Proceedings of the

National Avian-Wind Power Planning Meeting IV

Carmel, California

May 16-17, 2000

Avian Subcommittee

of the

National Wind Coordinating Committee

Meeting Facilitated by

RESOLVE, Inc.

Washington, D.C.

May 2001

Suggested Citation Format:

This volume:

PNAWPPM-IV. 2001. Proceedings of the National Avian-Wind Power Planning Meeting IV, Carmel, CA, May 16-17, 2000. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee, by RESOLVE, Inc., Washington, D.C., Susan Savitt Schwartz, ed., 179 p.

Preceding volumes:

PNAWPPM-III. 2000. Proceedings of National Avian-Wind Power Planning Meeting III, San Diego, CA, May 1998. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by LGL, Ltd., King City, Ont. 202 p.

PNAWPPM-II. 1996. Proceedings of National Avian-Wind Power Planning Meeting III, Palm Springs, CA, Sept. 1995. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by RESOLVE Inc., Washington, D.C., and LGL, Ltd., King City, Ont. 152 p.

PNAWPPM. 1995. Proceedings of the National Avian-Wind Power Planning Meeting, Denver, CO, July 1994. Report DE95-004090. RESOLVE Inc. Washington, D.C., and LGL, Ltd., King City, Ont. 145 p.

Ordering Information:

This volume is available, while the initial stock lasts, from

Avian Subcommittee of the National Wind Coordinating Committee,
c/o RESOLVE, Inc.
1255 23rd St. NW, Suite 275
Washington, D.C. 20037
(phone 202-944-2300; fax 202-338-1264)

Preceding volumes are available on the World Wide Web at

www.nationalwind.org/pubs/default.htm

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INTRODUCTION

Representatives of the wind industry, academia, conservation interests, and state and federal government agencies met in May 2000 to discuss research and regulatory approaches that could be helpful in predicting, measuring, and reducing the numbers of birds killed by collisions with wind turbines. The purposes of the meeting were to:

- share research results and update stakeholders on research conducted on avian/wind interactions;
- identify questions/issues stakeholders have about research results;
- develop conclusions about some avian/wind issues; and to identify stakeholder questions/issues for future avian/wind research

This meeting was the fourth in a series convened by the Avian Subcommittee of the National Wind Coordinating Committee (NWCC), as part of the Subcommittee's efforts to address and build consensus on issues of public policy, scientific research, and stakeholder/public involvement related to avian/wind power interactions. The Proceedings of the first three meetings, held in 1994, 1995, and 1998, can be accessed on the NWCC's website, or obtained from the National Technical Information Service (see p. ii of this volume for details). National Avian-Wind Power Planning Meeting (NAWPPM) IV opened with a brief history of the past three meetings, and an overview of studies that have been or are being conducted.

Overview of Previous Avian-Wind Power Planning Meetings

NAWPPM I: The first in this series of meetings was convened in Denver, Colorado in July 1994. Organized by the National Renewable Energy Laboratory (NREL), the Department of Energy (DOE), the American Wind Energy Association (AWEA), the National Audubon Society, Electric Power Research Institute (EPRI), and the Union of Concerned Scientists, the meeting was a response to the controversy generated by bird/wind power interactions, particularly in California. Stakeholder group representatives as well as independent scientists with relevant expertise met to identify and prioritize key issues, define a research agenda, and build consensus on approaches to the research needed to address the issues. Parallel to this collaborative effort to address technical questions concerning avian/wind power interactions, the National Wind Coordinating Committee and its Avian Subcommittee were formed to address broader issues associated with the sustainable commercialization of wind power in the U.S. The Proceedings of the first meeting were distributed under the auspices of the NWCC and its Avian Subcommittee, and those groups have sponsored subsequent National Avian Wind Power Planning Meetings.

NAWPPM II: The second meeting was held in Palm Springs, California, in September 1995. The purposes were to provide information and create a dialogue among regulators, researchers, and other stakeholders to help all parties understand the role research can play in responsible development and permitting of wind plants, and to propose research and appropriate sponsorship. The meeting included presentation and discussion of nine White Papers on the theory and methods for studying and understanding bird/wind power interactions. The second part of the meeting consisted of working group sessions on site evaluation and prepermit research and planning; operational monitoring; modeling and forecasting; and, avian behavior and mortality reduction. A final plenary session drew together the main recommendations. These included development of a conceptual model of the principal causes of avian mortality at wind plants; further definition of the most appropriate "metrics" or variables to be measured; and, further development of research protocols, data collection guidelines, and statistical analysis techniques.

Various research and monitoring projects were initiated subsequent to NAWPPM II, and a working group began to prepare a document that would offer guidance to researchers and regulators as to appropriate metrics and research procedures. The document has since been published by the NWCC and Avian Subcommittee.[1]

NAWPPM III: The third meeting was held in San Diego, California, on May 27-28, 1998. The purposes of this meeting were to facilitate scientific interchange, share information about study findings and about new and developing techniques for research and mitigation; and, to identify data gaps and set research priorities. Several specific field studies of birds at actual or planned wind energy sites had been started (and in some cases completed) between Meetings II and III. The third meeting therefore emphasized presentations of study results. Unlike earlier meetings, which focused on California, NAWPPM III included presentations on studies conducted at sites in several other parts of the United States and in Europe.

Overview of the Fourth National Avian-Wind Power Planning Meeting

NAWPPM IV took place at the Carmel Mission Inn in Carmel, California on May 16-17, 2000. The presentations made at the meeting, and summaries of the follow-up and panel discussions, are documented in this document. The meeting was structured in four sessions:

1) Site studies
2) Avian visual studies
3) Mortality reduction, impact avoidance, and deterrent considerations
4) Other research topics

Presenters were asked to provide an overview of their studies to date, briefly describing the focus of the study, timeline, methodology used, data analysis, and any conclusions that could be drawn from the study or studies. An open discussion period followed each presentation or set of presentations, during which participants explored the implications and significance of the studies for wind power planning or mitigation efforts. The meeting concluded with a plenary discussion reviewing: 1) overall conclusions regarding what we know (and do not yet know) about avian-wind turbine interactions; and, 2) promising areas of study with the potential for improving the planning and management of wind power generation to minimize negative impacts on avian species.

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[1] Anderson, R., M. Morrison, K. Sinclair, and D. Strickland, with H. Davis and W. Kendall. 1999. *Studying Wind Energy/Bird Interactions: A Guidance Document*. National Wind Coordinating Committee, c/o RESOLVE, 1255 23rd St., Suite 275, Washington, DC 20037. 87 p. Available at www.nationalwind.org/pubs/default/htm

Areas of focus new to this forum included research on:

- *Avian vision and turbine blade conspicuity*. Research demonstrates that birds are able to distinguish the presence of turbines in photos, including photos showing groups of turbines, isolated turbines, and parts of turbines. However, rotating blades become effectively transparent to the eye as the viewer (bird or human) approaches, a phenomenon known as *retinal blur*. Laboratory research indicates that black-and-white patterns staggered across a turbine's blades may be able to mitigate this impact, allowing for somewhat greater visibility of the rotating blades to approaching birds.

- *Avian hearing and acoustical data monitoring.* Because birds do not hear outside the range of human hearing, it is not possible to produce an acoustic "scarecrow" or deterrent device that would not also be audible to humans. However, it may be possible to modify blade noise so that moving blades are easier for birds to detect and localize. Research suggests that it might be possible to alter the spectral signature of blade noise so that birds can detect and localize a rotating turbine at the point where retinal blur renders the blades transparent.

- *Bat ecology and wind turbine considerations.* Bat fatalities due to collisions with wind turbines have been observed incidentally, and sometimes recorded, in conjunction with a number of avian studies, but not as the specific focus of research. Our knowledge regarding bats and wind turbines is roughly equivalent to where we were ten years ago with birds. Participants expressed interest in getting a better sense of the significance of bat-turbine collisions to bat populations.

The organization of these Proceedings follows the NAWPPM IV agenda. It includes written versions of the presentations on current and planned research and research techniques, along with summaries of discussions following individual presentations. Presentations included in these Proceedings are not peer-reviewed documents. The final section consists of a summary of discussion highlights and participants' review of "what we have learned" to date. Participants considered the effectiveness of the Avian Subcommittee's metrics/methods guidance document and next steps towards achieving standardization in studies, how much constitutes "enough" information, significant gaps in the current knowledge base and how to fill them, promising ideas, and concerns or areas that need more work. A list of research topics and "things to learn/work on" was generated at the conclusion of the Carmel meeting and distributed to all participants for prioritization. A list of participants and meeting agenda are included as Appendices to these Proceedings.

The NAWPPM IV Proceedings were edited by Susan Savitt Schwartz, under contract to RESOLVE, Inc., which facilitated the Meeting for the NWCC.

SITE STUDIES: WHAT ARE WE OBSERVING AT EXISTING SITES?

The first session of the fourth National Wind Power Planning Meeting took place during the morning of the first day, and consisted of six presentations on completed and ongoing research at existing wind sites in the United States.

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Thelander, Carl G. and L. Rugge: *Examining Relationships between Bird Risk Behaviors and Fatalities at the Altamont Wind Resource Area: a Second Year Progress Report.*

Hunt, W.G.: *Continuing Studies of Golden Eagles at Altamont Pass* [abstract and discussion summary only]

Hoover, Stacia, C.G. Thelander, and L. Rugge: *Response of Raptors to Prey Distribution and Topographical Features at Altamont Pass Wind Resource Area, California*

Smallwood, K. Shawn, L. Rugge, S. Hoover, M.L. Morrison, and C.G. Thelander: *Intra- and Inter-Turbine String Comparison of Fatalities to Animal Burrow Densities at Altamont Pass*

Other Site Studies

Strickland, Dale, G. Johnson, W.P. Erickson, and K. Kronner: *Avian Studies at Wind Plants Located at Buffalo Ridge, Minnesota*

Anderson, Richard: *Avian Monitoring and Risk Assessment at Tehachapi Pass and San Gorgonio Pass Wind Resource Areas, California* [abstract and discussion summary only]

Ugoretz, Steve: *Biological Studies of Wind Turbine Installations in Wisconsin*

Examining Relationships between Bird Risk Behaviors and Fatalities at the Altamont Wind Resource Area: a Second Year's Progress Report

by

Carl G. Thelander and Lourdes Rugge

BioResource Consultants[1]

Introduction

In March 1998, NREL initiated a research project to address a complex problem involving both wind energy development and wildlife conservation. Since about 1989, several research efforts in the Altamont Wind Resource Area (AWRA) have revealed large numbers of bird fatalities, especially among raptor species (Orloff and Flannery 1992, 1996, Howell 1997, Howell and DiDonato 1991). Researchers studying interactions between birds and turbines in the AWRA have for the most part attempted to locate bird fatalities and to calculate mortality rates.

Compared to other wind energy facilities, bird mortality is relatively high in the AWRA. For some species, this impact may have a significant effect on their regional populations. For example, recent studies show that Golden Eagles nest in extraordinary numbers throughout California's central Coast Ranges, a region that includes the AWRA. Also, numerous individuals pass through the area each year during the fall and winter months (Hunt 1994, 1997).

Several approaches are being considered as possible solutions to the bird mortality problem. These include modifying existing turbines to improve their safety and creating new turbine designs with characteristics that minimize bird fatalities. For the environmental effects of these turbine modifications to be correctly interpreted, we need to estimate two fundamental and independent parameters. These are bird fatalities and bird utilization, both of which are necessary to conduct a risk analysis. By quantifying risk, it may be possible to determine the effects of any facility's modifications, or the effects of siting new facilities. In the case of modifying existing turbine facilities, a risk analysis approach can help determine if any observed reductions in bird deaths are due to decreased risk, decreased utilization, or both.

This paper summarizes the preliminary results of 24 months of field work (March 1998 - February 2000) designed to assess risk to birds at selected turbines in the Altamont WRA. A comprehensive report on this research, which will be available via the Department of Energy's website (www.doe.gov/bridge), is scheduled for mid 2001.

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Objectives

In the present study, we are attempting to quantify bird utilization and bird deaths in order to estimate risk. Our basic approach is to observe, quantify, and interpret bird flight and perching behaviors in and around wind turbines, and to relate these behavioral (utilization) data to bird fatalities at these same turbines over the same time period. The objectives are: (1) to relate bird flight and perching behaviors to risk; and (2) to identify any relationships between bird flight and perching behaviors, and turbine type, weather, topography, habitat features and other factors that may predict high degrees of risk to birds.

Study Area

Altamont Pass is located approximately 90 km east of San Francisco, California. This is a relatively arid interior portion of the greater San Francisco Bay region. To the east of Altamont Pass are generally treeless foothills comprised mainly of annual grasslands. Hilltop elevations range from 230-470 m above the sea level. The lower valley elevations range from 78-188 m above the sea level (Howell 1997). The primary land use in the Altamont Hills is livestock grazing and dry farming.

In the AWRA, approximately 5,400 turbines are distributed over approximately 150 km^2. Generally, turbines are arranged in groups under common ownership. At least 13 different companies manage the energy produced in the AWRA . Six main turbine/tower types are installed in the AWRA: lattice horizontal, lattice diagonal, guyed pipe, tubular, and vertical axis. Some of the lattice diagonal and horizontal lattice towers are arranged in wind-wall configurations. One windwall design is made up of a row of 60-foot horizontal lattice towers and a row of 140-foot diagonal lattice towers located immediately downwind and spaced between the 60-foot towers. The rest of the towers in our study area are arranged in strings, or rows of towers, placed 30-35 meters apart. These range in height from 12-60 m, with rotor diameters as large as 44 m. Their outputs range from 40 to 750 kilowatts.

Methods

Our study design includes two fundamental field research tasks. Each requires a distinctly different set of methods and data collection procedures. The first task is characterizing and quantifying behavioral observations of birds in selected study plots. The second task is conducting intensive searches for dead birds in those same study plots.

We designed the behavioral observation methods to maximize the number of bird observations within each of the study plots. We used fatality search protocols that maximized the likelihood of discovering dead birds. The methods used follow the guidelines described in Anderson et al. (1996).

Bird Risk Behavior. We began by establishing a standardized sampling protocol, designing field data collection forms, and selecting our study plots. We designed the field studies to detect individual birds within the study plots and to characterize their specific activities. Each of these elements was tested in the field and refined as necessary before formal data collection began. The protocol developed for the present study follows the guidelines developed by Morrison (1996), Anderson et al. (1996), and Gauthreaux (1996).

We began the study by establishing 17 study plots containing 514 turbines. In February 1999, we increased this sample to 20 plots, for a new total of 685 turbines where we had access to conduct fatality searches and behavioral observations. Actually, the 20 sampling plots contain 785 turbines of six different types: Tubular/Bonus 150 (n = 100); Tubular/Bonus 120 (n = 220); Tubular/Danwin 110 (n = 25); Vertical Axis 250 (n = 20); Vertical Axis 150 (n = 120); and, Diagonal Lattice 100 (n = 200). We were unable to incorporate 76 horizontal lattice turbines and 24 Mycon-65 turbines on tubular towers into our fatality searches. Overall, our turbine/tower sample represents approximately 12% of the total turbine population in the AWRA.

Each study plot is irregularly shaped and their area varies, with the average being approximately 1600 m^2. The 785 turbines are arranged in 109 different strings. A turbine string is defined as a group, or row, of adjacent turbines separated from other turbines by more that 200 m or by some prominent geographic feature. In our plots, each string length varies from 2-18 turbines. We selected each of the study plots in a manner that would ensure that all of the turbine types, turbine string lengths, turbine sites, and general topography present were adequately represented in the total sample. We spaced the plots to minimize the likelihood of overlap between observations.

Each study plot has one observation point that is used consistently. The observer has the best view of the turbines and the surrounding terrain within any study plot from this fixed location. All turbines, and all corners of the plot, are easily viewed from this observation point to ensure accuracy for species identification and documentation of each bird activity.

One observer per observation point collects field data. The observer proceeds to collect observational data using a technique of circular visual scans (360°) known as variable-distance circular point observations (Reynolds et al. 1980). Each sampling event lasts 30 minutes. The observer records data entering alpha-numeric codes onto a standardized data sheet, and onto a map of the corresponding plot that shows all turbines in the plot and their identification numbers.

Once a bird is sighted, it is tracked continuously from the time it enters the plot until it departs. Each of its movements around the turbines is noted and recorded. The focus of the behavioral observations is to determine how close to a turbine each raptor flies, especially to the zone of risk (i.e., rotational width of a turbine's blades). The estimation of the closest pass to the zone of risk is critical to our study design; therefore, we frequently calibrate each observer's estimates of height and distance using known objects.

Each bird's "utilization duration" is defined as the length of time it is observed within the plot during a 30-minute observation event. The first level of discrimination is whether the bird is flying or perching. If a bird is observed flying only briefly, the minimum duration is one minute, even if the bird(s) departed in less than one minute. After the observation period is over, the observer moves to the next sampling plot to complete another 30-minute interval.

Field biologists conduct observations throughout the year and under all weather conditions. We have observed each of the study plots at least once every week. Each behavioral session takes approximately one hour to complete, including driving time. As many as eight observation sessions can be conducted per observer per day. We vary the order of sampling to ensure that all turbines are sampled equally during differing times and environmental conditions.

Observer bias. To reduce the effects of observer bias, we began the field studies by conducting observations using pairs of observers. This helped to calibrate any potential differences between observers, and for all observers to become familiar with the data sheets and the various bird behaviors. Once the observers' methods and observation skills were standardized, we began conducting separate observations. This calibration process is repeated once per month by conducting paired observations, comparing the observations, and adjusting any differences.

Prey availability. Understanding raptor prey availability often provides insights into understanding raptor flight activity, flight behavior, and their distribution. For purposes of this study, we record a prey availability measurement during each of the behavioral observations. Before the start and at the end of each observation period, we conduct a 360^0 visual scan of the study plot to count all visible ground squirrels and other small mammals. This information is not intended to yield an absolute count of the prey available to raptors; instead, it provides prey location data and an estimate of the relative prey availability at the time of the observations.

Bird Fatalities. The 685 turbines where behavior data are collected are also searched for bird fatalities. Since most of the turbines included in the present study are arranged in strings, they are most efficiently searched by walking a strip along both sides and around the ends. The resulting path, therefore, is best described as a tight zigzag pattern along the turbine string.

Two biologists search each turbine string simultaneously. At the beginning of each turbine string, the biologists walk parallel to the string some 50 m away from the first turbine. The two then walk in opposite directions from one another and perpendicular to the turbine string. Both biologists walk toward and away from the turbine string until the last turbine is reached.

We record all dead birds (or bird parts) found during each search within a 50 m radius of the turbine. Any evidence of a fatality we find is carefully examined to determine the species involved and the probable cause of death. We estimate the length of time the animal has been dead. We record the general condition of the carcass, the presence/absence of maggots, if the carcass is complete or dismembered, the types of injuries evident, whether scavenging is evident, and the distance to the nearest turbine.

Scavenging Activities. Failing to recognize and account for any effects of scavenging may result in an under estimation of the number of dead birds. Orloff and Flannery (1992) reported little evidence of raptor carcass removal by scavengers during their research at the AWRA. We are conducting carcass removal investigations to determine scavenging rates.

Each bird carcass we find at turbines operated by Enron is left in the field. The exact location is recorded and flagged. We then visit each carcass location at least every three days, or until the proper authorities collect the carcass. During the time the carcass is in the field, we record data on the condition of the carcass, amounts of decomposition over time, and any evidence of scavenging. This information will help us not only to evaluate the effectiveness of the frequency of our searches, but also to better estimate the approximate time of death for those carcasses we find with unknown dates of death. At non-Enron turbines, carcasses are left in the field, but they are reported to authorized representatives who usually remove the birds soon after we report them.

Preliminary Findings

The findings presented in this progress report are preliminary. For a comprehensive analysis of this study's results, please refer to Thelander and Rugge (2000) and a biannual report to NREL that is scheduled for May-June 2001.

Bird Risk Behavior. As of 1 January 2000 (21 months) we have completed 2,850 sampling events (i.e., 30-minute point counts). We have recorded some 4,500 individual bird sightings representing a minimum of 51 species; 60% (n = 2,700) were raptors and 40% (n = 1,800) were non-raptors. The five most frequently observed bird species during the behavioral sessions were: red-tailed hawk (n = 1,666 observations, 37%), followed by common raven (n = 720, 16%), turkey vulture (n = 694, 15%), American kestrel (n = 416, 9%) and golden eagle (n = 413, 9%).

We recorded flight-related behaviors more frequently than we did perching behaviors. To date, 80% (n = 3,600) of our observations are of birds flying within the study plots, while 20% (n = 900) of the sightings were birds observed perching. A total of 1,431 perching events were recorded, including multiple perching events for individual birds.

Turbines are the most commonly used perching structure in our study plots. For raptors (n = 915 perching observations, 64%), turbine towers were recorded in 36% of the perching observations, followed by 31% on power poles, 28% on anemometer towers, and 5% on fence posts and other landscape features such as on the ground or on rocks. For non-raptor species (n = 516 perching observations, 36%) turbine towers were recorded in 52% of the observations, followed by 30% on electrical poles, 12% on anemometer towers, and 6% on fence posts and other landscape features.

Fatality Searches. We found 314 dead birds, plus three bat fatalities, between 4 April 1998 and 28 February 2000. This is an overall rate of 0.23 fatalities/turbine/year in our study plots. Of these, 285 (90%) are fresh carcasses, 20 (6%) are the remains of raptors that clearly had been killed long before our studies began, and 12 (4%) are injured or retrieved birds. Overall, raptors represent 54% (n = 168) of all fatalities. Non-raptor bird species represent 46% (n = 146) of all fatalities. Of the 297 fresh fatalities plus injured/retrieved birds, 259 (87%) were confirmed collisions with turbines (256 birds plus 3 bats). Eleven (4%) were suspected to be the remains of predation and unrelated to turbine kills. Five (2%) were suspected electrocutions. Three (1%) were birds killed striking wires. Nineteen (6%) did not have an apparent cause of death, though we continue to investigate the circumstances surrounding some of these.

Of the 259 confirmed collisions, 139 (54%) were raptors; 117 (45%) were non-raptorial birds and 3 (1%) were bats (Table 1). Red-tailed hawks are killed most frequently, representing 29% (n= 74) of these fatalities. Based on the number of turbines in our plots, fatality rates are 0.19 collisions/turbine/year overall, and 0.10 raptor collisions/turbine/year.

TABLE 1. Frequency of bird and bat species (n = 259) killed between March 1998-February 1999 at 685 turbine towers in the Altamont Wind Resource Area.

Species	**# Killed**	**# Sightings**
Red-tailed Hawk *Buteo jamaicensis*	74	1,240
Rock Dove *Columba livia*	45	120
Western Meadowlark *Sturnella neglecta*	29	41
Burrowing Owl *Athene cunicularia*	26	24
Barn Owl *Tyto alba*	17	0
American Kestrel *Falco sparverius*	13	255
European Starling *Sturnus vulgaris*	11	37
Horned Lark *Eremophilia alpestris*	10	20
Golden Eagle *Aquila chrysaetos*	5	348
Mallard *Anas platyrhynchos*	5	25
Hoary Bat *Lasiurus cinereus*	3	0
Cliff Swallow *Hirundo pyrrhonota*	3	30
House Finch *Carpodacus mexicanus*	3	15
Brewer's Blackbird *Euphagus cyanocephalus*	3	203
Passerine *spp.*	2	98
Northern Harrier *Circus cyaneus*	2	95
California Gull *Larus californicus*	2	440
Red-winged Blackbird *Agelaius phoeniceus*	1	30
Loggerhead Shrike *Lanius ludovicianus*	1	57
Prairie Falcon *Falco mexicanus*	1	55
Violet-green Swallow *Tachycineta thalassina*	1	10
Great Horned Owl *Bubo virginianus*	1	0
Mourning Dove *Zenaida macroura*	1	5
Turkey Vulture *Cathartes aura*	0	722
Common Raven *Corvus corax*	0	630
Totals:	**259**	**4,500**

Fatality rates differed between the various turbine/tower configurations. We found 150 of the dead birds (93 raptors, 57 non-raptors) where collisions were confirmed near tubular tower turbines. This represents a fatality rate of 0.22 collisions/tubular tower turbine/year, or 0.13 raptor collisions/tubular tower turbine/year. We found 75 dead birds associated with diagonal lattice towers. This represents fatality rates of 0.11 collisions/diagonal lattice tower turbine/year, or 0.04 raptor collisions/diagonal lattice turbine/year. We found 31 dead birds near vertical axis turbines. This represents fatality rates of 0.19 collisions/vertical axis turbine/year, or 0.09 raptor collisions/vertical axis turbine/year.

Several factors such as slope, topography, and proximity to prey species may contribute to the varying fatality rates observed per turbine/tower configuration. We will address the relative importance of these additional factors in our upcoming report to NREL.

Forty dead raptors were found near turbines located at the end of a turbine string. Twenty-seven raptors were found at the second or third tower from the end of a string. In addition, 10 dead raptors were found within strings but where gaps of greater than 35 m occur between turbine towers. A preliminary assessment of these data appears to indicate that there is no significant difference in the rate of kills at end turbines compared to other turbines in the strings. However, where gaps occur, it appears that the rate of kills goes up significantly. This hypothesis will be tested using appropriate statistical treatments in our upcoming report.

Discussion

Raptors represent a majority of all recorded bird fatalities in the AWRA (Orloff and Flannery 1992, 1996; Howell 1997; Howell and DiDonato 1991). Howell and DiDonato (1991) reported 17 raptor fatalities and calculated a mortality rate of 0.05 deaths/turbine/year. In a subsequent study, Howell (1997) identified 72 confirmed fatalities over 18 months in the AWRA. Bird fatalities consisted of 44 raptors and 28 non-raptors, with a mean raptor mortality rate of 0.03 bird/turbine/year. Orloff and Flannery (1992) reported raptor species accounting for 119 (65%) of 182 dead birds they found. In their 1996 study, raptor mortality varied from 0.02 to 0.05 deaths/turbine/year.

In the present study, fatality data collected to date indicates that fatalities occur at rates greater in the study plots we have sampled than has been previously reported. We believe that this difference may be primarily the result of more intensive and systematic searching for dead birds in selected study plots. If this is the case, the actual fatality rate for raptors in the Altamont WRA has probably been under estimated. The environmental consequences of this under estimating have yet to be determined.

In Orloff and Flannery (1992) and (1996), the predominant species killed were red-tailed hawks (*Buteo jamaicensis*), American kestrels (*Falco sparverius*), and Golden Eagles. They also reported turkey vultures (*Cathartes aura*), various owl species, and common ravens (*Corvus corax*). This is similar to our results. In the former studies, the relative abundance of the five most common species being struck by wind turbines was disproportionate to their frequency of fatality. Golden Eagles, red-tailed hawks, and American kestrels were killed more frequently than were turkey vultures and common ravens, although the latter two species are more abundant in the AWRA. Our data confirm that the relative abundance of species does not predict the relative frequency of fatalities per species. Some species are apparently more susceptible than others to the risks posed by wind turbines.

Some researchers suggest that turbines placed near gullies and the turbines that are at the ends of strings pose a higher risk to birds (Hunt 1994, Orloff and Flannery 1996, 1992). As one might expect, turbines with the highest operating times are more likely to be involved in bird fatalities (Orloff and Flannery 1996). The latter observation also relates to the time of year, since wind turbine operation varies from month to month. Our findings indicate that, at least in our study plots, there may be no significant difference between the frequency of fatalities associated with turbines at the ends of turbine strings and that occurring within the turbine strings. Unique features such as gaps greater than 35 m may result in some behaviors that result in increased fatalities.

Orloff and Flannery (1992) suggest that birds use certain turbine types as perches more often than other available perches. This potentially increases the chances of turbine-related fatalities because of the bird's frequent proximity to the blades. In their comparative analysis of mortality between five turbine types (i.e. lattice towers, horizontal cross, vertical axis, guyed pipe and tubular), Orloff and Flannery (op.cit.) concluded that bird mortality was significantly higher at horizontal lattice tower turbines than at any other type. To date, our findings are not consistent with their conclusion since we have found similar (higher) mortality in study plots where horizontal lattice tower turbines are absent.

A relatively large number of bird species (and individuals) are represented in our fatality data. The species diversity highlights the fact that a wide spectrum of flight and perching behaviors occur near wind turbines. For example, we recorded 26 burrowing owl fatalities. This species is declining rapidly over much of its range, and it spends much of its time on or near the ground. In contrast, one prairie falcon was killed. This is a highly aerial predator that is seen relatively infrequently in the study area, though it nests in the general Altamont Pass region.

With so many species involved, each employing very different flight strategies, the underlying risk factors associated with wind turbines appear to vary greatly from species to species. Finding universal management solutions that will address the many bird species and flight strategies present in the Altamont WRA, and in other WRAs, continues to be perplexing conservation objective.

Acknowledgments

This project is funded through a contract between BioResource Consultants and the National Renewable Energy Laboratory (Karin Sinclair, NREL Project Manager). Michael L. Morrison, Ph.D. has provided valuable insights and guidance in all phases of the project. Field biologists who have participated include: Lourdes Rugge (Field Team Leader), Stacia Hoover, James Cain, Cherilyn Burton, Julia Camp, Angelique Harbin, Erin Harrington, Tammy Lim, Jessie Quinn, Shawn Smallwood, Ph.D., Danika Tsao, and Elizabeth van Mantgen. We especially thank AIC, ENRON, FORAS, and Altamont Wind Power for providing access to the wind facilities they own and/or operate.

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General Discussion

Most of the questions following this presentation related to the methods and metrics used. Some of these questions have been answered in the final paper as presented in these Proceedings; e.g., a standard deviation is given for the results, which were drawn from a large sample size and are therefore fairly robust.

Attendees focused on the fact that 100% of fatalities were associated with 25% of the turbines, and were associated with gaps in turbine strings. Given that a "gap" implies a space between turbines, what determined to which of the two turbines the fatality was assigned? In all cases, fatalities were assigned to the nearest turbine; it was then noted whether or not that turbine was located at a gap in the string. As to why fatalities tended to be associated with turbines located at gaps, C. Thelander speculated that "the appearance of an opportunity to go through rather than over" may draw raptors towards gaps. However, this is only a guess.

Other questions concerned methodology. How was time since death determined? How does the incidence of scavenging affect the measurement of fatalities? Observers do a monthly "sweep," so the freshness of the carcass can be gauged since the time of the previous sweep. There are categories for estimating the age of a carcass on the ground. The incidence of scavenging appears to be low. Asked whether researchers were planting birds and measuring their loss, C. Thelander replied that they were not.

Does the use of circular plot surveys add potential for observer bias? Does the presence of observers appear to affect the behavior of birds in the air? C. Thelander pointed out that observers do take steps to minimize observer impact, including flushing an area before making observations, staying low and relatively motionless, avoiding the color red. Observer impact does not appear to be a big factor overall, though some species tend to stay further away than others.

Continuing Studies of Golden Eagles at Altamont Pass

by

Grainger Hunt, Ph.D.[1]

Predatory Bird Research Group, University of California, Santa Cruz

Abstract

The Predatory Bird Research Group, University of California, Santa Cruz, has been conducting a field investigation of the ecology of Golden Eagles (*Aquila chrysaietos*) in the vicinity of the Altamont Pass Wind Resource Area since 1994. The main purpose of the study has been to assess the effects of turbine blade strike casualties on the eagle population of the region. Capture rates of eagles for radio-tagging since fall 1998 show decline in the numbers of nonbreeding eagles residing in the study area and a marked change in age ratios favoring the younger age categories. Both these observations are consistent with predictions of decline as reported at our last meeting. The breeding segment remains intact. Of 92 fatalities detected by means of radio-telemetry in the study area, 37 (40%) have resulted from turbine blade strikes. An additional eagle within our sample was killed at the Solano wind facility outside the study area. We continue to monitor the eagles and are assessing the distribution of blade strike fatalities within the WRA in relation to the distribution of other features.

[*Editor's note: Dr. Hunt did not submit a written paper for this Proceedings.*]

General Discussion

During the question and answer discussion took place following the presentations of G. Hunt, S. Hoover, and K.S. Smallwood, G. Hunt noted that encroachment on surrounding Golden Eagle habitat may make Altamont that much more important as habitat for this species. Hunt emphasized the importance of intensive observation around the turbines of the sort that Thelander and Rugge are conducting. Noting that there was no significant difference in the kill rate for lattice vs. non-lattice towers, Hunt added that there are a "rat's nest" of complex factors at play here; answers to these questions will not be simple, and it is important that researchers collaborate to tease out answers.

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Response of Raptors to Prey Distribution and Topographical Features at Altamont Pass Wind Resource Area, California

by

Stacia Hoover[1], Michael Morrison, Carl Thelander, Lourdes Rugge

BioResource Consultants

Introduction

Studies have shown that birds flying through the Altamont Wind Resource Area (WRA) are being killed by collisions with wind turbines. Raptors appear to be affected more than other types of birds. Golden eagle (*Aquila chrysaetos*), red-tailed hawk (*Buteo jamaicensis*), and American kestrel (*Falco sparverius*) fatalities are much higher than predicted from their abundance in the area (Orloff and Flannery 1992). One hypothesis for this result is that the specific foraging behavior and flight characteristics of these species make them more susceptible to accidental death (Orloff and Flannery 1992, Musters et al. 1996, Howell 1997, Hunt 1997). Therefore, more detailed knowledge of raptor behavior and habitat use of the wind resource area is essential. Elucidating what characteristics attract raptors disproportionately to some areas over others will provide information necessary in decreasing raptor mortality.

Two variables likely to be primary influences on raptor foraging activity are topography and prey. Raptors may be attracted to the relatively large ground squirrel (*Spermophilus beecheyi*) population that has most likely been accommodated by decades of cattle grazing as the primary form of land use. If prey occurs in discrete sites or clumps within the Altamont WRA there may be a correlation between the degree of raptor activity and prey activity in those areas.

However, although prey is undoubtedly important, a raptor may chose to hunt in an area with a relatively smaller food base because it contains topographical elements that make foraging more efficient. Raptors are well known for being adept manipulators of wind currents. They soar frequently by using thermals for lift and they exploit updrafts and declivity winds (the winds deflected off hills) when thermals are few (Dunne et al. 1988). Altamont Pass has a diversity of topographic relief and the weather often includes high winds. This may attract foraging raptors that manipulate the wind currents created by the sloping hillsides. Therefore, aspects of the topography and weather are likely to be variables in habitat selection by raptors foraging in this region.

Objectives

The goal of the present study is to determine the relative contributions of prey and topographical features in explaining raptor behavior and distribution within the Altamont Pass

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WRA. The specific objectives are to: (1) determine the relationship between relative ground squirrel abundance and raptor flight behavior; (2) determine whether topographical features, such as slope aspect, slope elevation, and slope inclination, are used randomly by foraging raptors; and, to (3) explore the relationship between raptor flight behavior and weather factors such as wind velocity, wind direction, ambient temperature, and cloudiness.

This report is intended solely as a progress report. It includes a brief summary of some of the findings extracted from the data to this point. Statistical analysis is not yet complete and so these findings should be considered preliminary and subject to revision.

Methods

The study site covers about 8 km^2 in the region of Altamont Pass Road and Interstate 580. It consists of 15 plots each roughly 0.25 km^2. Each plot was divided into distinct areas or slopes, and the aspect, elevation, and average inclination were measured. Sampling began April 1999 and ended June 2000.

Active squirrel burrow entrance counts. Active burrow entrances were counted and mapped to obtain a relative index of squirrel activity comparable between areas. Parallel transects separated by 20 meters were walked for each slope within a plot and the approximate location of every active burrow entrance was recorded onto an enlarged topographical map. Burrow entrances were determined to be in active use by squirrels based on well-used squirrel pathways, fresh droppings, claw marks, fresh dug dirt mounds, or the observation of a squirrel entering or leaving hole. Squirrel activity for all areas was defined as the number of active burrow entrances per hectare. Each plot was sampled once every three months to detect seasonal changes.

Behavioral observations. Thirty-minute behavioral observations were conducted using an instantaneous sampling rule. At 1.5-minute intervals the observer scanned the plot with 8x40 binoculars and recorded the following data on the location and behavior of raptors within the plot: type of flight, distance from ground, distance from turbine, and the slope where the raptor was sighted. Data on wind direction wind speed, ambient temperature, and cloud cover were recorded at the onset of the recording session. Each plot was observed once a week throughout a full year so as to sample during all seasons.

Preliminary Results

Raptor observations. By far the most common species observed during the study was the red-tailed hawk, which comprised 76% of the total raptor sightings (Table 1). The American kestrel made up 9% of the total sightings. Golden eagles and turkey vultures made up 5% each, and the northern harrier 3%. The season showing peak raptor activity was fall, during which time 59% of the sightings were made. This high activity spilled into the winter season, which accounted for 23% of the year's total raptor activity.

TABLE 1. Summary of raptor sightings after 693 observation sessions for 15 study plots in the Altamont WRA.

Species	Summer 1999	Fall 1999	Winter 1999	Spring 2000	Total
Red-tailed hawk ***Buteo jamaicensis***	531	5,037	1,755	565	7,888
American kestrel ***Falco sparverius***	62	482	299	49	892
Turkey vulture ***Cathartes aura***	170	225	74	86	555
Golden eagle ***Aquila chrysaetos***	55	133	195	133	516
Northern harrier ***Circus cyaneus***	16	239	60	7	322
Burrowing owl ***Athene cunicularia***				114	114
Prairie falcon ***Falco mexicanus***	44	2	1	3	50
Ferruginous hawk *Buteo regalis*		9	19		28
Rough-legged hawk ***Buteo lagopus***			8		8
Black shouldered kite ***Elanus caeruleus***		2	1		3
Total for season	**878**	**6,129**	**2,412**	**957**	**10,376**

There is strong indication that flight behavior and habitat requirements differ significantly among raptor species, thus it would be inappropriate to classify all species behavior data together as “raptor” behavior. Since the red-tailed hawk was the most common species observed within the Altamont Pass WRA, the following summaries are for their activity alone. Other raptor species will be analyzed individually at a later date.

Active burrow entrances and red-tailed hawk activity. In using active entrances as an index of abundance we made the assumption that more burrow openings equates to more burrow residents. At this early stage in the analysis, there is not a strong pattern relating squirrel abundance to red-tailed hawk activity. If raptors are attracted to regions within the WRA that contain dense patches of squirrels, then we would expect to see a disproportionate amount of raptor foraging activity in regions of high squirrel burrow density.

As can be seen in Table 2, red-tailed hawks were seen flying in areas with the lowest squirrel activity 21% of the time. Since 33% of the total sampled area fell into this density category, this may be an indication of avoidance of those areas. However, there appeared to be avoidance of the regions with the highest squirrel density as well. Red-tailed hawk activity was less than expected in areas with more than 375 burrow entrances/hectare. The regions that showed greatest hawk activity were those representing the middle density of squirrel burrows

(151-225/hectare). Statistical analysis of the data still is required; for example, seasonal variation of red-tailed hawk presence has not yet been correlated with seasonal variation in squirrel density. Thus these summaries should be considered preliminary. Nevertheless, these findings support the notion that squirrel activity is not the sole driving force for red-tailed hawk activity and distribution.

TABLE 2. Summary of active burrow density and Red-tailed hawk flight activity.

Mean # active burrow entrances/ hectare	% of total flight activity	% of total sample area	% difference
0-75	21	33	-12
76-150	17	11	6
151-225	30	12	18
226-300	2	6	-4
301-375	6	5	1
>375	25	31	-6

Weather factors, topography, and red-tailed hawk activity. A strong pattern is evident relating red-tailed hawk behavior to slope aspect and weather factors, most notably, wind direction and wind velocity. During strong winds, 19-38 mph, red-tailed hawks were more likely to be in flight over slopes that faced the direction of the wind – yet they perched on slopes opposite the wind (Figure 1).

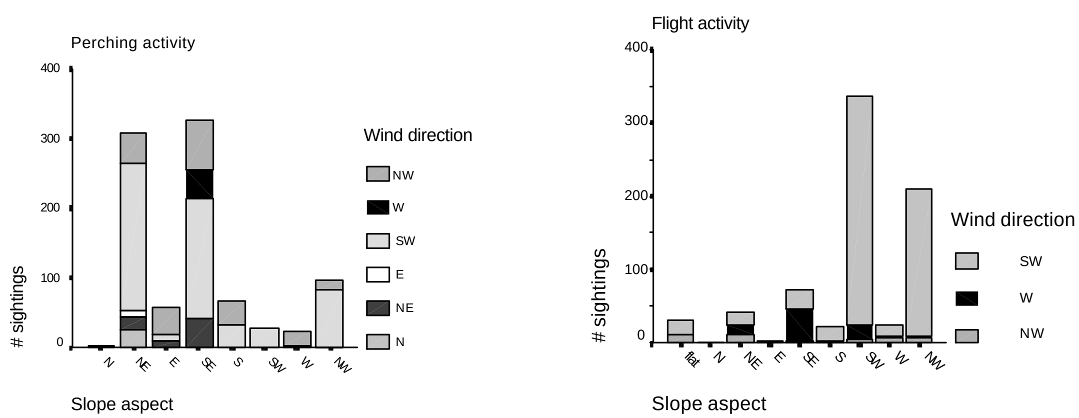

FIGURE 1. Effect of slope aspect and wind direction on Red-tailed hawk behavior in high winds (19-38mph)

Although the reason for this result is not yet clear, we made some field observations that offer a possible explanation. During very strong winds, red-tailed hawks often used kiting flight behavior if the temperatures were warm enough. This type of flight is performed when a strong declivity wind is generated off of a ridge or slope facing the direction of the wind. The strong updrafts allow them to hang suspended in flight like a kite. This behavior allows a bird to stay in one place while scanning for prey and is conceivably a very energy efficient form of foraging. In colder temperatures, however, there seemed to be far less flight activity – especially kiting behavior. The strong winds at Altamont Pass can reach up to 38 mph; this drops the temperature significantly due to the wind chill factor. It may be that in these cold conditions the hawks choose slopes on which to perch where they are protected from the wind. A second explanation may be that the birds, for whatever reason, need to perch regardless of temperature. In these near gale winds, perching on structures or on the ground is difficult because of the physical force of the blowing winds, and so they choose perch sites out of the wind. Further analysis of these issues will be informative. There is some indication that red-tailed hawks choose different perching structures depending on the wind speed. They tend to perch on the ground more at high winds but at low wind speeds they more often utilize turbines and power lines (Figure 2).

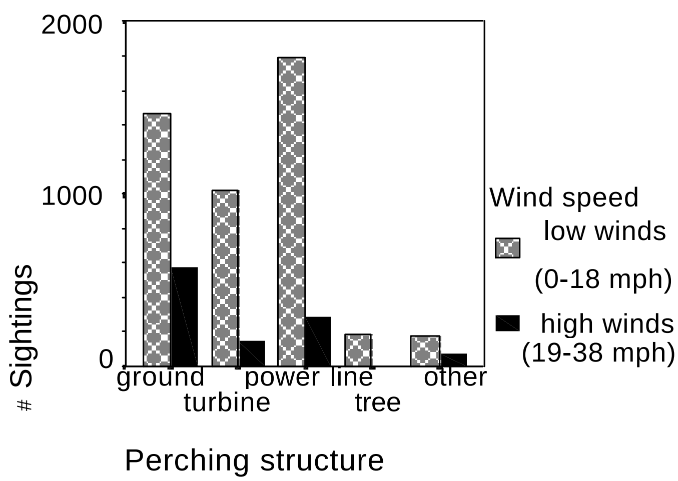

FIGURE 2. Summary of perching structures used in different wind conditions.

Discussion of Findings

Although the findings contained in this report are preliminary, they suggest that there are a number of environmental factors influencing red-tail hawk flight activity and distribution. Other raptors are most likely influenced in a similar manner. It is improbable that a single prey species, such as the California ground squirrel, would have an absolute effect on raptor activity. However, prey base is undoubtedly a contributing factor at some level.

Optimal foraging theory predicts that animals should maximize their net rate of energy intake. They can optimize that rate in two ways; by foraging in areas with an abundant prey base or by foraging in ways that reduces their energy expenditure. Raptors are adept manipulators of wind currents. The combination of weather factors such as wind speed, wind direction, and ambient temperature, combined with topographical features such as slope aspect, elevation and inclination, produce an array of scenarios to a foraging raptor. It is easy to imagine how the decision to forage in a particular spot would depend on prey abundance, topography, and weather.

This study seeks to shed light on the factors that influence raptor flight activity and fatalities. Analyzing such variables as prey abundance, topography, and weather may help us to develop predictive models of raptor behavior and mortality and thus to determine strategies for reducing raptor-turbine collisions. For example, steep slopes with available prey may be particularly attractive to red-tailed hawks in warm, strong winds if the aspect of the slope faces the wind direction. During these conditions the turbines on slopes that fit this model could be turned off or painted with bird-deterring visual cues.

Acknowledgements

This project is funded by the National Renewable Energy Laboratory (NREL) under the management of Karin Sinclair.

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General Discussion

Asked to clarify, Ms. Hoover explained that what observers noted was “kiting” activity, in which “strong updrafts allow [the birds] to hang suspended in flight like a kite” Researchers believe this kiting activity is an energy-efficient way for the birds to scan for prey, and is hence interpreted as foraging behavior.

Intra- and Inter-turbine String Comparison of Fatalities to Animal Burrow Densities at Altamont Pass

by

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Lourdes Rugge, Stacia Hoover, Michael L. Morrison, Carl Thelander
BioResource Consultants[2]

Abstract

Raptors, particularly Red-tailed Hawks (*Buteo jamaicensis*) and Golden Eagles (*Aquila chrysaietos*), appear to be involved in a disproportionate number of wind turbine collisions when compared to the number and type of birds in the Altamont Wind Resource Area. One hypothesis for this result is that the specific foraging behavior and flight characteristics of these species make them more vulnerable to accidental death. Altamont Pass has relatively large populations of ground squirrel (*Spermophilus beecheyi*) and pocket gopher (*Thomomys bottae*), which are prey species for Golden Eagles and Red-tailed Hawks. Both of these prey species possibly have been accommodated by decades of cattle-grazing in the Altamont area. Thus, raptors in the Altamont area may be susceptible to fatal collisions due to their preoccupation with squirrel and gopher activity.

For this study, we used a real-time differential Global Positioning System (GPS) to map the locations of burrow systems of ground squirrels and pocket gophers in the vicinity of 98 tubular and diagonal lattice wind turbines composing nine turbine strings at Altamont Pass. We mapped these burrows at increasingly greater distances from the turbine strings. The regression slope coefficient of burrow density regressed on distance from the turbine string was used as an index of contagion of gophers and ground squirrels around wind turbines. Unlike ground squirrels, pocket gophers appear to be attracted to the strings of wind turbines. *The number of dead hawks at turbine strings increased with increasing contagion of gophers and ground squirrels at turbine strings. Gophers clustered at every turbine string, but ground squirrels did not.* Gophers may be attracted to wind turbines due to the vertical and lateral edges created by the maintenance areas for the wind turbines. Vertical and lateral edges are created by cutting into the slopes for access roads and for placing the turbine base platforms on level ground. Raptors, attracted by gopher mounds in the turbine strings, may be hunting gophers or their commensal associates when they lose sight of the turbine blades and get struck. However, our results are preliminary, and therefore not conclusive.

