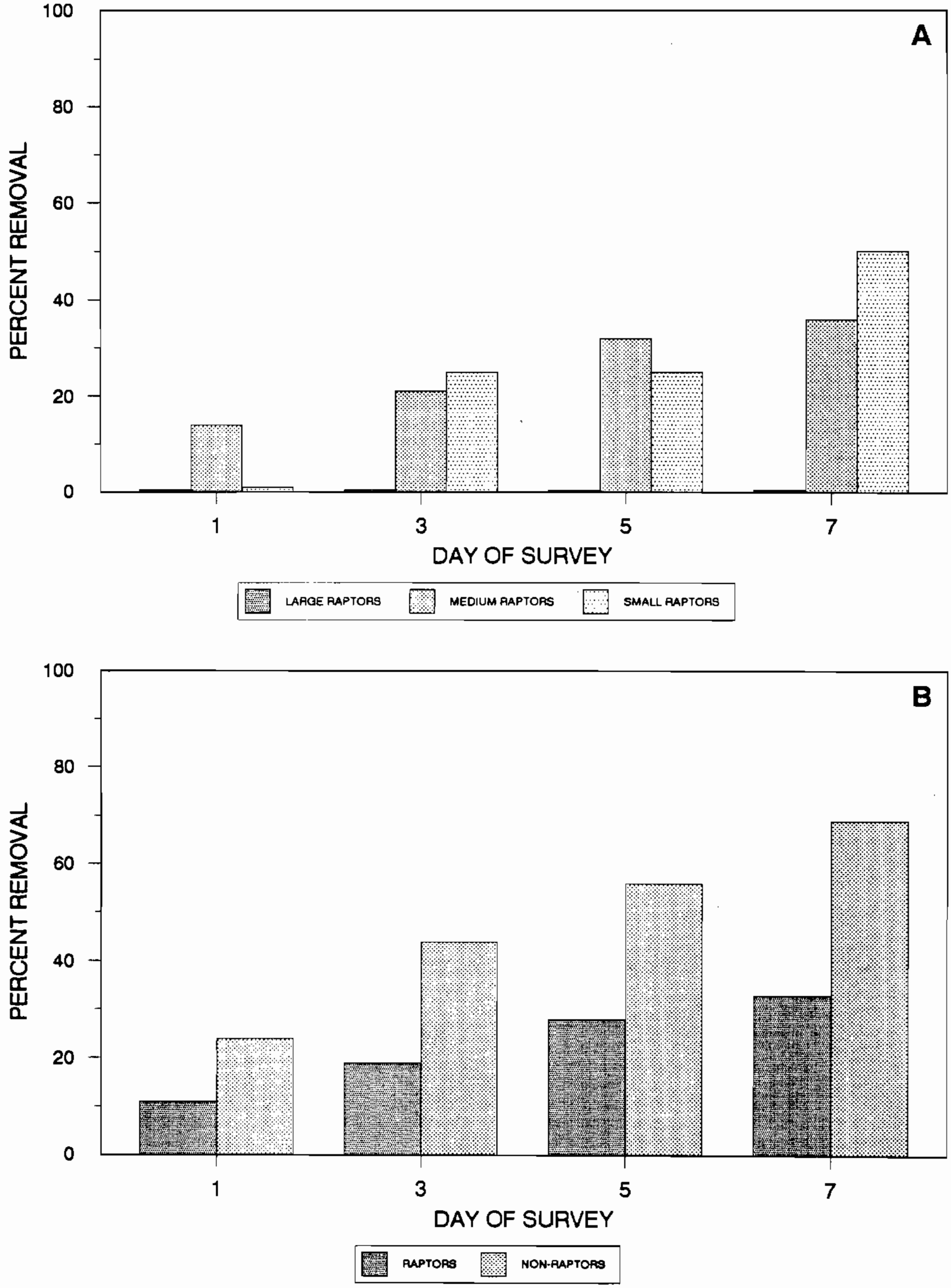

Figure B-6. Scavenger removal of A) three size classes of raptor carcasses, and B) raptor versus non-raptor carcasses, fall 1989, Altamont Pass WRA.

