DEVELOPING METHODS TO REDUCE BIRD MORTALITY IN THE ALTAMONT PASS WIND RESOURCE AREA

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- FINAL REPORT -

PIER-EA Contract No. 500-01-019

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PREFACE

The Public Interest Energy Research (PIER) Program managed by the California Energy Commission (Commission) supports public interest energy research and development that will help to improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace. The PIER Program annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions. PIER funding efforts are focused on the following six RD&D program areas:

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

What follows is the final report to the California Energy Commission for Contract Number 500-019-01, conducted by BioResource Consultants of Ojai, California, as a contribution to the Energy-Related Environmental Research Program. For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/research/index.html or contact the Publications Unit at 916-654-5200.

REPORT ORGANIZATION

Chapter 1, *Understanding the Problem*, reviews the hypotheses and speculations of the causal factors of bird mortality at wind farms. Beginning in Chapter 1, the term "wind farm" is used throughout. A wind farm consists of more than one wind turbine and the related infrastructure needed to collect the generated power. It presents a framework and terminology for discussion of the problem, as well as the experimental and analytical approaches used in this study, and why they were used. This chapter also describes the objectives and the study area.

Chapter 2, *Cause of Death and Locations of Bird Carcasses in the APWRA*, presents a summary of the causes of death attributed to carcasses found in the APWRA, and it analyzes the distances of carcasses found from wind turbines. The mortality estimates presented in Chapter 4 are adjusted based on an analysis of the distances that carcasses were found away from the wind turbines.

Chapter 3, *Bird Mortality in the Altamont Pass Wind Resource Area*, presents the fatality search methods and the mortality estimates. These estimates were adjusted by search effort and searcher deficiencies such as the limitations of the search radius, removal of carcasses by scavengers, and searcher detection rates. Mortality is estimated and compared inter-annually, as well as summarized for the study period with low and high estimate values for mortality per species.

Chapter 4, *Impacts to Birds Caused by Wind Energy Generation*, integrates standardized estimates of bird mortality among those wind energy facilities from which estimates have been reported. This chapter places the bird mortality of the APWRA in context with other wind energy facilities. It compares bird mortality and bird activity levels in the APWRA among studies that reported these metrics from the early 1990s through the present study nearly a decade later.

Chapter 5, *Range Management and Ecological Relationships in the APWRA*, summarizes ecological patterns observed in the APWRA and how they relate to rodent control, physiography, elevation, and other measured variables. This chapter examines vegetation height, cattle grazing intensity, the abundance of certain raptor prey species, and speculates on how each might relate to the wind turbine-caused mortality of various bird species.

Chapter 6, *Distribution and Abundance of Fossorial Animal Burrows in the APWRA and the Effects of Rodent Control on Bird Mortality*, presents an analysis of how ground squirrels and pocket gophers responded to a rodent control program conducted in the APWRA, as well as to other measured variables, such as slope grade and elevation. The distribution and abundance of ground squirrels and pocket gophers is related to raptor mortality in this chapter, and the effectiveness of the rodent control program is evaluated.

Chapter 7, *Bird Fatality Associations and Predictive Models for the APWRA*, begins by reviewing hypothesized causes of bird collisions with wind turbines. It then provides details about the variables that were measured and the methods used to test for significance of associations between predictor variables and bird fatalities. All possible relationships between fatalities and measured variables were tested. The most meaningful results are presented and used to formulate indicators of threat posed by wind turbines to selected bird species in the APWRA. Maps of predicted levels of threat are presented for future planning purposes (e.g., turbine siting).

Chapter 8, *Bird Behaviors in the Altamont Pass Wind Resource Area,* presents the experimental and analytical methods used to study bird activity levels and behaviors in the APWRA. Significant and meaningful associations between measured predictor variables and behaviors are summarized.

Chapter 9, *Conclusions and Recommendations*, identifies mitigation measures that follow from the research results and that will most effectively reduce bird mortality caused by the continued operation of the existing wind turbines in the APWRA. This chapter also prioritizes the recommended mitigation measures, and recommends discontinuing some that remain in use.