Introduction

The fatalities of raptorial birds at wind turbines have been attributed to various factors, including the occurrence of prey species in the vicinity of the wind turbines. At Altamont Pass, the principal species of interest appears to have been California ground squirrels

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(*Spermophilus beecheyi*) (Hunt et al. 1998). However, pocket gophers (*Thomomys bottae*) are abundant at Altamont Pass on both sides of Altamont Pass Road, whereas ground squirrels are abundant only on the north side. Because many raptorial birds have been killed on the south side of Altamont Pass Road, we suspected that ground squirrels might not be the species of principal interest among raptorial birds. Also, previous experience has led us to believe that pocket gophers are important prey of raptorial birds, and that gopher burrow systems serve as habitat for various other prey species of raptorial birds. For example, black-tailed jackrabbits (*Lepus californicus*) spend much of their time among the soil mounds excavated by pocket gophers in alfalfa stands (Smallwood and Geng 1993). Raptorial birds spend a disproportionate fraction of their flight time directly over pocket gopher burrow systems, where Smallwood (unpubl. data) has observed raptors capturing pocket gophers, voles, snakes, and black-tailed jackrabbits. Therefore, we decided to map the locations of pocket gopher and ground squirrel burrows in and around some strings of wind turbines.

Our objectives for this study were to compare the fatality rate of raptorial birds to the densities and degree of contagion of burrow systems actively used by potential prey species around individual turbines and turbine strings. The results that follow are preliminary, and therefore not conclusive. Our sample sizes were too small to lend much confidence to the results. The major shortfall in the data is the small sample of fatalities relative to the number of turbines included in our burrow mapping effort. Field work through 2000 could sufficiently increase the sample size of fatalities, which would add considerable confidence to the results of a more thorough mapping effort. This paper is intended to raise the issue and to present preliminary results.

Methods

We mapped burrows in the vicinity of 98 wind turbines composing nine turbine strings at Altamont Pass (e.g., Figs. 1 and 2). One string of 38 diagonal lattice turbines was operated by Enron on the south side of Altamont Pass Road. Eight strings (60 tubular turbines) were operated by EnXco (formerly FORAS) on the north side of Altamont Pass Road. Some of these strings were chosen by Rugge, who attempted to maximize the disparity in number of fatalities between strings. Others were chosen opportunistically by Smallwood.

The approximate centers of pocket gopher and ground squirrel burrows were mapped using a GPS (Trimble Pathfinder Pro-XR). These burrow systems were located based on fresh signs, such as freshly excavated soil or scats at the burrow entrance. Even though the boundaries of most individual pocket gopher and ground squirrel burrow systems were easily recognized, a pacing method (Smallwood and Erickson 1995) was used to arbitrarily separate burrows when continuity of sign rendered inter-burrow distinctions difficult. This pacing method has been worked out for pocket gophers, but not for ground squirrels, so the maps made of ground squirrel burrows are still preliminary. Burrows of cottontails and Burrowing Owls (*Athena cunicularia*) were mapped as they were encountered. These burrows also were identified by scats at the burrow entrance, and only the centers of burrow clusters were mapped using the GPS.

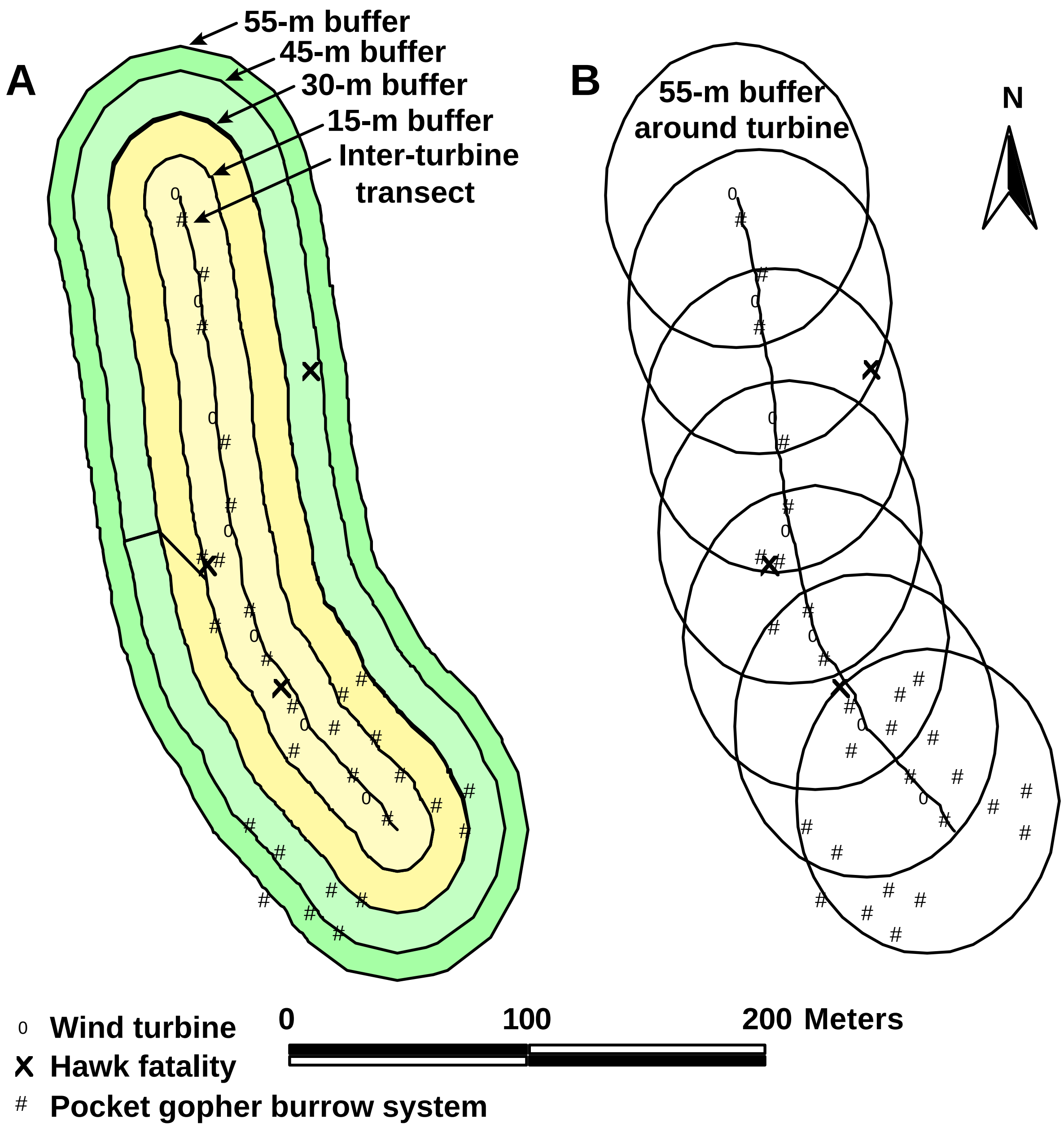

FIGURE 1. The density of pocket gopher burrow systems was calculated within each search area identified by the buffers expanding away from the inter-turbine transect (A) and within 55 m of each turbine (B). The same approach was used for burrow systems of ground squirrels, cottontails, and Burrowing Owls, which did not occur at Turbine String 9, shown here. Note that the gopher burrow systems are most strongly clustered near the wind turbines, and there is an additional cluster extending to the southwest of the turbine string.

At each turbine string included in our sample, the search pattern for burrows began in the string of turbines. A 7.5 m-wide strip transect was walked from 15 m beyond the turbine at one end of the string to 15 m beyond the turbine at the other end. Then perimeter transects were walked at 15 m, 30 m, and 45 m away from the turbine string, thus covering increasingly larger rectangular areas around the turbine string (Fig. 1A). A laser range-finder was used to maintain the intended distances away from the turbines while searching along perimeter transects. Densities of gopher and ground squirrel burrow systems were estimated within each of the corresponding buffers that were bounded by the outer search area of each transect. Using least squares linear regression, densities of burrow systems were then regressed on the corresponding buffer areas and the steepness of the regression slope used as an indicator of the contagion relative to the location of each turbine string. Also, the density of burrows within 55 m of each turbine was estimated and compared to fatality rates of raptors (Fig. 1B).

Using the GPS software, we also measured the distance of each burrow within 55 m of each turbine, and we counted the burrows of each species occurring within 55 m of each turbine (e.g., Fig. 1B). These counts were then aggregated as 0, 1 to 2, and $\geq$ 3 burrows. Also, Red-tailed Hawk fatalities were classified as either 0 or $\geq$1, and were associated with each turbine.

Because the turbine position in the string has been suspected of influencing fatality rates among avian species (Thelander and Rugge 2000), we also tested whether fatality rates were associated with the position in the string. We classified the turbines as positioned in the interior of the string, adjacent to the edge, at the edge of a gap in the string (i.e., an inter-turbine spacing that is greater than the spacing among the other turbines in the string), and at the edge of the string. These positions were compared to the locations of fatalities to test whether there might be an influence of turbine position on fatality rate. This test (χ^2 test) was limited to the 98 turbines composing the nine turbine strings used in this study.

Results

Usually, pocket gophers clustered within close proximity to the wind turbines, whereas ground squirrels established colonies farther away from the turbines (see Fig. 2).

Turbine string gaps, edges and interiors

Considering all bird fatalities together, and classifying their associations with turbines as either 0 fatalities or $\geq$1 fatality, more than the expected number of fatalities associated with turbines at the edges of gaps and turbine strings, and fewer than the expected number occurred in the interiors (χ^2 = 11.75, df = 3, P < 0.05). However, Red-tailed Hawk fatalities did not associate significantly with turbine position (χ^2 = 2.255, df = 6, P = 0.895; fatalities classified as 0, 1, and 2). Golden eagle fatalities were too few to test for a relationship statistically.

Intra-string comparison

Red-tailed Hawk fatalities tended to occur at turbines with 1 to 2 gopher burrows more often than expected by chance, and less often at turbines without gopher burrows within 55 m (χ^2 = 5.28, df = 2, P = 0.07). However, Red-tailed Hawk fatalities did not relate significantly to the occurrence of ground squirrel burrows at turbines (χ^2 = 2.88, df = 2, P = 0.24).

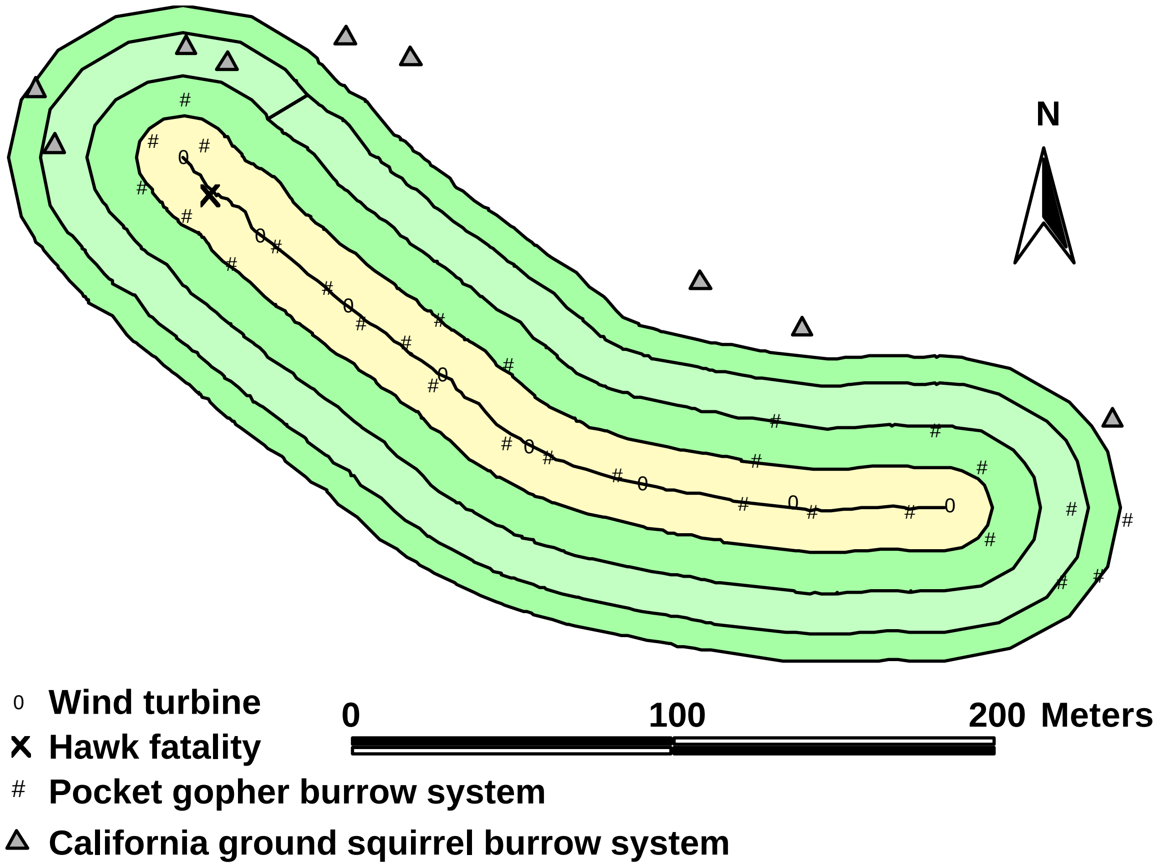

Figure 2. Gopher burrow systems were clustered within turbine string 3, whereas ground squirrel burrows were farther away (the largest portion of the colony was located north of this map, beyond the search area).

Golden eagle fatalities occurred more often than expected by chance at turbines with $\geq$ 3 ground squirrel burrows within 55 m ($\chi^2 = 7.72$, df = 2, P = 0.05), although half of the contingency table's expected cell values were less than 5, a condition requiring cautious interpretation of the test result. Burrowing Owl fatalities also occurred more often than expected at turbines with $\geq$ 3 ground squirrel burrows within 55 m ($\chi^2 = 13.35$, df = 2, P = 0.0001). Burrowing Owl fatalities occurred at the two turbines with the greatest numbers of Burrowing Owl burrows within 55 m (six and seven burrows, respectively, no statistical test performed). Golden eagle and Burrowing Owl fatalities did not correlate significantly with the density of pocket gopher burrow systems around turbine strings.

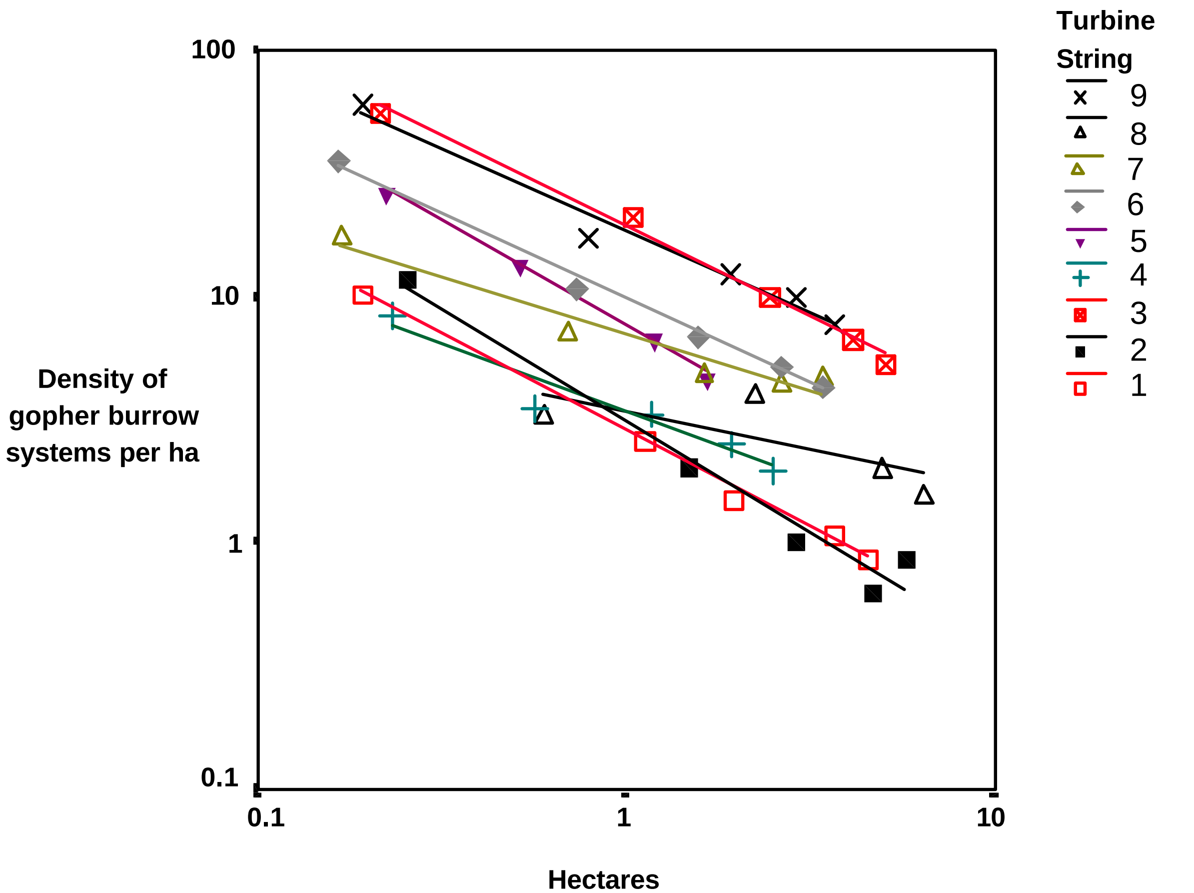

FIGURE 3. Gopher burrow density displays an inverse power relationship to the search area surrounding each turbine string.

Inter-string comparison

At the inter-string level of analysis, pocket gopher density consistently decreased as larger areas were searched around each turbine string (Fig. 3). All turbine strings demonstrated a relationship between gopher burrow density and study area size that was similar to the pattern reported by Smallwood and Morrison (1999). Steeper regression slopes indicated greater clustering of gopher burrow systems in the immediate vicinity of the turbines. Ground squirrel burrows did not occur within 55 m of four of the nine turbine strings, and ground squirrel burrow density increased as larger areas were searched at another turbine string (Fig. 4). At yet another string, the slope of -1 between log ground squirrel burrow density and study area size was determined by only one burrow, which occurred along the interior transect. Dividing a constant number (1 in this case) by a variable area forces a slope of -1.

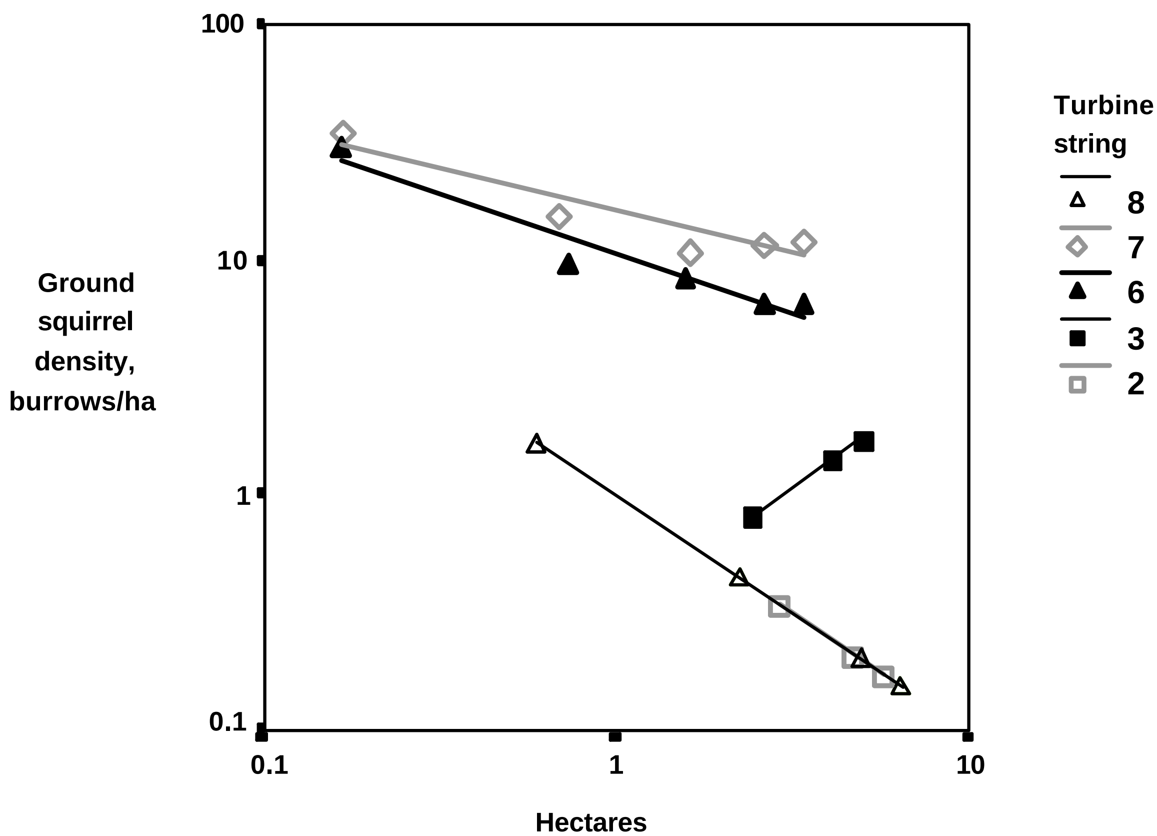

FIGURE 4. Ground squirrel burrow density displays two well-founded inverse power relationships to the search area surrounding the turbine string, but two others are based on one burrow system and ground squirrels were absent at the other four turbine strings.

As was the case for pocket gophers, the density of all species' burrow systems declined as larger areas around the turbine strings were included in the search effort (Fig. 5). This multi-species pattern was likely driven by the pocket gopher patterns, as many fossorial species take advantage of the burrows that are abandoned by gophers. Indeed, many gopher burrows were found in the vicinity of the 98 turbines that lacked ground squirrel burrows, but most ground squirrel burrows occurred in the vicinity of turbines that also had gopher burrows.

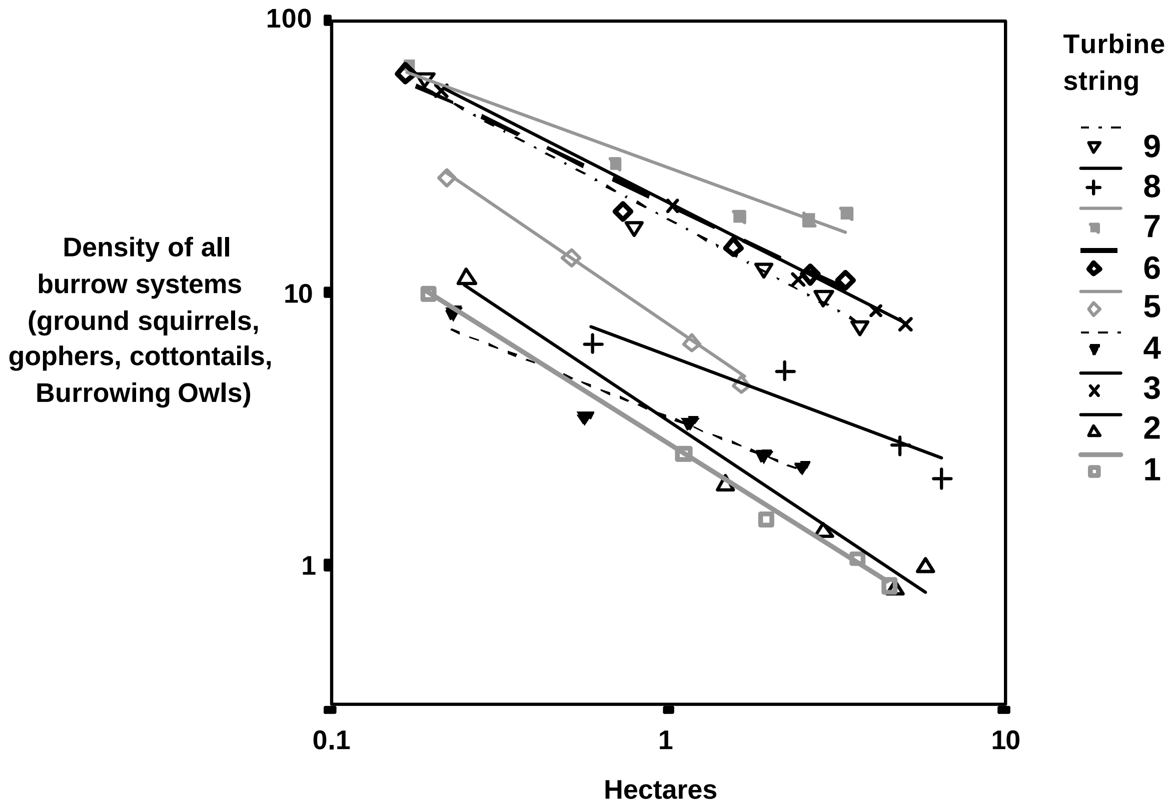

FIGURE 5. The density of all animal burrow systems displays an inverse power relationship to the search areas surrounding each turbine string, but is likely driven mostly by the clustering of gophers around the turbines.

Except for the turbine string at Enron, the number of Red-tailed Hawk fatalities per turbine string increased with an increasing slope of log gopher burrow density regressed on log study area size (Fig. 6):

Hawk fatalities = - 3.68 - 7.01 Regression slope coefficient

r^2 = 0.58, Root MSE = 0.97, df = 1, 7, $P < 0.05$ (not including Enron string).

The number of fatalities did not correlate significantly with the intercept of log gopher burrow density regressed on log study area size, nor did it correlate with the overall density of gopher burrows within the areas searched, nor with the maximum density recorded within the interior 7.5 m strip transect.

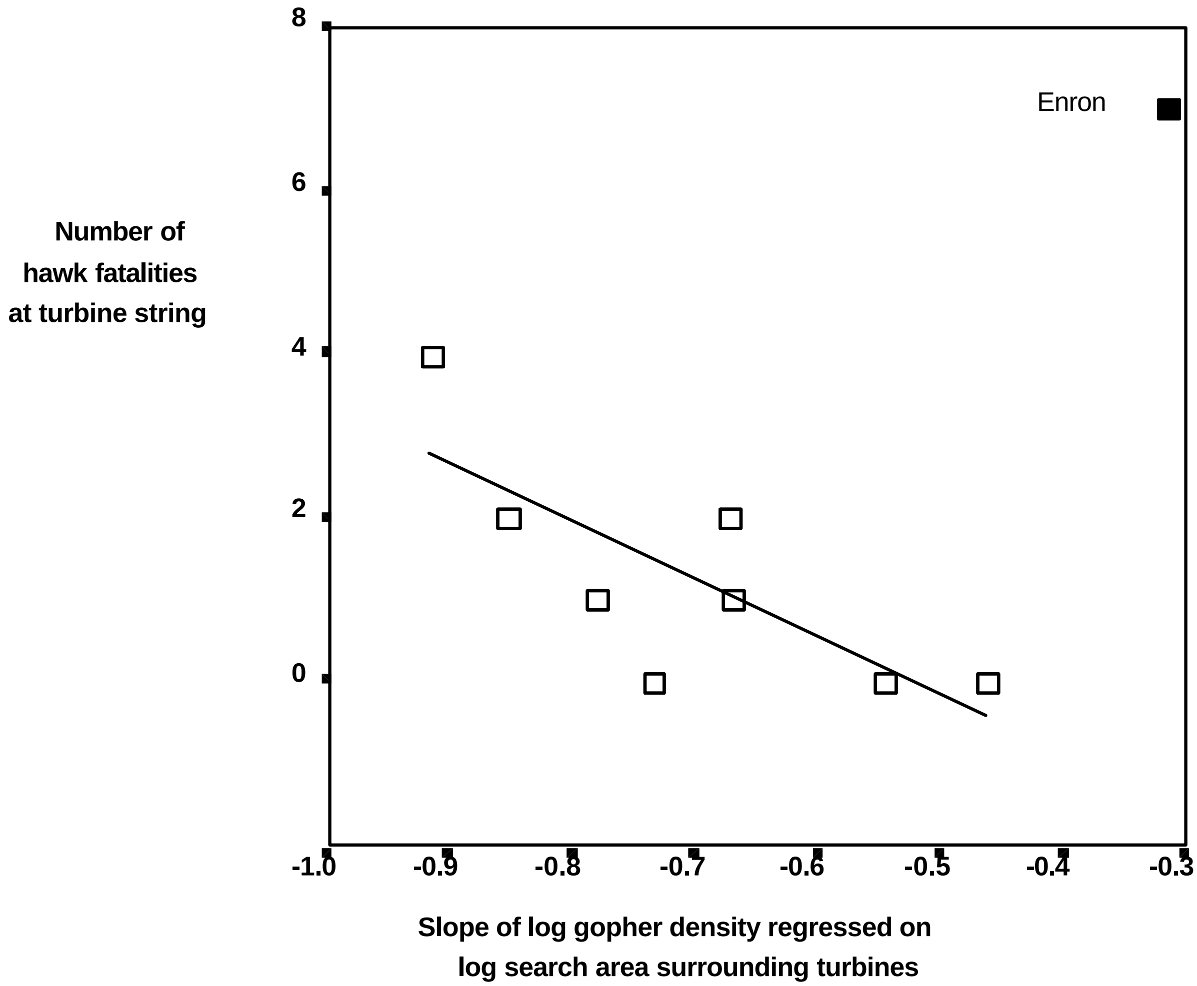

FIGURE 6. The number of hawk fatalities decreased with shallower slopes of log density of gopher burrow systems regressed on log study area size.

The turbine string at Enron, south of Altamont Pass Road, had accumulated the largest number of Red-tailed Hawk fatalities, even though it only had one ground squirrel burrow, and the larger area of the Enron operations had very few additional ground squirrel burrows on the premises. Of the remaining EnXco tubular turbine strings with ground squirrel burrows, the number of Red-tailed Hawk fatalities did not correlate significantly with the regression slope of log ground squirrel burrow density and log study area size (Fig. 7):

Hawk fatalities = 1.510 - 2.476 Regression slope coefficient

$r^2 = 0.48$, Root MSE = 2.54, df = 1,4, P = 0.20.

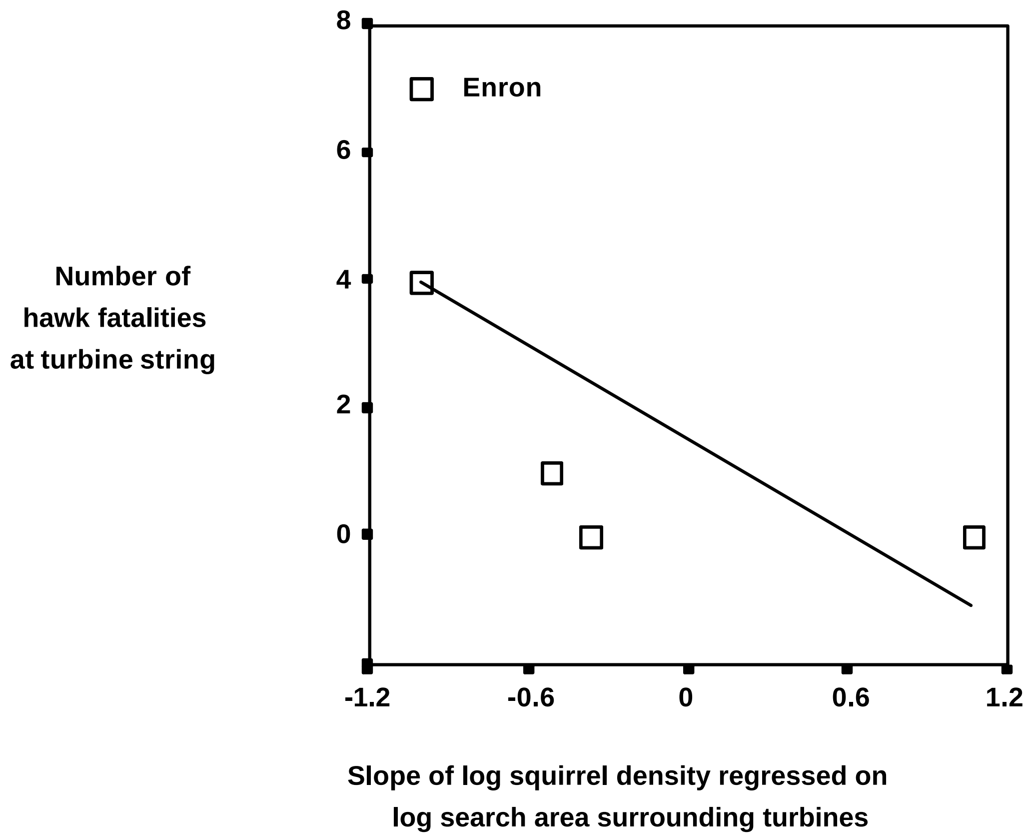

FIGURE 7. The number of hawk fatalities also decreased with shallower slopes of log density of ground squirrel burrow systems regressed on log study area size, although the regression was not statistically significant.

Discussion

Our results suggest that the occurrence of pocket gophers might be associated with the fatalities of many raptorial birds, especially Red-tailed Hawks, in the vicinity of wind turbines. They suggest that Golden Eagles may be attracted to ground squirrel burrows, and that Burrowing Owls are more likely to get killed by turbines where ground squirrels reside nearby turbines or where many Burrowing Owl burrows are found to be in the vicinity of wind turbines. We hypothesize that raptorial birds lose sight of the turbines while they focus on prey in the vicinity of gopher mounds, thereby increasing the chance they will be struck and fatally injured by the turbine. Rugge and Hoover have often observed Red-tailed Hawks kiting parallel to the turbine blades, and looking down in what appears to be hunting behavior (unpubl. data). The burrow systems of pocket gophers are clustered under the wind turbines, and may be the subject of the kiting behavior and frequent hunting of raptorial birds within short distances of the wind turbines.

Pocket gophers appear to be attracted to strings of wind turbines. We hypothesize that they are attracted to wind turbines due to the vertical and lateral edges created by the maintenance areas for the wind turbines (see Smallwood et al. 1998). Vertical and lateral edges are created by cutting into the slopes for access roads and for placing the turbine base platforms on level ground (Fig. 8). These edges appear to occur at greater densities on steeper slopes, because more slope engineering is necessary for turbines occurring on steeper slopes. However, some clusters of pocket gopher burrows also appeared to be spatially unrelated to the vertical and lateral edges created for turbine maintenance.

FIGURE 8. Rugge points to recently excavated pocket gopher mounds on the cut slope surrounding the maintenance area of a wind turbine. Gopher burrow systems appeared to be more numerous around turbines with more vertical and lateral edges (e.g., cut slopes, road cuts, turbine platforms).

Using the slope of log density of burrow systems regressed on log search area was more predictive than relying on density of burrow systems alone. We expected this difference because a hawk encountering a string of turbines will not likely compare gopher burrow density there to burrow densities elsewhere. Such a comparison would be difficult for all turbine strings occurring within the hunting territories of neighboring conspecifics, and it would be less productive than comparing the burrow densities more locally in the immediate vicinity of the hawk. Steeper negative slopes indicate much higher burrow densities in the immediate vicinity of wind turbines, and indicate the direction the hawks are likely to take while hunting the local area.

These regression slopes are estimated relative to local conditions, but are comparable among strings. For example, the entire search area around turbine string 2 had < 1 gopher burrow systems per ha, whereas the search area around turbine string 7 had > 4 gopher burrow systems per ha (Table 1). However, the lower-density turbine string 2 had a stronger clustering of burrow systems near the turbines, and four hawks were killed there. Hawks hunting the turbine string with < 1 gophers/ha were likely drawn in towards the turbine string because most of the gophers were immediately adjacent to the turbines. Hawks hunting the turbine string with > 4 gophers/ha need not have been drawn in towards the turbine string because there were more gophers in the outer buffers. The pattern of burrow systems around the turbines may be more important that the absolute number of burrow systems.

TABLE 1. Example of hawk fatalities being more frequent at a turbine string with greater clustering of burrow systems, but lower densities of burrow systems.

	Turbine string 2		**Turbine string 7**	
Burrow density	Pocket gophers	Ground squirrels	Pocket gophers	Ground squirrels
Within 7.5 m	11.73	0	17.54	35.09
Within 15 m	2.03	0	7.14	15.71
Within 30 m	1.03	0.34	4.90	11.02
Within 45 m	0.63	0.21	4.50	11.99
Within 55 m	0.86	0.17	4.68	12.27
Regression slope	-0.91	-1.00	-0.46	-0.37
Number of dead hawks	4		0	

Table 1 also exemplifies the stronger relationships between hawk fatalities and the distribution of gopher burrow systems as compared to the distribution of ground squirrel burrow systems. For example, turbine string 7 had many more ground squirrel burrows than did string 2, but string 7 was associated with no fatalities. However, these preliminary data will require follow-up research to confirm or reject these patterns.

This difference in distribution between gophers and ground squirrels around turbine strings may also affect Golden Eagle hunting patterns. The excavated soil mounds of both ground squirrels and gophers may help camouflage black-tailed jackrabbits and cottontails, which we often have observed in the vicinity of these burrow systems. However, ground squirrels are highly vigilant for avian predators (Tromborg 1999) and alarm call when a predator approaches. Upon hearing the alarm calls, jackrabbits and cottontails have open ground squirrel burrows available into which they can readily escape. At gopher burrow systems, jackrabbits and cottontails lack both alarm calls and open burrows useful for escape. It is possible that Golden Eagles hunt gopher burrow systems because jackrabbits and cottontails are more vulnerable there. Directed field observations of escape behaviors of jackrabbits and cottontails will be needed to determine whether these species are more vulnerable in the vicinity of pocket gopher burrow systems as compared to ground squirrel colonies.

Management Implications

If we can substantiate through additional research that pocket gophers are attracted to wind turbine platforms, then solutions can be found to discourage gophers from residing so close to turbines. Van Vuren and Smallwood (1995) describe a variety of non-abatement methods for discouraging mammals from occupying certain parts of managed landscapes. For example, grazing intensities could be reduced with fencing up to 60 m around the turbines, thereby increasing the average vegetation height. Both pocket gophers and ground squirrels generally prefer low-stature vegetation. Another approach might be to cultivate yellow-star thistle (*Centaurea solstitalis*) in the vicinity of the wind turbines, because Smallwood (unpubl. data) recently found that old-growth stands of yellow star-thistle are nearly devoid of pocket gophers and ground squirrels. Another approach might be to cultivate some other type of vegetation that is less conducive to supporting gophers, or to lay down an impervious surface such as crushed rock over these areas. Another approach may be to avoid placing turbines on steep slopes requiring road cuts, which create extra vertical and lateral edges preferred by gophers.

Also, small mammal abatement efforts by ranchers might exacerbate the clustering of gopher burrows at preferred locations, which happen to be turbine strings at Altamont Pass due to increased vertical and lateral edge road cuts and turbine platforms. In a large-scale gopher abatement study in forest clearcuts, Smallwood (1999) found that gophers quickly repopulated clearcuts in which gophers had been abated successfully with strychnine. In some of these clearcuts, the presumably subadult immigrants lived for several months at higher densities and with greater burrow excavation activity than did the resident gophers in untreated control plots. In alfalfa stands subjected to strychnine treatments and flood irrigation, immigrant gophers first occupied the field edge (Smallwood and Geng 1997), and apparent gopher clustering at the field edge declined with increasing density in the field (Smallwood 2001). Clusters of ground squirrel or gopher burrows within areas of low density might attract the attention of avian predators more so than areas of higher average density. Therefore, raptor foraging at Altamont Pass might be more focused on burrow complexes clustered at turbine strings. A solution may be to cease small mammal abatement efforts.

Acknowledgments

We thank Karin Sinclair and the National Renewable Energy Laboratory for funding support, and we thank the land holders and Enron and EnXco for access to their holdings.

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General Discussion

Asked to talk about gopher dispersal mechanisms, Shawn Smallwood explained that they travel above ground, both day and night. This means that if you do gopher control, it needs to be done in a widespread manner. Smallwood also noted that gophers will get back to an area within a few months after it has been depopulated, especially if there are other gophers nearby. Depopulation efforts sometimes result in a backlash, with population density actually increasing instead of decreasing.

Avian Studies at Wind Plants Located at Buffalo Ridge, Minnesota and Vansycle Ridge, Oregon

by

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Introduction

Buffalo Ridge, Minnesota. In 1994, Northern States Power Company (NSP) initiated a windpower development project that may eventually produce 425 megawatts (MW) of electricity. The first phase (P1) was developed by Kenetech Windpower, Inc. (Kenetech) in 1994 and consists of a 25 megawatt (MW) wind plant comprised of 73 turbines on Buffalo Ridge, Minnesota. The second phase (P2) consists of a 107.25 MW wind plant comprised of 143 turbines. This facility was completed by Enron Corporation in 1998, and is the world's largest single wind farm project. The third phase (P3) consists of a 103.5 MW wind plant comprised of 138 turbines. This facility was completed by Enron in 1999.

Results of a biological reconnaissance of the Buffalo Ridge Wind Resource Area (WRA) conducted prior to windpower development indicated that there was relatively low potential for avian fatalities to occur on this site because Buffalo Ridge was not in a major waterfowl staging area or migration route, and that passerines usually migrate at altitudes above the turbine blades. Radar studies of nocturnal avian migrants also showed that abundance of migrants was relatively lower on Buffalo Ridge than other areas sampled in west-central and southwestern Minnesota. Results of pilot avian monitoring studies conducted by South Dakota State University in 1994 and 1995 following construction of the first wind plant indicated that avian and bat fatalities within the wind development area were relatively low. In 1996, Western EcoSystems Technology (WEST, Inc.) was contracted by Northern States Power Company (NSP) to develop an avian monitoring protocol for the Buffalo Ridge WRA and to implement the protocol beginning with the 1996 field season.

Buffalo Ridge is a 62-mile-long segment of the Bemis Moraine located in Lincoln and Pipestone Counties in southwest Minnesota and Brookings County, South Dakota. Habitats in the study area consist primarily of agricultural crops including corn, soybeans, small grains and hay; pasture; and Conservation Reserve Program (CRP) fields. So far, there are three major phases of wind development within the WRA. In addition to those study sites within the WRA, a permanent reference area not scheduled for windpower development was selected

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along Buffalo Ridge northwest of the WRA in Brookings County, South Dakota.

The primary goal of this study was to evaluate risk to birds from each phase of development and the cumulative risk to birds from all windpower development in the WRA. The secondary goal was to provide information that can be used to reduce the risk to birds from subsequent developments. This monitoring study used the before/after and control/impact (BACI) design for assessing the effects of the P2 and 3 projects and the control/impact design for assessing the effects of P1. The design and analysis used a "weight of evidence" approach to assess effects of the project on species of concern.

Vansycle Ridge, Oregon. In December 1998, FPL Energy completed development of a 24.9 MW wind plant on Vansycle Ridge in Umatilla County, Oregon. The wind plant is comprised of 38 660-kilowatt Vestas turbines and related facilities, including distribution lines, meteorological towers, communications systems, transformers, a substation, roads, and operations and maintenance facilities. The turbines are arranged in two strings, with 28 turbines on String A and 10 on String B. Most of the project area is cultivated for wheat. One turbine block in Area A is grassland. The north edge of several turbine blocks includes approximately 10 m to 12 m of grassland. This edge is primarily non-native grasses which were seeded several years earlier when the strip was registered in the Conservation Reserve Program. Native grassland is found on the slopes to the north of the turbine blocks. This habitat is primarily bunchgrass, cheatgrass and weedy forbs. Area B is approximately half wheat and half grassland. Much of this grassland is disturbed and very weedy.

Carcass searches to locate dead birds and bats were initiated in January, 1999. The objective of the carcass searches was to estimate the number of avian and bat fatalities attributable to wind plant features at the Vansycle Ridge Wind Farm. This report presents results of the first year (1 January to 31 December 1999) of carcass search studies.

Methods

Buffalo Ridge. One hundred meter-radius point count surveys were conducted to estimate species composition, relative abundance, habitat use, flight behavior and relative risk during the period 15 March to 15 November, 1996-1999 at turbine locations and at randomly selected stations within the WRA. Raptor and other large bird (RLB) 0.8-km radius point count surveys were conducted at randomly located points throughout the WRA to estimate the same parameters for these birds. Carcass searches were conducted at turbine locations and at randomly selected plots throughout the WRA to estimate number of avian and bat fatalities attributable to wind turbine collisions for the entire Buffalo Ridge WRA, and to relate the fatalities by species to the relative abundance of each species, turbine characteristics, habitat, and other parameters, to aid in determining relative risk to that species. Found carcasses were corrected for scavenger removal and carcass detection biases. An estimate of the total number of avian and bat fatalities in each phase of the wind development area was made. A complete description of the methods used in the Buffalo Ridge study are presented in Strickland et al. (2000).

Vansycle Ridge. Mortality was measured by estimating the number of bird and bat carcasses in the wind development area whose death could be related to turbines, met towers, or other wind plant features. All avian and bat carcasses located within areas surveyed, regardless of species, were recorded and a cause of death determined, if possible, based on field examination and necropsy results. An estimate of the total number of carcasses was made. The total number of carcasses was estimated by adjusting for "length of stay" (scavenging) and searcher efficiency bias. Generally, the methods used were similar to those for carcass searches at Buffalo Ridge, Minnesota (Strickland et al., 2000). Deviations from the Buffalo Ridge protocol are described below.

Carcass searches were conducted at half the turbines once every two weeks during the study, with all turbines searched each 28-day period. Biologists trained in proper search techniques conducted the searches. Permanent rectangular plots 126 m in width were established on strings of turbines within the wind plant to ensure all areas within 63 m of each turbine were searched. Square or rectangular plots were used instead of circular plots to facilitate marking search boundaries and conducting the search. Transects were initially set at 6 m apart in the area to be searched, and the searcher initially walked at a rate of approximately 45-60 m/min along each transect searching both sides out to 3 m for casualties (Johnson *et al*. 1993). Transect width and search speed were adjusted based on visibility within the various habitats and crop stages. On average, approximately 30 to 60 minutes were spent searching each turbine per search, depending on habitat. Carcasses found while conducting other study activities also were recorded. For all casualties found, data recorded included species, sex and age when possible, date and time collected, location, habitat, condition, and any comments which may indicate time and cause of death.

