December 1999 • NREL/SR-500-26902

Subcontractor Report

Baseline Avian Use and Behavior at the CARES Wind Plant Site, Klickitat County, Washington

Final Report

W.P. Erickson, G.D. Johnson, M.D. Strickland, K. Kronner, and P.S. Becker
Western EcoSystems Technology, Inc.
Cheyenne, Wyoming

S. Orloff
IBIS Environmental Services
San Rafael, California

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

NREL is a U.S. Department of Energy Laboratory
Operated by Midwest Research Institute • Battelle • Bechtel

Contract No. DE-AC36-99-GO10337

December 1999 • NREL/SR-500-26902

Baseline Avian Use and Behavior at the CARES Wind Plant Site, Klickitat County, Washington

Final Report

W.P. Erickson, G.D. Johnson, M.D. Strickland, K. Kronner, and P.S. Becker
Western EcoSystems Technology, Inc.
Cheyenne, Wyoming

S. Orloff
IBIS Environmental Services
San Rafael, California

NREL Technical Monitor: K. Sinclair

Prepared under Subcontract No. ZAM-8-16454

NREL

National Renewable Energy Laboratory

1617 Cole Boulevard
Golden, Colorado 80401-3393

NREL is a U.S. Department of Energy Laboratory
Operated by Midwest Research Institute • Battelle • Bechtel

Contract No. DE-AC36-99-GO10337

Available electronically at http://www.doe.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/ordering.htm

Printed on paper containing at least 50% wastepaper, including 20% postconsumer waste

Foreword

Although the use of wind energy as an alternative electric generation source is now a viable choice, there is concern over the possible impacts of wind plants on birds. The concern includes two primary areas: the effect of avian mortality resulting from collisions with wind turbines on bird populations and possible litigation over the killing of even one bird protected by the Migratory Bird Treaty Act, the Endangered Species Act, or both.

The activities of the avian research program at the National Renewable Energy Laboratory (NREL) focus on minimizing the effects of wind turbines on birds and bird populations. Funded by the U.S. Department of Energy, NREL conducts research (1) to refine the methods developed to assess impacts on birds and bird populations within wind plants, (2) to understand how birds behave in and around wind turbines in different environments, and (3) to identify how birds recognize wind turbines and develop recommendations for making the turbines more conspicuous.

This report summarizes the avian research conducted at the Columbia Windfarm #1 in Klickitat County, Washington. The research was funded by the National Renewable Energy Laboratory and the Conservation and Renewable Energy System (CARES), a consortium of eight Washington State Public Utility Districts. The multi-year research project was originally designed to conduct pre and postconstruction avian utilization and fatality surveys to determine whether a specific treatment would affect the impact of wind turbines on avian species.

This report documents only the preconstruction data collected because development of the site was indefinitely postponed and the field surveys were suspended at the end of one year. If the site is developed, the information contained in this report may be useful for comparison with postconstruction data, if the data are collected using comparable methodologies.

Karin C. Sinclair
National Wind Technology Center
National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401
E-mail: karin_sinclair@nrel.gov
Phone: (303) 384-6946
Fax: (303) 384-6901

Table of Contents

List of Tables

List of Figures

List of Appendices

Introduction

An estimated 5 to 80 million birds die annually in the United States by colliding with man-made objects (Banks 1979, Avery et al. 1980). Although generally considered environmentally friendly, wind power has been associated with the deaths of birds colliding with turbines and other wind plant structures, especially in California (Orloff and Flannery 1992)*. Compared to other structures, such as communication towers and power lines, however, overall incidence of bird mortality in wind generation facilities is small (AWEA 1995). The range of avian mortality from turbine collisions is 0 to 37 birds per turbine per year in the United States and Europe (Howell and Noone 1992, Winkelman 1992). Studies indicate that raptors and passerines are the most susceptible to turbine collisions in the United States, whereas waterfowl and shore birds appear to be most susceptible in Europe (AWEA 1995).

Wind has been used to commercially produce energy in the United States since the early 1970s (American Wind Energy Association [AWEA] 1995). Recent advances in wind turbine technologies have reduced costs associated with wind power production, improving the economics of wind energy (Hansen et al. 1992). As a result, wind energy plants have been constructed or are currently planned in 13 states (AWEA 1995).

Early wind energy facilities in the United States were placed without regard to level of avian use, and some of these sites are located where birds are abundant and the risk of turbine collisions is high (AWEA 1995). As a result, extensive mortality has been reported at some wind generation facilities. In the Altamont Pass area near Livermore, California, where more than 5000 turbines exist within the wind resource area (WRA), an estimated 567 raptors were killed over a 2-year period from colliding with turbines (Orloff and Flannery 1992)*. Researchers estimated 6,800 birds were killed annually at the San Gorgonio, California wind facility based on 40 dead birds found while monitoring nocturnal migrants. Because most of these birds were passerines and large numbers of passerines migrate through this area, the authors concluded that this level of mortality was insignificant. Studies conducted on other wind generation facilities show that this level of mortality does not routinely occur (e.g., Johnson et al. 1999), and numerous factors including avian abundance and composition, presence of migration corridors, geographic area, landscape features, prey abundance, and wind plant features, determine the potential for avian mortality (Nelson and Curry 1995*, Orloff 1992).

Scientists have been trying to reduce the incidence of bird collisions with man-made structures for many years (Avian Power Line Interaction Committee [APLIC] 1994, Thompson 1978, Miller 1978, Colson and Luman 1978, Electric Power Research Institute [EPRI] 1993, Weir 1976) and the wind industry and its regulators are attempting to reduce the risk to birds from wind power development. Although scientists have made advances in understanding and resolving bird collision problems with a variety of utility structures, their understanding of collisions with wind turbines is still limited. Most studies of bird collisions with wind turbines have been conducted in Europe (California Energy Commission [CEC] 1996), and have focused more on disturbance than on methods to reduce collision mortality. Because European wind plants typically contain fewer than 10 turbines, the problem of bird/turbine collisions has not been considered significant and little effort has been made to reduce the mortality.

In response to growing controversy over potential impacts to birds from wind energy development in recent years, several studies were completed in the United States. Most of these studies assessed disturbance and mortality, flight behavior, and factors that may contribute to mortality (CEC 1996). Few studies have focused

---

*Document reviewed in Appendix G.

on evaluating techniques to reduce mortality. The authors of this report reviewed over 200 studies and articles on the impacts to birds of wind turbines, transmission lines, and man-made towers. The review included all articles in the two CEC annotated bibliographies on avian collisions and wind turbines (CEC 1995, 1996). Emphasis was placed on obtaining data on techniques that could be used to reduce avian mortality. To obtain additional data, the authors contacted Dr. Ib Clausager of Denmark and Dr. Johanna Winkelman of the Netherlands for information on recent European studies. They also contacted several researchers from the United States, including Hugh McIsaac (Raptor Research Center), Dick Anderson (CEC), Steve Ugoretz (Wisconsin Department of Natural Resources), and Monte Garrett (PacifiCorp).

Techniques evaluated for their potential to reduce avian mortality at wind turbines included painting turbine blades to make them more visible and installing anti-perching devices to deter avian use of turbines. Data collected by observing controlled flights of pigeons in wind plants and studies of the sensory capacities of raptors were used to evaluate avoidance behaviors and determine what visual and acoustic stimuli are most effective in improving recognition of a wind turbine as an obstacle to avoid. Another recent study compared bird deaths at the new-generation, larger turbines (KVS-33) to bird deaths at older, smaller turbines (KCS-56).

Preliminary results of experiments to determine effectiveness of painting turbines blades have been promising (Howell et al. 19910*, H. McIsaac, personal communication 1998). Howell et al. (1991)* research indicated that painting blades may reduce mortality, but the data were not statistically significant. Hugh McIsaacs' research indicated that carefully designed patterns can increase blade visibility under a variety of conditions; however, poorly designed patterns can decrease visibility (H. McIsaac, personal communication 1998). The research also indicated that the use of uniformly-colored blades do not reduce avian mortality as well as well-designed patterned blades. However, statistical validity of McIsaacs' reports has not yet been determined.

Perching behavior has been implicated in higher rates of mortality (Hunt 1994, Orloff and Flannery 1996*). Preliminary results from research conducted on perching behaviors indicate a 54% reduction in perching with the installation of perch guards (Nelson and Curry 1995)*. One means of reducing perching may be to install turbines with tubular towers that provide no place for raptors to perch (Hunt 1994, Nelson and Curry 1995*), there are no studies that show lower mortality at tubular towers than at lattice towers.

Other preliminary results indicate that larger turbines, that have almost three times the rotor-swept-area of smaller turbines, may have similar avian fatality rates per turbine as the smaller turbines (Howell 1995, Johnson et al. 1999). Therefore, if one larger turbine replaces three smaller turbines and produces the same amount of electricity, avian mortality could be reduced by nearly two-thirds.

In Tucker's (1996a, 1996b) theoretical model to predict avian mortality at wind turbines, rotor-swept-area was not a factor in the model. Tucker theorized that the main factors contributing to avian mortality were the number of blades (fewer would be better) and the tip speed (lower would be better). The model predicted that as the length of the blade is extended, the level of collision risk per turbine would diminish (Nelson and Curry 1995). However, the model did not consider the ability of birds to avoid turbines through evasive maneuvers and has not been tested with empirical data; therefore it has limited value.

Other proposed but untested techniques to reduce avian mortality at wind turbines include the use of pylons at the end of turbine rows and the use of luminescent or phosphorescent marking materials. Luminescent or phosphorescent marking materials would make them visible to birds that fly at night (Avery 1978, Brown 1993). Pylons would encourage birds to fly beyond the end-row turbine (H. McIsaac, personal

---

*Document reviewed in Appendix G.

communication 1998). Experiments have also determined that birds can detect pulsed microwave signals. Kreithen (1996) suggested that pulsed microwave signals could be used to warn birds of the presence of hazardous obstacles. The benefits of this system are that the signal travels at the speed of light, can penetrate fog and clouds, works in daylight or darkness, and does not require that the bird be looking toward the object to detect the signal. One of the drawbacks of the system is that if the birds do not perceive the obstacle as dangerous, they would only learn that the obstacle was there; not to avoid the obstacle. Another drawback is that the instrumentation for this technique has not yet been fully developed.

Many well designed studies have reported the effectiveness of using bird flight diverters (BFDs) on transmission lines to reduce collisions (APLIC 1994, Bealaurier 1981*, Brown and Drewien 1995*, EPRI 1993, Faanes 1987, Koops 1987, Miller 1990, Morkill and Anderson 1991*). A variety of markers have been tried, including ribbon, orange aviation markers, tape, spiral vibration dampers, and swinging plates. In several recent studies, BFDs have been shown to reduce collisions by 54% to 90% (Brown 1993, Morkill and Anderson 1991*, Koops 1993).

Warning devices that emit sounds or visual cues have been used at airports, agricultural fields, mine tailing ponds, utility poles, communication towers, and oil spills to deter birds (Avery 1978, DeFusco and Nagy 1983, Knittle and Porter 1988, Koshi et al. 1993, Marsh et al. 1991, Raevel and Tombal 1991). However, most of the studies found that birds become habituated to the devices, which reduces the long-term effectiveness of these techniques.

The effectiveness of nighttime illumination has not been adequately tested on man-made structures. Studies involving lighted man-made structures indicate that lights may attract or disorient birds rather than repel them (APLIC 1994, Cochran and Graber 1958*, Crockford 1992, Herbert 1970*, Weir 1976). This is mostly a problem for nocturnal migrants (primarily passerines) during poor visibility conditions. Studies have shown that different types of lights may have different effects on birds. Several studies indicate that when constant lights are replaced with intermittent lights, mortality may be reduced or eliminated (APLIC 1994, EPRI 1985, Jaroslow 1979*, Weir 1976). In addition, studies show that replacing white flood lights with red-colored lights reduces mortality by as much as 80% (Weir 1976). This may be due to the reduction in light intensity rather than to the change to a red wavelength (Weir 1976). Avery (1978) reported that use of strobe lights and high frequency distress sound devices on communication and transmission towers has had limited success in reducing avian collision mortality.

In 1994, Conservation and Renewable Energy Systems (CARES) proposed construction of a wind plant in Klickitat County, Washington. Baseline studies conducted at the proposed CARES wind plant site and an adjacent Kenetech site in Columbia Hills, Washington (Jones & Stokes Associates, Inc. 1995), identified many avian species using the area, including 16 raptor species. Overall raptor occurrence on the CARES project site averaged 1.21 raptors per 20 minute observation period. The proposed CARES Columbia Wind Plant # 1 was to consist of 91 FloWind AWT-26 turbines, capable of generating 25 MW, situated in 9 rows on a 975-acre site. Unlike most turbine types currently in use, the AWT-26 turbines are supported by guy wires.

It is well documented that collision with wires from transmission lines is a common cause of avian mortality (Avery et al. 1980, CEC 1995). Bird flight diverters have been shown to be effective in reducing mortality at transmission lines (APLIC 1994). Diverters have been shown to reduce collisions by 57% to 89% (EPRI 1993, Koops 1987).

---

*Document reviewed in Appendix G.

Although numerous studies of avian/wind power interaction have been conducted since the mid-1980s, few of these studies have evaluated effects of guy wires on avian mortality. Early researchers speculated that guy wires on turbines could pose a greater threat to birds than rotating blades (Bonneville Power Administration [BPA] 1987*), particularly under conditions of poor visibility (Jones & Stokes Associates Inc. 1987). Results of a study conducted in California, however, suggest that guy wires do not necessarily contribute to mortality (BioSystems Analysis 1992). In that study, of the five turbine types evaluated, the two with guy wires (vertical axis and guyed pipe) had the lowest rates of mortality. During the BioSystems study, no mortalities were recorded at the 48 meteorological towers, most of which were supported by guy wires; however, other wind plant studies have documented avian mortality at meteorological towers with guy wires. One study in Wyoming documented several mortalities, mostly passerines, associated with guy wires attached to a single meteorological tower (Bureau of Reclamation 1984). Another study in California found two dead passerines under a single meteorological tower that had guy wires in Solano County (EPRI 1985). Other studies have documented avian deaths likely caused by guy wires associated with meteorological towers in Minnesota (Johnson et al. 1999) and in Europe (Winkelman 1992).

There is still much to be learned about whether guy wires contribute to avian mortality at wind plants. The effect of guy wires may be dependent on many site-specific factors, such as local avian composition, prey availability, and height and diameter of the area covered by guy wires. To date only the BioSystems' study (BioSystems Analysis 1992) has studied turbines with guy wires to determine avian mortality in the United States or in Europe.

This report presents results of a one-year avian baseline study conducted at the site of the proposed CARES wind energy development in Klickitat County, Washington. The main study objective was to scientifically evaluate the effectiveness of placing BFD's on guy wires supporting the turbines as a risk reduction management treatment. Development of this site was proposed to begin in 1998. Due to several factors, the development is no longer being pursued by CARES, and this report only presents results of baseline avian monitoring studies conducted prior to any development.

Study Area

The Washington Wind Plant #1 site is located near the western edge of the Columbia Plateau. The project site is near Juniper Point in the Columbia Hills area of Klickitat County, Washington (Figure 1). The project was to have been located on lands leased from Columbia Aluminum approximately 6 miles southeast of Goldendale, Washington, on a ridge approximately 2 miles north of the Columbia River. Elevation in the vicinity of the site ranges from 305 m (1000 ft) to about 880m (2890 ft). Habitat at or near the site is primarily rangeland used for cattle grazing (62%) and cultivated farmland (18%). Minor vegetation classes occurring in the vicinity of the site include oak and juniper woodlands, native shrub steppes, bunch grass steppe, and riparian areas. Representative photographs of the study area are provided in Figures 2 through 5. A detailed description of the study area can be found in the Draft Environmental Impact Statement prepared for the project (BPA and Klickitat County 1994).

Methods

We implemented a Before-After/Control-Impact (BACI) design (Skalski and Robson 1992) for the CARES wind plant project. In Phase I, we selected 24 observation stations along the proposed turbine strings for

*Document reviewed in Appendix G.

recording avian use and behavior (Figure 6). We expected that in Phase II of the wind plant, each turbine string would be divided into two sets of turbines, and half of the turbines would be randomly selected to receive the BFD's.

Avian Use Surveys

The objective of the avian use surveys was to estimate spatial and temporal use and behavior by birds within the entire proposed wind plant during Phase I and to compare these estimates to estimates obtained after the treatment was applied. Relative use of the proposed wind plant site by avian species was measured through point count surveys conducted during daylight hours. Avian use is considered an index to the density (number of individuals per unit area) of species using the study areas. Use was measured by counting birds observed within sample plots. It was assumed use is influenced by biological and physical characteristics of the site and/or the home range of the bird. Each bird detected during counts was located in relation to existing or measured information regarding the physical and biological characteristics of the site (covariates) such as bird position relative to the rim edge. This survey was primarily suited for raptors, waterfowl, and other large wide-ranging birds, but observations of all bird species were recorded.

Twenty-four observation stations were located within the proposed wind plant study area (Figure 6). Each plot within the proposed turbine string (9 total strings in the wind plant) is a 0.4-km radius circle centered on an observation point. This intensity provided complete coverage of the area around all proposed turbines. Landmarks and other prominent topographic features were located to help identify the 0.4-km boundary of each station. Observations of birds beyond the 0.4-km radius were also recorded but analyzed separately from data collected within the plot.

Observations at each station were made on one day every two weeks throughout the year. Each station was visited twice each sampling day; once during the morning (8:00 a.m. - 12:00 p.m.) and once during the afternoon (12:00 p.m. - 4:00 p.m.). Efforts were made to ensure each station was surveyed about the same number of times during each period of the day.

Data collected during each station visit consisted of continuous counts of birds and duration of observations during a 20-minute interval to establish use of stations by species. All avian sightings were recorded on data sheets at the time of observation, and locations of raptors and other large birds (RLB) and species of concern were plotted on a map of the site. Location of first sighting and path of flight were mapped in the field on U.S. Geological Survey (USGS) 7.5 ft. quadrangles. These locations and flight paths were later digitized and overlaid on a map of the study area. A unique observation number was assigned to each RLB sighting (or species of concern) to identify the location when first observed. The date, plot number, begin and end times of the observation period, and species were recorded. Weather information (temperature, wind speed and direction, cloud cover, precipitation, sound levels) was also recorded each visit.

Flight height was estimated and recorded to the nearest meter when each bird was first observed. Each additional flight height of the same bird while in the plot was recorded by checking one of several flight height categories on the data sheet (i.e., 0-7 m, 8-25 m, 26-50 m, >50 m). The nearest distance to the observer and duration of time spent within the 0.4-km radius plot were also recorded for each observation. Any comments or unusual observations were recorded in the comments section of the data form.

Data Analysis

Species lists were generated by season. The number of birds by species observed during each point count survey was standardized to a unit area and unit time surveyed. For example, if three raptors were observed during a survey, these data were standardized to 3 raptors per 0.50 km^2 per 20 minutes. The duration of observation by species was also tabulated and recorded as the number of minutes per unit area per unit effort. Point estimates were tabulated and plotted to illustrate and compare differences in avian use between (1) groups, (2) seasons, and (3) stations. Differences were considered significant if 95% of the confidence intervals (mean ± 2*standard error) around the estimates being compared did not overlap. Week to week variability was used to estimate precision of the estimates because data from point to point was not considered independent. For all analyses, the sample size for comparisons of avian use was the number of survey weeks.

A relative index to turbine exposure (*E*) was calculated for all bird species observed in the study area by season using the following formula:

$$E = A*P_f*P_t$$

where *E* is defined to be an index to the probability of exposure to turbine collision, *A* = mean intensity of use for species *I*, P_f = proportion of all observations of species *I* where activity was recorded as flying (an index to the approximate percentage of time species *I* spends flying during the daylight period), and P_t = proportion of all flight height observations of species *I* within the rotor-swept height of the turbines. For this index we used a rotor-swept height of 25 to 75 m (82 to 245 ft.), which encompasses the height of most newer-generation turbines. Results are presented by avian groups to alleviate differences resulting from visibility bias.

Quality Assurance/Quality Control (QA/QC)

QA/QC measures were implemented at all stages of the study, including field data collection, data entry, data analysis, and report preparation. At the end of each survey day, the field technician reviewed the data forms for completeness, accuracy, and legibility. These forms were also reviewed in the office for completeness, accuracy, and legibility. Data were entered into electronic files by a qualified technician. These files were compared to the raw data forms and any errors detected were corrected. Any irregular codes detected, or any unclear or ambiguous data were discussed with the observer and study team leader. All changes made to the raw data were documented for future reference. After the data were keyed and verified, a QA/QC technician checked a 5% sample of data forms against the final computer file.

A database was established to store, retrieve, and organize field observations. Data from field forms were keyed into electronic data files using a predefined format that made subsequent data analysis straight-forward. All field data forms, field notebooks, and electronic data files were retained for ready reference.

Results

Avian Use and Species Composition

Seventy-three species were documented during sightings of 5406 groups totaling 9484 birds while conducting surveys on the study area (Appendix A). The number of birds observed by species used to obtain use and composition estimates are presented in Appendix B. The most species (54) were observed in summer (June–August), followed by spring (March–May) and fall (September–October), with 44 species recorded in each of these seasons. Only 19 species were observed in the winter (November–February) (Table 1). Based on surveys and wildlife observations conducted on the study area in 1998, threatened or endangered species are very rare in the study area. The only threatened or endangered species observed in the study area was the bald eagle. Five bald eagles were observed only during winter.

Differences in mean use and frequency of occurrence among species primarily reflect differences in flocking behavior among species. Many of the species with the highest use were seen less often than several other species, but tended to occur in large flocks when they were observed (Appendix D).

Statistically significant differences in comparisons at the $\alpha=0.10$ level are indicated by $p<0.10$, and non-significant differences by $p>0.10$ in the following results.

The mean number of species observed per survey was used as an index to species richness. The richness index were highest in the spring (2.32 species/survey) followed by summer (2.14), fall (1.74), and winter (0.39) (Table 1). Although avian richness in the spring, summer, and fall were not significantly different, the index in the winter was significantly lower ($p<0.10$) than the other three seasons (Figure 7). Avian use was similar ($p>0.10$) in the spring (5.69/survey), summer (4.63) and fall (4.86). Mean avian use in the winter (1.11/survey) was significantly lower ($p<0.10$) than the other three seasons (Table 1).