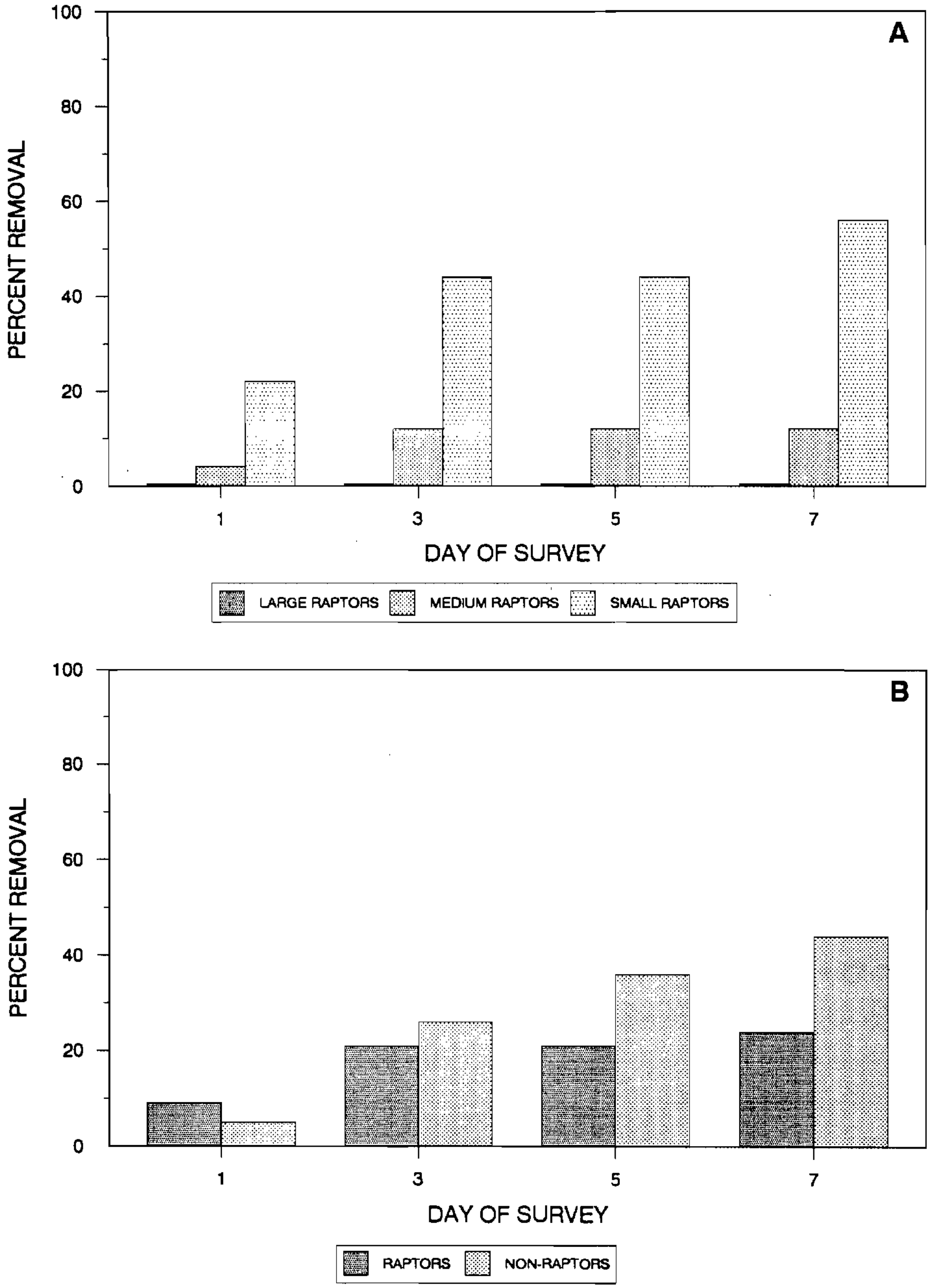

Figure B-7. Scavenger removal of A) three size classes of raptor carcasses, and B) raptor versus non-raptor, winter 1990, Altamont Pass WRA.

Table B.1. Number of turbines in each turbine-type category, Altamont Pass WRA.

TURBINE TYPES	TOTAL NUMBER	PERCENTAGE OF TOTAL	NUMBER SURVEYED	PERCENTAGE SURVEYED
Three-blade lattice - downwind	3,359	46.0%	460	39.4%
Three-blade lattice - upwind	248	3.4%	77	6.6%
Guyed-pipe tower	1,559	21.0%	236	20.2%
Two-blade lattice	346	4.7%	- -	- -
Medium tubular	1,421	19.4%	242	20.7%
Large tubular	135	1.8%	- -	- -
Vertical axis	169	2.3%	82	7.0%
Windwall	103	1.4%	72	6.2%
TOTAL	7,340 [1]	100.0%	1,169	100.0%

[1] In 1990, 281 3-blade lattice turbines were added by U.S. Windpower, bringing the total to 7,621.

Table B.2. Species composition and percent occurrence of birds observed during driving surveys, all seasons combined, 1989-1990, Altamont Pass WRA.