Results

Buffalo Ridge. We documented 218 species of birds in the Buffalo Ridge study area during the four-year study. Six of the species observed are listed as threatened by the State of Minnesota and/or U.S. Fish and Wildlife Service. Observations consisted of six peregrine falcons, 51 Bald Eagles, three Wilson's phalaropes, 16 loggerhead shrikes, two horned grebes and one common tern. Most of these birds were observed during the spring or fall migration and were likely migrants. Two pairs of loggerhead shrikes were documented breeding in the study area.

During the study, 164 species were identified during sightings of 25,471 groups totaling 70,727 birds while conducting point count surveys on all four study areas on Buffalo Ridge. Avian richness was highest in the summer (1 June - 15 August), followed by spring (15 March - 31 May) and fall (16 August - 15 November), whereas avian abundance was highest in the fall and lowest in the summer. The three most abundant bird groups during the spring period were blackbirds, longspurs, and sparrows. Blackbirds, sparrows and swallows were most abundant in summer, and blackbirds, longspurs, and sparrows were most abundant in fall.

Sixty-two species were identified during sightings of 3,546 groups totaling 20,035 birds while conducting RLB surveys in the Buffalo Ridge study area. Avian richness was highest in the spring, whereas avian abundance was highest in the fall. The three most abundant RLB groups on Buffalo Ridge during the spring were waterfowl, waterbirds, and shorebirds. In summer, the three most abundant groups were raptors, waterbirds, and waterfowl, and in fall, the three most abundant groups were waterbirds, waterfowl and corvids.

Observations were made of 15,247 flying flocks comprised of 55,607 birds during point count surveys on Buffalo Ridge. Mean flight height was lowest for wrens (1.8 m), upland gamebirds (2.3 m) and sparrows (6.0 m). Highest mean flight heights were recorded for waterfowl (46.9 m), waterbirds (44.3 m) and blackbirds (17.2 m). Flight height data were examined separately for the P1 turbines (Turbine A) and P2/P3 turbines (Turbine B) on Buffalo Ridge due to different turbine heights. For Turbine A, 20.1% of flying birds were within the rotor-swept height (19.5-52.5 m), whereas 11.3% were observed flying within the rotor-swept height of Turbine B (26-74 m). Bird groups most often observed flying within the rotor-swept height were waterbirds, waterfowl, longspurs, raptors, and corvids. There were no significant differences in flight height as a function of habitat or presence or absence of turbines.

Observations were made of 3,156 flying flocks comprised of 18,144 birds during RLB surveys on Buffalo Ridge. Mean flight height was highest for waterfowl (73.4 m), followed by waterbirds (36.3 m), raptors (26.6 m), shorebirds (21.5 m) and corvids (13.5 m). Forty-five percent of flying birds were within the rotor-swept height of Turbine A, and 36% were within the rotor-swept height of Turbine B. Bird groups most often observed flying within the rotor-swept height during RLB surveys were shorebirds, waterbirds, raptors and waterfowl. Flight height data collected during daylight hours indicate the larger Turbine B may pose less risk to some groups of birds than the smaller Turbine A (Figure 1).

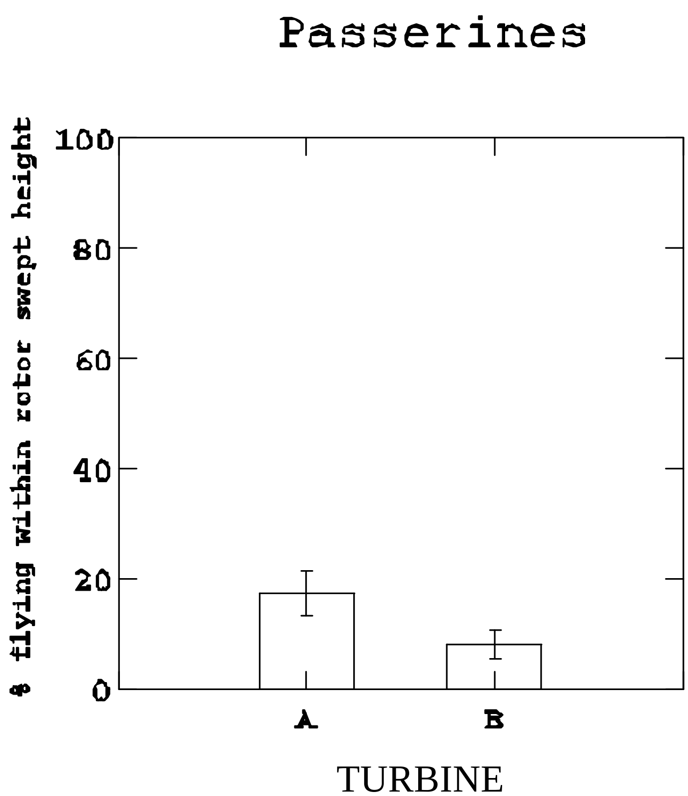

FIGURE 1. Proportion of observations of passerines flying within the rotor swept area of Turbine Type A

and Turbine Type B.

Turbine exposure indices based on mean abundance adjusted for visibility bias, proportion of daily activity budget spent flying, and proportion of flight heights within the rotor-swept height of turbines were calculated for all species observed during surveys. For point count survey data, species with the highest exposure to turbines, depending on season, were lapland longspur, red-winged blackbird, horned lark, cliff swallow, barn swallow, and European starling. Using data collected during RLB surveys, species with the highest exposure index, depending on season, were mallard, Franklin's gull, Canada goose, and double-crested cormorant. This analysis was based on observations of birds during the daylight period and did not take into consideration flight behavior or abundance of nocturnal migrants. This analysis also does not account for differences among species in their ability to detect and avoid turbines, habitat selection, turbine characteristics, and other factors that may influence exposure to turbines; therefore, actual risk may be higher or lower than predicted by this index.

Based on point count survey data, avian relative use over the entire Buffalo Ridge study area was highest in woodland habitat (1,381/km^2), followed by wetland (787), pasture (365), hayfields (351), CRP (256) and croplands (184) (Figure 2). Relative use of woodland and wetland was significantly higher than cropland and CRP; there were no significant differences in use among CRP, pasture, and hayfields. For larger birds recorded during RLB surveys, highest use occurred in wetlands (76.3/km^2), followed by cropfields (10.9), pasture (7.0) and CRP (6.1); however, there were no significant differences in use among habitats. Effects of distance to the nearest wetland and woodland on avian use were modeled using stepwise linear regression. Results of the analysis indicated a significant ($p<0.05$) relationship between avian use and distance to the nearest wetland for waterfowl, upland gamebirds, sparrows and finches. A significant ($p<0.05$) relationship between avian use at the plot and distance to the nearest woodland was found for several groups, including doves, woodpeckers, swallows, blackbirds, wrens, corvids, vireos/warblers, and thrushes.

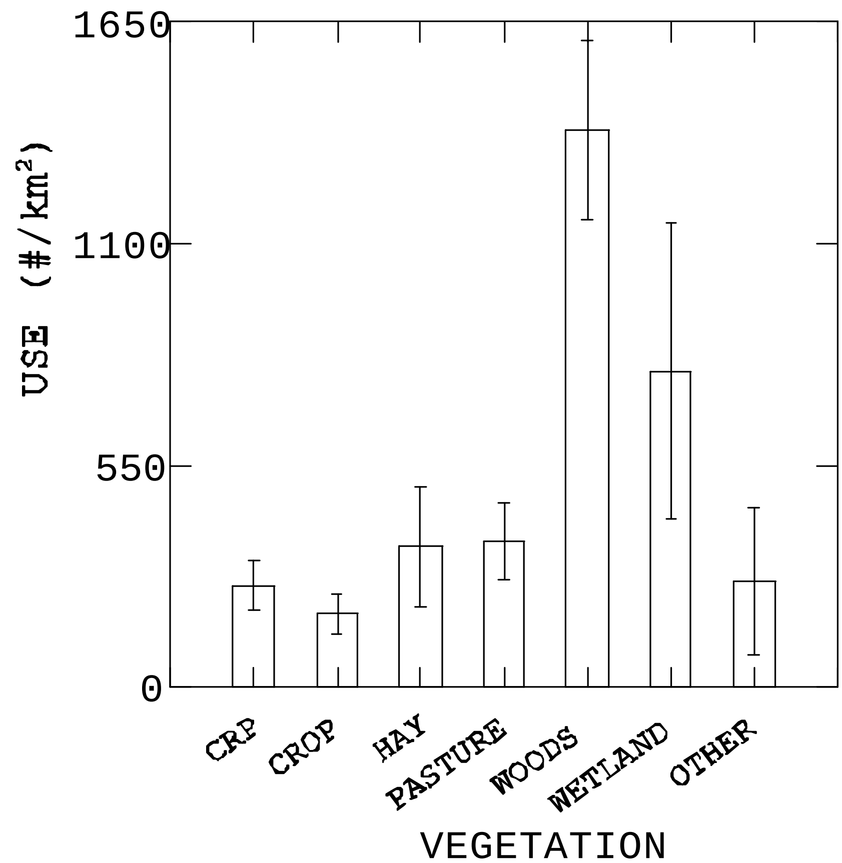

FIGURE 2. Use of the Buffalo Ridge Wind Resource area by major vegetation type.

The BACI analysis of both point count and RLB survey data indicated that use of the wind development areas following construction was lower than expected for several groups of birds. The area of reduced use occurred primarily in close proximity (i.e., $\leq$ 100 m) to turbines; however, the area of reduced use was larger for certain avian groups during some seasons. On a large-scale basis (i.e., within the entire WRA), reduced use by birds associated with wind power development appears to be relatively minor and would not likely have any population consequences on a regional level. A positive effect of reduced avian use around turbines would be reduced potential for collision fatality. Lower avian use where turbines are present may be due to avoidance of turbine noise, maintenance activities, and less available habitat due to the presence of maintenance roads and cleared gravel pads surrounding turbines. Another potential factor in the lowered avian use noted at turbine plots is that turbine noise may reduce observer detection rates of birds, especially those that observers detected by sound only.

During the 4-year study, 5,322 fatality searches were conducted on study plots, 2,482 (46.6%) of which were conducted on plots without turbines to estimate reference fatalities in the study area, and 2,840 (53.4%) of which were conducted on plots associated with operational turbines. Thirty-one avian fatalities comprised of 15 species were found on reference plots during the study period, and 55 avian fatalities comprised of at least 31 species were found associated with operational wind plant features. Avian fatalities associated with turbines were comprised of 76.4% passerines, 9.1% waterfowl, 5.5% waterbirds, 5.5% upland gamebirds, 1.8% raptors and 1.8% shorebirds (Table 1).

A total of 184 bat fatalities were found in 1998 and 1999 within the three wind development areas. All bat fatalities were found associated with turbines and appeared turbine-related. Most bats were tree bats, with hoary bat being the most common fatality (Table 1).

Overall searcher efficiency averaged 38.7%, and mean length of stay for carcasses before being removed or consumed by scavengers was 7.01 days for birds and 10.36 days for bats. Based on the number of turbine-related casualties found per search adjusted for searcher efficiency and scavenger removal rates, total avian fatalities in the P1 wind development area were estimated to average 72 per 8-month field season during the 4-year study. The resulting estimated annual mean fatality rate was 0.98 birds per turbine. In the P2 study area, total avian fatalities were estimated to be 265 in 1998 and 383 in 1999, for a 2-year average of 2.27 fatalities per turbine. In the P3 wind plant, total avian fatalities in 1999 were estimated to be 613, which equates to 4.45 fatalities per turbine.

Total bat fatalities in the P1 study area were estimated to be 19 in 1999 (0.26/turbine). In the P2 study area, total bat fatalities were estimated to be 231 in 1998 and 277 in 1999, which equates to a 2-year average of 1.78 bats killed per turbine in the P2 wind development area per year. The total bat fatality estimate for the P3 wind plant in 1999 was 282 (2.04/turbine).

TABLE 1. Avian and bat fatalities associated with the Buffalo Ridge, Minnesota windpower development.

Year	Phase I Wind plant				Phase II Wind plant				Phase III Wind plant				Reference Area	
	Wind plant Fatalities		Reference Fatalities		Wind plant Fatalities		Reference Fatalities		Wind plant Fatalities		Reference Fatalities		Reference Fatalities	
	Birds	Bats	Birds	Bats	Birds	Bats	Birds	Bats	Birds	Bats	Birds	Bats	Birds	Bats
1996	3	0	2	0	na[a]	na	1	0	na	na	1	0	2	0
1997	3	0	0	0	2[b]	na	7	0	na	na	4	0	4	0
1998	4	2	1	0	6	76	2	0	na	na	1	0	3	0
1999	3	5	0	0	14	57	2	0	20	44	0	0	1	0
Total	13	7	3	0	22	133	12	0	20	44	6	0	10	0

[a] na = not applicable, wind plant became operational in 1998 (Phase II) and 1999 (Phase III)

[b] Two fatalities associated with collisions with meteorological towers, no turbines present in P2 until 1998

For all reference plots combined, mean number of avian fatalities found per study plot per year was 1.10. In the P1 study area, the estimated mean number of bird fatalities per turbine per year was actually lower than the estimated mean number of bird fatalities per reference plot per year. Estimated mean number of avian fatalities per turbine in the P2 study area was approximately 2.1 times that of natural fatalities, and the estimated mean number of avian fatalities per turbine per year in the P3 study area was approximately 4.0 times that of expected natural fatalities in the study area.

Compared to several other wind plants in the U.S., avian fatalities (2/turbine/year) appear to be relatively low on Buffalo Ridge (Table 2). Avian fatalities were most numerous during the fall migration period while bat fatalities were most common during the spring (Figure 3). Our data indicate that wind plant-related avian fatalities on Buffalo Ridge primarily involve nocturnal migrants. Fatalities of resident breeding birds appears very low, involves primarily common species, and would not likely have any population consequences within the Buffalo Ridge WRA. Based on the estimated number of birds that migrate through Buffalo Ridge each year, the number of wind plant-related avian fatalities at Buffalo Ridge is likely inconsequential from a population standpoint. Information on bat abundance, behavior or habitat use at Buffalo Ridge is lacking.

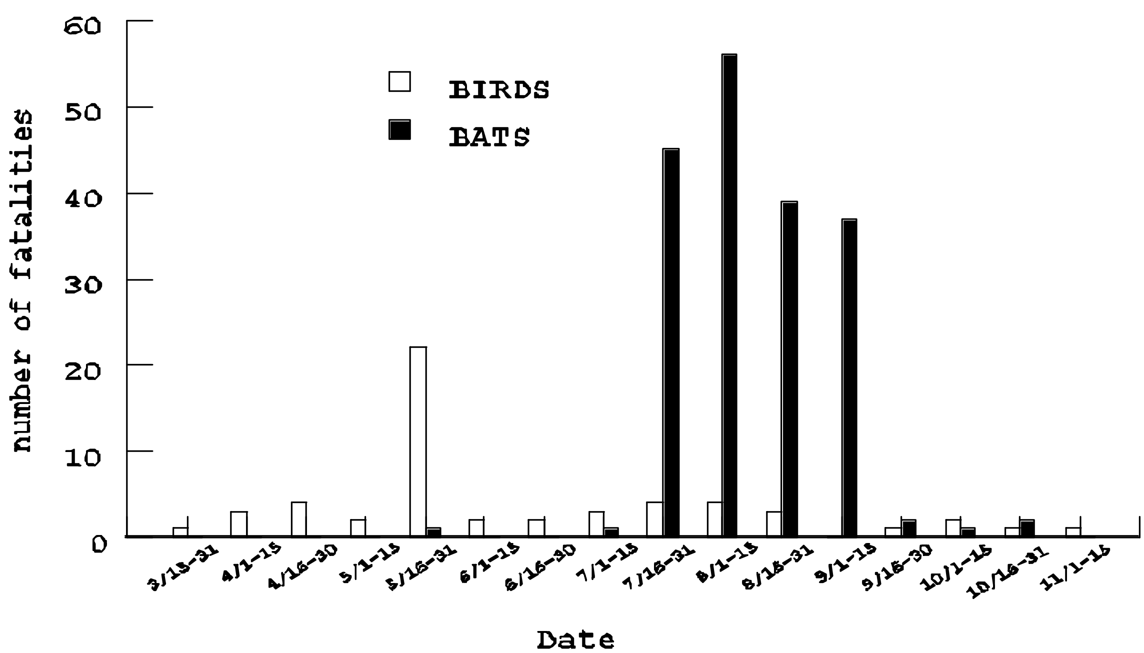

FIGURE 3. The total number of wind power related avian and bat fatalities on Buffalo Ridge, Minnesota by time period.

TABLE 2. Estimates of turbine-related bat mortality for the Buffalo Ridge wind resource area, March through November 1996-1998.

Phase I Study Area				
Year	Total Fatality Estimate	90% Confidence Interval	No. Fatalities per Turbine per Year	90% Confidence Interval
1999	19	4 - 33	0.26	0.06 - 0.46
Phase II Study area				
Year	Total Fatality Estimate	90% Confidence Interval	No. Fatalities per Turbine per Year	90% Confidence Interval
1998	231	172 - 290	1.62	1.21 - 2.03
1999	277	219 - 335	1.94	1.53 - 2.35
1998-1999 Mean	254	213 - 295	1.78	1.61 - 1.95
Phase III Study area				
Year	Total Fatality Estimate	90% Confidence Interval	No. Fatalities per Turbine per Year	90% Confidence Interval
1999	282	199 - 365	2.04	1.46 - 2.62

TABLE 3. Avian and bat fatalities found on the Vansycle Wind Project in 1999.

BIRDS

Species	Date	Habitat	Comments
White-crowned	4-30-99	Grassland	Feather Spot with one half of a wing[a]
White-crowned	5-10-99	Wheat	Intact with fractured skull and wings
White-crowned	5-11-99	Wheat	Scavenged with wing and body feathers
White-throated Swift	7-31-99	Wheat	Scavenged with no obvious signs of
Gray Partridge	8-3-99	Wheat	Feather Spot consisting of two primaries
Lewis' Woodpecker	8-5-99	Grassland	Scavenged, desiccated with fractured
Horned Lark	9-21-99	Grassland	Scavenged with fractured skull, desiccated
Chukar	10-6-99	Grassland	Scavenged, head and neck, legs, wing
Unidentified Sparrow	10-10-99	Grassland	Feather Spot with wing and breast feathers
Gray Partridge	10-21-99	Wheat Stubble	Scavenged
White-crowned	10-22-99	Grassland	Scavenged, primaries missing from one
Unidentified Partridge	11-18-99	Wheat Stubble	Feather Spot

BATS

Species	Date	Habitat	Comments
Hoary Bat	8-23-99	Wheat Stubble	Dismembered, missing wing, body
Hoary Bat	8-24-99	Wheat Stubble	Scavenged, desiccated[a]
Hoary Bat	8-24-99	Wheat Stubble	Scavenged, desiccated
Hoary Bat	8-24-99	Wheat Stubble	Scavenged, desiccated
Little Brown Bat	9-13-99	Wheat Stubble	Scavenged with injuries to leg and
Hoary Bat	9-13-99	Wheat Stubble	Scavenged with no obvious injuries
Silver-haired Bat	9-13-99	Wheat Stubble	Scavenged, desiccated with fractured wing
Unidentified Bat	9-13-99	Wheat Stubble	Intact - reported by maintenance worker B string but not relocated by study
Silver-haired Bat	9-19-99	Wheat Stubble	Intact with fractured wing
Silver-haired Bat	9-21-99	Wheat Stubble	Scavenged with torn wing membranes

[a] these specimens were submitted to the Wyoming State Vet Lab for necropsy

Vansycle Ridge. Twelve avian fatalities were located on the Vansycle wind plant during the first year of carcass searches (Table 3). The 12 avian casualties were comprised of at least six species. Seven (58%) of the casualties found were passerines. The most common passerine found was white-crowned sparrow, with four casualties. With the exception of the Lewis' woodpecker, which is classified as a sensitive species in Oregon, all avian species found appear to be relatively common in the state. Seven of the avian casualties (58%) were scavenged, four (33%) were feather spots, and one (8%) was intact. Ten of the casualties were found during scheduled carcass searches and the remaining two were incidental finds. All carcasses found during the study were used to estimate mean number of carcasses per study plot and total wind plant fatalities. Avian casualties were found from 3 m to 76 m away from turbines, and the mean distance was 37.0 m. Avian casualties were found at 11 of the 38 turbine plots. Only one turbine (A9) had more than one avian casualty (2).

Casualty data indicate that passerine migrants and resident upland gamebirds appear most prone to turbine collisions on Vansycle Ridge. Based on the time period each passerine casualty was found, it is likely that all four white-crowned sparrows and the unidentified sparrow were migrating through the area. The white-throated swift and horned lark were likely summer breeders and the Lewis' woodpecker may have been a migrant or resident breeder. The four partridges are introduced gamebirds that are permanent residents on the study site.

Weather did not appear to be strongly related to avian mortality. Of the 12 bird casualties found during the study, eight were estimated to have been dead for less than one week, which allowed weather at the estimated time of death to be recorded. Six of these likely collided with turbines when weather conditions were mild, one may have collided with a turbine during gusty winds, and one may have collided with a turbine during a rainstorm.

Bat Fatalities

Ten dead bats were found during the first year of carcass searches (Table 3). Species found included hoary bat (5), silver-haired bat (3), and little brown bat (1). Hoary and little brown bats are relatively common in Oregon, but the silver-haired bat is considered a sensitive species in the state. Whereas bird fatalities were found throughout the year, bat casualties were all found during the period from 23 August to 21 September 1999 (Table 3). Five of the bats were found during scheduled carcass searches; the remainder were incidental discoveries. All carcasses found were used to estimate mean number of carcasses found per study plot and total wind plant fatalities. Bats were found at eight of the 38 turbine plots searched. All of the bats were found when weather conditions were mild.

No data on habitat use or behavior of bats in the Vansycle Ridge study area have been collected as part of wind development area monitoring activities. Hoary and silver-haired bats roost in deciduous trees. Little brown bats also roost in trees, but may roost in other habitats including rock crevices, wood piles, buildings and other structures (Clark and Stromberg 1987). Bat roost sites in the project area likely include nearby riparian areas. Hoary and silver-haired bats are migratory species. These bats migrate north in May and June, and begin their southward movement in late August or early September (Fitzgerald *et al*. 1994). The little brown bat spends the winter in hibernacula, and may migrate several hundred miles to hibernate. According to Fitzgerald *et al*. (1994), hoary bats typically forage from treetop level to within a meter of the ground; however, Clark and Stromberg (1987) report that these bats may circle to high altitudes while feeding. Silver-haired bats spend most of their time foraging at heights less than 6 m, and little brown bats generally forage at heights of 1.5 to 6 m near or over water.

Searcher efficiency varied by season, habitat and size class of bird. Searchers detected 50.0% of the small birds and 87.5% of the large birds. For both size classes combined, searcher efficiency ranged from 59.1% in spring to 86.7% in winter. Searcher efficiency was lowest in grassland (56.7%) and highest in wheat stubble (76.0%). The overall searcher efficiency for all size classes, habitats, and seasons combined was 68.2%.

Large carcasses lasted an average of 26.7 days, and small carcasses lasted an average of 23.4 days. Carcasses lasted the longest in the summer (39.8 days), followed by winter (26.5 days), fall (23.3 days) and spring (18.1 days). The overall mean length of stay for all carcasses and seasons was 25.0 days. Species observed in the project area that may scavenge carcasses include raptors, ravens, coyotes, badgers, mice and insects. During summer, one of the main causes of carcass removal was scavenging by insects, including carrion beetles and maggots.

The total number of turbine-related casualties in 1999 for the Vansycle Ridge wind plant was estimated to be 24 birds (90% CI= 22-26) and 28 bats (90% CI = 10-59). The estimated fatality rate per year was estimated to be 0.57 birds/turbine (90% CI = 0.54 - 0.60) and 0.40 bats/turbine (90% CI = 0.26 - 0.86). Most of the wind plant-related avian casualties on Vansycle Ridge were passerines, and many of these were likely nocturnal migrants. No raptor casualties were found during the study period. Due to the low scavenger removal rate and high searcher efficiency for large carcasses, it is likely that no raptors or other large birds besides the chukar and gray partridge were killed during the study period. Mortality of large birds during the first year was apparently limited to chukars and gray partridge, two introduced upland gamebirds.

Data collected during the first year of operation indicate that avian fatalities appear to be relatively low on Vansycle Ridge. Avian fatality rates on the Vansycle Ridge project (0.57/turbine) are much lower than those reported at some wind plants in California (AWEA 1995) as well as wind plants in Minnesota, where annual fatalities were estimated to be 1.95 birds/turbine (Johnson *et al*. 1999a), and in Wyoming, where annual fatalities were estimated to be 1.99 birds/turbine (Johnson *et al*. 1999b). The estimated number of bats killed per turbine at Vansycle Ridge (0.40) also is much lower than annual bat fatality estimates for wind plants in Minnesota (2.3/turbine) (Johnson *et al*. 1999a) and Wyoming (2.48/turbine) (Johnson *et al*. 1999b). We are not aware of any other studies that have quantified bat fatality rates at wind plants in the U.S.

Conclusions

Northern States Power. The results of our study suggest the diurnal surveys provide an estimate of risk exposure for diurnally active species and breeding species. While fatalities to these species in wind plants are typically of most concern, concern does exist for risk to nocturnal migrants. While our survey methods do not estimate the abundance of nocturnal migrants, the fatality data do not indicate a large risk for this group of birds. Both bird use and fatalities suggest that siting turbines away from high concentrations of birds would reduce risk. In our study these habitats include wetlands and woodlands.

Bird use was reduced adjacent to turbines for some species but large scale effects, such as reduced use of the entire wind resource area, were minimal. Decreased use adjacent to towers did not appear to be due to fatalities and likely was due to disturbance effects of turbines and their operation and maintenance and changes in habitat around the towers.

Weather appeared to be an important factor in fatalities. Thirty-seven of fifty-five fatalities were associated with poor weather. Season also appeared to influence fatalities. Most bird fatalities occurred during Fall migrations while bat fatalities were concentrated in the Spring. Little correlation existed between exposure index and fatalities during the Spring and Fall. Fatalities appeared to be nocturnal migrants, while our exposure index related to diurnally active species. Even though estimated fatalities were primarily nocturnal migrants, the number of fatalities was very small in comparison to the number of migrants thought to move through the area.

Vansycle. The estimated fatality rate was very low (0.63 birds/turbine) as expected since the area has poor habitat for birds. There was no obvious correlation between fatalities and weather. Bird use and fatalities is very low in this area compared to other wind plant sites.

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General Discussion

Q: What species are you finding at turbine sites vs. what you're finding at other habitat sites? *A:* There is no difference between turbine vs. non-turbine plots

Q: Regarding the slide of turbine A and turbine B (the Kenetech and Enron turbines)… It would also be interesting to look at injuries and fatalities in terms of megawatts. Also, injuries per kilowatt-hour. *A:* Yes. We have talked to companies about trying to get that kind of information.

Q: Did you determine the cause of death of those birds discovered outside of the study area? *A:* We did blind necropsy studies… [A detailed answer to this question was provided by Dale Strickland in time to be included in these Proceedings]:

Many of the avian fatalities had been scavenged or were too desiccated or decomposed to allow for meaningful necropsies. Necropsies that were conducted on suitable carcasses indicated that injuries included fractured skulls, wings, necks, ribs, sternums and vertebrae; gashes; fragmentation of the liver and kidney; bruised muscle and abraded skin. Cause of fatality for all carcasses found under turbines that were suitable for necropsy was diagnosed as blunt trauma (E. Williams, Wyoming State Vet Lab, unpubl. necropsy reports).

Q: What were the turbine heights of A (Kenetech) and B (Enron)? *A:* The Kenetech turbine is 120 feet, and the Enron turbine's hub height is 160 feet.

Q: There are high numbers of birds in wetland and woodlands. Were wind turbines located in these areas? *A:* No. Our recommendation is to get turbines away from these areas to reduce bird deaths.

Avian Monitoring and Risk Assessment at Tehachapi Pass and San Gorgonio Pass Wind Resource Areas, California

by

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Wallace Erickson, Dale Strickland, and Michelle Bourassa,[2]
Judith Tom and Natasha Neumann[1]

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[Editor's Note: *Dick Anderson presented substantially the same information a few weeks prior to the National Avian Wind Power Planning Meeting at the annual conference of the American Wind Energy Association (April 30-May 4, 2000). An abstract of his paper is reproduced below; the complete version of the paper is included in the* Windpower 2000 Proceedings*, available from AWEA* <*www.awea.org*>.]

Abstract

This paper provides preliminary results for a cooperative research project undertaken by the California Energy Commission, the National Renewable Energy Laboratory (NREL), and Western EcoSystem Technology, Inc. (WEST). The project includes studies in California's Tehachapi Pass and San Gorgonio Pass Wind Resource Areas (WRAs). The studies were designed to determine bird behavior, bird use, bird fatality, and bird risk as a function of turbine size, turbine type, turbine density, and wind plant characteristics and environmental variables within the operating wind plants. These differences can be important in new wind plant site selection and layout. The results also provide information that can help developers and regulators estimate effects at new development sites.

Tehachapi and San Gorgonio Pass WRAs differ in numerous ways including vegetation type, climate, topography, standing water, and bird species and numbers. These two WRAs also differ in bird utilization, bird mortality, and bird risk. San Gorgonio has a higher utilization rate, due to the presence of a watered area. Tehachapi has higher bird mortality and a higher relative bird risk than San Gorgonio. This may be due to different species and how they use the area. Raptor use was compared for San Gorgonio, Tehachapi, Altamont, and Solano WRAs. Although the numbers are derived using somewhat different methods, the magnitude of difference is significant. With 19-36 times more raptors using Altamont Pass WRA than San Gorgonio Pass WRA, and 10-18 times more raptors using Altamont Pass WRA than Tehachapi Pass WRA, finding fewer dead raptors in San Gorgonio and Tehachapi WRAs

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than in Altamont Pass WRA seems logical. Solano WRA has 2-3.6 times more raptor use than Altamont. Expansion of new wind energy development in the Solano WRA could result in raptor fatality numbers similar to those of the Altamont Pass WRA.

Differences in bird utilization, mortality, and risk were noted among Tehachapi and San Gorgonio WRA study subareas. Subareas represent differing vegetation, topography, elevation, and bird species. The relatively high bird utilization in the watered area of San Gorgonio illustrates the potential for great variability within as well as between WRAs. This may be useful in siting future projects or modifying existing facilities. Seasonal differences were also noted.

All turbine sizes and tower types studied caused bird kills. Differences noted were not significant at this stage of analysis. Turbine position was also considered. Orloff and Flannery's (1992) findings for the Altamont Pass WRA show end-row turbines causing a disproportionate level of raptor deaths compared to mid-row turbines. Our results for both Tehachapi and San Gorgonio found bird risk higher at mid-row turbines. This again illustrates that there can be differences between WRAs.

General Discussion

The point was made that one important difference between raptors, on the one hand, and corvids, waterfowl, and passerines, on the other, is the position of the eyes. Raptors' eyes face forward, whereas other birds have more panoramic vision.

There have been some conflicting results when people have attempted to measure the significance of mid- vs. end-string position. For example, Dick Anderson noted, some of Judd Howell's work showed no significant difference with regard to row position. How, then, to better capture the effect of topography? The problem with hypotheses about potential risk factors (e.g., string vs. topographical position, one tower type vs. another) is that people take these as "fact" on which to base mitigation measures, when in reality the problem is not so simple.

There is a need to standardize the definition of a "gap" – what someone is calling a single string with a gap may be what someone else is calling two separate strings.

Asked whether he has looked at different turbine types in a particular habitat, Anderson said yes, the various types of turbines (lattice/tube/vertical axis) all cause bird fatalities, but added that he felt there were many other factors, possibly more important than turbine type.

Wind/Bird Interaction Studies in Wisconsin

by

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Up to this date wind/bird interaction studies in Wisconsin have been mostly prospective. When commercial scale development occurs, it probably will look much like development at Buffalo Ridge, in Southwestern Minnesota. At the time this paper was written there were only two large-scale turbines in operation in the state – part of the Low Speed Wind Turbine Verification development program sponsored by the National Renewable Energy Laboratory, EPRI, and the Wisconsin utilities.

Most of the projected wind resource development is centered along the Niagaran Escarpment, which runs from the Door County peninsula in an arc through Dodge County, in East Central Wisconsin. This is because that feature is elevated up to 200 feet above the landscape to the West. The LSWT project is located on the escarpment, near the City of Green Bay. An 11.25 MW "green power" project, comprised of 17 turbines, was proposed by Madison Gas and Electric Company. It considered two sites, one in Calumet County – East of Lake Winnebago, the other in Kewaunee County – at the base of the Door Peninsula. (Subsequently, the project was constructed at the Kewaunee County site. A second, slightly smaller, project sponsored by Wisconsin Public Service Corp., was installed in a nearby township.)

Other resources that are relevant to bird and bat interactions with wind energy facilities are: Green Bay, to the West of the Escarpment; Lake Michigan – forming the Eastern boundary of the State; the Fox River Valley and Lake Winnebago – comprising a major water resource South of Green Bay; and, the Horicon Marsh State and National Wildlife Refuges – paralleling the southernmost extension of the Escarpment as a distinct landscape feature. There is a major (estimated at 300,000) bat hibernaculum at an abandoned underground iron mine at Neda on the face of the escarpment. The wildlife refuges and bat hibernaculum are the resources we are most concerned about protecting.

Within that context, a stakeholder team, mostly comprised of biologists from the Public Service Commission (PSC), Department of Natural Resources (DNR), U.S. Fish and Wildlife Service, the main investor-owned utilities, and the Audubon Society, are trying to address issues of land use, aesthetics, and bird/bat mortality. This collaborative group is engaging in two main tasks:

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- Gathering data on bird concentration areas, migration corridors and flight patterns, and developing a study of bird movements around the Horicon Marsh

- Developing a GIS-based map of resource areas that may be relevant to siting decisions

We have selected five counties in East-Central Wisconsin as the focus of the GIS exercise. Starting with existing GIS layers such as land cover, wetlands, water features, parks, and wildlife areas, we have added information gathered in our survey of bird experts familiar with the area.

The results are being used to delineate areas of higher or lower concern based on the presence of, and likely interactions between, birds and bats and these features. We will recommend that sites proposed within the areas of high concern be given a more thorough environmental review than sites located in low-concern areas. This may be an Environmental Impact Statement (EIS) for the former, and an Environmental Assessment (EA) or Categorical Exclusion for the latter. (Subsequently, the PSC's EIS rules were amended to require an EA for wind facilities more than 10 MW in size, and subject to PSC authority.) The information we have developed may also provide the basis for a generic EIS on wind energy facilities in the State of Wisconsin.

Ryan Atwater, a graduate student at the University of Wisconsin, Green Bay, was conducting a study of bird activity around the Horicon Marsh Wildlife Area. His intent was to establish scientifically-based setback distances for wind energy development around such major wildlife aggregations. Atwater's study has established the distances where large numbers of waterfowl may be within the rotor-swept area of turbines, and the directions that the geese and other birds take in their daily feeding flights. This should be useful in evaluating the potential for interactions of future proposals in the vicinity of Horicon or other such wildlife areas. In short, Atwater found that by 8 km from the marsh, most species are well above blade height. (His detailed results are the subject of another paper.)

Pre-siting activity studies were done at the 2-turbine Green Bay area site. Fatality searches were done around tall broadcast towers in the area to "sift" for birds flying through, especially at night. This, in conjunction with the activity studies on the site itself, should give a good picture of the likelihood for significant bird interactions at Wisconsin sites. However, the broadcast towers themselves may be an influence on bird behavior in the area, which will have to be accounted for in deciding how widely applicable this data really is.

Pre-siting avian data also was gathered at the two areas being considered for the utility project described earlier. Fatality searches will be conducted during the first two years of operation at these sites. (Results to date show very low levels of bird fatalities, but a greater number of bats killed.)

Another, larger wind site has been proposed for western Washington County. That facility would consist of up to 33 large turbines on tubular towers. Activity studies are being conducted at that site, and mortality searches will begin if the facility is developed. The data from this site and from the Kewaunee County installations should give a good picture of bird and bat interactions with wind turbines in this type of landscape.

We hope that with the careful approach we are taking, wind energy development in the state will occur in a manner that considers and minimizes the impacts to flying vertebrates – i.e., birds and bats. If development proceeds at a faster pace in the future, we feel that the groundwork we've laid will reduce the likelihood of unacceptable levels of wildlife fatalities.

AVIAN VISUAL STUDIES

The second session took place on the afternoon of the first day. Consisting of two presentations and a discussion, this session focused on the question: *What are we learning about avian vision that can help us better understand avian-wind power interactions?* The presentations were:

McIsaac, Hugh: *Raptor Acuity and Wind Turbine Blade Conspicuity*

Hodos, William, A. Potocki, T. Storm, and M. Gaffney: *Reduction of Motion Smear to Reduce Avian Collisions with Wind Turbines*

Raptor Acuity and Wind Turbine Blade Conspicuity

by

Hugh P. McIsaac

Raptor Research Center, Boise State University[1]

Introduction

This report summarizes the results of several studies that were undertaken in an effort to increase the conspicuity of wind turbine blades and reduce raptor fatalities in the wind resource area of the Altamont Pass in central California. The Altamont Pass contains a commercial wind plant that converts wind energy into electricity using large wind turbines. Unfortunately, the wind turbines kill some birds (Orloff and Flannery 1992). Furthermore, relative to other bird species in the area, the turbines kill a disproportionate number of diurnal raptors (Howell and DiDonato 1991, Howell and Noone 1992, Orloff and Flannery 1992). The incidence of raptor deaths at turbines is relatively rare (0.02-0.05 per turbine per year), and only a few collisions have been directly observed; in most cases dead birds are found near the bases of turbines. There are very few data to suggest the circumstances, and bird behaviors, associated with collisions. Kenetech Windpower, Inc., now Green Ridge Power, Inc., is a major operator of wind turbines in the area, and in 1992 this company convened a panel of biologists, called the Avian Task Force, to provide advice about how to reduce the risk of bird collisions with the turbines (Gipe 1995).

The Avian Task Force reviewed the reports and data assembled to date, and considered a variety of scenarios that might contribute to collisions between birds and wind turbines. They then evaluated a variety of practical management actions that might be used to reduce the fatalities. The Task Force concluded that bird vision likely was the most important factor for understanding the problem, and, thus, in implementing a solution. The anatomy and physiology of raptor vision have received considerable attention (e.g., Frost et al. 1990, Inzunza and Bravo 1993, Inzunza et al. 1991, Meyer 1977, Shlaer 1972, Snyder and Miller 1978, Walls 1942), but there is a paucity of measures concerning how birds, especially raptors, behave in response to complex stimuli under diverse circumstances (e.g., Emmerton 1990). Consequently, we have little behavioral information from which to infer bird-vision capabilities and limitations, and, thus, a poor basis for predicting how changes in a raptor's visual environment will affect its behavior. On the basis of the Task Force's recommendation, several behaviorally-based studies of raptor visual capacity were undertaken to determine whether the vision of raptors enabled clear resolution and localization of turbine blades.

With the help of several colleagues and assistants, I directed seven studies concerning

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raptor visual acuity and the capacity of raptors to see wind-turbine blades. This work was conducted between 1993 and 1996 at the Raptor Research Center, Boise State University, Boise, ID. What follows is a brief summary of this work; a detailed report of each study has been submitted to the National Renewable Energy Laboratory (NREL) [McIsaac, McIsaac and Chastain, McIsaac et al., McIsaac and McDonald (a), McIsaac and McDonald (b), McIsaac and Whitlock (a), McIsaac and Whitlock (b)], along with an extensive summary (McIsaac and Fuller).

The goal driving this research was to design patterns that could be painted on wind-turbine blades in order to make them more conspicuous to birds in flight than are the uniformly off-white blades now used by many wind-energy companies. Our studies involved basic research of bird visual acuity, and the conspicuity of blade patterns. Results from our first few studies indicated that the visual acuity of raptors was insufficient to resolve and localize turbine blades under some conditions, and that the application of a pattern to the blades might reduce this problem. Several patterns were tested in an attempt to develop a pattern that when applied to the blades of turbines would alert raptors to the presence and location of the blades. This report summarizes the results of our studies, specifically as it relates to the raptors' abilities to detect and locate wind turbines.

Our studies followed three different approaches designed to determine how well raptors resolve visual features and their capacity to see turbine blades. First, we tested raptor acuity using both stationary and rotating stimuli. Second, we tested the conspicuity of patterns on turbine-like blades, and, third, we tested raptors' capacity to group turbines into a cognitive category. These studies involved two species of raptors, the American kestrel (*Falco sparverius*), and the Red-tailed Hawk (*Buteo jamaicensis*). In addition, one study measured the conspicuity of patterns as a function of human perception.

General Methods

Behavioral-conditioning methods provided the basis to test raptor acuity and pattern conspicuity. Most of these studies involved standard two-stimulus forced-choice procedures (Blough and Blough 1977) to train and test each bird to discriminate between test and control stimuli. Study 7, a test of kestrel capacity to group images of turbines into a cognitive category, involved a modified go/no-go procedure (Blough and Blough 1977).

In two-stimulus forced-choice procedures test and control stimuli, positioned side by side, were presented simultaneously to the test bird. The bird received a food reward each time it correctly indicated which of the two stimuli presented the test stimulus; the food rewards reinforced the bird's behavior and encouraged it to repeat the action. Selection of the control stimulus generated a short delay and no food reward. We randomly switched the test stimulus between left and right stimulus-presentation positions. Thus, the bird could not predict on which side the test stimulus would appear. Eventually the bird learned to reliably indicate on which side the test stimulus was positioned, as evidenced by a higher proportion of correct responses. After the bird had learned to reliably discriminate the stimuli, the visual condition under which test and control stimuli were presented was changed so that discrimination of test and control stimuli became more difficult. For example, in the acuity studies (see below), the widths of the parallel black-and-white lines that composed the test stimulus pattern were narrowed, making the lined stimulus more difficult to distinguish from the uniformly gray control stimulus. The bird's capacity to discriminate was again tested but under the new visual conditions. As the visual conditions "deteriorated" the difference between test and control stimuli became difficult for the bird to detect, and the proportion of correct discriminations declined. Eventually, the test stimulus become too difficult for the bird to detect, and its discrimination rate fell to random; with two stimuli this corresponds to a discrimination level near 50%. With the exception of Studies 1 and 5, computers were used to control the experiments and associated apparati. The computers randomized the sequence of stimulus presentations (i.e., the left or right position of the test stimulus), monitored the birds' responses and recorded the data, and controlled the food-delivery component of the apparatus, dispensing food rewards for correct discriminations of test stimuli.

In our four studies of raptor acuity (Studies 1-4), we trained birds to discriminate between uniformly gray fields and square-wave gratings of alternating black-and-white lines. Within a given test stimulus the widths of all lines, black and white, were the same. However, several different test stimuli were presented to the birds, and these differed in line width. The birds' discrimination performances tended to be high with wide lines and declined toward random with progressively narrower lines. Following convention, we defined acuity to correspond to the line widths associated with 75% correct discrimination (e.g., Blough 1973, Hodos et al. 1985, Harvey 1986). Also by convention, test-stimulus line widths and acuity are reported in cycles/degree, (cyc./deg.; Hodos et al. 1985, Hahmann and Güntürkün 1993); this standardizes stimulus-image size on the birds' retinas independent of the distance separating the bird and stimulus.

Study Descriptions, Results, and Discussion

Study 1 - Visual Acuity of the American Kestrel (McIsaac, et al. - submitted to NREL). To better understand how well raptors see detail in objects such as wind turbines, and the role of distance in visual performance, we measured the visual acuity of the American kestrel. Visual acuities of four kestrels were obtained at several stimulus-presentation distances (SPD), i.e., the distances separating the subjects from the stimuli. This study was conducted by hand, with a technician manually setting up the apparatus and stimuli, observing the bird's behavior, rewarding the bird, and recording the data. The birds indicated their left-hand or right-hand stimulus selection by hopping from a starting position toward the selected stimulus; each stimulus had a perch in front of it on which the bird could land. This procedure has been used in most earlier studies of raptor acuity (Fox et al. 1976, Hirsch 1982, Reymond and Wolfe 1981, Reymond 1985). The assumption in these studies has been that the bird discriminated the test and control stimuli while at the starting position, before moving toward the stimuli, yet discrimination could occur during the bird's movement toward the stimuli. Thus, the distance at which the bird actually discriminates between the test and control stimuli is unknown. Incomplete control of the distance between bird and stimulus may have allowed birds to discriminate the stimuli at distances shorter than the SPDs and this could inflate the acuity estimates.

The results obtained in our study were as follows. Three birds exhibited similar acuities, 16.5, 21.7, 19.5 cyc./deg., at an intermediate distance of 92 cm. Two of these birds also were tested at a longer SPD, 160 cm. At 160 cm one bird showed twice the acuity, 40.5 cyc./deg., of its intermediate-SPD acuity, while the second bird showed an acuity, 19.2 cyc./deg., similar to its intermediate-SPD acuity. We obtained a third acuity of 15.9 cyc./deg. from one of the kestrels at a second intermediate SPD of 76 cm. A single acuity was obtained from the fourth kestrel at a 50 cm SPD; this acuity estimate, 4.9 cyc./deg., was considerably lower than any of the acuities obtained from the other kestrels. The results obtained suggest that the acuity of the American Kestrel is on the order of 20 cyc./deg. This is less than half the acuity of humans and conflicts with common-lore notions of exceptional acuity in diurnal raptors (e.g., Fox et al. 1976, Johnsgard 1990, Walls 1942).

Study 2 - Spatial Visual Acuity in American Kestrels and the Influence of Bird-Stimulus Distance on Acuity (McIsaac and Whitlock (a) - submitted to NREL). During the course of Study 1 we became concerned that incomplete control of the distance at stimulus discrimination may have produced inflated acuity measurements in our study (McIsaac et al. - submitted to NREL) and in previously published reports (Fox et al. 1976, Hirsch 1982, Reymond 1985, Reymond and Wolfe 1981). To address this concern we repeated our study of visual acuity using an automated apparatus that controlled stimulus-discrimination distance (SDD). Visual acuities of five American kestrels were obtained at several SPDs: 21 cm, 92 cm (or 100 cm), and 200 cm. Training and testing of the kestrels in this study was automated so that stimulus presentation, monitoring of the bird’s responses, delivery of food rewards, and data collection were controlled by computer. During an experiment the bird perched near two windows in the front of a small box. The windows directed the bird’s view toward each of the two stimuli, with only a single stimulus visible through a given window. The bird indicated its selection of one stimulus or the other by extending its head into the window directed at the selected stimulus. The bird’s head interrupted an infrared light beam that traversed the window, and the computer recorded the interruption. Successful discriminations of the stimuli were rewarded with the delivery of food through a small port located slightly below and between the two windows in the front of the box. Food rewards were extruded from a syringe and consisted of ground quail meat (see Fig. 1). This procedure completely controlled the distance at which the kestrels discriminated the stimuli, SDD, and prevented inflation of acuity estimates. In this case SPD equals SDD.