The only species of waterfowl observed was Canada goose; one flock was observed during winter. The only water birds and shore birds observed were one pair of unidentified gulls and two groups totaling three individual killdeer. Upland game birds (Appendix C) were observed throughout the year. More game birds were observed during the winter (0.26/survey) than during summer (0.04), but differences between seasons were not significant (Figure 8). Raptor use was highest in the fall (0.38), similar in the spring (0.24) and summer (0.23), and lowest in the winter (0.04). Passerine use was similar in the spring (5.33), summer (4.36) and fall (4.31); winter use (0.81) was significantly lower (Figure 8).

The raptor species with the highest use in the spring were red-tailed hawks (0.09/survey), golden eagles (0.05), and American kestrels (0.05) (Table 3). The five passerines with the highest mean use during spring surveys were western meadowlarks (2.00/survey), horned larks (1.27), vesper sparrows (0.66), American robins (0.50), and common ravens (0.18). Based on frequency of occurrence (percent of surveys each species was recorded), the most commonly occurring raptor species in the spring were also the three species with the highest use, although American kestrels were observed more frequently than golden eagles (Table 4). The most frequently occurring passerine species in spring were western meadowlarks (68.3% of surveys), horned larks (59.8%), vesper sparrows (30.7%), common ravens (9.7%), and American robins (9.3%) (Table 4).

In summer, the raptor species with the highest mean use and highest frequency of occurrence were American kestrels (0.12/survey), red-tailed hawks (0.06), and northern harriers (0.03) (Table 3). The passerines with the highest mean use were horned larks (1.29/survey), western meadowlarks (1.23), vesper sparrows (0.65), common ravens (0.19), and cliff swallows (0.16). Passerines with the highest frequency of occurrence during summer surveys were western meadowlarks (49.7% of surveys), horned larks (42.6%), vesper sparrows (29.5%), rock wrens (9.9%), and black-billed magpies (7.2%) (Table 4).

During fall surveys, the raptors with highest mean use and highest frequency of occurrence were northern harriers (0.12/survey), red-tailed hawks (0.12), and Cooper's hawks (0.04). Passerines with the highest mean use were American robins (1.29/survey), common ravens (0.73), horned larks (0.68), western meadowlarks (0.28), and western bluebirds (0.18). The passerines with the highest frequency of occurrence were horned larks (25.7% of surveys), common ravens (20.7%), western meadowlarks (14.9%), Townsend's solitaires (11.1%), and black-billed magpies (9.4%).

In winter, the raptors with the highest mean use and frequency of occurrence were golden eagles (0.02/survey), followed by red-tailed hawks (0.01), prairie falcons (0.01), and bald eagles (0.01). The passerine species with the highest use were horned larks (0.36/survey), American robins (0.17), common ravens (0.09), Townsend's solitaires (0.05), and white-winged crossbills (0.04). Passerines with the highest frequency of occurrence were horned larks (15.0% of surveys), common ravens (5.7%), Townsend's solitaires (4.0%), black-billed magpies (2.0%) and American robins (1.9%) (Table 4).

Duration Within Plot

The above data provide standardized information on species composition and relative use of the study area, but provide little information on length of time birds spend in the area. Species that spend more time within the plot may have greater exposure to turbines than species that may be observed more often but spend less time in the plot. The average amount of time passerines spent within plots ranged from 1.15 minutes/survey in winter to 40.98 minutes/survey in the spring (Table 2). The amount of time spent within study plots by passerines was significantly lower in winter than during the other three seasons, which were similar (Figure 9). Game birds spent the most time within plots during fall (0.95 minutes/survey) and the least in summer (0.15 minutes/survey), but differences between seasons were not significantly different. Raptors spent much less time within plots than the other groups, ranging from 0.05 minutes per survey in winter to 0.77 minutes per survey during fall (Table 2). The amount of time spent within plots by raptors during winter was significantly lower than during the other three seasons, which were similar (Figure 9).

Species spending the most time within plots during both spring and summer were, in order, western meadowlark, horned lark, and vesper sparrow (Appendix C). In fall, American robins spent the most time within plots, followed by common ravens and horned larks. Those species spending the most time within plots during the winter season were horned lark, gray partridge, and Townsend's solitaire (Appendix C).

Flight Height

Observations were made of 5844 flying birds in 2668 flocks during avian surveys. Mean flight height was 14m (45.9 ft.) for all individual birds and 12m (39.3 ft.) for all flocks observed (Table 5). Sample sizes for shore birds, water birds, and waterfowl were too small to provide meaningful estimates of flight height within the study area. Mean flight height was 1m (3.2 ft.) for upland game birds, 12m (39.3 ft.) for passerines, and 34m for raptors. Species with the highest average flight heights were osprey 79m (259.1 ft.), common raven 60m (196.8 ft.), red-tailed hawk 49m (160.7 ft.), golden eagle 40m (131.2 ft.), and Cooper's hawk 39m (127.9 ft.) (Appendix D).

Flight height data were examined in relation to height of the rotor-swept area of turbines potentially used in the study area. The area from 25 to 75 m above ground encompasses the rotor-swept height of most turbines currently being constructed. During the study, 83.1% of all flying birds observed were below the rotor-swept height, 13.0% were within the rotor-swept height, and 3.9% were above the rotor-swept height (Table 6). The percentage of flying birds within the rotor-swept height was highest for raptors (41.6%). A total of 10.7% of all passerines and no upland game birds were observed flying within the rotor-swept height. For species with observations of at least 50 flying birds, the five with the greatest proportion of observations within the rotor-swept height were red-tailed hawk (62.0%), common raven (33.6%), American kestrel (25.0%), Lewis' woodpecker (22.2%), and cliff swallow (21.2%) (Appendix E).

Exposure Indices

Relative exposure indices, defined as an index to the probability of being exposed to collision with a turbine, were calculated for all species observed during surveys (Appendix F) based on mean use, proportion of daily activity spent flying, and proportion of flight heights within the rotor-swept height of turbines. Based on this index, species with the highest probability of exposure to turbine collision during spring are American robin, common raven, red-tailed hawk, golden eagle, and horned lark. During the summer season, species with the highest exposure index are common raven, cliff swallow, red-tailed hawk, American kestrel, and horned lark. During the fall, common raven, American robin, red-tailed hawk, northern harrier, and Cooper's hawk have the highest exposure index. In winter, species with the highest exposure index were common raven, American robin, golden eagle, horned lark, and bald eagle (Table 7). Common ravens may have lower exposure relative to other species than the exposure index indicates because use estimates (a major factor in the risk index) may have been biased against other smaller species. The plot radius was 0.4 km; therefore, many of the smaller species may go undetected, especially those near the outer edge of the search plot, whereas virtually all ravens within this radius are likely detected. High winds, topography, and vegetation also sometimes affected the observers ability to detect birds.

This analysis may provide insight into what species might be the most likely turbine casualties. However, this index only considers relative risk based on use, proportion of daily activity spent flying, and flight height of each species. This analysis is based on observations of birds during the daylight period and does not take into consideration flight behavior or use of nocturnal migrants. It also does not take into consideration varying ability among species to detect and avoid turbines, habitat selection and other factors that may influence risk; therefore, the actual risk may be lower or higher than indicated by these data. For example, in the Altamont Pass WRA in California, mortality among the five most common species was not related to their abundance. American kestrels, red-tailed hawks, and golden eagles were killed more often, and turkey vultures and common ravens were killed less often than predicted based on abundance (Orloff and Flannery 1992). Similarly, at the Tehachapi Pass WRA in California, common ravens were found to be the most common large bird in the WRA, yet no fatalities for this species have been documented during intensive studies (Richard Anderson, personal communication, May 1998).

Spatial Use

The mean number of passerines and raptors observed per survey point over the entire study period was plotted to determine location of potential high use regions within the study area. From examining the plots, it appears that passerine use may be slightly higher on the western side of the study area than on the eastern side. For raptors, however, it appears that the eastern side of the study area may receive slightly more use (Figure 10). For both passerines and raptors, use appears to be higher at those plots on the edge of the rim (Figures 10 and 11). Due to variability in the data collected over one year, we believe that additional data collection would be required to ensure that high use areas are identified on a regional scale so that they could be avoided when siting turbines.

Plots of flight paths of all raptors observed during the study indicate varying use of the study area among species. Flight paths of both golden eagles and red-tailed hawks were strongly clustered near the rim, and a majority of the flight paths were parallel with the rim edge (Figures 12 and 13). Northern harrier and American kestrel use of the rim was distributed more evenly between the rim edge and other areas of the study area (Figures 14 and 15).

Conclusions/Discussion

Comparisons of use and other variables between species could be made within groups of species with similar detection rates (e.g., raptors, passerines, game birds). Detection out to 400m is probably most similar for the raptor group, while detection probably varies between some passerine species. Because the primary groups of interest are raptors and other large birds, no attempt was made to estimate visibility bias for individual passerine species. Furthermore, data would be sufficient for only a few more abundant species because of the sample size requirements for detection probability estimation (Buckland et al. 1993).

After reviewing results of the first year of data collection, several conclusions may be made. Avian use data indicate that the CARES study area receives similar use by birds during the spring, summer and fall. Use in winter is substantially lower than during the other three seasons. Although there was some variation among seasons, the raptors with the highest use within the study area are red-tailed hawk, golden eagle, American kestrel, and northern harrier. The passerines with the highest use are western meadowlark, horned lark, vesper sparrow, American robin, and common raven. Turbine-related risk to threatened and endangered species appears to be very low on this site, as only one species (bald eagle) was observed, and only on 5 occasions throughout the entire year (Figure 16).

Flight height data collected prior to any turbine construction and operation indicate relatively low risk of turbine collision in the study area for passerines and game birds, as only 10.7% of passerines and 0% of game birds observed flying were seen within the 25–75 m rotor-swept height of most new generation turbines. Based strictly on flight height, raptors would appear to be more at risk from collision, since 41.6% of raptors observed flying were within the 25–75 m rotor-swept height. The two raptors with the greatest proportion of flight heights within the rotor-swept height were red-tailed hawk and American kestrel. Passerines with the largest proportion of flight heights within the rotor-swept height were common raven, Lewis' woodpecker, and cliff swallow.

Based on relative use, proportion of observations recorded as flying, and proportion of flight heights recorded within the rotor-swept height, raptors with the greatest potential turbine exposure are red-tailed hawk and golden eagle, whereas passerines with the highest exposure are common raven, American robin, and horned lark. Spatial use data indicate that avian use of the CARES study area tends to be concentrated near the rim edge, indicating that risk may be reduced by placing turbines away from the rim edge. High use of rim edges by raptors has also been documented at other sites (Johnson et al. 1998).

Raptor abundance indices on the CARES study area are very similar to raptor abundance indices for the Buffalo Ridge wind plant in Minnesota. Passerine abundance indices at the CARES site is only about half that of Buffalo Ridge. Although other factors besides avian abundance may influence the mortality of birds at wind plants, no raptor mortalities and only minimal passerine mortalities have been documented at the Buffalo Ridge site (Johnson et al. 1999). Therefore, avian use data at the CARES site indicate that if a wind plant is constructed in the future, avian mortality would be relatively low.

Literature Cited

Avian Power Line Interaction Committee (APLIC) (1994). Mitigating Bird Collisions with Power Lines: The State of the Art in 1994. 06-94-33. Edison Electric Institute, Washington, D.C.

American Wind Energy Association (AWEA) (1995). "Avian Interactions with Wind Energy Facilities: A Summary." Prepared by Colson & Associates for AWEA, Washington, D.C.

Avery, M.L. ed. (1978). *Impacts of Transmission Lines on Birds in Flight: Proceedings of a Workshop.* Oak Ridge Associated Universities, Oak Ridge, Tennessee. 31 January-2 February 1978. FWS/OBS-78/48. 151pp. United States Fish and Wildlife Service, Biological Services Program.

Avery, M.L., Springer, P.R., and Dailey, N.S. (1980). *Avian Mortality at Man-Made Structures: An Annotated Bibliography.* FWS/OBS-80/54. United States Fish and Wildlife Service.

Banks, R.C. (1979). *Human Related Mortality of Birds in the United States.* United States Fish and Wildlife Service Scientific Report - Wildlife No. 215.16 pp.

Bealaurier, D. (1981). *Mitigation of Bird Collisions with Transmission Lines.* Bonneville Power Association (BPA), Portland, Oregon. 83 pp.

BioSystems Analysis (1992). *Wind Turbine Effects on Avian Activity, Habitat Use, and Mortality in Altamont Pass and Solano County WRAs.* Prepared by BioSystems Analysis, Inc., Tiburon, California, for California Energy Commission, Sacramento.

Bonneville Power Administration (BPA) (1987). *Cape Blanco Wind Farm Feasibility Study.* DOE/BP-11191-13. Bonneville Power Administration (BPA), Portland, Oregon.

Bonneville Power Administration (BPA) and Klickitat County (1994). *Preliminary Draft: Joint NEPA/SEPA Environmental Impact Statement, Washington Windplant #1*. DOE/EIS-0205.

Brown, W.M. (1993). "Avian Collisions with Utility Structures: Biological Perspectives." *Proceedings: Avian Interactions with Utility Structures*. International Workshop, Miami, Florida. Sponsored by Avian Power Line Interaction Committee (APLIC) and Electric Power Research Institute (EPRI).

Brown, W.M. and Drewien, R.C. (1995)."Evaluation of Two Power Line Markers to Reduce Crane and Waterfowl Collision Mortality." Wildlife Society Bulletin 23(2):217-217.

Buckland, S.T., Anderson, D.R., Burnham, K.P., and Laake, J.L. (1993). "Distance Sampling: Estimating Abundance of Biological Populations." Chapman & Hall, New York. 446 pp.

Bureau of Reclamation (1984). *Status Report on System Verification Units: Wind–Hydroelectric Energy Project, Wyoming.* Bureau of Reclamation, Wyoming.

California Energy Commission (CEC) (1995). *Avian Collision and Electrocution: An Annotated Bibliography.* California Energy Commission, Sacramento, California.

California Energy Commission(CEC) (1996). *Effects of Wind Energy Development: An Annotated Bibliography.* California Energy Commission, Sacramento, California.

Cochran, W.W. and Graber, R.R. (1958). "Attraction of Nocturnal Migrants by Lights on a Television Tower." Wilson Bulletin 70(4):378-380.

Colson, E.W. and Luman, I.D. (1978). "Routing Transmission Lines Through Water Bird Habitat in California." *Impacts of Transmission Lines on Birds in Flight: Proceedings of a Workshop.* ed. Avery, M.L., Oak Ridge Associated Universities, Oak Ridge, Tennessee. 31 January-2 February 1978. FWS/OBS-78/48. United States Fish and Wildlife Service, Biological Services Program. 151 pp.

Crockford, N.J. (1992). *A Review of the Possible Impacts of Wind Farms on Birds and Other Wildlife.* Joint Nature Conservation Committee, JNCC Report No. 27, Peterborough, United Kingdom.

DeFusco, R.P. and Nagy, J.G. (1983). *Frightening Devices for Airfield Bird Control.* Bird Damage Research Report 274. United States Fish and Wildlife Service, Denver Wildlife Resource Center, Denver, Colorado. 78 pp.

Electric Power Research Institute (EPRI) (1985). *MOD-2 Wind Turbine Field Experience in Solano County, California.* Report No. AP-4239. Prepared by Pacific Gas and Electric Company, San Ramon, California.

Electric Power Research Institute (EPRI) (1993). "Proceedings: Avian Interactions with Utility Structures." International Workshop. EPRI TR-1032685. Miami, Florida, 1992.

Faanes C.A. (1987). *Bird Behavior and Mortality in Relation to Power Lines in Prairie Habitats.* Fish and Wildlife Technical Report 7, Washington DC.

Hansen, P., Grand, B., and Lange, N. (1992). *Power to Spare in the Upper Midwest.* Izaak Walton League of America. Minneapolis, Minnesota. 33 pp.

Herbert, A.D. (1970). "Spatial Disorientation in Birds". Wilson Bulletin 82(4):400-419.

Howell, J.A. (1995). *Avian Mortality at Rotor Swept Area Equivalents Altamont Pass and Montezuma Hills, California.* Prepared for Kenetech Windpower [formerly U.S. Windpower Inc.], San Francisco, California.

Howell, J.A., and Noone, J. (1992). *Examination of Avian Use and Mortality at a United States Windpower Wind Energy Development Site, Solano County, California.* Final report to Solano County Department of Environmental Management, Fairfield, California. 41 pp.

Howell, J.A., Noone, J., and Wardner, C. (1991). *Visual Experiment to Reduce Avian Mortality Related to Wind Turbine Operations, Altamont Pass, Alameda and Contra Costa Counties, California, April 1990 through March 1991.* Final report. Prepared for U.S. Windpower, Inc., Livermore, California.

Hunt, G. (1994). *A Pilot Golden Eagle Population Project in the Altamont Pass Wind Resource Area, California.* Prepared by The Predatory Bird Research Group, University of California, Santa Cruz, for The National Renewable Energy Laboratory, Golden, Colorado. Report NREL/TP-441-7821. 212 pp.

Jaroslow, B. (1979). "A Review of Factors Involved in Bird-Tower Kills, and Mitigative Procedures." Swanson, G.A., Technical Coordinator. *The Mitigation Symposium: A National Workshop on Mitigation Losses of Fish and Wildlife Habitats.* RM-65. United States Forest Service General Technical Report. 469-473 pp.

Johnson, G.D., Young, Jr., D.P., Derby, C.E., Erickson, W.P., Strickland, M.D., and Kern, J.W. (1998). *Wildlife Monitoring Studies, SeaWest Wind Power Plant, Carbon County, Wyoming, 1995-1997.* Prepared for SeaWest Energy Corporation and Bureau of Land Management. 184 pp.

Johnson, G.D., Erickson, W.P., Strickland, M.D., Shepherd, M.F., and Shepherd, D.A. (1999).*Avian Monitoring Studies, Buffalo Ridge Wind Resource Area, Minnesota, 1996-1998.* Prepared for Northern States Power Co., Minneapolis, Minnesota. 212 pp.

Jones & Stokes Associates, Inc. (1987). *Bird Abundance and Movements at the Potrero Hills Wind Turbine Site, Solano County, California.* Prepared for Solano County Department of Environmental Management, Fairfield, California.

Jones & Stokes Associates, Inc. (January 31, 1995). *Avian Use of Proposed Kenetech and CARES Wind Farm Sites in Klickitat County, Washington.* (JSA 93-303). Bellevue, Washington. Prepared for Beck, R.W. Seattle, Washington.

Knittle, C.E. and Porter, R.D. (1988). *Waterfowl Damage and Control Methods in Ripening Grain: An Overview.* United States. F.W.S., Washington, DC. 17 pp.

Koops, F.B.J. (1987). *Collision Victims of High-Tension Lines in the Netherlands and Effects of Marking.* KEMA Report 01282-MOB 86-3048.

Koops, F.B.J. (1993). *Collision Victims of High-Tension Lines in the Netherlands and Effects of Marking.* Unpublished report, KEMA, N.V. Arnhem. 6 pp.

Koshi, W.R., Kevan, S.D., and Richardson, W.J. (1993). "Bird Dispersal and Deterrent Techniques for Oil Spills in the Beaufort Sea." Environmental Studies Research Funds (ESRF), Calgary, Alberta. Report 126. 100 pp.

Kreithen, M.L. (1996). "Development of a Pulsed Microwave Warning System to Reduce Avian Collisions with Obstacles." *2nd International Conference on Raptors.* Urbino, Italy. Abstract.

Marsh, R.E., Erickson, W.A., and Salmon, T.P. (1991). *Bird Hazing and Frightening Methods and Techniques.* California Department Water Resource Control, Department of Wildlife & Fisheries Biology, University of California, Davis, California. Report No. B-57211. 233 pp.

McCrary, M.D., McKernan, R.L., and Schreiber, R.W. (1986). *San Gorgonio Wind Resource Area: Impacts of Commercial Wind Turbine Generators on Birds, 1985 Data Report.* Prepared for Southern California Edison Company. 33 pp.

McIsaac, Hugh (Personal Communication, 1998). Raptor Research Center, Boise State University, Boise, Idaho.

Miller, W. A. (1978). "Transmission Line Engineering and Its Relationship to Migratory Birds." *Impacts of Transmission Lines on Birds in Flight: Proceedings of a Workshop.* Avery, M.L. Oak Ridge Associated Universities, Oak Ridge, Tennessee. 31 January-2 February 1978. FWS/OBS-78/48. United States Fish and Wildlife Service, Biological Services Program. 151 pp.

Miller, A.D. (1990). *A Study to Determine the Effectiveness of Power Line Marking Systems to Reduce Avian Collision Mortality.* Unpublished report for Avian Power Line Interaction Committee (APLIC). 15 pp.

Morkill A.E. and Anderson, S.H. (1991). "Effectiveness of Marking Power Lines to Reduce Sandhill Crane Collisions." Wildlife Society Bulletin. 19(4): 442-449.

Nelson, H.K. and Curry, R.C. (1995). "Assessing Avian Interactions with Wind Plant Development and Operation." *61st North American Wildlife and Natural Resources Conference.* Wildlife Management Institute, Washington, D.C.

Orloff, S. (1992). *Tehachapi Wind Resource Area Avian Collision Baseline Study.* Prepared for California Energy Commission by BioSystems Analysis, Inc., Tiburon, California. 21 pp.

Orloff, S. and Flannery, A. (1992). *Wind Turbine Effects on Avian Activity, Habitat Use, and Mortality in Altamont Pass and Solano County Wind Resource Areas, 1989-1991.* P700-92-001. Final Report to Alameda, Contra Costa and Solano Counties and the California Energy Commission by BioSystems Analysis, Inc., Tiburon, CA.

Orloff, S. and Flannery, A. (1996). *A Continued Examination of Avian Mortality in the Altamont Pass Wind Resource Area.* P700-96-004CN. California Energy Commission, Sacramento, California.

Raevel, P. and Tombal, J.C. (1991). "Impact des Lignes Haute-Tension sur L'avi Faune." Les Cahiers de L'A.M.B.E. et Environnement, Vol. 2. 31 pp.

Skalski, J.R. and Robson, D.S. (1992). *Techniques for Wildlife Investigations.* Academic Press Inc. New York. 237 pp.