Appendix A is a paper entitled, *Measuring Impacts to Birds Caused by Wind Turbines*. The standard measurement of mortality currently being used by researchers is the number of fatalities per wind turbine per year. This paper presents a new metric for reporting bird mortality at energy generation facilities, including wind energy facilities. This metric, the number of deaths per megawatt of power generation per year, standardizes comparisons of impacts among wind farms composed of very different wind turbine models, as well as between wind power generation and other forms of power generation. The term will be easier for the public to comprehend because it is one simple step away from presenting the impacts on a per capita or a per household basis. This chapter, and this metric, provides much of the foundation for data presented in Chapter 4.

Additional technical appendices (B, C, and D) are provided in the order in which they are referenced in the report.

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EXECUTIVE SUMMARY

For decades, research has shown that wind turbines in the Altamont Pass Wind Resource Area (APWRA) kill many birds, including raptors, which are protected by the Migratory Bird Treaty Act, the Bald and Golden Eagle Protection Act, and/or state and federal Endangered Species Acts. Each violation of these acts can result in fines and/or criminal convictions.

Early research in the APWRA on these bird fatalities mainly attempted to identify the extent of the problem. However, in 1998, the National Renewable Energy Laboratory (NREL) initiated research to address the causal relationships between wind turbines and bird mortality. The Public Interest Energy Research Environmental Area (PIER-EA) of the California Energy Commission funded a project by BioResource Consultants to build upon and expand those previous endeavors and determine whether measures could be implemented to reduce bird collisions with wind turbines in the APWRA.

Two factors heighten the urgency and importance of resolving this issue. First, one goal of California's renewable portfolio standard (RPS) is meeting 20% of the State's electricity needs through renewable energy sources by 2010. Second, Alameda County placed a moratorium on issuing permits to increase electrical production capacity in the APWRA beyond the existing 580 MW permitted capacity until there is demonstrable progress toward significantly reducing bird mortality.

With more than 2,000 megawatts (MW) of installed generating capacity in California, wind turbines provide up to 3.5 billion kilowatt-hours (kWh) of emissions-free electricity for the state annually. By identifying and implementing new methods and technologies to reduce or resolve bird mortality in the APWRA, power producers may be able to increase wind turbine electricity production at the site and apply the mortality-reduction methods at other sites around the state and country.

It is the mission of PIER-EA to develop cost-effective approaches to evaluating and resolving environmental effects of energy production, delivery, and use in California. In addition, an objective of the PIER Renewable Area is to expand renewable distributed generation technologies to help provide electricity generation in high-demand, high-congestion areas. By addressing bird mortality issues in the APWRA, the PIER-EA is helping to alleviate the most important environmental issue being associated with wind power generation, while also supporting the development of renewable energy generation in the State.

Objectives

This four-year research effort involving more than 4,000 wind turbines was aimed at better understanding bird mortality at the world's largest wind farm—the Altamont Pass Wind Resource Area (APWRA) in central California. Electricity-generating wind turbines installed in the APWRA kill large numbers of birds of many different species, including many raptors. Researchers studied bird behaviors, raptor prey availability, wind turbine/tower design, inter-turbine distribution, landscape attributes, and range management practices in their effort to explain the variation in bird mortality with the goal of developing predictive models that could be useful for future planning decisions in the APWRA.

The primary objectives of this research were to: (1) quantify bird use, including characterizing and quantifying perching and flying behaviors exhibited by individual birds around wind turbines; (2) evaluate the flying behaviors and the environmental and topographic conditions associated with flight behaviors; (3) identify possible relationships between bird mortality and bird behaviors, wind tower design and operations, landscape attributes, and prey availability; and (4) develop predictive, empirical models that identify areas or conditions that are associated with high vulnerability.

Approach

Other studies have evaluated bird mortality in the APWRA. For this study, researchers adopted the following approaches to help improve accuracy and the usability of the resulting data. For example, the researchers:

- conducted searches at 2,548 wind turbines in addition to the 1,526 wind turbines they had studied previously,
- adjusted mortality estimates to account for errors in detection rates and the rates of removal of carcasses by scavengers,
- used the number of fatalities per MW per year as the mortality metric, thereby avoiding the potentially false appearance that larger wind turbines kill more birds, and
- presented mortality estimates as ranges, where the lower end of the range was the mortality adjusted for fatalities that were likely missed beyond the 50-m search radius, and the upper end was the mortality adjusted for fatalities missed due to undetected carcass removal by scavengers.

Outcomes

Researchers found that at least three years of carcass searches are needed before the sample of wind turbines sufficiently stabilizes in the percentage of non-zero mortality values. Using a monitoring duration less than three years may yield unreliable estimates of mortality.