SPECIES	TOTAL	MEAN/SCAN	PERCENT OCCURRENCE
American kestrel	224	0.128	4.68
Bald eagle	22	0.013	0.46
Burrowing owl	7	0.004	0.15
Cooper's hawk	3	0.002	0.06
Ferruginous hawk	115	0.065	2.40
Golden eagle	550	0.313	11.50
Great horned owl	1	0.001	0.02
Merlin	2	0.001	0.04
Northern harrier	54	0.031	1.13
Osprey	1	0.001	0.02
Prairie falcon	29	0.015	0.61
Rough-legged hawk	27	0.015	0.56
Red-tailed hawk	791	0.450	16.54
Turkey vulture	814	0.464	17.02
Unknown raptor	312	0.178	6.52
Unknown buteo	182	0.104	3.81
Unknown eagle	23	0.013	0.48
Unknown falcon	11	0.006	0.23
Sub-total	3,168	1.804	66.30
Common raven	1,430	0.814	29.90
Great blue heron	2	0.001	0.04
Long-billed curlew	1	0.001	0.02
Unknown goose	100	0.057	2.09
Unknown duck	72	0.041	1.51
Unknown gull	7	0.004	0.15
Sub-total	1,612	0.918	33.70
TOTAL	4,780		100.0

Table B.3. Species composition and percent occurrence of birds observed during the Solano County driving survey, 1989, Solano County WRA.

SPECIES	TOTAL	MEAN/SCAN	PERCENT OCCURRENCE
American kestrel	129	0.777	16.41
Barn owl	1	0.006	0.13
Ferruginous hawk	11	0.066	1.40
Golden eagle	13	0.078	1.65
Northern harrier	31	0.187	3.94
Prairie falcon	10	0.060	1.27
Rough-legged hawk	32	0.193	4.07
Red-tailed hawk	233	1.404	29.64
Turkey vulture	238	1.434	30.28
Unknown raptor	40	0.241	5.09
Unknown buteo	25	0.150	3.18
Unknown eagle	1	0.006	0.13
Unknown falcon	1	0.006	0.13
Sub-total	765	4.608	97.33
Common raven	21	0.127	2.67
Sub-total	21	0.127	2.67
TOTAL	786		100.0

Table B.4. Species composition and percent occurrence of birds observed on site-specific surveys, all seasons combined, 1989-1991, Altamont Pass WRA.

SPECIES	TOTAL	MEAN/SCAN	PERCENT OCCURRENCE
American kestrel	286	0.053	2.89
Bald eagle	63	0.012	0.64
Burrowing owl	2	0.000	0.02
Black-shouldered kite	4	0.001	0.04
Cooper's hawk	3	0.001	0.03
Ferruginous hawk	275	0.051	2.78
Golden eagle	1,056	0.194	10.67
Northern harrier	77	0.014	0.78
Osprey	1	0.000	0.01
Peregrine falcon	1	0.002	0.01
Prairie falcon	54	0.008	0.55
Rough-legged hawk	26	0.005	0.26
Red-tailed hawk	1,633	0.301	16.50
Sharp-skinned hawk	3	0.001	0.03
Turkey vulture	1,937	0.356	19.57
Unknown raptor	933	0.172	9.43
Unknown buteo	364	0.067	3.68
Unknown eagle	121	0.022	1.22
Unknown falcon	21	0.004	0.21
Unknown accipiter	1	0.000	0.01
Sub-total	6,861	1.264	69.31
Common raven	2,635	0.485	26.62
Great blue heron	2	0.000	0.02
American white pelican	72	0.013	0.73
Unknown goose	1	0.000	0.01
Unknown duck	148	0.027	1.50
Unknown gull	180	0.033	1.82
Sub-total	3,038	0.559	30.69
TOTAL	9,899		100.0

Table B.5. Correlations between variables*.

CORRELATIONS

VARIABLE	ELEVATION	SLOPE POSITION	NUMBER OF SLOPES	DISTANCE TO CANYON	CLOSE TO CANYON	FIRST TURBINE ROW	END TURBINE	DISTANCE TO STRUCTURE	STRUCTURE DENSITY	TURBINE TYPE LATTICE	TURBINE TYPE TUBULAR	TURBINE TYPE GUYED-PIPE	TURBINE TYPE WIND-WALL
ELEVATION	1.000000	.400743	.504983	(.367590)	.218662	.253999	(.071157)	.249567	(.230551)	.231219	(.049064)	(.424246)	.273647
SLOPE POSITION	.400743	1.000000	.642949	(.292014)	.277166	.261990	(.031110)	.320426	(.246744)	.007043	.039936	(.149008)	.181148
NUMBER OF SLOPES	.504983	.642949	1.000000	(.266660)	.259520	.169923	(.025033)	.281697	(.315217)	.117372	(.068790)	(.196659)	.145528
DISTANCE TO CANYON	(.367590)	(.292014)	(.266660)	1.000000	(.530457)	.141739	(.000032)	(.079786)	(.020123)	(.056159)	(.278230)	.399511	(.064513)
CLOSE TO CANYON	.218662	.277166	.259520	(.530457)	1.000000	.028535	.000787	.076767	(.006762)	(.054756)	.173322	(.146294)	.019446
FIRST TURBINE ROW	.253999	.261990	.169923	.141739	.028535	1.000000	.015463	.373538	(.338449)	(.022080)	.055663	(.071935)	.129948
END TURBINE	(.071157)	(.031110)	(.025033)	(.000032)	.000787	.015463	1.000000	(.042087)	.020687	(.085071)	.078447	(.012113)	.005877
DISTANCE TO STRUCTURE	.249567	.320426	.281697	(.079786)	.076767	.373538	(.042087)	1.000000	(.628940	.218982	(.025120)	(.372682)	.241520
STRUCTURE DENSITY	(.230551)	(.246744)	(.315217)	(.020123)	(.006762)	(.338449)	.020687	(.628940)	1.000000	(.389193)	.178834	.366375	(.196743
TURBINE TYPE													
LATTICE	.231219	.007043	.117372	(.056159)	(.054756)	(.022080)	(.085071)	.218982	(.389193)	1.000000	(.483258)	(.474826)	(.203216)
TUBULAR	(.049064)	.039936	(.068790)	(.278230)	.173322	.055663	.078447	(.025120)	.178834	(.483258)	1.000000	(.267303)	(.114400)
GUYED-PIPE	(.424246)	(.149008)	(.196659)	.399511	(.146294)	(.071935)	(.012113)	(.372682)	.366375	(.474826)	(.267303)	1.000000	(.112404)
WINDWALLS	.273647	.181148	.145528	(.064513)	.019446	.129948	.005877	.241520	(.196743)	(203216)	(.114400)	(.112404)	1.000000