Thompson, L.A. (1978). "Transmission Line Wire Strikes: Mitigation Through Engineering Design and Habitat Modification." *Impacts of Transmission Lines on Birds in Flight: Proceedings of a Workshop.* Avery, M.L.. Oak Ridge Associated Universities, Oak Ridge, Tennessee. 31 January-2 February 1978. FWS/OBS-78/48. United States Fish and Wildlife Service, Biological Services Program. 151 pp.

Tucker, V.A. (1996a). "A Mathematical Model of Bird Collisions with Wind Turbine Rotors." *Journal of Solar Energy Engineering*. 118:253-262.

Tucker, V.A. (1996b). "Using a Collision Model to Design Safer Wind Turbine Rotors for Birds." *Journal of Solar Energy Engineering*. 118:263-269.

Weir, R.D. (1976). *Annotated Bibliography of Bird Kills at Man-Made Obstacles: A Review of the State of the Art and Solutions.* Canadian Wildlife Services, Ontario Region, Ottawa.

Winkelman, J.E. (1992). De invloed van de Sep-proefwindcentrale te Oosterbierum (Fr.) op vogels, 1. Aanvaringsslachtoffers (The impact of the Sep Wind Park near Oosterbierum [Fr.], The Netherlands, on birds, 1. Collision victims; English summary). Rijksinstituut voor Natuurbeheer, Arnhem. RIN-Rapport 92/2.

Table 1. Avian Use Estimates and Species Richness Indices by Season in the CARES Project Area

Use/Richness Measure	Season			
	Spring	Summer	Fall	Winter
Number of Species	44	54	44	19
Mean Number/Survey	5.69	4.63	4.86	1.11
Mean Number Species/Survey	2.32	2.14	1.74	0.39

Table 2. Mean Use, Duration in Plot, and Percent Frequency of Occurrence of Avian Groups Observed During Surveys on the Study Area

Avian Group	Mean Use				Duration in Plot (minutes)				% Frequency Of Occurrence			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Game Birds	0.122	0.041	0.165	0.261	0.536	0.145	0.953	0.131	7.2	1.4	3.9	3.1
Raptors	0.236	0.232	0.380	0.042	0.315	0.532	0.766	0.048	17.3	18.2	26.3	4.2
Waterfowl	0	0	0.014	0	0	0	0.014	0	0	0	0.280	0
Water Birds/Shore Birds	0.005	0.004	0	0	0.003	0.004	0	0	0.3	0.4	0	0
Passerines	5.331	4.357	4.305	0.811	40.981	28.960	18.970	1.154	86.7	79.1	68.4	29.0
Total	5.694	4.634	4.864	1.114	41.835	29.641	20.703	1.333	na	na	na	na

Table 3. Raptor and Passerine Species with the Highest Use by Season (Based on Mean Number Observed Per Survey)

Spring		Summer		Fall		Winter	
Species	#/Survey	Species	#/Survey	Species	#/Sur	Species	#/Survey
Raptors							
Red-Tailed Hawk	0.09	American Kestrel	0.12	Northern Harrier	0.12	Golden Eagle	0.02
Golden Eagle	0.05	Red-Tailed Hawk	0.06	Red-Tailed Hawk	0.12	Red-Tailed Hawk	0.01
American Kestrel	0.05	Northern Harrier	0.03	Cooper's Hawk	0.04	Prairie Falcon	0.01
						Bald Eagle	0.01
Passerines							
Western Meadowlark	2.00	Horned Lark	1.29	American Robin	1.29	Horned Lark	0.36
Horned Lark	1.27	Western Meadowlark	1.23	Common Raven	0.73	American Robin	0.17
Vesper Sparrow	0.66	Vesper Sparrow	0.65	Horned Lark	0.68	Common Raven	0.09
American Robin	0.50	Common Raven	0.19	Western Meadowlark	0.28	Townsend's Solitaire	0.05
Common Raven	0.18	Cliff Swallow	0.16	Western Bluebird	0.18	White-Winged Crossbill	0.04

Table 4. Most Commonly Occurring Raptor and Passerine Species by Season (Based on Percent Frequency of Occurrence)

Spring		Summer		Fall		Winter	
Species	% Freq.	Species	% Freq.	Species	% Freq.	Species	% Freq.
Raptors							
Red-Tailed Hawk	7.0	American Kestrel	9.8	Northern Harrier	10.4	Golden Eagle	1.8
American Kestrel	4.9	Red-Tailed Hawk	5.6	Red-Tailed Hawk	8.9	Red-Tailed Hawk	0.8
Golden Eagle	4.1	Northern Harrier	2.3	Cooper's Hawk	3.1	Prairie Falcon	0.6
						Bald Eagle	0.6
Passerines							
Western Meadowlark	68.3	Western Meadowlark	49.7	Horned Lark	25.7	Horned Lark	15.0
Horned Lark	59.8	Horned Lark	42.6	Common Raven	20.7	Common Raven	5.7
Vesper Sparrow	30.7	Vesper Sparrow	29.5	Western Meadowlark	14.9	Townsend's Solitaire	4.0
Common Raven	9.7	Rock Wren	9.9	Townsend's Solitaire	11.1	Black-Billed Magpie	2.0
American Robin	9.3	Black-Billed Magpie	7.2	Black-Billed Magpie	9.4	American Robin	1.9

Table 5. Flight Heights of Avian Groups Recorded During Surveys on the CARES Study Area

Species	No. Observed Flying				Flock	Individual
	Individuals	Flocks	Min.	Max.	Mean	Mean
Game Birds	122	24	0.5	5	1.4	0.8
Passerines	5271	2242	0.5	300	8.0	12.1
Raptor	441	397	0.5	750	33.8	33.5
Shore Bird	3	2	2	25	13.5	9.7
Water Bird	2	2	10	100	55.0	55.0
Waterfowl	5	1	35	35	35.0	35.0
Total	5844	2668			11.9	13.5

Table 6. Percent of Avian Groups Observed Flying Below, Within, and Above the Rotor-Swept Heights of Turbines

			Weight by Individual			Weight by Group		
Group	Individ.	Flocks	1-25 meters(m)	25-75m	>75m	1-25m	25-75m	>75m
Game Birds	122	24	100.0	0.0	0.0	100.0	0.0	0.0
Passerines	5271	2242	85.8	10.7	3.5	91.2	7.6	1.2
Raptors	441	397	48.8	41.6	9.6	50.4	39.8	9.8
Shore Birds	3	2	66.7	33.3	0.0	50.0	50.0	0.0
Water Birds	2	2	50.0	0.0	50.0	50.0	0.0	50.0
Waterfowl	5	1	0.0	100.0	0.0	0.0	100.0	0.0
All Birds	5844	2668	83.1	13.0	3.9	85.1	12.4	2.5

Table 7. Species with Highest Exposure to Turbines in CARES Study Area Based on Mean Use, Proportion of Activity Budget Spent Flying, and Proportion of Flight Heights Within Rotor-Swept Height of Turbines

Spring		Summer	
Species	Exposure Index[a]	Species	Exposure Index
Raptors		Raptors	
Red-Tailed Hawk	0.048	Red-Tailed Hawk	0.032
Golden Eagle	0.027	American Kestrel	0.023
American Kestrel	0.009	Turkey Vulture	0.005
Passerines		Passerines	
American Robin	0.058	Common Raven	0.063
Common Raven	0.058	Cliff Swallow	0.033
Horned Lark	0.021	Horned Lark	0.021
Tree Swallow	0.012	Lewis' Woodpecker	0.019
Mountain Bluebird	0.005	American Robin	0.009

Fall		Winter	
Species	Exposure Index[a]	Species	Exposure Index
Raptors		Raptors	
Red-Tailed Hawk	0.059	Golden Eagle	0.009
Northern Harrier	0.019	Bald Eagle	0.006
Cooper's Hawk	0.018	Red-Tailed Hawk	0.004
Passerines		Passerines	
Common Raven	0.238	Common Raven	0.030
American Robin	0.152	American Robin	0.019
Western Bluebird	0.017	Horned Lark	0.006
Horned Lark	0.011	Unidentified Woodpecker	0.004
Northern Flicker	0.010	American Goldfinch	0.001

[a] Exposure index calculated by multiplying mean use (#/survey) times proportion of all observations where species *I* was observed flying times proportion of all flying observations where species *I* was observed within the rotor-swept height of turbines.

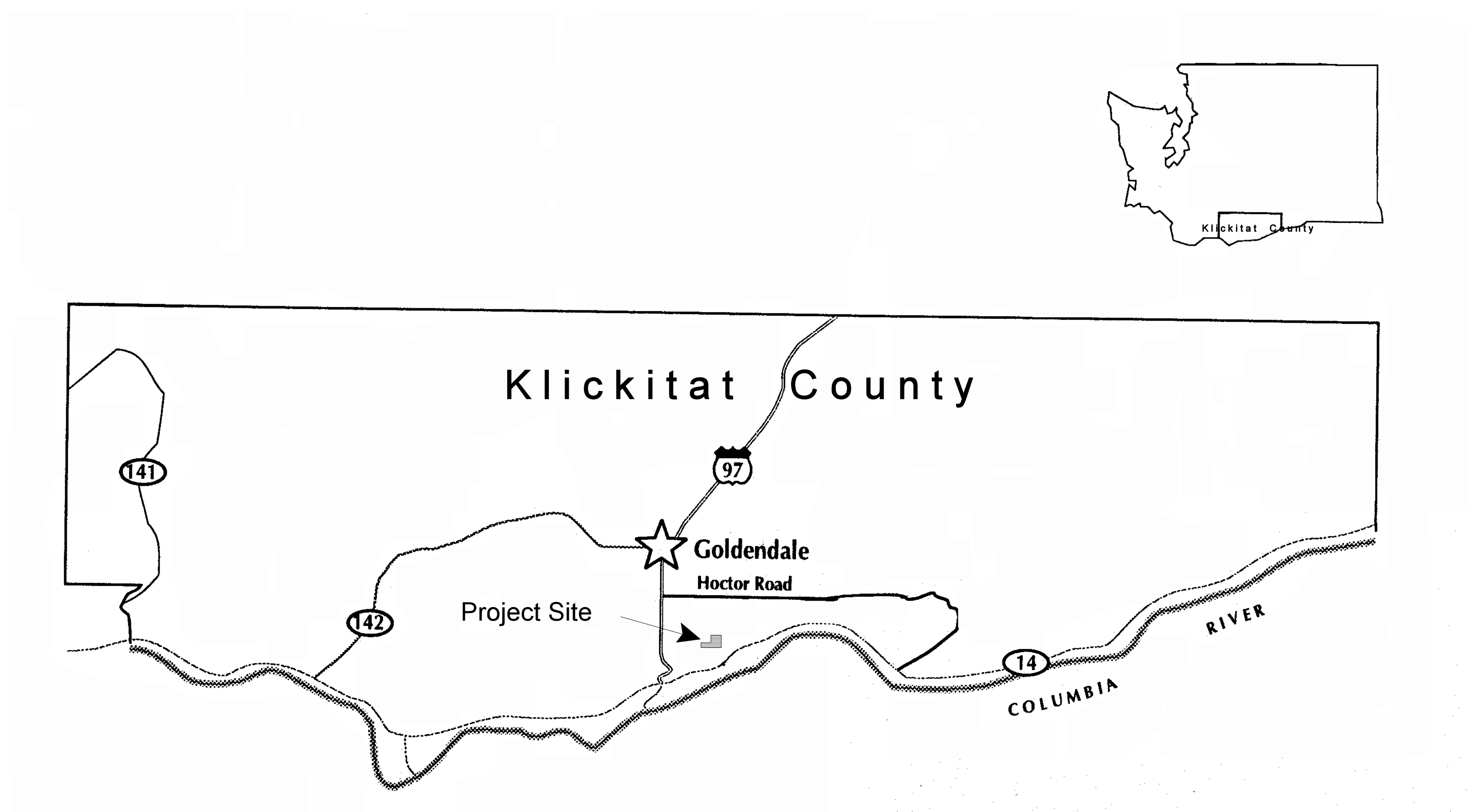

Figure 1. Location of Proposed CARES Wind Plant

Figure 2. Looking West to Juniper Point Within the CARES Site

Figure 3. Juniper Point Within the CARES Site

Figure 4. Oak-Pine and Grassland Habitat Near the CARES Site

Figure 5. Grassland Habitat with Oak-Pine in Draw Near CARES Site

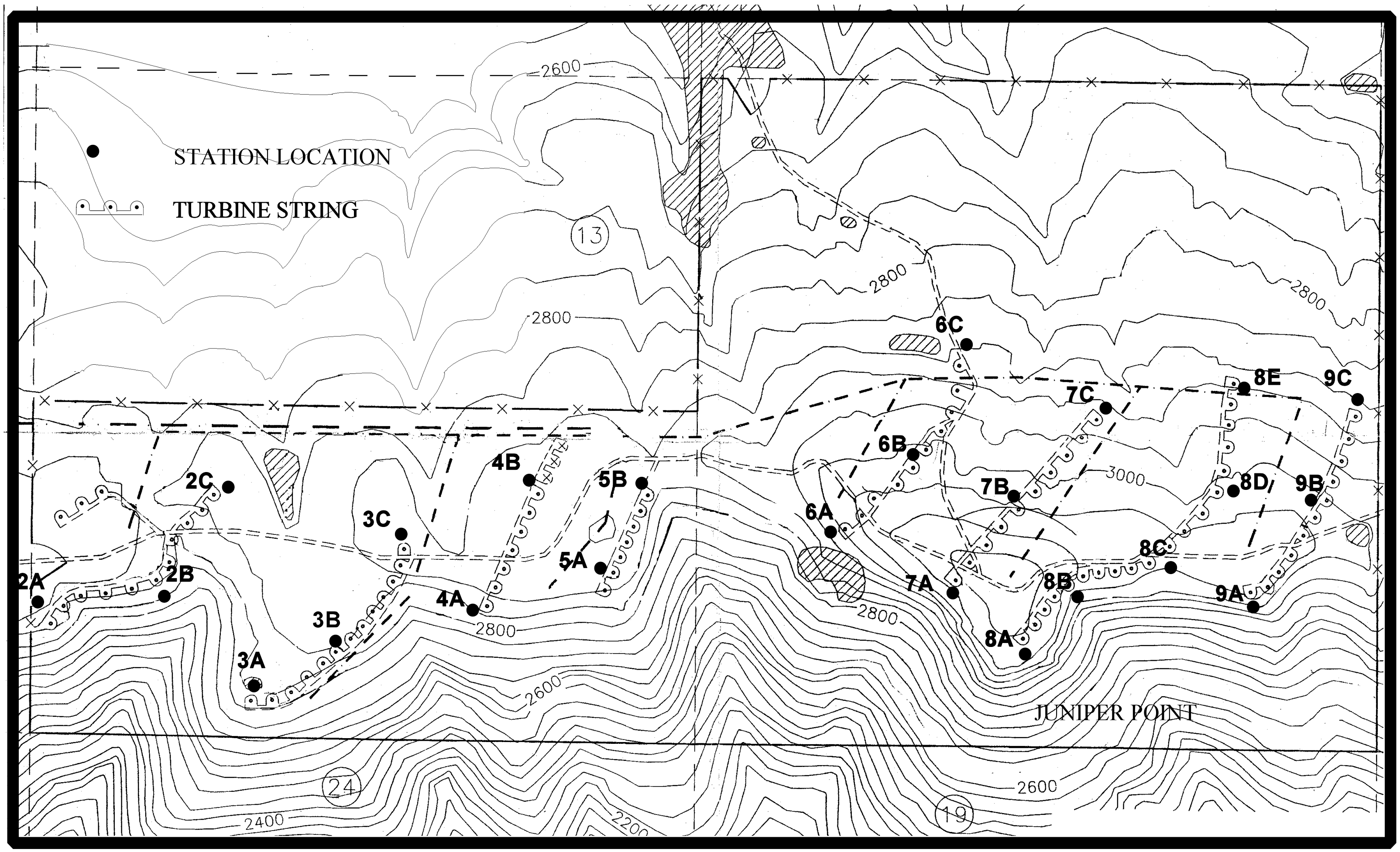

Figure 6. CARES Washington Wind Plant # 1 Study Area

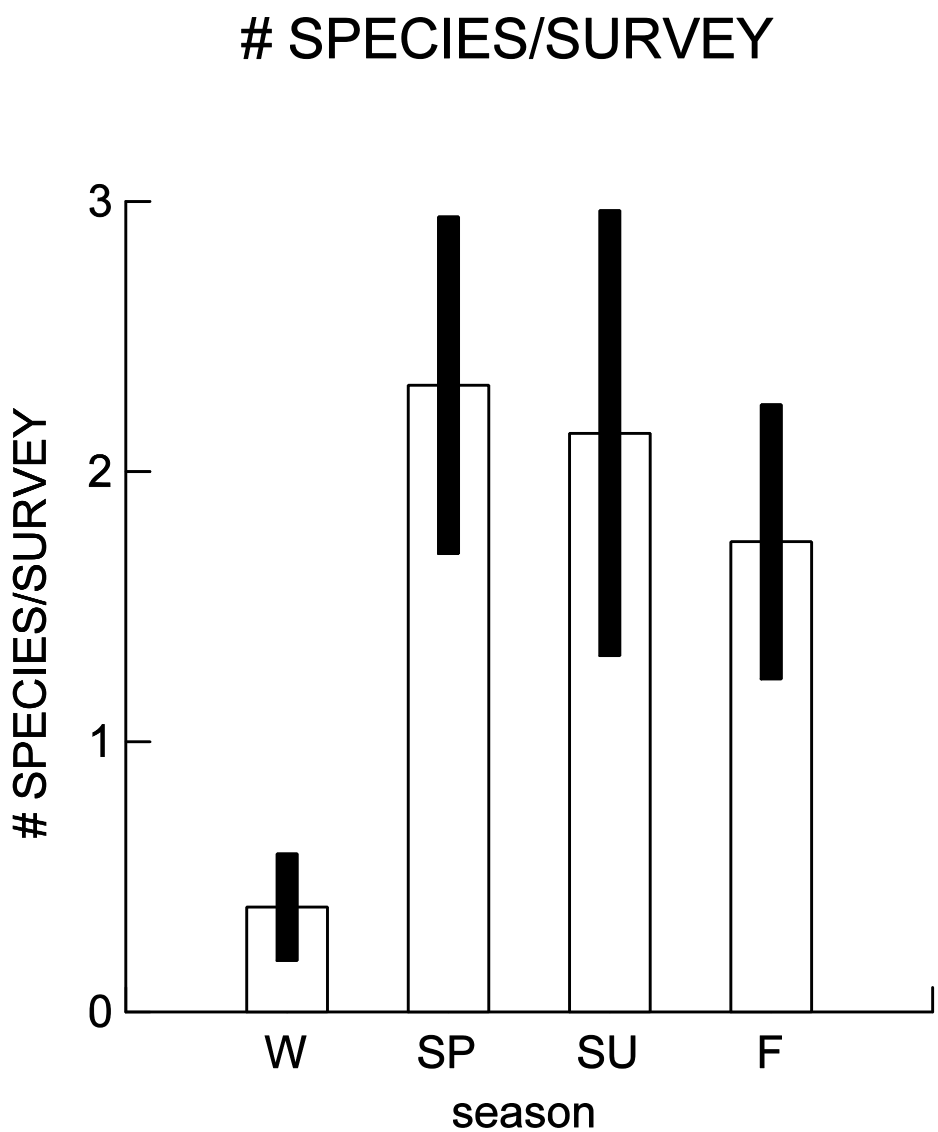

Figure 7. Index to Species Richness (Expressed as the Number of Species Per Survey) at the CARES Wind Plant #1 Site

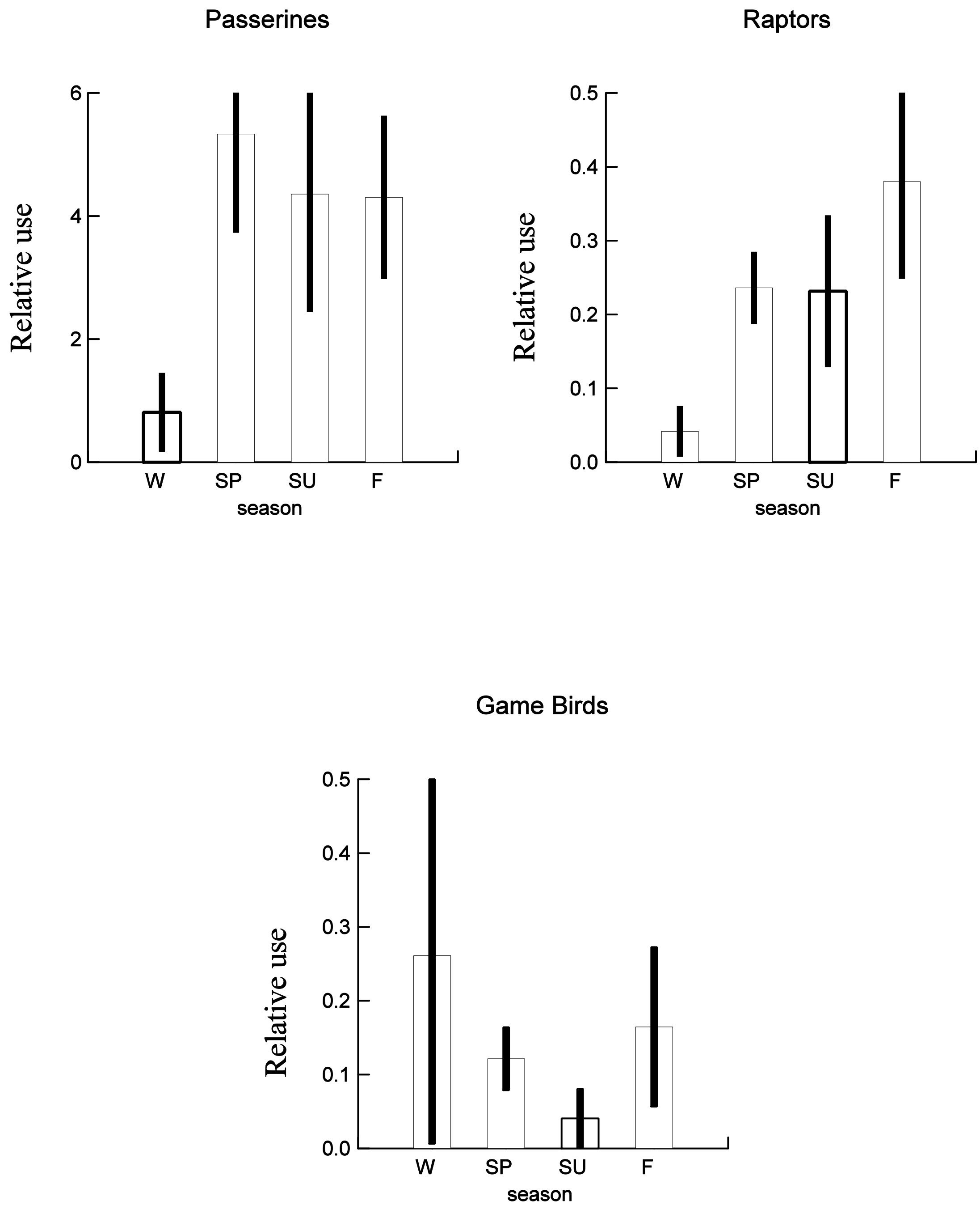

Figure 8. Avian Use (Expressed as Number Observed Per Survey) at the CARES Wind Plant Site