Researchers explored the relationship between the time each bird species spent close to wind turbines and the number of fatalities. They found that:

- inter-specific variation in mortality could not be explained by variation in the number of flights within close proximity to wind turbines, and
- some bird species spent more time flying within 50 meters (m) of wind turbines than expected, and they spent less time within 51–100 m or 101–300 m, which indicated that those species were attracted to the areas near to wind turbines,
- most flights by golden eagles, red-tailed hawks, American kestrels and all raptors combined were at heights at or below the rotor planes existing wind turbines in the APWRA.

Unique suites of attributes are related to mortality of each species, so the researchers conducted species-specific analyses to understand the factors that underlie wind turbine-caused fatalities. They found the following:

- Golden eagles are killed more frequently than expected by chance alone at wind turbines located in areas in the APWRA characterized as canyons.
- Higher mortality of a number of species within part of the APWRA was related to rock piles that were produced during wind tower installation. This correlation could be a result of desert cottontails and ground squirrels (prey species for large raptors) inhabiting these rock piles.
- The degree of clustering by pocket gophers around wind towers was associated with red-tailed hawk mortality, and the degree of clustering of gophers appeared greatest on steeper slopes where laydown areas and access roads were cut. The degree of clustering of pocket gophers and desert cottontails was also greatest where rodent control measures were applied.

In terms of bird fatalities attributable to turbine designs or arrangements, researchers found the following:

- Turbines mounted on tubular towers killed disproportionately more red-tailed hawks and other raptors—as did wind turbines on taller towers, those with larger rotor diameter, and those with slower to intermediate blade tip speeds.
- Perching on wind turbines or their towers is a less important factor contributing to mortality than previously suspected.
- Wind turbines installed in wind wall configurations[1] are safer for birds, as are wind turbines within dense clusters of turbines and those forming the interior of wind turbine strings.
- Wind turbines were most dangerous at the ends of turbine strings, at the edges of gaps in strings, and at the edges of clusters of wind turbines.
- The most isolated wind turbines killed disproportionately more birds.

Researchers also observed seasonal variations:

- Winter and summer were the two seasons of the year when disproportionately larger numbers of birds were killed, although there were species-specific differences.

The study estimated that between 881 and 1,300 raptors are killed annually in the APWRA. For all birds combined, that number is estimated at between 1,766 and 4,721. These estimates translate to 1.5 to 2.2 raptor fatalities/MW/year and 3.0 to 8.1 bird fatalities/MW/year. Over 40 different bird species are represented in the fatalities. Among these, researchers estimate that the APWRA wind turbines are annually killing 75 to 116 golden eagles, 209 to 300 red-tailed hawks, 73 to 333 American kestrels, and 99 to 380 burrowing owls.

[1] A *wind wall configuration* consists of parallel rows of wind turbines closely aligned to each other but with alternating tower heights.

Over the past 15 years, the risk to birds of turbine-caused fatalities increased substantially in the APWRA. The number of raptors observed per hour declined while mortality remained steady, so the ratio of the number of deaths per MW to the number of raptors seen per hour increased.

To assert that the APWRA is anomalous in its bird mortality may be misleading when comparing it to other wind energy facilities. While a relatively large number of raptors are killed per annum in the APWRA, the ratio of the number killed to the number seen during behavior observations is similar among wind farms where both rates of observation have been reported. It appears, based on the research reports reviewed for this project, that when comparing wind energy facilities birds tend to be killed at rates that are proportional to their relative abundance among wind farms.

For the development of the predictive models, researchers performed tests that accounted for differential search efforts among groups of wind turbines, and examined test results for associations that were both statistically and biologically sound. The models ranged in predictive power from 37% to 82% correct classification, and projected that of the 4,075 wind turbines in the sample, 6% to 67% posed greater threat levels, depending on the bird species considered. To demonstrate the utility of the modeling approach, the report focused on four raptors species, even though the fatality associations used for model development were also estimated for multiple other species. The modeling results were more reliable for golden eagles and burrowing owls than they were for red-tailed hawks and American kestrels.

Conclusions, Recommendations, and Benefits to California

The researchers conclude that many of the bird collisions with wind turbines are associated with factors that could not be understood within the scope of this project, or that may simply be random. Most of the variation for some species may be explained by factors not addressed in this study. However, the findings are sufficiently robust for the wind industry to begin repowering with larger turbines according to recommended guidelines, or implementing a series of mitigation measures that will avoid, reduce, and offset impacts caused by existing and future wind turbines in the APWRA.