*( ) = Negative numbers

APPENDIX C

OBSERVATION SURVEY CODE SHEET
MORTALITY CODE SHEET

Driving Survey ·m Codes

Description	Codes
Route	A (Southern Route) or B (Northern Route)
Observer	Personal Initials
Foggy	Yes/No and describe in Notes
Cloud Cover	Estimated %
Temperature	°F
Wind Direction	Alpha 8-Point Compass Heading (e.g., NW)
Site #	1-40
Observation #	Each bird sighted is numbered sequentially. (Map)
Military Time	At start of 10-minute interval
Species Abbrev.	AK - American kestrel BAO - Barn owl BE - Bald eagle BO - Burrowing owl CH - Cooper's hawk FH - Ferruginous hawk GE - Golden eagle GH - Goshawk GBH - Great blue heron GHO - Great horned owl NH - Northern harrier MER - Merlin OSP - Osprey PR - Prairie falcon PGF - Peregrine falcon RAV - Raven RLH - Rough-legged hawk RSH - Red-shouldered hawk RTH - Red-tailed hawk SEO - Short-earred owl SSH - Sharp-shinned hawk SWH - Swainson's hawk TV - Turkey vulture WTK - White-tailed kite
General codes:	ACC - Accipiters BUT - Buteos DU - Duck EAG - Eagles FAL - Falcons GE - Geese UID - Unidentified
Ageclass	A - Adult I - Immature U - Undetermined

Description	Codes
Distance to Observer at First Observation	At 200-foot intervals See scale below: 200 ft.= 1/8in. 1000 ft.=1/2in. 2000 ft.= 1 in.
Height Above Ground at First Observation	0 - On Ground 1 - 1-50 ft 2 - 50-100 ft 3 - 100-200 ft 4 - 200-300 ft 5 - >300 ft
Distance to Closest Structure at First Observation	0 - On Structure 1 - 1-50 ft 2 - 50-100 ft 3 - 100-200 ft 4 - 200-300 ft 5 - >300 ft
Type of Structure (Add "+" to symbol if turbine in running)	TU - Turbine TX - Transmission Line MT - Meteorological Tower
Direction of Movement (For Obvious Flybys Only)	Alpha 8-Point Compass Heading
Notes	Remember to include description of fog

Explanations of Fields on Mortality Form (Mortbase File)

1. Record Number	=	Sequential number starting with No. 1 (right justified)
2. Species	=	Common name of bird, unknown raptor, or unknown
3. Number	=	The number of dead or injured birds
4. Age	=	Adult (A) Immature (I) Unknown (U)
5. Sex	=	Male (M), Female (F), Unknown (U)
6. Date Found	=	Date bird was discovered (--/--/--)
7. Estimated time since death	=	Fresh kill - less than 2 days old (FK) Few days - maggots starting to appear (FD) 1 week - maggots over entire body (1W) 2 weeks - flesh at least half gone (2W) 1 month - no flesh left, just bones and feathers (1M) Over 6 months bones and feathers disassembled (6M) Undetermined (UD)
8. Cause of death	=	Collision with turbine (COLT) Collision with wire (COLW) Electrocution (ELEC) Unknown (UNKN)
9. Index of probability (degree of certainty for cause of death)	=	1 thru 10 (1 = low probability, 10 high probability)
10. Condition (Also describe in detail on back of sheet)	=	Dead (D) Injured (I)
11. Injuries (For both dead and alive birds)	=	Wing sheared off (WSO) Head sheared off (HSO) Feet sheared off (FSO) Body sheared in half (BSH) Multiple dismemberment (MUD) Broken wing bone (BWB) Broken neck bone (BNB) Broken leg bone (BLB) Injury to wing (ITW) Injury to legs (ITL) Injury to eyes (ITE) Injury to body (ITB) Injury to head (ITH) Feather damage (FED) Decomposed - body and feathers intact (DBI) Decomposed - feathers and bones disassembled (DBD) Decomposed - just feathers (DJF) Decomposed - just bones (DJB) Wing only (WGO) Electric burns on feet (EBF) Electric burns on wings (EBW) Internal injuries (IIN) Impact, then continued on (ITC)