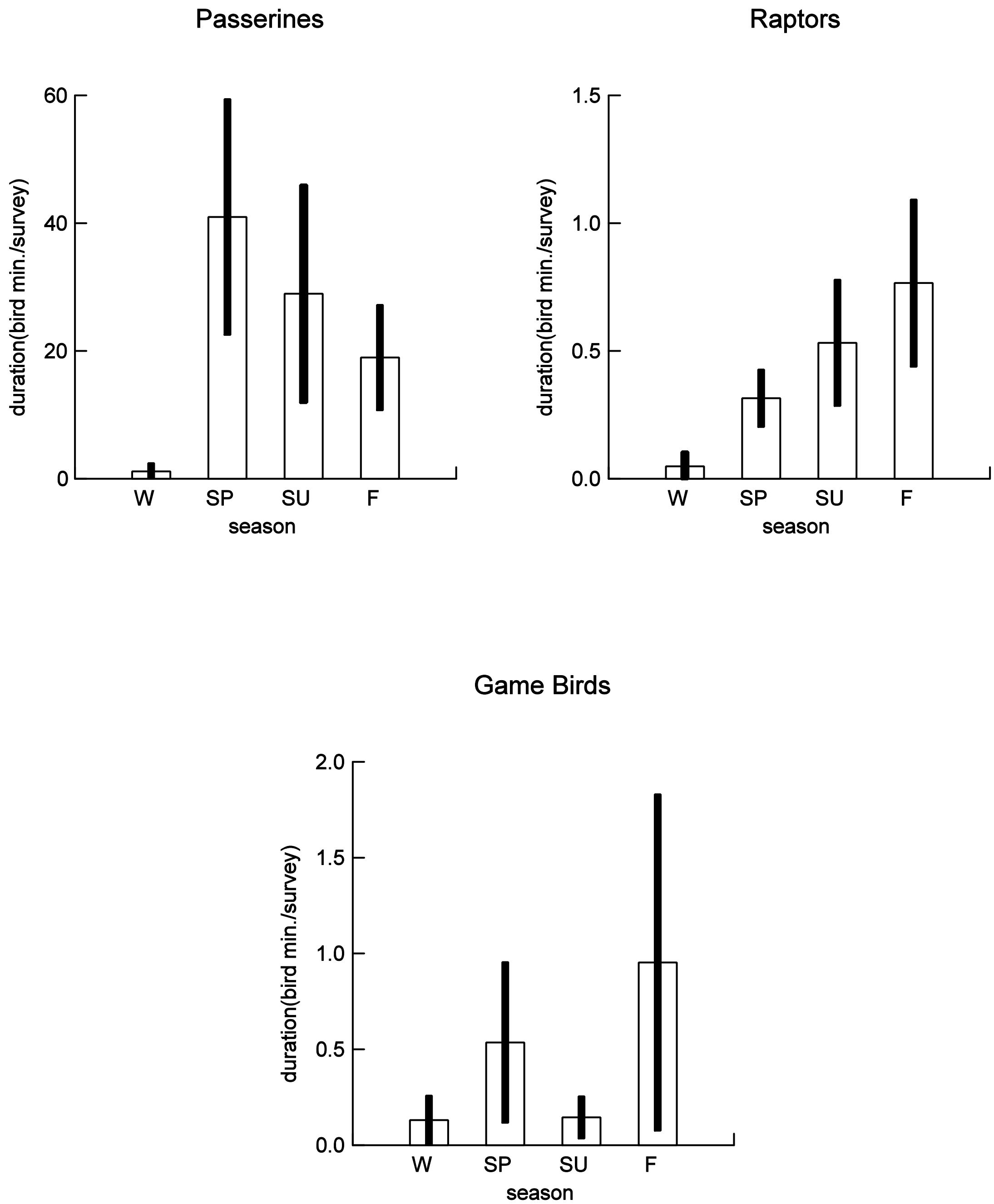

Figure 9. Duration of Time With Study Plots for Avian Groups Observed at the CARES Wind Plant Site

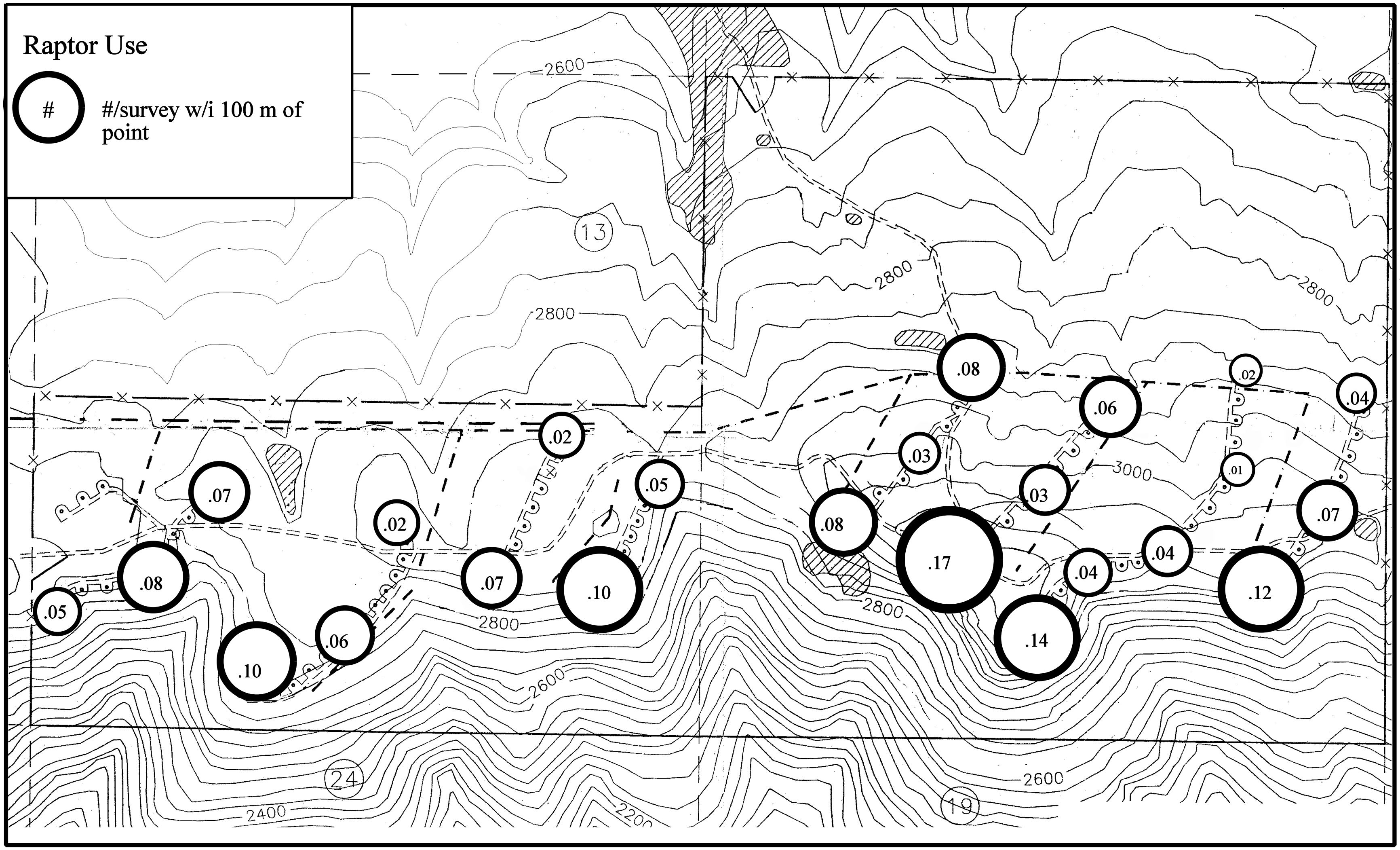

Figure 10. Raptor Use (Mean No./Survey) Among Survey Points on the CARES Wind Plant Site

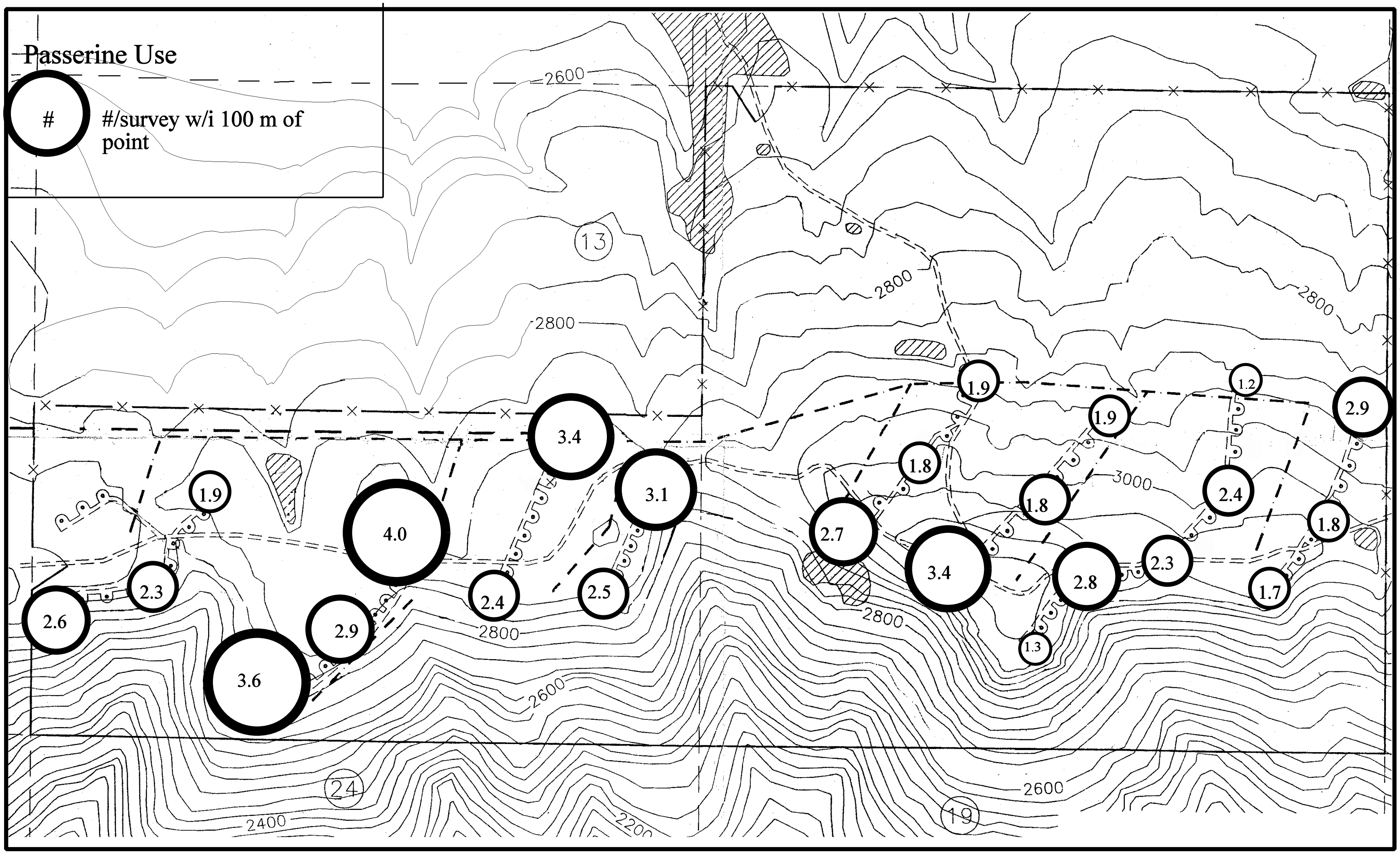

Figure 11. Passerine Use (Mean No./Survey) Among Survey Points on the CARES Wind Plant Site

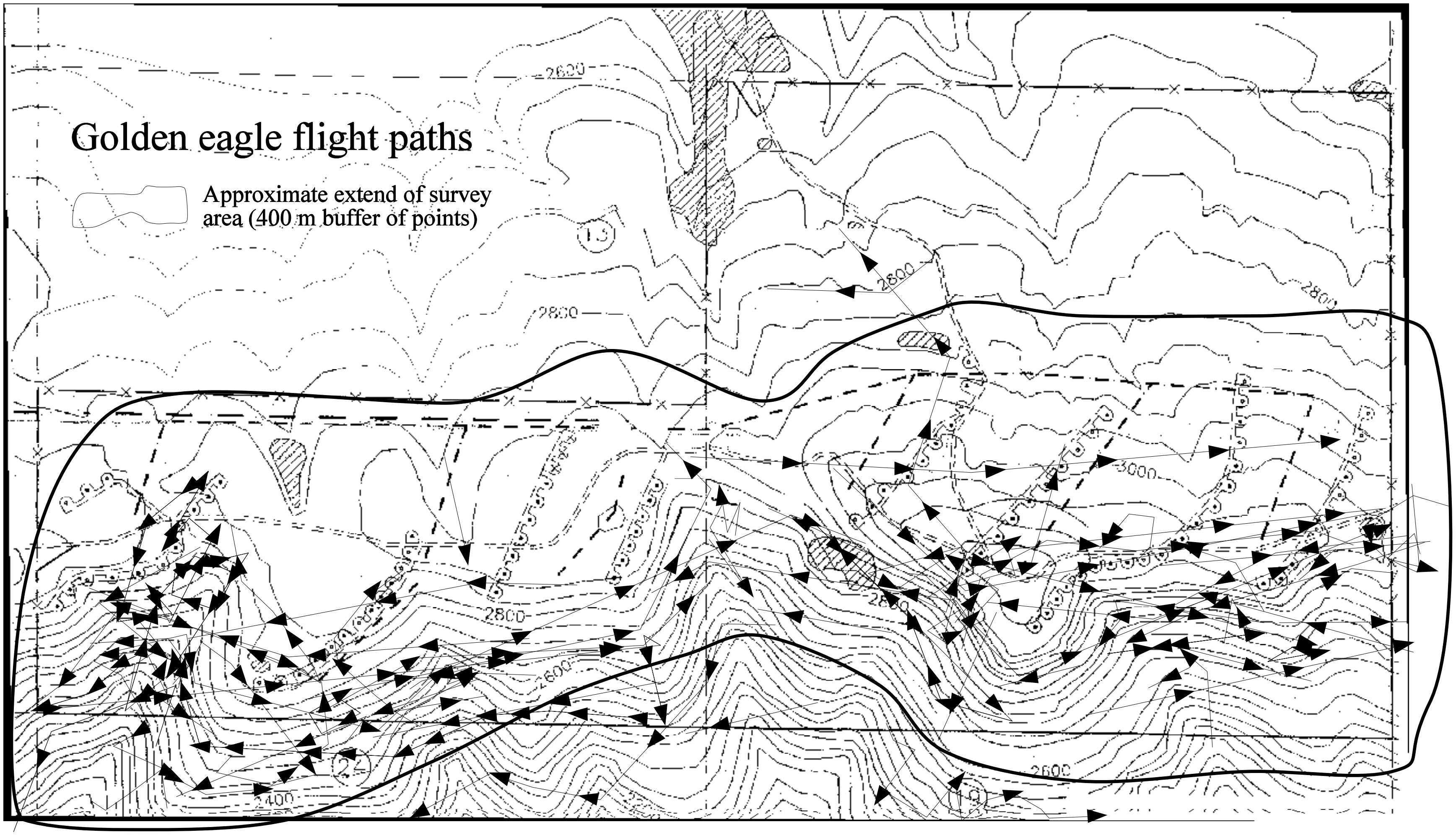

Figure 12. Location of First Observation and Flight Paths of Golden Eagles Observed on the CARES Wind Plant Site

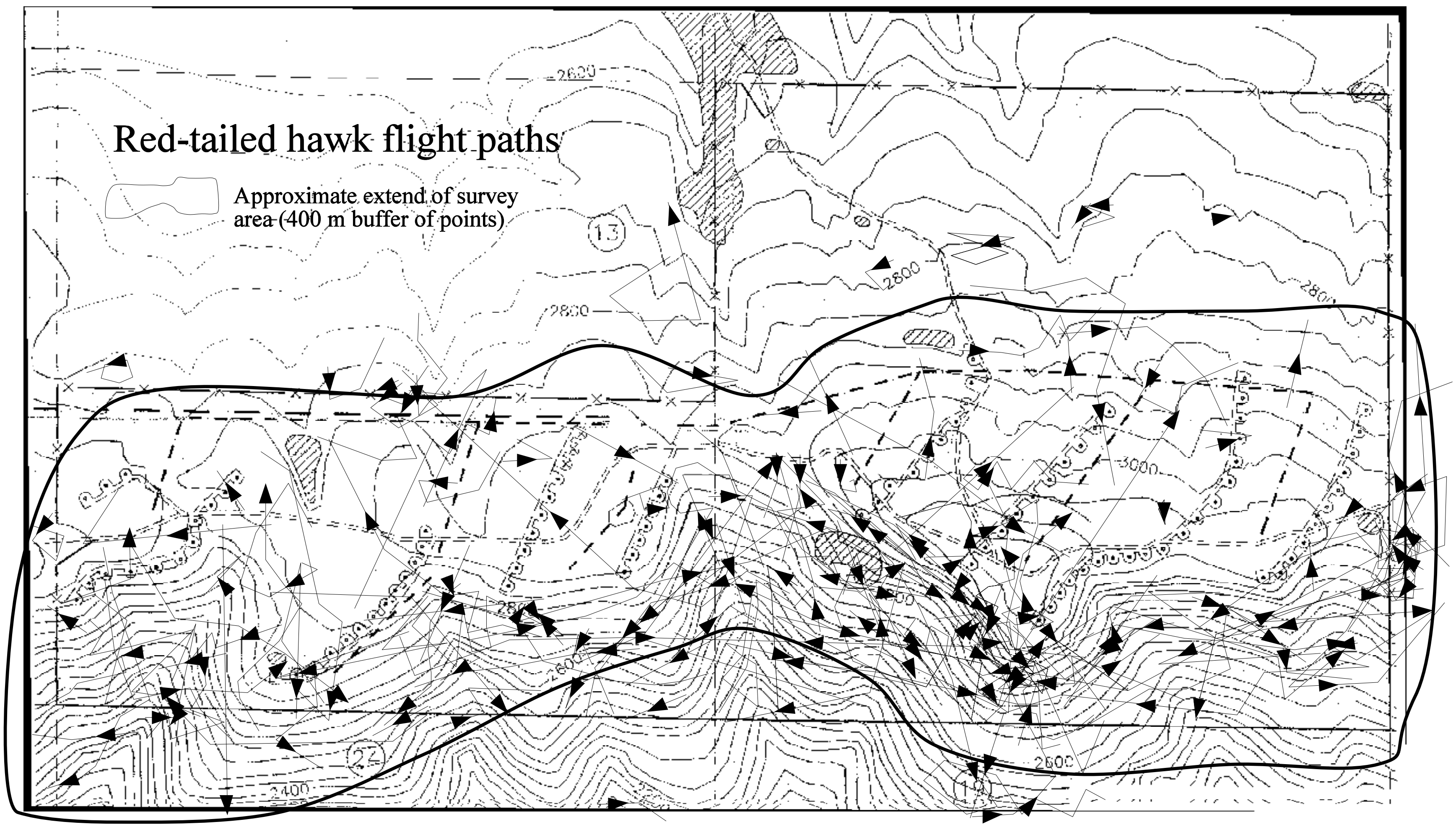

Figure 13. Location of First Observation and Flight Paths of Red-Tailed Hawks Observed on the CARES Wind Plant Site