The researchers conclude that the most effective solution to reduce bird mortality would be to replace the numerous small turbines currently installed with fewer, larger turbines. A repowering program is beginning in the APWRA that replaces many of the existing turbines at a ratio of approximately seven to twelve older, smaller turbines with one newer, larger turbine. The effect that the repowering program will have on bird mortality is unknown; however, the research presented in this report suggests that repowering may reduce mortality, especially if turbines are installed on the tallest practicable towers. Also, these research results should aid the siting process of any new turbines with a primary goal being to install new turbines in locations and in arrangements that will result in fewer bird kills than in the past.

If the wind turbine owners fail to repower with larger turbines, then the report provides the foundation for the aggressive implementation of management strategies that will most likely

promote a partial reduction in bird mortality. To help alleviate bird mortality in the APWRA, the project researchers recommend implementing the following mitigation measures:

- Cease the rodent control program
- Relocate selected, highly dangerous wind turbines
- Move rock piles away from wind turbines
- Retrofit tower pads to prevent under-burrowing by small mammals
- Remove broken and non-operating wind turbines
- Install wind turbine designs beneficial to the APWRA bird fatality issue
- Implement the means to effectively monitor the output of each wind turbine
- Retrofit, using APLIC guidelines (minimum), noncompliant power poles

The following measures would be appropriately applied experimentally, due to the degree of uncertainty in their likely effectiveness. However, these measures could also be applied universally, but with the understanding that they might not substantially reduce bird mortality.

- Reduce vertical and lateral edge in slope cuts and nearby roads
- Exclude cattle from around wind turbines
- Install flight diverters
- Paint blades using the Hodos et al. scheme
- Experiment with devices that will identify when to operate problem wind turbines with the least effect on birds.

Researchers also recommend that certain measures be abandoned by the owner/operators as options for reducing bird mortality in the APWRA:

- Rodent control program
- Installing perch guards on wind turbines
- Providing alternative perches
- Barricading the rotor planes of turbines

If all mitigation measures supported by this project's findings were implemented, mortality might be reduced by up to 20–40%, depending on the species, and perhaps as high as 40–50% should the mitigation measures act synergistically to reduce mortality. The remaining, random portion of the mortality would likely continue in the APWRA for as long as the existing wind turbines operate at or above the current output capacity. To compensate suitably for these continuing and unavoidable losses of birds, off-site mitigation directed to protecting regionally important wildlife habitat may be warranted.

Benefits to California will accrue if there is a demonstrable reduction of bird mortality in the APWRA. Doing so will encourage more energy capacity to be permitted by Alameda and Contra Costa counties. By repowering with fewer, larger wind turbines mounted on the tallest practicable towers, and/or implementing some or all of the recommended mitigation measures identified in this report, the owner/operators of the APWRA can expect to achieve improved compliance with state and federal laws and regulations protecting birds.

ABSTRACT

Wind turbines in the Altamont Pass Wind Resource Area (APWRA) provide on average 1.1 billion kilowatt-hours (kWh) of emissions-free electricity annually, enough to power almost 200,000 average households per annum, but these turbines also kill birds that are legally protected, and have been doing so for decades.

This five-year research effort focused on better understanding the causes of bird mortality at the world's largest wind farm. Researchers studied 2,548 wind turbines and combined their data with results from 1,526 wind turbines they had studied previously. They sought to: (1) quantify bird use, including characterizing and quantifying perching and flying behaviors of individual birds around wind turbines; (2) evaluate flight behaviors and the environmental and topographic conditions associated with them; (3) identify possible relationships between bird mortality and bird behaviors, wind tower design and operations, landscape attributes, and prey availability; and (4) develop predictive, empirical models that identify turbine or environmental conditions that are associated with high vulnerability.

Researchers concluded that bird fatalities at the APWRA result from various attributes of wind turbine configuration and placement, and that species-specific behavior plays a large role in how each contributory factor affects mortality. The report details numerous specific observations.

Researchers identified and evaluated possible measures to mitigate bird mortality in the APWRA. They offer recommendations to discontinue or modify some current management actions, to implement new ones immediately, and to experiment with others. Data presented in the report support these recommendations. The results suggest that repowering with carefully placed, modern wind turbines mounted on taller towers may be the preferable means to substantially reduce bird mortality.