Stunned (STU)
Entangled in wires (IIW)
No obvious signs (NOS)

12. Maximum distance at which bird could be observed = In feet

13. Scavenged (at time of discovery = Yes (Y), No (N), Unknown (U)

14. Closest Structure to mortality = Wind Turbine Machine (WTM)
Power line associated with WTM (WPL)
General utility power line (GPL)
Telephone line (TPL)
Large distribution line (LDL)
Meteorological tower (MET)

15. If another type of structure is in close proximity and could have caused the mortality - list second structure = Wind Turbine Machine (WTM)
Power line associated with WTM (WPL)
General utility power line (GPL)
Telephone line (TPL)
Large distribution line (LDL)
Meteorological tower (MET)

16. Location = Land ownership (Souza)
For Biologist: Turbine site and letter (e.g., USW1 Ab)

17. WindFarm Company = Fayette, US Windpower, WindMaster, AEC, Flowind, Seawest, Altamont Energy Corp., Zond, Am. Divers.

18. WindFarm Structure Number (closest structure) = Tu (turbine) #, Tx (power pole) #

19. Is closest structure an EndRow = Yes (Y), No (N)

20. Within CEC study mortality site = Yes (Y), No (N)

21. UTM = 8 digit number

22. Distance to closest Structure = Distance (in feet) the bird was from the structure

23. Distance to second type of structure = Distance (in feet) the bird was from the structure

24. Aspect from closest structure to site of mortality = 8 point compass heading (NW, SE)
Biologists use degrees also

25. Elevation = In feet (from map)

26. Slope Angle of Hill = 0-10 degrees (1)
11-20 degrees (2)
21-30 degrees (3)
31-45 degrees (4)
over 45 degrees (5)

27. Aspect of dominant slope = 8 point compass heading (NW, SE)

28. Configuration of WTM =
Vertical axis (VRA)
Three blade lattice - Downwind (3LD)
Three blade lattice - Upwind (3LU)
Two blade lattice (2BL)
Three blade - Guyed wires (3GW)
Steel Tubular - Medium (STM)
Steel Tubular - Large e.g., Howden (STL)
WindWalls (WWS)

29. Configuration of Power Pole = From enclosed diagram, choose the pole number which most closely matches. Place an X on the spots where the bird made contact with structure - there should be darken burned areas (arcs) where contact was made. If burn marks are not obvious, circle any uninsulated wires or conductors that might have caused an electrocution.

30. Riser Pole = Yes (Y), No (N)

31. Number of lines (conductors) = One digit number

32. Number of Cross Beams (arms) = One digit number

<u>Beam A (top)</u>

33. •Length = In feet

34. •Material = Wooden (WO), Metal (ME), Ceramic (CE), Metal with Wooden Braces (MW)

35. •Oriented perpendicular to prevailing wind (at estimated time of incident = Yes (Y), No (N), Unknown (U)

36. •Number of wires that extend upward = One digit

37. •Are these wires insulated = Yes (Y), No (N), Partially (P)

38. •Are wildlife insulation caps used = Yes (Y), No (N), Partially (P)

39. •Perchability = Adequate (A), Little (L), None (N), Unknown (U)

<u>Beam B (middle)</u>

40. •Length = In feet

41. •Material = Wooden (WO), Metal (ME), Ceramic (CE), Metal with Wooden Braces (MW)

42. •Oriented perpendicular to prevailing wind (at estimated time of incident = Yes (Y), No (N), Unknown (U)

43. •Number of wires that extend upward = One digit

44. •Are these wires insulated = Yes (Y), No (N), Partially (P)

45. •Are wildlife insulation caps used = Yes (Y), No (N), Partially (P)

46. •Perchability = Adequate (A), Little (L), None (N), Unknown (U)

Beam C (bottom)

47.	•Length	=	In feet
48.	•Material	=	Wooden (WO), Metal (ME), Ceramic (CE), Metal with Wooden Braces (MW)
49.	•Oriented perpendicular to prevailing wind (at estimated time of incident	=	Yes (Y), No (N), Unknown (U)
50.	•Number of wires that extend upward	=	One digit
51.	•Are these wires insulated	=	Yes (Y), No (N), Partially (P)
52.	•Are wildlife insulation caps used	=	Yes (Y), No (N), Partially (P)
53.	•Perchability	=	Adequate (A), Little (L), None (N), Unknown (U)
54.	Are all Cross Beams Parallel	=	Yes (Y), No (N)
55.	Shortest distance between lines (conductors)	=	Lines more than 60 inch apart (M60) Lines less 60 inch apart (L60) Lines less 50 inch apart (L50) Lines less 40 inch apart (L40) Lines less 30 inch apart (L30)
56.	Are there other manmade or natural perches available in general area (< ¼ mi)	=	Yes (Y), No (N)
57.	Frequency of human activity	=	Low - roads seldom used, no building in area (L) Medium - road use occasion, no building in area (M) High - road use common or buildings in area (H)
58.	Topography of pole site	=	Top of hill (T) In valley (V) On slope (S)
59.	Configuration of Met.Towers	=	Wide Lattice (WL) Narrow Lattice (NL) Guy Wires (GW)
60.	Height of Met. Tower	=	In feet
61.	Incident Observed	=	Yes (Y), No (N)