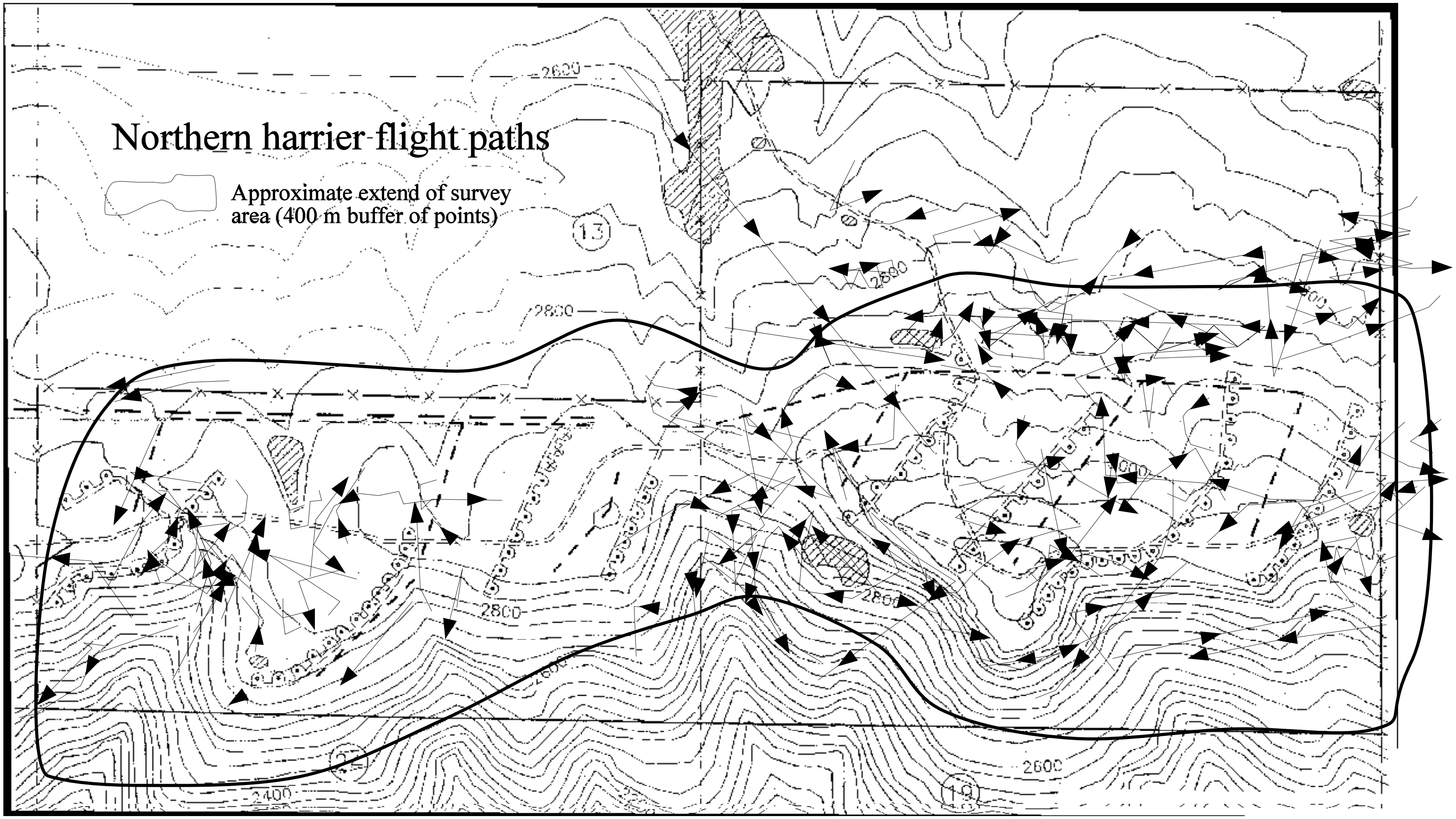

Figure 14. Location of First Observation and Flight Paths of Northern Harriers Observed on the CARES Wind Plant Site

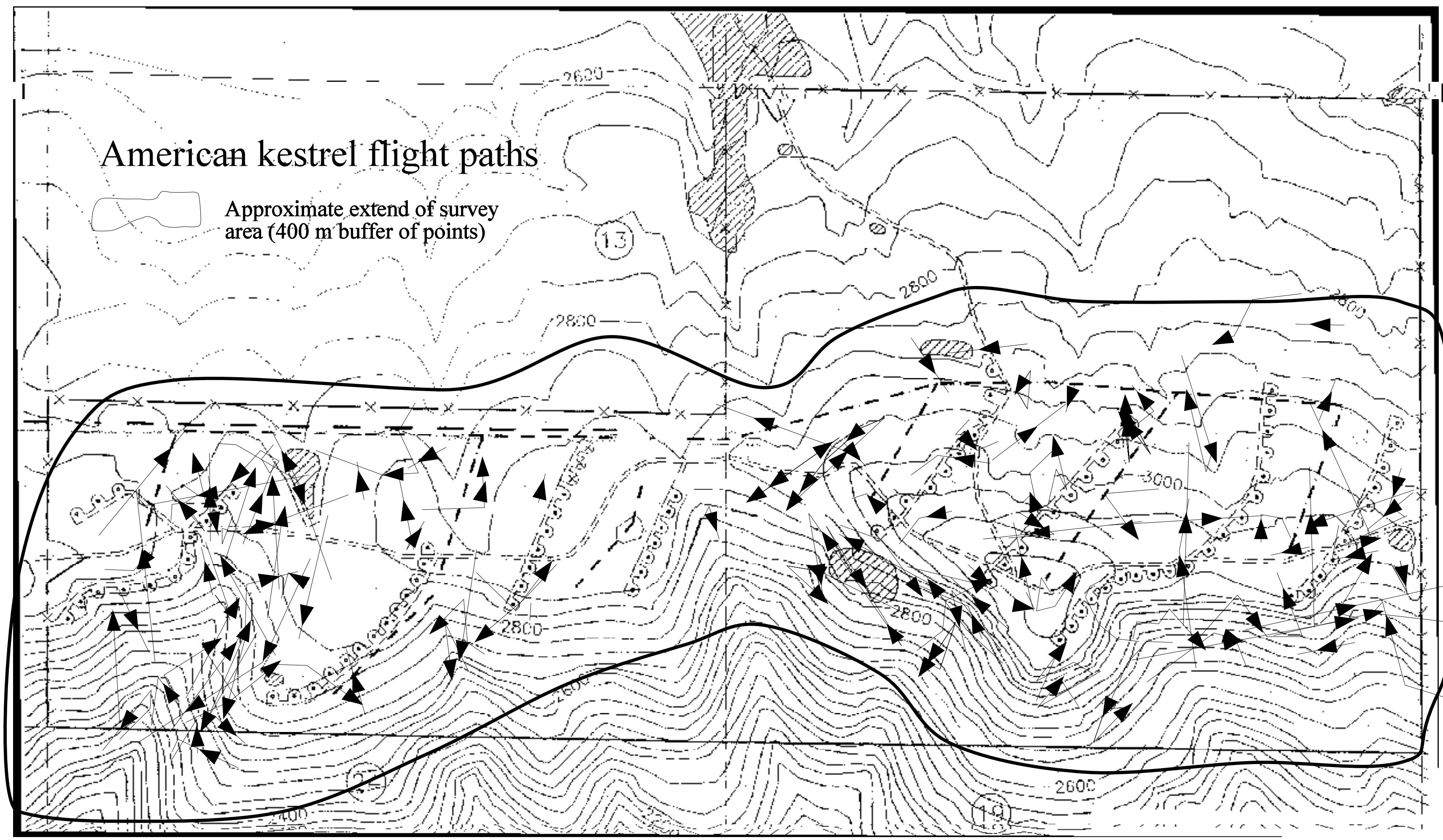

Figure 15. Location of First Observation and Flight Paths of American Kestrels Observed on the CARES Wind Plant Site

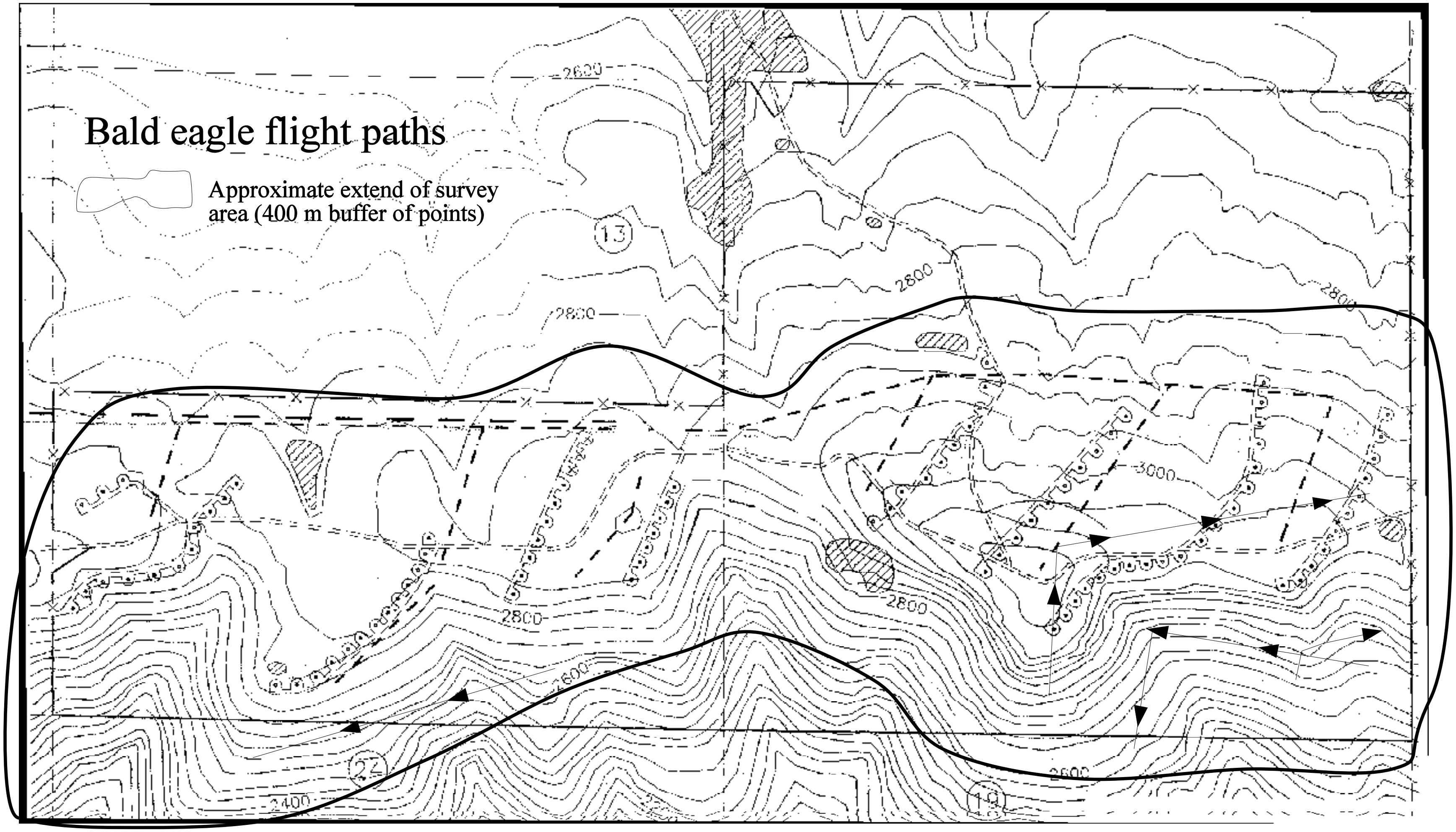

Figure 16. Location of First Observation and Flight Paths of Bald Eagles Observed on the CARES Wind Plant Site

Appendix A. List of Birds Seen in Vicinity of Study Area

Common Name	Scientific Name
Turkey Vulture	*Cathartes aura*
Canada Goose	*Branta canadensis*
Sharp-Shinned Hawk	*Accipiter striatus*
Cooper's Hawk	*Accipiter cooperi*
Red-Tailed Hawk	*Buteo jamaicensis*
Rough-Legged Hawk	*Buteo lagopus*
Northern Harrier	*Circus cyaneus*
Golden Eagle	*Aquila chrysaetos*
Bald Eagle	*Haliaeetus leucocephalus*
Osprey	*Pandion haliaetus*
Prairie Falcon	*Falco mexicanus*
Merlin	*Falco columbarius*
American Kestrel	*Falco sparverius*
Ring-Necked Pheasant	*Phasianus colchicus*
Chukar	*Alectoris chukar*
Gray Partridge	*Perdix perdix*
Killdeer	*Charadrius vociferus*
Unidentified Gull	*Larus sp.*
Common Nighthawk	*Chordeiles minor*
Vaux's Swift	*Chaetura vauxi*
Rufous Hummingbird	*Selasphorus rufus*
Northern Flicker	*Colaptes auratus*
Lewis's Woodpecker	*Melanerpes lewis*
Say's Phoebe	*Sayornis saya*
Western Wood Pewee	*Contopus sordidulus*
Gray Flycatcher	*Empidonax wrightii*
Ash-Throated Flycatcher	*Myiarchus cinerascens*
Northern Shrike	*Lanius excubitor*
Loggerhead Shrike	*Lanius ludovicianus*
Clark's Nutcracker	*Nucifraga columbiana*
Black-Billed Magpie	*Pica pica*
Common Raven	*Corvus corax*
Horned Lark	*Eremophila alpestris*
Tree Swallow	*Tachycineta bicolor*
Barn Swallow	*Hirundo rustica*
Cliff Swallow	*Hirundo pyrrhonota*
Red-Breasted Nuthatch	*Sitta canadensis*
White-Breasted Nuthatch	*Sitta carolinensis*
Rock Wren	*Salpinctes obsoletus*
Canyon Wren	*Catherpes mexicanus*
Golden-Crowned Kinglet	*Regulus satrapa*
Western Bluebird	*Sialia mexicana*
Mountain Bluebird	*Sialia currucoides*
Townsend's Solitaire	*Myadestes townsendii*
American Robin	*Turdus migratorius*

Appendix A (Continued). List of Birds Seen in Vicinity of Study Area

Common Name	*Scientific Name*
Hermit Thrush	*Catharus guttatus*
Varied Thrush	*Ixoreus naevius*
European Starling	*Sturnus vulgaris*
American Pipit	*Anthus spinoletta*
Bohemian Waxwing	*Bombycilla garrulus*
Yellow-Rumped Warbler	*Dendroica coronata*
Townsend's Warbler	*Dendroica townsendi*
Western Tanager	*Piranga ludoviciana*
Spotted Towhee	*Pipilo maculatus*
Savannah Sparrow	*Passerculus sandwichensis*
Grasshopper Sparrow	*Ammodramus savannarum*
Vesper Sparrow	*Pooecetes gramineus*
Lark Sparrow	*Chondestes grammacus*
Dark-Eyed Junco	*Junco hyemalis*
Chipping Sparrow	*Spizella passerina*
White-Crowned Sparrow	*Zonotrichia leucophrys*
Lazuli Bunting	*Passerina amoena*
Western Meadowlark	*Sturnella neglecta*
Brewer's Blackbird	*Euphagus cyanocephalus*
Brown-Headed Cowbird	*Molothrus ater*
Bullock's Oriole	*Icterus bullockii*
Cassin's Finch	*Carpodacus cassinii*
Red Crossbill	*Loxia curvirosta*
White-Winged Crossbill	*Loxia leucoptera*
American Goldfinch	*Carduelis tristis*
Gray-Crowned Rosy Finch	*Leucosticte tephrocotis*

Appendix B. Total Number of Birds Observed and Flock Size Characteristics

Species		No. Observed at Stations	No. Observed in Study Area	No. Flocks	Mean	Min.	Max.
Turkey Vulture		14	16	15	1.07	1	2
Canada Goose		30	30	2	15.00	5	25
Osprey		5	5	5	1.00	1	1
Unidentified Accipiter		13	16	16	1.00	1	1
Bald Eagle		4	5	5	1.00	1	1
Northern Harrier		98	120	112	1.07	1	2
Sharp-Shinned Hawk		11	18	15	1.20	1	2
Cooper's Hawk		27	32	29	1.10	1	2
Swainson's Hawk	*		1	1	1.00	1	1
Red-Tailed Hawk		202	250	227	1.12	1	4
Rough-Legged Hawk		13	17	17	1.00	1	1
Unidentified Buteo		11	16	16	1.00	1	1
Golden Eagle		72	90	79	1.14	1	3
Unidentified Eagle		1	1	1	1.00	1	1
American Kestrel		118	146	135	1.08	1	3
Merlin		1	1	1	1.00	1	1
Unidentified Falcon	*		1	1	1.00	1	1
Prairie Falcon		13	15	15	1.00	1	1
Unidentified Raptor		8	11	9	1.22	1	2
Gray Partridge		97	121	15	8.07	1	15
Chukar		146	154	77	2.00	1	5
Ring-Necked Pheasant		6	6	4	1.50	1	3
Killdeer		3	3	2	1.50	1	2
Unidentified Gull		2	2	2	1.00	1	1
Common Nighthawk		5	5	4	1.25	1	2
Vaux's Swift		11	11	3	3.67	3	4
Unidentified Swift		1	1	1	1.00	1	1
Rufous Hummingbird		2	2	2	1.00	1	1
Unidentified Hummingbird		24	26	25	1.04	1	2
Lewis's Woodpecker		98	100	58	1.72	1	10
Northern Flicker		77	77	63	1.22	1	3
Unidentified Woodpecker		2	2	2	1.00	1	1
Western Wood Peewee		8	8	7	1.14	1	2
Gray Flycatcher		9	9	7	1.29	1	2
Say's Phoebe		5	5	5	1.00	1	1
Ash-Throated Flycatcher		1	1	1	1.00	1	1
Unidentified Flycatcher		2	2	2	1.00	1	1
Northern Shrike		3	3	3	1.00	1	1
Loggerhead Shrike		5	7	7	1.00	1	1

* Not observed during station surveys

Appendix B (Continued). Total Number of Birds Observed and Flock Size Characteristics

Species	No. Observed at Stations	No. Observed in Study Area	No Flocks	Mean	Min.	Max.
Unidentified Shrike	4	4	4	1.00	1	1
Clark's Nutcracker	4	4	4	1.00	1	1
Black-Billed Magpie	161	163	132	1.25	1	16
Common Raven	908	928	380	2.45	1	25
Horned Lark	2016	2083	1049	1.99	1	35
Tree Swallow	20	20	9	2.22	1	4
Violet-Green Swallow *		4	1	4.00	4	4
Barn Swallow	52	52	31	1.68	1	5
Cliff Swallow	99	99	40	2.48	1	10
Unidentified Swallow	18	19	5	3.80	1	8
Red-Breasted Nuthatch	3	3	3	1.00	1	1
White-Breasted Nuthatch	1	1	1	1.00	1	1
Rock Wren	119	119	101	1.19	1	4
Canyon Wren	1	3	2	1.50	1	2
Golden-Crowned Kinglet	20	20	13	1.54	1	4
Western Bluebird	119	120	36	3.33	1	12
Mountain Bluebird	77	99	22	4.50	1	15
Townsend's Solitaire	94	97	84	1.15	1	3
Hermit Thrush	1	1	1	1.00	1	1
American Robin	989	1079	187	5.77	1	55
Varied Thrush	2	2	2	1.00	1	1
European Starling	8	8	3	2.67	1	4
American Pipit	75	125	4	31.25	10	50
Bohemian Waxwing	13	13	1	13.00	13	13
Yellow-Rumped Warbler	41	41	21	1.95	1	5
Townsend's Warbler	2	2	2	1.00	1	1
Western Tanager	1	1	1	1.00	1	1
Spotted Towhee	6	6	5	1.20	1	2
Chipping Sparrow	33	39	21	1.86	1	6
Vesper Sparrow	786	787	575	1.38	1	4
Lark Sparrow	7	7	7	1.00	1	1
Savannah Sparrow	2	2	2	1.00	1	1
Grasshopper Sparrow	24	24	23	1.04	1	2
White-Crowned Sparrow	30	30	6	5.00	2	13
Dark-Eyed Junco	77	78	23	3.39	1	15
Lazuli Bunting	1	1	1	1.00	1	1
Western Meadowlark	2100	2102	1424	1.48	0	6
Brewer's Blackbird	20	20	5	4.00	1	15
Brown-Headed Cowbird	28	28	10	2.80	1	6
Bullock's Oriole	4	4	4	1.00	1	1

* Not observed during station surveys

Appendix B (Continued). Total Number of Birds Observed and Flock Size Characteristics

Species	No. Observed at Stations	No. Observed in Study Area	No Flocks	Mean	Min.	Max.
Cassin's Finch	1	1	1	1.00	1	1
Red Crossbill	20	20	5	4.00	1	8
White-Winged Crossbill	10	18	2	9.00	8	10
American Goldfinch	59	59	41	1.44	1	5
Unidentified Passerine	277	282	119	2.41	1	25
Gray-Crowned Rosy-Finch	3	3	2	1.50	1	2

Appendix C. Mean Use, Duration in Plot, and Percent Frequency of Occurrence of Birds Observed During Surveys on the Study Area

Spring

Group	Species	#/Survey		Duration in Plot (Minutes)		% Freq.
		Mean	Standard error	Mean	Standard error	
Game Birds	Ring-Necked Pheasant	0.002	0.002	0.002	0.002	0.20
	Gray Partridge	0.005	0.003	0.013	0.012	0.35
	Chukar	0.115	0.022	0.521	0.213	6.65
	TOTAL	0.122	0.021	0.536	0.210	7.19
Passerines	Cassin's Finch	0.002	0.002	0.006	0.006	0.15
	Savannah Sparrow	0.002	0.002	0.003	0.003	0.15
	Townsend's Warbler	0.002	0.002	0.002	0.002	0.15
	Unidentified Swift	0.002	0.002	0.001	0.001	0.15
	Unidentified Woodpecker	0.002	0.002	0.002	0.002	0.15
	Say's Phoebe	0.002	0.002	0.010	0.010	0.20
	Lark Sparrow	0.003	0.002	0.018	0.015	0.30
	Spotted Towhee	0.003	0.002	0.030	0.019	0.30
	Unidentified Hummingbird	0.004	0.002	0.003	0.002	0.35
	Unidentified Swallow	0.006	0.004	0.009	0.006	0.30
	Loggerhead Shrike	0.008	0.004	0.029	0.017	0.79
	Red Crossbill	0.009	0.007	0.009	0.007	0.30
	Yellow-Rumped Warbler	0.010	0.010	0.067	0.067	0.30
	Townsend's Solitaire	0.012	0.004	0.069	0.031	1.04
	Northern Flicker	0.020	0.009	0.042	0.018	1.84
	Tree Swallow	0.021	0.016	0.089	0.077	0.79
	American Goldfinch	0.024	0.012	0.025	0.012	1.04
	Chipping Sparrow	0.027	0.016	0.185	0.141	1.49
	Rock Wren	0.037	0.017	0.304	0.153	2.98
	Brown-Headed Cowbird	0.039	0.025	0.277	1.340	1.34
	Western Bluebird	0.041	0.016	0.377	0.155	1.98
	Black-Billed Magpie	0.043	0.014	0.213	0.074	3.74
	Dark-Eyed Junco	0.045	0.045	0.402	0.402	0.60
	White-Crowned Sparrow	0.045	0.045	0.446	0.446	0.89
	Unidentified Passerine	0.096	0.061	0.216	0.141	2.58
	American Pipit	0.112	0.112	1.116	1.116	0.30
	Mountain Bluebird	0.118	0.046	0.386	0.148	2.33
	Common Raven	0.177	0.039	0.373	0.099	9.74
	American Robin	0.496	0.344	1.874	0.999	9.28
	Vesper Sparrow	0.664	0.246	5.994	2.311	30.70
	Horned Lark	1.266	0.179	9.721	2.178	59.75
	Western Meadowlark	1.998	0.436	18.686	4.488	68.29
	TOTAL	5.331	0.796	40.981	9.230	86.73
Raptors	Sharp-Shinned Hawk	0.002	0.002	0.005	0.005	0.15
	Unidentified Raptor	0.002	0.002	0.001	0.001	0.15
	Merlin	0.002	0.002	0.001	0.001	0.20
	Cooper's Hawk	0.003	0.003	0.015	0.015	0.30
	Turkey Vulture	0.003	0.002	0.006	0.005	0.30