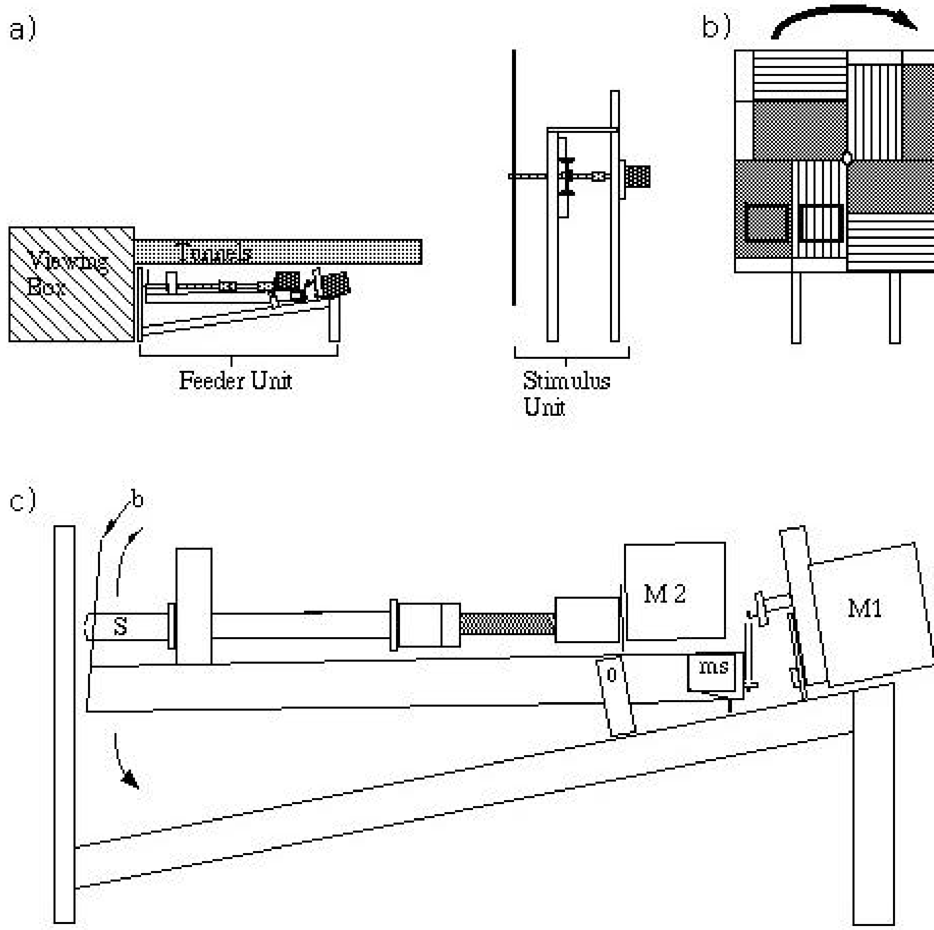

FIGURE 1. Apparatus used to test kestrel spatial visual acuity. *The apparatus consisted of three major components:*

a) The viewing box (side view) confined the kestrel and maintained stimulus-presentation distance (SPD) so that stimulus-discrimination distance (SDD) was known. The viewing box in conjunction with viewing tunnels directed the subject's view to the stimuli on the stimulus unit (see b) below), and the feeder unit delivered food rewards (see c) below).

b) *The stimulus unit (front view) included a board that carried four test- and control-stimulus pairs. The paired rectangles in the lower left quarter of the board indicate the field of view seen through the viewing tunnels. The board rotated to bring different stimulus pairs into the subject's view from one trial to the next. Two pairs presented the test stimulus to the left of the control stimulus, and two pairs presented the test stimulus to the right.*

c) *The feeder unit (side view) reinforced kestrels with food rewards of ground quail that were extruded from a syringe (S). A baffle (b) and vertical board (at far left) masked the unit from the kestrel. Motor M1 lifted the food syringe up and down to make the syringe accessible, and inaccessible, to the subject through a hole in the vertical board. Motor M2 advanced the syringe plunger to deliver rewards. (ms - microswitch)*

The following results were obtained. At the short SPD (21 cm), the acuities of three birds were: 3.2, 3.9, 5.0 cyc./deg. At intermediate SPDs (92 cm and 100 cm), acuities of 9.0, 11.8, 20.3 cyc./deg. were obtained from three birds. At a longer SPD (200 cm) acuities of 12.1 and 15.2 cyc./deg were obtained from two birds (see Fig. 2). Careful control of SDD in this study probably accounts for the differences in acuity reported here and those of earlier studies (e.g., Fox et al. 1976). Thus, the acuity of American kestrels appears to be lower than has been commonly assumed for diurnal raptors (Johnsgard 1990, Walls 1942) and lower than previous reports indicated (Fox et al. 1976, Hirsch 1982, McIsaac et al. - submitted to NREL).

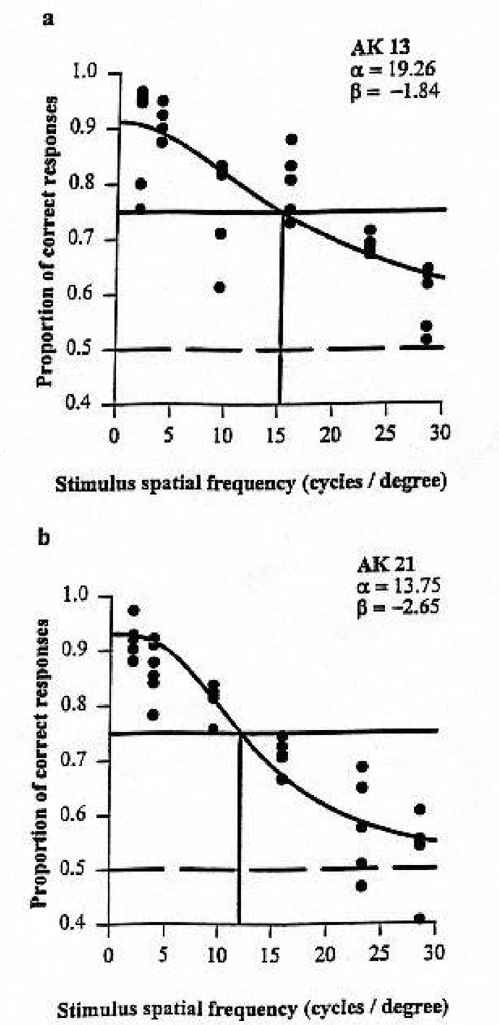

FIGURE 2. Visual acuities of two American kestrels tested at a 200 cm SPD. *These psychometric curves illustrate the kind of data, and its analysis, obtained in our acuity studies. Analysis of such data includes the fitting of logistic curves and calculation of acuity, in cycles/degree of stimulus-grating spatial frequency. Acuity is derived from the logistic regression at the 0.75 rate of correct discrimination. The solid horizontal lines depict the 0.75 correct-discrimination rate, and the vertical lines indicate acuities. The dashed line represents a random performance with a correct-discrimination rate of 0.5. Inflection point and slope of the logistic curves are specified by a and b, respectively.*

Additionally, the results of this study and Study 1 suggest an effect of SPD on acuity (see Fig. 3). All of the acuities obtained at SPDs of less than 76 cm were lower than those obtained at the longer SPDs. One possible interpretation of these data suggests that kestrels view close objects with one visual field of low acuity, and more distant objects with a different visual field of higher acuity; a parallel situation has been documented in pigeons (Blough 1973). Although we did not attempt to document the use of different visual fields with different SPDs, Frost et al. (1990) suggest that kestrels use one visual field when viewing close objects (less than 1 - 1.5 m) and a second visual field with more distant objects.

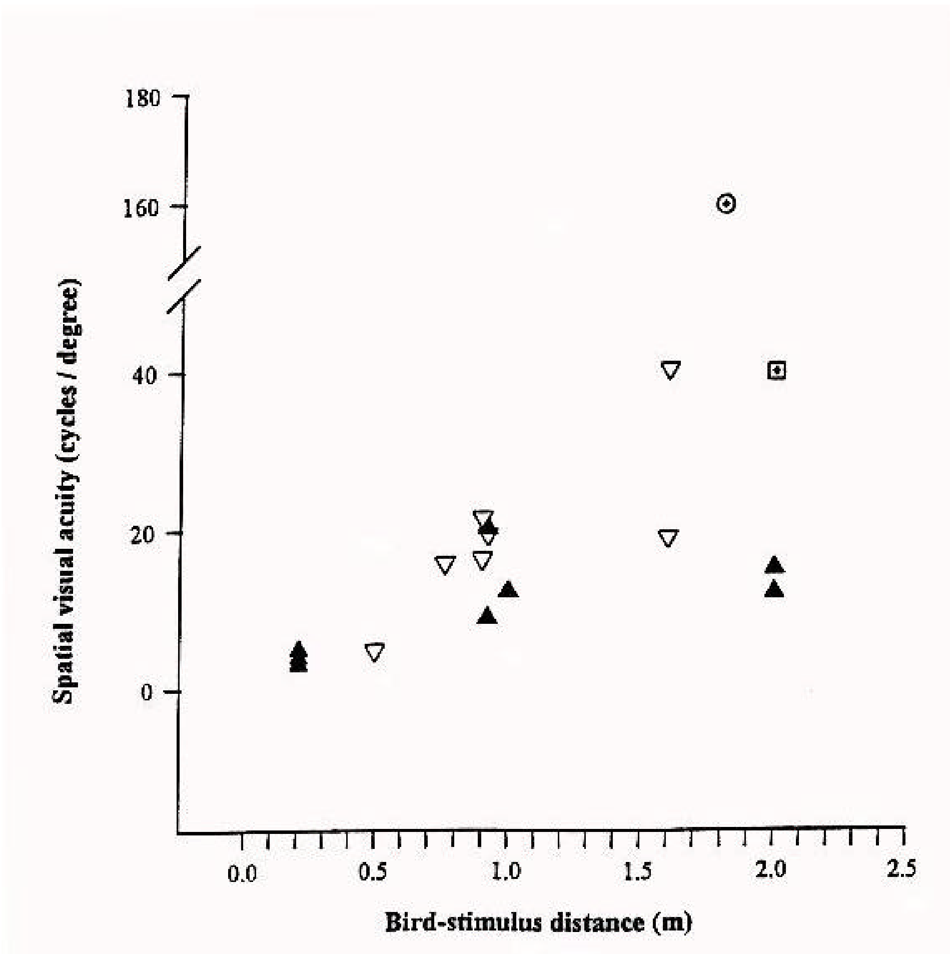

FIGURE 3. Relationship between kestrel visual acuities and the distance separating bird and stimulus. *The kestrel acuities obtained in this study are represented by filled black triangles. Kestrel acuities reported by McIsaac et al. (submitted to NREL, open triangles), Hirsch (1982, open square with cross-hairs), and Fox et al. (1976, open circle with cross-hairs) are presented for comparison with this study. Each symbol represents the acuity of a single subject. Note that the only acuity above 40 cyc./deg. is that reported by Fox et al. (1976).*

Study 3 - Visual Acuity in American Kestrels and the Influence of Stimulus Rotation on Acuity (McIsaac and Whitlock (b) - submitted to NREL). In this study we examined the effects of rotation on acuity; rotation is an important feature of wind turbines and likely contributes to raptor fatalities in the Altamont Pass wind-resource area. Visual acuities of two American kestrels were obtained with four stimulus-rotation rates: 0, 43, 68.5, and 90 rpm. The black-and-white lines of the test stimulus were arranged radially around the center of stimulus rotation, rather than as a pattern of parallel lines. Thus, the black-and-white lines of the test stimuli were arranged as the teeth of a gear, and a gray annulus served as the control stimulus (see Fig. 4). Other than the stimuli the procedure and apparatus used in this study were similar to those used in Study 2.

FIGURE 4. Stimulus-presentation unit used in the rotation-study. *This unit presented the test- and control-stimuli in left or right positions. Only those portions of the two stimuli encompassed by the dashed lines in this diagram were visible through the viewing tunnels. The test stimulus had solid black centers surrounded by annuli of radiating black-and-white spokes, while the control stimulus had solid black centers surrounded gray annuli. One motor (M1) rotated the large supporting discs so that the positions of CS and US could be switched between one trial and the next, and another motor (M2) rotated the individual stimuli during trials.*

Visual acuities were obtained from both kestrels with all stimulus-rotation rates except 0 rpm; we obtained an acuity from one bird only with 0 rpm. The acuities obtained were: 13 cyc./deg. with 0 rpm, 3 and 2 cyc./deg. with 43 rpm, 2 and 1 cyc./deg. with 68.5 rpm, and 1 and 1 cyc./deg. with 90 rpm (see Fig. 5). These acuities are low and indicate that moderate motion significantly influences kestrel acuity. The effect of stimulus rotation on visual resolution appears pronounced even with the slower rotation rates. These results suggest that kestrels may be unable to clearly resolve all portions of turbine blades under some conditions. Particularly difficult conditions likely include blade rotation, low contrast of blade against background, and dim illumination.

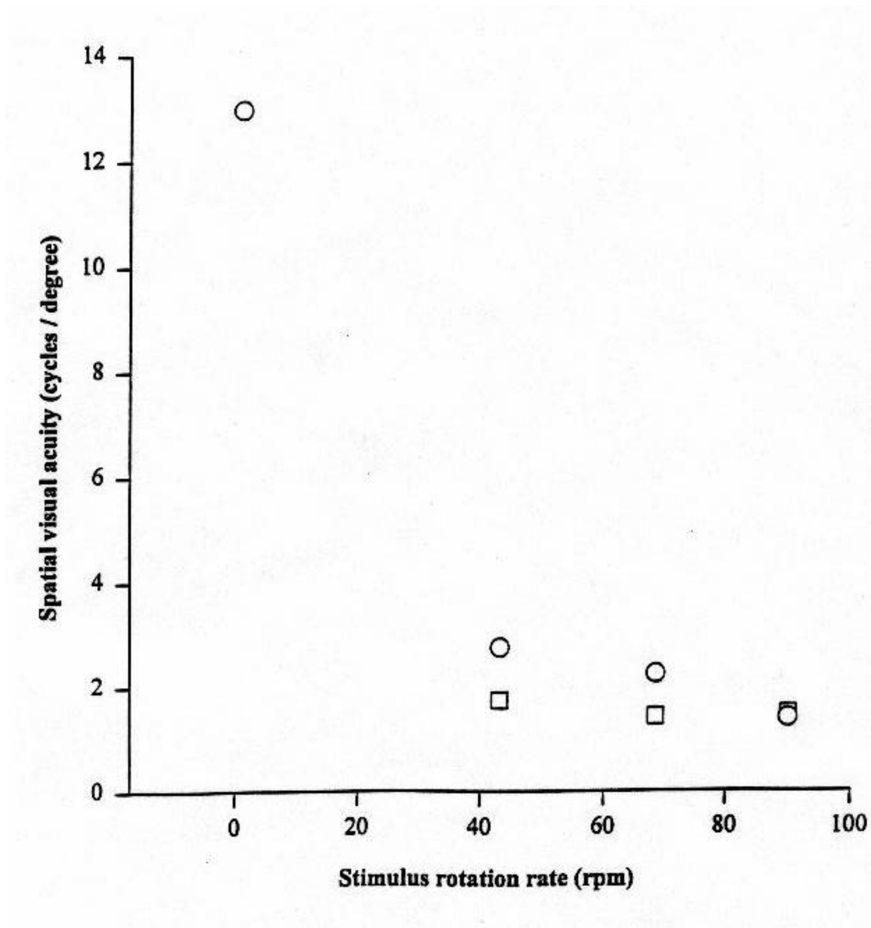

FIGURE 5. Effects of stimulus rotation on kestrel acuity. *The effects of stimulus rotation on acuity are shown for two American kestrels. Kestrel Ak22 is represented by circles and Ak14 by squares. Each symbol represents an acuity derived from psychometric curves similar to those presented in Fig. 2.*

Study 4 - Visual Acuity of a Red-Tailed Hawk (McIsaac and McDonald (a) - submitted to NREL). After determining that kestrel acuity did not match previous expectations we tested a second, and larger, raptor species to determine if other species also exhibited lower acuity than expected. The visual acuity of a red-tailed hawk was measured using an apparatus similar to that of Study 2, but larger (see Fig. 6). Acuity was found to be 16.8 cyc./deg. when tested with stationary stimuli and 83 cm SPD/SDD (see Fig. 7). Unfortunately, we were forced to terminate this study prematurely and could not test more than one bird. This finding is consistent with our results concerning kestrel acuity and suggests that hawk acuity, like that of the kestrel, may be relatively unremarkable.

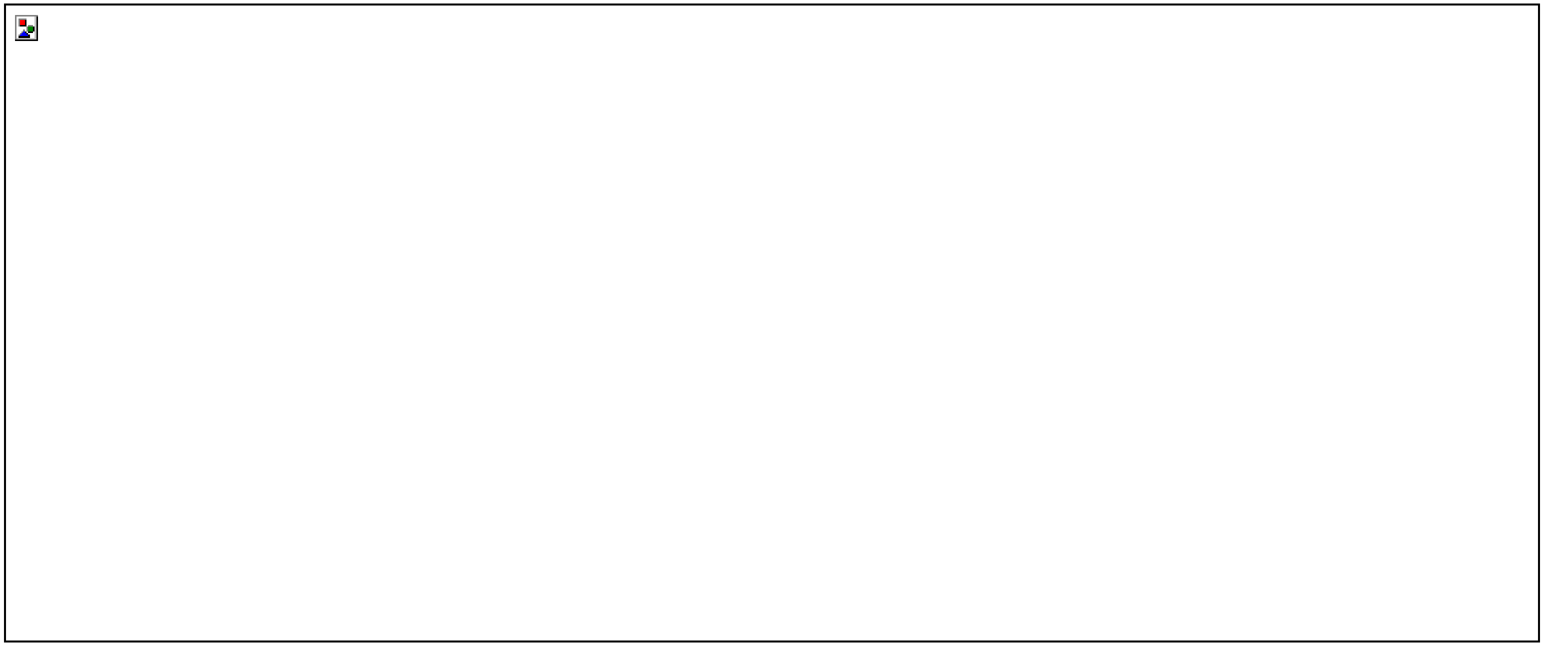

FIGURE 6. Test apparatus used to test hawk acuity.

This apparatus is larger, but otherwise functioned almost identically to the apparatus shown in Fig. 1. Only the critical components are shown; supporting structures, drive motors, and electrical connections have been omitted. The computer that controls the apparatus has been omitted as well. The principal components included a bird box (Bb) to contain the hawk and maintain SPD, stimulus-presentation device (St), and feeding unit (Fe) that delivered food from a syringe (Sy). Ba - baffle, Fp - feeder port, P - partition, Sh - shutter, Vw - viewing windows.

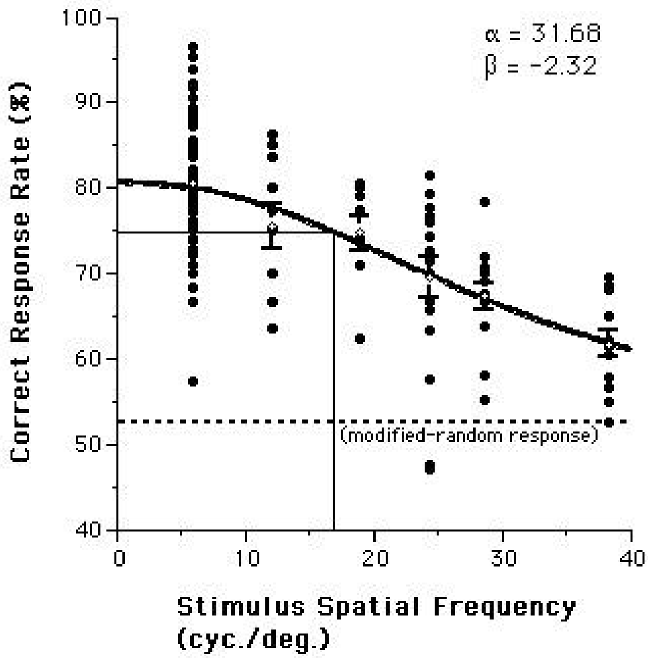

FIGURE 7. Visual acuity of a red-tailed hawk. *This psychometric curve shows the hawk's discrimination performances with a variety of test-stimulus-grating frequencies. Acuity, obtained from the modified logistic curve, falls at 16.8 cyc./deg. Inflection point and slope of the logistic curve are specified by a and b, respectively. Open diamonds represent the mean correct-response rate with each grating frequency. The error bars show one standard error from the mean; for those means not showing error bars the bars were too small to represent in the diagram.*

Because we had obtained acuities from two raptor species that were lower than expected we decided to test the acuity of a well-studied bird, the pigeon, to make sure that our procedures were appropriate. We obtained acuities from two pigeons (see Fig. 8), and these fell within the normal range of pigeon acuities that have been obtained by others (Blough 1973, Güntürkün and Hahmann 1994, Hahmann and Güntürkün 1993, Hodos et al. 1985).

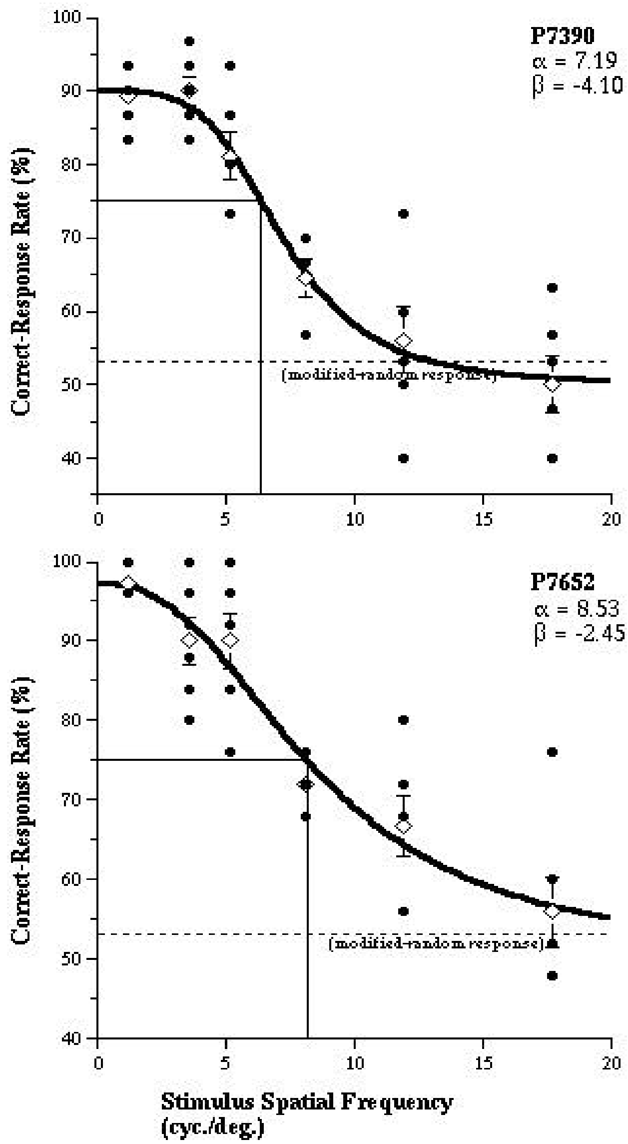

FIGURE 8. Psychometric curves and visual acuity estimates for two pigeons. *The upper diagram presents the results for pigeon 7390 with an acuity of 6.4 cyc/deg. The lower diagram presents pigeon 7652 with an acuity of 8.1 cyc/deg. Refer to Fig. 2 for an explanation of graph features.*

Our results from Studies 1-4 indicate that the visual acuity of raptors is only moderate, and not exceptional as had been previously thought (e.g., Fox et al. 1976, Johnsgard 1990, Walls 1942). Two studies of American kestrels indicate that kestrel acuity falls below human capacity and that rotation dramatically reduces acuity. In addition, red-tailed hawk acuity also appears to be moderate rather than exceptional. These results suggest that raptors may not clearly see rotating turbine blades under some environmental conditions such as dim illumination (overcast, dusk to dawn) and low contrast (haze, fog, or overcast).

Study 5 - Effects of Patterns on Blade Conspicuity of Propeller-type Rotors (McIsaac and Chastain - submitted to NREL). This study of pattern conspicuity was conducted with human subjects because these data could be obtained quickly and the results were used to design a blade-pattern conspicuity study involving raptors (see Study 6). Raptors and humans share many of the basic features of the vertebrate eye (Tansley 1965). We report the relative visual conspicuities, as perceived by humans, of six patterns presented on three-bladed representations of turbine rotors. Conspicuity estimates were obtained of full-blade lengths and of the distal-quarter blade (tip).

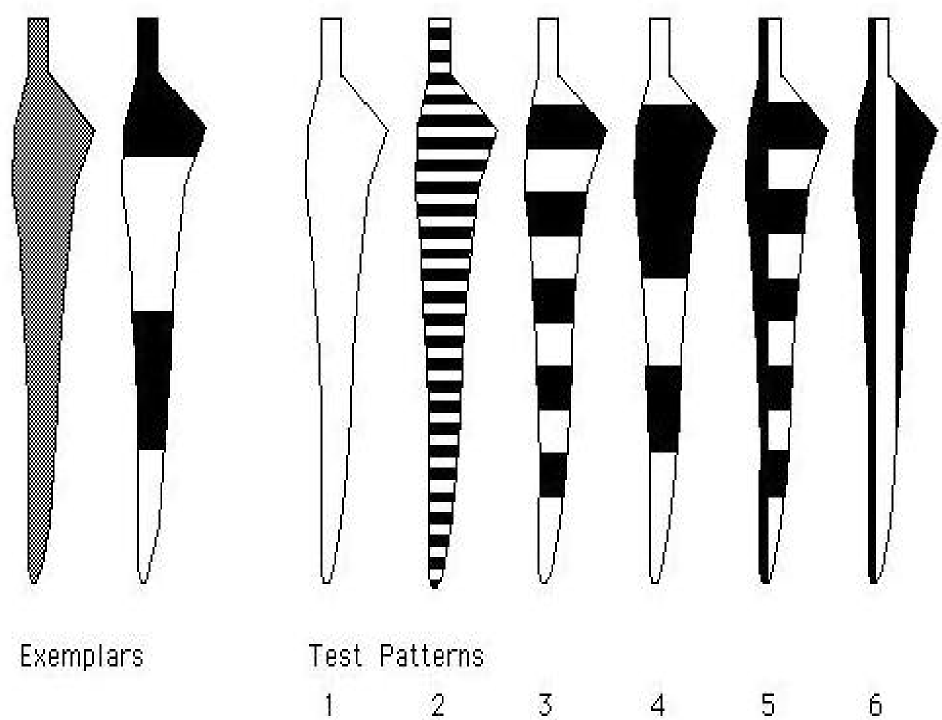

FIGURE 9. Human-perceived blade-pattern conspicuity: stimulus blade patterns.

In order to obtain human-perceived conspicuity ratings of blade patterns, college students rated the conspicuities of six test patterns relative to standardized conspicuities of two exemplars. This human-based study provided a quick assessment of pattern conspicuity based on a fairly generalized vertebrate eye.

College students evaluated blade-pattern conspicuity in this study. Before the start of the study subjects received explanations of the purpose, objectives, and procedures of the study. At this time subjects were shown two exemplars of blade patterns (see Fig. 9) against which they were to compare the test patterns. This provided a common basis on which the responses of all subjects were standardized; the two exemplar patterns demonstrated relatively high and low conspicuities. With the exemplars to anchor their ratings the subjects ranked the full-blade visibility of the six test patterns (see Fig. 9) on a scale of 0 to 100 and the blade tips as clearly visible (1.0) or not clearly visible (0.0).

Blade patterns were tested under a variety of conditions. First, the three-bladed rotor stimulus was either rotating or stationary. The stimuli were rotated at approximately 88 rpm, slightly faster than Green Ridge Power's 56-100 turbines (Gipe 1995). Second, illumination conditions were manipulated to alter stimulus brightness and contrast. A third test condition, the background against which the stimulus rotor blades were viewed, also was varied between a uniformly blue-gray background and a mottled background of tan patches on a blue-gray background. A black curtain blocked the subjects' views of the stimuli while patterns, rotation, and illumination were changed between trials.

The results demonstrate that blade patterns differed significantly in conspicuity (see Fig. 10, Table 1a and b). Patterns with components running across the width of the blades tended to be more conspicuous than either those with components running the length of the blades and those with uniformly colored blades. Other factors significantly influencing conspicuity included stimulus rotation, illumination, and under some conditions, background. Significant interactions were obtained among these factors and blade patterns (Table 1a and b).

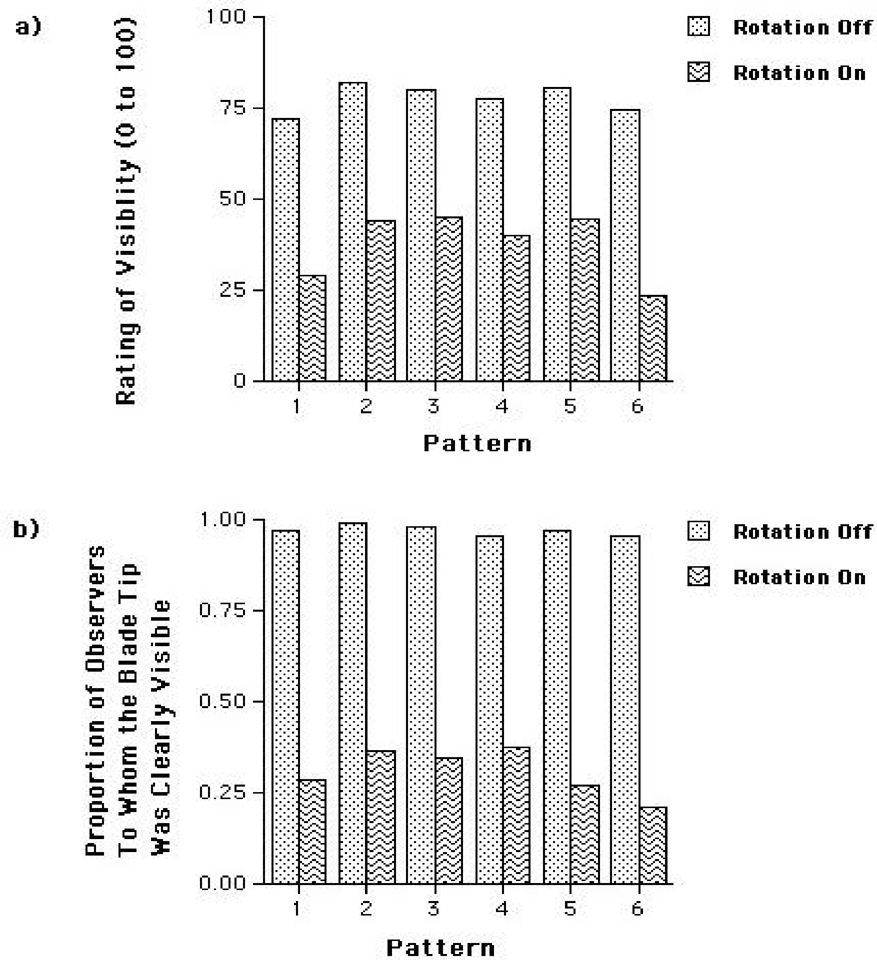

FIGURE 10. Human-perceived blade-pattern conspicuity: two-factor interactions of pattern and rotation. *These diagrams show the relationship between blade-pattern conspicuity and the effects of rotation. Illustrations of the blade patterns are presented in Fig. 9. Both blade pattern and rotation significantly affected conspicuity. Two ratings of pattern conspicuity are presented, a) full-blade visibility ratings, b) blade-tip visibility ratings.*

TABLE 1. Human-perceived blade-pattern conspicuity. *The main effects of the four experimental factors are listed independent of significance. All combinations among factors were tested for interactions, however, only those significant at a probability level of 0.05 and less are shown.*

(a) ANOVA results for the full-blade visibility ratings.

ANOVA		Factor	F	df	p
Main effects	i)	pattern	47.47	5	0.0000
	ii)	rotation	641.27	1	0.0000
	iii)	illumination	58.75	3	0.0000
	iv)	background	0.56	1	0.4551
Two-factor interactions	i)	pattern x rotation	19.63	5	0.0000
	ii)	pattern x illumination	13.12	15	0.0000
	iii)	rotation x illumination	31.03	3	0.0000
Three-factor interactions	i)	pattern x rotation x illumination	11.37	15	0.0000
	ii)	rotation x illumination x background	3.03	3	0.0296

(b) ANOVA results for the blade-tip visibility rating.

ANOVA		Factor	F	df	p
Main effects	i)	pattern	6.91	5	0.0000
	ii)	rotation	935.30	1	0.0000
	iii)	illumination	47.30	3	0.0000
	iv)	background	3.25	1	0.0741
Two-factor interactions	i)	pattern x rotation	4.53	5	0.0005
	ii)	pattern x illumination	6.24	15	0.0000
	iii)	pattern x background	3.78	5	0.0023
	iv)	rotation x illumination	49.24	3	0.0000
Three-factor interactions	i)	pattern x rotation x illumination	4.86	15	0.0000
	ii)	pattern x rotation x background	2.39	5	0.0366

Study 6 - A Method to Assess Animal Perception of Stimulus Conspicuity with Application to Patterned Wind-turbine Blades Using an American Kestrel (McIsaac and McDonald (b) - submitted to NREL). In this study we developed a new method to assess the relative conspicuities of patterns based on the responses of the target organism, in this case the American kestrel. Although we were forced to terminate this study prematurely (resulting in a small sample size), our results demonstrate the effectiveness of the method, and provide support for the concept that patterns conspicuous to humans (e.g., Study 5) also are conspicuous to raptors. A kestrel was trained to discriminate patterned (experimental) stimuli from uniformly gray (control) stimuli using a forced-choice procedure. The stimuli simulated the three-bladed turbine rotors of commercial wind turbines in relative dimension and motion (see Fig. 11). The blades of the experimental rotor stimulus carried one of several test patterns (see Fig. 12), and the background behind the rotor was uniformly gray. A similar turbine-rotor representation and background served as the control stimulus, except that the control blades were uniformly gray with only a black outline. Both test- and control-stimulus rotors rotated at 30 rpm. As with our other studies based on two-stimulus forced-choice procedures, the test- and control-stimulus rotors were randomly switched between left and right positions. The kestrel discriminated the test- and control-stimulus rotors under a range of stimulus-illumination levels selected to produce psychometric curves with discrimination rates that tended to be high with brighter stimulus illumination, e.g., 2.0 Lux, and to decline toward random as illumination dimmed, e.g., 0.02 Lux. Multiple-regression analysis of logistic curves fit to the bird's discrimination performance with each blade pattern provided the basis for comparing conspicuities among different patterns.

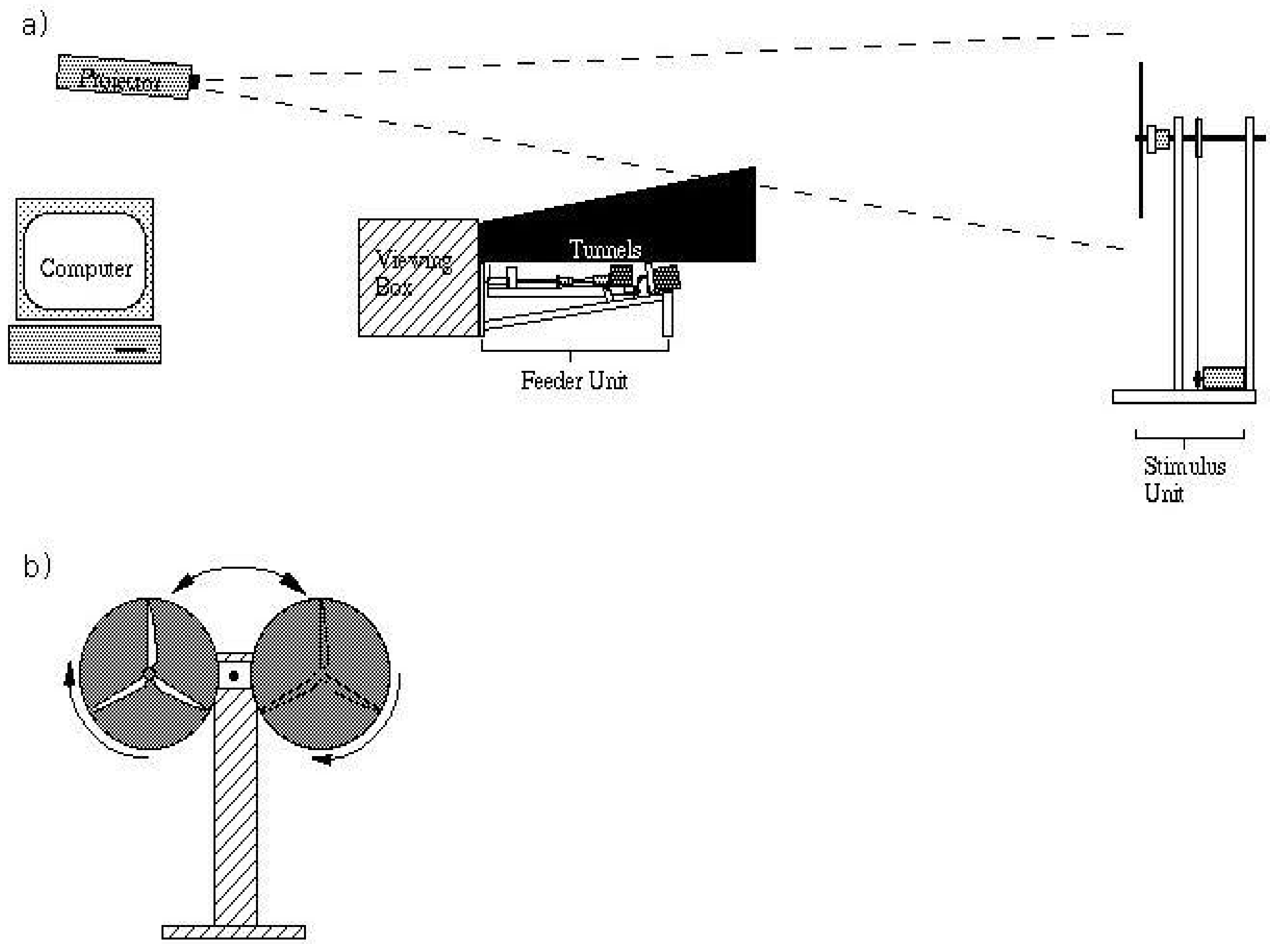

FIGURE 11. Kestrel-perceived blade-pattern conspicuity: the experimental apparatus. a) The experimental apparatus comprised four principal parts, as shown here in side view. *First, a viewing box confined the kestrel and directed its view toward the stimuli. Second, a stimulus unit presented stimuli of three-bladed rotors showing the various blade patterns. The stimuli were illuminated by a slide projector, and neutral-density filters were used to regulate illumination of the stimuli. Third, a feeder unit delivered food rewards of ground meat. Finally, a computer regulated the apparatus and recorded data. However, the neutral-density filters were operated by hand.* b) Frontal view of the stimulus unit.

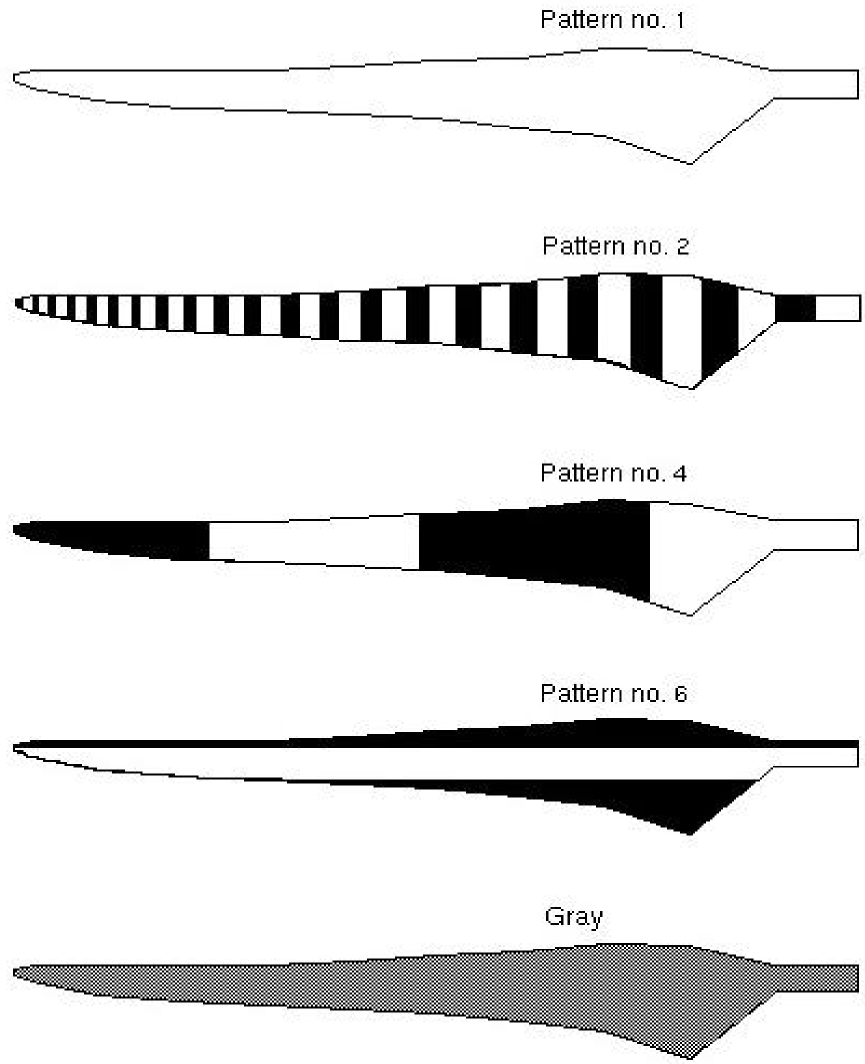

FIGURE 12. Kestrel-perceived blade-pattern conspicuity: stimulus blade patterns. *Depicted are the four black-and-white test patterns and the gray control pattern that were used to determine pattern conspicuity as perceived by a kestrel.*

We found that the relationship between discrimination rate and stimulus-illumination varied significantly among patterns (Table 3 - refer to McIsaac and McDonald (b) for additional details of the statistical analysis), and, thus, that patterns differed in relative conspicuity (see Fig. 13). A pattern of two broad black bands (pattern no. 4) running across the width of the white blade provided the highest conspicuity of the patterns tested. A plain white blade, pattern no. 1, also provided relatively high conspicuity. A pattern of stripes running the length of the blades (pattern no. 6) was less conspicuous, while fine stripes running across the width of the blades (pattern no. 2) provided the lowest conspicuity rating. However, the results of Studies 2 and 3 indicate that the kestrel could not resolve the fine stripes of this pattern under the conditions presented, which explains its low conspicuity. The results of Study 5 and this study suggest that carefully selected blade patterns will increase the conspicuity of turbine-rotor blades in the field. Tentatively, we recommend a pattern composed of square-wave, black-and-white components that run across the blade width. See below for additional discussion of blade pattern specifications.