If incident observed:

62.	•Time of incident	=	24 hours clock
63.	•Turbine operating during incidence	=	Yes (Y), No (N)

64.	•Adjacent turbines operating	=	Yes (Y), No (N)
65.	•Wind speed at time of incident	=	In MPH
66.	•Describe incident in detail	=	On back of sheet and in memo in DBASE

If incident observed or less than 1 week old record the following information (from the time of discovery to estimated time of death):

67.	•Fog	=	Yes (Y),No (N), Unknown (U)
68.	•Rain	=	No (N), Light (L), Medium (M), Heavy (H), Unknown (U)
69.	•Storm	=	Yes (Y), No (N), Unknown (U)
70.	•Gusty Winds	=	Yes (Y), No (N)
71.	•Maximum Wind Speed	=	In MPH (if incident was observed - record max. MPH for day of incident)
72.	•Average Wind Speed	=	In MPH (if incident was observed - record average MPH for day of incident)
73.	•Wind Direction	=	8 point compass bearings - (e.g. NW). If too variable record (VAR).
74.	•Percent time WTM operating - (from time of discovery to estimated time of death)	=	Percent

75. Other Contributing Factors (can have more than one entry) =

- Closest structure within 500 feet of large valley (SNV)
- Closest structure within 500 feet of trees (SNT)
- Closest structure within 500 feet of wetland or water (SNW)
- Closest structure within 500 feet of large drainage or canyon (SNC)
- Closest structure within 500 feet of large transmission line (SLT)
- First row in area (FRA)
- Line parallels road (LPR)
- Starvation, weakened condition (STA)
- Pesticide poisoning (PPP)

76. Index of Structure Density (within 500 feet of closest structure - includes closest structure row) =

- Isolated structure (1)
- Short row of structures <4 - [turbines or transmission lines] (2)
- One row of structures [turbine or transmission lines] (3)
- One row of structures and one single structure [i.e. met tower] (4)
- Two rows of structures (5)
- Two rows of structures and one single structure (6)
- Three rows of structures (7)
- Three rows of structures and one single structure (8)
- Four rows of structures (9)
- Four rows of structures and one single structure (10)

Five rows of structures (11)
Five rows of structures and one single structure (12)
Six rows of structures (13)
Six rows of structures and one single structure (14)

77. Number of isolated structures - i.e., met towers (within 500 feet of closest structure) = Number

78. Number of turbines rows (within 500 feet of closest structure) = Number (includes the row in which the mortality was found)

79. Number of transmission rows (within 500 feet of closest structure) = Number (includes the row in which the mortality was found)

80. Total number of isolated structures or rows (from above three fields) = Number

81. Are structure rows all parallel = Yes (Y), No (N)

82. Distance from closest structure to next closest row or isolated structure = In feet

83. Index of ground squirrel density (within 500 feet of closest structure =
None (1)
Few (2)
Scattered (3)
Common (4)
Abundant (5)