Appendix C (Continued). Mean Use, Duration in Plot, and Percent Frequency of Occurrence of Birds Observed During Surveys on the Study Area

Spring

Group	Species	#/Survey		Duration in Plot (Minutes)		% Freq.
		Mean	Standard Error	Mean	Standard error	
Raptors (cont')	Osprey	0.005	0.002	0.004	0.002	0.45
	Rough-Legged Hawk	0.005	0.003	0.007	0.006	0.50
	Prairie Falcon	0.010	0.004	0.006	0.003	0.99
	Northern Harrier	0.012	0.005	0.011	0.005	1.19
	American Kestrel	0.049	0.014	0.045	0.014	4.91
	Golden Eagle	0.052	0.016	0.049	0.012	4.07
	Red-Tailed Hawk	0.093	0.011	0.166	0.034	7.04
	TOTAL	0.236	0.024	0.315	0.056	17.31
Shore birds	Killdeer	0.005	0.003	0.003	0.002	0.30

Appendix C (Continued). Mean Use, Duration in Plot, and Percent Frequency of Occurrence of Birds Observed During Surveys on the Study Area

Summer

Group	Species	#/Survey		Duration in Plot (Minutes)		% Freq.
		Mean	Standard Error	Mean	Standard Error	
Game Birds	Chukar	0.018	0.006	0.109	0.055	1.09
	Gray Partridge	0.022	0.022	0.036	0.036	0.30
	TOTAL	0.041	0.020	0.145	0.055	1.39
Passerines	Ash-Throated Flycatcher	0.002	0.002	0.002	0.002	0.15
	Canyon Wren	0.002	0.002	0.002	0.002	0.15
	Lazuli Bunting	0.002	0.002	0.015	0.015	0.15
	Loggerhead Shrike	0.002	0.002	0.015	0.015	0.15
	Mountain Bluebird	0.002	0.002	0.015	0.015	0.15
	Townsend's Warbler	0.002	0.002	0.003	0.003	0.15
	White-Breasted Nuthatch	0.002	0.002	0.003	0.003	0.15
	European Starling	0.002	0.002	0.002	0.002	0.20
	Savannah Sparrow	0.002	0.002	0.020	0.020	0.20
	Say's Phoebe	0.002	0.002	0.020	0.020	0.20
	Townsend's Solitaire	0.002	0.002	0.020	0.020	0.20
	Red-Breasted Nuthatch	0.003	0.002	0.019	0.012	0.25
	Brewer's Blackbird	0.003	0.003	0.006	0.006	0.15
	Brown-Headed Cowbird	0.003	0.003	0.030	0.030	0.15
	Golden-Crowned Kinglet	0.003	0.003	0.030	0.030	0.15
	Spotted Towhee	0.003	0.003	0.022	0.022	0.30
	Western Tanager	0.003	0.003	0.012	0.012	0.30
	Rufous Hummingbird	0.004	0.002	0.004	0.002	0.35
	Unidentified Flycatcher	0.004	0.002	0.007	0.006	0.35
	Dark-Eyed Junco	0.005	0.005	0.030	0.030	0.30
	Tree Swallow	0.006	0.004	0.012	0.009	0.30
	Bullocks's Oriole	0.006	0.002	0.020	0.008	0.64
	Western Bluebird	0.007	0.006	0.054	0.039	0.45
	Lark Sparrow	0.009	0.006	0.042	0.027	0.89
	Common Nighthawk	0.010	0.010	0.038	0.038	0.60
	Yellow-Rumped Warbler	0.012	0.012	0.107	0.107	0.60
	Northern Flicker	0.014	0.005	0.036	0.017	1.39
	Gray Flycatcher	0.014	0.010	0.039	0.026	0.79
	Vaux's Swift	0.018	0.018	0.018	0.018	0.50
	Chipping Sparrow	0.020	0.008	0.068	0.039	1.44
	Red Crossbill	0.021	0.013	0.092	0.082	0.45
	Western Wood Pewee	0.025	0.008	0.106	0.048	2.18
	Unidentified Hummingbird	0.033	0.017	0.033	0.016	3.32
	Grasshopper Sparrow	0.039	0.021	0.262	0.165	3.47
	American Goldfinch	0.040	0.015	0.068	0.035	3.54
	Unidentified Passerine	0.053	0.023	0.118	0.054	2.80
	Barn Swallow	0.073	0.023	0.240	0.151	4.46
	American Robin	0.074	0.018	0.282	0.066	5.41
	Black-Billed Magpie	0.084	0.020	0.312	0.090	7.19
	Lewis' Woodpecker	0.120	0.047	0.425	0.251	5.96

Appendix C (Continued). Mean Use, Duration in Plot, and Percent Frequency of Occurrence of Birds Observed During Surveys on the Study Area

Summer

Group	Species	#/Survey		Duration in Plot (Minutes)		% Freq.
		Mean	Standard error	Mean	Standard error	
Passerines (cont')	Rock Wren	0.127	0.025	0.701	0.183	9.92
	Cliff Swallow	0.156	0.077	0.536	0.175	5.21
	Common Raven	0.193	0.078	0.614	0.440	6.35
	Vesper Sparrow	0.653	0.288	5.273	2.436	29.51
	Western Meadowlark	1.225	0.422	9.736	4.080	49.69
	Horned Lark	1.290	0.244	9.508	2.217	42.63
	TOTAL	4.357	0.957	28.960	8.510	79.09
Water Birds	Unidentified Gull	0.004	0.002	0.004	0.002	0.35
Raptors	Golden Eagle	0.002		0.002		0.15
	Osprey	0.002		0.006		0.20
	Cooper's Hawk	0.006		0.007		0.60
	Prairie Falcon	0.006		0.006		0.60
	Turkey Vulture	0.006		0.010		0.60
	Northern Harrier	0.026		0.041		2.28
	Red-Tailed Hawk	0.062		0.166		5.56
	American Kestrel	0.122		0.293		9.82
	TOTAL	0.232		0.532		18.20

Appendix C (Continued). Mean Use, Duration in Plot, and Percent Frequency of Occurrence of Birds Observed During Surveys on the Study Area

Fall

Group	Species	#/Survey		Duration in Plot (Minutes)		% Freq.
		Mean	Standard error	Mean	Standard error	
Game Birds	Ring-Necked Pheasant	0.006	0.006	0.063	0.063	0.21
	Chukar	0.075	0.029	0.460	0.192	2.81
	Gray Partridge	0.083	0.051	0.431	0.323	0.83
	TOTAL	0.165	0.054	0.953	0.439	3.85
Passerines	Hermit Thrush	0.002	0.002	0.021	0.021	0.21
	Northern Shrike	0.002	0.002	0.021	0.021	0.21
	Red-Breasted Nuthatch	0.002	0.002	0.008	0.008	0.21
	Chipping Sparrow	0.004	0.004	0.042	0.042	0.21
	Spotted Towhee	0.004	0.004	0.042	0.042	0.21
	Varied Thrush	0.004	0.003	0.023	0.020	0.42
	Vesper Sparrow	0.004	0.004	0.042	0.042	0.21
	Gray-Crowned Rosy Finch	0.006	0.004	0.025	0.017	0.38
	Say's Phoebe	0.006	0.004	0.063	0.042	0.63
	Tree Swallow	0.006	0.006	0.006	0.006	0.21
	Barn Swallow	0.008	0.008	0.008	0.008	0.21
	European Starling	0.008	0.008	0.008	0.008	0.28
	Clark's Nutcracker	0.009	0.009	0.067	0.067	0.90
	Unidentified Shrike	0.010	0.010	0.052	0.052	0.97
	Mountain Bluebird	0.015	0.015	0.077	0.077	0.42
	Unidentified Swallow	0.017	0.017	0.167	0.167	0.28
	Lewis's Woodpecker	0.019	0.014	0.015	0.010	1.25
	American Goldfinch	0.027	0.010	0.027	0.010	1.90
	Rock Wren	0.029	0.020	0.173	0.133	2.08
	Brewer's Blackbird	0.038	0.033	0.038	0.033	0.63
	Golden-Crowned Kinglet	0.038	0.021	0.212	0.110	2.50
	Yellow-Rumped Warbler	0.054	0.036	0.200	0.127	3.13
	Dark-Eyed Junco	0.091	0.061	0.783	0.574	3.29
	Northern Flicker	0.122	0.043	0.494	0.176	8.89
	Black-Billed Magpie	0.138	0.030	0.410	0.033	9.44
	Townsend's Solitaire	0.147	0.042	0.841	0.261	11.06
	Western Bluebird	0.183	0.088	0.765	0.497	3.82
	Western Meadowlark	0.283	0.188	2.086	1.482	14.93
	Unidentified Passerine	0.326	0.038	0.668	0.104	13.99
	Horned Lark	0.684	0.218	3.125	1.176	25.68
	Common Raven	0.727	0.393	3.760	3.183	20.68
	American Robin	1.292	0.653	4.702	2.321	9.03
	TOTAL	4.305	0.662	18.970	4.127	68.43
Raptors	Osprey	0.002	0.002	0.002	0.002	0.21
	Prairie Falcon	0.002	0.002	0.002	0.002	0.21
	Rough-Legged Hawk	0.002	0.002	0.002	0.002	0.21
	Unidentified Buteo	0.002	0.002	0.002	0.002	0.21
	Unidentified Raptor	0.004	0.004	0.004	0.004	0.38
	Turkey Vulture	0.013	0.008	0.015	0.009	1.04
	Golden Eagle	0.018	0.004	0.029	0.010	1.76

Appendix C (Continued). Mean Use, Duration in Plot, and Percent Frequency of Occurrence of Birds Observed During Surveys on the Study Area

Fall

Group	Species	#/Survey		Duration in Plot (Minutes)		% Freq.
		Mean	Standard error	Mean	Standard error	
Raptors (cont')	American Kestrel	0.019	0.014	0.130	0.088	1.46
	Sharp-Shinned Hawk	0.021	0.010	0.033	0.015	1.88
	Unidentified Accipiter	0.022	0.008	0.030	0.016	1.94
	Cooper's Hawk	0.039	0.018	0.063	0.037	3.08
	Red-Tailed Hawk	0.115	0.018	0.298	0.020	8.86
	Northern Harrier	0.123	0.037	0.156	0.050	10.43
	TOTAL	0.380	0.066	0.766	0.164	26.33
Waterfowl	Canada Goose	0.014	0.014	0.014	0.014	0.28

Appendix C (Continued). Mean Use, Duration in Plot, and Percent Frequency of Occurrence of Birds Observed During Surveys on the Study Area

Winter

Group	Species	#/Survey		Duration in Plot (Minutes)		% Freq.
		Mean	standard error	Mean	standard error	
Game Birds	Chukar	0.023	0.016	0.011	0.008	0.75
	Gray Partridge	0.239	0.135	0.119	0.067	2.35
	TOTAL	0.261	0.127	0.131	0.064	3.10
Passerines	Northern Flicker	0.002	0.002	0.001	0.001	0.17
	Unidentified Woodpecker	0.004	0.004	0.002	0.002	0.35
	Northern Shrike	0.004	0.003	0.005	0.003	0.41
	American Goldfinch	0.007	0.007	0.004	0.004	0.17
	European Starling	0.014	0.014	0.007	0.007	0.35
	Black-Billed Magpie	0.020	0.008	0.020	0.008	2.00
	Bohemian Waxwing	0.023	0.023	0.011	0.011	0.17
	White-Winged Crossbill	0.035	0.035	0.017	0.017	0.35
	Unidentified Passerine	0.038	0.031	0.019	0.015	0.98
	Townsend's Solitaire	0.046	0.021	0.098	0.062	3.99
	Common Raven	0.093	0.036	0.074	0.030	5.67
	American Robin	0.165	0.163	0.089	0.081	1.91
	Horned Lark	0.362	0.165	0.809	0.581	14.97
	TOTAL	0.811	0.319	1.154	0.638	29.01
Raptors	Northern Harrier	0.002	0.002	0.001	0.001	0.23
	Rough-Legged Hawk	0.002	0.002	0.001	0.001	0.23
	Bald Eagle	0.006	0.004	0.006	0.005	0.58
	Prairie Falcon	0.006	0.004	0.003	0.002	0.58
	Red-Tailed Hawk	0.008	0.004	0.004	0.002	0.75
	Golden Eagle	0.018	0.008	0.033	0.020	1.79
	TOTAL	0.042	0.017	0.048	0.028	4.17

Appendix D. Mean Flight Height by Species for Birds Observed on the CARES Project Area

		Observed Flying		Flight height (meters)			
Group	Species	Ind.	Flocks	Min.	Max.	Group Mean	Individual Mean
Game Bird	Chukar	42	18	0.5	5	1.3	1.3
	Gray Partridge	52	2	2	4	3	0.2
	Ring-Necked Pheasant	3	1	1	1	1	1
Raptors	American Kestrel	104	96	1	750	24.8	24
	Cooper's Hawk	23	21	0.5	125	39.7	38.9
	Golden Eagle	43	35	1	150	45	40
	Merlin	1	1	20	20	20	20
	Northern Harrier	79	74	1	100	13.4	14
	Osprey	4	4	40	125	78.8	78.8
	Prairie Falcon	12	11	4	75	24	22
	Red-Tailed Hawk	132	117	1	200	47.6	48.5
	Rough-Legged Hawk	5	4	1	30	14.8	11.8
	Sharp-Shinned Hawk	11	10	1	200	36.1	38.3
	Turkey Vulture	11	10	5	80	34.5	33.6
	Unidentified Accipiter	10	10	2	125	53.5	53.5
	Unidentified Buteo	1	1	35	35	35	35
	Unidentified Raptor	3	3	10	85	48.3	48.3
Passerines	American Goldfinch	58	39	3	50	13.4	13.1
	American Pipit	75	3	1	1	1	1
	American Robin	884	128	0.5	50	7.6	10.6
	Ash-Throated Flycatcher	1	1	3	3	3	3
	Barn Swallow	52	31	1	30	5.6	7.2
	Black-Billed Magpie	68	41	1	15	5.2	6.2
	Brewer's Blackbird	20	5	4	18	8.8	8
	Brown-Headed Cowbird	26	8	1	10	3.3	2.3
	Bullock's Oriole	3	3	2	4	3	3
	Cassin's Finch	1	1	3	3	3	3
	Chipping Sparrow	20	10	1	3	1.9	2
	Clark's Nutcracker	4	4	1	1	1	1
	Cliff Swallow	99	40	1	60	11.2	15.5
	Common Nighthawk	4	3	15	30	23.3	21.3
	Common Raven	568	218	1	300	34.2	60.4
	Dark-Eyed Junco	69	18	0.5	4	1.4	1.3
	European Starling	8	2	4	5	4.5	2.1
	Golden-Crowned Kinglet	19	12	1	5	2.5	2.5
	Grasshopper Sparrow	3	3	1	1	1	1
	Gray Flycatcher	7	5	2	3	2.8	2.9
	Gray-Crowned Rosy Finch	3	2	1	1	1	1
	Hermit Thrush	1	1	1	1	1	1

Appendix D (Continued). Mean Flight Height by Species for Birds Observed on the CARES Project Area

				Flight Height (meters)			
		Observed Flying		Min.	Max.	Group Mean	Individual Mean
Group	Species	Ind.	Flocks				
Passerines	Horned Lark	1832	856	0.5	50	4.4	3.9
	Lark Sparrow	2	2	1	5	3	3
	Lewis's Woodpecker	90	54	1	50	14	14.7
	Loggerhead Shrike	4	4	1	4	2.3	2.3
	Mountain Bluebird	70	14	1	25	6	6.1
	Northern Flicker	38	25	2	50	7.6	9.7
	Northern Shrike	3	1	3	3	3	1
	Red Crossbill	20	5	10	30	19.4	14.8
	Red-Breasted Nuthatch	2	2	2	3	2.5	2.5
	Rock Wren	25	15	0.5	1	1	1
	Rufous Hummingbird	2	2	4	4	4	4
	Say's Phoebe	5	5	0.5	10	2.9	2.9
	Spotted Towhee	3	3	0.5	2	1.2	1.2
	Townsend's Solitaire	55	32	1	30	5.8	3.9
	Tree Swallow	20	9	2	50	20	24
	Unidentified Gull	2	2	10	100	55	55
	Unidentified Hummingbird	23	23	1	10	2.9	2.9
	Unidentified Passerine	253	97	1	50	12.3	12.4
	Unidentified Shrike	2	2	4	4	4	4
	Unidentified Swallow	10	3	10	30	17.3	14.4
	Unidentified Swift	1	1	40	40	40	40
	Unidentified Woodpecker	2	1	50	50	50	25
	Vaux's Swift	11	3	8	10	8.7	8.7
	Vesper Sparrow	164	119	0.5	10	1.5	1.5
	Western Bluebird	113	31	1	40	7.5	10.2
	Western Meadowlark	445	329	1	10	2.1	2
	White-Crowned Sparrow	30	6	0.5	2	1.1	1
	Yellow-Rumped Warbler	40	20	1	15	4.6	4.8
Shore birds	Killdeer	3	2	2	25	13.5	9.7
Waterfowl	Canada Goose	5	1	35	35	35	35
	All Birds	5829	2668			11.9	13.5

Appendix E. Percent of Birds Flying Below, Within and Above the Rotor-Swept Height of Turbines

Species	Ind.	Flocks	Weighted by Individual 1-25 meters(m)	25-75m	>75m	Weighted by Group 1-25m	25-75m	>75m
American Goldfinch	58	39	92.6	7.4	0.0	92.3	7.7	0.0
American Kestrel	104	96	72.1	25.0	2.9	72.9	24.0	3.1
American Pipit	75	3	100.0	0.0	0.0	100.0	0.0	0.0
American Robin	884	128	81.4	18.6	0.0	91.4	8.6	0.0
Ash-Throated Flycatcher	1	1	100.0	0.0	0.0	100.0	0.0	0.0
Bald Eagle	1	1	NA	NA	NA	NA	NA	NA
Barn Swallow	52	31	92.3	7.7	0.0	96.8	3.2	0.0
Black-Billed Magpie	68	41	100.0	0.0	0.0	100.0	0.0	0.0
Bohemian Waxwing	13	1	NA	NA	NA	NA	NA	NA
Brewer’s Blackbird	20	5	100.0	0.0	0.0	100.0	0.0	0.0
Brown-Headed Cowbird	26	8	100.0	0.0	0.0	100.0	0.0	0.0
Bullock’s Oriole	3	3	100.0	0.0	0.0	100.0	0.0	0.0
Canada Goose	5	1	0.0	100.0	0.0	0.0	100.0	0.0
Cassin’s Finch	1	1	100.0	0.0	0.0	100.0	0.0	0.0
Chipping Sparrow	20	10	100.0	0.0	0.0	100.0	0.0	0.0
Chukar	42	18	100.0	0.0	0.0	100.0	0.0	0.0
Clark’s Nutcracker	4	4	100.0	0.0	0.0	100.0	0.0	0.0
Cliff Swallow	99	40	78.8	21.2	0.0	85.0	15.0	0.0
Common Nighthawk	4	3	50.0	50.0	0.0	33.3	66.7	0.0
Common Raven	568	218	33.6	33.6	32.7	53.2	33.9	12.8
Cooper’s Hawk	23	21	39.1	47.8	13.0	38.1	47.6	14.3
Dark-Eyed Junco	69	18	100.0	0.0	0.0	100.0	0.0	0.0
European Starling	8	2	100.0	0.0	0.0	100.0	0.0	0.0
Golden Eagle	43	35	31.6	52.6	15.8	31.4	51.4	17.1
Golden-Crowned Kinglet	19	12	100.0	0.0	0.0	100.0	0.0	0.0
Grasshopper Sparrow	3	3	100.0	0.0	0.0	100.0	0.0	0.0
Gray Flycatcher	7	5	100.0	0.0	0.0	100.0	0.0	0.0
Gray Partridge	25	3	100.0	0.0	0.0	100.0	0.0	0.0
Gray-Crowned Rosy Finch	3	2	100.0	0.0	0.0	100.0	0.0	0.0
Hermit Thrush	1	1	100.0	0.0	0.0	100.0	0.0	0.0
Horned Lark	1832	856	97.4	2.6	0.0	96.6	3.4	0.0
Gray Partridge	52	2	100.0	0.0	0.0	100.0	0.0	0.0
Killdeer	3	2	66.7	33.3	0.0	50.0	50.0	0.0
Lark Sparrow	2	2	100.0	0.0	0.0	100.0	0.0	0.0
Lewis’s Woodpecker	90	54	77.8	22.2	0.0	81.5	18.5	0.0
Loggerhead Shrike	4	4	100.0	0.0	0.0	100.0	0.0	0.0
Merlin	1	1	100.0	0.0	0.0	100.0	0.0	0.0
Mountain Bluebird	70	14	92.9	7.1	0.0	92.9	7.1	0.0
Northern Flicker	38	25	84.2	15.8	0.0	88.0	12.0	0.0
Northern Harrier	79	74	82.1	16.7	1.3	83.8	14.9	1.4
Northern Shrike	3	1	100.0	0.0	0.0	100.0	0.0	0.0
Osprey	4	4	0.0	50.0	50.0	0.0	50.0	50.0
Prairie Falcon	12	11	45.5	54.6	0.0	45.5	54.6	0.0
Red Crossbill	20	5	90.0	10.0	0.0	60.0	40.0	0.0
Red-Breasted Nuthatch	2	2	100.0	0.0	0.0	100.0	0.0	0.0
Red-Tailed Hawk	132	117	22.5	62.0	15.5	24.8	59.8	15.4
Ring-Necked Pheasant	3	1	100.0	0.0	0.0	100.0	0.0	0.0

Appendix E (Continued). Percent of Birds Flying Below, Within and Above the Rotor-Swept Height of Turbines