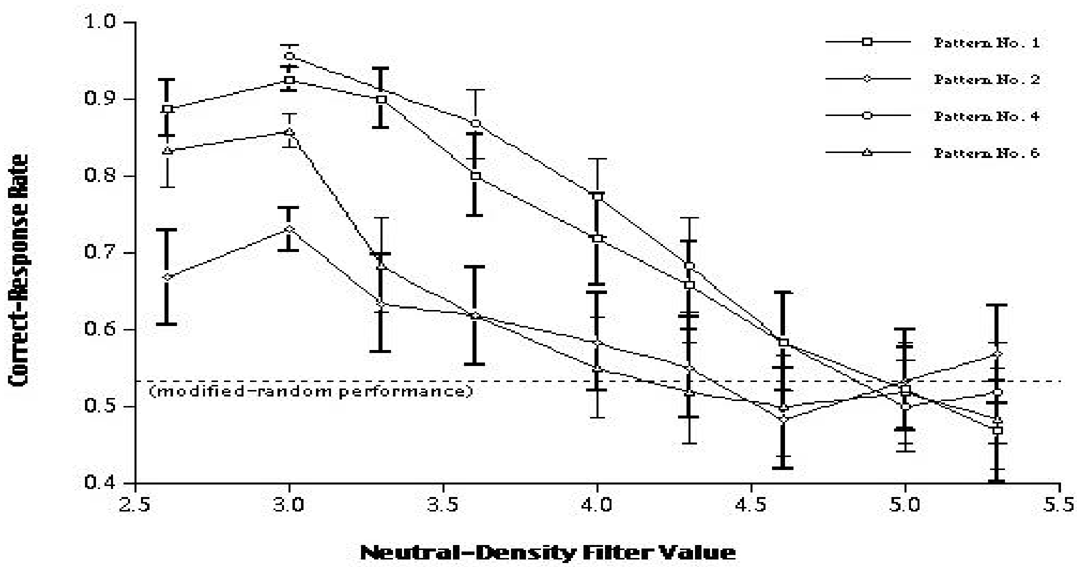

FIGURE 13. A Kestrel's conspicuity rating of four blade patterns. *Discrimination performances of a kestrel serve as a measure of conspicuity of four blade patterns (see Fig. 12 for illustrations of the blade patterns). Each pattern was tested at several illumination levels. In this diagram the X axis, neutral-density filter value, represents illumination level. Discrimination performances, proportion of correct responses with binomial standard deviations (vertical bars), are shown for each blade pattern and illumination level. Where standard deviations are not shown the bars were too short to represent in the diagram.*

TABLE 3. Kestrel-perceived blade-pattern conspicuity: Odds ratios for the logistic regression analyses. *Those patterns that did not differ significantly from pattern no. 1 (see Fig. 12) are not included in this table. The odds ratios for shaded cells are not statistically different from pattern no. 1, based on 95% confidence intervals for the odds ratios.*

Filter	2.6	3.0	3.3	3.6	4.0	4.3	4.6	5.0	5.3
Pattern no. 2	0.10	0.14	0.18	0.24	0.33	0.43	0.55	0.76	0.98
Pattern no. 4	2.39	2.09	1.90	1.72	1.51	1.37	1.24	1.09	0.99

Study 7 - Categorical Discrimination in American Kestrels (McIsaac - submitted to NREL). The capacity of raptors to learn and generalize what they learn to new situations may prove important in developing mitigation procedures to reduce raptor fatalities in the Altamont Pass. In order for raptors to generalize they must have the capacity to associate new situations with those present when learning took place, i.e., they must group both types of situations as belonging to the same category. For example, if raptors learn to avoid a specific set of turbines, then in order for them to generalize to avoid all turbines they must categorize all turbines as a group of related objects.

In order to test the capacity of raptors to recognize objects as members of one category or another, I relied on a go/no-go psychometric method (Blough and Blough 1977), rather than the two-stimulus forced-choice method described above. Go/no-go methods are similar to forced-choice methods in that both procedures measure a bird's capacity to discriminate between stimuli. In the case of the go/no-go procedure, however, only one stimulus is presented at a time. Two kestrels learned to discriminate color photographs of grassy hillsides containing wind turbines (including supporting towers, nacelles, and blades), set against mostly cloudy skies, from those of grassy hillsides set against mostly cloudy skies and without turbines. Photographs containing turbines varied in the number of turbines shown and presented the turbines from a variety of perspectives. Several examples, converted to black-and-white representations, of the color photographic stimuli are shown in Fig. 14. The color photographic images were projected from 35 mm color slides onto a rear-projection screen. The kestrels viewed each stimulus through a single window in the front of the viewing box (see Fig. 15).

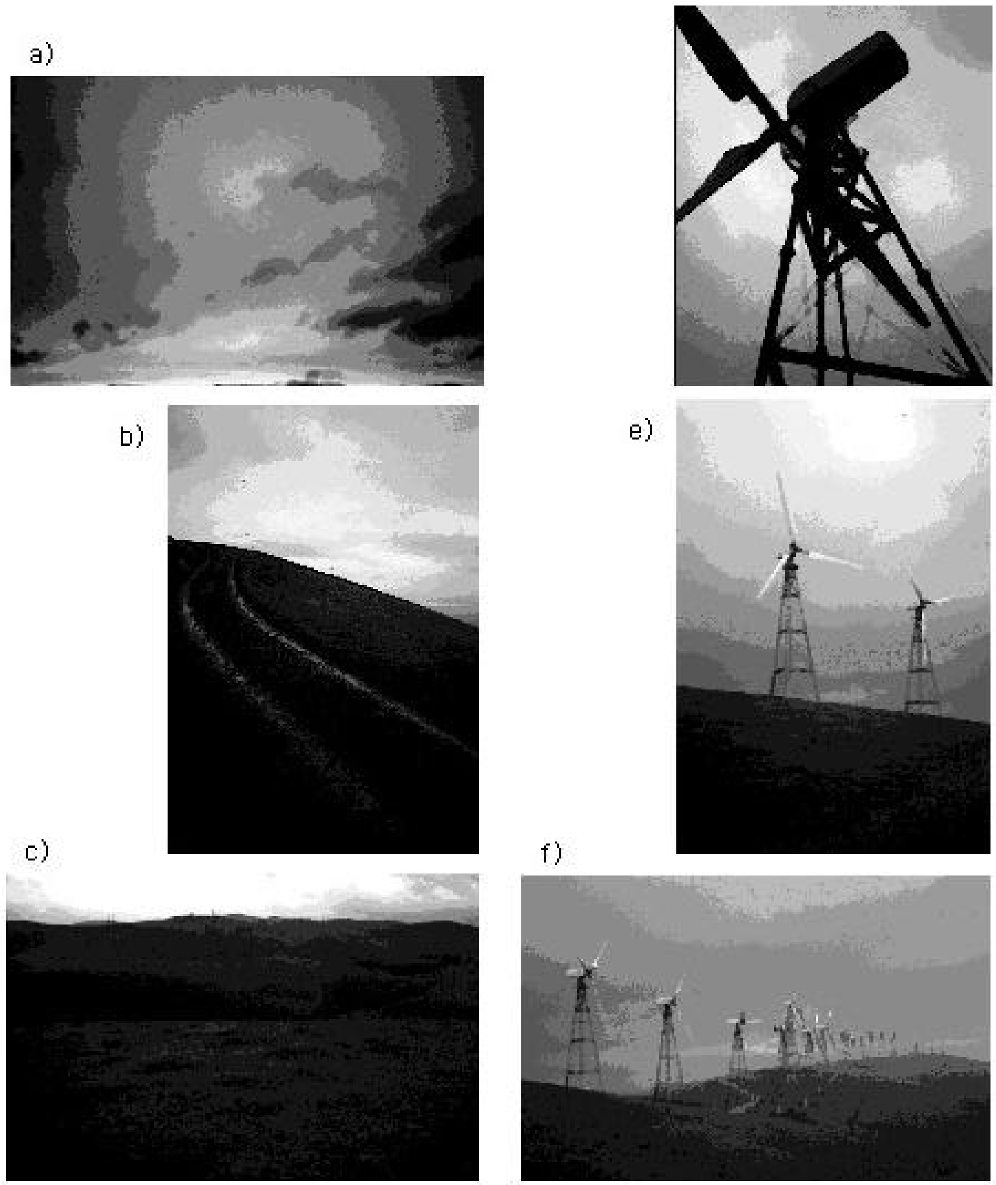

FIGURE 14. Examples of photographs used to demonstrate category formation and discrimination in kestrels. *These black-and-white representations of color photographs show a few of the hundreds of photographs used to train and test two American kestrels to discriminate photographs showing wind turbines from those lacking turbines.*

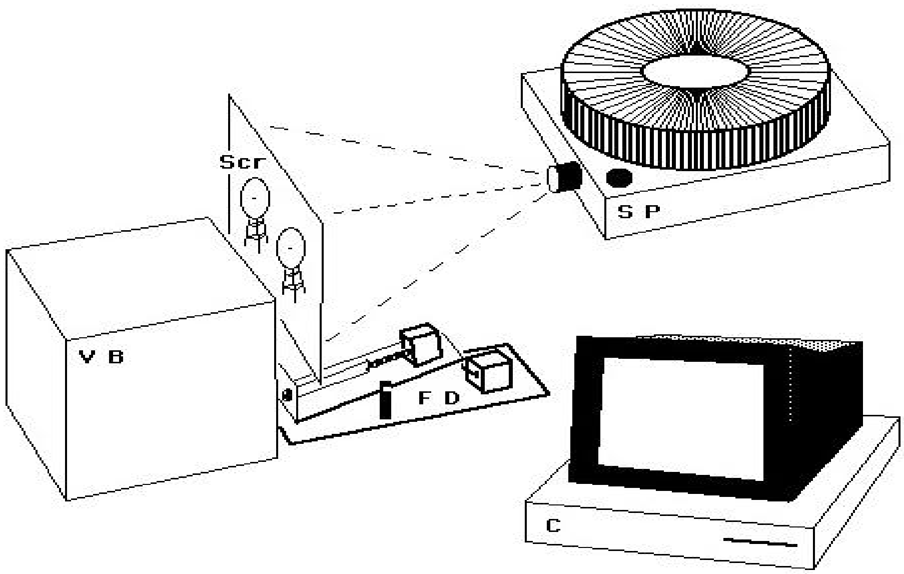

FIGURE 15. Training and test apparatus used to study category formation and discrimination in kestrels. *Four principal components composed the apparatus: a viewing box (VB), a food dispenser (FD), a slide projector (SP) with rear-projection screen (Scr), and a computer (C). Only critical components are shown; supporting structures and electrical connections have been omitted.*

As with the forced-choice method, the birds observed the stimulus from a perch located near the front of the viewing box. If a given stimulus photograph contained wind turbines, the bird could indicate this by thrusting its head into the window and receiving a food reward through the computer-controlled apparatus. If, however, the photograph lacked turbines, the bird could indicate this by refraining from thrusting its head through the viewing window[3] until the computer removed the stimulus (ten seconds). Alternatively, the bird could indicate an absence of turbines in the photograph by hopping to a perch at the rear of the viewing box. No food reward was given for appropriate responses to photographs without turbines. On the other hand, when the bird responded inappropriately to either stimulus type, that is, head thrust into viewing window in response to a photograph without turbines or absence of a head thrust (wait or hop to rear perch) in response to a photograph containing turbines, a ten second delay was imposed before the presentation of the next stimulus photograph.

The kestrels were trained to discriminate photographs of turbines from photographs without turbines using the same set of 40 training photographs again and again. The presentation sequence of the two photograph types was randomized so that the birds could not predict what photograph type would be presented next. After the kestrels had mastered the training photographs, critical-tests were performed with 210 photographs the birds had never seen before. Each novel photograph was shown only once during each kestrel's critical tests.

[3] While this is a standard component of go/no-go procedures, the kestrels appeared to have difficulties waiting without responding in some way. This generated a very high error rate until a perch was installed at the rear of the viewing box and provided an alternative mechanism for the birds to indicate stimuli without turbines.

Both kestrels demonstrated a capacity to categorize, into groups, objects with which they were not directly familiar. They correctly identified both photographs containing turbines and those without turbines in approximately 96% of the critical-test trials (see Fig. 16). These performances were significantly above random based on statistical analysis using the Test of Significance of a Binomial Proportion (Snedecor and Cochran 1967), kestrel Ak19: Z_C = 12.582, p « 0.0001; kestrel Ak16: Z_C = 12.444, p « 0.0001. These results provide the first demonstration of categorical discrimination in a raptor.

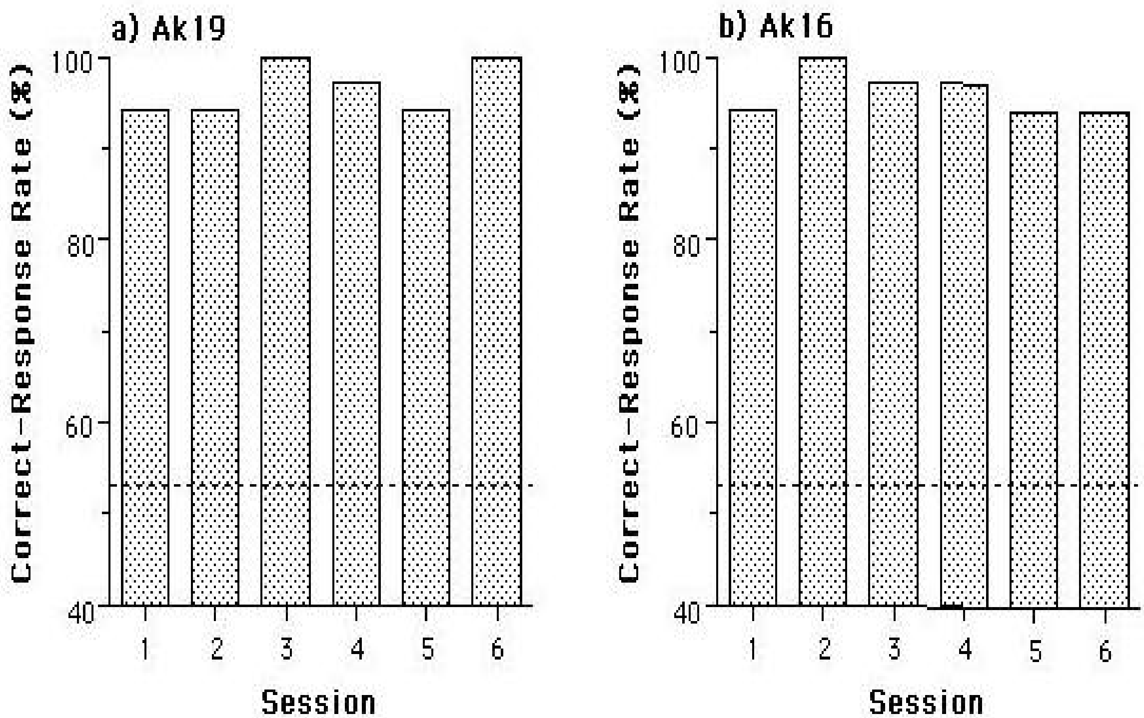

FIGURE 16. Category formation and discrimination in American kestrels. *Two kestrels, a) Ak19 and b) Ak16, successfully discriminated between photographs showing wind turbines and similar photographs lacking turbines (see Fig. 14); the kestrels' discrimination rates significantly exceeded random performance rates. These results demonstrate that kestrels are capable of grouping objects into categories. Random performances would have fallen at the level of the dashed lines. The dashed lines at the 53.1% correct-response rate represents a modified-random performance (McIsaac - submitted to NREL).*

The capacity to categorize objects may enable kestrels to learn information about a group of objects, such as wind turbines, and to associate such information with members of the group never before encountered. Such a capacity could provide the basis of mitigation procedures to deter close contact with turbines, or to avoid turbines altogether. See McIsaac and Fuller (submitted to NREL) for additional discussion of this topic. Aversive-conditioning procedures intended to keep California condors away from dangerous man-made structures are being used with condors (Davis and Sorenson NAWPPM IV); such procedures require the capacity to group objects into categories.

Discussion of Findings

Our results indicate that raptors may not clearly see turbine blades under some environmental conditions, and that applying high-contrast patterns to turbine blades may increase the conspicuity of the blades. Based on the results from all of our studies we make several recommendations concerning turbine-blade patterns. We tentatively recommend a pattern with square-wave, black-and-white[4] bands that run across the blade (e.g., see Fig. 9, pattern nos. 2-4). Across-blade pattern components produced significantly better conspicuity in our test kestrel (McIsaac and McDonald (b) - submitted to NREL) and in humans (McIsaac and Chastain - submitted to NREL) than did components running the length of the blade. The across-blade components should run the entire width of the blade, front and back (i.e., a band around the blade). However, the distance the component runs along the length of the blade should be set according to the target species' visual acuity, and the distance between blade and bird at which visual resolution is desired, e.g., sufficient distance for the bird to maneuver around the turbine in strong wind.

For a given bird-to-blade distance, pattern components large enough to be resolved by a kestrel also should be large enough to be seen by larger-eyed raptor species such as the Golden Eagle (*Aquila chrysaetos*) and Red-tailed Hawk; these are the three raptor species found dead most frequently in the Altamont Pass wind plant (Howell and DiDonato 1991, Howell and Noone 1992, Orloff and Flannery 1992). For example, blade-pattern components must have at least one dimension extending 20 cm or more in order for kestrels to first resolve the coarsest details of the blade at a distance of 34.4 m. This calculation assumes an acuity of 1.5 cyc./deg., high contrast, bright illumination (McIsaac and Whitlock (b) - submitted to NREL), and a moderate rotational rate (68.5 rpm). The Green Ridge Power 56-100 turbines rotate at 71 rpm (Gipe 1995).

If the bird is flying downwind at 30 mph (air speed) in a 30 mph wind then the resulting ground speed will be 60 mph, which leaves the bird 1.3 seconds until it reaches the blade plane (McIsaac and Fuller - submitted to NREL). Such a short time interval may not leave the bird sufficient time to process the visual information, decide on a course of action, and then execute that action, before it is at risk of striking the blades. Thus, the dimensions of blade-

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[4] The white components should reflect in the ultraviolet spectrum as well as in the visible, and the black should absorb in the ultraviolet spectrum as well as in the visible. Ultraviolet spectra should be incorporated into the pattern because birds can see this region of the spectrum (Bennett and Cuthill 1994, Kreithen and Eisner 1978, Parrish et al. 1984, Viitala et al. 1995), and can potentially obtain additional information concerning the pattern and blade from these spectra.

pattern components should take into account not only the visual capacities of raptors but also the species flight characteristics and wind conditions in the field. See McIsaac and Fuller (submitted to NREL) and McIsaac and Whitlock (submitted to NREL) for additional discussion of this topic. While I have provided guidelines for the design of turbine-blade patterns based on our laboratory studies, ultimately any blade pattern must be carefully tested in the wind-energy operations environment to verify its effectiveness.

Acknowledgments

We thank Boise State University, Kenetech Windpower, Inc. (grant no. 04-01-692-L615-43), and the National Renewable Energy Laboratory (contract no. XAM-7-16454-02) who provided financial support for this work. Dr. Thomas Cade, Dr. Mark Fuller, Dr. Melvin Kreithen, Dr. Vance Tucker, and Dr. Charles Walcott provided much-appreciated oversight of the work summarized in this report in their capacity as members of a panel of senior scientists assembled by Kenetech Windpower, Inc. Dr. Dennis McDonald helped design and constructed the computer-driven apparati. Dan Gossett, Peter Whitlock assisted in the running of experiments and in maintaining the birds, and Greg Draheim and George Carpenter also helped to maintain the birds.

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General Discussion

Asked whether he had considered using video footage to test bird reactions to painted vs. unpainted turbines, Dr. McIsaac agreed that it would be a good idea, but said he had not had the funding or time to do field studies or observations. Preliminary before and after field observations have suggested that painting does make a difference, but there were a number of confounding factors and not enough data from which to draw firm conclusions.

One participant asked whether Dr. McIsaac was finding that birds really were able to recognize turbines in photographic images of wind turbines in the distance. Dr. McIsaac answered that "they were able to tell that there were groups of things (in this case, turbines) that were in the photos. And even parts of wind turbines."

Reduction of Motion Smear to Reduce Avian Collisions with Wind Turbines

by

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Abstract

Motion smear is the degradation of the visibility of rapidly moving objects. It results from the inability of the retina of the eye to process the high temporal frequencies of stimulation that result from high velocities of retinal-image motion. In the case of wind turbines, motion smear occurs primarily at the tips of the blades, making them deceptively transparent at high retinal-image velocities. Attempts to minimize motion smear must take into account its causes and attempt to reduce the temporal frequency of stimulation of the retina. Anti-motion-smear patterns are designed to do this by not repeating a pattern in one location on a turbine blade at the same location on any other blade. In a three-blade turbine, the temporal frequency of stimulation is thereby reduced by a factor of three.

To simulate turbines in the laboratory, we are using a variable-speed motor to spin an array of three blades with a diameter of 64 cm. The blades with anti-motion-smear patterns are compared with blades that have no patterns or blades with patterns that are not staggered to reduce the temporal frequency of stimulation. Because this apparatus is relatively close to the subject's eye, we are able to simulate retinal-image velocities that would occur in a real environment with wind turbines having diameters of 20 m or more. The subjects used are American kestrels (*Falco sparverius*). Each kestrel is anesthetized and electrodes are inserted under the eyelids in contact with the cornea to record the pattern electroretinogram (PERG) from the retina. The amplitude of the PERG in microvolts is our measure of pattern visibility.

Our current data show that anti-motion-smear patterns produce a higher PERG amplitude, which translates into a higher pattern visibility at a given distance. For example, at a retinal velocity of 120 deg of visual angle/sec, the most effective anti-motion-smear patterns produced PERG amplitudes that were three times the amplitude of the blades with no patterns. Our most recent studies suggest that a single, solid-black blade, paired with two white blades, is the most visible stimulus, possibly because it stimulates a larger area of the retina than striped blades. Even though the anti-motion-smear patterns are more visible at a distance of approximately 25 m than blank blades or blades with unstaggered, repeating patterns, as the bird gets closer to the blades, the retina is unable to process the progressively higher retinal-image velocities and all patterns rapidly lose visibility with decreasing distance.

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Introduction

The development of wind power as a source for the generation of electricity has led to the establishment of wind resource areas such as at Altamont Pass, California, in which thousands of wind turbines have been erected. While generally conceded to be environmentally safe, wind turbines have been reported to be hazardous to flying birds (Howell 1990; Colson & Associates 1995; NRL wind-power meeting proceedings 1994, 1995). The research that is described in this report is designed to take into account what is known from human research on the degradation of the perception of rapidly moving objects and to apply it to the problem of the reduction of avian collisions with wind turbines. An important consideration here, however, is to keep in mind that there are considerable differences between the avian and human visual systems that must be taken into account in designing experiments.

Visual hypotheses to account for collisions. Among various hypotheses to account for avian-turbine collisions based on vision, at least three deserve serious consideration:

1. ***Inability to divide attention between surveying the ground for prey and monitoring the horizon and above for obstacles .*** This hypothesis derives from directly substituting our knowledge of human vision for that of avian vision. Humans are foveate animals; we have a 2.5*m* fovea (centered in the 5*m* macula), which is our area of sharpest vision, with which we search the visual world, like someone searching a dark room with a narrow-beam searchlight. This results from our very low ratio (approximately 1:1) of photoreceptors to ganglion cells in the macular region of the retina. Once outside the macular region, the ratio of receptors to ganglion cells increases progressively to 50:1-100:1 and our visual acuity drops sharply. Birds, on the other hand, and many other animals as well, have universal macularity, which means that they have a low ratio of receptors to ganglion cells (4:1-8:1) out to the periphery of the retina, which means that they maintain quite good acuity even in peripheral vision. (Hodos, Miller and Fite 1991; Hodos 1993). In addition, a specialization of raptors is the presence of two foveal regions; one for frontal vision and one for looking at the ground. Moreover, birds have various optical methods for keeping objects at different distances simultaneously in focus on the retina (Hodos and Erichsen, 1990). Because of these considerations, this seems a most unlikely hypothesis.

2. ***Motion smear: Reduced visibility of the blades, especially at the tips***. As an object moves across the retina with increasing speed, it becomes progressively blurred; this phenomenon is known as "motion smear" or "motion blur" and is well known in human psychophysical research. It results from the fact that the human visual system is sluggish in its response to temporal stimulation; i.e., the visual system summates signals over periods of about 120 msec in daylight (Burr 1980; Bex et al. 1995). The advantage of this summation is that it enhances visual sensitivity, but at the price of the smearing or blurring of moving targets. Some scientists have offered evidence that the human retina has a mechanism for sharpening blurred, moving images (Bex et al. 1995; Hemmett and Bex 1996). Others disagree (Burr and Morgan 1997). Whether or not birds have such a mechanism is unknown.

The phenomenon of motion smear is apparent at the tips of wind-turbine rotor blades turning at the rate of approximately 35 RPM and higher. The more central regions of the blades do not suffer from motion smear because of their lower velocity. Since both the central regions and the tips are rotating at the same RPM, it seems most likely that the relevant variable is the velocity of the blades at the more peripheral regions. The higher velocity of the blade tip has placed it in the temporal-summation zone in which the retina is sluggish in its ability to resolve temporally separated stimuli, whereas the lower velocities of the more central portions are below the transition point and the individual blades can be seen more or less clearly.

3. ***Angle of approach to the blades.*** A serious problem in attempting to solve the problem of collisions is the absence of data on the angle of approach to the blades at the moment of collision. If the birds are struck while approaching the blades from a direction that is parallel to the long axis of the blade, then the problem of motion smear is compounded by the very small profile of the blades from that line of sight. A solution to this problem must (1) effectively increase the profile of the blades in this orientation and (2) take into account the causes of motion smear.

The principle of motion-smear reduction. The solution to the problem of motion smear is to maximize the time between successive stimulations of the same retinal region. Any type of pattern applied to the blades that does not take this into account will be ineffective. The typical approach is to apply the same pattern to each blade, which does nothing to maximize the time between successive stimulations of the same retinal region. Our approach is to use different patterns on each blade. The patterns are designed so that a pattern on any given blade region is not repeated on the equivalent region of the other two blades. Thus stimulations per second of any given retinal region are reduced by a factor of three and the time between stimulations is virtually tripled.

Motion smear reduction in frontal approaches to the blades. Fig. 1 shows an anti-motion-smear pattern with the black stripes staggered across the blade in such a way that a given stripe appears in only one location on any of the three blades. In this example, one blade has stripes in locations 1, 4, and 7. Another blade has stripes in locations 3 and 6, and the third blade has stripes in locations 2 and 5.

In our laboratory, we constructed an anti-motion-smear rotor-blade assembly from foam board and mounted it on a variable-speed motor. As the speed of the motor increased, human observers reported that the individual bars at the more peripheral regions of the blade are no longer seen as individual bars, but are gradually replaced by a series of grey, concentric rings that pulsate slightly. The spaces between the rings, however, continue to show the transparency associated with motion smear. The effect is quite dramatic at high tip velocities. Blades on which the bars have been placed at the same location on all blades also show a concentric-ring effect, but not as dramatically as the staggered-pattern blades. Blades that are uniformly white or uniformly black, show the typical motion-smear effect. We must caution, however, that this is an effect on human observers.

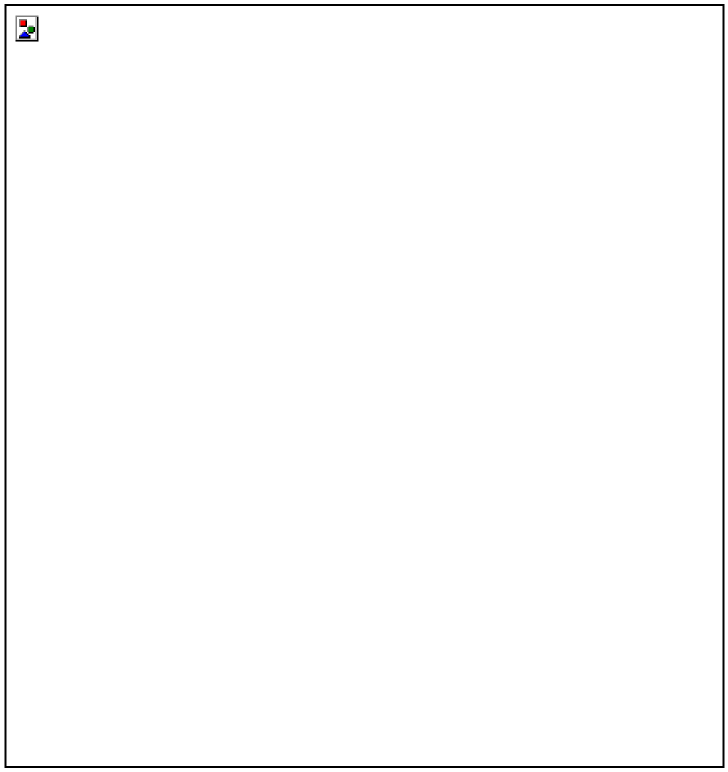

FIGURE 1. An anti-motion-smear pattern. A black bar is not repeated in the same location on either of the two other blades.

Motion-smear reduction in lateral approaches to the rotor blades. The combination of motion smear and a very narrow profile offered by the fast moving tips of rotor blades approached from the side could be quite deadly for a bird. The solution to this problem is a rectangular attachment to the outer tip of the blade. This attachment, which should probably be 0.5 - 0.75 m long and 0.3 m high, and painted black, should be fastened so as to be at right angles to the long axis of the blade (see. Fig. 2). The attachment ideally would be positioned on only one blade to minimize motion smear. Should a single such device have sufficient weight to cause an imbalance of the rotor assembly, additional rectangles could be added to the other two blades for balance. These preferably should be transparent, or at least painted white. We have not yet evaluated the visibility of these lateral anti-motion-smear devices.

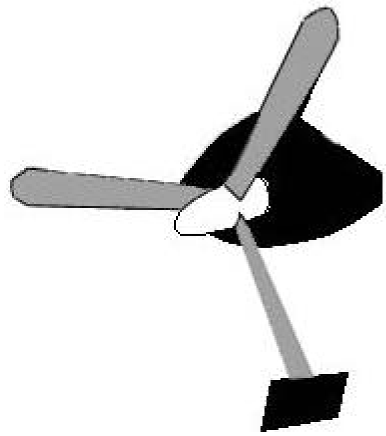

FIGURE 2. A black rectangle affixed to the tip of a single rotor blade.

Retinal images and retinal-image velocities. Retinal-image velocity is calculated from the law of the visual angle, which is illustrated in Fig. 3. As may be seen in this figure, all objects, at whatever distance, that cast the same size image on the retina, subtend the same angle. The angle inside the eye is the same as that from the eye to the object. These angles are called "visual angles" and are the conventional units to describe object size since they are directly related to retinal-image size, which is the only relevant variable for these purposes. In the experiments described below, the tip velocity will be retinal velocity and will be expressed in degrees of visual angle/sec (dva/sec). Degrees of visual angle are calculated as 57.3 X h/d, in which h is the object size (height, width, or area), d is the distance, and 57.3 is the conversion factor from radians to degrees. The advantage of these units for laboratory research is that the tip velocity of a rotor blade many meters in length as seen from a distance of 10-20 m can be simulated in the laboratory with a much smaller blade located 0.5-0.6 m from the eye and moving at a much higher RPM rate.

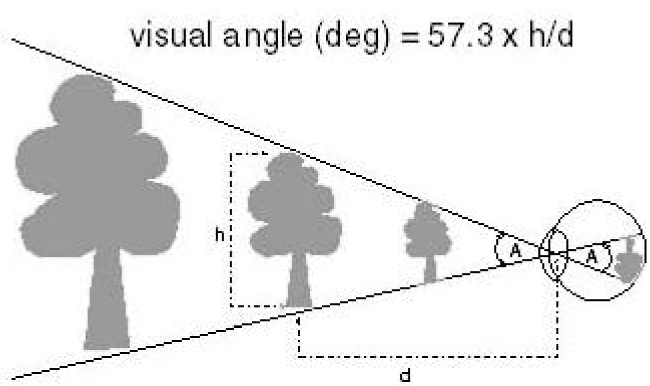

FIGURE 3. The law of the visual angle. Objects of different sizes and distances that subtend the same

angle will cast the same size image on the retina. Angles A and A' are the same.

In addition to the type, location and configuration of the stimuli, the question of which is the relevant motion variable to consider is important. As discussed above, simple RPM most likely is not a relevant variable because it is the same for both the peripheral and central regions of the blades, yet the perceptual effects of the same RPM on each region are very different. This is because the central and peripheral regions of the blades are moving at different velocities. As is well known in human visual perception, however, the actual velocity of stimulus (the rotor blades in this case) typically is irrelevant; what is crucial is the velocity of the image of the blade as it sweeps across the retina of the eye. As the bird approaches the rotor blades, the size of their retinal image increases just as a photographic image increases in size as the camera approaches the subject (Fig. 4). This means that as the bird approaches the rotor blades, its retinal velocity increases because the tip of the blade must cover a greater distance in the same time. This is related to the phenomenon of "motion parallax"(Goldstein, 1984), which we can observe by looking out the side window of a rapidly moving train or car; objects close to the window race by with great speed and have considerable motion smear, while distant objects move by at a more leisurely pace and remain sharply in focus. Therefore the proper way to express the velocity of the rotor tips is in units of retinal-image velocity, which take into account the distance as well as the size of the object.

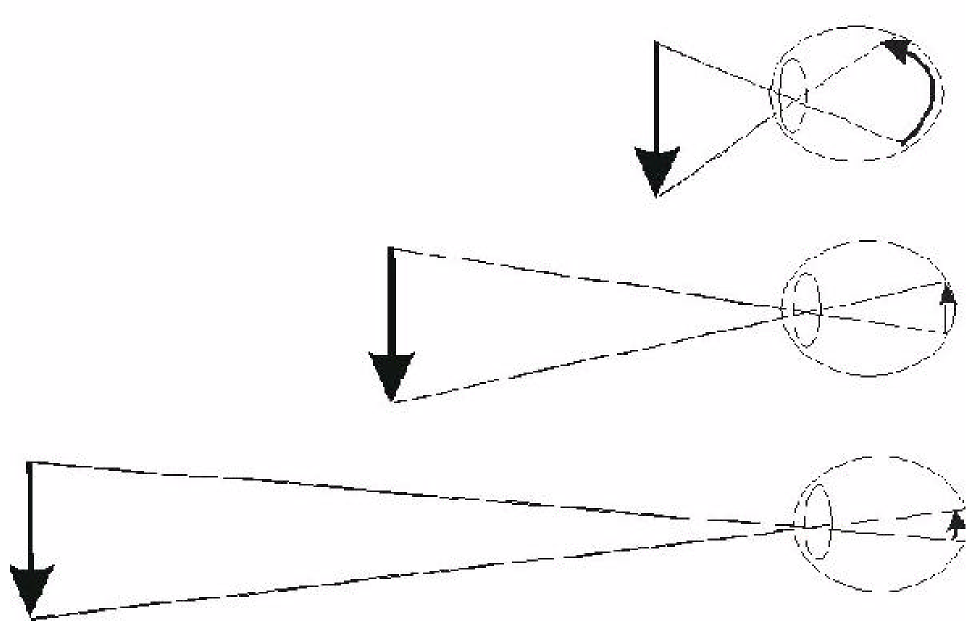

FIGURE 4. As an object moving perpendicularly to the axis of the eye, such as a turbine blade, gets closer to the eye, as when a bird is flying towards the blade, its visual angle increases and the image of the blade must cover a larger area of the retina in the same period of time; i.e., its retinal-image velocity increases.

The foregoing discussion should make several points clear to the reader: (1) The RPM of the blades tells nothing about the velocity of the image of those blades as they sweep across the retina of the eye, and hence their visibility, unless one takes into account the distance. (2) Beyond a certain point, the visibility of a constant-RPM blade will decrease as the observer approaches the blades due to motion smear. (3) Even though our stimulus display is minuscule in comparison to the absolute size of a wind-turbine rotor, because of the very short viewing distance, the retinal image sizes and retinal velocities are comparable.

The pattern electroretinogram. Behavioral psychophysical methods to determine the optimal parameters of the patterns to minimize motion smear are extremely slow, time consuming and labor intensive. A more rapid method, that has been used for psychophysical purposes is the pattern electroretinogram or PERG (Fitzke et al. 1984, 1985a,b; Hodos et al.1985; Porciatti et al. 1991) which is generated whenever there is a local contrast change on the retina, such as would be produced by a black bar moving across the retina. The PERG is generated when the retinal area goes from lighter to darker as the leading edge of the bar enters it and again when it goes from darker to lighter as the trailing edge exits it. Similar effects would be achieved by the images of rotating blades as they passed a given retinal area. Blank rotor blades should generate a lower PERG amplitude than striped blades because they have a lower contrast against the background than do the stripes, which have nearly 100% contrast. In this case, contrast is defined as $(L_L - L_D / L_L + L_D)$ X 100, in which L_L is the luminance of the brighter area and L_D is the luminance of the dimmer area. The pattern electroretinogram has been used to measure visual acuity, contrast sensitivity, and a variety of other psychophysical indicators.

Methods

Subjects. The subjects were seven American kestrels (*Falco sparverius*) on loan from the Patuxent Wildlife Research Center of the US Department of the Interior, Laurel, MD. The birds were housed in the laboratory for 3-4 days per week and returned to their large, outdoor flight cages at the Patuxent Center at all other times for fresh air and exercise.

Apparatus. The PERG was recorded and analyzed by an ENFANT electrophysiology system (Neuroscientific Corp., Farmington, NY). This instrument is capable of presenting a wide range of visual stimuli on a video display monitor and recording, amplifying, displaying, and analyzing electrical potentials such as those generated by the PERG. Among the analytical techniques available on this instrument are signal averaging, curve fitting, variable high-pass and low-pass filtering, various regression analyses, Fourier analysis of frequency components, and others.

To produce the simulated blade stimuli, a variable-speed motor was fitted with 32 cm-long rotor blades made from 5 mm-thick white foam board. These were displayed against a background of the same material to provide a worst-case, minimal-contrast situation between blades and the background. Additional sets of blades of the same material also were prepared with black stripes positioned according to variations on the principle displayed in Fig. 1. The diameter of the circle formed by the outer tips of the blades (64 cm), at a viewing distance of 60 cm, formed a retinal image that subtended a visual angle of 61.1*m*. The birds, however, saw only the lower half of this circle, so the angular subtense of the display that they saw was approximately 30.6*m*. This would be the same size retinal image as a 20 m diameter rotor would make at a distance of 19 m.

Procedure. In order to record the PERG, the animal was anesthetized with 20% chloral hydrate (365 mg/kg, IM) and its head was placed in a rigid metal head holder. All pressure points were treated with local anesthetic. Platinum electrodes (0.5 mm diameter) were inserted in each lower eyelid so that the electrode made good contact with the cornea, just below the pupil. Care was taken not to obscure the pupil. A third electrode was inserted in the skin of the scalp to serve as a ground. One eye was covered with a black patch and the electrode in this eye served as the indifferent electrode. This technique is minimally invasive and the anesthesia depth is lighter than that required for major surgery.

Velocity parameters of the blades. Eight blade velocities ranging from 36 to 134 RPM were used in the experiment. Table 1 shows the blade velocities in RPM, m/sec, and deg/sec, the velocity of the retinal image in degrees of visual angle per sec (dva/sec).

TABLE 1. Blade velocities used in experiment

A. Blade Velocity (RPM)	**B. Blade-tip Velocity (m/sec)**	**C. Blade-tip Velocity (deg/sec)**	**D. Blade-tip Retinal-image Velocity (dva/sec)**
36	1.2	216	115
48	1.6	288	153
56	1.9	336	179
66	2.2	396	211
80	2.7	480	256
96	3.2	576	307
105	3.5	630	336
134	4.5	804	428

Do these stimulus parameters realistically model what would occur in the field? A 20 m diameter rotor has a circumference of 62.8 m. At 70 RPM, the tip velocity is 4,398 m/min or 263,894 m/hr or 264 km/hr (165 mph). 4,398 m/min also equals 73.3 m/sec. Its retinal-image velocity, however, depends on the distance at which it is viewed (see above). At a distance of 36.5 m it will have a retinal-image velocity of 115 dva/sec, which is the equivalent of the retinal-image velocity of our 64 cm-diameter stimulus at 36 RPM (Column D in the table). At a distance of 9.8 m, however, the 20 m rotor will have a retinal-image velocity of 428 dva/sec, which is the same as our 134 RPM stimulus.

Table 2 describes the series of patterns that was used in the studies reported here. The baseline against which all blade patterns is compared with is the noise condition, which is the measure of biological noise and ambient electrical noise. The amplitude of the PERG is judged not only in terms of its absolute amplitude in *m*V, but also in its relationship to the noise level. The higher the signal-to-noise ratio, the more visible the moving images on the retina are. The standard of comparison for the relative visibility of any striped pattern is the PERG amplitude of the blank blades, which are intended to simulate the typical, unpatterned, wind-turbine blade array. Our initial preliminary observations suggested that a way to deal with the different velocities of the central and peripheral regions of the blade would be to have thick stripes between the center of the blade and the hub, and thin stripes between the center of the blade and the tip. We also investigated anti-motion-smear patterns made up only of thin stripes and only of thick stripes. Finally, we attempted the simplest type of anti-motion-smear design; i.e., a single black blade, paired with two blank blades, as illustrated in Figure 5.

TABLE 2. Summary of the blade patterns

Pattern type	**Description**
Noise	both eyes covered; no visual stimulation
Blank	white blades without stripes
Non-staggered (thin)	the same thin-stripe pattern on each blade
Staggered thin	anti-motion-smear; thin stripes
Staggered (thick and thin)	anti-motion-smear; thick stripes from center of blade to hub; thin stripes from center to tip
Single-blade (thin)	anti-motion-smear; thin stripes on one blade; two blades blank
Single-blade (thick and thin)	anti-motion-smear; thick stripes from center of blade to hub; thin stripes from center to tip on one blade; two blades blank
Single-blade (solid black)	anti-motion-smear; one blade solid black; two blades blank.

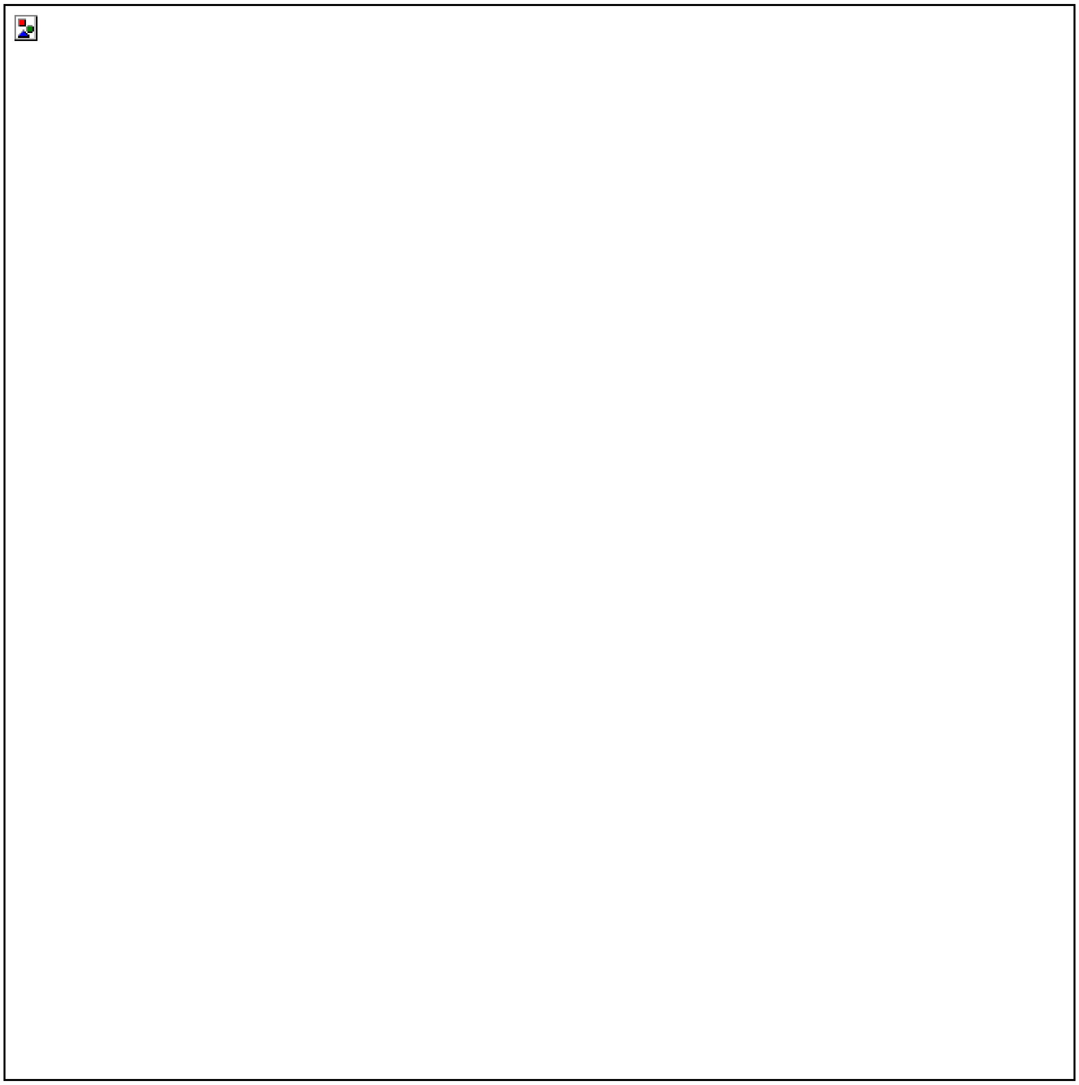

FIGURE 5. The single, black blade, anti-motion-smear pattern.

Refractive studies and visual acuity. Before conducting any visual experiments, it is vital to carry out a preliminary study of the refractive state of the eye. By determining which corrective lens gives the highest visual acuity (the precise equivalent of an optometric examination), we are assured that the image of the stimulus display is in focus on the retina. The PERG is used for this procedure as well. The method is based on the observation that PERG amplitude decreases as the spatial frequency of a grating stimulus increases. By increasing the spatial frequency (decreasing the width of the bars and spaces) until the PERG amplitude reaches the noise level, an estimate of visual acuity can be obtained (Porciatti et al. 1991). Such a refractive study was carried out on each kestrel.

Results

Refractive state and visual acuity. Our results collected thus far from seven kestrels indicate that the mean refractive state is +0.07 diopters ± 0.07 s.e.m., which indicates that for this population of young, adult kestrels, no effective refractive error was found. The mean visual acuity was 20.6 cycles/dva ± 2.7 s.e.m. These data were collected, however, while attempting to establish the optimum position on the retina for best acuity and not all data points were from the optimum region. The data from this optimal retinal location in five kestrels indicate that mean acuity was 23.2 cycles/dva, which corresponds to an acuity of 20/26 on the Snellen eye chart, common to optometry and ophthalmology offices, on which 20/20 equals normal human visual acuity. The best bird, however, had an acuity of 33.5 cycles per degree of visual angle, corresponding to 20/18 on the Snellen chart.

PERG results with rotating blades. We have collected data from four kestrels using the following stimuli: (1) blank blades; (2) blades with thin stripes in our staggered pattern; (3) blades with thick stripes in our staggered pattern; (4) no stimulus; i.e., the eyes are covered so that they cannot see the blades or anything else. Fig. 6 shows the mean results of seven recording sessions with each of the four types of stimulus configuration. The figure plots the mean amplitude (n = 7) of the pattern electroretinogram (PERG) in *m*V as a function of the velocity of the retinal image of the blade as it sweeps across the retina. Retinal velocity is in degrees of visual angle per second (dva/sec). Later in this report, we will translate retinal velocity into practical terms that are of relevance to a bird approaching a moving wind turbine.