84. Percent of ground surface area with squirrel burrows (within 500 of feet of closest structure) = Percent

85. Nearest ground squirrel colony = In feet

86. Direction of nearest ground squirrel colony = 8 point compass heading (NW,SE)

87. Nearest open valley (flat area) =
1-250 feet (1)
250-500 feet (2)
500 ft - ¼ mi (3)
¼ mi - ½ mi (4)
Over ½ mi (5)

88. Direction of nearest valley (only if < ¼ mi away) = 8 point compass heading (NW,SE)

89. Index of ground squirrel density within nearest valley (only if < ¼ mi away) = None (1)

		Few (2) Scattered (3) Common (4) Abundant (5)
90. Nearest Trees	=	1-250 feet (1) 250-500 feet (2) 500 ft - ¼ mi (3) ¼ mi - ½ mi (4) Over ½ mi (5)
91. Direction of trees (only if < ¼ mi away)	=	8 point compass heading (NW, SE)
92. Nearest Water (pond, wetland)	=	1-250 feet (1) 250-500 feet (2) 500 ft - ¼ mi (3) ¼ mi - ½ mi (4) Over ½ mi (5)
93. Direction of water (only if < ¼ mi)	=	8 point compass heading (NW, SE)
94. Nearest Canyon	=	1-250 feet (1) 250-500 feet (2) 500 ft - ¼ mi (3) ¼ mi - ½ mi (4) Over ½ mi (5)
95. Direction of nearest canyon (only if < ¼ mi away)	=	8 point compass heading (NW,SE)
96. Report Completed By	=	Initials of person completing this form
97. Source of Information	=	Person that discovered the bird (full name)
98. Did this incident cause a site event (feeder trip, blown fuse, etc.)	=	Yes (Y), No (N), Unknown (U)
99. Name of Rehabilitation Center (if used)	=	Type name of center
100. Ultimate disposition of bird sent to rehab.	=	Dead (D) Euthanized (E) Released (R)
101. Name of wildlife agency or person contacted	=	Type name of person or agency
102. Comments	=	Place on back of sheet (In memo in dBASE)

APPENDIX D

RAPTOR DENSITY CONTOURS AND SURFER

RAPTOR DENSITY CONTOURS

The following paragraphs provide more detail about how raptor density contour maps were created: what data were used, how data were applied, and what the computer program Surfer (Golden Software, Inc.) did with them. Input data were derived from raptor sightings recorded on driving surveys, averaged over the 8-day survey; one set of data was used for each season and each location (Altamont Pass WRA and Solano County WRA). One set of raptor density contours was created for each season and location. The unit of measurement on the contours is average number of raptors seen per square mile during the two-week sampling period.

Input data were derived from raptor sightings on driving surveys. Each bird sighted on the surveys was plotted on USGS (U.S. Geological Survey) topographic maps. These sightings, as well as the locations of survey sample points, were digitized into our Geographic Information System (GIS) which was then able to generate a list of all sightings occurring within a circle of one-half-mile radius around each survey stop (or within an area of 0.78 mi^2). The list included the species (raptor and non-raptor species) and number observed for each sighting. From this list, we summed all raptor sightings (we eliminated sightings of non-raptors) to get a total number of birds seen within the specified area (0.78 mi^2 around each survey stop) over the 8-day survey period. This sum was divided by 8, the number of days in the survey, to get a daily average number of birds seen within this area at each stop. We then extrapolated to get an average number of birds seen within one mi^2 during the period of the survey, and this number we called raptor density. The data entered into Surfer consisted of the X and Y coordinates of each survey stop and the calculated raptor density, or Z coordinate, at each stop.

Surfer takes irregularly-spaced X,Y,Z data and interpolates regularly-spaced X,Y,Z values from them. Within an area with dimensions specified either by the input data or by the user, Surfer creates a grid of a specific number of rows and columns which it superimposes on the input data. The user specifies the number of rows and columns to compose the grid. The intersection of each row and column grid line (called the grid element) represents an X,Y coordinate. From the irregularly-spaced data provided by the user, in this case raptor density, Surfer interpolates a Z value for each grid element. Three methods of interpolation are available: kriging, inverse distance, and minimum curvature (Golden Software, Inc.).

We specified a grid spacing of 65 rows by 79 columns, which created grid nodes spaced every 755 ft in the X dimension (east-west) and 759 ft in the Y dimension (north-south). We used the minimum curvature method of interpolation (see Briggs 1974), with a maximum absolute error of 0.005 and 500 iterations. The Surfer Reference Manual (Golden Software, Inc.) describes the minimum curvature interpolation process this way:

This process first calculates initial values of the grid elements based on the data. Any grid element with data present within a grid cell centered about it will have its value fixed during the computation, thus honoring the data. Then the method applies an equation repeatedly to the surface with each application counted as one iteration. The equation attempts to smooth the gridded surface. Each grid element is recalculated until successive changes in its value are less than the maximum absolute error [0.005 in our case], or the maximum number of iterations [500] has been reach. This process is begun on a coarse grid and repeated for finer and finer grid spacings until the actual grid spacing has been reached.

Each interpolation algorithm (kriging, inverse distance, or minimum curvature) has its relative advantages and disadvantages (Golden Software, Inc.). The minimum curvature and kriging methods are considered more accurate than the inverse distance method, but sacrifice speed. Because the minimum curvature and kriging methods project trends, results are more unpredictable in areas of missing data than with the inverse distance method.

Adjusting the spacing of rows and columns in the grid affects smoothness of contours and accuracy (though not necessarily precision); we found the grid spacing and methods we selected provided optimum smoothness and accuracy. We also applied optional smoothing modifications to our grids; the spline smoothing option smoothed the grids using cubic spline interpolation to increase the number of grid elements in the interior of the previously-created grid.

APPENDIX E

SELF-MONITORING PROGRAM INFORMATION SHEET, REPORT FORM, AND CODE SHEET

INFORMATION SHEET FOR MONITORING BIRD MORTALITY

This information fact sheet was designed to be given to all field personnel to define the purpose, identify the types of data needed, and describe monitoring procedures of the mortality monitoring program. All raptors, waterfowl, and water birds are protected by federal law under the Migratory Bird Protection Act and many are also protected by other state and federal laws. This mortality monitoring system should be used by all participating windfarm operators for reporting any bird deaths or injuries that they observe in the field. This system will allow developers and resource agencies to continue to assess bird mortality over time. The data form, called Wildlife Incident Report, and the accompanying code sheet are attached.