			Weighted by Individual			Weighted by Group		
Species	Ind.	Flocks	1-25 meters(m)	25-75m	>75m	1-25m	25-75m	>75m
Rock Wren	25	15	100.0	0.0	0.0	100.0	0.0	0.0
Rough-Legged Hawk	5	4	50.0	50.0	0.0	50.0	50.0	0.0
Rufous Hummingbird	2	2	100.0	0.0	0.0	100.0	0.0	0.0
Say's Phoebe	5	5	100.0	0.0	0.0	100.0	0.0	0.0
Sharp-Shinned Hawk	11	10	54.6	36.4	9.1	60.0	30.0	10.0
Spotted Towhee	3	3	100.0	0.0	0.0	100.0	0.0	0.0
Townsend’s Solitaire	55	32	97.6	2.4	0.0	96.9	3.1	0.0
Tree Swallow	20	9	45.0	55.0	0.0	55.6	44.4	0.0
Turkey Vulture	11	10	9.1	81.8	9.1	10.0	80.0	10.0
Unidentified Accipiter	10	10	40.0	30.0	30.0	40.0	30.0	30.0
Unidentified Buteo	1	1	0.0	100.0	0.0	0.0	100.0	0.0
Unidentified Gull	2	2	50.0	0.0	50.0	50.0	0.0	50.0
Unidentified Hummingbird	23	23	100.0	0.0	0.0	100.0	0.0	0.0
Unidentified Passerine	253	97	74.9	25.1	0.0	82.5	17.5	0.0
Unidentified Raptor	3	3	33.3	33.3	33.3	33.3	33.3	33.3
Unidentified Shrike	2	2	100.0	0.0	0.0	100.0	0.0	0.0
Unidentified Swallow	10	3	80.0	20.0	0.0	66.7	33.3	0.0
Unidentified Swift	1	1	0.0	100.0	0.0	0.0	100.0	0.0
Unidentified Woodpecker	2	1	0.0	100.0	0.0	0.0	100.0	0.0
Vaux’s Swift	11	3	100.0	0.0	0.0	100.0	0.0	0.0
Vesper Sparrow	164	119	100.0	0.0	0.0	100.0	0.0	0.0
Western Bluebird	113	31	85.0	15.0	0.0	90.3	9.7	0.0
Western Meadowlark	445	329	100.0	0.0	0.0	100.0	0.0	0.0
White-Crowned Sparrow	30	6	100.0	0.0	0.0	100.0	0.0	0.0
Yellow-Rumped Warbler	40	20	100.0	0.0	0.0	100.0	0.0	0.0

Appendix F. Relative Exposure Indices for Birds Observed on the CARES Study Area

Spring

Group	Species	Exposure Index[a]	Mean Use	% Fly	25-75m
Game Birds	Chukar	0.000	0.115	31.8	0.0
	Gray Partridge	0.000	0.005	50.0	0.0
	Ring-Necked Pheasant	0.000	0.002	50.0	0.0
Passerines	American Robin	0.058	0.496	63.2	18.6
	Common Raven	0.058	0.177	97.2	33.6
	Horned Lark	0.021	1.266	62.4	2.6
	Unidentified Passerine	0.019	0.096	80.2	25.1
	Tree Swallow	0.012	0.021	100.0	55.0
	Mountain Bluebird	0.005	0.118	57.1	7.1
	Western Bluebird	0.004	0.041	63.1	15.0
	American Goldfinch	0.002	0.024	100.0	7.4
	Northern Flicker	0.002	0.020	52.6	15.8
	Unidentified Swift	0.002	0.002	100.0	100.0
	Unidentified Woodpecker	0.002	0.002	100.0	100.0
	Unidentified Swallow	0.001	0.006	100.0	20.0
	Red Crossbill	0.001	0.009	100.0	10.0
	Townsend's Solitaire	0.000	0.012	43.3	2.4
	Western Meadowlark	0.000	1.998	20.1	0.0
	Vesper Sparrow	0.000	0.664	18.8	0.0
	American Pipit	0.000	0.112	50.0	0.0
	Dark-Eyed Junco	0.000	0.045	48.0	0.0
	White-Crowned Sparrow	0.000	0.045	50.0	0.0
	Black-Billed Magpie	0.000	0.043	59.3	0.0
	Brown-Headed Cowbird	0.000	0.039	50.9	0.0
	Rock Wren	0.000	0.037	23.0	0.0
	Chipping Sparrow	0.000	0.027	40.0	0.0
	Yellow-Rumped Warbler	0.000	0.010	57.1	0.0
	Loggerhead Shrike	0.000	0.008	44.4	0.0
	Unidentified Hummingbird	0.000	0.004	96.0	0.0
	Lark Sparrow	0.000	0.003	22.2	0.0
	Spotted Towhee	0.000	0.003	37.5	0.0
	Say's Phoebe	0.000	0.002	50.0	0.0
	Cassin's Finch	0.000	0.002	50.0	0.0
	Savannah Sparrow	0.000	0.002	0.0	0.0
	Townsend's Warbler	0.000	0.002	0.0	0.0
Raptor	Red-Tailed Hawk	0.048	0.093	82.6	62.0
	Golden Eagle	0.027	0.052	100.0	52.6
	American Kestrel	0.009	0.049	74.1	25.0
	Prairie Falcon	0.005	0.010	100.0	54.5
	Turkey Vulture	0.002	0.003	100.0	81.8
	Osprey	0.002	0.005	100.0	50.0
	Northern Harrier	0.002	0.012	94.1	16.7
	Rough-Legged Hawk	0.002	0.005	71.4	50.0
	Cooper's Hawk	0.001	0.003	95.8	47.8
	Sharp-Shinned Hawk	0.000	0.002	84.6	36.4
	Unidentified Raptor	0.000	0.002	75.0	33.3
	Merlin	0.000	0.002	100.0	0.0
Shore bird	Killdeer	0.001	0.005	60.0	33.3

[a] Exposure index calculated by multiplying mean use (#/survey) times proportion of all observations where species *i* was observed flying times proportion of all flying observations where species *i* was observed within the rotor-swept height of turbines.

Appendix F (Continued). Relative Exposure Indices for Birds Observed on the CARES Study Area

Summer

Group	Species	Exposure Index[a]	Mean Use	% Fly	25-75m
Game Birds	Gray Partridge	0.000	0.022	50.0	0.0
	Chukar	0.000	0.018	31.8	0.0
Passerines	Common Raven	0.063	0.193	97.2	33.6
	Cliff Swallow	0.033	0.156	100.0	21.2
	Horned Lark	0.021	1.290	62.4	2.6
	Lewis's Woodpecker	0.019	0.120	73.2	22.2
	Unidentified Passerine	0.011	0.053	80.2	25.1
	American Robin	0.009	0.074	63.2	18.6
	Barn Swallow	0.006	0.073	100.0	7.7
	Common Nighthawk	0.005	0.010	100.0	50.0
	Tree Swallow	0.003	0.006	100.0	55.0
	American Goldfinch	0.003	0.040	100.0	7.4
	Red Crossbill	0.002	0.021	100.0	10.0
	Northern Flicker	0.001	0.014	52.6	15.8
	Western Bluebird	0.001	0.007	63.1	15.0
	Mountain Bluebird	0.000	0.002	57.1	7.1
	Townsend's Solitaire	0.000	0.002	43.3	2.4
	Western Meadowlark	0.000	1.225	20.1	0.0
	Vesper Sparrow	0.000	0.653	18.8	0.0
	Rock Wren	0.000	0.127	23.0	0.0
	Black-Billed Magpie	0.000	0.084	59.3	0.0
	Grasshopper Sparrow	0.000	0.039	12.0	0.0
	Unidentified Hummingbird	0.000	0.033	96.0	0.0
	Western Wood Pewee	0.000	0.025	0.0	0.0
	Chipping Sparrow	0.000	0.020	40.0	0.0
	Vaux's Swift	0.000	0.018	100.0	0.0
	Gray Flycatcher	0.000	0.014	46.7	0.0
	Yellow-Rumped Warbler	0.000	0.012	57.1	0.0
	Lark Sparrow	0.000	0.009	22.2	0.0
	Bullock's Oriole	0.000	0.006	42.9	0.0
	Dark-Eyed Junco	0.000	0.005	48.0	0.0
	Rufous Hummingbird	0.000	0.004	100.0	0.0
	Unidentified Flycatcher	0.000	0.004	0.0	0.0
	Brewer's Blackbird	0.000	0.003	100.0	0.0
	Brown-Headed Cowbird	0.000	0.003	50.9	0.0
	Golden-Crowned Kinglet	0.000	0.003	50.0	0.0
	Spotted Towhee	0.000	0.003	37.5	0.0
	Red-Breasted Nuthatch	0.000	0.003	40.0	0.0
	Western Tanager	0.000	0.003	0.0	0.0
	Canyon Wren	0.000	0.002	0.0	0.0
	European Starling	0.000	0.002	100.0	0.0
	Savannah Sparrow	0.000	0.002	0.0	0.0
	Say's Phoebe	0.000	0.002	50.0	0.0
	Ash-Throated Flycatcher	0.000	0.002	50.0	0.0
	Lazuli Bunting	0.000	0.002	0.0	0.0
	Loggerhead Shrike	0.000	0.002	44.4	0.0
	Townsend's Warbler	0.000	0.002	0.0	0.0
	White-Breasted Nuthatch	0.000	0.002	0.0	0.0

[a] Exposure index calculated by multiplying mean use (#/survey) times proportion of all observations where species *I* was observed flying times proportion of all flying observations where species *I* was observed within the rotor-swept height of turbines.

Appendix F (Continued). Relative Exposure Indices for Birds Observed on the CARES Study Area

Summer

Group	Species	Exposure Index[a]	Mean Use	% Fly	25-75m
Raptor	Red-Tailed Hawk	0.032	0.062	82.6	62.0
	American Kestrel	0.023	0.122	74.1	25.0
	Turkey Vulture	0.005	0.006	100.0	81.8
	Northern Harrier	0.004	0.026	94.1	16.7
	Prairie Falcon	0.003	0.006	100.0	54.5
	Cooper's Hawk	0.003	0.006	95.8	47.8
	Osprey	0.001	0.002	100.0	50.0
	Golden Eagle	0.001	0.002	100.0	52.6
Water bird	Unidentified Gull	0.000	0.004	100.0	0.0

[a] Exposure index calculated by multiplying mean abundance (#/survey) times proportion of all observations where species *i* was observed flying times proportion of all flying observations where species *i* was observed within the rotor-swept height of turbines.

Appendix F (Continued). Relative Exposure Indices for Birds Observed on the CARES Study Area

Fall

Group	Species	Exposure Index[a]	Mean Use	% Fly	25-75m
Game Birds	Gray Partridge	0.000	0.083	50.0	0.0
	Chukar	0.000	0.075	31.8	0.0
	Ring-Necked Pheasant	0.000	0.006	50.0	0.0
Passerines	Common Raven	0.238	0.727	97.2	33.6
	American Robin	0.152	1.292	63.2	18.6
	Unidentified Passerine	0.066	0.326	80.2	25.1
	Western Bluebird	0.017	0.183	63.1	15.0
	Horned Lark	0.011	0.684	62.4	2.6
	Northern Flicker	0.010	0.122	52.6	15.8
	Tree Swallow	0.003	0.006	100.0	55.0
	Unidentified Swallow	0.003	0.017	100.0	20.0
	Lewis's Woodpecker	0.003	0.019	73.2	22.2
	American Goldfinch	0.002	0.027	100.0	7.4
	Townsend's Solitaire	0.002	0.147	43.3	2.4
	Barn Swallow	0.001	0.008	100.0	7.7
	Mountain Bluebird	0.001	0.015	57.1	7.1
	Western Meadowlark	0.000	0.283	20.1	0.0
	Black-Billed Magpie	0.000	0.138	59.3	0.0
	Dark-Eyed Junco	0.000	0.091	48.0	0.0
	Yellow-Rumped Warbler	0.000	0.054	57.1	0.0
	Brewer's Blackbird	0.000	0.038	100.0	0.0
	Golden-Crowned Kinglet	0.000	0.038	50.0	0.0
	Rock Wren	0.000	0.029	23.0	0.0
	Unidentified Shrike	0.000	0.010	50.0	0.0
	Clark's Nutcracker	0.000	0.009	50.0	0.0
	European Starling	0.000	0.008	100.0	0.0
	Say's Phoebe	0.000	0.006	50.0	0.0
	Gray-Crowned Rosy Finch	0.000	0.006	50.0	0.0
	Chipping Sparrow	0.000	0.004	40.0	0.0
	Spotted Towhee	0.000	0.004	37.5	0.0
	Varied Thrush	0.000	0.004	0.0	0.0
	Vesper Sparrow	0.000	0.004	18.8	0.0
	Hermit Thrush	0.000	0.002	50.0	0.0
	Northern Shrike	0.000	0.002	50.0	0.0
	Red-Breasted Nuthatch	0.000	0.002	40.0	0.0
Raptor	Red-Tailed Hawk	0.059	0.115	82.6	62.0
	Northern Harrier	0.019	0.123	94.1	16.7
	Cooper's Hawk	0.018	0.039	95.8	47.8
	Turkey Vulture	0.010	0.013	100.0	81.8
	Golden Eagle	0.009	0.018	100.0	52.6
	Unidentified Accipiter	0.006	0.022	100.0	30.0
	Sharp-Shinned Hawk	0.006	0.021	84.6	36.4
	American Kestrel	0.003	0.019	74.1	25.0
	Unidentified Buteo	0.002	0.002	100.0	100.0
	Prairie Falcon	0.001	0.002	100.0	54.5

[a] Exposure index calculated by multiplying mean use (#/survey) times proportion of all observations where species *I* was observed flying times proportion of all flying observations where species *I* was observed within the rotor-swept height of turbines.

Appendix F (Continued). Relative Exposure Indices for Birds Observed on the CARES Study Area

Fall

Group	Species	Exposure Index[a]	Mean Use	% Fly	25-75m
Raptor (cont')	Osprey	0.001	0.002	100.0	50.0
	Unidentified Raptor	0.001	0.004	75.0	33.3
	Rough-legged Hawk	0.001	0.002	71.4	50.0
Waterfowl	Canada Goose	0.014	0.014	100.0	100.0

[a] Exposure index calculated by multiplying mean abundance (#/survey) times proportion of all observations where species *i* was observed flying times proportion of all flying observations where species *i* was observed within the rotor-swept height of turbines.

Appendix F (Continued). Relative Exposure Indices for Birds Observed on the CARES Study Area

Winter

Group	Species	Exposure Index[a]	Mean Use	% Fly	25-75m
Game Birds	Gray Partridge	0.000	0.239	50.0	0.0
	Chukar	0.000	0.023	31.8	0.0
	Gray Partridge	0.000	0.000	50.0	0.0
	Ring-Necked Pheasant	0.000	0.000	50.0	0.0
Passerine	Common Raven	0.030	0.093	97.2	33.6
	American Robin	0.019	0.165	63.2	18.6
	Unidentified Passerine	0.008	0.038	80.2	25.1
	Horned Lark	0.006	0.362	62.4	2.6
	Unidentified Woodpecker	0.004	0.004	100.0	100.0
	American Goldfinch	0.001	0.007	100.0	7.4
	Townsend's Solitaire	0.000	0.046	43.3	2.4
	Northern Flicker	0.000	0.002	52.6	15.8
Raptor	Golden Eagle	0.009	0.018	100.0	52.6
	Bald Eagle	0.006	0.006	100.0	100.0
	Red-Tailed Hawk	0.004	0.008	82.6	62.0
	Prairie Falcon	0.003	0.006	100.0	54.5
	Rough-Legged Hawk	0.001	0.002	71.4	50.0
	Northern Harrier	0.000	0.002	94.1	16.7

[a] Exposure index calculated by multiplying mean abundance (#/survey) times proportion of all observations where species *I* was observed flying times proportion of all lying observations where species *I* was observed within the rotor-swept height of turbines.

APPENDIX G. Statistical Review of Select Reports and Papers

Introduction

A general review of the literature on avian-wind turbine interactions was conducted by Sue Orloff. This review was based on results reported in executive summaries, abstracts, and results sections as well as communication with several researchers studying avian-wind turbine interactions. The methods and statistics used as a basis for the conclusions were not included in this initial review because of time constraints. The following is a review of the methods and the application of statistics in a subset of the initial body of literature. The selected literature describes studies that investigated factors related to risk or evaluated ways of minimizing risk of collision of birds with turbines. Some original papers could not be located in a timely fashion, so were not included in the review. In other cases, the detail in the paper or report was not sufficient to allow an objective judgement of whether the conclusions reached from the study were appropriate given the design and analysis. A more detailed review is provided for papers or reports where authors provided a very detailed methods section (e.g., Orloff and Flannery 1992). Most of the peer reviewed published manuscripts and other reports we reviewed did not have the same detail, so the evaluations are much more limited in those cases.

This review should assist the evaluation of methods that have been tested for their ability to minimize risk of collision to birds. The reports that were reviewed are listed in alphabetical order. It is anticipated that this review will be extended in the study conducted at the Sea West wind plant near Arlington, Wyoming.

Overall Comments

Most of the studies relied on descriptive statistics from observational studies as the basis for the conclusions made. In many cases, conclusions drawn cannot be based on statistical inferences. Furthermore, none of the studies reviewed investigated the power of the study to detect differences in the parameters of interest. In a few cases, some comments are made regarding small sample size limitations, but estimates of the power of the tests are not given.

When statistical tests and/or confidence intervals were presented, the authors attempted to determine if the design and analysis could justify the statistical inferences made by the researcher. The authors looked for indications of "pseudo replication," where an inappropriate experimental unit is used to estimate variability in the data. For example, if fatalities are collected at random for systematically selected plots within a wind plant, variation should be measured from plot to plot, as opposed to treating each fatality as the experimental unit. The reports/papers reviewed include:

Beaulaurier, D.L. (1981). *Mitigation of Bird Collisions with Transmission Lines.* Bonneville Power Administration, Portland, Oregon. 83 pp.

Bonneville Power Administration (BPA) (1987). Cape Blanco Wind Farm Feasibility Study Summary.

Brown, W.M. and Drewien, R.C. (1995). "Evaluation of Two Power Line Markers to Reduce Crane and Waterfowl Collision Mortality." *Wildlife Society Bulletin*.

Cochran, W.W. and Graber, R.R. (1958). "Attraction of Nocturnal Migrants by Lights on Television Tower."

Herbert, A.D. (1970). "Spatial Disorientation in Birds." *The Wilson Bulletin*.

Howell, J.A., Noone, J., and Wardner, C. (1991). *Visual Experiment to Reduce Avian Mortality Related to Wind Turbine Operations, Altamont Pass, Alameda, and Contra Costa Counties, California.*

Jaroslow, B.N. (1979). "A Review of Factors Involved in Bird-Tower Kills and Mitigative Procedures." *The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habits.*

Kreithen, M.L. (1996). "Development of a Pulsed Microwave Warning System to Reduce Avian Collisions with Obstacles." *2nd International Conference on Raptors, Urbino, Italy.*

Morkill, A.E. and Anderson, S.H. (1991). "Effectiveness of Marking Power Lines to Reduce Sandhill Crane Collisions." *Wildlife Society Bulletin*.

Nelson, H.K. and R.C. Curry (1995). "Assessing Avian Interactions with Wind Plant Development and Operations." *Transactions of the 61st North American Wildlife and Natural Resources Conference.*

Orloff S. and Flannery, A. (1992). *Wind Turbine Effects on Avian Activity, Habitat Use, and Mortality in Altamont Pass and Solano County Wind Resource Areas.* Prepared by BioSystems Analysis, Inc., Tiburon, California, for the California Energy Commission, Sacramento.

Orloff S. and Flannery, A. (1996). *A Continued Examination of Avian Mortality in the Altamont Pass Wind Resource Area.* Prepared by BioSystems Analysis, Inc., Tiburon, California, for the California Energy Commission, Sacramento.

Tucker, V.A. (1996a). "A Mathematical Model of Bird Collisions with Wind Turbine Rotors." Journal of Solar Energy Engineering.

Tucker, V.A. (1996b). "Using a Collision Model to Design Safer Wind Turbine Rotors for Birds." Journal of Solar Energy Engineering.

REVIEW

Beaulaurier, D.L. (1981). *Mitigation of Bird Collisions with Transmission Lines.* Bonneville Power Administration, Portland, Oregon. 83 pp.

This study investigated avian mortality associated with power lines over a 6-month period in 1980 and 1981 at two sites. One site was located in south central Washington and the other in Northwestern Oregon. At each study site, a single segment of transmission line defined the experimental unit. Primary data were collected before and after the removal of the ground wire. Data collected included carcass counts from standardized searches, search efficiency and scavenging bias trials, and bird use of power lines and behavior. The sample size reported at 67 days was a total of 282 hours of bird use and flight data collections (219 day observations, 63 night observations). Primary results stated that mortality rates at the lines with the ground wire removed were approximately half the mortality rates estimated prior to removal.

In the text, only methods for calculating descriptive statistics (mean collision rates, etc.) are reported. Results described in the text are only descriptive, although some of the tables contain what appear to be confidence intervals. The methods used to calculate the confidence intervals are probably suspect given the lack of replication across space and time. Inference regarding lower fatality as a result of ground wire removal is based on descriptive statistics and professional judgment. Differences in use during the two periods may have affected results. Some replication in space and time would have yielded more statistically based results.

Bonneville Power Administration (BPA) (1987). ***Cape Blanco Wind Farm Feasibility Study Summary.***

This report contains predicted bird collision and mortality estimates for three types of wind turbines, using an equation developed by McCrary et al. (1983, 1984). This equation predicts the number of collisions depending on: (1) An assumed migration traffic rate (MTR); (2) Birds at risk = (max turbine ht/max migration ht)*MTR*max width of turbine; (3) Time of migration period; (4) Strike zone; (5) Hazard zone; and (6) Probability of avoidance behavior (calculated by P = (number of turbine blades*blade rotational speed*average depth of blade)/bird's axial velocity). The predicted values indicate there would be negligible impacts on birds. In this study, the model was not tested for prediction error using empirical data.

Brown W.M. and Drewien, R.C. (1995). "Evaluation of Two Power Line Markers to Reduce Crane and Waterfowl Collision Mortality." ***Wildlife Society Bulletin*****.**

This study was designed to evaluate the use of yellow spiral vibration dampers and yellow fiberglass swinging plates for reducing crane and waterfowl fatalities from power line collisions. The principal study area was the Monte Vista National Wildlife Reserve in the San Luis Valley of south-central Colorado. Eight power-line segments were divided in half and each half randomly selected for marking with spiral vibration dampers or swinging plates. The unmarked "1/2" segments were used as a control. The authors do not say how the power line segments were selected. A random selection process would have been preferred and necessary for making statistical inference to a universe larger than the studied segment.