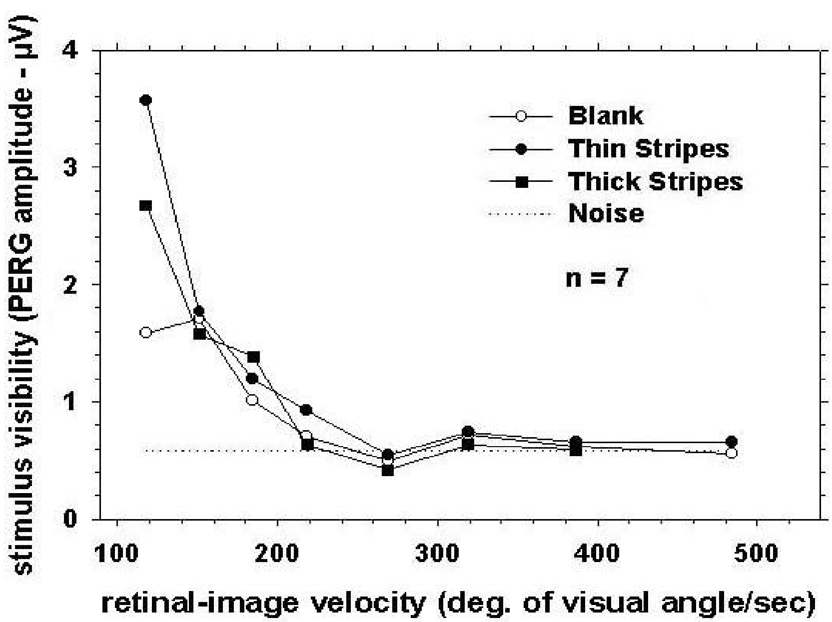

FIGURE 6. PERG amplitudes as a function of retinal-image velocity for four stimulus types.

In the figure, the dotted line indicates the average PERG amplitude when the eyes are closed, which represents the level of biological noise and hence no visibility. We are assuming here that visibility varies linearly with the PERG amplitude that is above the noise level. Thus, doubling the amplitude above the noise level represents a doubling of visibility. Our noise level is approximately 0.6 *m*V. If PERG amplitude above noise varies linearly with visibility, then for blank blades, the visibility at 118 dva/sec is about 1.0 (1.6 *m*V minus 0.6 *m*V). By about 185 dva/sec the visibility has dropped in half, and by about 220 dva/sec it has dropped to zero (i.e., to the noise level). In contrast, the thick stripes have a visibility of 2.05 (2.6 *m*V minus 0.6 *m*V) at 118 dva/sec, whereas the thin stripes have a visibility of 3.0 (3.6 *m*V minus 0.6 *m*V) at the same retinal-image velocity. Thus we can say that the thin, staggered stripes have a visibility that is approximately three times greater than the blank blades at 118 dva/sec. The next higher speed that we used was150 dva/sec. At this retinal velocity, all the patterns performed equally poorly, depending on your perspective. At 220 dva/sec, thick stripes and the blank blades have achieved zero visibility, while the thin stripes have a slight (but probably meaningless) visibility advantage of 0.4. Thereafter, all the stimuli are essentially have no visibility as individual blades, but rather appear as a blur or smear.

What does this mean in practical terms? Fig. 7 gives some idea. In this figure, the X-axis has been changed to represent distance from the eye. We can make this conversion because for any moving stimulus, the retinal-image velocity increases linearly as the distance to the eye decreases. In this figure, we have made this conversion for a hypothetical 20-m diameter turbine rotating at 45 RPM. The figure shows that at distances from the stimulus of 23 m, the three types of stimuli are clearly different, but the difference is gone when the distance shortens to 18 m and closer. By 12 m, the visibility of all the patterns has dropped effectively to zero.

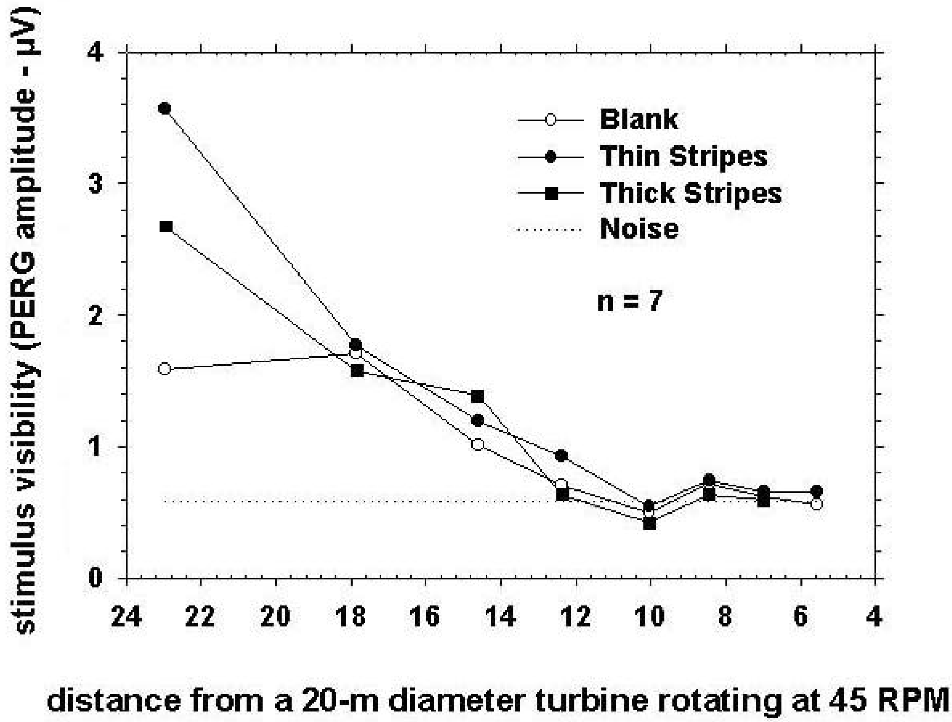

Figure 7. Blade visibility as a function of distance from a hypothetical 20-m diameter turbine rotating at 45 RPM in the field.

Fig. 8 shows the full range of patterns that we have tested thus far. At present, these visibility data have been collected only at a retinal-image-velocity of 120 dva/sec. At present, we have data from three recording sessions from three kestrels. We plan to have data from at least five sessions from each of five kestrels before attempting a statistical analysis to determine which patterns differ significantly from any of the others. Pattern 1 represents the noise condition (eyes covered) and, as in Figures 1 and 2, constitutes the baseline against which other patterns are compared. In these experiments the average noise amplitude was approximately 0.5 *m*V. Pattern 2 indicates the PERG amplitude of three blank blades, which have a visibility of about 0.9 (*m*V above noise). Patterns 3 and 4 had visibilities of about 1.4. Pattern 3 was a single blade pattern with thick and thin stripes and pattern 4 was a three-blade pattern with unstaggered stripes. The latter is a blade type that is in experimental use in the Altamont wind area. Pattern 5 had thick and thin stripes staggered in an anti-motion-smear configuration. Its visibility was 2.0, which is slightly more than double that of the blank blades. Pattern 6 had the same thin stripes as pattern 4, but on only on a single blade, which conforms to the anti-motion-smear principle. It had a somewhat better visibility of 2.3 (*m*V above noise). Pattern 7, which was a single, solid black blade with two blank blades, had a visibility of 2.5. Pattern 8 was the staggered, thin-stripe, anti-motion-smear pattern that was used to collect the data in Figs. 5 and 6. It proved to be the most effective stimulus with a visibility of 2.7 (*m*V above noise).

FIGURE 8. Visibility of seven blade patterns relative to the "noise" condition (pattern 1), which is also represented as a horizontal line.

Discussion

Refraction and visual acuity. Our data indicate that the seven kestrels were free of refractive errors that could have affected their vision. In addition, we determined that under the conditions of our experiment, the average visual acuity of the five from which we had the optimal measurements was 23.2 cycles/dva. The best bird of these five had an acuity of 33.5 cycles/dva. Published behavioral data from a single kestrel by Hirsch (1982), indicate an acuity of 40 cycles/dva. We recently have reported elsewhere (Hodos et al. 2000), however, that the PERG underestimates visual acuity by approximately 79% as compared to acuity determined by behavioral methods. Increasing 23.2 cycles/dva by 79% indicates an acuity of

41 c/dva, comparable to the behavioral result reported for this species by Hirsch (1982). The acuity of our best kestrel (33.5 cycles/dva) increased by 79% would be approximately 60 cycles/dva.

PERG studies of blade patterns. An ideal visual deterrent for avian-turbine collisions is one that continues to provide high visibility as the bird gets closer and closer to the whirling blades. Our analysis of the problem from the velocity detection literature and from our own experiments, reported here, indicate that the physiology of the retina will not permit such a situation. Beyond a certain point, the velocity of the retinal images of the blades sweeping across the retina will overwhelm the retina's ability to keep up. The initial effect will be a smearing or blurring of the image of the blades, and finally their complete transparency, which could appear as an illusory safe place to fly, with deadly consequences for the bird. Our findings indicate that for a hypothetical turbine with a 20-m diameter blade circumference and rotating at 45 RPM, our anti-motion smear patterns are quite visible at distances of about 23 m. By 18 m, however, visibility has dropped sharply and no blade pattern, of those we have tested, has an advantage. By 12 m, visibility has effectively dropped to zero as motion smear and transparency become the dominant visual events.

How useful is good blade visibility at 23 m? A kestrel with the wind at its back could safely maneuver at about 25 m (M. Morrison, personal communication). Closer than that, however, the bird would be at risk for not being able to avoid the blades should a sudden wind gust push it forward. Moving closer to the blades to about 14.5 m, the blank blades have lost 50% of their visibility at 23 m, and by 12 m, all the blade patterns have become totally blurred. Good visibility at a distance of approximately 23 m would seem to be a useful deterrent, if low tip visibility is a factor in collisions. On the other hand, since the blade tips at distances of 10-12 m and closer appear to be transparent blurs, the birds might interpret them as being "safe"; i.e., as the bird gets closer, the threatening looking blades disappear and the bird might feel safe in approaching closer or even trying to fly through the transparent visual smear.

The results of our comparison of different blade patterns, while not yet complete, is highly suggestive that the thin-stripe, staggered, anti-motion-smear pattern is the most visible of any that we tested. Its visibility (*m*V above noise) was 2.7, which is three times the visibility of the blank blades. (0.9). This is what the anti-motion-smear principle would predict. Not far behind was the single black blade with a visibility of 2.5, which almost certainly will not be statistically different from the 2.7 of the thin, staggered stripes. We now have to determine whether these patterns will maintain their superiority at distances shorter than 18 m.

Additional laboratory research. The optimal color of the blade patterns is a variable that needs to be investigated. The human motion-smear literature suggests that if color is important, it probably would be only be so at the lower velocities (Burr et al. 1998); this, however, would have to be investigated in the avian eye, which is much more specialized for color-vision processing than the human eye. In particular, we need to determine whether color offers any advantage over black in increasing visibility at the shorter distances and will shortly be beginning some studies on this question. Finally, we will be evaluating the optimal size, shape, and color of devices to deter lateral approaches to blades.

Applications to the wind-power industry. The finding that anti-motion-smear patterns increase the visibility of turbine blades at distances at which raptors could safely maneuver away from them should be of interest to the industry. These data, however, only apply to conditions of bright illumination. We have no idea at present to what extent these stimuli retain their improved visibility under sub-optimal viewing conditions, such as mist, rain, etc. Nor will they (or any other visual pattern, for that matter) retain their visibility once the animal gets close enough for the retinal-image velocity to exceed 200 dva/sec, at which point the bird's retina has passed the limit of its ability to process temporally changing stimuli. Nevertheless, such patterns are worth testing in the field to determine whether the visibility advantages they offer will reduce avian mortality. The finding that a single, solid-black blade, paired with two blank blades is a highly visible stimulus could have useful economic consequences for wind power companies that have an interest in testing this type of deterrent, as there would be no requirement for the precision application of stripes in specific positions on each of three blades.

Acknowledgments

The authors wish to thank Dr. John French of the Patuxent Wildlife Research Center for the generous loan of the kestrels. This research was supported by NREL Subcontract Number XAM 9292 1101.

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General Discussion

Dr. Hodos initiated the general discussion following his presentation by asking the group, “What do wildlife biologists think about this?

One respondent suggested the use of strobes mounted on the hub of the turbine to “freeze” the moving image, giving the appearance that the blade is moving more slowly (and therefore becomes more visible). Another participant pointed out that this would not help a bird avoid the blades, “because the bird would not see the blade where it actually is.”

One participant asked Dr. Hodos how well he expected his laboratory findings to carry over into the field, given the greater complexity of the natural world. Dr. Hodos acknowledged the difference, but noted that, “once the bird is 15 to 20 meters away [from the turbine] …there probably isn’t much of the natural world left that it is viewing.”

Dr. Hodos agreed that it might be interesting to run the experiment with different blade widths. As to whether a larger turbine rotating more slowly would be beneficial from the standpoint of visibility to birds, he noted that it is the tip velocity and the distance that are the critical factors, not the RPM. However, the bird “might be able to get closer” to a slower-moving turbine.

MORTALITY REDUCTION, IMPACT AVOIDANCE, AND DETERRENT CONSIDERATIONS

Day 1 concluded with a third session which focused on the question, *What are we learning about how to reduce avian fatalities due to avian-wind power interactions?* The presentations looked at a variety of mitigation measures being undertaken in the field (in Wyoming and California) and in the laboratory.

Strickland, Dale, W.P. Erickson, G. Johnson, D. Young, and R. Good: *Risk Reduction Avian Studies at the Foote Creek Rim Wind Plant in Wyoming*

Dooling, R.J. and B. Lohr: *The Role of Hearing in Avian Avoidance of Wind Turbines*

Gray, L. Darryl: *State-of-the-Art Permitting and Environmental Review Process for Wind Repowering Projects: New Avoidance and Mitigation Strategies*

Risk Reduction Avian Studies at the Foote Creek Rim Wind Plant in Wyoming

by

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Western EcoSystems Technology, Inc.[1]

Introduction

SeaWest Energy Corporation (SeaWest) began development of the Foote Creek Rim (FCR) Wind Plant in Carbon County, Wyoming, in late 1996. As part of the Bureau of Land Management (BLM) right-of-way permitting process, wildlife risk assessment and monitoring studies associated with the wind plant were initiated by Western EcoSystems Technology, Inc. (WEST) in March 1995. With the exception of 1996, these studies will continue through 2000. A detailed description of the studies are given in previous annual reports (Johnson et al. 1999) and (Strickland et al. 2000a). An additional study began in 1999 with the objective of determining the effect on bird risk of applying a UV gel coat on turbines. The UV gel coat study is funded by the National Renewable Energy Laboratory (NREL) in Golden, Colorado. The study contrasts risk associated with FCR Phase I and II turbines, treated with the gel coat, with risk associated with FCR Phase III turbines which do not have the gel coat. While the primary objective of the risk assessment and monitoring studies is to determine the impact of the wind plant on birds, results of these studies and the UV study provide data potentially helpful in reducing risk to birds. The risk we refer to throughout this paper is risk to birds from construction and operation of a wind turbine facility. Alternatively, risk could be defined as the risk of a single bird colliding with a turbine, risk of indirect impacts such as displacement, and so on.

The first development unit was completed on Foote Creek Rim (FCR), in January 1999, when 69 turbines became fully operational (FCR I). FCR II added three turbines in August 1999 and FCR III added 33 turbines in August 1999. The wind plant currently consists of 105 turbines capable of generating 67.95 MW of electricity.

Methods

The basic study is designed as a before/after control/impact (BACI) study including the wind plant and two reference areas. The wind plant is considered the impact area and two similar areas without wind development are considered control or references areas. Resource selection sampling and analysis (Manly et al. 1993) is used to determine habitat preference. Details of study design are reported in Johnson et al. (1999) and Strickland et al. (2000a). Raptor and other large bird (RLB) surveys using point count observations are conducted year-long to estimate spatial and temporal use of FCR and the two reference areas. Surveys of smaller birds are conducted during the breeding season. Fatality searches are conducted

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throughout the wind plant. An index to relative exposure to the rotor-swept area of turbines based on mean use, proportion of observations recorded as flying, and proportion of flight heights recorded within the rotor-swept height of turbines is calculated for all species. Observations of birds and their locations also provide an indication of how the birds use the wind plant and the surrounding area. The areas surrounding the base of turbines are searched for carcasses. The total number of carcasses is estimated by extrapolating from samples corrected for carcass removal and detection bias. Fatalities provide a direct measure of impact and thus risk to birds. Finally, surveys for prey availability and raptor nesting are conducted throughout the wind resource area.

Prior to initiating the UV studies NREL requested an extensive literature review to identify potential risk reduction methods. After the selection of FCR and UV paint as the experimental treatment, an additional search of the literature focused on information on UV light and its relationship to bird vision.

Results

Literature Review. In-depth studies of avian use and mortality at larger wind plants began in the mid 1980s. Many earlier studies involved only a few turbines or focused on nocturnal migrants (waterfowl or passerines) (see CEC 1995). In recent years there have been numerous studies in the United States and Europe that have intensively investigated the effects of wind turbine development on birds (see CEC 1996), several specifically dealing with raptors at larger windfarms. However, few have addressed the effects of various turbine design features (treatments) or techniques that may reduce mortality.

After reviewing over 200 studies and popular articles, several general observations were possible. Most of the studies relied on descriptive statistics from observational studies. Thus, most conclusions in the studies were not based on statistical inference. In particular, judgments about the effectiveness of risk reduction measures were strictly subjective. None of the studies investigated statistical power, and small sample sizes were the norm. The following techniques were identified as potential risk reducing treatments:

- Painting turbine blades to make them more visible to birds
- Anti-perching devices
- Larger rather than smaller turbines
- Bird flight diverters
- Warning devices using sound or visual cues
- Lighting

Among the painting methods suggested in the literature, UV painting of turbines and turbine blades was considered a possible risk reduction technique. No data exists on the effects of UV paint on bird/wind turbine collisions. We conducted a literature review of biological studies of birds and UV vision, focusing on the following questions to determine if painting turbine blades with UV reflective paint could potentially decrease avian collisions.

- What is UV light and how much ambient UV light exists?
- Are birds particularly sensitive to UV light?
- Can birds better detect UV reflective objects than non-UV reflective objects?

Based on our review of the literature we concluded the following:

- Most birds active diurnally likely can detect UV light (320-400 nm)
- Two raptors have been documented with UV vision (Eurasian kestrel and rough-legged buzzard)
- Species that are primarily nocturnally active probably cannot detect UV
- UV vision is probably important for most aspects of birds life (e.g., foraging, predator avoidance, sexual selection, migration, orientation).
- The extent of bird sensitivity to UV vs. non-UV light is controversial
- UV apparently is especially prevalent at high elevations
- More applied research on UV light and bird vision is needed

Given the level of knowledge about bird vision in the UV spectrum it seemed reasonable to hypothesize that UV light would improve a diurnally active species' ability to see wind turbines coated with a UV reflecting covering.

Phase I and II turbines (72 600-kW Mitsubishi Turbines) were coated with a UV reflecting gel coat (UV turbines) at the time of construction. Phase III turbines (33 750-kW NEG Micon NM Turbines) were painted with a standard paint (NUV turbines) of the same color as the Phase I and II turbines but without the UV gel coat. Phase I and II turbines were constructed together on the south end of the rim while Phase III turbines are immediately north of Phase I and II.

The data from these two areas of the wind plant are treated as observational data from a control/treatment design. Use, avian behavior, and fatalities are used to evaluate risk in association with the Phase I and II turbines (treatment) contrasted with risk associated with Phase III turbines (control). For this analysis we define risk as the probability of death per unit of use, with use being any activity within a defined critical zone near the turbines.

Results of use and fatality surveys. Based on this exposure index, RLB species with the highest exposure to turbines on FCR relative to other species are Golden Eagle (*Aquila chrysaetos*), American crow (*Corvus brachyrhynchos*), red-tailed hawk (*Buteo jamaicensis*), common raven (*Corvus corax*) and black-billed magpie (Pica pica).

Spatial use data collected on FCR indicated that raptors appear to use the rim edge (+ 50 m) significantly more than other portions of the study area (Figure 1). Raptors observed near the rim edge also had a greater tendency to fly within the turbine rotor-swept height than when observed on other portions of the study area. These data suggest that placing turbines >50 m away from the rim edge is likely to reduce collision risk to raptors on FCR.

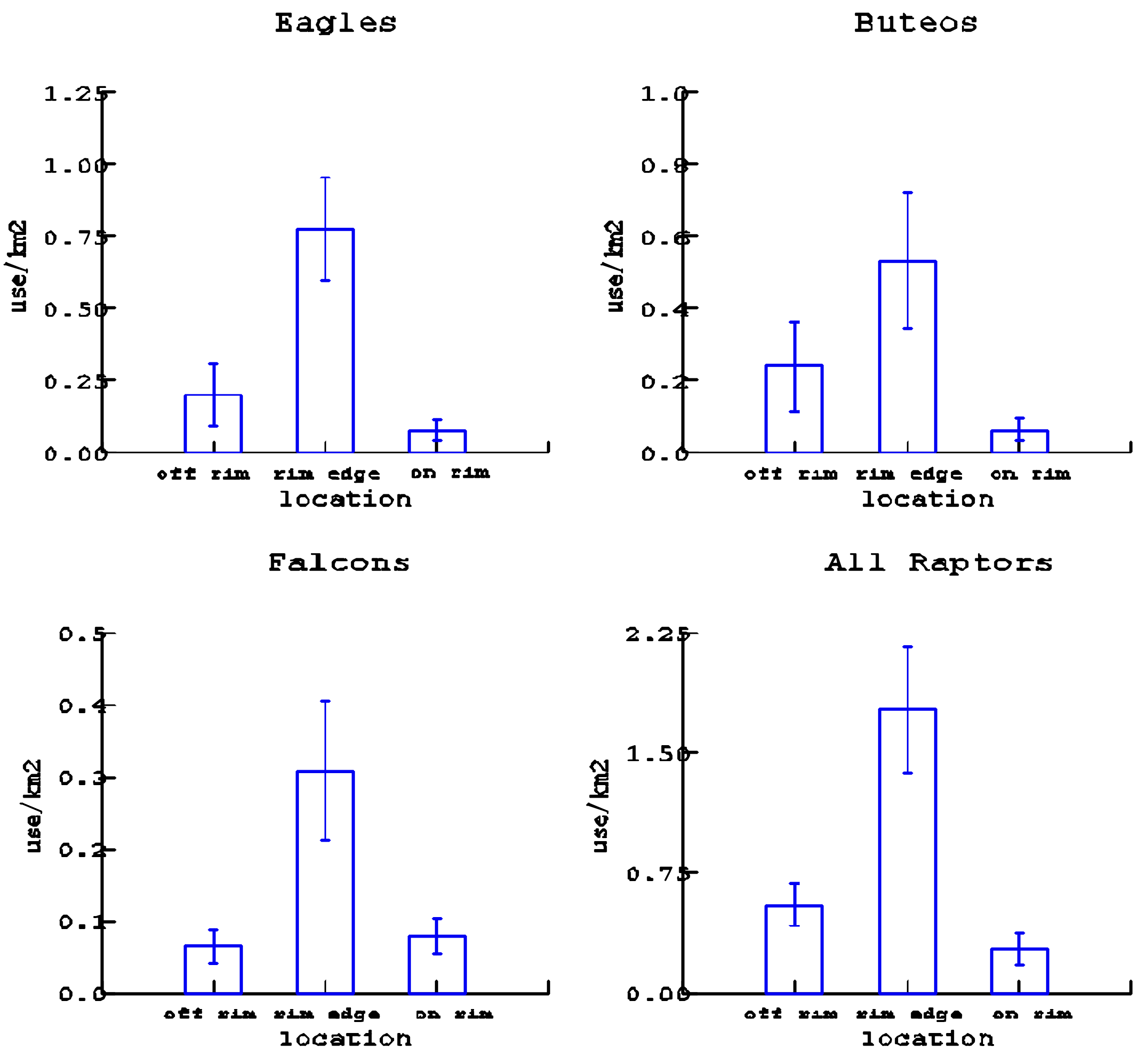

FIGURE 1. Spatial use of FCR by raptors as determined by point count estimates of use.

Aerial and ground surveys for raptor nests were conducted within an area defined by a 16-km buffer surrounding the outermost edge of each study area. Mean number of active raptor nests for all species was 178 for all three areas. Nesting surveys focused on three species of primary interest, Golden Eagle, Bald Eagle (*Haliaeetus leucocephalus*), and ferruginous hawk (*Buteo regalis*). The wind plant construction schedule was designed to avoid disturbance of nesting raptors within approximately one mile of construction activities, reducing risk of an impact to nesting success.

Mountain plover surveys were conducted to estimate use and reproductive effort of mountain plovers on FCR. Prior to initiation of construction activities, plovers used the entire rim, but observations were more concentrated on the northern end. Since the wind plant occupied the south end of the rim, the construction schedule was successfully designed to encourage plovers to nest on the north end. However, use of the southern portion of the rim remained low the year following construction. Data from the reference area and other regional data collected on mountain plovers (e.g., Pawnee National Grassland, Colorado data) also indicate a recent region-wide decrease in mountain plover abundance.

UV Study

We have completed only 10 months of an 18 month study. The preliminary results for this 10-month period are contained in Table 1. Use (i.e., observations per point count) of the immediate area around non-UV gel coated turbines (NUV turbines) by small birds appears higher than areas adjacent to UV gel coated turbines (UV turbines). However, fatalities were lower (0.44/turbine/year) at the NUV turbines than at the UV turbines (1.62/turbine/year). When considering both use and fatalities bird risk appears higher at UV turbines (0.87) versus NUV turbines (0.16). When considering only raptors, use was higher (0.24 observations per point count) at NUV turbines versus UV turbines (0.11 observations per point count). Several avoidance behaviors were recorded for diurnally active birds. For example, several raptors flew above turbines while crossing the rim, rather than flying through the turbines. Two common ravens flared away from operating turbines on one occasion. On two different occasions a prairie falcon came very close to colliding with turbine blades, once chasing a horned lark and another time chasing another prairie falcon.

TABLE 1. Preliminary estimates of avian use (observations per point count), estimated fatalities (per turbine per year) and bird risk (fatalities per unit of use per turbine).

Turbine	Group	Use	Fatality	Bird Risk
NUV	Small Birds	2.76	0.44	0.16
UV	Small Birds	1.87	1.62	0.87
NUV	Raptors	0.24		
UV	Raptors	0.11		

These data are preliminary and a small sample size limits comparisons of the NUV with UV turbines. It is too early to draw conclusions from the study. Nevertheless, if these patterns continue then it would seem that UV turbines have no advantage over NUV turbines in reducing the mortality of passerines (small) birds at the FCR wind plant. UV turbines may or may not reduce risk to large diurnally active birds (primarily raptors) within the wind plant. However, this is the standard by which the treatment should be judged since reducing risk to diurnally active birds, primarily raptors, was the management objective for the treatment. It also appears that the small sample size (few carcasses) will limit our ability to make an inference on the effect of tower coating on raptors. This is a common problem with the use of short-term observational studies for separating treatment effects from other effects, particularly when the response variable is a rare event.

It is possible that the rarity of raptor fatalities on the FCR wind plant is a byproduct of all the pre-construction measures taken to reduce risks to birds. The FCR wind plant was constructed using many of the management methods thought to reduce risk to raptors. The wind plant was constructed with tubular towers and underground electrical service when possible, reducing perching opportunities for birds near turbines. SeaWest also designed the wind plant to avoid high eagle use areas, including the rim edge setbacks discussed above. The construction also was staged to avoid nesting mountain plovers. The general monitoring of the wind plant has identified a new problem. The fatality rate per structure is approximately six times higher at met towers than at turbines. In response to these data, SeaWest is planning to minimize the use of met towers as much as possible in future expansion of the plant.

Comparison of Fatalities

We have conducted similar studies using similar methods at three different wind plants, Buffalo Ridge in southwestern Minnesota (Strickland et al. 2000b), Foote Creek Rim in south-central Wyoming, and Vansycle Ridge in northeastern Oregon. Estimates of annual per-turbine fatalities for the three sites are contained in Table 2. The fatalities are estimates from carcasses discovered during fatality surveys, corrected for carcass detection and carcass removal biases. Buffalo Ridge (1.95 fatalities/turbine/year) is an agricultural area with small patches of tree cover and relatively low overall bird use. The site does have numerous ephemeral wetlands resulting in more use by waterfowl and shore birds. Numerous nocturnal migrants apparently over fly the site (Hawrot and Hanowski 1997). FCR (1.99 fatalities/turbine/year) is a table-top mesa covered with native short grass prairie with a relatively high level of use by raptors and other diurnally-active large birds. Vansycle (0.57 fatalities/turbine/year) is a very intensively managed agriculture area with little bird habitat and very low bird use during diurnal periods. The birds killed at the Buffalo Ridge site were primarily nocturnal migrants killed during fall migration. At this site the resident bird fatalities along with the greatest amount of bird use occurred near wetlands and woodlands. The fatalities at FCR and Vansycle were both migrant and resident birds.

TABLE 2. Comparison of estimated annual per-turbine fatalities for Buffalo Ridge, Minnesota, Foote Creek Rim, Wyoming, and Vansycle Oregon.

Project	# of Turbines	Bird Fatalities/ Turbine/Year
Buffalo Ridge	354	1.95
Foote Creek Rim	105	1.99
Vansycle	38	0.57

Conclusions

Fatalities at all three wind power sites discussed above appear to be primarily nocturnal migrating passerines. While no comparable estimates exist for most wind plants, Howell and Noone (1992) estimated that bird fatalities at wind plants around the world range from 0 to 37 birds/turbine/year. Fatalities and bird use at all three of our study sites are on the low end of this range. Our data suggest a link between abundance of some species and the risk of fatalities within a wind plant and suggest that sites selected for wind power should have relatively low bird use (e.g., Buffalo Ridge and Vansycle). In addition, when constructing wind plants every effort should be made to reduce risk factors (e.g., reduction of perching opportunities). When bird use of a chosen wind plant site is relatively high, then the construction plan should avoid high use areas (e.g., FCR edge, wetlands, woodlands). Finally, mitigation measures should be evaluated objectively before they are routinely recommended for application to new and existing wind plants.

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General Discussion

Hugh McIsaac pointed out that painting a blade with a uniform UV color against a high UV background might actually reduce the blade's visibility. Another participant questioned whether it might be reasonable to interpret the Foote Creek data as saying that UV might actually attract birds rather than repel them. ("Possibly," was the response.)

Another participant questioned whether anything can be concluded from this study, given the lack of baseline data. Dale Strickland responded by saying that the only conclusion one can draw is that "painting [blades] with UV paint may not be automatically a good idea." Dr. Strickland went on to note that the study could have been improved if they could have randomly allocated the turbine tower treatment. It may be that, if fatalities are occurring at night, the UV treatment was irrelevant. However, in this case the primary concern was for diurnal species, and use by diurnal species happened to be higher near the UV-painted towers.

Foote Creek Phase IV will be not UV treated.

The Role of Hearing in Avian Avoidance of Wind Turbines

by

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Overview

Hearing in birds. There are a number of long-standing myths about what birds can or cannot hear. One myth is that birds hear better at high frequencies than do humans or other mammals. Another myth is that birds can hear things that humans cannot. A considerable amount of work over the past 50 years has repeatedly shown that neither of these notions is true. This report gives a brief review what we know about basic hearing capabilities in birds in relation to the characteristics of noise generated by wind turbines. This report is largely a review of existing data on bird hearing with some preliminary estimates of environmental noise and wind turbine noise at Altamont Pass in the summer of 1999.

Measuring hearing in animals. The sense of hearing in animals may be studied using anatomical, physiological, and behavioral approaches and each method has advantages and disadvantages. Hearing traditionally and most generally is defined as the behavioral response to sound involving the whole, awake organism. The data presented below are mostly from behavioral or psychoacoustic procedures, which are the most direct and most appropriate means of assessing an animal's hearing capabilities. In a few cases, we consider data from physiological approaches where there is strong evidence that the particular methods used correlate well with other (behavioral) estimates of absolute sensitivity and hearing range.

Avian Audibility Curves

Absolute thresholds and bandwidths. The minimum audible sound pressure level (SPL) that can be detected at frequencies throughout an animal's range of hearing defines the audibility curve. This is the most basic measure of hearing and one that we all are familiar with from having our own hearing tested. Over the past fifty years, behavioral audibility curves have been collected for 38 species of birds, and this database can be extended by another 10 species of birds by including data from physiological recordings. To standardize the descriptions of audibility curves for each species, polynomial functions were fitted to published behavioral or physiological data so that threshold estimates could be compared at the same frequencies throughout each species' hearing range.

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To give a rough idea of the variation among species, we show average audibility curves for three groups of birds (Figure 1): the songbirds (or Passeriformes in this sample), the evolutionarily older orders of birds constituting many of the non-Passeriformes (Anseriformes, Caprimulgiformes, Casuariformes, Charadriiformes, Columbiformes, Falconiformes, Galliformes, and Psittaciformes), and a rather special group of birds that are nocturnal predators, the Strigiformes (Tytonidae and Strigidae). Roughly equal numbers of species have been tested behaviorally in each of these three broad groups of birds. By summarizing the data this way we can get an idea of the variation in hearing sensitivity among birds as a whole.

FIGURE 1. Audiograms from three different groups of birds.

Species differences in audibility curves. The curves in Figure 1 illustrate the general trends reported in earlier reviews (Dooling 1980, 1982, 1992a). Birds hear best at frequencies between about 1 and 5 kHz, with absolute sensitivity often approaching 0-10 dB SPL at the most sensitive frequency, which is usually in the region of 2-3 kHz (Dooling 1980, 1982, 1992a). Nocturnal predators hear better in general than either songbirds or non-songbirds over their entire range of hearing. Songbirds tend to hear better at high frequencies than non-songbirds, and non-songbirds tend to hear better at low frequencies than songbirds. On average, the limit of "auditory space" available to a bird for vocal communication extends from about 0.5 kHz to 6.0 kHz (the frequency range or bandwidth 30 dB above the most sensitive point of the typical audibility curve). The long-term average power spectrum of most bird vocalizations falls well within this frequency region and there tends to be a correlation between hearing sensitivity at high frequencies and the highest frequencies contained in the species' vocalizations (Dooling 1980, 1982; Dooling, Lohr, and Dent 2000).

There are some well-known exceptions to this homogeneous picture of avian hearing. Common pigeons (*Columbia livia*) may have an unusual auditory sensitivity to very low frequency sounds (Quine 1978; Yodlowski 1980). By some estimates they may be almost 50 dB more sensitive than humans in the frequency region of 1 - 10 Hz (Kreithen and Quine 1979). The absolute auditory sensitivity of nocturnal predators, such as barn owls (*Tyto alba*) and great horned owls (*Bubo virginianus*) are another exception. Absolute thresholds are unusually low and are probably driven more by the predatory lifestyle of these birds than anything else (Konishi 1973a, b; Van Dijk 1973; Dyson et al. 1998).

Birds are unusual among vertebrates in the remarkable consistency of their auditory structures and in their basic hearing capabilities, such as absolute thresholds and range of hearing. It is intriguing to consider whether the characteristics of the audibility curves of different orders of birds are related to other biological parameters such as a bird's size. Center frequency and high frequency cutoff are significantly and inversely correlated with a bird's size and weight. Perhaps the simplest explanation for these trends is that body size puts a constraint on the low frequency sensitivity of small birds.

The significance of poor high- and low-frequency hearing in birds. Compared to most mammals including humans, birds do not hear well at either high or low frequencies. At the high frequency end of the audiogram, even with the exceptions above, there are no cases where birds hear at frequencies higher than about 15 kHz. This means that a number of acoustic "scarecrow" devices on the market purporting to use ultrasonic energy (i.e. above 20 kHz) as a deterrent are producing noises that are simply inaudible to birds and are unlikely to have any effect. Birds do not hear as well as mammals, including humans, at the low frequency end of the audibility curve either. This is significant because the bulk of the energy generated by wind turbines is at low frequencies (less than 1-2 kHz). In simple terms, this means that a bird would need to be closer to a wind turbine in order to hear it than would a human.

Masking. Absolute auditory sensitivity is, by definition, the minimum sound pressure level that can be heard *in the quiet*. It should be obvious that in normal everyday life – for humans or other animals – hearing is taking place against a background of noise. For many animals, this background noise is usually environmental noise from a variety of sources including wind and animal vocalizations. It should come as no surprise that auditory scientists have spent a great deal of effort investigating the masking effect of noise on hearing in humans and other animals, including a number of species of birds. For present purposes, we are concerned with estimating the distance at which a bird can hear wind turbine blades in a background consisting predominantly of wind noise. Some basic knowledge of masking experiments and of noise measurements is required. Specifically, data from two kinds of masking experiments are particularly relevant for detecting wind turbine blades in a noisy environment: the detectability of tones in noise, and the masking of one noise by another. To understand the data from these experiments one must first understand how environmental noise is measured.

Decibels, noise levels, and spectra. A critical concept when considering signal levels, noise levels, and bandwidths of noise is that of the decibel. Because it is the logarithm of a ratio between two sound powers or pressures, decibels do not add in a simple way. In other words, summing two pure tones of 60 dB SPL does not result in a single pure tone of 120 dB SPL. By the same token, adding energy at a single frequency (say, 2 kHz) in a broadband noise (say, from 0.1 kHz to 10 kHz or 9,999 other frequencies) has little effect on the overall SPL measurement. That is because energy is summed over the entire band of noise so that the contribution of the 2 kHz component becomes very small indeed. These issues are relevant to the discussion below. Engineers and environmental scientists concerned about the level of noise generated by a wind turbine often measure the noise in dB(A) SPL. This gives an overall sound pressure level of noise extending from below 1 kHz to about 10 kHz. For instance, a sound pressure level of 65 dB(A) SPL means all of the energy within this frequency region, summed together, equals 65 dB(A) SPL. The “A” weighting on a sound level meter is particularly useful for estimating effects on humans because it is a filter shaped roughly like the human audiogram.

Scientists who study auditory masking, however, use a different standard convention for describing noise levels and signal-to-noise levels at threshold as shown below. Auditory scientists typically measure noise levels in terms of power per Hertz (or power per cycle). This is known as the spectrum level of noise and it is very different from the more familiar broadband measure of noise that one obtains from a sound level meter that is set to the “A-weighting” scale. The spectrum level reflects the amount of energy in a single Hertz, while the typical sound level meter reflects the total amount of energy summed over the entire range of frequencies, from a few hundred Hertz to 10 kHz. If the noise is relatively flat, the difference between these two measures is about 40 dB. In the case where an overall noise level registering on a sound level meter is 65 dB SPL, the spectrum level is roughly 40 dB lower than this – about 25 dB SPL.

This difference is relevant because overall sound pressure level readings from a sound level meter are used to describe the noise generated by a wind turbine blade, but the auditory system is concerned only with noise immediately surrounding the signal. The two are not the same. An understanding of the difference is critical to estimating how close a bird must be to a turbine blade before it can hear it against a background of environmental (wind) noise. When we consider whether a noise is sufficient to mask a signal, we are talking about a spectrum level (the lower number) of noise, not an overall level (the higher number) of noise.

Detectability of tones in noise. Measuring pure tone thresholds in broadband noise is the simplest kind of masking experiment. Auditory scientists use spectrum level when describing the level of noise that masks a signal because they know that it is the noise in the frequency region of a signal that is most important in masking the signal – not noise at more distant frequency regions. In a typical masking experiment, the ratio between the power in a pure tone at threshold and the power per Hertz (spectrum level) of the background noise is called the critical ratio.

Critical ratio data have been obtained behaviorally for several mammals, including humans, and for 13 species of birds including songbirds, non-songbirds, and even nocturnal predators. Typically, there is an orderly increase of about 3 dB in critical ratio with each doubling of frequency over a frequency range of 2-3 octaves. In birds, there are some exceptions to this general rule, including the budgerigar, the great tit, and the barn owl. How common such exceptions are is not known. In mammals, this orderly increase in critical ratio is related to the mechanics of the peripheral auditory system, and the logarithmic organization of traveling wave maximum displacement along the basilar membrane (Békésy 1960; Greenwood 1961a, b; Buus et al. 1995). In practical terms, what this curve describes is the level in dB above the spectrum level of the background noise required for a tone to be heard. For the average bird, a pure tone of 3 kHz must be at least 28 dB above the spectrum level of noise in order to be detected.

Detectability of noise in noise. Just as noise can mask a tone, it can also mask another noise. Experiments have been done in humans to determine how much the level of a noise must be increased for the change to be detected and the answer is about 0.5-1.0 dB (Miller, 1947). Similar data are available for three species of birds – the budgerigar, the starling, and the barn owl – in the form of modulation transfer functions (Dooling, Lohr, and Dent, 2000). Without going into the details of this test, we know that all three species can hear about a 1.5 dB change in level of white noise. Here once again, human acoustic discrimination abilities are slightly better than those of birds. For humans, one noise needs to be about a 0.5 dB greater than the background noise to be detected, while birds require at least 1.5 dB.

In summary, the thresholds from these two types of auditory tests – the critical ratio and the threshold for masking of one noise by another – are the relevant thresholds to use when estimating how far away a bird can hear a wind turbine blade against a background of environmental noise. Table 1 shows the signal-to-noise levels that must be exceeded for a bird to detect either a pure tone (at several different frequencies) or a broadband noise.

TABLE 1. Signal/Noise in dB to be exceeded for detection of tones or noise

1 kHz	2 kHz	3 kHz	4 kHz	Noise
24 dB	27 dB	28.5 dB	30 dB	1.5 dB

Environmental Noise Versus Wind Turbine Noise

On a brief visit to the Altamont Pass in the summer of 1999, we measured ambient noise levels and the noise generated by several different types of wind turbines. Wind was only moderate during the days we sampled and the overall levels were about 70 dB(A) SPL +/- 5 dB. The spectral distribution of energy in these readings corresponded well with what is typically found in the literature. Wind noise and turbine blade noise are predominantly low frequency and have very similar spectra. For a normal wind turbine, our measurements indicated that blades of the turbine moving through the air roughly have the effect of increasing the sound pressure level equally all across the spectrum.

We also discovered several turbines with blade defects. These blades produced a high frequency whistle. An example from a relatively quiet Danwin turbine (low level of broadband blade noise) with a blade defect is shown in Figure 2a. Here the whistle due to the blade defect is about 18 dB above the background noise. (The whistle level actually is 28 dB above the spectrum level because of the size of the FFT used to calculate the ambient noise spectrum). Interestingly, the energy in this whistle falls in the region of best hearing in birds of 2-5 kHz. This might provide a serendipitous test of whether birds fail to avoid collisions with wind turbines because they cannot hear them above the background noise. All other things being equal, we would hypothesize that turbines with whistling blades may experience fewer avian collisions than turbines without whistling blades.

FIGURE 2a. Spectrum of noise produced by a Danwin tubular turbine producing a "whistle" due to a defect in a single blade.

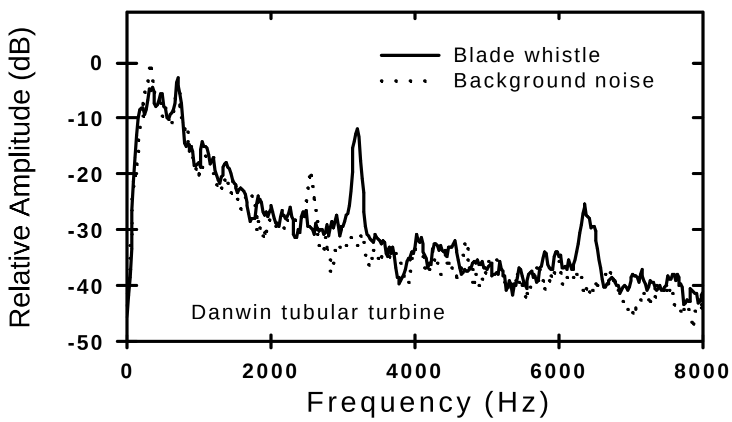

FIGURE 2b. Spectrum of a Flowind vertical axis turbine.

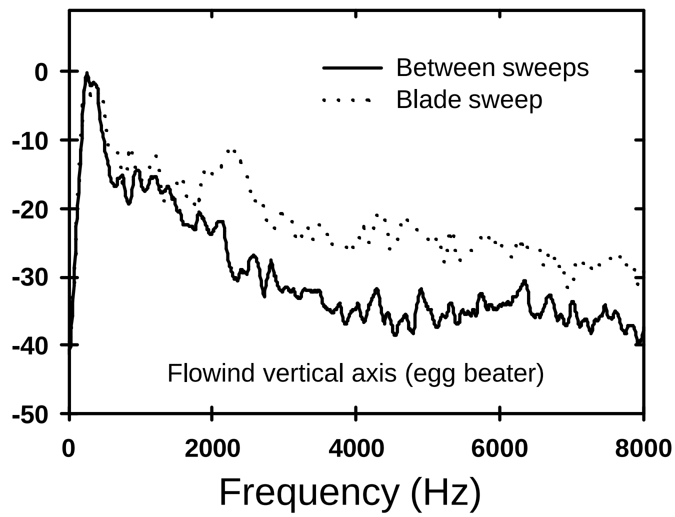

Figure 2b shows an example of a spectrum for a particularly noisy vertical axis turbine. In this case, at 10 meters from the base of the turbine, the blade noise is about 10 dB above the ambient noise level. Detecting noise in noise is similar to the auditory test described above. By the inverse square law, sound pressure level decreases by 6 dB with every doubling of distance. Once noise due to a turbine blade decreases to within 1.5 dB of the level of ambient wind noise, the blade can't be heard by a bird (though it could still be heard by a human).

These spectra are independent and relative comparisons are not appropriate. For instance, we do not know the relative noise levels generated by vertical axis versus Danwin turbines, nor does every blade defect produce the same kind of whistle. We use these two particular spectra only because they represent the extremes of what we sampled (a quiet tubular turbine with a whistle versus a noisy vertical axis turbine) simply to provide an example of how to estimate the distance at which a bird can hear a turbine blade.

In the case of the normal wind turbine, blade noise simply adds to the background noise rather evenly all across the spectrum, and is similar to tests of noise increment detectability. In the case of the whistling blade, the blade whistle is nearly a pure tone and is being heard against a background of broadband noise. In terms of the auditory tests described above, this is equivalent to the critical ratio experiment where one measures the level of a tone just audible above the spectrum level of noise. The results from these tests form the basis of the predictions we make in this report.

Detectability of wind turbine blade noise. Using the two cases described above, we can estimate the distance at which wind turbine blade noise would become inaudible to birds. First we consider the vertical axis turbine where the blade noise has a very similar spectrum to that of wind noise. Figure 3 shows how signal-to-noise ratio varies with distance for three different overall noise levels – 60, 70, and 80 dB (A) SPL. Here blade noise represents the signal, which decreases in level with distance relative to the background noise (measured as the overall noise level), which remains constant. A bird threshold for power in a pure tone versus power in spectrum level of noise (critical ratio) is shown.