When a dead or injured bird is discovered by a field worker, the type of bird (as specifically as possible), exact location (turbine or pole number), and date found should be noted. It should then be immediately reported to a wildlife manager. The wildlife manager is responsible for completing the wildlife incident report and reporting the injured bird to the local rehabilitation center. This person should be trained in the exact methods required to report mortalities and should be able to identify protected or migratory bird species. The wildlife manager will be responsible for the following tasks:

- completing wildlife incident reports,
- consolidating all raptor incident reports into a monthly listing and submitting them to USFWS,
- coordinating with the USFWS,
- ensuring that incidents involving eagles are reported to the USFWS within 24 hours,
- ensuring that dead eagles are preserved and stored for the USFWS, and
- assisting in capture and transportation of live injured birds under the direction of a licensed rehabilitator.

Any bird (whole or part) or area of scattered feather debris is considered a mortality. An injured bird is any raptor that is alive but not behaving normally. It should be noted, however, that raptors on the ground may not be injured; they may simply have a prey item they are killing or eating. Raptors also mantle, or hold their wings down, to hide prey from other predators, and so may appear injured. If a raptor is indeed injured, a rehabilitation center should be notified immediately of the condition and location of the bird. The wildlife manager should ensure that the rehabilitation people receive accurate directions and have access to the site.

Injured raptors should not be approached. All injured raptors should be monitored from a safe distance until the bird can be transported to the rehabilitation center. A "safe distance" is far enough away that the bird is not visibly uneasy with the observer's presence.

The Five Mile Creek Rehabilitation Center is the closest center to Livermore. Kathy and Don Crumps operate this facility. Their phone number is: (209) 477-0602.

WILDLIFE INCIDENT REPORT

Report Number	Company	Date of discovery	Date of report
Discovered by		Reported by	
Property Location		Map location (township, range, section, ¼ section)	
Tower or Pole #	Type of Turbine	End turbine?	Species
Adult/Immature	Banded? Which leg(s)?	Band No.	Band color(s)
Male/Female	Dead or injured		
Bearing and distance from closest tower or pole center to site of discovery (e.g., 25 feet north-northeast)			
Probable cause of death (electrocution, collision with turbine, collision with wires, unknown)			
Describe physical condition of bird with as much detail as possible.			
If death was possible electrocution or bird was near a power pole, describe the poletop configuration.			
If bird appears to have been dead less than one week, were any of the following weather patterns present between the estimated time of death and time of discovery: fog, rain, storm, gusty winds? Which, and give details.			
If bird was injured, name of rehabilitation center used			
Ultimate disposition of bird, if known			

CODE SHEET FOR WILDLIFE INCIDENT REPORT

ITEM	EXAMPLE	EXPLANATION
Report number	101	A sequential number for all reports
Company		
Date of find	2/2/90	Date of first discovery
Date of report	2/4/90	Date report was filled out
Discovered by	A. Doolittle	First person to find bird
Reported by	J. Bomber	If different from "Discovered by"
Property location	Souza Ranch	Property name or owner
Map Location	T2S, R3E, S25, SE¼	Township, range, section, and ¼secton
Tower or pole #	TU 900	Number of tower or pole nearest discovery
Type of turbine	3 blade lattice - upwind	3-blade lattice - upwind 3-blade lattice - downwind 2-blade lattice medium tubular large tubular 3-blade guyed pipe vertical axis windwall
End turbine?	yes	Is closest structure an end turbine, i.e., a turbine located at the end of a row?
Species	red-tailed hawk	If uncertain of species, use categories such as large raptor, small raptor, sparrow-sized bird, duck
Banded? Which leg(s)?	Yes, right	Does the bird have aluminum or plastic leg band on either leg? Which leg?
Band no. Band colors	1596-43231 red, green, yellow, aluminum	Describe any band numbers, band colors, or other characteristics of bands. Details are important.
Bearing and distance	25 feet east	Bearing and distance from structure to bird
Probable cause of death	collision with wires	collision with turbine collision with wire electrocution unknown
Describe physical condition of bird	Carcass was just a pile of feathers and bones. Or, bird was limp, eyes appeared glazed, or most flesh was gone but feathers were still attached to carcass	Include such details as condition of eye, presence of flesh, presence of maggots, whether all bones and feathers appeared to be in one place
Poletop configuration	Riser pole, partially insulated	If find was an apparent electrocution or was discovered near a pole, describe poletop configuration. Describe extent of insulation on pole wires.
Weather	Heavy fog 2/2/90 wind storm, heavy rain	Indicate date and extent of occurrences or conditions
Ultimate disposition	Died at rehab. center	What happened to bird?