A total mortality was estimated as (found mortality)/[(1-proportion of carcasses removed by scavengers in 24 hrs.)*(estimated search efficiency)]. Comparisons of mortality rates (proportion of mortalities/overflights) were made for sandhill cranes, Canada geese, and ducks between marked and unmarked segments. Two estimates were generated, one for a total mortality rate and the other for a minimum mortality rate where only observed collisions were used. Low collision mortality rates for some seasons necessitated combining numbers of species groups to make seasonal comparisons. A binomial test was used to test equal proportions. A log-linear model was used to look for effects and interactions of line marking, marker type, year, season, and individual species groups.

The collision mortality rate was lower on marked portions in fall, spring, and when combined across seasons. Z statistics and p-values are reported. Collision mortality rates were lower on lines marked with plates for data combined across seasons (Z statistic and p-value reported).

The only significant main effect was whether lines were marked or not. Predicted marker types were lower for both marker types, all species groups, and in all seasons and years (p-value reported). There was a significant interaction between marker type and season, showing that the effectiveness of plates and dampers was not consistent, with the mortality rate being higher for dampers in fall and plates in spring.

Relative effectiveness of marker types for cranes, geese, and ducks also varied among years and obscured the main effects and 2-way interactions of these parameters.

Flocks flew higher above marked lines than unmarked lines. Cranes reacted more to marked lines and geese to unmarked lines; however, the sample size for geese was very small. Ducks had the highest proportion of flocks crossing the line at >6 m, cranes had the smallest. Birds that visibly reacted to lines flew higher than those that did not. Cranes that did not react to lines were more likely than ducks or geese to be <3 m above the line when crossing. Marking did not appear to change these behaviors. The most frequent reaction to lines was adjusting altitude followed by flaring or changing direction. Ducks flew under lines most frequently, especially unmarked lines. Birds reacted at greater distances to marked lines and birds that reacted at greater distances flew higher above lines.

Although the collision rate increased for both marked and unmarked lines on windy days (>24 mph), fewer collisions occurred with marked lines. The proportion of night collisions was higher in fall than in spring, which may be the result of hunters disturbing birds in the pre-dawn hours.

It appears that most of the statistical tests (for example, binomial test, log-linear model) used individual fatalities as the unit of replication. The more appropriate experimental unit would probably be the eight matched plots. Independence of bird fatalities is assumed, which may not be appropriate. The lack of independence would have the effect of decreasing the variance of the data, but the same patterns would still exist. A strength of the study is the amount of data collected based on replication across both time and space. Power was not addressed in the report.

Cochran, W.W. and Graber, R.R. (1958). "Attraction of Nocturnal Migrants by Lights on Television Tower."

This article is a note describing the increased number of migrating birds seen and heard around a lighted 984-ft. television tower near Champaign, Illinois. The authors monitored the migration through the night and summarized their information by averaging the number of bird notes (calls) heard per minute and the number of birds seen per minute. No other statistics were presented. Informal surveys conducted near the tower revealed that there were many more birds near the lighted tower than in areas adjacent. When the lights on the tower were turned off, the avian congestion around the tower dissipated. No statistical inferences can be made.

Herbert, A.D. (1970). "Spatial Disorientation in Birds." ***The Wilson Bulletin*****.**

This 20-page paper describes similarities in how human pilots and birds become disoriented in flight and provides anecdotes concerning bird collisions. The most difficult flying conditions for birds described in this paper occur at night when artificial lighting, a low cloud ceiling, and precipitation are present. Artificial lighting causes unnatural shadows that confuse birds that adjust for different visual cues; however, physiological cues provide birds with different information in addition to visual cues. Flying disorientation could have been caused by the inability to reconcile the two types of information. No statistics are presented, so results are considered solely based on professional judgment.

Howell, J.A., Noone, J., and Wardner, C. (1991). ***Visual Experiment to Reduce Avian Mortality Related to Wind Turbine Operations, Altamont Pass, Alameda, and Contra Costa Counties, California.***

An experiment was conducted to assess:

1) The effects on bird fatalities of painting turbine blades with a pattern. Of the 15 available turbine strings with 5 turbines each, 10 were randomly selected for the control group (no paint) and 5 for the treatment group (paint). Blades of the treatment group were painted with an alternating pattern of red and white.

2) The relationship of topography on bird-turbine collisions. The group of 15 original sites were matched with 15 adjacent sites. The adjacent turbine sites were considered the control group, although it is unclear what the treatment is.

3) Whether turbine sites at the end of strings resulted in higher mortality rates than within string turbines. The treatment group consisted of 9 turbines at the end of strings (i.e., the 5 terminal turbines) and was compared with the control group of 21 turbine sites designated as mid-string sites.

Sites were searched weekly for 12 months. Chi-square analyses were used to compare sites. Data from the two control strings were pooled with those from the strings where the flutter devices were never fully operational. Chi-square tables used turbine strings as the experimental unit.

No significant ($p<0.05$) differences were found as a result of the three studies; however, the authors say that lower p-values for the paint experiment may suggest a significant effect would be detected were the sample size larger. While there is little doubt that a statistical difference would exist with a large enough sample size, no judgement as to the biological significance of the study results could be made.

Statistical analyses appear appropriate, but small sample sizes may have limited the strength of conclusions.

Jaroslow, B. N. (1979). "A Review of Factors Involved in Bird-Tower Kills and Mitigative Procedures." ***The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habits.***

This review examines (1) Conditions that lead to collision mortality; (2) Physiological and behavioral factors that contribute to collisions; and (3) Some successful and proposed mitigation procedures.

No statistics are presented in this article. The author lists three main factors that contribute to collisions: (1) Invisibility, (2) Deception, and (3) Confusion and describes each. The author describes some avian behavioral characteristics that may play a part in collisions and discusses possible mitigation measures. No statistics are available for evaluation.

Kreithen, M.L. (1996). "Development of a Pulsed Microwave Warning System to Reduce Avian Collisions with Obstacles." ***2nd International Conference on Raptors, Urbino, Italy.***

In this study, 20 homing pigeons were tested for their ability to detect pulsed microwaves. Capability of detection was determined by cardiac accelerations. The study used a control and a test group. For 707 trials, 84.3% of the birds responded to pulsed microwaves (n=426); 17.1% of birds responded to control trials (used to establish background cardiac acceleration rates) (n=281).

The sample sizes reported are based on individual trials, and should not be considered independent events. Results based on variability between the 20 birds should have served as the basis for statistical inferences. The differences in proportion of response is so great between the control and test groups, that the results would probably be significant even if the analysis used the bird as the unit. Study results should not be used to make statistical inference to species of birds other than the homing pigeons used in the study.

Morkill, A.E. and Anderson, S.H. (1991). "Effectiveness of Marking Power Lines to Reduce Sandhill Crane Collisions." ***Wildlife Society Bulletin.***

This study was conducted near the Platte River in portions of Dawson, Buffalo, and Kearney Counties in south-central Nebraska to evaluate the effectiveness of marking power lines to reduce sandhill crane collisions. Nine segments of static wires were divided into spans that were either marked or unmarked with yellow aviation balls containing vertical black stripes. Experimental units consisted of adjacent marked and unmarked spans of static wires throughout nine segments of high-voltage transmission line ranging from 1.0 to 2.5 km in length. It is unclear how the segments or spans were selected; although, they do bisect one or more habitat types that the cranes use daily. There are 29 marked spans and 29 unmarked spans.

Chi-square tests were used to detect significant differences in (1) The number of cranes flying over marked and unmarked spans; (2) The number of dead cranes between marked and unmarked spans of static wires; and

(3) Distances categories at which cranes exhibited avoidance behavior. Of the 36 carcasses used for comparison, 25 died from collisions with unmarked spans. The test statistics, degrees of freedom, and p-values are presented. They found that: (1) There was no significant difference between the number of birds flying over marked an unmarked transmission lines; (2) Significantly more cranes were killed in collisions with unmarked spans; and (3) Cranes reacted sooner to marked spans than unmarked. The design of the study is appropriate and strong. There may be some pseudo replication issues because the chi-square analyses may have used individual fatalities as independent units of replication. Analyses using each of the 29 matched pairs of plots should have been used in making comparisons. If the individual kills can be considered independent events, then inferences are appropriate. Pattern in data is consistent with Brown and Drewien (1995).

Nelson, H.K. and Curry, R.C. (1995). "Assessing Avian Interactions with Wind Plant Development and Operations." ***Transactions of the 61st North American Wildlife and Natural Resources Conference.***

This study was conducted to assess whether perch guides reduced the number of birds perching at turbines in the Altamont Pass. Wind Resource Area Researchers installed wires or wire screens to prevent perching and nesting on 50 turbines. A before-after analysis was conducted. The study estimated a 54% reduction in perching. No confidence intervals or hypothesis tests were conducted to determine the significance of the results. In addition, no power analyses were conducted to evaluate sample size. Although the magnitude of the reduction appears quite large, the validity of the inferences cannot be ensured.

Orloff S. and Flannery, A. (1992). ***Wind Turbine Effects on Avian Activity, Habitat Use, and Mortality in Altamont Pass and Solano County Wind Resource Areas.*** **Prepared by BioSystems Analysis, Inc., Tiburon, California, for the California Energy Commission, Sacramento.**

This large-scale study was conducted at the Solano County and Altamont Pass wind resource areas (WRAs) to study, among other things, the relationship among bird use, fatalities, turbine characteristics, and physical variables associated with the site. Turbine types were grouped into eight categories based on structural features. Of the eight, five turbine types were selected that represented the most widely used or unique types. Eighteen sample sites were chosen randomly within areas containing each of the five types. Mortality and bird use data were collected at 10 sample sites the first season, two within each turbine type. Eight additional sampling sites were added in the five subsequent seasons. More sample sites were added after the spring season as spring scavenger surveys suggested scavengers were removing few carcasses. Spring sample sites included 8.5% (625/7340) of the turbines at Altamont Pass WRA. Sample sites during the following seasons represented 15.9% (1169/7340) of the turbines.

Sample sites were selected by generating random coordinates and plotting them on a map. Most sample sites had only one turbine. If other types of turbines were present, only one type was surveyed.

Sample sites were divided into 8 or 12 sample plots. To include an adequate number of sample plots of a particular turbine type, some sites were larger than others. All turbines within a plot were sampled.

There were 208 sample plots in the 18 sample sites. The sample plots were approximately 500 by 400 feet (200 feet on each side of the turbine row). Turbines were spaced 80-150 feet depending on type, so each plot included three to six turbines. In addition to sample plots, searches for dead or injured birds were also conducted at end-row turbines, met towers, and all transmission lines within each sample site.

Driving Surveys

Data on the relative abundance and area of use by raptors were collected via four driving surveys at Altamont Pass in 1989 and 1990. Surveys were conducted for eight days each season. Two survey routes covered the WRA. Each route had 25 randomly selected points located at least 0.5 mi apart to reduce duplicate observations. Ten-minute scans for raptors were conducted at each point. Starting times were staggered to remove temporal bias. The 10-minute scans were considered independent of each other and were used as replicates for the statistical test.

The smaller Solano County WRA was surveyed for eight days one season. There were only 20 10-minute scans at this area. Data were compared to those from Altamont Pass.

Site-Specific Surveys

Site-specific data were collected within sample sites where carcass searching was done. Counts were conducted concurrently with carcass searching. During the first spring season observations consisted of one 10-minute count per day at each of three established points, twice a week for five weeks and three days of observation at each site. During subsequent seasons, the number of sample sites increased from 10 to 18 and three points were sampled in each site each day; however, the frequency was reduced to once a week for five weeks and one full day of observation at each site (30 10-min periods). Each 10-min scan was considered a discrete sample and each sample site had the same number of scans. Using discrete rather than continuous observations standardized census times equalizing sampling effort. Ten-minute scans were not used at replicates for statistical purposes with the site-specific data because these scans were not independent and their use would represent pseudo replication. Days were considered more independent and were used as replicates for the statistics. To determine whether differences in seasonal abundance were statistically significant, only data from the all-day surveys were used.

Mortality Surveys

Mortality sampling sites were surveyed spring, fall, and winter of 1989 and summer, fall, and winter 1990. Each sample site was surveyed for 5 weeks, twice per week in spring and once a week in other seasons. The radius of the search area was variable (100 to 200 feet), depending on the size and height of the tower. The survey area was cleared of carcasses when searches started, and carcasses found in subsequent surveys were considered to have died the week before. Because birds were included that were believed to have died the week prior to the beginning of the survey, the survey period was considered to be 6 weeks long.

Tests and Inferences

Site-Specific Surveys - To determine statistical significance in seasonal abundance, only the data collected from all surveys were used, with day representing a sample unit. Observed abundance only included birds observed on sample sites less than 500 ft. from observers and less than 200 ft. above the ground. A Kruskal-Wallace test indicated that the seasonal differences in abundance were statistically significant with the highest relative abundance of raptors (1.68 raptors/10-minute count +/- 2.02 SD) in the fall (N=1624).

Another Kruskal-Wallis test indicated that the number of birds seen per day for all seasons combined was significantly associated (P=0.04) with maximum daily wind speed. Most birds were seen when the wind was 6-10 mph.

Flight Heights - Kestrels appeared to fly lower than other raptors, 75% within 200' of the ground and 50% within 100' of the ground. All raptors tended to fly higher in the fall than in other seasons. Seventeen percent of raptors were seen flying at or below the maximum blade height of the majority of turbines in three turbine types. Thirty-one percent of raptors were observed below maximum blade height of four turbine types. Thirty-nine percent were below blade height of all five turbine types. Thirty-eight percent of golden eagles and thirty-nine percent of turkey vultures were observed flying within turbine-blade range of the ground. Seventy-two percent of American kestrels and sixty-five percent of common ravens were seen flying within turbine-blade range of the ground. Forty-seven percent of red-tailed hawks were recorded in this range.

Distance from Turbines - An analysis of distance to turbine by turbine type, using ANOVA, suggested that for all raptors combined, the frequency of birds flying within 50' of turbine structures did not differ significantly among turbine types. Another analysis, using ANOVA, of the frequency of perching by turbine type indicated a significant difference between the 5 turbine types ($P<0.01$). Perching was most common on guyed-pipe turbines, followed by windwall, lattice, tubular, and vertical turbine types. A test of whether birds flew closer or farther from operating turbines indicated significant associations but no meaningful or consistent trends.

Mortality Surveys - No off-site mortalities were included in the statistical analyses.

A chi-square test indicated that the number of mortalities was not related to abundance ($P<0.01$).

McNemar's matched pair study was conducted comparing mortalities between four windwall turbines and four three-blade lattice turbine plots (control sites). Experimental and control plots were matched as closely as possible with respect to topography and siting conditions. The sample size for this test was too small to test statistically.

Contributing Factors - Researchers used statistical techniques to determine which variables were most closely associated with mortality. Factors that showed statistical significance along with those felt to have biological relevance were included in a multivariate discriminate analysis to determine which factors had the greatest association with mortality.

A two-way ANOVA analysis of five other habitat and structural variables including elevation, number of steep-sided slopes (0-4), canyon proximity, structure distance, and structure density, showed that end-row turbines were independent of these variables.

Chi-square analysis of the following turbine characteristics suggested a significant association of the variable with higher raptor mortality: End row turbines, turbines close to canyons, and number of steep-sided slopes (0-4). Using the same analysis, the following turbine characteristics were not found to have a significant association with raptor mortality: first turbine row, degree of slope, slope aspect, length of turbine row, position on slope, and ground squirrel density. A t-test of the following turbine characteristics showed an association with higher raptor mortality: elevation and structure density. A t-test of distance to closest turbine row did not have a significant effect on raptor mortality. None of these turbine characteristics were significant for non-raptors though the authors caution that low sample size requires cautious interpretation. Also, the authors question the biological significance of the effect of the elevation of turbines for the following reasons: (1) The mean difference in elevation between turbines that killed and turbines that did not kill was only 157'; (2) The distribution of elevations between killing and non-killing turbines was similar, and (3) Elevation was associated with two variables that were themselves related to mortality; proximity to canyon and number of steep slopes.

A discriminate analysis indicated three turbine characteristics were significantly associated with raptor mortality, end-row, proximity to canyon, and elevation.

A chi-square analysis indicated a significant association between higher raptor mortality and lattice type turbines than non-lattice type turbines. Comparisons of mortality associated with different turbine types are complicated by several factors: (1) The proportion of important habitat and structural variables differs for each type of turbine; (2) The analysis of habitat variables indicates that turbine types are not randomly distributed with respect to habitat characteristics within the WRA, and (3) relative abundance of raptors, frequency of perching on turbines, scavenging rates, and percentage of time turbines are in operation can differ among turbine types.

Estimating Mortality - Seasonal, yearly, and annual site-wide mortality rates were estimated. The extrapolation included data only from fresh carcasses and from dead birds found within the sample plots and along transmission wires. Mortalities from the extra end-row turbines surveyed were excluded from the data set. The following correction factors were used to estimate mortality: Scavenger correction factor (SCF) and observer correction factor (OCF). Estimated mortality (EM) is calculated as: EM = (C/OCF)/SCF, where C is assumed the number of mortalities counted.

Review

Although numerous statistical techniques were used in this study (chi-square tests, discriminate analysis, ANOVA, t-tests, logistic regression), in general, it appears they were used appropriately. Most analyses consider the plot as the experimental unit for making statistical inferences. Some of the more substantive conclusions are independently corroborated in Orloff and Flannery (1996). The conclusion that a pattern existed suggesting that more fatalities were associated with end row turbines and distance to canyon appears appropriate given the design and the analysis. One caution, in large observational studies like these where a large number of tests of hypothesis are conducted, the overall Type I error rate (probability of rejecting the hypothesis of no difference when there is no difference) is increased.

Orloff, S. and Flannery, A. (1996). ***A Continued Examination of Avian Mortality in the Altamont Pass Wind Resource Area.*** **Prepared by BioSystems Analysis, Inc., Tiburon, California, for the California Energy Commission, Sacramento.**

This study is an extension of the studies reported in Orloff and Flannery (1992). In this report, additional variables associated with turbines were generated to help explain the fatality data. An additional one-time fatality survey was also conducted to attempt to substantiate the findings from the surveys conducted in 1992. Because the same basic statistical design and analyses were conducted as in the first report (Orloff and Flannery [1992]), this review addresses only the more substantive findings and a summary of conclusions regarding the validity of the statistical design and analysis.

Some important turbine characteristics such as tip speeds, large rotor diameters, variable-pitch blades, and operation percentage time suggested univariate associations with fatalities, but because of the potential for confounding with the actual turbine type, these relationships should be interpreted with caution. This confounding is recognized in Orloff and Flannery (1996) and further study into these relationships is recommended. When multivariate analyses are conducted (discriminate analysis and logistic regression analysis), proximity to canyon and end-row versus non-end row variables dominate the models.

Although numerous statistical techniques were used in this study (chi-square tests, discriminate analysis, ANOVA, t-tests, logistic regression), in general, it appears they were used appropriately. Most analyses consider the plot as the experimental unit for making statistical inferences.

In large observational studies with a large number of tests of hypothesis, the overall Type I error rate (probability of rejecting the hypothesis of no difference when there is no difference) is increased.

Tucker, V.A. (1996a). "A Mathematical Model of Bird Collisions with Wind Turbine Rotors." Journal of Solar Energy Engineering.

Tucker, V.A. (1996b). "Using a Collision Model to Design Safer Wind Turbine Rotors for Birds." Journal of Solar Energy Engineering.

Both of Tucker's papers use a mathematical model to predict the number of collisions that will occur when a bird passes through the blade-swept area. The probability of collision occurring depends on:

$$p = \frac{Bb}{2p} \quad \frac{W}{A \backslash V_{bx} + (1 - a) \quad U} + \frac{\sin Y}{r} \div$$

where:

A	=	aspect ratio of bird
a	=	axial induction factor
B	=	number of blades in rotor
b	=	wing span of bird
V_{bx}	=	component of bird velocity relative to air (m/s)
U	=	wind velocity relative to ground
Ψ	=	azimuth angle on rotor disk (radians)
Ω	=	angular speed of rotor blades (radians/s)
r	=	radius (m)

The model does not account for attractiveness of a turbine as a perch, prey base for raptors, location of the turbine, or height of the rotor above the ground. Empirical evidence presented indicates that the model correctly predicts that the number of carcasses found below large variable speed rotors is not proportional to those found below small constant speed rotors. We feel that the findings are not a rigorous test of the model because of the previously mentioned uncontrolled variables.

REPORT DOCUMENTATION PAGE

Form Approved
OMB NO. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
December 1999

3. REPORT TYPE AND DATES COVERED
Final Report

4. TITLE AND SUBTITLE
Baseline Avian Use and Behavior at The CARES Wind Plant Site, Klickitat County, Washington

Final Report

5. FUNDING NUMBERS
C: ZAM-8-16454
TA: WE00.1910

6. AUTHOR(S)
Wallace P. Erickson; Gregory D. Johnson; M. Dale Strickland; Karen Kronner; Paula S. Becker; and Sue Orloff

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Western EcoSystems Technology, Inc.
2003 Central Avenue
Cheyenne, WY 82001
And
IBIS Environmental Services
340 Coleman Dr.
San Rafael, CA 94901

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
SR-500-26902

11. SUPPLEMENTARY NOTES
NREL Technical Monitor: Karin Sinclair

12a. DISTRIBUTION/AVAILABILITY STATEMENT
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This report presents a literature review on avian-wind turbine interactions and the results of a one-year avian baseline study conducted in 1998 at the proposed Conservation and Renewable Energy System (CARES) wind development site in Klickitat County, Washington. Avian use of the site ranged from 1.11/survey in the winter to 5.69/survey in the spring. Average use by passerines in the study plots ranged from 1.15 minutes/survey in the winter to 40.98 minutes/survey in the spring. Raptors spent much less time within plots than other groups, ranging from 0.05 minutes/survey in the winter to 0.77 minutes/survey during the fall. Thirteen percent of all flying birds were within the rotor-swept height (25 to 75 m); 41.6% of all raptors were flying at this height. Raptors with the greatest potential turbine exposure are red-tailed hawks and golden eagles. Passerines with the highest turbine exposure are common ravens, American robins, and horned larks. Spatial use data for the site indicate that avian use tends to be concentrated near the rim, indicating that placing turbines away from the rim may reduce risk. Avian use data at the CARES site indicate that if a wind plant is constructed in the future, avian mortality would likely be relatively low.

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT
UL