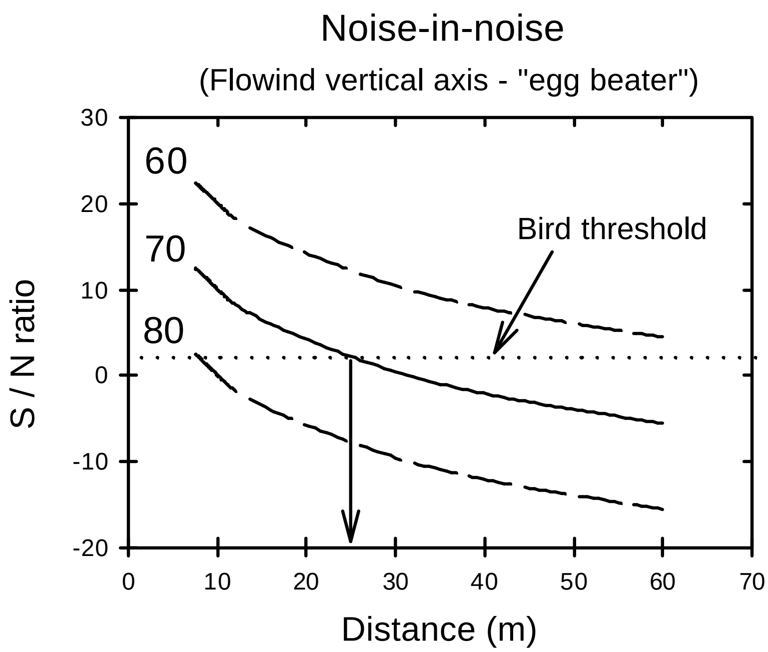

FIGURE 3. Signal-to-noise ratio versus distance for 3 ambient noise levels (60, 70, and 80 dB (A)).

The distance needed for detection is determined using a bird's detection threshold for an increment in noise. At 25 meters from the base of the turbine, the noise from the blade is less than 1.5 dB above the background noise at 70 dB (A) SPL (i.e. the bird's signal-to-noise level at masked threshold). At this point the blade noise would be inaudible to birds but still audible to humans. Higher and lower ambient noise levels have a dramatic effect on the hearing distance. If the overall noise level is increased 10 db to 80 dB (A) SPL, the blade noise would not be audible to a bird until it was within 10 meters of the blade.

In the case of the whistling blade on the Danwin turbine we can use the critical ratio to estimate how far away a bird can hear the whistle. At a point 15 meters from the blade, the whistle stands out above the background level of ambient (wind) noise and noise from the turbine. Because the noise level is 10 dB lower than shown, the whistle centered around 3 kHz is actually about 28 dB above the spectrum level of the background noise. This is already on the edge of detectability for the typical bird (i.e. the bird's signal-to-noise ratio at masked threshold). As in the previous figure, Figure 4 shows the distance under these wind conditions at which the blade whistle would become inaudible to a bird. A bird threshold for power in a pure tone versus power in spectrum level of noise (critical ratio) is shown.

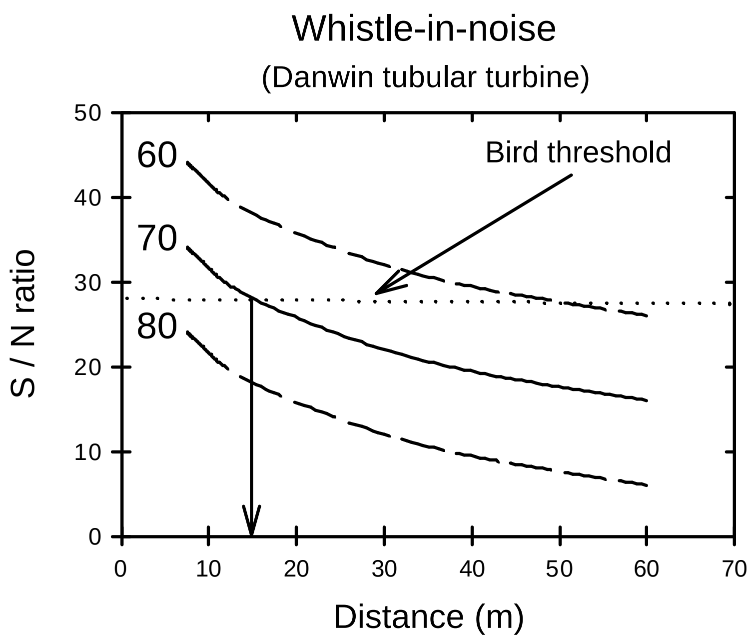

FIGURE 4. Signal-to-noise ratio versus distance for 3 ambient noise levels (60, 70, and 80 dB (A)).

These two examples describe how one would estimate the distance at which turbine blade noise could be heard by a bird. They also represent somewhat of a best case from the bird's perspective since the level of ambient noise (70 dB (A) SPL) was quieter than normal given that the wind velocities were described to us as mild-to-moderate. One would expect higher ambient noise levels with higher wind velocity, which would decrease the detection distance dramatically.

Conclusions

1. Birds hear best between about 1-5 kHz. Birds do not hear as well as humans. Acoustic "scarecrow" devices that purport to use sound frequencies outside the hearing range of humans are most certainly inaudible to birds as well.

2. Birds cannot hear the noise from wind turbine blades as well as humans. In practical terms, a normal hearing human can hear noise from a turbine blade at 1.5-2.0 times the distance a bird would need under the same conditions to hear the same blade noise clearly.

3. Depending on the level of the whistle produced from a blade defect, and the level of the background noise, this acoustic cue may help birds avoid turbine blades.

4. Because turbine noise and wind noise are predominantly low frequency, almost all of the contribution to an overall sound pressure level reading, say 65 dB (A) SPL, comes from frequencies below 1-2 kHz. This fact, and the existence of blade defects that produce whistles, suggests that minor modifications to the acoustic

signature of a turbine blade could make blades more audible to birds, while at the same time making no measurable contribution to overall noise level.

5. The acoustic hypothesis for avian wind turbine avoidance is untested. It is entirely possible, especially under high wind conditions, that as birds approach a wind turbine they lose the ability to see the blade (due to motion smear) before they are close enough to be able to hear the blade.

Recommendations

1. Compare fatalities at turbines with noticeable whistles and those without.

2. Make comprehensive and systematic noise measurements at wind turbines (with and without whistles) that include the variation in noise levels and wind velocity.

3. Ask field workers to make informal judgments about the distances (e.g., how many paces from the turbine base) at which blade noise becomes inaudible during their on-site visits.

4. Compare results from #2 and #3.

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General Discussion

There was some discussion of whether wind rushing past the ears of a flying bird is so loud as to mask other sounds. Dr. Dooling indicated that, while he wouldn't describe a bird flying at 40 mph as being effectively deaf to other sounds, "but [for the bird] to hear it [the noise] would have to be pretty loud." One participant noted that the ambient background at Altamont is 65 DB.

Research ideas included monitoring to see whether noisier blades result in fewer fatalities, and further research to see whether a relatively small increase in a turbine's dB might make a significant difference in eliminating the so-called "dead spot" – the are where the turbine's rotating blades are no longer visible but are not yet audible. Karin Sinclair of NREL suggested targeting "trouble spots" with a blend of visual and acoustical strategies. Targeted turbines could be in middle of the site and not near residents.

State-of-the-Art Permitting and Environmental Review Process for Wind Repowering Projects: New Avoidance and Mitigation Strategies

by

L. Darryl Gray

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Alameda County is home to the Altamont Pass Wind Resource Area (APWRA), one of the largest and longest-running wind power areas in the world. In 1998, Alameda in cooperation with Contra Costa County prepared a comprehensive permitting program to address a host of issues and concerns commonly raised by new and repowered wind power plants. The process responds directly to State law related to land use and environmental impact assessment, but also is generally applicable and transferable to other projects and jurisdictions.

These permitting processes were developed in cooperation with the industry and community as part of the recent repowering proposals for 187 MW of capacity over 30,000 acres of land. They will be tested further as new projects are proposed and are subject to the process. The program includes:

- ***Design standards*** - rated capacity, height/diameter, rotational speed, tower design, guy wires, underground utilities, power pole design/retrofits
- ***Siting standards*** - avoidance of “high risk” bird flight areas, setbacks from other land uses
- ***Application submittal requirements*** - maps, descriptions, studies
- ***Review process requirements*** - public input, environmental assessment, hearings
- ***Standardized permit conditions*** - 45 standard conditions of approval
- ***Special conditions*** - related to avian mortality and fire safety
- ***Monitoring protocols*** - reports, fees, technical advisory committee and possible response

The California Environmental Quality Act (CEQA) establishes legal, procedural, and substantive requirements for evaluating projects that could have a substantial adverse impact on the environment. Alameda County was the Lead Agency in preparing a comprehensive

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Environmental Impact Report (EIR) for the individual repowering projects, for the program components, and for anticipated buildout under the Program. The EIR is similar to a federal EIS; analysis methods and conclusions could be transferable to other projects subject to federal or state review.

Particular issues addressed in the EIR include:

- ***visual character*** from close and distant viewpoints, including the visual effect of the transition from older (more numerous) machines to newer technology (larger and fewer turbines);
- ***noise***, particularly as it affects newer residential enclaves, and the net effect of removal and replacement of turbines on noise levels;
- ***construction activity***, including truck traffic, staging areas, erosion control, and habitat avoidance;
- the need for ***biological resource surveys*** before, during, and after project construction.

Limitation on Development

The primary purpose of the Counties' Repowering Program is to establish a set of criteria to guide further wind power development in the Altamont Pass WRA for the next three to five years and, in particular, to respond to the problem of avian collisions with wind turbines in the APWRA.

Under the Repowering Program, the total amount of the rated capacity in the APWRA may not increase above existing capacity levels. Thus, with new turbines designed to reduce avian hazards and increase efficiency, applicants for repowering projects are required to retire old turbines with a total capacity equal to the total capacity of the turbines being installed.

For example, an existing project with 15 100-kW turbines in operation has a total capacity of 1,500 kW. One approach would allow removal of all 15 turbines and installation of two new 750 kW turbines, for a replacement ratio of 1:7.5. An alternative would be to replace 12 of the 15 turbines with two 600 kW turbines, retaining three of the existing turbines for a replacement ratio of 1:6. Yet another approach would be to replace ten of the turbines with two 500 kW turbines, retaining five of the existing turbines for a replacement ratio of 1:5. Any combination would be suitable under the repowering program, as long as the proposed capacity does not significantly exceed the wind farm's existing capacity. New permits, other than those approved under the Repowering Program, are not likely to be granted until the Program has been reevaluated.

Development of a Biological Resource Management Plan

A key component of the Repowering Program is the Biological Resource Management Plan (BRMP), similar to the federal Habitat Conservation Plan (HCP), which was prepared to document habitat and species, identify potential impacts, and develop avoidance and mitigation strategies. Past use permit conditions relied on mitigation based in part on self-monitoring efforts by wind farm operators (as reported by windsmiths working in the field). Questions continued to be raised about the possibility that avian fatalities occur more frequently and are too randomly reported to the U.S. Fish and Wildlife Service (USFWS), with copies of the reports provided to Alameda and Contra Costa Counties. Specific repowering proposals by Green Ridge Power, LLC, Altamont Power, LLC, and Venture Pacific, Inc./SeaWest Wind Farms, Inc. have provided an opportunity to improve standards and guidelines that better address the possible impacts of windfarms on birds.

The BRMP is divided into three main parts: Avian Impact Avoidance (Part I), Management of Special-Status Species (Part II), and Management of Biologically Unique Habitats (Part III).

Part I. The Avian Impact Avoidance element establishes design, operational, and siting standards that have demonstrated potential to reduce avian mortality. These standards will be applied to new wind farm projects and repowering projects in the APWRA. Standards are established for the following design and operational elements:

- rotational speed
- tower design
- guy wires
- power pole design/retrofits
- perchless nacelles
- power lines and utility poles.

Part I establishes criteria that restrict development or focus repowering efforts in areas that are identified as potentially creating a risk to birds. For example, turbines situated on steep hillsides or in valleys, particularly those at the end of turbine rows are to be avoided. A monitoring program has been designed to evaluate the effects on avian mortality of removing old turbines and siting new turbines within specific Project areas. A Technical Advisory Committee (TAC) will be established to review research and monitoring data, make technical determinations regarding avian fatalities, and advise the Counties regarding remedial measures. Members of the TAC will include government officials, windpower operators and technical advisors.

The TAC will determine whether avian fatalities can be attributed to particular wind turbines and if so, the reason for the fatality. While it is somewhat difficult to identify the individual turbine involved in a collision incident, the TAC will be responsible for analyzing all available data on the fatality, and advising the Counties regarding the need to implement appropriate remedial measures. Remedial action initiated by each County may include shutting down a turbine or turbines until a determination can be made that a violation of one or more federal laws and regulations exists. If so, the Counties will make a finding that the project is out of compliance with its permit conditions and the turbine or turbines in question will be subject to remedial measures that may include:

- Installing improvements around turbines that are designed to avert avian impacts
- Retrofitting turbines with marking or devices that are designed to avert avian collisions
- Enhancing off-site nesting locations to promote or encourage raptor reproduction
- Removing or relocating turbines

Part II. The Management of Special-Status Species establishes measures to avoid and mitigate effects of turbine removal, installation, maintenance, and operation on certain "special-status" plant and wildlife species that are subject to special legal protections because they are rare or endangered.

Part III. The Management of Biologically Unique Habitats establishes additional measures to avoid and mitigate effects on riparian woodlands, alkali wetlands, emergent marshes, and rock outcrops.

The Counties' Repowering Program applies to all current and future windpower development projects in the APWRA. These standards include only those elements that, using the best available data, are consistent with reducing the potential for raptor mortality based on research conducted in the APWRA and elsewhere. However, current provisions of the BRMP and standard conditions imposed on use permits for repowering project do not preclude the potential for additional mitigation measures for individual projects based on site-specific conditions and demonstrated effectiveness. Over the three to five-year time period after implementation, provisions of the BRMP are intended to show an overall reduction in the problem of avian collisions with wind turbines in the APWRA.

General Discussion

The Technical Advisory Committee which will review monitoring data and make recommendations to the Counties includes representatives of government permitting and regulatory agencies, the scientific community, and the wind industry. The Counties agree to follow the recommendations of the TAC.

Review of conditional use permits issued in accordance with the BRMP. Several questions were raised with regard to how the Repowering Program – and specifically the conditions established by the BRMP – can both contribute and respond to new empirical knowledge about mitigation measures. The Repowering Program is designed to grant 20-year conditional use permits to wind developers, with the permit and its conditions scheduled for review every five years during that 20-year period. (Under CEQA, Mr. Gray explained, the permitting agencies are required to look at all phases of a project.)

Several people raised the question whether there were other opportunities or procedures to review or change the conditions of a permit in response to new or updated information about the impact of a required mitigation measure. As one participant put it, there "probably will be surprises that need to be accounted for… how is this addressed?" Mr. Gray responded that the Program establishes a review process as part of the conditional use plan, and if "something comes up" that review process can be implemented. He added that avian issues can be addressed at any time. Asked whether there should be some sort of peer review before establishing the conditions, Mr. Gray responded, "I am not sure the Industry has definitive results from all the necessary studies to provide Alameda County with the information needed to establish conditions prior to receiving a project."

Dick Anderson pointed out the importance of requiring studies to evaluate the impact of a proposed or required mitigation measure before implementing it – or requiring it to be implemented – on a full scale. Others agreed that ideas such as those being discussed at this meeting (UV paint and use of patterns to reduce motion-smear, acoustical approaches, etc.) require well-designed studies to determine if they really are effective. "We will never know if we are truly mitigating [avian fatalities] unless we spend the time and money to do this." The problem is that regulators have to develop their guidelines and then use them, but research is always coming up with new theories which may or may not bear up under field testing.

Moreover, the regulatory environment is slow-paced. Researchers trying to find answers get data "in leaps and bounds," which may not correspond to the five-year regulatory review cycle. Given that the research and regulatory spheres operate like "two different worlds" at very different paces, there needs to be a mechanism for reevaluating mitigation requirements and other permit conditions to incorporate new scientific conclusions as they become available. At the same time, scientists "need to be able to bring up ideas, but also to test them before they get widely publicized, implemented, or etched in regulatory stone."

Adaptive management. The concept of adaptive management generated several comments and discussion. Adaptive management is a way of testing hypotheses; there is no guarantee that a suggested mitigation measure will prove effective or that it will not have unanticipated negative impacts. At the same time, "is not equivalent to trial and error – although this is how it often is being used," according to one comment. There evidently is some tension between the idea of adaptive management as a way of testing hypotheses – a management plan that "allows you to learn something" – and the idea that "adaptive management will achieve mitigation." Developers, one participant observed, do not want to have to go back and re-think the hypothesis behind a mitigation measure once they have undertaken to implement it.

Is there an "acceptable level of fatalities"? There was some discussion as to what constitutes an "acceptable level of fatalities" for regulatory purposes. Mr. Gray responded (and Dr. Manville of the USFWS subsequently confirmed) that there is no "acceptable level" above zero. However, Mr. Gray remarked that while "the goal is zero, any reduction is a move in the right direction."

Interim evaluations. Noting that the BRMP was completed two years ago, while repowering was not expected to actually occur for another year, Karin Sinclair asked whether there would be any opportunity to reevaluate the BRMP given what researchers have learned in the interim. The morning session's discussion of gaps in turbine strings was cited as an example; would there be an opportunity to incorporate such ideas before repowering begins to take place? Mr. Gray responded that, "if you can substantiate that a change in methodology or strategy reduces mortality, it's not necessary to wait [for the five-year review]; but we would not want to make changes based on unsubstantiated hypotheses."

OTHER RESEARCH TOPICS

The fourth session took place on the second day of the Meeting. It included both individual and panel presentations on a variety of topics. Some presenters chose to submit their presentation overheads for inclusion in these Proceedings, in lieu of a more detailed paper.

Panel Discussion: Bat Ecology and Wind Turbine Considerations. Brian Keeley, Steve Ugoretz, and Dale Strickland, panel members

Carlton, Richard: *Improved/Alternate Techniques for Use in Avian Research: Bird Activity Monitoring*

Manville, Albert: *U.S. Fish and Wildlife Service Perspective, Concerns, Recommendations*

Panel Discussion: Taking Account of Differences at Each Site. Dick Anderson, Mike Morrison, Dale Strickland, panel members

Davis, Jim, and K. Sorenson: *California Condor Reintroduction - Potential Wind Power-Related Impacts* [abstract only]

Ugoretz, Steve: *Comparison to Other Stationary Structures*

Bat Ecology and Wind Turbine Considerations

Panel:

Brian Keeley, Bat Conservation International[1]

Steve Ugoretz, Wisconsin Department of Natural Resources[2]

Dale Strickland, Western EcoSystems Technology, Inc.[3]

I. Bat Interactions With Utility Structures - *Brian W. Keeley*

[Conference Presentation: Avian Interactions with Utility Structures. Charleston South Carolina, December 2-3, 1999. Sponsored by Electric Power Research Institute (EPRI)]

Abstract

The impacts of utility structures on bat communities are not well documented. However, dead bats are reported — primarily in association with wind turbines and cable-anchored communications towers. Four U.S. studies (two unpublished) indicate that tree bats in the genus Lasiurus represent 85% (122/143) of the dead bats collected, with 86% of all species found between late August and early October. An Australian study also reports bat mortality from wind turbines, but a European study indicates no bats have been reported. Such studies suggest significant impacts may be occurring on bat populations in some areas. Bat surveys conducted prior to wind farm or tower installation may help to avoid unnecessary mortality. Existing facilities with bird mortality monitoring programs can easily incorporate bat-specific studies. Survey designs are discussed. Reproducible and comparable studies are needed on bat interactions with utility operations to help identify management needs.

Introduction

Although there have been many studies on the impacts of utility structures on bird communities, little has been done to examine impacts on bats. Bat mortality has been reported from wind turbines and cable-anchored communications towers. Recent unpublished studies indicate that in some cases bat fatalities dramatically outnumber bird fatalities (Puzen, pers. comm.). Unlike birds, bats have been slow to attract public interest and legal protection resulting in a lack of information. However, as environmental awareness increases and regulations become more stringent, it may be prudent to include bat-specific studies during environmental site assessments prior to facility installation and during operations. This report provides a preliminary review and explanation of bat interactions with specific utility

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structures and suggestions on designing bat studies.

Background and Literature Review

There are nearly 1,000 species of bats, representing a quarter of all mammal species worldwide. Bats are essential allies, both ecologically and economically. Seventy percent of the world's tropical fruits eaten by humans come from plants that rely on bats for pollination or seed dispersal, including such favorites as bananas, avocados, and cashews. Insect eating bats save foresters and farmers millions of dollars annually by consuming night-flying insects, many of which are agricultural pests. For example, Bracken Cave in central Texas is home to a nursery colony of an estimated 20 million Mexican free-tailed bats (*Tadarida brasiliensis*). This one colony consumes an estimated 200 tons of insects in a single night, including one of North America's most costly agricultural pests, the corn-earworm moth (*Helicoverpa zea*) (McCracken 1996).

A literature review of scientific journals, magazine articles, conference proceedings, and company reports revealed few reports on impacts to bats from utility structures such as wind turbines and communications towers (Bach et al. 1999; Crawford and Baker 1981; Hall 1972; Osborn et al. 1996; Van Gelder 1956). In a European study, bats were observed foraging within one meter of an operating wind turbine but no dead bats were found (Bach et al. 1999). However, in the U.S. high bat mortality was found in association with both wind turbines and communications towers (Crawford and Baker 1981; Osborn et al. 1996; Puzen, pers.comm; Van Gelder 1956). Hall (1972) reported 22 Australian free-tailed bats (*Tadarida australis*) with broken wings, necks or backs and severe bruising in association with wind turbines. Such reports suggest that utility structures can have a major impact on bat populations and may have long-term impacts on bat communities. Although no reports were encountered, electrocution and collisions with horizontal distribution and transmission lines may also be a cause of injury and death in bats, especially where large tropical bats occur.

A review of four U.S. bat-specific mortality studies conducted at three mid-western wind farms (Osborn et al. 1996; Puzen, pers.comm.) and a Florida communications tower (Crawford and Baker 1981) revealed interesting trends. In a recent unpublished study conducted at a U.S. wind farm in Wisconsin, 34 bats were encountered in a 2 month period (Puzen, pers.comm.). Presumably, commuting bats are critically injured or killed when they fly into tower cables or are struck by wind turbine blades. With all studies combined, tree bats in the genus *Lasiurus* represented 85% (122/143) of the dead bats collected. Eighty six percent of all bats were found between late August and early October (Crawford and Baker 1981; Osborn et al. 1996; Puzen, pers.comm; Van Gelder 1956). Although there is not enough information to conclusively determine the reasons behind the trends, plausible explanations may be related to *Lasiurus*-specific behaviors, seasonal temperate bat behaviors, researcher biases, and/or structure designs.

Discussion of Findings

The large number of *Lasiurus* bats is interesting, as they typically are solitary and probably not the most common bat species in the area. If it is true that less common bats represent the majority being killed, then large numbers of these bats encountered at any facility could have a significant impact on the population. At least five of the six U.S. *Lasiurus* species are believed to migrate (Barbour and Davis 1969). For example, the Hoary bat (*Lasiurus cinereus*) is considered capable of migrating from Alaska to Central America. Migrating *Lasiurus* bats may be more likely than other species to fly through open areas or at heights that would bring them in contact with wind turbines or cable-anchored communications towers. Reports indicate that commuting or migrating bats may save energy by reducing the number of echolocation calls made while traveling through open terrain (Van Gelder 1956). Most other common U.S. bat species, such as those in the genus *Myotis*, are not known to travel such great distances and may be less likely to fly through open areas or at heights where wind turbines or communications towers are located.

In late summer, young bats begin to disperse from parents. Most temperate zone bats begin moving in early fall to seek suitable over-wintering sites. Although the age of the bats from these studies was not reported, it would be interesting to know how many of all species were young of the year versus migrating adults. Kunz (1982) describes techniques for determining young of the year.

Researchers may be more likely to find large and colorful (and often strikingly patterned) downed *Lasiurus* bats; the majority of the remaining common U.S. species are smaller and usually drab-colored. Furthermore, *Lasiurus* prefer to roost in open foliage and may be less likely to hide in a tiny secluded area preferred by an injured, crevice-dwelling bat species.

Bats may be drawn to structures that attract insects to lights, that make curious sounds, or that may offer potential roosting sites. Studies on bat responses to these factors may help to find ways to minimize mortality.

Conducting Bat Surveys

Bat surveys conducted prior to wind farm or communications tower installation may help to avoid unnecessary mortality. A literature review will provide a list of species and may identify key roosts in the area. A site visit will help to identify prominent geologic features, waterways, and vegetational communities which bats may use for roosting, foraging, or as major flyways. Large bat concentrations are most likely to occur in association with natural or man-made roosting areas such as caves, cliffs, and abandoned buildings. Bats may move through a particular area only during a specific season. As with all wildlife studies, it is advisable to conduct surveys in spring, summer, and fall. Bat survey techniques are described in Kunz (1982). One effective survey technique involves the use of bat detectors, which make bat ultra-sonic vocalizations audible to humans. Detectors can be used to measure bat activity in an area. Computer software is available for identifying bats from vocalizations (Gannon and Sexton 1996; Gannon et al. 1998). A remote nocturnal monitoring technique used to listen for migrating birds is being modified to include bats (Evans 1999).

Bird mortality monitoring programs at existing facilities can easily incorporate bat-specific studies by collecting bat remains for later identification. This will provide important information about the numbers and time of year bats are killed. Carcass examination by an expert will provide species identification, and may provide information on sex, age, and cause of death. There are some important differences between locating downed bats versus birds. Injured bats may be drab-colored and smaller than most birds and may not flush from cover, making them more difficult to find. Additionally, if predators are removing carcasses from a site, bat remains may be absent altogether or less obvious than bird remains that may leave feathers. The use of a trained dog may increase the number of both birds and bats found.

Conclusion

Bats are being killed by certain types of utility structures in certain areas and sometimes in surprisingly large numbers. While no federally protected species have been reported, at least one species (*Myotis austro*) is listed as sensitive in several states. Growing public awareness of bats' economic and ecological benefits suggest that bat interactions with wind power facilities could take on a higher profile.

Although there are observable trends which may have serious ecological implications, there is not yet enough information to make any solid management recommendations. Reproducible and comparable studies are needed on bat interactions with utility structures. Understanding how species-specific behaviors, site location, and structural designs affect bats will help to identify management needs.

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General Discussion - *Brian Keeley's presentation*

Of 178 bats found at two wind sites and one cable-anchored communications tower, 123 were tree bats. Because tree bats tend to live about 12 years and do not reproduce quickly, finding 123 fatalities at three sites may be significant. It is not clear whether fatalities were associated with weather conditions; tree bats may have been looking for a place to roost in inclement weather.

Lourdes Rugge has some information about hoary bats at Altamont. Is anyone gathering overall bat fatalities throughout the WRA projects? B. Keeley interested in sharing, publishing information. To date, information on bats killed at wind sites has been coming in by word-of-mouth, in anecdotal fashion. More and better information is needed.

Why are echolocating bats running into objects? It does seem strange, but it may be that bats conserve energy when by not sending signals while traveling, particularly in open areas where objects like cable towers and wind turbines are located. Also, echolocation may not be effective with certain smooth, featureless surfaces, such as windows.

II. Bat Collision With Wind Energy Structures - *Steve Ugoretz*

While it may seem inconsistent that bats, with their echolocation ability, would collide with structures such as wind turbines, experience shows that this is what is happening at many wind energy installations, in many parts of the country. Attention to the biological effects of wind energy facilities focused initially on raptors, and on birds in general, as a result of observations made at California's Altamont Pass Wind Resource Area. Subsequent studies of avian mortality have noted finding dead bats around the turbines, and it is becoming apparent that bat interactions need to be considered along with potential bird mortality.

Dead bats at wind turbines were first reported by Osborn et al. (1996) at the Buffalo Ridge Wind Resource Area. They found small numbers of bats, mainly in the Lasiurid family of tree-roosting species. The authors concluded that this level of mortality was not likely to be a concern, but indicated that they could not generalize from that conclusion to large populations of cave-dwelling bats. As it turned out, there was just such a population in Eastern Wisconsin.

The Neda Mine is an abandoned iron mine in the Niagara Dolomite escarpment in Dodge County, Wisconsin. Estimates indicate that there are several hundred thousand bats hibernating there every winter. These are primarily little brown bats, big brown bats (Myotids) and Eastern pipistrelles, along with smaller numbers of other species. Bats enter the mine through protected openings in late fall, and emerge in the spring, usually in April. The bats spend some days before and after hibernation feeding in the local area, then head out to their breeding areas for the summer and fall.

The Niagara escarpment also is the location of the best continuous wind resource in Wisconsin. Therefore, there was a real potential for just the kind of adverse impacts reported by Osborn et al. Together with Bat Conservation International and the University of Wisconsin Milwaukee, the Wisconsin Department of Natural Resources (DNR) has been working towards expanding the studies around the Neda Mine to investigate the bats' use of habitat in the surrounding area. Expanded studies would include looking at use during feeding before and after hibernation, and also at bats' use of the southwest to northeast trending escarpment as a migration corridor. This should help us to assess the risk to this large aggregation of bats, should large scale wind development approach the hibernaculum.

In the meantime, there have been other reports of bats, again mainly Lasiurids, killed at wind energy facilities in other parts of the country. Wally Erickson et al. have reported finding more dead bats in ongoing monitoring at Buffalo Ridge. Dead bats also have been found at Foote Creek Rim in Wyoming, and at Vansycle in Eastern Oregon. Shawn Puzen, of Wisconsin Public Service Corporation, is managing biological studies at two small wind facilities in Kewaunee County, Wisconsin. His investigators have reported several bat fatalities, outnumbering the bird carcasses that have been recovered. Dick Anderson's workers have even found a few dead bats at California wind farms. We have not heard of any reports of bat mortalities at European facilities at this point. I understand that there is a study going on in Germany, and we may see some results on that in the future.

What we have learned from this is that despite common expectations bats are vulnerable to collision mortality at wind turbines. This seems mainly focused on a particular group of bats. Brian Keeley's paper at this workshop discusses the biological factors that may be involved, and should be investigated to reach an understanding of what is happening here.

I would strongly recommend that biologists involved in considering the impacts of wind energy facilities add bats to the regular scope of field studies. Shawn Puzen of WPS has begun a study of bat use of the Kewaunee County wind installations, using bat detectors to monitor bat use of the area around and within the wind farms. The results should help move forward our attempts to learn the magnitude and significance of bat mortality in wind siting. Studies in other locations will expand our understanding, much as nearly one-and-a-half decades of reporting and considering bird studies have expanded our understanding of birds' interactions with wind installations.

References

Osborn, R. G., K.F. Higgins, C.D. Dieter, and R. E. Usgaard. 1996. Bat collisions with wind turbines in southwestern Minnesota. Bat Res. News 37:105 – 108

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III. Bats and Wind Power: Vansycle Ridge, Buffalo Ridge, and Foote Creek Rim - *Dale Strickland*

Vansycle Ridge, Oregon

A total of 10 carcasses were found in 1999:

- Hoary (6)
- Silver-haired (3)
- Little brown (1)

Fatalities appear to have occurred between August 23 and September 21. The estimated fatality rate is 0.74/turbine/year.

Buffalo Ridge, Minnesota

A total of 13 carcasses were found in 1994 and 1995, in Phase 1 of the project. A total of 184 carcasses were found in 1998 and 1999 in Phases 1, 2 and 3 of the project. The species breakdown is as follows:

- Hoary (108)
- Red (37)
- Silver-haired (6)
- Eastern pipistrelles (6)
- Little brown (6)
- Unknown (21)

Carcasses were found between May 20 and October 19, with 97% of the fatalities appearing to have occurred between July 15 and September 15. The estimated fatality rate is 2.3/turbine/year.

Foote Creek Rim, Wyoming

A total of 45 carcasses were found in 1999:

- Hoary (38)
- Little brown (4)
- Big brown (1)
- Unknown (2)

Carcasses were found between May 27 and September 14, with 92% of fatalities appearing to have occurred between July14 and September 14. The estimated fatality rate is 2.48/turbine/year.

FIGURE 1. Carcass identification in the field

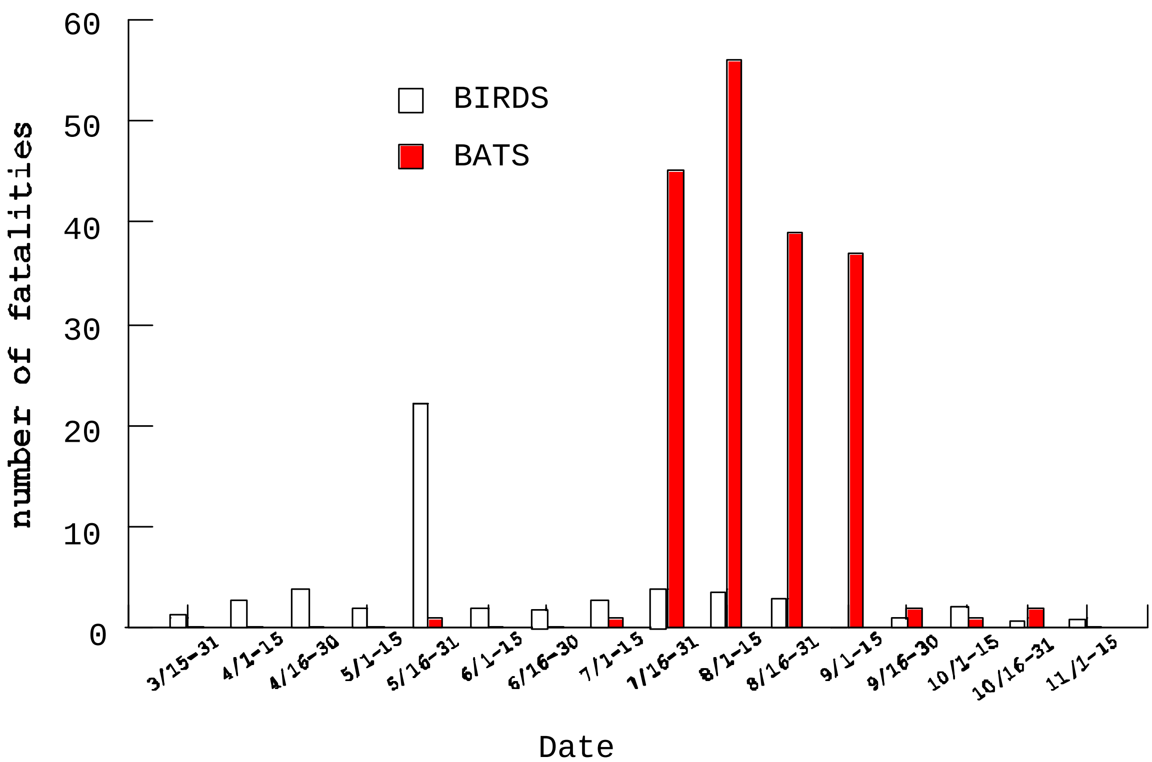

FIGURE 2. Plotting bird vs. bat fatalities by semi-monthly period

Conclusions

Vansycle Ridge:

- Lowest fatality rate of three sites
- Probably lowest bat densities based on available habitat

Buffalo Ridge:

- P2 and 3 fatality rate much higher than P1 rate
- Fatalities widespread
- Majority of fatalities (76%) appear related to weather events
- Significantly closer to wetlands and distant from CRP
- All fatalities of species common to the area

Foote Creek Rim:

- Majority (~ 84%) of fatalities related to weather events
- All fatalities of species common to the area
- Roosting habitat east of rim and feeding habitat east and west of rim

Common to all Sites. Most fatalities were species common to the area, occurred in late summer and early fall, and most associated with weather events.

IV. General Discussion - *all panelists*

The panel presentations sparked discussion of what is known so far about bat interactions with wind power facilities, the implications of that knowledge and the gaps that need to be filled, and what steps might be taken in terms of site selection, monitoring, and evaluation.

"Where we were with birds ten years ago." One participant noted that our current knowledge about bat-wind power interactions is equivalent to our understanding of avian-wind power interactions ten years ago. As a first step, it was suggested that researchers gather existing information, including any data or anecdotal observations that have been picked up in the course of conducting avian studies at wind power plants. "We need to see what more can be learned from existing studies."

Appropriate metrics and methods. There was some discussion of appropriate methods to use in studying bat interactions with wind power facilities. Researchers cannot rely on the same methods that have been used in avian studies, particularly with respect to carcass recovery. Bat experts need to be consulted regarding appropriate study design, including a preliminary identification of the threats to bats, appropriate metrics, and carcass recovery methods.

Utilization and mortality rates. As with avian studies, the point was made that researchers should not focus on collisions without looking at utilization in order to get good picture of mortality rates: i.e., how many bats are passing through and how many dying. Another participant pointed out that "we need to study when bats *aren't* dying as well as when and why they are dying." To this end, it was suggested that observers be posted at wind sites with bat detectors to find out what bats are doing there: passing through, circling, attempting to roost? It was pointed out that it is hard to tell by observation whether you are seeing different bats or the same bat making multiple passes through an area.

Specific research questions. Several specific questions drew focus. Why are tree bats disproportionately found? What is the significance of the seasonal peak? Why the association with bad weather? Bats do emerge during light to moderate rain, but tend not to come out during heavy rains because it interferes with their use of echolocation. Is it possible bats are going to wind turbines to perch, particularly if caught in bad weather? This could be the case. From which direction are the bats approaching turbines – side? front? (Asked whether there is any sense to doing searches after storms rather than on specific cycles, B. Keeley responded that “it depends on what one is trying to find. If looking for the biggest number of fatalities, then do searches following storms; however, to get a clearer picture of what is going on, it would be better to take more regular samples.”)

Finally, the point was made that researchers should focus on factors that we can affect, for example, the location of turbines rather than weather effects as such. Given the high seasonal concentration of fatalities recorded to date, it may be that a facility could respond by selectively turning turbines off (perhaps during severe weather events) during months when there is a lot of bat activity.

Bird Activity Monitoring

by

Richard Carlton, Ph.D.[1] *and Richard E. Harness*[2]

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[2]EDM International, Inc.

Abstract

Avian activities around utility structures can result in collisions (with wind turbine blades, guy wires, transmission lines, illuminated towers) and electrocutions (lines, transformers, substations). While much is understood about general bird behaviors (perching, nesting, hunting) that can lead to these negative interactions, there have been few direct scientific observations of such events. Similarly, although there is a wide variety of mitigative devices (e.g., perch guards) and measures (e.g., nest relocation) available for reducing negative avian interactions, few have been evaluated scientifically. The primary category of needed data is high-resolution visual documentation of the interaction event. Necessary ancillary information includes recent and current weather conditions, general bird activities in the area, landscape attributes, and prey availability for raptors.

The Bird Activity Monitoring System (BAMS), currently under development, will consist of day and night video cameras, digital video recorder, meteorological sensors, and controlling computer/data logger. Other potential plug-in modules will include radar and acoustic sensing equipment that can, respectively, monitor longer-range avian activity and identify species. Potential applications for the BAMS include trial siting exercises for new wind turbine sites and transmission corridors, *in situ* calibration of Pacific Gas & Electric's Bird Strike Monitor, analysis of bird use of poles, towers, and wires, and evaluation of devices such as perch guards, nesting platforms, and alternative perches. The system will reduce the number of person-hours in the field, and provide high resolution data that will be useful throughout the industry in efforts to reduce impacts on avian communities.

Goals of EPRI Avian Research and Activities

- Reduce impacts of utility structures on birds
- Reduce impacts of birds on utility structures to ensure reliability of power delivery
- Determine and reduce impacts of utility emissions on birds
- Provide stewardship and develop technology for the industry, its customers, and the public

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Past Projects

- Effects of Transmission Lines on Bird Flights (1977)
- Transmission Line Impact on Migrating Birds (1978)
- Effects of Power Line Construction on Activity Patterns and Habitat Use of Southern Bald Eagles (1979)
- Wind Turbine Generation Impact on Migrating Birds (1980)
- Bird-related Problems on Electric Transmission Systems in Canada (1980)
- Insulator Dry Cleaning System (1982)
- Unexplained Transmission Line Outages (1983)
- Osprey Nesting on Transmission Lines (1983)
- Bird Damage to Wood Poles (1983)
- Investigation of Bird-Caused Electrical Outages (1984)
- Wind Turbine Raptor Studies (1985)
- Electric Line Deterrent Study (1989)
- Lake Ontario Shoreline Bird Mitigation Study (1992)
- First International Workshop on Avian Interactions with Utility Structures (1992)
- Avian Interactions with Wind Power Structures (1995)
- Patterns of Movement of Dark-Rumped Petrels and Newell's Shearwaters on Kauai (1995)
- Sensitivity of Waterfowl and Passerines in the Central Plains to Possible Climate Change (1996)
- Mitigation of Woodpecker Damage to Utility Poles (1997)
- Technologies for the Inspection of Transmission Lines (1997)
- National Wind Coordinating Committee Facilitation Services (1998 -)
- Second International Workshop on Avian Interactions with Utility Structures (Charleston, December 2-3, 1999, proceedings available in 2000)

Subjects Covered at the Charleston Workshop

- Cooperative Management of the Bird / Power Line Issue
- Solving the Problem of Raptor Electrocutions
- Remote Sensing Technologies for Assessing Bird Interactions

- Devices Designed to Lower the Incidence of Avian Power Line Strikes
- Bird Streamers as Cause of Raptor Electrocutions
- Risk-Based Approach to the Cost of Implementing Raptor Mitigation Measures
- Effectiveness of Perch Guards
- Bat Biology and Behavior Around Utility Structures
- Development of Migratory Bird Management Program
- Hawk Shooting: Not Just a Problem of the Past
- Avian Interactions with Wind Generation Projects
- Never Say Always: the Same Solution Won't Always Solve the Same Problem

Pending Avian Interactions Research at EPRI

Avian Warning Systems for Wind Powered Generation Sites. The goal of this research is to develop devices/methods to reduce raptor collisions with turbine blades. Approaches under consideration include:

- Noise makers
- Reflective coatings
- "Scare crows"

Ongoing Avian Interactions Research at EPRI

Mitigating the Effects of Vultures on 525 kV Structures. The impetus for this research is $250,000 in costs resulting from outages caused by vultures. Objectives are 1) to deter vulture perching above insulators by installing perch guards and providing alternative perch sites; and 2) to develop resistant covers for insulators.

Use of Weather Radar and Acoustical Recording to Predict Bird and Bat Mortality at Wind Energy Facilities in the Southeastern U.S. The design of this new project is based on the NWCC metrics and methods guidance document. Data will be gathered both pre- and post-construction, and will include:

- avian and bat population surveys
- nocturnal migration and activity surveys
- avian and bat mortality studies

Reducing Impacts of Vultures on Fiberoptic Cables. In cooperation with the communications industry, EPRI is looking at alternative perch sites, perch guards, and new insulated coatings for cables.

Interactions Between Bats and Wind Turbines. Only recently recognized as a potential problem, very little is known about bat-wind turbine interactions. Most of the information available is anecdotal evidence collected during avian studies. In some regions, endangered species such as the Southern brown bat may need to be given consideration. In the course of a current study in Wyoming, 55 carcasses/year were found under 105 turbines (during 1999). Most fatalities appear to occur during the breeding season.

Characterizing Common Loon Mercury Exposure and Quantifying Effects.

- Lake environmental factors (pH, dissolved organic matter) affect mercury bioavailability
- Field and lab research to determine loon tissue mercury concentrations and associated effects on reproduction
- Loon chick exposure model will be incorporated into EPRI's Mercury Cycling Model
- Results necessary for EPA's development of wildlife criteria

Peregrine Falcon Metal Exposure at Utility Stack Sites.

- Utility stack nest sites are currently producing about 41% of the Peregrine population in the Great Lakes states.
- Program has been instrumental in recovery of the Peregrine population from near extinction due to DDT exposure.
- The question: *Are falcons nesting on fossil plant stacks receiving a yearly burden of trace metals?*

Future EPRI Avian Interactions R&D

The Bird Activity Monitoring System (BAMS). A standardized high-tech integrated system, BAMS will feature:

- Radar, acoustic, or image-analysis detection of bird approach
- Visible and active infrared video cameras
- Digital sound and video recording
- Full-time data logging of meteorological conditions
- Possible to integrate with Bird Strike Monitor

The Bird Activity Monitoring System will document:

- bird use of poles, towers, and wires
- bird / bat activity near wind turbine sites
- effectiveness of perch guards, alternative perches, nest platforms, and other new designs
- flight patterns of different species, ages

BAMS is intended to determine which species are impacted (addressing the problem of unrecovered carcasses) and to monitor trial siting exercises.

The Bird Strike Indicator. Developed by Pacific Gas & Electric (J.R. Smith and Sheila Byrne), the Bird Strike Indicator is currently in the 'beta' stage of development. Features:

- mounts on a power line, using integral accelerometers to detect bird strikes
- telemetry to ground unit
- in high demand around the country
- to be updated and integrated with the BAMS

Avian Interactions R&D Priorities

- Develop a national database to enable assessment of the problem of avian mortality
- Enable USFWS-compatible proactive approaches for the electric utility industry
- Field test existing mitigative devices
- Evaluate the need for new mitigative approaches
- Partner with other industries with similar problems and goals (especially the communications industry)

A Question and a Comment

- Can we predict local ecological changes that will result from development of wind power?
- Wind power utilization should be developed with a national strategy, not state by state.

General Discussion

The Bird Activity Monitoring System (BAMS) can be used to learn more about bird behavior in problem areas, to test the effectiveness of mitigation devices, and to do some pre-siting evaluations of bird use. R. Carlton suggests the development of a reporting form (like the bird fatality form developed for use by the utility industry) for the wind industry. Such a form would include a place to report weather conditions. One problem with current survey data is that there is no way of knowing how much effort was made to search for carcasses. A standard "level of effort" indicator would make such data reporting more useful.

Communications Towers, Wind Generators, and Research: Avian Conservation Concerns

by

Albert M. Manville II, Ph.D.[1]

U.S. Fish and Wildlife Service (FWS)

[*Editor's Note: Dr. Manville's remarks were delivered via speaker phone.*]

Wind generators and communications towers share some interesting parallels.

- Both the Avian Subcommittee of the National Wind Coordinating Committee (formed in 1994 with FWS a co-founding member) and the Communications Tower Working Group (CTWG, created in 1999 with FWS chairing), are in developmental stages. For purposes of comparison, wind generators and the renewable energy resource can be considered to be *developing,* communications towers *evolving,* while electric power lines are in a *fine tuning* and *reassessment* stage.

- Some of the individuals doing research on bird strikes at wind generator rotors also are looking at bird strikes at communications towers. These include Sid Gauthreaux, Paul Kerlinger, Steve Ugoretz, Bill Evans, and Adam Kelly. We also see some shared contacts between the wind generation and the electric utility/power line industries.

- Research is considerably further along with the wind industry, especially with the December 1999 publication of *Studying Wind Energy-Bird Interactions: a Guidance Document* by Dick Anderson, Mike Morrison, Karin Sinclair, Dale Strickland, Holly Davis, and Bill Kendall. A nationwide draft research protocol for communications towers was approved April 17, 2000, by the CTWG Research Subcommittee. Protocol implementation is likely to borrow heavily from the wind energy's *Guidance Document*.

- Both utilities kill birds and bats, although songbirds presently are far more at risk from towers at night than from wind generators, while raptors are more susceptible to rotor-swept collisions with wind turbines during daytime.

- Some of the mitigation measures being studied in one industry – e.g., lights on towers – may be applicable to the other.

U.S. Fish and Wildlife Service Perspective

Migratory birds are a trust responsibility for the U.S. Fish and Wildlife Service (FWS,

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or the Service). The Service is responsible for the conservation and management of 836 species of migratory birds. This includes 778 so-called nongame species, and 58 species legally hunted as game, all of which are protected under the Migratory Bird Treaty Act of 1918 (MBTA), as amended. While populations of some species are doing well (some too well – e.g., snow geese, urban Canada geese, cowbirds, and cormorants), many others are not. We are seeing continuing declines of over 200 species:

- 77 endangered and 15 threatened under the Endangered Species Act (ESA)
- 124 on the list of nongame species of management concern – birds whose populations are declining, some precipitously. The next step for these species could be the ESA.

For some one-third of the 836 bird species, we have essentially no population data.

The greatest threat to all wildlife is loss and/or degradation of habitat. In addition, the *individual factors* that kill birds – including collisions with towers, wind generators, electric power lines, and glass windows; oil spills, aircraft, cars, electrocutions, cats, pesticides, and other causes – all are of growing concern. Of even greater concern are the cumulative or combined impacts of these mortality factors, including those impacts to bird populations.

Birds are big business in North America. Some 63 million Americans feed, photograph, and watch birds and other wildlife, and spend some $29 billion pursuing these activities each year. Birdwatching has become America's fastest growing hobby next to gardening – increasing 150% in the past decade. More Americans reportedly go on vacations to watch birds today than to play golf.

Birds pollinate flowers and remove insect pests from many important commercial food crop and forest species, making possible a multi-billion-dollar industry extremely dependent on birds for their success. Birds remove countless weed seeds – including exotic species – that compete for food crop and forest production. Birds also distribute seeds of important forest tree and shrub species whose survival would not exist without bird seed dispersal. The global reduction of pollinators – including birds – raises alarm. Fully two-thirds of our flowering plants are pollinated by birds, insects, and bats, producing a global economic benefit estimated at $117 billion per year. In short, birds are extremely important to us all.

Brief History of FWS Involvement

While the FWS plays other roles in the review of communications tower permitting and placement through the National Environmental Policy Act and Section 7 of the ESA, the Division of Migratory Bird Management (MBM) became actively involved in the tower-kill issue early in 1998. On January 22, a snowy foggy night in western Kansas, up to 10,000 Lapland Longspurs (*Calcarius lapponicus*) – a migratory songbird – were killed at and in the vicinity of three towers and a natural gas pumping station in Rochester, Kansas.

Almost immediately, the issue was brought to our attention by the environmental community. In April, 1998, I was asked to brief the Policy Council of the American Bird Conservancy on, among other things, bird mortality from tower strikes. At that time, I provided a partial but certainly not complete literature review and abstract put together by MBM staff member John Trapp. Following that meeting, informal discussions continued with representatives from the Federal Communications Commission (FCC) and the FWS' offices of Habitat Conservation and Migratory Bird Management.

On November 17, 1998, representatives of the Service's regional, field and Washington offices met in Panama City, Florida, to discuss "Migratory Bird Conservation and Communications Towers: Avoiding and Minimizing Conflicts." Some of you may have had a chance to review this document (copies may be requested via e-mail). In late December 1998, I met with representatives of the environmental dispute resolution group RESOLVE (Abby Arnold and Robert Fisher) to discuss the need for a facilitated meeting with stakeholders to review and discuss research needs and gaps, put concerns on the table, and begin a dialogue with the various players. That facilitated meeting took place on June 29, 1999, with 42 participants representing stakeholders from:

- ***government agencies*** **–** including the FCC, Federal Aviation Administration, Federal Highway Administration, U.S. Dept. of Agriculture's National Wildlife Research Center, FWS, and the Wisconsin Dept. of Natural Resources;
- the ***research community*** **–** including the Illinois Natural History Survey, Buffalo Museum of Science, State University of New York Geneseo, Cornell and Clemson Universities, Geo-Marine, and Curry & Kerlinger;
- ***industry*** **–** including the Personal Communications Industry Association, the Cellular Telecommunications Industry Association, Motorola, SBC Wireless, and Environmental Resources Management; and
- the ***environmental community*** **–** which was broadly represented.

On August 11th, the first-ever public workshop on "Avian Mortality at Communications Towers" was held at Cornell University in conjunction with the 117th meeting of the American Ornithologists' Union, co-sponsored by the Service, the Ornithological Council, and the American Bird Conservancy. Bill Evans and I had the pleasure of co-chairing the meeting which included presentations by 17 speakers and a discussion of research and funding needs, gaps, and next steps by a panel of 23 experts. Complete transcripts of the meeting are available on the Web at the following sites:
<**http://migratorybirds.fws.gov/issues/towers/agenda.html**> and <**www.towerkill.com**>.

What have we learned about birds and communications towers?

Published accounts of birds striking tall, lit structures such as lighthouses – although often anecdotal – have appeared in the literature back to at least 1880. The earliest report of birds dying from a tower collision was published in 1949 from a radio-tower strike in Baltimore the previous fall.

The first long-term study of the impact of communications towers on birds was begun in 1955 by Tall Timbers Research Station at a television station in north Florida. Over a 25-year period, 42,384 bird carcasses representing 189 species were collected and identified from collisions with this tower, its guy wires, other birds, or the ground. The longest study yet conducted was by physician Dr. Charles Kemper over a 38-year period, beginning in 1957. He collected 121,560 birds representing 123 species. In 1963 he collected over 12,000 dead birds – a one-night record kill even without accounting for the almost certain scavenging by cats, dogs, foxes, raccoons, skunks, owls, crows, and others species then present.

Much other information about bird strikes with communications towers – including radio, television, cellular, microwave, paging, messaging, open video, public safety, wireless data, government dispatch, or emergency broadcast – has been published since the 1970s. Unfortunately, most accounts review only carcass counts and species variability, not the presumed or suspected causes of bird collisions. Research into causes is sorely lacking.

Published accounts do, however, answer one question. Birds vulnerable to communications towers comprise nearly 350-species of so-called neotropical migratory songbirds – thrushes, vireos, and warblers being the species that seem the most vulnerable. These are birds that breed in North America in the spring and summer and migrate to the southern United States, the Caribbean, or Latin America during the fall and winter. These species generally migrate at night and appear to be most susceptible to collisions with lit towers on foggy, misty, rainy, low-cloud-ceiling nights during their migrations. Lights seem to play a key role in attracting the birds.

Federal Aviation Administration (FAA) regulations currently require towers greater than 199 feet above ground level (AGL) to contain a pilot warning light(s). Based on the Federal Communications Commission (FCC)'s February 2000 Antenna Structure Registry database, there are currently some 46,000 lit towers greater than 199 feet AGL (not including towers classified as "poles") in the U.S., plus an additional 23,000 unlit. In April, cumulative FCC tower total was approximately 74,000. (Lighted towers registered with the FCC numbered around 49,000 as of October 2000.) While some groups argue that the database understates the number of lit towers, suggesting that upwards of 80,000 currently are lighted, we do know that tower construction has increased exponentially in the past three years and continues to grow at 6-8% per year.

What is it specifically about the towers that seems to attract the birds? Lighting is critical. While the retina of a bird's eye is far more sensitive to the red and infrared spectrums, current thinking would indicate that light duration – the "off" phase of lights between the blink or flash phases of the light pulses – is far more critical in altering bird behavior than is color. Solid or blinking red lights seem to attract birds on foggy, misty nights far more than do white strobes which may flash once every 1-3 seconds. Preliminary research by Avery and Gauthreaux supports the hypothesis that the <u>longer</u> the duration of the "off" phase, the <u>less likely</u> a light is to attract birds during foggy, misty, rainy, low-cloud-ceiling nights. This hypothesis will need testing in a systematic and statistically significant way.

The literature strongly supports the hypothesis that the taller the tower, the more birds are likely to be killed. Guy wires are critical. The more the guys, the greater the risk for bird strikes. On inclement nights, birds appear to shut off their normal "nocturnal" migratory cues of star and magnetic compass orientation, and appear to switch on their "diurnal" cues. They become attracted to the lights, flying around the towers in a "tornado" of birds, striking the guy wires, the tower, each other or the ground – and dying. Thus the worst case scenario would be a 1,000+-foot tower, multiple-guyed, with multiple solid or pulsating lights, in a bird migratory corridor, near or next to a wetland. Unfortunately, the Telecommunications Act of 1996 will only exacerbate this problem: all television stations must be digitized by 2003, adding a potential 1,000 new 1,000-+-foot "mega-towers" on the scene.

What about the impacts of electromagnetic radiation and radio waves? Research by Beason and others indicates that – except for microwave – this is not a problem. This, however, still needs more review and testing.

What is the Service Doing to Deal with the Problem?

The Migratory Bird Treaty Act of 1918, as amended, is a strict liability law. The killing of any bird technically is not allowed under law unless permitted. "Incidental taking" of migratory birds is not allowed by law – in fact it is not even mentioned in MBTA or Congressional report language – and the Service does not issue "takings" permits.

While the Service recognizes that research into the actual causes of bird collisions with towers is scant, some (previously mentioned) preliminary but promising findings provide insight into ways of minimizing or even avoiding bird collisions with towers. In an effort to provide significant protection for migratory birds, the Service is about to release a series of voluntary interim guidelines to the industry. The guidelines at this time are still in draft form.[2] For companies planning to site, construct, and operate new towers, we strongly recommend the following:

- ***Collocate*** proposed communications equipment onto an existing structure – a tower, steeple, monopole, spire, water tower, or billboard – as the first option in siting a communications source. The Service recommends at least two additional clients on an existing tower. Crown Castle International averages nine per tower in Pittsburgh, PA, with as many as 120 tenants per tower there.
- If collocation is not practical we strongly suggest keeping towers ***under 200 feet, unguyed, and unlit***. Such towers do not require lighting under FAA regulations unless near airports or major travel corridors.
- If possible, ***locate new towers in existing "antenna farms,"*** preferably in areas not used by Federally or state-listed threatened or endangered species, or where birds are listed as species of management concern. Avoid siting towers in or near wetlands, or near other known bird concentration areas (National Wildlife Refuges). Avoid areas with a high incidence of fog or low-cloud ceilings, especially during spring and fall migrations.
- If a tower must be over 199 feet (the FAA's threshold for pilot warning lighting), we strongly suggest using a ***lattice*** or ***monopole*** structure with no supporting guy wires; ***locating the tower in an existing antenna farm***; and ***using the minimum amount of warning and obstruction lighting*** required by FAA. Only white strobe

[2] *Note:* These guidelines were released by the Service on September 20, 2000, and are available at **<http//migratorybirds.fws.gov/issues/towers/comtow.html>**

lights should be used at night, upshielded to minimize disruption to local residents, and these should have the minimum number, minimum intensity, and minimum number (3 second-duration) flashes per minute allowed by FAA. The use of solid red or red pulsating lights should be avoided at night.

- Guyed towers constructed in known raptor or waterbird concentration areas should ***use daytime visual markers*** (*e.g.,* bird diverter devices) on guy wires to prevent collisions by these diurnally-active species. Suggested bird avoidance guidelines are available from electric utility industry (APLIC 1994, 1996) and a few recommendations mentioned for wind generation industry (Anderson *et al.* 1999).
- Towers should be constructed in way that ***limits or minimizes habitat loss*** due to tower "footprint."
- If significant populations of breeding birds are known to occur within the proposed tower footprint, construction should be limited to those months when birds are not nesting.
- If a tower is constructed, allow Service personnel and/or researchers from the CTWG or their designees the ***opportunity to conduct dead-bird searches*** each dawn, especially following nights of fog, mist, or low ceilings. Allow ***placement of catchment nets*** below the towers, but above the ground. Allow the placement and use of radar, GPS, infrared, thermal imagery, and acoustical ***monitoring equipment*** to assess and verify bird migrations and habitat use.
- Encourage the removal within 12 months of towers no longer in use or determined to be obsolete.

What are the Next Steps?

At the RESOLVE meeting in June 1999, the Communications Tower Working Group was created, then with 15 representatives from federal and state agencies, research, industry, and the conservation community. The task of the Working Group is to develop and implement a research protocol that it is hoped will determine what causes bird collisions with towers, and what can be done to avoid them.

The Working Group held its first meeting on November 2, 1999. I chair the Group on behalf of the FWS. With representatives from one state and seven Federal agencies, nine research organizations and universities, eight industry representatives, and six non-government organizations, the Working Group has grown – and continues to grow – considerably. New participants include the National Park Service, U.S. Forest Service, U.S. Coast Guard, South Florida Water Management District, Sprint Spectrum, American Tower Corporation, Pennsylvania Audubon, and others.

Subcommittees were created to deal with research, funding, and legal issues, reporting to the full Working Group on June 16, 2000. The Research Subcommittee met on April 17, 2000, with more than 30 stakeholders attending the all-day session, and approved a draft nationwide research protocol. The protocol calls for the following research:

- Quantify, with statistical certainty, the cause(s) and effects of lighting color, lighting duration, and the correlation between bird kills and weather.

- Attempt to determine critical tower height and whether there is a height threshold above which bird kills increase significantly.
- Attempt to assess and quantify the most dangerous situations for birds.
- Assess radar, acoustic, and ground survey techniques that could be used to determine major migratory corridors or routes (not necessarily flyway-oriented) to avoid siting towers in these areas.
- Develop an effective dead bird monitoring protocol, which will borrow heavily from wind generation industry (Anderson *et al.* 1999) and power line industry (APLIC 1994, 1996).
- Assess the cumulative impacts of all towers on bird populations in North America.

In 1979, Dick Banks published a FWS special scientific report estimating annual fatalities at nearly 1.3 million birds. Banks' estimate was based on 50% of the 1,010 television transmitting towers then existing in the U.S. He did not account for radio transmitting towers and airport ceilometers, or for the other half of existing television towers. Based on Banks' calculations, models from Tall Timbers Research Station, extrapolations from Bill Evans and others, and the current number of lit towers, the Service currently estimates annual fatalities at 4-5 million birds. This is a conservative estimate; it could be off by an order of magnitude.

A systematic research study may take three to five years to complete, with field testing and verification of anticipated mitigation measures (*e.g.,* likely lighting "fixes," possible infrasound warning devices) requiring still further research. Such a study may cost $5-8 million. A detailed budget has yet to be worked up. It is hoped that the industry will share in the cost of this effort. Signs, to date, have been positive. Once the research is completed, recommendations would then be presented to both the FCC and to industry.

[The full CTWG met on June 16th, 2000, and approved the framework for a nationwide research monitoring study, which likely will cost over $15 million for 3-5 years. Southwestern Bell Wireless, Inc. solicited research proposals for pilot studies – several of which are about to be peer-reviewed – and the Cellular Telecommunications Industry Association solicited a full-blown research proposal for nationwide monitoring to assess the impacts of towers on birds (cumulative impact study), determine what it is about towers that attracts birds, and what can be done to reduce the problem. The pilot studies likely will begin in Spring 2001, and the nationwide monitoring effort could begin as early as Fall 2001.]

Meanwhile, Paul Kerlinger was hired to review and synthesize the current and recent literature. Kerlinger completed a detailed review in March 2000, synthesizing the findings from North and Latin American, European and Australian data.

Two partnerships which have worked very well to date may serve as models for work with the communications industry. These include the Avian Power Line Interaction Committee (APLIC) co-founded by the FWS in the 1970s, and the Avian Subcommittee of the National

Wind Coordinating Committee, co-founded by the Service in 1994.

Clearly, we have our work cut out for us – but the ground work has been laid, the team is in place, and we're anxious for some positive results.

General Discussion

Questions for Dr. Manville included what steps, if any, could be taken to look at the impact of communications towers on bats. In response, Dr. Manville noted that his office's focus is limited to migratory birds.

The possibility of federal funding for research was raised. Dr. Manville noted that, while we "don't want to leave any stones unturned with regard to funding," the problem with Congressional appropriations is that it takes two years to get on the radar screen. For this reason, partnerships are key.

One participant raised the point that birds strike other structures besides communications towers and wind turbines: the figures are "huge" with regard to building strikes. The difficulty with taking action on this front is that buildings are issued to many, whereas towers generally have more limited ownership. It is possible to take potential impacts on birds into consideration when siting towers, and thus one goal is to get tower owners to avoid sites that are likely to be problematic with regard to bird strikes.

Another participant asked Dr. Manville to comment on the geographic distribution of the problem of communications tower strikes: primarily east coast or west coast? According to Dr. Manville, tower strikes are a problem mainly to the east of the Rockies.

Asked about the June CTWG meeting, Dr. Manville said that attendance is open, and encouraged NREL to send a representative.

Taking Account of Differences at Each Site

Panel: *Richard L. Anderson,*[1] *Michael L. Morrison,*[2] *Dale Strickland*[3]

[1]California Energy Commission

[2]California State University

[3]Western EcoSystems, Inc.

Introduction

NREL / DOE-funded work enables us to build upon earlier studies, identify where problems are and develop and test mitigations strategies. Factors to consider in taking account of differences between sites include:

- **Species presence and relative abundance**
- **Habitat**
- **Wind plant characteristics**
- **Methods used for data collection**
- **Methods used for parameter estimation and data analysis**
- **Metrics used**
- **Meta-analysis and weight-of-evidence**

Bear in mind that there is a difference between the way science happens in the lab vs. in the real world – out in the world, researchers have to make a lot of assumptions. One cannot assume that what happens at one site is what will happen at another site, even if the other site appears to have identical characteristics. Remember that we are studying rare events in non-randomly chosen widely-scattered sites. In the field you cannot do a true experiment, only observational studies. If we do enough observational studies with consistent methods and metrics, we can begin to make subjective "weight of evidence" judgments about what is going on. However, keep in mind that these judgments, while they may be useful, are not scientific conclusions.

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General Discussion

Don Bain: It would be nice to see this kind of summary (bullets from overhead) up front, so that the reader doesn't have to wade through each study to find out the type of species, habitat, methods, metrics used, etc.

Brian Keeley: Researchers don't always have the luxury of time to do baseline studies. "Snapshot in time" feasibility studies don't necessarily give good information.

Dale Strickland: People sometimes take away the wrong message. For example, at Foote Creek Rim, 85% of the activity is happening at the edge of the rim, so strings of turbines are located back from edge. The study author told someone "don't ever put turbine strings at rim edges or ridge tops." But this was the wrong message; it depends on the species, orientation of the site to prevailing winds and updrafts, etc.

Larry Mayer: If you think of this as an epidemiological study, you hope to be able to make a recommendation. As a scientist, I feel nervous about making recommendations outside of my area of expertise, yet here [at NAWPPM] we throw out ideas about all sorts of possible recommendations (e.g., architecture)...

… Maybe we should have two different types of sessions: one for scientists to speculate freely and brainstorm, and one to bring in industry and policy people to talk about what we can say with any degree of scientific confidence and implications for policy and practice.

Dick Anderson (in response to a question): Work at Tehachapi is finished, and should be published soon. Work at San Gorgonio – phase I is completed; we are continuing NREL-funded work, looking later this summer at larger turbines to be compared to smaller turbines.

Steve Steinhour: What can be extracted from the studies to date about what we should be monitoring over the longer term? For example, when looking at the disappearance of small towns, there is a marked tendency for towns to disappear when its school closes down. Is there any comparable indicator or indicators that we should be monitoring in the case of wind sites?

Panel (in response to Steve's question): There is no comparably simple indicator to monitor. However, one can use meta-analysis and weight-of-evidence. The more we understand about different sites, the more professional judgments we can begin to make. We can estimate or forecast problem sites, or problem locations within a site.

Mike Morrison: Don't just say "monitor." It is important to specify *what* you want to monitor and with what degree of precision.

D. Strickland: You have to know what you want to know before deciding what to measure. If the Federal government is interested in learning about renewable technologies, there should be an integrated monitoring research program that will give us an idea about ecosystem responses. Look at some variable or variables over a long period of time. Scientists need to discuss what these variable might be. We are not looking at ecosystems now, we're looking at pieces of ecosystems.

M. Morrison: Altamont deserves attention. We may be close to starting to try things in the field. Then there are all the other locations. Altamont is a good place for field trials because there are so many dead birds.

B. Keeley: A lot of the projects are industry-driven. Where is the big picture for the research strategy?

L.Mayer: It is important to prioritize within research categories.

Grainger Hunt: We should have continued to monitor at Altamont as Orloff did over all these years since.

Steve Ugoretz / M. Morrison: The siting and metrics documents are valuable: tell people to read them.

Carl Thelander: It may be time to hold workshops just on the Altamont.

D. Bain: With regard to repowering – the industry is moving towards larger and fewer turbines – how do we look at that?

M. Morrison: The hope is that the newer towers will be (more) bird friendly, but we don't know that.

Lee Langstaff: We can't tell you what works and what doesn't. However, we can tell you what to take into consideration   What is transferable from site to site is not "what to do" but what questions to ask, what factors to take into consideration.

There are going to be time and costs associated with siting your facility. Period.

California Condor Reintroduction - Potential Wind-Power Related Impacts

by

Jim Davis and Kelly Sorenson

Ventana Wilderness Society[1]

Abstract

The Ventana Wilderness Society in conjunction with the U.S. Fish and Wildlife Service proposes to conduct releases of California condors in the Hamilton Range of the Diablo Mountains in Santa Clara County, California. Defenders of Wildlife and Ventana Wilderness Society are cooperatively preparing an Environmental Assessment for the release proposal. The California Condor is a fully protected endangered species in California. California condors released in the Mount Hamilton Range could potentially interact with Wind Resource Areas (WRAs). California condors are obligate scavengers very similar to turkey vultures in foraging and flight patterns. Since turbine-related fatalities are rare in turkey vultures, a low fatality rate may be expected in condors if no attempt is made to reduce its threats. California condors previously released at central and Southern California locations are likely to eventually frequent the Hamilton Range even if no condors are released there since it is within their recent historic range. In the best interest of both WRAs and California condors, pre- and post-release aversion training as well as other measures are proposed in conjunction with the release itself. Based on the success of a similar type of training with power pole avoidance, aversion with wind turbines is feasible. Experimental measures to reduce the possibility of condor mortality associated with turbines regarding the release proposal include: perching avoidance, turbine avoidance from a distance, and discouraging condors from habituating to the area surrounding WRAs by trapping and removing.

General Discussion

In their presentation, Mr. Davis and Mr. Sorenson indicated that pre-release training with a wired mimic power pole (giving a 6-volt shock) is shown to cut mortality in the wild from 31% to about 3%. In the case of wind turbines, it would be necessary to train them not only not to perch, but also to avoid turbines from a distance. This might be done by mounting a small shocking unit on the bird's wing or tail, the unit to be activated by an observer at the training/release site. It is less clear how this kind of avoidance training might be conducted at an actual wind energy site. It is also unclear how this type of training will be carried forward to future generations through cultural transmission. Ventana Wilderness Society seeks funding to conduct research projects to investigate the effectiveness of this type of training.

One comment was that one needs to be cautious how conditioning is applied, especially if the animal might learn that there is a reward for tolerating the aversive stimulus

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(the “dinner bell effect”). The issue of scale effect, i.e., the need to train birds to avoid not merely an individual turbine but “something that looks like a wind farm” also was raised. The use of strobes was suggested, but the point was made that one would need to consider the effect of strobes on humans and others.

Dead cattle on the Altamont range could constitute an attractive nuisance to condors. If so, it may be necessary to remove large, attractive carrion from zones near active turbines. Another approach might be to provide feeding stations away from turbines. (Condor feeding stations are being provided in any case for the first few years following release.) The presenters noted that the release program has not done anything to train condors to avoid road kill, yet birds getting hit by cars has not been a problem so far.

Avian Mortalities at Tall Structures

by

Steve Ugoretz[1]

While considerable attention has been focused on avian mortalities at wind energy facilities, other tall structures are also causing mortality, often at much greater numbers than wind turbines. Apparently, any tall structure that extends into a bird's airspace may cause a collision. Taller and lighted structures seem to increase the probability of collisions, and certain structures, including very tall broadcast towers and tall buildings, can cause very large mortalities, essentially overnight during periods of migration.

Several reviews (CEC, 1995, Colson, 1995, Avery et. al., 1980) have discussed all reported sources of collision mortality. Winkelman (1995) has compared estimated turbine mortality in the Netherlands to other sources, and found the rates comparable to or even less than highways and other man-made obstacles. Reports of very large kills of birds at tall T.V. and radio towers are very common in the literature. For example, Dr. Charles Kemper (1996) has monitored kills at a T.V. tower in Eau Claire, WI since 1957. He routinely reports estimated mortalities in the thousands. Similar reports come from many towers East of the Rockies.

Tall, illuminated buildings in large cities can also produce large mortalities during the spring and fall migrations, particularly under poor visibility conditions (FLAP, 1999). Mortalities at industrial chimneys, lighthouses, power lines and pylons have all been reported.

Certain factors seem to be implicated:

1) Height – the U.S. Fish & Wildlife Service has focused on towers in the 400 ft. and greater category as being of greater concern. This may be partly due to a lack of documentation of mortality levels at smaller towers, or because of several factors discussed below.

2) Lighting – FAA-required lighting of towers greater than 200 feet seems to have a role in attracting birds, and holding them in a circling mass around tall towers. Birds are more sensitive to red light, and appear to be attracted to that color. Blinking red marker lights in poor visibility conditions appear to be disorienting birds and simulating stars as navigational cues. The birds orient themselves at right angles to the lights, which produces the circling masses of birds reported by Kemper and others. Quickly flashing white strobes appear to be less attractive to birds.

3) Construction – guy wires appear to be responsible for a major component of avian mortality at communications towers. During the low visibility conditions that produce these major mortality events, the birds are attracted to the lights and circle as described above. Many of them strike the guy wires, which are unlighted, as well as the tower and each other.

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4) Location – there are few clear indications of what location factors are implicated in mass collisions. Some sites, like the Tall Towers Research Station in Florida are at points where birds are crossing onto the North American mainland. Other towers may be along major north-south migration routes. Also, apparently there are few, if any, reports of these occurrences west of the Rocky Mountains. The reason for this observation needs to be investigated. Whether mortality is occurring at urban sites, such as the Eau Claire tower, or at sites with natural cover also needs to be established.

The U.S. Fish and Wildlife Service effort described by Al Manville is attempting to address all of these questions. Hopefully, some lessons can be learned that also apply to the location and construction of wind energy facilities.

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SUMMARY AND CONCLUSIONS

In addition to the general discussions following individual presentations, meeting participants paused following the first three sessions and again after the fourth session to review key points. Highlights of these general discussions are summarized below. The meeting concluded with a three-part discussion, touching on what we have learned regarding avian-wind power interactions, on the effectiveness of the guidance document in establishing good basic design principles for field research, and on which areas merit further exploration or research.

Summary of Discussion Highlights

The presentations stimulated productive and interesting discussions among participants. Highlights of these discussions are summarized below. The order in which they appear roughly reflects the organization of the agenda, and is *not an indication of priority*.

Do Tower Type, Turbine Size, or Tower Position Matter?

The question of whether tower type affects avian mortality remains elusive. On the one hand, studies specifically trying to identify whether tubular towers (offering fewer perching opportunities) result in fewer collisions than lattice towers have not supported the hypothesis that lattice towers present a higher risk. On the other hand, at least one participant questioned the conclusion that different types of tower don't matter, and others agreed that there seems to be some discontinuity in such findings. For instance, 100% of the fatalities at Altamont occurred at 25% of the turbines, an apparently non-random distribution. Research at another site suggests that guyed meteorological towers appear more likely to kill birds per structure than wind turbines, but this hypothesis has yet to be confirmed.

One response to this paradox is that perching (or the opportunity to perch) may not be as critical a factor as is the utilization of the landscape for foraging, independent of tower type. This would explain why researchers have found equal or greater fatality rates at areas without horizontal lattice towers.

Another hypothesis that has not yet been borne out (nor disproved) by the data is whether larger, slower-turning turbines pose less of a risk to birds than smaller turbines.[1] Research conducted at the Buffalo Ridge wind resource area considered the question of tower size, seeking to determine if larger and slower turbines have potential for lower impact. This research showed that impacts of different size turbines may depend on the species and whether they are diurnal or nocturnal. Large turbines appear to be problematic for passerines migrating at night through the Buffalo Ridge WRA. However, it was noted that this is an area without many raptors. Researchers at Altamont Pass, where raptors are prevalent and turbine-related fatalities have been a problem, also are considering the impact of tower size. Some anticipated changes at Altamont Pass WRA include the removal of turbines in high-risk areas and the use of fewer, larger turbines to replace a larger number of smaller turbines. Researchers are

[1] Larger turbines with longer blades have the same tip speed as smaller turbines, but the rotor speed (RPM) is higher on the smaller-bladed turbines. Conversely, the larger-bladed turbines have a slower rotor speed (RPM) in order to maintain the same tip speed.

hoping to document the impact of this change on bird mortality.

With regard to tower placement, some observations seem to indicate higher numbers of collisions associated with gaps in turbine strings, particularly for raptors. Meeting attendees agreed that a closer look at gaps in turbine strings may reveal promising information, but noted that researchers need to define what they mean by a tower and be consistent about describing its position: different people are using different criteria for gaps, middles, ends.

Mitigation Strategies

Focus on prey species. Regarding the removal of prey species as a possible mitigation strategy, participants noted the need to be "careful of public perception," especially when it comes to "advocating prey elimination" as a solution. "We don't want to reduce numbers of dead birds by killing ground squirrels," summarized one participant. Others felt that, despite the risk of arousing opposition, prey removal should be considered as a strategy. The idea of managing the landscape in the vicinity of turbines by planting grasses so predators cannot easily see the prey animals was suggested. Another landscaping alternative might be to make areas near the base of turbines less attractive for burrowing, thereby discouraging the presence of prey animals (such as gophers) in the vicinity of the turbines.

Location, location – and design. One conclusion about which there seems to be a strong consensus is that the location of the wind plant is important. As one participant put it, "I think everyone would agree that we can reduce bird fatalities by siting wind plants in areas with less bird use." As a first step, high bird-use areas (as determined on a site- and species-specific basis) should be avoided.

The hierarchy continues with looking at "micro use" of the site to further reduce avian interactions. This includes looking at which species use the site and how, selecting appropriate equipment, taking site topography and habitat into consideration, and other site-specific issues of site design. For example, guyed meteorological (met) towers apparently kill more birds than turbines do; therefore, designing for fewer met towers (and fewer guy wires) should reduce fatalities. (Note: this hypothesis needs further confirmation.)

The site specificity of wind energy plant design issues is especially salient where raptors are the primary species of concern, because the behaviors that appear to be associated with raptors' turbine-related fatalities are more site-specific than for any other species.

Reducing use reduces fatalities. One participant remarked that the objective of most of the proposed mitigation strategies is to reduce bird use of wind power facilities – e.g., by burying utilities, reducing perching opportunities, painting turbines, possibly manipulating prey species to make the high-risk zones less attractive to raptors, etc. A number of these measures are ready to be field tested at Altamont.

Reducing risk. Participants pointed out the confusion over the terms "fatalities" and "mortality." Often the term mortality is confused with fatalities. Fatalities are the number of birds killed at a site; mortality is the rate at which birds using the site are killed.

Another (related) source of confusion involves the terms "utilization" and "risk," which sometimes are (inappropriately) used interchangeably. The point was made that while reducing bird use of wind power facilities may achieve the goal of reducing the level of fatalities, it is important not to confuse *use reduction* with *risk reduction*. *Use* is a unit of exposure – e.g., incidence of bird activity within the rotor-swept area of a wind turbine. *Risk* is the probability that a given incident of bird use will result in a fatality, or individual bird death. (Note that the risk to individual birds is different than the risk to a population of birds, and the risk to one species may differ from the risk to another species. For example, an individual Golden Eagle fatality is of greater significance to the population of eagles than is an individual pigeon fatality to the population of pigeons, because the eagle population is more vulnerable to the loss of an individual bird.)

The data indicate that raptors are at greater risk than other birds (e.g., ravens, vultures, waterbirds, pigeons) of colliding with turbines, particularly end-of-string turbines. Passerines being killed in large numbers appear to be migrants traveling in large flocks mostly at night, with peak fatalities occurring in the fall and spring, often associated with weather events. (It was noted, however, that some resident passerine species also are being killed – e.g., meadowlarks at Altamont Pass WRA – and that, because smaller birds are scavenged rapidly, they are likely to be under-represented in most fatality surveys.)

In considering impacts and mitigation strategies, it is important to remember that there are differences among raptors regarding when they may be at risk; for example, eagle exposure is highest in winter and spring, whereas the red-tailed hawk exposure is highest in summer and fall. Yet similarities in raptor ecology, behavior, and use of habitat seem to put them at higher risk than other birds with comparable levels of exposure. The higher mortality rate of raptors is particularly significant given that raptor species are more vulnerable to the loss of individual birds. Thus the emphasis on looking for ways to reduce exposure (e.g., by manipulating prey, reducing perching opportunities, or taking slope aspect and kiting behavior into consideration when siting turbines). Other approaches, such as efforts to increase the visibility and acoustic profile of rotating turbine blades, aim at reducing risk – i.e., making turbines easier to sense and avoid for raptors using the area.

Other Points to Consider

Several points were raised by participants:

- "We should not be acting as decision-makers in isolation." When thinking about measures to reduce exposure or risk, it is important to consider unintended consequences. One has to look at "what works biologically" but "also look at legal and human aspects."

- What constitutes an "appropriate level of take" is one of the legal aspects to be considered.
- Researchers should "use the information we have now to advise industry of what we know" – but this doesn't mean there won't be new information five years from now.
- Recommendations may differ with regard to what to do at a new installation vs. what do with an old one.
- There is no one solution – it is important not to reject the small changes and improvements.

Conclusions

What We Have Learned

In an attempt to summarize what we have learned about avian wind power interactions, participants generated the following brief list.

- In addition to being killed by collisions with other man-made structures, birds and bats are killed by collisions with wind turbines.
- Bird impacts can be significant or insignificant.
- Raptors are a high-risk bird group in some locations.
- Bird use, mortality, and risk vary between and within wind resource areas.
- Wind turbine impact on birds is a site-specific issue.
- There is no conclusive data as to whether a) large or small turbines reduce risk, or b) tube or lattice towers reduce risk.
- Nothing is known for sure to reduce avian fatalities significantly.
- Avoidance of areas with high bird use is the only proven way to avoid high levels of avian fatalities.

Many meeting attendees feel that there continues to be inadequate understanding of the extent to which avian fatalities associated with wind power generation facilities are actually significant to avian populations. In addition to uncertainty about the specific significance of avian-wind turbine interaction, questions remain about the relative impact of wind turbines compared to other sources of avian fatalities such as transmission lines, radio towers, buildings, etc.

Some support the need to define the level of "take" that is acceptable for avian species interactions with wind turbines. It was acknowledged that where threatened and endangered species are concerned, a target of zero is likely to be the rule. Under the Endangered Species Act, incidental take permits may be issued. However, there is no such accommodation for takings under the Migratory Bird Treaty Act (MBTA), under which the U.S. Fish and Wildlife Service (USFWS) is responsible for protecting migratory birds. Reducing and/or minimizing anthropogenic sources of bird fatalities is an issue regardless of the relative contribution of different specific causes. However, there is much to be gained from sharing information across industries in order to maximize the collective ability to reduce risk.

Effectiveness of Standard Methods and Metrics

Meeting attendees discussed the effectiveness of standard methods and metrics used in avian research. The group agreed that good basic design principles have been established in the document. It was further agreed that more time is needed to gain experience with field application of the standard methods and metrics before making judgments. They indicated that one to two years of experience with them is needed, and feedback needs to be gathered before any attempt is made to revise and improve them.

The following specific points were made based on experience to date with the standard methods and metrics.

- The methods and metrics for nocturnal surveys are weak and may need specific attention. Likewise, for bat surveys.
- Regarding carcass removal or deterioration time - using mallards as a standard probably results in overestimating the speed of removal and biases results. Preference was expressed for using raptor carcasses as a standard instead. However, large raptor carcasses tend to stay longer than those of small songbirds, but this may be site-specific. Using frozen carcasses is not a promising option as experience has shown that they go largely untouched by scavengers.
- The recommended 60-meter search area for carcasses seems to be adequate.

It was suggested that a mechanism be established for soliciting input from the field on the usefulness and applicability of the standard methods and metrics document for use in future review and revision.

Areas Needing Further Exploration or Research

The group acknowledged that we are in a continual learning process and agreed that what is recommended today may not be recommended tomorrow. As to the question, “Will we know when we have enough information?” the sense of the group was that we will know when we have enough information about avian interactions when we have reasonable predictive capability with regard to siting to minimize and mitigate impacts.

Drawing on the presentations and discussions, and on their own individual expertise and experience, participants dedicated some time to compiling a list of areas where they believe future research is needed and in which additional exploration is likely to yield useful information for improving our predictive capabilities. The resulting list appears in Appendix A. While it is *not* a prioritized list, it could be used as the starting point for further discussion of research priorities.

Finally, while targeted, rigorous research is needed, it needs to be combined with true experiments and long-term monitoring. For example, we still do not know whether tubular towers are better than lattice towers, or large towers better or worse than small ones. Other points raised included:

- the need for a system to record fatalities in wind plants in the future;

- the need to find a way to learn collectively rather than place the burden on a few companies as has been the case, “because this won’t last;”

- the possibility of dovetailing parts of the Avian Subcommittee’s agenda with those of other groups that have money (for example, with Bat Conservation International); and,

- the need for a national as well as regional perspectives.

APPENDIX A: LIST OF RESEARCH TOPICS

Drawing on the presentations and discussions, and on their own individual expertise and experience, participants dedicated some time to compiling a list of areas where they believe future research is needed and in which additional exploration is likely to yield useful information for improving our predictive capabilities. Topics suggested during this brainstorming session are presented below. The list has not been prioritized, but may serve as a point of departure for further discussion of research priorities.

- Need to get a better understanding of significance of numbers of individual birds killed to their populations (species-specific) so that actions or remedies can be focused on the most significant problems
- Development of nocturnal survey methods and metrics (for birds and bats)
- Increase and/or expand avian vision studies – including field applications
- Prey management (relationship between prey abundance and fatalities, and the potential for managing prey)
- Extent to which other features associated with wind plants contribute to avian risk (use by prey species)
- Relative impacts of large vs. small turbines (new vs. old)
- Evaluate whether risk-reducing devices or actions work or not
- Develop estimates on distance from blade at which birds can hear it (need information regarding acoustic signature of blade noise) – and assess implications for role of acoustics in bird avoidance of blades
- Need interim evaluation of actions currently being implemented (as at Altamont)
- Standardization of self-monitoring studies
- Evaluation of aversion training (condors) as a risk reduction strategy
- Need more/better integration with permitting process
- Meta-analysis of existing data
- Gaps in tower strings (including species-specific implications at Altamont)
- Extent to which risk is reduced by turning turbine off (for different species)
- What considerations need to be addressed in re-powering decision-making and planning

- Information regarding operational status of turbines would be helpful in determining risk (need from operator).

- Calibration studies on carcass removal speed

APPENDIX B: MEETING ATTENDEES

Dick Anderson, California Energy Commission
Don Bain, Oregon Office of Energy
R.T. "Hap" Boyd, Enron Wind Corporation
Charles Bragg, National Audubon Society
Richard Carlton, Electric Power Research Institute
Jim Davis, Ventana Wilderness Society
Robert Dooling, University of Maryland College Park
Thomas Gray, American Wind Energy Association
Darryl Gray, Alameda County Planning Department
Larry Hartman, Minnesota Environmental Quality Board, MN Planning
William Hodos, University of Maryland College Park
Stacia Hoover, BioResource Consultants
Grainger Hunt, Predatory Bird Research Group
Brian Keeley, Bat Conservation International, Inc.
Todd Mabee, ABR Inc.
Jim Maloney, Eugene Water & Electric Board
Lawrence Mayer, Banner Health Research Institute
Gail McEwen, Oregon Department of Fish and Wildlife
Hugh McIsaac, Department of Biological Science
Thomas Meehan, Oregon Office of Energy
Kimia Mizany, UC Santa Cruz
Michael Morrison, Dept. of Biological Sciences, Cal. State University
Charles Nicholson, Tennessee Valley Authority
John F. Nunley III, Wyoming Business Council, Energy Office
Michael C. Robinson, National Renewable Energy Laboratory
Lourdes Rugge, BioResource Consultants
Sharon Sarappo, Northern States Power
Susan Savitt Schwartz, Writing & Editing Services
Karin Sinclair, National Renewable Energy Laboratory
Shawn Smallwood, BioResource Consultants
Robert Snow, U.S. Fish and Wildlife Service
Kelly Sorenson, Ventana Wilderness Society
Steve Steinhour, SeaWest
Joan Stewart, Altamont Infrastructure Co.
Dale Strickland, Western Ecosystems Technology, Inc.
Carl Thelander, BioResource Consultants
Rick Thompson, Public Service Company of Colorado
Steve Ugoretz, Wisconsin Department of Natural Resources Energy Team
Rick Williams, Duke Engineering & Services

Facilitators: Lee Langstaff, RESOLVE, Inc.
Lori Riggs, RESOLVE, Inc.

APPENDIX C: MEETING AGENDA

May 16-17, 2000
Carmel Mission Inn
3665 Rio Road
Carmel, California

Purpose of Meeting:

- Share research results and update research conducted on avian wind interactions
- Identify questions/issues stakeholders have about research results
- Develop conclusions about some avian/wind issues
- Identify questions/issues stakeholders have for future avian research

Tuesday, May 16, 2000

8:00 – 8:30 Continental Breakfast

8:30-8:45 **Welcome and Introductions** *Lee Langstaff, RESOLVE*

- Introductions
- Review purpose of meeting
- Review product we want to develop at the meeting

8:45-9:05 **Setting the Context: Overview of Avian/wind Power**

***History and Overview of Studies Conducted to Date** – Dick Anderson, CA Energy Commission, and Chair of NWCC Avian Subcommittee*

- History and conclusions of past three meetings
- What studies have been conducted or are currently being conducted

9:05-12:00 **SESSION I – Site Studies – What are we observing at existing sites?**

Overview of each study, (brief overview of methodology used in study, what is being studied, data analysis, timeline, conclusions if any)

Altamont Pass Wind Resource Area

9:05 – 9:35 Carl Thelander

9:35 – 10:05 Grainger Hunt

10:05 – 10:20 BREAK

10:20 – 10:40 Stacia Hoover & Shawn Smallwood – Prey Studies

10:40 – 11:10 Discussion: what questions or issues are raised and what conclusions can be drawn from these studies?

Other Site Studies

11:10 – 11:40 Buffalo Ridge/Vansycle – Dale Strickland, WEST

11:40 – 12:10 San Gorgonio Pass/Tehachapi - Dick Anderson

12:10 – 12:20 Kewaunee, WI – Steve Ugoretz

12:20 – 12:40 Discussion: what questions or issues are raised and what conclusions can be drawn from these studies?

12:40 – 1:40 LUNCH

1:40 – 3:10 SESSION II – Avian Visual Studies: What are we learning about avian vision that can help us better understand avian-wind power interactions?

1:40 – 2:10 Hugh McIsaac, Denver University

2:10 – 2:40 Bill Hodos, University of Maryland

2:40 – 3:10 Discussion: what questions or issues are raised and what conclusions can be drawn from these studies?

3:10 – 3:30 BREAK

3:30 - 5:30 SESSION III – Mortality Reduction, Impact Avoidance, and Deterrent Considerations: What are we learning about how to reduce avian fatalities due to avian-wind power interactions?

3:30–4:00 Foote Creek Rim – Dale Strickland, WEST

4:00-4:30 Acoustical Data Monitoring - Bob Dooling

4:30 – 5:00 Altamont – L. Darryl Gray, Alameda County

5:00 – 5:30 Discussion: what questions or issues are raised and what conclusions can be drawn from these efforts?

5:30 – 6:30 **<u>Summary of What We Heard Today, Conclusions/Observations</u>**

<u>Wednesday, May 17, 2000</u>

8:00 – 8:30 Continental Breakfast

8:30-8:45 **<u>Overview of the Day</u>**

8:30 – 12:00 **<u>SESSION IV - Other Research Topics</u>**

8:45-10:00 ***Bat Ecology and Wind Turbine Considerations***

- *<u>Panel</u>: Brian Keeley, Steve Ugoretz, Dale Strickland*
- *<u>Discussion</u>: what are the implications of this information for site selection, monitoring and evaluation?*

10:00 – 10:15 BREAK

10:15-12:00 ***Improved/alternate Techniques for Use in Avian Research***

10:15-10:45 *Bird Activity Monitoring* - Rick Carlton, EDM

10:45-11:30 *Communications Towers and Wind Generators* – Albert Manville, USFWS

11:30-12:00 *<u>Discussion</u>: what questions or issues are raised and what conclusions can be drawn?*

12:00-1:00 **LUNCH**

1:00-2:00 ***Taking account of differences at each site***

- *Panel: Dick Anderson, Mike Morrison, Dale Strickland*
- *<u>Discussion</u>: what questions or issues are raised and what conclusions can be drawn?*

2:00-2:30 *California Condor Reintroduction - Potential Wind-Power Related Impacts*

- *Jim Davis & Kelly Sorenson – Ventana Wilderness Society*

2:30 – 2:50 ***Comparison to other Stationary Structures***

- *Steve Ugoretz*

2:50 – 3:30 *<u>Discussion</u>: What questions or issues are raised and what conclusions can be made?*

3:30-3:45 **BREAK**

3:45-6:30 **<u>Review of What We Have Learned</u>**

Effectiveness of the standard M&M, comparisons of collision fatality trends between ecoregions and bird groups; conclusions about patterns of collision fatalities related to site and technology factors. (Format to be determined)

- What Have We Learned – long vs. short term studies
- What are the next steps to achieve standardization in studies?
- How do we know when we have enough information?
- What do we still need to learn, work on?
- How can we get that information?

6:30 **<u>ADJOURN</u>**

<u>Thursday, May 18</u>

8:00-9:30 **<u>Breakfast Meeting of NWCC Avian Subcommittee</u>**

Open to interested individuals to discuss future role and activities of the Subcommittee